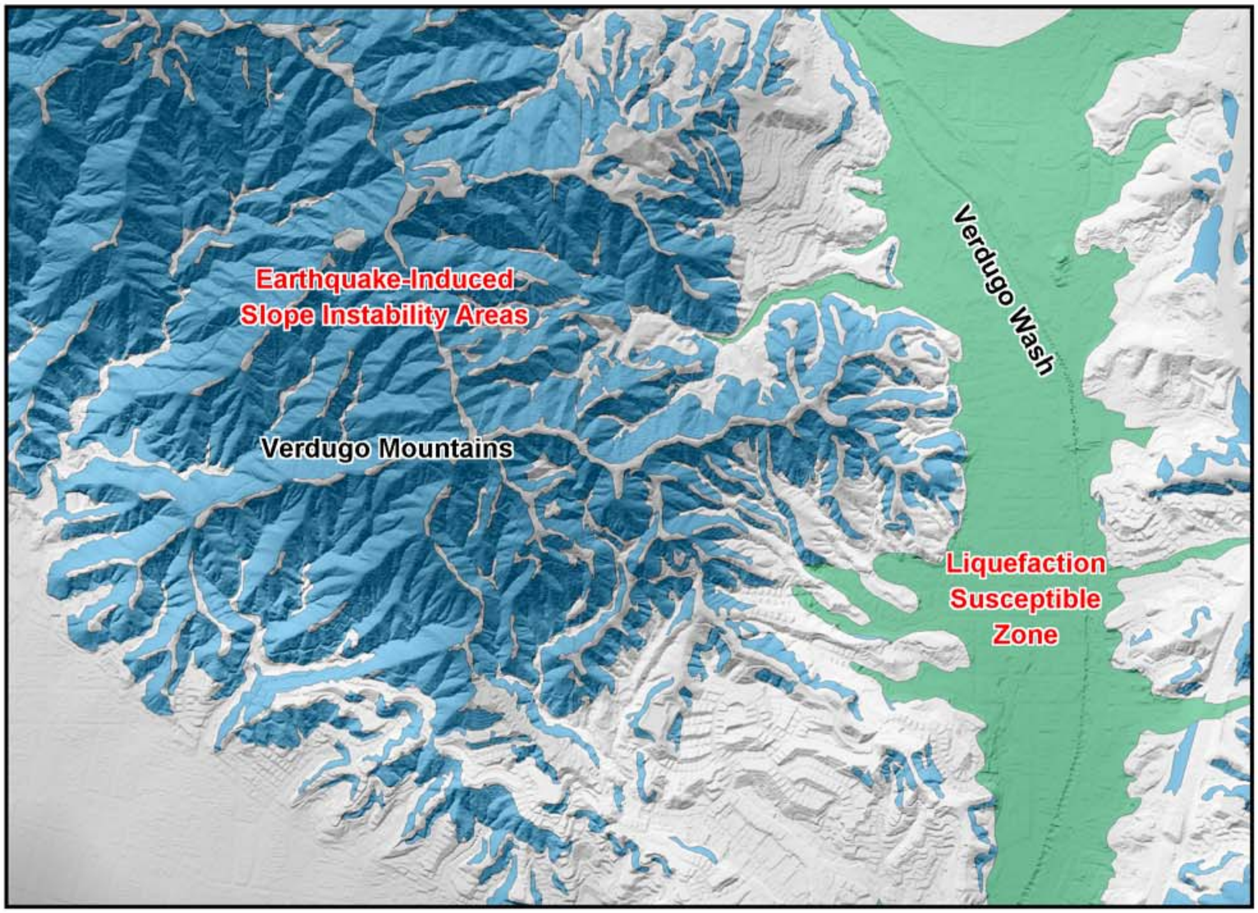

Technical Background Report to the Safety Element of the General Plan City of Glendale, California

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Introduction to the Technical Background Report of the Safety Element for the City of Glendale

Welcome! The Safety Element of the General Plan is the disaster mitigation plan for Glendale. Its ultimate goal is to improve the safety of the community. However, for appropriate hazard management, including effective emergency preparedness and response, communities need to know in advance what are the potentially hazardous conditions specific to their area. A major part of this knowledge base is based on maps that identify the vulnerable areas in the community. This is covered in the Technical Background Report of the Safety Element.

Therefore, in this report you are going to read about your City. Natural geologic processes are responsible for much of the natural beauty that makes Glendale such a special place to live and work. Unfortunately, many of these processes are not gradual, but rather, are sudden and often violent. Periodic large earthquakes are responsible for the uplift and continued growth of the San Gabriel Mountains that form the spectacular backdrop to Glendale, and the steep bedrock highlands, such as the Verdugo Mountains and the San Rafael Hills, right in the heart of the City. Flooding, erosion, and sediment transport are responsible for forming the broad sloping surfaces in the Crescenta and San Fernando Valleys, as well as for carving the impressive Verdugo Canyon that connects the northern and southern portions of the City. When these geologic processes occur within an urban environment, they become hazards, and when they do occur, they can create a disaster for those impacted by them.

Most of the hazards covered in this report are “natural” hazards, such as earthquakes (Chapter 1), landslides (Chapter 2), floods (Chapter 3), and fire (Chapter 4). In reality, however, these natural conditions do not pose a hazard in the wild, and it is only when they interact with the built environment that they become an issue. For example, a landslide in an undeveloped area is just a landslide, no buildings or structures are damaged, and no one is hurt or killed. But when a landslide occurs in a developed residential area, it has the potential to cause extensive damage and monetary losses, frequently never recovered by the victims. This does not need to happen though. From past experience, we have learned how to correct slope instability, how to measure and contain flood waters, and how to design earthquake and fire resistant structures. We have also learned that avoidance is sometimes the best defense.

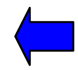
The last two chapters of this report cover other safety issues that are not “natural.” Chapter 5 discusses ways to reduce the harmful effects to our environment posed by many of the substances that we depend on for our every day comfort – substances such as gasoline, herbicides, fertilizers, and chemical compounds used to manufacture an amazing array of objects and products. Chapter 6 discusses crime, terrorism, and civil unrest and other safety issues of this type.

So, what is the best way to use this report? As the saying goes, “a picture is worth a thousand words.” Thus, we recommend that you first refer to the maps that accompany this report. If you are like almost everybody else, you will want to look for the area where you live or work, or where you are thinking of moving. These maps will show you at a glance whether the area you are interested in is located, for example, on or near an earthquake fault, an area susceptible to ground failure, or a highly hazardous fire area. Keep in mind, however, maps are by necessity generalized, and therefore, the boundaries shown on the map are only approximate – you do not want to be lulled into a false sense of security because your lot is across the street from where we have placed a contact between a hazardous and a non-hazardous zone. Or, alternatively, decide to move because you are currently living in an area zoned as hazardous. This is where reading the text comes in. Read about the specific hazards that you are concerned with, then apply that knowledge to your lot and house. How old is your house? Is it tied down to its foundation? Does it have a fire-resistant roof? There are specific actions that you can take to make your house specifically, or Glendale in general, a safer place.

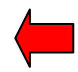
Key paragraphs or sections in the text of special interest are identified with symbols along the right-hand margin of the pages. The three symbols used, and their significance, are as follows:

Datum of general interest -

Datum of interest to the City of Glendale -



Mitigation measures that could be implemented -
to reduce a given hazard



The primary point of this document is to educate and inform the citizens, workers, and officials of Glendale of the potential hazards in the community. By doing so, you can take action to reduce the hazards specific to your area to a level that you, your family and your community are comfortable with. Through appropriate action, the hazard does not need to become a disaster.

Glendale is a relatively mature city; many areas of the City are fully developed, and in these areas, nearly all mitigation will be through redevelopment. As a result, disaster mitigation in these sections of the City will require decades to complete. Other areas, primarily in or adjacent to the hillsides, are still in a fairly natural state, but slated for future development. In these areas, there are opportunities to develop sensibly, avoiding some hazards altogether, like active faults, and implementing mitigation measures to reduce other hazards to acceptable levels. Although hazard reduction is a moving target, it must be accomplished. Government is tasked with the responsibility for citizen health, safety, and welfare. In the end though, all mitigation is local. Without the support of the citizens of Glendale, no governmental programs will be successful. It is hoped that this document will assist you in understanding the issues and the risks you and Glendale face. Through such an understanding you will be ready to support and implement the programs necessary to reduce your risk to community-accepted levels.

We hope that you enjoy reading this document, and that the data presented herein provides you with the impetus to demand action of yourself and others in Glendale to make it an even safer City to live and work in.

TECHNICAL BACKGROUND REPORT to the 2003 SAFETY ELEMENT
CITY of GLENDALE, CALIFORNIA

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CHAPTER 1: SEISMIC HAZARDS

1.1 Introduction

While Glendale is at risk from many natural and man-made hazards, an earthquake is the event with the greatest potential for far-reaching loss of life or property, and economic damage. This is true for most of southern California, since damaging earthquakes are frequent, affect widespread areas, trigger many secondary effects, and can overwhelm the ability of local jurisdictions to respond. Earthquake-triggered geologic effects include ground shaking, surface fault rupture, landslides, liquefaction, subsidence, and seiches, all of which are discussed below. Earthquakes can also cause human-made hazards such as urban fires, dam failures, and toxic chemical releases. These man-made hazards are also discussed in this document.

In California, recent earthquakes in or near urban environments have caused relatively few casualties. This is due more to luck than design. For example, when a portion of the Nimitz Freeway in Oakland collapsed at rush hour during the 1989, MW 7.1 Loma Prieta earthquake, it was uncommonly empty because so many were watching the World Series. The 1994, MW 6.7 Northridge earthquake occurred before dawn, when most people were home safely in bed. Despite such good luck, California's urban earthquakes have resulted in significant losses. The moderate-sized Northridge earthquake caused 54 deaths and nearly $30 billion in damage. Glendale is at risk from earthquakes that could release more than 10 times the seismic energy of the Northridge earthquake.

Although it is not possible to prevent earthquakes, their destructive effects can be minimized. Comprehensive hazard mitigation programs that include the identification and mapping of hazards, prudent planning, public education, emergency exercises, enforcement of building codes, and expedient retrofitting and rehabilitation of weak structures can significantly reduce the scope of an earthquake's effects and avoid disaster. Local government, emergency relief organizations, and residents must take action to develop and implement policies and programs to reduce the effects of earthquakes.

1.2 Earthquake and Mitigation Basics

1.2.1 Definitions

The outer 10 - 70 kilometers of the Earth consist of enormous blocks of moving rock, called **plates**. There are about a dozen major plates, which slowly collide, separate, and grind past each other. In the uppermost plates, friction locks the plate edges together, while movement continues at depth. Consequently, the near-surface rocks bend and deform near plate boundaries, storing strain energy. Eventually, the frictional forces are overcome and the locked portions of the plates move. The stored strain energy is released in waves.

By definition, the break or fracture between moving blocks of rock is called a **fault**, and such differential movement produces a **fault rupture**. The place where the fault first ruptures is called the **focus** (or **hypocenter**). The released energy waves radiate out in all directions from the rupture surface, making the earth vibrate and shake as the waves travel through. This shaking is what we feel in an **earthquake**.

Although faults exist everywhere, most earthquakes occur on or near plate boundaries. Thus, southern California has many earthquakes, because it straddles the boundary between the North American and Pacific plates, and fault rupture accommodates their motion. The Pacific Plate is moving northwesterly, relative to the North American Plate, at about 50 mm/yr. This is about the rate at which fingernails grow, and seems unimpressive. However, it is enough to accumulate enormous amounts of strain energy over dozens to thousands of years. Despite being locked in place most of the time, in another 15 million years (a short time in the context of the Earth's history), due to plate movements, Glendale will be hundreds of kilometers north of San Francisco.

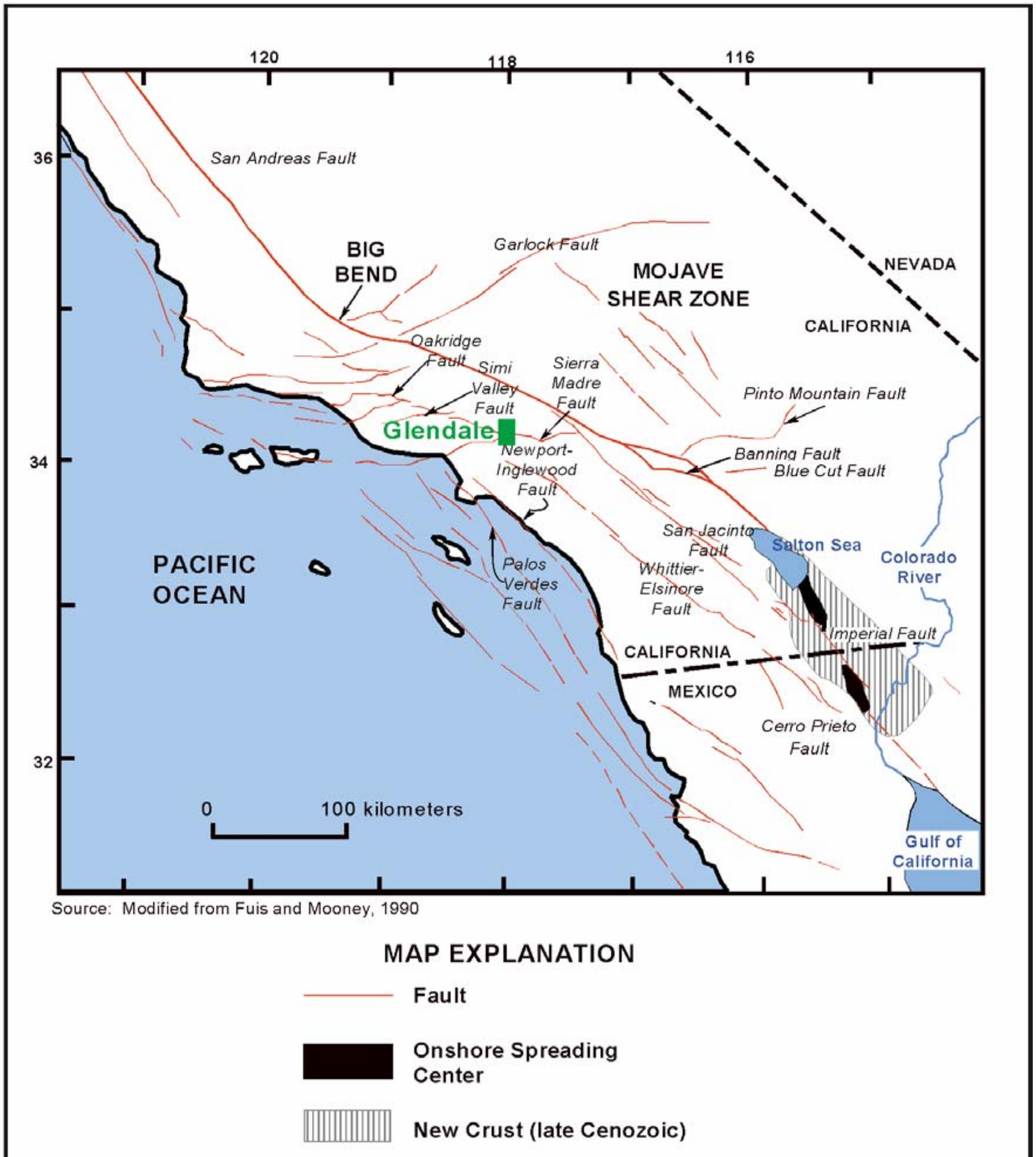
Although the San Andreas fault marks the actual separation between the Pacific and North American plates, only about 70 percent of the plate motion occurs on the San Andreas fault itself. The rest is distributed among other faults of the San Andreas system, including the San Jacinto, Whittier-Elsinore, Newport-Inglewood, Palos Verdes, plus several offshore faults; and among faults of the Eastern Mojave Shear Zone, a series of faults east of the San Andreas, responsible for the 1992, MW 7.3 Landers and 1999 MW 7.1 Hector Mine earthquakes (Figures 1-1 and 1-2). (MW stands for moment magnitude, a measure of earthquake energy release, discussed below.) Thus, the zone of plate-boundary earthquakes and ground deformation covers an area that stretches from the Pacific Ocean to Nevada.

Because the Pacific and North American plates are sliding past each other, with relative motions to the northwest and southeast, respectively, all of the faults mentioned above are aligned northwest-southeast, and are **strike-slip faults**. On average, strike-slip faults are nearly vertical breaks in the rock, and when a strike-slip fault ruptures, the rocks on either side of the fault slide horizontally past each other.

However, there is a kink in the San Andreas fault, commonly referred to as the "Big Bend". The northwest corner of the Big Bend is located about 75 miles northeast of Glendale (Figure 1-1). Near the Big Bend, the two plates do not slide past each other. Instead, they collide, causing localized compression, resulting in folding and **thrust faulting**. Thrust faults meet the surface of the Earth at a low angle, dipping 25 – 35 degrees from the horizontal. Thrusts are a type of **dip-slip fault**, where rocks on opposite sides of the fault move up or down relative to each other. When a thrust fault ruptures, the top block of rock moves up and over the rock on the other side of the fault.

In southern California, ruptures along thrust faults have built the Transverse Ranges geologic province, a region with an east-west trend to its landforms and underlying geologic structures. This orientation is anomalous, virtually unique in the western United States, and a direct consequence of the plates colliding at the Big Bend. Many of southern California's most recent damaging earthquakes have occurred on thrust faults that are uplifting the Transverse Ranges, including the 1971 MW 6.7 San Fernando, the 1987 MW 5.9 Whittier Narrows, the 1991 MW 5.8 Sierra Madre, and the 1994 MW 6.7 Northridge earthquakes. Thrust faults can be particularly hazardous because many are **blind thrust faults**, that is, they do not extend to the surface of the Earth. These faults are extremely difficult to detect before they rupture. Some of the most recent earthquakes, like the 1987 Whittier Narrows earthquake, and the 1994 Northridge earthquake, occurred on blind thrust faults.

The City of Glendale is situated in the Transverse Ranges Province, an area that is exposed to risk from multiple earthquake fault zones. The highest risks originate from the Sierra Madre (dip-slip, reverse) fault zone, the Verdugo (dip-slip, reverse) fault zone, the Hollywood (predominantly strike-slip, left lateral) fault, the Elysian Park (blind thrust) fault zone, and the Raymond (predominantly strike-slip, left lateral) fault zone. Each one of these faults will be discussed in more detail in Section 1-5.



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Regional Fault Map

Figure 1-1

1.2.2 Evaluating Earthquake Hazard Potential

When comparing the sizes of earthquakes, the most meaningful feature is the amount of energy released. Thus scientists most often consider **seismic moment**, a measure of the energy released when a fault ruptures. We are more familiar, however, with scales of magnitude, which measure amplitude of ground motion. Magnitude scales are logarithmic. Each one-point increase in **magnitude** represents a ten-fold increase in amplitude of the waves as measured at a specific location, and a 32-fold increase in energy. That is, a magnitude 7 earthquake produces 100 times (10 x 10) the ground motion amplitude of a magnitude 5 earthquake. Similarly, a magnitude 7 earthquake releases approximately 1,000 times more energy (32 x 32) than a magnitude 5 earthquake. Recently, scientists have developed the **moment magnitude (Mw)** scale to relate energy release to magnitude.

An early measure of earthquake size still used today is the seismic **intensity scale**, which is a qualitative assessment of an earthquake's effects at a given location. Although it has limited scientific application, intensity is still widely used because it is intuitively clear and quick to determine. The most commonly used measure of seismic intensity is called the Modified Mercalli Intensity (MMI) scale, which has 12 damage levels (Table 1.1).

A given earthquake will have one moment and, in principle, one magnitude, although there are several methods of calculating magnitude, which give slightly different results. However, one earthquake will produce many intensities because intensity effects vary with the location and perceptions of the observer.

Few faults are simple, planar breaks in the Earth. They more often consist of smaller **strands**, with a similar orientation and sense of movement. A strand is mappable as a single, fairly continuous feature at a scale of about 1:24,000. Sometimes geologists group strands into **segments**, which are believed capable of rupturing together during a single earthquake. The more extensive the fault, the bigger the earthquake it can produce. Therefore, multi-strand fault ruptures produce larger earthquakes.

The bigger and closer the earthquake, the greater the likelihood of damage. Thus fault dimensions and proximity are key parameters in any hazard assessment. In addition, it is important to know a fault's style of movement (i.e. is it dip-slip or strike-slip, discussed above), the age of its most recent activity, its total displacement, and its slip rate (all discussed below). These values indicate how often a fault produces damaging earthquakes, and how big an earthquake should be expected the next time the fault ruptures.

Total displacement is the length, measured in kilometers (km), of the total movement that has occurred along the fault over as long a time as the geologic record reveals. It is usually estimated by measuring distances between geologic features that have been split apart and separated (**offset**) by the cumulative movement of the fault over many earthquakes. **Slip rate** is a speed, expressed in millimeters per year (mm/yr). Slip rate is estimated by measuring an amount of offset accrued during a known amount of time, obtained by dating the ages of geologic features. Slip rate data also are used to estimate a fault's **earthquake recurrence interval**. Sometimes referred to as "repeat time" or "return interval", the recurrence interval represents the average amount of time that elapses between major earthquakes on a fault. The most specific way to derive recurrence interval is to excavate a trench across a fault to obtain **paleoseismic** evidence of earthquakes that have occurred during prehistoric time.

Table 1-1: Abridged Modified Mercalli Intensity Scale

Intensity Value and Description		Average Peak Velocity (cm/sec)	Average Peak Acceleration (g = gravity)
I.	Not felt except by a very few under especially favorable circumstances (I Rossi-Forel scale). Damage potential: None.	<0.1	<0.0017
II.	Felt only by a few persons at rest, especially on upper floors of high-rise buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale). Damage potential: None.	0.1 – 1.1	0.0017 – 0.014
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale). Damage potential: None.		
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like a heavy truck striking building. Standing automobiles rocked noticeably. (IV to V Rossi-Forel scale). Damage potential: None. Perceived shaking: Light.	1.1 – 3.4	0.014 - 0.039
V.	Felt by nearly everyone; many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale). Damage potential: Very light. Perceived shaking: Moderate.	3.4 – 8.1	0.039-0.092
VI.	Felt by all; many frightened and run outdoors. Some heavy furniture moved, few instances of fallen plaster and damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale). Damage potential: Light. Perceived shaking: Strong.	8.1 - 16	0.092 -0.18
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars. (VIII Rossi-Forel scale). Damage potential: Moderate. Perceived shaking: Very strong.	16 - 31	0.18 - 0.34
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (VIII+ to IX Rossi-Forel scale). Damage potential: Moderate to heavy. Perceived shaking: Severe.	31 - 60	0.34 - 0.65
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale). Damage potential: Heavy. Perceived shaking: Violent.	60 - 116	0.65 – 1.24
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (X Rossi-Forel scale). Damage potential: Very heavy. Perceived shaking: Extreme.	> 116	> 1.24
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.		
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into air.		

Modified from Bolt (1999); Wald et al. (1999).

Paleoseismic studies show that faults with higher slip rates often have shorter recurrence intervals between major earthquakes. This makes sense. A high slip rate indicates rocks that, at depth, are moving relatively quickly. Thus the locked, surficial rocks are storing more strain energy, so the forces of friction will be exceeded more often, releasing the strain energy in more frequent, large earthquakes.

Faults have formed over millions of years, usually in response to regional stresses. Shifts in these stress regimes do occur over millennia. As a result, some faults change in character. For example, a thrust fault in a compressional environment may become a strike-slip fault in a transpressive (oblique compressional) environment. Other faults may be abandoned altogether. Consequently, the State of California, under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act of 1972 (Hart and Bryant, 1999), classifies faults according to the following criteria:

Active: faults showing proven displacement of the ground surface within about the last 11,000 years (within the Holocene Epoch), that are thought capable of producing earthquakes;

Potentially Active: faults showing evidence of movement within the last 1.6 million years, but that have not been shown conclusively whether or not they have moved in the last 11,000 years; and

Not active: faults that have conclusively NOT moved in the last 11,000 years.

These definitions are used primarily for residential subdivisions. Other definitions of activity are used by other agencies or organizations, depending on the type of facility being planned or developed. For example, longer periods of inactivity may be required for dams or nuclear power plants. An important subset of active faults are those with historical earthquakes. In California, that means faults that have ruptured since 1769, when the Spanish first arrived in the area.

The underlying assumption in this classification system is that if a fault has not ruptured in the last 11,000 years, it is not likely to be the source of a damaging earthquake in the future. In reality, however, most potentially active faults have been insufficiently studied to determine their hazard level. Also, although simple in theory, the evidence necessary to determine whether a fault has or has not moved during the last 11,000 years can be difficult to obtain. For example, some faults leave no discernable evidence of their earthquakes, while other faults stop rupturing for millennia, and then are "reactivated" as the tectonic environment changes.

1.2.3 Causes of Earthquake Damage

Causes of earthquake damage can be categorized into three general areas: strong shaking, various types of ground failure that are a result of shaking, and ground displacement along the rupturing fault. The State definition of an active fault is designed to gauge the surface rupture potential of a fault, and is used to prevent development from being sited directly on an active fault. This helps to reduce damage from the third category. Below, the three categories are discussed in order of their likelihood to occur extensively:

1) **Strong Ground Shaking** causes the vast majority of earthquake damage. Horizontal ground **acceleration** is frequently responsible for widespread damage to structures, so it is commonly estimated, as a percentage of **g**, the acceleration of gravity. Full characterization of shaking potential, though, requires estimates of peak (maximum) ground displacement and velocity, the duration of strong shaking, and the periods (lengths) of waves that will control each of these factors at a given location. We look to the recorded effects of damaging earthquakes worldwide to understand what might happen in similar environments here in the future. In general, the degree of shaking can depend upon:

- **Source effects**. These include earthquake size, location, and distance, as discussed above. In addition, the exact way that rocks move along the fault can influence shaking. For example, the 1995, MW 6.9, Kobe, Japan earthquake was not much bigger than the 1994, MW 6.7 Northridge, California earthquake, but Kobe caused much worse damage. During the Kobe earthquake, the fault's orientation and movement directed seismic waves into the city. During the Northridge earthquake, the fault's motion directed waves away from populous areas.

- **Path effects**. Seismic waves change direction as they travel through the Earth's contrasting layers, just as light bounces (reflects) and bends (refracts) as it moves from air to water. Sometimes seismic energy gets focussed into one location and causes damage in unexpected areas. Focussing of 1989's MW 7.1 Loma Prieta earthquake waves caused damage in San Francisco's Marina district, some 100 km distant from the rupturing fault.

- **Site effects**. Seismic waves slow down in the loose sediments and weathered rock at the Earth's surface. As they slow, their energy converts from speed to amplitude, which heightens shaking. This is like the behavior of ocean waves - as the waves slow down near shore, their crests grow higher. In addition, seismic waves can get trapped at the surface and reverberate (resonate). Whether resonance will occur depends on the period (the length) of the incoming waves. Waves, soils and buildings all have resonant periods. When these coincide, tremendous damage can occur.

We keep talking about periods. What do we mean? Waves repeat their motions with varying frequencies. Slow-to-repeat waves are called long-period waves. Quick-to-repeat waves are called short-period waves. Long-period seismic waves, which are created by large earthquakes, are most likely to reverberate and cause damage in long-period structures, like bridges and high-rises. ("Long-period structures" are those that respond to long-period waves.) Shorter-period seismic waves, which tend to die out quickly, will most often cause damage fairly near the fault, and they will cause most damage in shorter-period structures such as one- to three-story buildings. Very short-period waves are most likely to cause near-fault, interior damage, such as to equipment.

2) **Liquefaction and Slope Failure** are very destructive secondary effects of strong seismic shaking.

- **Liquefaction** typically occurs within the upper 50 feet of the surface, when saturated, loose, fine- to medium-grained soils (sand and silt) are present. Earthquake shaking suddenly increases pressure in the water that fills the pores between soil grains, causing the soil to lose strength and behave as a liquid. This process can be observed at the beach by standing on the wet sand near the surf zone. Standing still, the sand will support your weight. However, when you tap the sand with your feet, water comes to the surface, the sand liquefies, and your feet sink.

When soils liquefy, the structures built on them can sink, tilt, and suffer significant structural damage. Liquefaction-related effects include loss of bearing strength, ground oscillations, lateral spreading and flow failures or slumping. The excess water pressure is relieved by the ejection of material upward through fissures and cracks. A water-soil slurry bubbles onto the ground surface, resulting in features called “sand boils”, “sand blows” or “sand volcanoes”. Site-specific geotechnical studies are the only practical, reliable way to determine the liquefaction potential of a site.

- **Landslides and Rockfall (Mass Wasting).** Gravity inexorably pulls hillsides down and earthquake shaking enhances this on-going process. Slope stability depends on many factors and their interrelationships. Rock type and pore water pressure are arguably the most important factors, as well as slope steepness due to natural or human-made undercutting. Where slopes have failed before, they may fail again. Thus, it is essential to map existing landslides and soil slumps. Furthermore, because there are predictable relationships between local geology and the likelihood that mass wasting will occur, field investigations can be used to identify failure-prone slopes before an earthquake occurs. This, combined with GIS-based analyses of slope gradient, land use, and bedrock or soil materials can be used to identify high-risk areas where mitigation measures would be most effective.

3) **Primary Ground Rupture Due to Fault Movement** typically results in a relatively small percentage of the total damage in an earthquake, yet being too close to a rupturing fault can result in extensive damage. It is difficult to safely reduce the effects of this hazard through building and foundation design. Therefore, the primary mitigation measure is to avoid active faults by setting structures back from the fault zone. Application of this measure is subject to requirements of the Alquist-Priolo Earthquake Fault Zoning Act and guidelines prepared by the California Geological Survey – previously known as the California Division of Mines and Geology (CDMG Note 49). The final approval of a fault setback lies with the local reviewing agency.

Earthquake damage also depends on the characteristics of human-made structures. The interaction of ground motion with the built environment is complex. Governing factors include a structure’s height, construction, and stiffness, which determine the structure’s resonant period; the underlying soil’s strength and resonant period; and the periods of the incoming seismic waves. Other factors include architectural design, condition, and age of the structure.

1.2.4 Choosing Earthquakes for Planning and Design

It is often useful to create a **deterministic** or **design earthquake scenario** to study the effects of a particular earthquake on a building or a community. Often, such scenarios consider the largest earthquake that is believed possible to occur on a fault or fault segment, referred to as the **maximum magnitude earthquake** (**Mmax**). Other scenarios consider the **maximum probable earthquake (MPE)** or **design basis earthquake (DBE)** (1997 Uniform Building Code - UBC), the earthquake with a statistical return period of 475 years (with ground motion that has a 10 percent probability of being exceeded in 50 years). For public schools, hospitals, and other critical facilities, the California Building Code (1998) defines the **Upper Bound Earthquake** (UBE), which has a statistical return period of 949 years and a ground motion with a 10 percent probability of being exceeded in 100 years. As the descriptions above suggest, which earthquake scenario is most appropriate depends on the application, such as the planned use, lifetime or importance of a facility. The more critical the structure, the longer the time period used between earthquakes and the larger the design earthquake should be.

Geologists, seismologists, engineers, emergency response personnel and urban planners typically use maximum magnitude and maximum probable earthquakes to evaluate seismic hazard. The assumption is that if we plan for the worst-case scenario, we establish safety margins. Then smaller earthquakes, that are more likely to occur, can be dealt with effectively.

Seismic design parameters define what kinds of earthquake effects a structure must be able to withstand. These include peak ground acceleration, duration of strong shaking, and the periods of incoming strong motion waves.

As is true for most earthquake-prone regions, many potential earthquake sources pose a threat to Glendale. Thus it is also important to consider the overall likelihood of damage from a plausible suite of earthquakes. This approach is called **probabilistic seismic hazard analysis (PSHA)**, and typically considers the likelihood of exceeding a certain level of damaging ground motion that could be produced by any or all faults within a 100-km radius of the project site, or in this case, the City. PSHA is utilized by the U.S. Geological Survey to produce national seismic hazard maps that are used by the Uniform Building Code (ICBO, 1997).

Regardless of which fault causes a damaging earthquake, there will always be **aftershocks**. By definition, these are smaller earthquakes that happen close to the **mainshock** (the biggest earthquake of the sequence) in time and space. These smaller earthquakes occur as the Earth adjusts to the regional stress changes created by the mainshock. The bigger the mainshock, the greater the number of aftershocks, the larger the aftershocks will be, and the wider the area in which they might occur.

On average, the largest aftershock will be 1.2 magnitude units less than the mainshock. Thus, a MW 6.9 earthquake will tend to produce aftershocks up to Mw 5.7 in size. This is an average, and there are many cases where the biggest aftershock is larger than the average predicts. The key point is this: any major earthquake will produce aftershocks large enough to cause additional damage, especially to already-weakened structures. Consequently, post-disaster response planning must take damaging aftershocks into account.

1.3 Laws To Mitigate Earthquake Hazard

1.3.1 Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Special Studies Zones Act was signed into law in 1972 (in 1994 it was renamed the Alquist-Priolo Earthquake Fault Zoning Act). The primary purpose of the Act is to mitigate the hazard of fault rupture by prohibiting the location of structures for human occupancy across the trace of an active fault (Hart and Bryant, 1999). This State law was passed in direct response to the 1971 San Fernando earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings and other structures. Surface rupture is the most easily avoided seismic hazard.

The Act requires the State Geologist (Chief of the California Geological Survey) to delineate "Earthquake Fault Zones" along faults that are "sufficiently active" and "well defined." These faults show evidence of Holocene surface displacement along one or more or their segments (sufficiently active) and are clearly detectable by a trained geologist as a physical feature at or just below the ground surface (well defined). The boundary of an "Earthquake Fault Zone" is generally about 500 feet from major active faults, and 200 to 300 feet from well-defined minor faults. The Act dictates that cities and counties withhold development permits for sites within an Earthquake Fault Zone within their jurisdiction until geologic investigations demonstrate that the sites are not threatened by surface displacements from future faulting (Hart and Bryant, 1999).

The Alquist-Priolo maps are distributed to all affected cities and counties for their use in planning and controlling new or renewed construction. Local agencies must regulate most development projects within the zones. Projects include all land divisions and most structures for human occupancy. State law exempts single-family wood-frame and steel-frame dwellings which are less than three stories and are not part of a development of four units or more. However, local agencies can be more restrictive than State law requires. Alquist-Priolo Earthquake Fault Zone mapping has been completed by the State Geologist for the northwestern Glendale area, in the Sunland and Burbank Quadrangles (CDMG, 1979a; 1979b).

1.3.2 Seismic Hazards Mapping Act

The Alquist-Priolo Earthquake Fault Zoning Act only addresses the hazard of surface fault rupture and is not directed toward other earthquake hazards. Recognizing this, in 1990, the State passed the Seismic Hazards Mapping Act (SHMA), which addresses non-surface fault rupture earthquake hazards, including strong ground shaking, liquefaction and seismically induced landslides. The California Geological Survey (CGS) is the principal State agency charged with implementing the Act. Pursuant to the SHMA, the CGS is directed to provide local governments with seismic hazard zone maps that identify areas susceptible to amplified shaking, liquefaction, earthquake-induced landslides, and other ground failures. The goal is to minimize loss of life and property by identifying and mitigating seismic hazards. The seismic hazard zones delineated by the CGS are referred to as "zones of required investigation." Site-specific geological hazard investigations are required by the SHMA when construction projects fall within these areas.

The CGS, pursuant to the 1990 SHMA, has been releasing seismic hazards maps since 1997. In the Glendale area, the CGS has mapped the Sunland, Burbank, Pasadena, Hollywood and Los Angeles quadrangles. These maps indicate that liquefaction and earthquake-induced landslides are hazards present locally in the Glendale area.

1.3.3 Real Estate Disclosure Requirements

Since June 1, 1998, the **Natural Hazards Disclosure Act** has required that sellers of real property and their agents provide prospective buyers with a "Natural Hazard Disclosure Statement" when the property being sold lies within one or more State-mapped hazard areas. If a property is located in a Seismic Hazard Zone as shown on a map issued by the State Geologist, the seller or the seller's agent must disclose this fact to potential buyers. The law specifies two ways in which this disclosure can be made. One is to use the new Natural Hazards Disclosure Statement as provided in Section 1102.6c of the California Civil Code. The other way is to use the Local Option Real Estate Disclosure Statement as provided in Section 1102.6a of the California Civil Code. The Local Option Real Estate Disclosure

Statement can be substituted for the Natural Hazards Disclosure Statement only if the Local Option Statement contains substantially the same information and substantially the same warning as the Natural Hazards Disclosure Statement.

California State law also requires that when houses built before 1960 are sold, the seller must give the buyer a completed earthquake hazards disclosure report, and a copy of the booklet entitled "The Homeowner's Guide to Earthquake Safety." This publication was written and adopted by the California Seismic Safety Commission. The most recent edition of this booklet is available from the web at www.seismic.ca.gov/. The booklet contains a sample of a residential earthquake hazards report that buyers are required to fill in, and it provides specific information on common structural weaknesses that can fail, damaging homes during earthquakes. The booklet further describes specific actions that can be taken by homeowners to strengthen their home.

The Alquist-Priolo Earthquake Fault Zoning Act and the Seismic Hazards Mapping Act also require that real estate agents, or sellers of real estate acting without an agent, disclose to prospective buyers that the property is located in an Earthquake Fault or Seismic Hazard Zone.

1.3.4 California Environmental Quality Act

The California Environmental Quality Act (CEQA) was passed in 1970 to insure that local governmental agencies consider and review the environmental impacts of development projects within their jurisdictions. CEQA requires that an Environmental Impact Report (EIR) be prepared for projects that may have significant effects on the environment. EIRs are required to identify geologic and seismic hazards, and to recommend potential mitigation measures, thus giving the local agency the authority to regulate private development projects in the early stages of planning.

1.3.5 Uniform Building Code and California Building Code

The City of Glendale has been enforcing building code provisions since 1920, when it passed Ordinance 411 regulating garages, filling stations, gasoline pumps and buggies. In 1922, it expanded its regulations to address the State Tenement House Act and other matters dealing with buildings. Ordinance 522 established the term "Superintendent of Buildings", the forerunner of the Building Official, as the overseer of enforcement of the regulations governing the construction of buildings on private property in the City of Glendale. Since then, Glendale has regularly updated its building code regulations to protect the safety of the community.

The International Conference of Building Officials (ICBO) was formed in 1922 to develop a uniform set of building regulations; this led to the publication of the first Uniform Building Code (UBC) in 1927. In keeping with the intent of providing a safe building environment for our community, the technical provisions of the City's building codes have been updated on a regular basis as new editions of the UBC have been published. In addition to updating the regulations concerning fire and life, this has also kept Glendale current with the latest provisions for the seismic design of buildings.

Recognizing that many building code provisions are not affected by local conditions, like exiting from a building, and to facilitate the concept that industries working in California should have some uniformity in building code provisions throughout the State, in 1980 the legislature amended the State's Health and Safety Code to require local jurisdictions to adopt the latest edition of the Uniform Building Code (UBC). The law states that every local agency, City and County, enforcing building regulations must adopt the provisions of the California Building Code (CBC) within 180 days of its publication. The publication date of the CBC is established by the California Building Standards Commission and the code is known as Title 24 of the California Code of Regulations. Based upon the publication cycle of the UBC, the CBC has been updated and republished every three years since the initial action by the legislature.

To further the concept of uniformity in building design, in 1994 ICBO joined with the two other national building code publishers, the Building Officials and Code Administrators International, Inc. (BOCA) and the Southern Building Code Congress International, Inc. (SBCCI), to form a single organization, the International Code Council, (ICC). In 2000, the group published the first International Building Code (IBC) as well as an entire family of codes, (i.e. building, mechanical, plumbing and fire) that were coordinated with each other. As a result, the last (and final) version of the UBC was issued in 1997.

Since the formation of the ICC and the publication of the IBC, the California legislature has not addressed the matter of updating the CBC with a building code other than the UBC. Therefore, even though the seismic design provisions have not been brought up to the current standards of the IBC, the Building Standards Commission has chosen to continue to adopt the old 1997 UBC for the CBC through the 2004 cycle.

In addition to adopting the provisions of the CBC, local jurisdiction may adopt more restrictive amendments provided that they are based upon local geographic, topographic or climatic conditions. The City of Glendale, along with 55 other local jurisdictions, have worked together to make our local amendments consistent with the rest of southern California. Currently, Glendale's Building and Safety staff are very active in the code development process and all regional activities to improve the technical provisions of the building code and the understanding of the purpose of the building codes by the public. They participate in the Los Angeles Regional Uniform Code Program, (LARUCP), and promote the adoption of uniform amendments to the CBC by other local jurisdictions.

1.3.6 Unreinforced Masonry Law

Enacted in 1986, the Unreinforced Masonry Law (Section 8875 et seq of the California Government Code) required all cities and counties in Seismic Zone 4 (zones near historically active faults) to identify hazardous unreinforced masonry (URM) buildings in their jurisdictions, establish a URM loss reduction program, and report their progress to the State by 1990. The owners of such buildings were to be notified of the potential earthquake hazard these buildings pose. The loss reduction program to be implemented, however, was left to each local jurisdiction, although the law recommends that local governments adopt mandatory strengthening programs by ordinance and that they establish seismic retrofit standards. Some jurisdictions did implement mandatory retrofit programs, while others established voluntary programs. A few cities only notified the building owners, but did not adopt any type of strengthening program.

The Glendale area lies entirely within Seismic Zone 4. Therefore, and in compliance with the Unreinforced Masonry Law, Glendale issued Chapter 58 of the City Code – Earthquake Hazard Reduction in Existing Buildings. The provisions of Chapter 58 apply to all URM buildings constructed before June 7, 1938, or buildings for which a building permit was issued prior to June 7, 1938. The Code requires all URMs, except for detached one- or two-family dwellings and apartment houses with less than 5 dwelling units, to be identified and catalogued. Owners of applicable URMs are then to retain a civil or structural engineer or architect licensed in California to conduct a structural analysis of the building to determine whether the structure meets the minimum earthquake standards specified in the City Code. If the building does not meet the minimum requirements, the owner is to either retrofit or demolish the building. The Code establishes time limits to comply with these requirements depending on the use of the building; essential and high-risk structures are to be surveyed and retrofitted more quickly than other types of buildings.

1.4 Notable Historic Earthquakes in the Glendale Region

Figure 1-2 shows the approximate epicenters of earthquakes that have resulted in significant ground shaking in the Los Angeles basin, including Glendale. The most significant of these events are summarized below. Plate 1-1 shows the historical seismicity in the immediate vicinity of Glendale. The map shows that small earthquakes, of magnitude between 1 and 3, have occurred historically in the area, but that no moderate to large earthquakes have occurred beneath Glendale in historical times.

1.4.1 Long Beach Earthquake of 1933

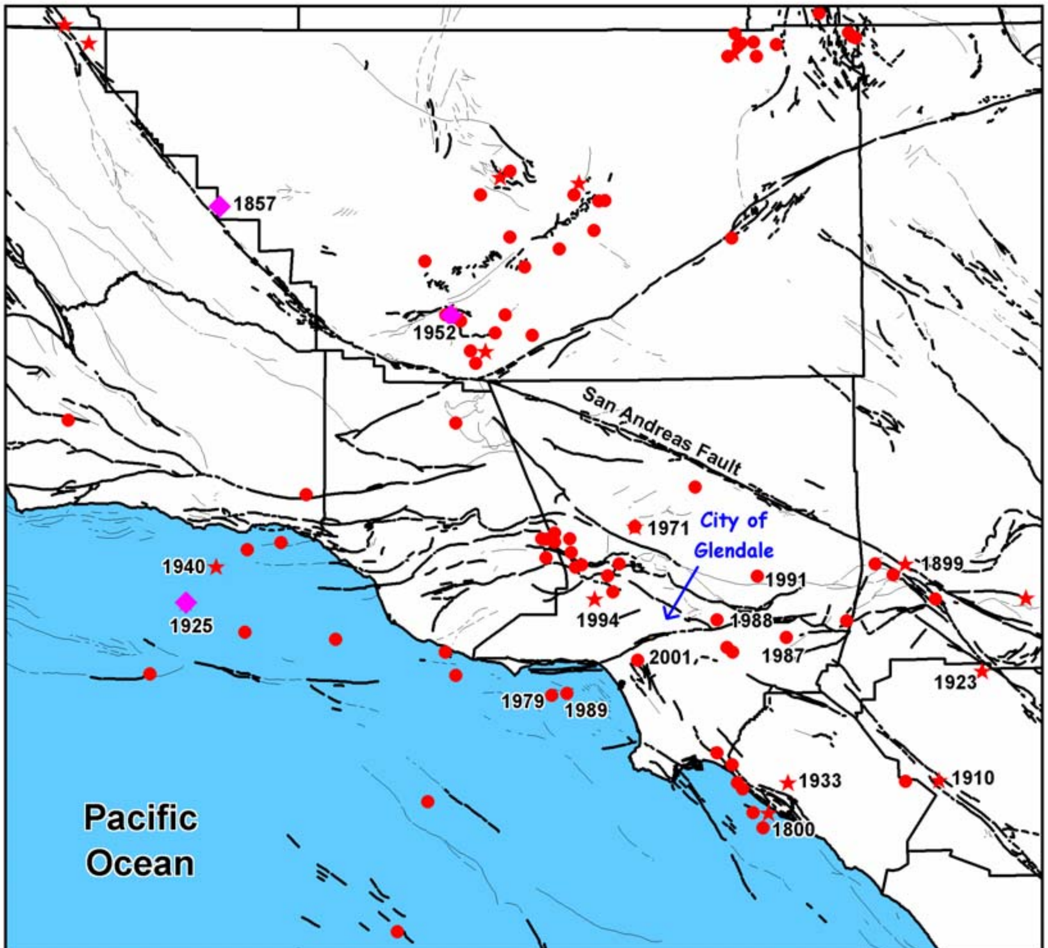
This Mw 6.4 earthquake occurred on March 10, 1933, at 5:54 in the afternoon. The location of the earthquake's epicenter has been re-evaluated, and determined to have occurred approximately 3 miles south of present-day Huntington Beach. However, it caused extensive damage in Long Beach, hence its name. The earthquake occurred on the Newport-Inglewood fault, a right-lateral strike slip fault that extends across the western portion of the Los Angeles basin (see Figure 1-1). The Newport-Inglewood fault did not rupture the surface during this earthquake, but substantial liquefaction-induced damage was reported. The earthquake caused 120 deaths, and over $50 million in property damage (Wood, 1933).

Most of the damaged buildings were of unreinforced masonry, and many school buildings were destroyed. Fortunately, children were not present in the classrooms at that time, otherwise, the death toll would have been much higher. This earthquake led to the passage of the Field Act, which gave the Division of the State Architect authority and responsibility for approving design and supervising construction of public schools. Building codes were also improved.

1.4.2 San Fernando (Sylmar) Earthquake of 1971

This Mw 6.6 earthquake occurred on the San Fernando fault zone, the western-most segment of the Sierra Madre fault, on February 9, 1971, at 6:00 in the morning. The surface rupture caused by this earthquake was nearly 12 miles long, and occurred in the Sylmar-San Fernando area, just a few miles northwest of Glendale. The maximum slip measured at the surface was nearly 6 feet.

The earthquake caused over $500 million in property damage and 65 deaths. Most of the deaths occurred when the Veteran's Administration Hospital collapsed. Several other hospitals, including the Olive View Community Hospital in Sylmar suffered severe damage. Newly constructed freeway overpasses also collapsed, in damage scenes similar to those which occurred 23 years later in the 1994 Northridge earthquake. Loss of life could have been much greater had the earthquake struck at a busier time of day. Thirty-one buildings in Glendale were so severely damaged that they had to be demolished, and approximately 3,250 masonry chimneys in the City collapsed. The total building loss in Glendale as a result of this earthquake was estimated at more than $2 million (Oakeshott, 1975).



Source: Jennings, 1994; SCEC earthquake catalog; NEIC earthquake catalog

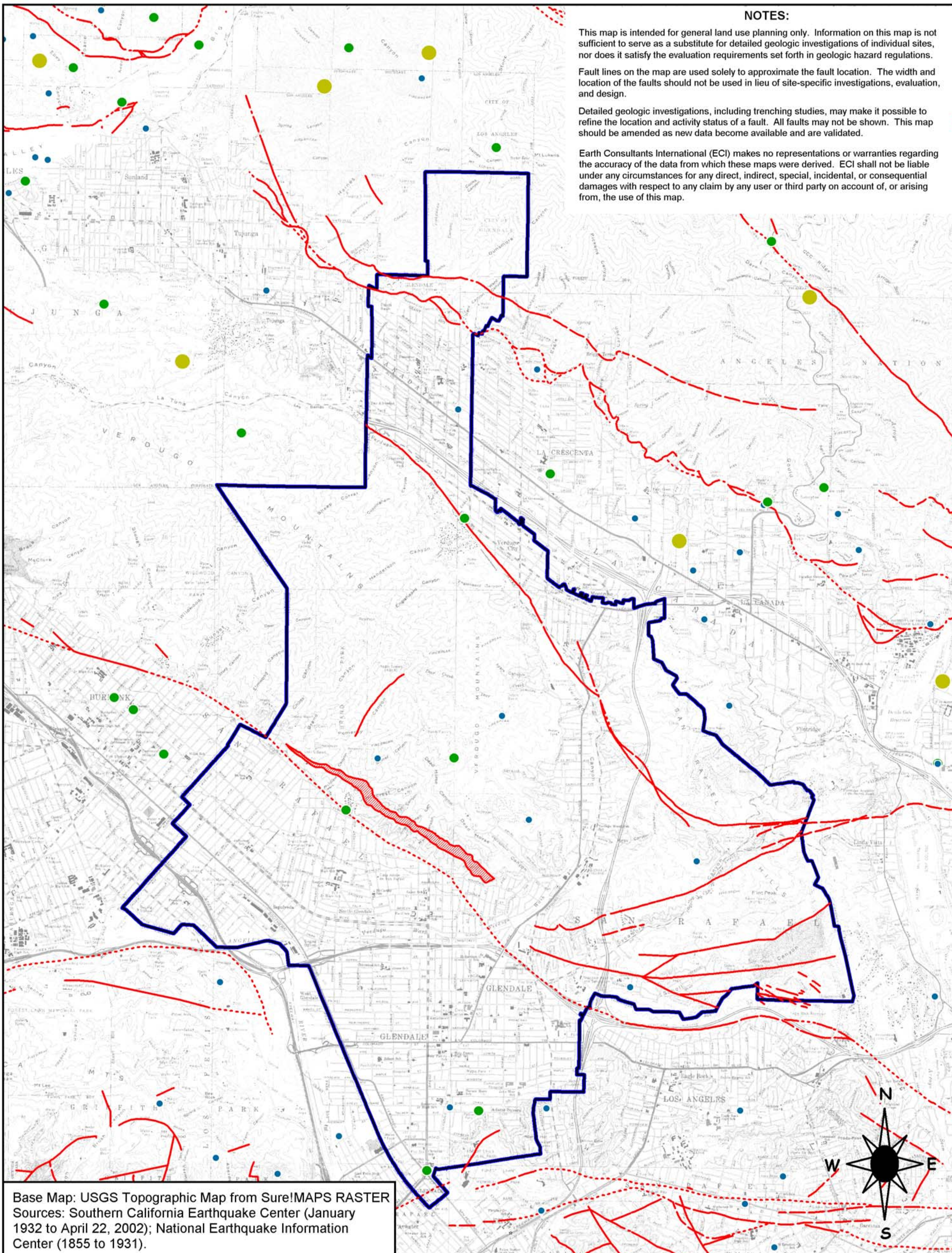
Map Explanation

Magnitude 7+
Magnitude 6 - 7
Magnitude 5 - 6
Quaternary faults

Earth Consultants International
Project Number: 2103
Date: July, 2003

Regional Seismicity Map

Figure 1-2



NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Fault lines on the map are used solely to approximate the fault location. The width and location of the faults should not be used in lieu of site-specific investigations, evaluation, and design.

Detailed geologic investigations, including trenching studies, may make it possible to refine the location and activity status of a fault. All faults may not be shown. This map should be amended as new data become available and are validated.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Southern California Earthquake Center (January 1932 to April 22, 2002); National Earthquake Information Center (1855 to 1931).

Scale: 1:60,000

1000 0 1000 2000 3000
Meters

5000 0 5000 10000 15000
Feet

Explanation

Earthquake Magnitude

- 3 to 4
- 2 to 3
- 1 to 2

Fault, solid where location known, dashed where approximate, dotted where inferred; hatchured where defined as a zone, (for more information refer to Plate 1-2).

Glendale City Limit

CITY OF GLENDALE CALIFORNIA

Earth Consultants International

Project Number: 2103
Date: July, 2003

Historical Seismicity Map (1855-2002)

Glendale, California

Plate 1-1

As with the Long Beach earthquake, legislation was passed in response to the damage caused by the 1971 earthquake. In this case, the building codes were strengthened and the Alquist Priolo Special Studies (now Earthquake Fault) Zone) Act was passed in 1972.

1.4.3 Malibu Earthquake of 1979

This earthquake occurred on January 1, 1979 at 3:15 in the afternoon. The epicenter of the ML5.2 earthquake was approximately 8 miles south of Malibu, and 23 miles west of Los Angeles. Although it caused only minor damage in the areas closest to its epicenter, the earthquake was felt as far away as Kings, Kern and San Diego counties.

1.4.4 Whittier Narrows Earthquake of 1987

The Whittier Narrows earthquake occurred on October 1, 1987, at 7:42 in the morning, with its epicenter located approximately 12 miles southwest of Glendale (Hauksson and Jones, 1989). The ML 5.9 earthquake occurred on a previously unknown, north-dipping concealed thrust fault (blind thrust) now called the Puente Hills fault (Shaw, and Shearer, 1999). The earthquake caused eight fatalities, over 900 injured, and $358 million in property damage. Severe damage was confined mainly to communities east of Los Angeles and near the epicenter. Areas with high concentrations of URMs, such as the "Uptown" district of Whittier, the old downtown section of Alhambra, and the "Old Town" section of Pasadena, were severely impacted. Several tilt-up buildings partially collapsed, including tilt-up buildings built after 1971, that were built to improved building standards but were of irregular configuration, revealing seismic vulnerabilities not previously recognized. Residences that sustained damage usually were constructed of masonry, were not fully anchored to foundations, or were houses built over garages with large door openings. Many chimneys collapsed and in some cases, fell through roofs. Wood-frame residences, in contrast, sustained relatively little damage, and no severe structural damage to high-rise structures in downtown Los Angeles was reported.

1.4.5 Pasadena Earthquake of 1988

The Pasadena earthquake occurred at 3:38 in the morning on December 3, 1988, directly underneath the city of Pasadena. The ML5.0 earthquake occurred on the Raymond fault (Hauksson and Jones, 1991), and helped determine that the Raymond fault is a left-lateral strike-slip fault (prior to this earthquake, the geological community was divided on this issue – the fault forms a well-defined scarp that many attributed to reverse faulting). This earthquake was also notable because it was followed by an unusually small number of aftershocks, and these were of small size (the largest was only a magnitude 2.4).

1.4.6 Malibu Earthquake of 1989

This ML5.0 earthquake occurred on January 18, 1989 at 10:53 in the evening. The earthquake's epicenter was about 10 miles south of Malibu. As a result of this earthquake, several people were injured, shelved items fell in local stores, and some windows were broken. Hardest hit was the coastal region encompassing Malibu, Santa Monica, and Redondo Beach, though damage was low even in that area. Slight damage was also reported in Los Angeles, Hollywood, Monterey Park, and Lancaster.

1.4.7 Sierra Madre Earthquake of 1991

The Sierra Madre earthquake occurred on June 28, 1991 at 7:43 in the morning approximately 18 miles northeast of Glendale. The Mw 5.8 earthquake probably occurred on the Clamshell-Sawpit Canyon fault, an offshoot of the Sierra Madre fault zone in the San Gabriel Mountains (Haukson, 1994). Because of its depth and moderate size, it caused no surface rupture, but it did trigger rockslides that blocked some of the local mountain roads. Roughly $40 million in property damage occurred in the San Gabriel Valley; URM buildings were hardest hit, and many brick chimneys collapsed. Two deaths resulted from this earthquake -- one person was killed in Arcadia, and one person in Pasadena died from a heart attack. In all, at least 100 others were injured, though the injuries were mostly minor.

1.4.8 Landers and Big Bear Earthquakes of 1992

On the morning of June 28, 1992, most people in southern California were awakened at 4:57 by the largest earthquake to strike California in 40 years. Named “Landers” after a small desert community near its epicenter, the earthquake had a magnitude of 7.3. More than 50 miles of surface rupture associated with five or more faults occurred as a result of this earthquake. The average right-lateral strike-slip displacement was about 10 to 15 feet, but a maximum of 18 feet of slip was observed. Centered in the Mojave Desert, approximately 120 miles from Los Angeles, the earthquake caused relatively little damage for its size (Brewer, 1992). It released about four times as much energy as the very destructive Loma Prieta earthquake of 1989, but fortunately, it did not claim as many lives (one child died when a chimney collapsed). The power of the earthquake was illustrated by the length of the ground rupture it left behind. The earthquake ruptured 5 separate faults: Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock faults (Sieh et al., 1993). Nearby faults also experienced triggered slip and minor surface rupture. There are no Modified Mercalli Intensity (MMI) reports for this earthquake in the Glendale area, but in Pasadena three individuals reported MMIs of IV, and in Burbank, MMIs of IV to V were reported (see Table 1-1) (http://pasadena.wr.usgs.gov/shake/ca/).

The magnitude 6.4 Big Bear earthquake struck little more than 3 hours after the Landers earthquake on June 28, 1992 at 8:05:30 A.M. PDT. This earthquake is technically considered an aftershock of the Landers earthquake (indeed, the largest aftershock), although the Big Bear earthquake occurred over 20 miles west of the Landers rupture, on a fault with a different orientation and sense of slip than those involved in the main shock. From its aftershock, the causative fault was determined to be a northeast-trending left-lateral fault. This orientation and slip are considered “conjugate” to the faults that slipped in the Landers rupture. The Big Bear earthquake did not break the ground surface, and, in fact, no surface trace of a fault with the proper orientation has been found in the area. The Big Bear earthquake caused a substantial amount of damage in the Big Bear area, but fortunately, it claimed no lives. However, landslides triggered by the quake blocked roads in the mountainous areas, aggravating the clean-up and rebuilding process (SCEC-DC, 2001).

1.4.9 Northridge Earthquake of 1994

The Northridge Earthquake of January 17, 1994 woke up most of southern California at 4:30 in the morning. The earthquake’s epicenter was located 20 miles to the west-northwest of downtown Los Angeles, on a previously unknown blind thrust fault now called the Northridge (or Pico) Thrust. Although moderate in size, this earthquake produced the strongest ground motions ever instrumentally recorded in North America. The Mw 6.7 earthquake is one of the most expensive natural disasters to have impacted the United States. Damage was widespread, sections of major freeways collapsed, parking structures and office buildings collapsed, and numerous apartment buildings suffered irreparable damage. Damage to wood-frame apartment houses was very widespread in the San Fernando Valley and Santa Monica areas, especially to structures with “soft” first floor or lower-level parking garages. The high accelerations, both vertical and horizontal, lifted structures off of their foundations and/or shifted walls laterally. The death toll was 57, and more than 1,500 people were seriously injured.

In the Glendale area, this earthquake caused predominantly Modified Mercalli intensities of VII (44 individuals reported MMIs of VII and one individual reported MMIs of VIII) (http://pasadena.wr.usgs.gov/shake/ca/). High-profile damage in Glendale includes the following cases: A section of the third level above grade in the Glendale City Center parking structure collapsed, sections of the Glendale Galleria parking structure settled 4 to 8 inches due to damage to pedestals, and the Glendale Fashion Center had damage to exterior columns.

Despite the losses, gains made through earthquake hazard mitigation efforts of the last two decades were obvious. Retrofits of masonry building helped reduce the loss of life, hospitals suffered less structural damage than in 1971 San Fernando earthquake, and emergency response was exemplary. Extensive documentation regarding this earthquake and its effects on the built environment is available on the world wide web. Additional information can be found at the following web sites as well as others:
http://geohazards.cr.usgs.gov/northridge/
www.eqe.com/publications/northridge/northridge.html.

1.4.10 West Hollywood Earthquake of 2001

A M4.2 earthquake occurred in West Hollywood at 4:59 in the afternoon on September 9, 2001. This earthquake was widely felt throughout the Los Angeles Basin and in parts of San Fernando Valley. No significant damage was reported. This is the largest earthquake to occur in the Los Angeles basin since the 1994 Northridge earthquake and its aftershocks. The earthquake's epicenter was located near the intersection of the Newport-Inglewood and Hollywood faults. The focal mechanism showed horizontal strike-slip motion on a north-northwest striking plane, suggesting that this event may be associated with the north end of the Newport-Inglewood fault (Hauksson, Hutton and Jones, 2001; at http://Pasadena.wr.usgs.gov/eqinthenews/ci09703873/index.html). This earthquake caused MMIs in Glendale of between III and IV (http://pasadena.wr.usgs.gov/shake/ca/).

1.5 Potential Sources of Seismic Ground Shaking

Seismic shaking is the geologic hazard that has the greatest potential to severely impact Glendale given the City's proximity to several active seismic sources (faults). As discussed in Section 1.4 above, some of these faults caused moderate-sized earthquakes in the last century; but, given their length, are thought capable of generating even larger earthquakes in the future that would cause strong ground shaking in Glendale and nearby communities.

To give the City a better understanding of the hazard posed by these faults, we performed a deterministic seismic hazard analysis using software that is an industry standard [EQFAULT, by Blake (2000a)], to estimate the Peak Horizontal Ground Accelerations (PHGA) that can be expected at Glendale's City Center due to earthquakes occurring on any of the known active or potentially active faults within 100 km (62 miles) from the City. We also conducted probabilistic seismic hazard analyses using FRISKSP (Blake, 2000b) to estimate the median PHGA at twelve different sites throughout the City. The difference between these two approaches is that, while a deterministic hazard assessment addresses individual sources or scenario events, probabilistic assessments combine all seismic sources and consider the likelihood (or probability) of each source to generate an earthquake. In a probabilistic analysis, a mathematical equation is used to estimate the combined risk posed by all known faults within 100 km, and for each fault, a suite of possible damaging earthquakes is considered, each weighed according to its likelihood of occurring in any particular year.

To conduct these seismic shaking analyses, we used the same fault database (including fault locations and earthquake magnitudes of the maximum magnitude and maximum probable earthquakes for each fault) used by the CGS and USGS for the National Seismic Hazard Maps (Peterson and others, 1996). The PHGA estimates obtained from these analyses provide a general indication of relative earthquake risk in Glendale. However, studies that better constrain the distance from a given site to the various faults in the region, and that consider the near-surface soil types should be conducted for site-specific projects.

Those faults that, based on the ground shaking analyses described above, can cause peak horizontal ground accelerations of about 0.1g or greater (Modified Mercalli Intensities greater than VII) in the Glendale area are listed in Table 1-2. For a map showing most of these faults, refer to Figure 1-3. Those faults included in Table 1-2 that have the greatest impact on the Glendale area, or that are thought to have a higher probability of causing an earthquake, are described in more detail in the following pages.

Table 1-2 shows:

- The closest approximate distance, in miles and in kilometers, between Glendale's City Hall and each of the main faults considered in the deterministic and probabilistic analyses;
- the maximum magnitude earthquake (Mmax) each fault is estimated capable of generating;
- the intensity of ground motion, expressed as a fraction of the acceleration of gravity (g), that could be experienced in the Glendale area if the Mmax occurs on one of these faults; and
- the Modified Mercalli seismic Intensity (MMI) values estimated to be felt in the City as a result of the Mmax on each one of these faults.

In general, peak ground accelerations and seismic intensity values decrease with increasing distance away from the causative fault. However, local site conditions, such as the top of ridges, can amplify the seismic waves generated by an earthquake, resulting in localized higher accelerations than those listed here. The strong ground motion values presented here should therefore be considered as average values; higher values may occur locally in response to site-specific conditions.

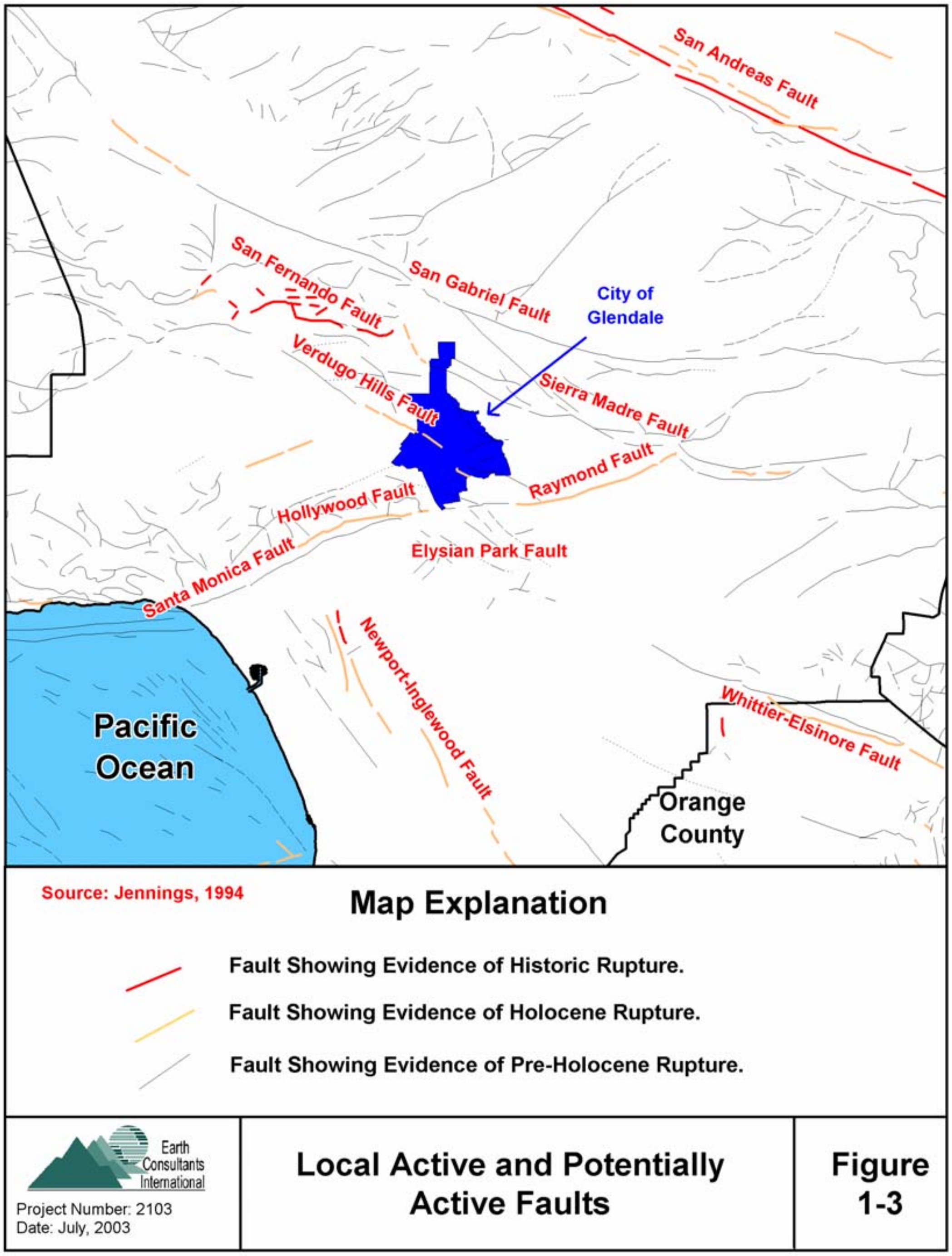
The probabilistic seismic analyses performed for this study indicate that the Glendale area has a 10 percent chance of experiencing ground accelerations greater than 55 to 70 percent the force of gravity (0.55g to 0.70g) in 50 years. These probabilistic ground motion values for the City of Glendale are in the high to very high range for southern California, and are the result of the City's proximity to major fault systems with high earthquake recurrence rates.

Table 1-2
Estimated Horizontal Peak Ground Accelerations and Seismic Intensities in the Glendale Area

Fault Name	Distance to Glendale (mi)	Distance to Glendale (km)	Magnitude of Mmax *	PGA (g) from Mmax	MMI from Mmax
Verdugo	<1	<1	6.7	0.61	X
Hollywood	<2	~1	6.4	0.55	X
Raymond	<2	~1	6.5	0.55	X
Sierra Madre	5	9	7.0	0.46+	X
Elysian Park Thrust	6	10	6.7	0.38	IX
Sierra Madre (San Fernando)	9	15	6.7	0.28	IX
Santa Monica	10	16	6.6	0.25	IX
Newport-Inglewood	11	17	6.9	0.24	IX
Compton Thrust	12	19	6.8	0.25	IX
San Gabriel	12	19	7.0	0.23	IX
East Oak Ridge (Northridge)	12	20	6.9	0.26	IX
Clamshell-Sawpit	13	21	6.5	0.20	VIII
Malibu Coast	17	28	6.7	0.18	VIII
Whittier	17	28	6.8	0.16	VIII
Santa Susana	19	30	6.5	0.16	VIII
San Jose	21	33	6.5	0.14	VIII
Palos Verdes	21	34	7.1	0.16	VIII
Holser	24	39	6.5	0.13	VIII
Cucamonga	27	43	7.0	0.15	VIII
Chino-Central Avenue	27	44	6.7	0.13	VIII
Anacapa Dume	28	45	7.3	0.17	VIII
San Andreas (1857 Rupture)	29	46	7.8	0.18	VIII
San Andreas - Mojave	29	46	7.1	0.12	VII
Oakridge (Onshore)	31	49	6.9	0.13	VIII
Simi-Santa Rosa	33	53	6.7	0.11	VII
San Cayetano	36	57	6.8	0.11	VII

* The Mmax reported herein are based on the fault parameters published by the CGS (CDMG, 1996). However, as described further below, in the text, recent paleoseismic studies suggest that some of these faults, like the Sierra Madre fault, can generate even larger earthquakes than those listed above. These PGAs were calculated using Blake's (2000a) deterministic analysis software. In general, areas closer to a given fault will generally experience higher accelerations than areas farther away, therefore the northern portion of the City, next to the Sierra Madre fault, would experience higher accelerations than those reported herein.

Abbreviations used in Table 1-2:
mi – miles; **km** – kilometers; Mmax – maximum magnitude earthquake; **PGA** – peak ground acceleration as a percentage of g, the acceleration of gravity; **MMI** – Modified Mercalli Intensity.



Local Active and Potentially Active Faults

Figure 1-3

1.5.1 San Andreas Fault Zone

As discussed previously, the San Andreas fault is the principal boundary between the Pacific and North American plates, and as such, it is considered the “Master Fault” because it has frequent (geologically speaking), large, earthquakes, and it controls the seismic hazard in southern California. The fault extends over 750 miles (1,200 kilometers), from near Cape Mendocino in northern California to the Salton Sea region in southern California. At its closest approach, the San Andreas fault is approximately 24 miles (38 km) north of Glendale.

Large faults, such as the San Andreas fault, are generally divided into segments in order to evaluate their future earthquake potential. The segments are generally defined at discontinuities along the fault that may affect the rupture length. In central and southern California, the San Andreas fault zone is divided into five segments named, from north to south, the Cholame, Carrizo, Mojave, San Bernardino Mountains, and Coachella Valley segments (Working Group on California Earthquake Probabilities - WGCEP, 1995). Each segment is assumed to have a characteristic slip rate (rate of movement averaged over time), recurrence interval (time between moderate to large earthquakes), and displacement (amount of offset during an earthquake). While this methodology has some value in predicting earthquakes, historical records and studies of prehistoric earthquakes show that it is possible for more than one segment to rupture during a large quake or for ruptures to overlap into adjacent segments.

The last major earthquake on the southern portion of the San Andreas fault was the 1857 Fort Tejon (Mw 7.8) event. This is the largest earthquake reported in California. The 1857 surface rupture broke the Cholame, Carrizo, and Mojave segments, resulting in displacements of as much as 27 feet (9 meters) along the rupture zone. Peak ground accelerations in the Glendale area as a result of the 1857 earthquake are estimated to have been as high as 0.18g. Rupture of these fault segments as a group, during a single earthquake, is thought to occur with a recurrence interval of between 104 and 296 years.

The closest segment of the San Andreas fault to Glendale is the Mojave segment, located approximately 29 miles to the northeast of the City Center area. This segment is 83 miles (133 km) long, extending from approximately Three Points southward to just northwest of Cajon Creek, at the southern limit of the 1857 rupture (WGCEP, 1995). Using a slip rate of 30±8 millimeters per year (mm/yr) and a characteristic displacement of 4.5±1.5 meters (m), the Working Group on California Earthquake Probabilities (WGCEP, 1995) derived a recurrence interval of 150 years for this segment. The Mojave segment is estimated to be capable of producing a magnitude 7.1 earthquake, which could result in peak ground accelerations in the Glendale area of about 0.13g. The WGCEP (1995) calculated that this segment has a 26 percent probability of rupturing sometime between 1994 and 2024.

The next closest segment of the San Andreas fault to the City of Glendale is the Carrizo segment, located approximately 41 miles from downtown. This fault segment, which is about 75 miles (121 km) long, also ruptured during the 1857 earthquake. Slip on this segment of the San Andreas fault was greater than on either of the two other segments, averaging 6 to 7 m, and locally displaying offsets of as much as 8 to 10 m. Several paleoseismological studies have been conducted on this segment of the San Andreas fault. This would suggest that this segment is well understood, but the data are often conflicting or inconclusive. Past earthquakes have been resolved in some trench exposures but not in others only a few miles away, and the slip estimates for past earthquakes as determined from these exposures also vary. To account for and resolve these discrepancies, the 1995 WGCEP used a slip rate of

34±3 mm/yr, and a slip per event of 7±4 m. The error bars on the slip-per-event data reflect the varying measurements that have been made along the fault length for the 1857 event. These values resolve into a recurrence interval of 206 (+149, -125 years). This segment is thought capable of producing a magnitude 7.2 earthquake, which could result in peak ground accelerations in the Glendale area of about 0.10g. The WGCEP (1995) also calculated an 18 percent probability that this fault segment will generate an earthquake sometime between 1994 and 2024.

The San Bernardino Mountains segment, located about 43 miles from downtown Glendale, is approximately 49 miles (78 km) long, and extends from Cajon Creek to the San Gorgonio Pass. This segment is a structurally complex zone that is poorly understood, and for which there are scant data on fault behavior. Using a slip rate of 24±5 mm/yr and a characteristic displacement of 3.5±1.0 m, the WGCEP (1995) derived a recurrence interval on this fault of 146 years. This fault segment is estimated capable of producing a magnitude 7.3 earthquake, which could result in peak ground accelerations in Glendale of about 0.1g. If this fault segment ruptures together with the Mojave and Coachella Valley segments, higher ground motions would be expected. In 1994, the WGCEP (1995) calculated that this fault segment had a 28 percent probability of rupturing sometime in the next 30 years. Since the fault has not ruptured yet, the probability that it will before the year 2024 has increased.

1.5.2 Verdugo Fault

The Verdugo fault is a 13 to 19-mile (21 to 30 km) long, southeast-striking fault that that extends along the northeastern edge of the San Fernando Valley, and at or near the southern flank of the Verdugo Mountains, through the cities of Glendale and Burbank. Weber et al. (1980) first reported southwest-facing scarps 2 to 3 meters high in the alluvial fan deposits in the Burbank and west Glendale areas, and other subsurface features indicative of faulting. Weber et al. (1980) relied on these scarps, on offset alluvial deposits at two localities, and on a subsurface groundwater cascade beneath Verdugo Wash to suggest that movement on this fault is youthful, but no age estimates were provided. Weber et al. (1980) further suggested that this fault is a shallow, north-dipping reverse fault responsible for uplift of the Verdugo Mountains, and proposed that the fault zone is approximately 1 km wide. For nearly 20 years since Weber et al.'s (1980) report, the Verdugo fault was not studied, but in the last few years, recognizing the potential threat that this fault poses to the Los Angeles metropolitan region, several researchers have started to investigate this fault.

Some researchers have relied on deep subsurface data, primarily oil well records and geophysical data to review the subsurface geology of the San Fernando Valley area, including the characteristics of the Verdugo fault (Tsutsumi and Yeats, 1999; Langenheim et al., 2000; Pujol et al., 2001). Results of these studies suggest that the Verdugo fault changes in character from a reverse fault adjacent to the Pacoima Hills, near its northwestern terminus, to a normal fault at the southwest edge of the Verdugo Mountains. To the north, the Verdugo fault appears to merge with both the Mission Hills and Northridge Hills faults. To the south, the fault is on trend with the Eagle Rock fault, but it is still unclear whether these faults are connected. Vertical separation on the Verdugo fault is at least 1,000 meters (3,300 feet), based on the structural relief between the valley floor and the crest of the Verdugo Mountains and other indicators (Tsutsumi and Yeats, 1999). Even though some of the data suggest that the Verdugo fault is a reverse fault, there are several researchers who now propose that the Verdugo fault is a left-lateral strike-slip fault (Walls et al., 1998; Dolan, personal communication, 2002).

Other investigators have taken a more direct, hands-on approach to study this fault, but finding locations suitable for trenching has been difficult in the extensively developed San Fernando Valley. Dolan and Tucker (1999) tried to better define the location and recency of activity of the Verdugo fault by conducting geological and geophysical studies across the inferred trace of the fault in Brand Park. They used closely spaced boreholes drilled in a line perpendicular to the trend of the fault, and ground penetrating radar to look for stratigraphic anomalies that could be suggestive of faulting. They identified one possible anomaly that could be the Verdugo fault and excavated a trench across the suspect area. However, the sediments exposed in the trench were too friable to maintain the trench open long enough to conduct their study. Dolan and Tucker believe that they did locate a fault, but they are uncertain about whether or not the fault is a recent strand of the Verdugo fault. Realizing that the Brand Park site may not yield any additional, useful information, Dolan and Tucker (1999) shifted their attention to another potential trenching site, at Palm Park in Burbank. Unfortunately, their studies at Palm Park were equally unsuccessful at locating and characterizing this fault (Dolan, personal communication, 2002).

Slip rate on the Verdugo fault is poorly constrained, and currently estimated at about 0.5 mm/yr (CDMG, 1996). The fault's recurrence interval is unknown; however, the fault's southern segment is thought to have ruptured during the Holocene, and the fault is therefore considered active (Jennings, 1994). Based on its length, the Verdugo fault is thought capable of generating magnitude 6.0 to 6.8 earthquakes. A magnitude 6.7 earthquake on this fault would generate peak ground accelerations in the Glendale area of about 0.6g to 0.7g. Higher accelerations can be expected locally. Given the high accelerations that this fault is estimated capable of generating in Glendale, an earthquake scenario on this fault was modeled for loss estimation using HAZUS (see Section 1.9, below).

1.5.3 Hollywood Fault

The Hollywood fault is the eastern 9-mile (14 km) long segment of the Santa Monica – Hollywood fault system that forms the southern margin of the Santa Monica Mountains (locally known as the Hollywood Hills). It has also been considered the westward extension of the Raymond fault (see Section 1.5.4 below). From east to west, the fault traverses the Hollywood section of Los Angeles, and the cities of West Hollywood and Beverly Hills. Its eastern end is mapped immediately south of Glendale's southern boundary (see Plate 1-2). Movement on the Hollywood fault over geologic time is thought responsible for the growth of the Hollywood Hills, which is why earlier researchers characterized this fault as a northward-dipping reverse fault. However, recent studies by Dolan et al. (1997, 2000a) and Tsutsumi et al. (2001) show that the Hollywood fault is primarily a left-lateral strike-slip fault. A lateral component of movement on this fault is consistent with its linear trace and steep, 80- to 90-degree dips (reverse faults typically have irregular, arcuate traces and shallow dips).

The Santa Monica – Hollywood fault system has not produced any damaging historical earthquakes, and it has had only relatively minor microseismic activity. Subsurface studies by Dolan et al. (2000a) suggest that the Hollywood fault moves infrequently. The most recent surface-rupturing earthquake on this fault appears to have occurred 7,000 to 9,500 years ago, and another earthquake appears to have occurred in the last 10,000 to 22,000 years (Dolan et al., 2000a). These data suggest that the fault either has a slow rate of slip (of between 0.33 and 0.75 mm/yr), or that it breaks in large-magnitude events. Interestingly, the recent past history of earthquakes on the Hollywood fault is remarkably similar to that of the Sierra Madre fault. Paleoseismologists are currently researching the possibility that earthquakes on the Sierra Madre fault trigger rupture of the Santa Monica – Hollywood fault system. If this is the case, then large earthquakes in the Los Angeles region may cluster in time, releasing a significant amount of strain over a geologically short time period, followed by lengthy periods of seismic quiescence.

Based on its length, the Hollywood fault is thought capable of generating a Mw ~6.4 to 6.6 earthquake. A conservative magnitude 6.4 earthquake on the Hollywood fault is thought capable of generating peak ground accelerations of about 0.55g in Glendale, near City Hall. Even higher accelerations, of as much as 0.7g can be expected along the southernmost portion of the City, near the eastern end of the fault.

1.5.4 Raymond Fault

The Raymond (or Raymond Hills) fault is a left-lateral, strike-slip fault about 13 miles (20 km) long that extends across the San Gabriel Valley, along the eastern and southern margins of Pasadena, and through the northern reaches of Arcadia, San Marino and South Pasadena. The westernmost portion of the Raymond fault is mapped just south of the City of Glendale (see Plate 1-2). The fault produces a very obvious south-facing scarp along much of its length, which led many geologists to favor reverse-slip as the predominant sense of fault motion. However, left-deflected channels, shutter-ridges, sag ponds, and pressure ridges indicate that the Raymond fault is predominantly a left-lateral strike-slip fault. This sense of motion is confirmed by the seismological record, especially by the mainshock and aftershock sequence to the 1988 Pasadena earthquake of local magnitude (ML) 5.0 that probably occurred on this fault (Jones et al., 1990; Hauksson and Jones, 1991). Investigators have suggested that the Raymond fault transfers slip southward from the Sierra Madre fault zone to other fault systems (Walls et al., 1998).

The Raymond fault was recently trenched in San Marino, at the Los Angeles Arboretum in Arcadia (Weaver and Dolan, 2000), and in eastern Pasadena (Dolan et al., 2000b) where significant data on the recent history of this fault were collected. These studies indicate that the most recent surface-rupturing earthquake on this fault occurred 1,000 to 2,000 years ago, and that between three and five earthquakes occurred on this fault between 41,500 and 31,500 years ago. This suggests that the fault either breaks in cluster earthquakes, or that several more surface-rupturing earthquakes have occurred on this fault that were not detected in the trenches. Proposed slip rates on the fault vary from a minimum of 1.5 mm/yr (Weaver and Dolan, 2000) to 4 (+1, -0.5) mm/yr (Marin et al., 2000; Dolan et al., in review). Weaver and Dolan (2000) also suggest an average recurrence interval for this fault of about 3,000 years.

A conservative magnitude 6.5 earthquake on the Raymond fault would generate peak ground accelerations in the Glendale area of about 0.55g. However, the paleoseismic data suggest that this fault is capable of generating larger earthquakes, in the 7.0 magnitude range (Dolan et al., 2000b). If this is the case, stronger ground shaking as a result of an earthquake on this fault could be experienced in Glendale.

1.5.5 Sierra Madre Fault

The Sierra Madre fault zone is a north-dipping reverse fault zone approximately 47 miles (75 km) long that extends along the southern flank of the San Gabriel Mountains from San Fernando to San Antonio Canyon, where it continues southeastward as the Cucamonga fault. The Sierra Madre fault has been divided into five segments, and each segment seems to have a different rate of activity.

The northwestern-most segment of the Sierra Madre fault (the San Fernando segment) ruptured in 1971, causing the Mw 6.7 San Fernando (or Sylmar) earthquake. As a result of this earthquake, the Sierra Madre fault has been known to be active. In the 1980s, Crook and others (1987) studied the Transverse Ranges using general geologic and geomorphic mapping, coupled with a few trenching locations, and suggested that the segments of the Sierra Madre fault east of the San Fernando segment have not generated major earthquakes in several thousands of years, and possibly as long as 11,000 years. By California's definitions of active faulting, most of the Sierra Madre fault would therefore be classified as not active. Then, in the mid 1990s, Rubin et al. (1998) trenched a section of the Sierra Madre fault in Altadena, at the Loma Alta Park, and determined that this segment has ruptured at least twice in the last 15,000 years, causing magnitude 7.2 to 7.6 earthquakes. This suggests that the Los Angeles area is susceptible to infrequent, but large near-field earthquakes on the Sierra Madre fault. Rubin et al.'s (1998) trenching data show that during the last earthquake, this fault trace shifted as much as 13 feet (4 meters) at the surface, and that total displacement in the last two events adds to more than 34 feet (10.5 meters)!

Although the fault seems to slip at a rate of only between 0.5 and 1 mm/yr (Walls et al., 1998), over time, it can accumulate a significant amount of strain. The paleoseismic data obtained at the Loma Alta Park site were insufficient to estimate the recurrence interval and the age of the last surface-rupturing event on this segment of the fault. However, Tucker and Dolan (2001) trenched the east Sierra Madre fault at Horsethief Canyon and obtained data consistent with Rubin et al.'s (1998) findings. At Horsethief Canyon, the Sierra Madre fault last ruptured about 8,000 to 9,000 years ago. Using a slip rate of 0.6 mm/yr and a slip per event of 5 meters, resolves into a recurrence interval of about 8,000 years. If the last event occurred more than 8,000 years ago, it is possible that these segments of the Sierra Madre fault are near the end of their cycle, and therefore likely to generate an earthquake in the not too distant future.

Given the data presented above, and since the Sierra Madre fault extends across the northern reaches of the Glendale area, this fault poses a significant hazard to the City. The deterministic analysis for the Glendale City Center area estimates peak ground accelerations of about 0.46g, based on a magnitude 7.0 earthquake on the segment of the Sierra Madre fault that extends through the City of Glendale. A larger earthquake on this fault, of magnitude between 7.2 and 7.6, could generate significantly stronger peak ground accelerations, especially in the northern portion of the City. Specific losses in Glendale as a result of an earthquake on the Sierra Madre fault are discussed in detail in Section 1.9, below. If the San Fernando segment of the Sierra Madre fault ruptured, causing a magnitude 6.7 earthquake, peak ground accelerations of about 0.28g are anticipated in the southern portion of Glendale, near City Hall. As before, stronger ground accelerations would be expected in the northern reaches of the City, closer to the fault.

1.5.6 Elysian Park Fault

The Whittier Narrows earthquake of October 1, 1987 occurred on a previously unknown blind thrust fault underneath the eastern part of the Los Angeles basin. Davis et al. (1989) used oil field data to construct cross-sections showing the subsurface geology of the basin, and concluded that the Whittier Narrows earthquake occurred on a thrust ramp they called the Elysian Park thrust fault. They modeled the Elysian Park as a shallow-angle, reverse-motion fault 6 to 10 miles below the ground surface generally located between the Whittier fault to the southeast, and the Hollywood fault to the west-northwest. Although blind thrusts do not extend to the Earth's surface, they are typically expressed at the surface by a series of hills or mountains. Davis et al. (1989) indicated that the Elysian Park thrust ramp is expressed at the surface by the Santa Monica Mountains, and the Elysian, Repetto, Montebello and Puente Hills.

Davis et al. (1989) estimated a long-term slip rate on the Elysian Park of between 2.5 and 5.2 mm/yr. Dolan et al. (1995) used a different approach to estimate a slip rate on the Elysian Park fault of about 1.7 mm/yr with a recurrence interval of about 1,475 years. Then, in 1996, Shaw and Suppe re-interpreted the subsurface geology of the Los Angeles basin, proposed a new model for what they call the Elysian Park trend, and estimated a slip rate on the thrust ramp beneath the Elysian Park trend of 1.7±0.4 mm/yr. More recently, Shaw and Shearer (1999) relocated the main shock and aftershocks of the 1987 Whittier Narrows earthquake, and showed that the earthquake sequence occurred on an east-west trending buried thrust they called the Puente Hills thrust (rather than the northwest-trending Elysian Park thrust).

Given the enormous amount of research currently underway to better characterize the blind thrust faults that underlie the Los Angeles basin, the Elysian Park thrust fault will most likely undergo additional significant re-interpretations. In fact, Shaw and Shearer (1999) suggest that the Elysian Park thrust fault is no longer active. However, since this statement is under consideration, and the Elysian Park thrust is still part of the active fault database for southern California (CGS, previously CDMG, 1996), we have considered this fault as a potential seismic source in Glendale. If this fault caused a magnitude 6.7 earthquake, it is estimated that Glendale would experience peak ground accelerations of about 0.38g.

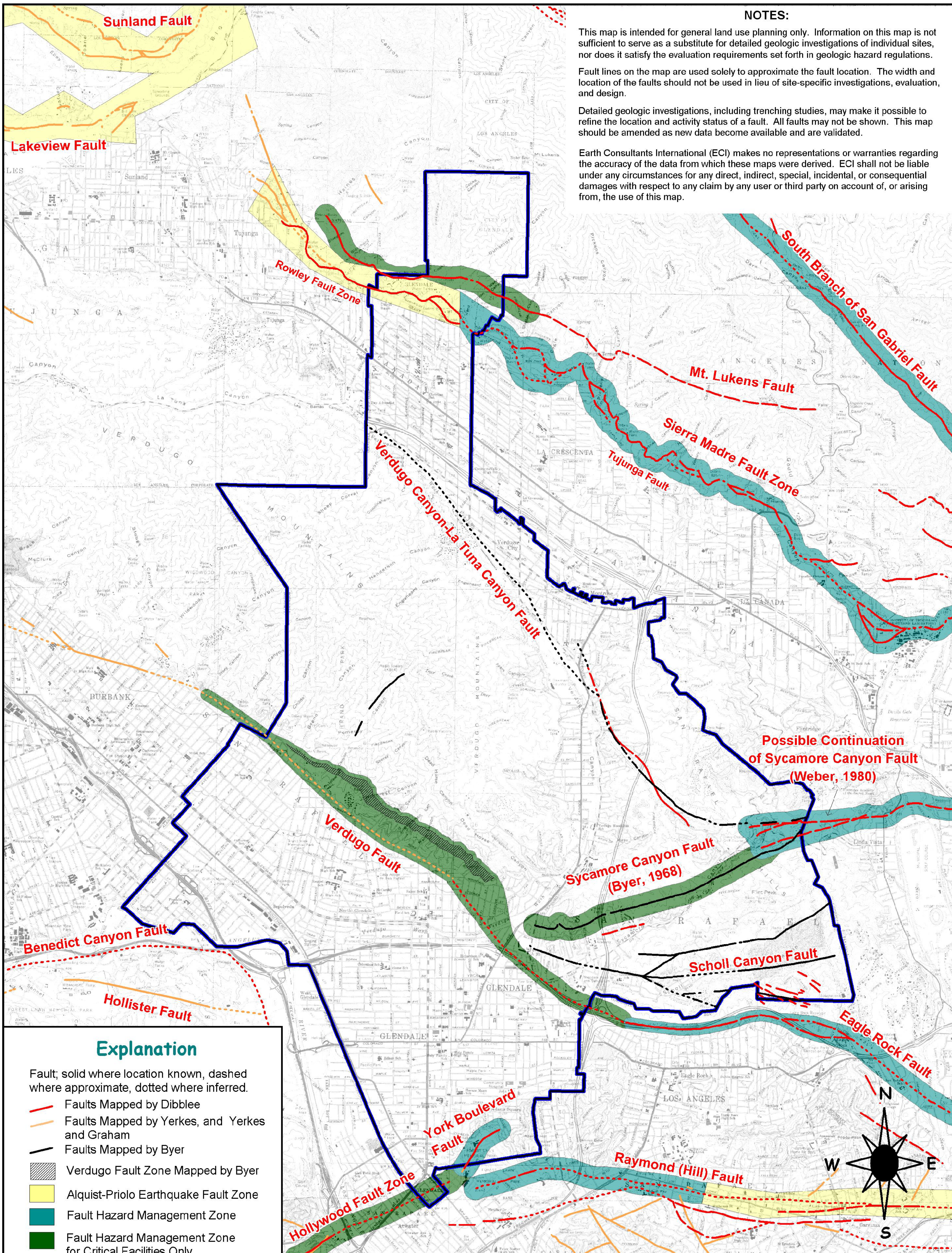
1.6 Potential Sources of Fault Rupture

1.6.1 Primary Fault Rupture

Primary fault rupture refers to fissuring and offset of the ground surface along a rupturing fault during an earthquake. Primary ground rupture typically results in a relatively small percentage of the total damage in an earthquake, but being too close to a rupturing fault can cause severe damage to structures. As discussed previously, development constraints within active fault zones were implemented in 1972 with passage of the California Alquist-Priolo Earthquake Fault Zoning Act. The Alquist-Priolo Act prohibits the construction of new habitable structures astride an active fault and requires special geologic studies to locate, and evaluate whether a fault has ruptured the ground surface in the last about 11,000 years. If an active fault is encountered, structural setbacks from the fault are defined.

In the Glendale vicinity, the CGS has identified the Rowley fault (a section of the Sierra Madre fault) and the Raymond fault as sufficiently active and well defined to require zoning under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act. The Alquist-Priolo zones designated by the CGS for these faults are shown on Plate 1-2. Only the Rowley fault zone extends into the City of Glendale proper, so the Raymond fault is not discussed further below. Other faults that have been mapped in Glendale but have not been zoned by the California Geological Survey are discussed in more detail below.

The **Rowley fault** is the first segment of the **Sierra Madre fault** to the east of the fault traces that ruptured the ground surface during the 1971 Sylmar earthquake (see Plate 1-2; the Lakeview fault is the easternmost fault that ruptured the surface in 1971. The Sunland fault to the north did not break, but extensive landsliding occurred in the Sunland fault area in response to movement on the Lakeview fault). Where the Rowley fault has been mapped in



NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Fault lines on the map are used solely to approximate the fault location. The width and location of the faults should not be used in lieu of site-specific investigations, evaluation, and design.

Detailed geologic investigations, including trenching studies, may make it possible to refine the location and activity status of a fault. All faults may not be shown. This map should be amended as new data become available and are validated.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Explanation

Fault; solid where location known, dashed where approximate, dotted where inferred.

- Faults Mapped by Dibblee
- Faults Mapped by Yerkes, and Yerkes and Graham
- Faults Mapped by Byer
- Verdugo Fault Zone Mapped by Byer
- Alquist-Priolo Earthquake Fault Zone
- Fault Hazard Management Zone
- Fault Hazard Management Zone for Critical Facilities Only

Scale: 1:60,000

1000 0 1000 2000 3000
Meters

5000 0 5000 10000 15000
Feet

Glendale City Limit

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Weber, 1980; Dibblee, 1989a, 1989b, 1991a, 1991b, 2002; Rubin, 1992; Yerkes, 1997; Yerkes and Graham, 1997; Byer, 1968.

City of Glendale California

Earth Consultants International

Project Number: 2103
Date: October, 2003

Fault Map

Glendale, California

Plate 1-2

the town of Tujunga, it consists of at least three fault planes in a zone of brecciated granodiorite that is thrust over very coarse conglomerate and basalt flows. In Glendale, the Rowley fault has been mapped as a single strand that bifurcates at its eastern end, near Ward Canyon (see Plate 1-2). The fault has been well located as evidenced by a single solid line on the map. Farther to the east, the fault is not as well defined and is therefore not currently zoned under the Alquist-Priolo Act criteria.

Geologic studies conducted soon after the 1971 earthquake suggested that the last rupture on the San Fernando segment of the Sierra Madre fault prior to 1971 had occurred less than 200 years before (Bonilla, 1973). However, a more recent trenching study in the immediate vicinity of Bonilla's trench suggests that this fault has only broken twice in the last 3,500 to 4,000 years, including the 1971 rupture (Fumal et al., 1995), which suggests this fault has a recurrence interval of about 2,000 years rather than 200 years. Nevertheless, the San Fernando segment appears to be more active than other segments of the Sierra Madre fault, as first suggested by Crook et al. (1987), who proposed that the rest of the fault zone has not moved in many thousands of years, possibly since before the Holocene. Relatively recent trenching studies by Rubin et al. (1998) in Altadena, approximately 6 miles to the southeast of Glendale, have shown that the segment of the Sierra Madre fault through Altadena, and possibly through Glendale, has a long recurrence interval, but that it has moved in the Holocene and is therefore active. The segment of fault that Rubin et al. (1998) trenched has ruptured the ground surface twice in the last about 15,000 years, with the most recent earthquake having occurred probably 8,000 to 9,000 years ago. Other studies farther to the southeast, at Horsethief Canyon in the San Dimas area, also showed that this section of the Sierra Madre fault has not broken in the last 8,000 years, but that the fault has slipped as much as 46 feet (14 m) between 8,000 and 24,000 years ago (Tucker and Dolan, 2001). These two studies suggest that the central segments of the Sierra Madre fault, between the San Fernando segment on the north and the Cucamonga fault on the south, ruptures at the same time in infrequent but large magnitude (M>7) events.

Based on the data presented above, the section of the Rowley fault not currently zoned by the State should nevertheless be considered active. A fault hazard management zone that includes and extends beyond the inferred traces of the fault is proposed, as shown on Plate 1-2. Geologic studies similar in scope to those required by the CGS in Alquist-Priolo Earthquake Fault Zones should be conducted if new development or redevelopment is proposed in the fault hazard management zone. As detailed geological investigations are conducted, the location and activity status (some of the splays may be proven to have not moved within the last 11,000 years) of the faults shown on Plate 1-2 may be refined or modified. The map should be amended as new data become available and are validated.

The **Mt. Lukens fault** is a west- to northwest-trending thrust fault that extends across the south flank of the San Gabriel Mountains, between Haynes Canyon on the northwest, and the Los Angeles Crest Highway on the southeast. In the Glendale area, the fault is mapped about 1,500 feet to the north of the Sierra Madre fault. Because of its closeness to the Sierra Madre fault, Smith (1978) previously mapped this fault as part of the Sierra Madre fault system. The fault was mapped more recently by Crook et al. (1987), and Dibblee (1991a, 1991b, 2002). Although the Mt. Lukens thrust fault appears to be a separate fault system, in the Glendale area this fault is so close to the Sierra Madre fault that if the Sierra Madre fault ruptured, it could trigger co-seismic movement on the Mt. Lukens thrust fault. Therefore, a fault hazard management zone for critical facilities is herein proposed for the Mt. Lukens fault.

The **Verdugo Canyon – La Tuna Canyon fault** is oriented in a northwesterly direction through Glendale, where it inferred at the base of the northeast flank of the Verdugo Mountains, but changes to a more westerly orientation in the La Tuna Canyon, where the fault reportedly controls the location of the drainage. This fault was proposed by geologists from the Metropolitan Water District (as mentioned in Envicom, 1975), who indicated that the fault is north-dipping in the La Tuna Canyon, and south-dipping farther east. The fault was also inferred under the Verdugo Wash, where a deep, northwest-trending depression in the basement rocks has been reported (California State Water Rights Board, 1962 as discussed in Envicom, 1975). The sections of the fault described above are not recognized by Dibblee (1991a, 1991b) in his geologic maps of the area, but farther to the east, in the San Rafael Hills, Dibblee maps a fault that is consistent with Byer's (1968) mapping. Farther to the east, the fault appears to swing to the east, where it may join the Sycamore Canyon fault (see Plate 1-2). There are no data available to suggest that this fault is active; Envicom (1975) indicate that the fault is not a barrier to groundwater flow in the Verdugo Wash area, and should therefore be considered inactive.

The **Sycamore Canyon fault** zone consists of a series of discontinuous faults that trend northeasterly in the vicinity of Sycamore Canyon, in the western part of the San Rafael Hills. Byer (1968) extended this fault zone westward across and along the north side of Sycamore Canyon, but more recent geologic maps of the area (Dibblee, 1989b) do not show this trace (see Plate 1-2). Although the presence of sheared clays along a portion of the fault, in the eastern San Rafael Hills, has contributed to some slope instability problems, Weber (1980) reported that no evidence that the fault zone is active has been found. Weber (1980) also suggested that topographic lineaments observed in the northeastern San Rafael Hills (within Pasadena) might be an extension of the Sycamore Canyon fault. This connection has not been proven out by field evidence. However, Weber's (1980) lineaments coincide with lineaments in the younger alluvial fan deposits in the Pasadena area mapped by Rubin (1992) that may be the surface expression of the most recently active traces of the Sierra Madre fault. Therefore, in the Pasadena area, the Sycamore Canyon fault has been zoned, with geological studies required in this zone if the proposed development is a critical facility. A similar approach is recommended for the southwest-trending section of the Sycamore Canyon fault that extends through the San Rafael Hills in the Glendale area. Even if the fault is not active, the sheared clays that have been reported along the fault zone may be highly expansive. If a structure is built across the surface trace of these clays, and these clays swell when wetted, the structure could experience some structural damage (see Section 2.4.3). Engineered mitigation measures such as deep removals along the clay zone and replacement with non-expansive materials may be warranted.

The **Verdugo fault** strikes southeasterly across the southern edge of the Verdugo Mountains, through the central portion of Glendale, and across the foot of the San Rafael Hills, where it seems to merge with the Eagle Rock fault. The Verdugo fault separates the plutonic and metamorphic rocks that crop out in the Verdugo Mountains from the alluvial fan deposits to the southwest. The fault is probably coincident with the sharp break in slope along the southwestern edge of the Verdudo Mountains, where many of the alluvial fans that emanate from the mountains merge together to form the gently southwest-facing alluvial surface between the mountains and the Los Angeles River. In older aerial photographs of the area, Dolan and Tucker (1999) interpreted several small scarps that could represent the last surface rupturing event on this fault, but these scarps have all been obliterated by development. In fact, the inferred trace of the Verdugo fault is covered with buildings and roads along almost its entire length, which makes it difficult to find suitable field study areas where the fault can be exposed and studied.

To date, there has been only one study in Glendale that attempted to locate and date the most recent surface rupturing events on this fault. This study, conducted in Brand Park (Dolan and Tucker, 1999) may have constrained the location of the fault zone in the area, but the actual fault trace could not be identified due to the discontinuous nature of the alluvial fan deposits that they encountered, and because the trench excavated was too unstable to be entered safely. Dolan and Tucker (1999) proposed that the trace of the Verdugo fault in this area is approximately 300 feet (90 m) farther to the north of where it is inferred by Dibblee (1991), extending in a southeasterly direction through the area between the Tea House and the Dr.'s House at Brand Park. Unfortunately, Dolan and Tucker (1999) could not confirm the fault location elsewhere due to landscaping and previous ground surface modifications at the park (for parking lots and playing fields) that precluded the possibility of excavating another trench.

Previous investigators (Byer, 1968) also identified a wide zone of faulting farther to the north that consists of laterally discontinuous fault planes that generally dip to the northeast. Locally, they observed minor shearing of the terrace deposits, which suggested to them relatively youthful movement on the fault. This zone of faulting is identified in Plate 1-2 with cross-hatchures. This zone of faulting may not be the most recent fault trace, but there are insufficient data to determine whether or not these faults are active. Therefore, this fault zone should be investigated in the future if development is proposed in the area..

Although the most recently active traces of the Verdugo fault are not well located, most investigators agree that the Verdugo fault is active and therefore has the potential to generate future surface-rupturing earthquakes. Earlier investigators suggested that this fault is primarily a thrust fault, responsible for uplift of the Verdugo Mountains (R.T. Frankian & Associates, 1968; Weber et al., 1980; Weber, 1980), but more recently, it is thought that the fault displays primarily left-lateral strike-slip movement (Walls et al., 1998; Dolan, personal communication, 2002). A fault hazard management zone that includes the inferred trace of the fault as mapped by Dibblee (1991), but is wider to the north, to include the break in slope and the zone of faulting mapped by Byer (1968) is proposed. As with the fault hazard management zone for the Rowley fault, geological studies should be conducted for sites within the Verdugo fault hazard management zone if new development or significant redevelopment is proposed.

The **Eagle Rock fault** crosses the southwestern part of Pasadena and the northernmost portion of Los Angeles, including along a 2-mile stretch of the Ventura (134) Freeway, where it separates crystalline bedrock on the north from sedimentary rock on the south (see Plates 1-2 and 2-1). The portion of the Eagle Rock fault east of the San Rafael Hills was originally termed the "San Rafael fault" by Weber (1980), who suggested the fault was active in late Quaternary time. This conclusion was based on the presence of linear topographic features across the Pleistocene alluvial fan surface east of the San Rafael Hills. Farther to the southeast, the fault appears to join the Raymond fault, however the exact location of the eastern terminus of the Eagle Rock fault is not well defined, and its geomorphology in this area is much more subdued than that of the Raymond fault. Consequently, Weaver and Dolan (2000) concluded that a connection with the Raymond fault could not be established with certainty. To the west, the Eagle Rock fault lies on trend with the Verdugo fault, although in the subsurface, based on gravity data, Weber (1980) suggests that there may be a step or bend between the two fault zones. Although very little is known about the Eagle Rock fault, given that it appears to be related to active faults in the area, such as the Verdugo fault, it should be considered potentially active, subject to further study. For example, although the Eagle Rock fault may not be capable of generating an earthquake, it may break co-seismically with movement on the Verdugo fault. A fault hazard management zone for this fault has been recommended in the Pasadena area, similar to that for the Sierra Madre and Verdugo faults (Plate 1-2). Extension of this zone between Pasadena and Glendale is recommended, but the limits of this zone are predominantly outside the City of Glendale.

The **Scholl Canyon faults** were mapped by Byer (1968), and Envicom (1975) suggested that this fault zone connects the Verdugo fault in the west to the Eagle Rock fault in the east. However, more recent mapping by Dibblee (1989b) does not even show these faults, and there are no data data available to indicate that these fault traces, if even present, are active.

The **York Boulevard fault** is a short, northeast trending fault first mapped by Lamar (1970), and more recently by Dibblee (1989a, 1989b) in the Adams Hill area of southern Glendale. According to Lamar (1970) the fault does not offset older, Pleistocene-age deposits, and is therefore not active. However, the York Boulevard fault does appear to separate the Raymond fault from the Hollywood fault, in an area where according to Weber (1980) there is step or bend in the fault zones at depth. Alternatively, the York Boulevard fault may be the eastern extension of the Hollywood fault. Based on these relationships, and given that both the Raymond and Hollywood faults are active, Envicom (1975) suggested that the York Boulevard fault may be active also. Given its length, the York Boulevard fault is not likely to generate an earthquake, but it may move co-seismically with an earthquake on the Hollywood fault. Therefore, a hazard management zone for this fault is proposed, where geological studies to locate and characterize the fault would be required prior to development of a critical facility.

The eastern terminus of the **Hollywood fault** has been mapped along the southwesternmost corner of the City of Glendale (see Plate 1-2). This fault has been shown to be active in the Los Angeles and West Hollywood areas, where recently obtained data indicate that this fault breaks in infrequent, but large magnitude earthquakes. In the West Hollywood area, the inferred location of the fault along Sunset Boulevard has been proven to be incorrect; the fault is farther south, in the valley. However, in the Los Angeles area, the fault does appear to be at the mountain front. The fault has been well located in the Hollywood Hills, just to the west of Glendale, by Yerkes (1967) and Dibblee (1991b), but as it extends across the Los Angeles River and into the Glendale area, its location is less well defined. Given that this fault is considered active, the inferred location of the fault in Glendale is herein included in a fault hazard management zone. Because of its location in the floodplain of the Los Angeles River, where shallow ground water and deep Holocene sediments are anticipated, geologic studies to locate this fault may prove to be difficult and expensive, requiring the use of deep boreholes rather than trenching.

A few other minor, **unnamed faults** have been mapped both in the San Rafael Hills and in the Verdugo Mountains (see Plate 1-2). These faults appear to be confined to the older bedrock units, with no impact on the younger terrace and alluvial deposits, and are therefore not considered active. Fault hazard management zones for these faults are not considered warranted, however, geologists studying these areas should continue to look for evidence of Holocene movement on these faults. As new data are developed and verified by third-party reviewers, Plate 1-2 should be amended to reflect any changes in the location, recency of activity and need for future studies on these faults.

MITIGATION OF PRIMARY FAULT RUPTURE

Paleoseismic studies on the Sierra Madre fault suggest that slip per event on this fault exceeds 13 feet (4 m). Other faults in the area may experience similar amounts of displacement if they break during an earthquake. Most engineered structures are not designed to withstand this amount of movement, so buildings that straddle a fault will most certainly be damaged beyond repair if and when the fault breaks. Since it is impractical to reduce the damage potential to acceptable levels by engineering design, the most appropriate mitigation measure is to simply avoid placing structures on or near active fault traces. However, because of the complexity of most active fault zones, particularly at the surface where they may become braided, splayed or segmented, locating and evaluating the active traces is often not an easy task. A geologic investigation, which may include fault trenching, must be performed if structures designed for human occupancy are proposed within an Alquist-Priolo Earthquake Fault Zone. The study must evaluate whether or not an active segment of the fault extends across the area of proposed development. Based on the results of these studies, appropriate structural setbacks can be recommended. Specific guidelines for evaluating the hazard of fault rupture are presented in Note 49, published by the CGS, which is available on the world wide web at: www.consrv.ca.gov/DMG/pubs/notes/49/index.htm. Similar studies are proposed herein for the fault hazard management zones defined around faults not yet zoned as active by the State, but which have either been shown to be active, or are thought to be active by association with other nearby, active faults.

A common misperception regarding setbacks is that they are always 50 feet from the active fault trace. In actuality, geologic investigations are required to characterize the ground deformation associated with an active fault. Based on these studies, specific setbacks are delineated. If a fault trace is narrow, with little or no associated ground deformation, a setback distance less than 50 feet may be recommended. Conversely, if the fault zone is wide, with multiple splays, or is poorly defined, a setback distance greater than 50 feet may be warranted. Structural setbacks from reverse faults, such as the Sierra Madre, may also be asymmetrical across the trace of the fault, with a wider setback zone defined for the upper plate, where past earthquakes have shown that most damage occurs. State law allows local jurisdictions to establish minimum setback distances from a hazardous fault, and some communities have taken a prescriptive approach to this issue, establishing specific setbacks from a fault, rather than allowing for different widths depending on the circumstances. For example, the City of West Hollywood requires a 50-foot setback from the Hollywood fault for conventional structures, and 100-foot setback for critical and high-occupancy facilities.

1.6.2 Secondary Fault Rupture and Related Ground Deformation

Primary fault rupture is rarely confined to a simple line along the fault trace. As the rupture reaches the brittle surface of the ground, it commonly spreads out into complex fault patterns of secondary faulting and ground deformation. In the 1992 Landers earthquake, the zone of deformation around the main trace ranged up to hundreds of feet wide (Lazarte et al., 1994). Surface displacement and distortion associated with secondary faulting and deformation can be relatively minor or can be large enough to cause significant damage to structures.

Secondary fault rupture refers to ground surface displacements along faults other than the main traces of active regional faults. Unlike the regional faults, these subsidiary faults are not deeply rooted in the Earth's crust and are not capable of producing damaging earthquakes on their own. Movement along these faults generally occurs in response to movement on a nearby regional fault. The zone of secondary faulting can be quite large, even in a moderate-sized earthquake. For instance, in the 1971 San Fernando quake, movement along subsidiary faults occurred as much as 2 km from the main trace (Ziony and Yerkes, 1985).

Secondary faulting in thrust fault terrain is very complex, and numerous types of faulting have been reported. These include splays, branches, tear faults, shallow thrust faults, and back-thrusts, as well as faults that form in the shallow subsurface as a result of folding in sedimentary layers. Identified by Yeats (1982), fold-related types include flexural slip faults (slippage along bedding planes), and bending-moment faults (tensional or compressional tears in the axis of folding). A striking example of flexural slip along bedding planes occurred during the Northridge earthquake, when numerous bedding plane faults ruptured across the surface of newly graded roads and pads in a subdivision near Santa Clarita. The ruptures were accompanied by uplift and warping of the nearby ground (Treiman, 1995).

Secondary ground deformation includes fracturing, shattering, warping, tilting, uplift and/or subsidence. Such deformation may be relatively confined along the rupturing fault, or spread over a large region (such as the regional uplift of the Santa Susana Mountains after the Northridge earthquake). Deformation and secondary faulting can also occur without primary ground rupture, as in the case of ground deformation above a blind (buried) thrust fault.

MITIGATION OF SECONDARY FAULT RUPTURE AND GROUND DEFORMATION

Geotechnical investigations for future developments, especially in the hillside areas of the City, should consider this hazard. The methodology for evaluating these features is similar to that used for evaluating primary fault rupture (CGS, previously CDMG Note 49).

Lazarte (1994) outlined three approaches to mitigation of fault rupture hazard, which could be applied to secondary deformation as well. The first is avoidance, by the use of structural setback zones. The second is referred to as “geotechnical engineering.” This method consists of placing a compacted fill blanket, or a compacted fill blanket reinforced with horizontal layers of geogrid, over the top of the fault trace. This is based on observations that the displacement across a distinct bedrock fault is spread out and dissipated in the overlying fill, thus reducing the severity of the displacement at the surface. The third method is “structural engineering.” This refers to strengthening foundation elements to withstand a limited amount of ground deformation. This is based on studies of foundation performance in the Landers earthquake showing that structures overlying major fault ruptures suffered considerable damage but did not collapse. Application of the second and third methods requires a thorough understanding of the geologic environment and thoughtful engineering judgment. This is because quantifying the extent of future displacement is difficult, and there are no proven engineering standards in place to quantify the amount of mitigation needed (for instance how thick a fill blanket is needed).

1.7 Geologic Hazards Resulting from Seismic Shaking

1.7.1 Liquefaction and Related Ground Failure

Liquefaction is a geologic process that causes various types of ground failure. Liquefaction typically occurs in loose, saturated sediments primarily of sandy composition, in the presence of ground accelerations over 0.2g (Borchardt and Kennedy, 1979; Tinsley and Fumal, 1985). When liquefaction occurs, the sediments involved have a total or substantial loss of shear strength, and behave like a liquid or semi-viscous substance. Liquefaction can cause structural distress or failure due to ground settlement, a loss of bearing capacity in the foundation soils, and the buoyant rise of buried structures. The excess hydrostatic pressure generated by ground shaking can result in the formation of sand boils or mud spouts, and/or seepage of water through ground cracks.

As indicated above, there are three general conditions that need to be met for liquefaction to occur. The first of these – strong ground shaking of relatively long duration - can be expected to occur in the Glendale area as a result of an earthquake on any of several active faults in the region (see Section 1.5 above). The second condition - loose, or unconsolidated, recently deposited sediments consisting primarily of silty sand and sand - occurs along the Verdugo Wash and the lower reaches of its tributaries, and in the alluvial plain south of the Verdugo Mountains and the San Rafael Hills. Young alluvial sediments have also been mapped in the area between the San Gabriel and Verdugo Mountains, in the northern portion of the City, but close to the San Gabriel Mountains these sediments are coarser grained and may therefore not be susceptible to liquefaction. Alluvial sediments have also been mapped in the canyons emanating from the San Rafael Hills, such as Scholl and Sycamore canyons (see Plate 2-1, in Chapter 2). The third condition – water-saturated sediments within about 50 feet of the surface – has been known to occur historically only in the Verdugo Wash north of surface projection of the Verdugo fault, and in the floodplain of the Los Angeles River. Therefore, these are the areas with the potential to experience future liquefaction-induced ground displacements. The areas are shown on Plate 1-3, and are discussed further below.

The Verdugo fault appears to cause a step or series of steps in the ground water surface, with groundwater levels consistently lower on the south side of the fault zone. Brown (1975) indicated that these steps in the groundwater surface are due to offsets in the bedrock surface at depth along the fault zone, but that no surface evidence of a fault forming groundwater barrier has been found in the area. Nevertheless, a barrier to groundwater must be present in this area to cause the water on the north side of the fault zone to rise to within 50 feet of the ground surface. Although not mapped, shallow groundwater conditions may occur locally in those sections of the south-flowing canyons emanating from the Verdugo Mountains that are located north of the Verdugo fault zone. Ground water may be perched on top of the bedrock surface, and ponded behind the fault zone. Since the bedrock that forms these mountains weathers to sand-sized particles, some of the canyons may contain sediments susceptible to liquefaction. The potential for these areas to liquefy should be evaluated on a case-by-case basis.

The San Fernando Valley narrows to essentially a point in the area of Glendale between the Verdugo Mountains to the north, and the Hollywood Hills to the south, in the area where the Los Angeles River veers to the south. Due to this constriction, or reduction in the cross-sectional area of the water-bearing section of the valley, the ground water rises. Historically the ground water in this area has risen to within less than 50 feet of the ground surface. As a result, this portion of the basin, which is underlain by unconsolidated, young sediments, is susceptible to liquefaction. Plate 1-3 shows those areas of Glendale that the California Geological Survey (CDMG, 1999) has identified as susceptible to liquefaction based on an extensive database of boreholes and groundwater levels measured in wells. Areas near existing stream channels, such as Verdugo Wash and the Los Angeles River, are thought to be especially vulnerable to liquefaction. Much of the liquefaction-related ground failure in the city of Simi Valley during the Northridge earthquake was concentrated near the Arroyo Simi. A study by the CGS found that most of the property damage occurred in poorly engineered fills placed over the natural, pre-development channels of the Arroyo Simi, where ground water is very shallow (Barrows et al., 1994).

The types of ground failure typically associated with liquefaction are explained below.

Lateral Spreading - Lateral displacement of surficial blocks of soil as the result of liquefaction in a subsurface layer is called lateral spreading. Even a very thin liquefied layer can act as a hazardous slip plane if it is continuous over a large enough area. Once liquefaction transforms the subsurface layer into a fluid-like mass, gravity plus inertial forces caused by the earthquake may move the mass downslope towards a cut slope or free face (such as a river channel or a canal). Lateral spreading most commonly occurs on gentle slopes that range between 0.3° and 3°, and can displace the ground surface by several meters to tens of meters. Such movement damages pipelines, utilities, bridges, roads, and other structures. During the 1906 San Francisco earthquake, lateral spreads with displacements of only a few feet damaged every major pipeline. Thus, liquefaction compromised San Francisco's ability to fight the fires that caused about 85 percent of the damage (Tinsley et al., 1985).

Flow Failure - The most catastrophic mode of ground failure caused by liquefaction is flow failure. Flow failure usually occurs on slopes greater than 3°. Flows are principally liquefied soil or blocks of intact material riding on a liquefied subsurface. Displacements are often in the tens of meters, but in favorable circumstances, soils can be displaced for tens of miles, at velocities of tens of miles per hour. For example, the extensive damage to Seward and Valdez, Alaska, during the 1964 Great Alaskan earthquake was caused by submarine flow failures (Tinsley et al., 1985).

Ground Oscillation - When liquefaction occurs at depth but the slope is too gentle to permit lateral displacement, the soil blocks that are not liquefied may separate from one another and oscillate on the liquefied zone. The resulting ground oscillation may be accompanied by the opening and closing of fissures (cracks) and sand boils, potentially damaging structures and underground utilities (Tinsley et al., 1985).

Loss of Bearing Strength - When a soil liquefies, loss of bearing strength may occur beneath a structure, possibly causing the building to settle and tip. If the structure is buoyant, it may float upward. During the 1964 Niigata, Japan earthquake, buried septic tanks rose as much as 3 feet, and structures in the Kwangishicho apartment complex tilted as much as 60° (Tinsley et al., 1985).

Ground Lurching - Soft, saturated soils have been observed to move in a wave-like manner in response to intense seismic ground shaking, forming ridges or cracks on the ground surface. At present, the potential for ground lurching to occur at a given site can be predicted only generally. Areas underlain by thick accumulation of colluvium and alluvium appear to be the most susceptible to ground lurching. Under strong ground motion conditions, lurching can be expected in loose, cohesionless soils, or in clay-rich soils with high moisture content. In some cases, the deformation remains after the shaking stops (Barrows et al., 1994).

LIQUEFACTION MITIGATION MEASURES

In accordance with the SHMA, all projects within a State-delineated Seismic Hazard Zone for liquefaction must be evaluated by a Certified Engineering Geologist and/or Registered Civil Engineer (this is typically a civil engineer with training and experience in soil engineering). Most often however, it is appropriate for both the engineer and geologist to be

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

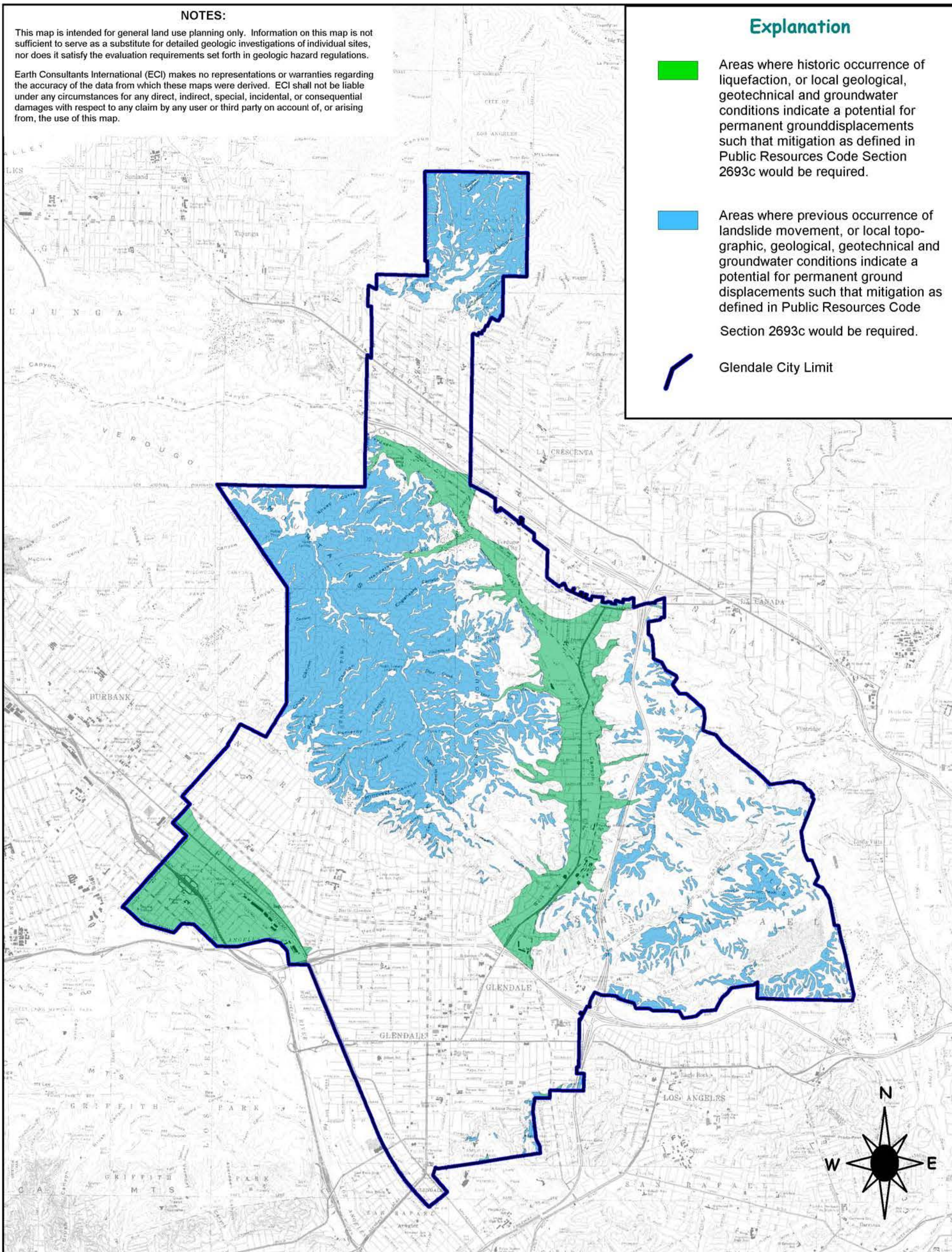
Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Explanation

Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent grounddisplacements such that mitigation as defined in Public Resources Code Section 2693c would be required.

Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693c would be required.

Glendale City Limit



Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER

Sources: California , Division of Mines and Geology, 1999 (Sunland Los Angeles, Burbank, Hollywood, and Pasadena Quadrangles)

City of Glendale California

Earth Consultants International

Project Number: 2103
Date: July, 2003

Seismic Hazards Map

Glendale, California

Plate 1-3

involved in the evaluation, and in the implementation of the mitigation measures. In order to assist in the implementation of the SHMA, the State has published specific guidelines for evaluating and mitigating liquefaction (California Division of Mines and Geology, 1997). Furthermore, in 1999, a group sponsored by the Southern California Earthquake Center (SCEC, 1999) published recommended procedures for carrying out the CGS guidelines. In general, a liquefaction study is designed to identify the depth, thickness, and lateral extent of any liquefiable layers that would affect the project site. An analysis is then performed to estimate the type and amount of ground deformation that might occur, given the seismic potential of the area.

Mitigation measures generally fall in one of two categories: ground improvement or foundation design. Ground improvement includes such measures as removal and recompaction of low density soils, removal of excess ground water, in-situ ground densification, and other types of ground improvement (such as grouting or surcharging). Special foundations that may be recommended range from deep piles to reinforcement of shallow foundations (such as post-tensioned slabs). Mitigation for lateral spreading may also include modification of the site geometry or inclusion of retaining structures. The type (or combinations of types) of mitigation depend on the site conditions and on the nature of the proposed project (CGS, previously CDMG, 1997).

It should be remembered that Seismic Hazard Zone Maps may not show all areas that have the potential for liquefaction, nor is information shown on the maps sufficient to serve as a substitute for detailed site investigations.

1.7.2 Seismically Induced Settlement

Under certain conditions, strong ground shaking can cause the densification of soils, resulting in local or regional settlement of the ground surface. During strong shaking, soil grains become more tightly packed due to the collapse of voids and pore spaces, resulting in a reduction of the thickness of the soil column. This type of ground failure typically occurs in loose granular, cohesionless soils, and can occur in either wet or dry conditions. Unconsolidated young alluvial deposits are especially susceptible to this hazard. Artificial fills may also experience seismically induced settlement. Damage to structures typically occurs as a result of local differential settlements. Regional settlement can damage pipelines by changing the flow gradient on water and sewer lines, for example.

Fracturing and offset of the ground can also occur. During the Northridge earthquake, extensive ground fracturing developed along the margins of Potrero Canyon at the alluvium/bedrock contact. Investigations after the earthquake showed that the fractures, which were both tensional and compressional in nature, formed as a result of ground lurching and differential settlement in the alluvium (Rymer et al., 1995).

Those portions of the Glendale area that may be susceptible to seismically induced settlement are the alluvial surfaces and larger drainages that are underlain by late Quaternary alluvial sediments (similar to the liquefaction-susceptible areas shown on Plate 1-3). Sites near the base of the Verdugo and San Gabriel Mountains and the San Rafael Hills, and along the margins of the larger drainage channels may be particularly vulnerable.

MITIGATION OF SEISMICALLY INDUCED SETTLEMENT

Mitigation measures for seismically induced settlement are similar to those used for liquefaction. Recommendations are provided by the project's geologist and soil engineer, following a detailed geotechnical investigation of the site. Overexcavation and recompaction is the most commonly used method to densify soft soils susceptible to settlement. Deeper overexcavation below final grades, especially at cut/fill, fill/natural or alluvium/bedrock contacts may be recommended to provide a more uniform subgrade. Overexcavation should also be performed so that large differences in fill thickness are not present across individual lots. In some cases, strengthened foundations and/or fill compaction to a minimum standard that is higher than that required by the UBC may be recommended.

1.7.3 Seismically Induced Slope Failure

Strong ground motions can worsen existing unstable slope conditions, particularly if coupled with saturated ground conditions. Seismically induced landslides can overrun structures, people or property, sever utility lines, and block roads, thereby hindering rescue operations after an earthquake. Over 11,000 landslides were mapped shortly after the Northridge earthquake, all within a 45-mile radius of the epicenter (Harp and Jibson, 1996). Although numerous types of earthquake-induced landslides have been identified, the most widespread type generally consists of shallow failures involving surficial soils and the uppermost weathered bedrock in moderate to steep hillside terrain (these are also called disrupted soil slides). Rock falls and rock slides on very steep slopes are also common. The 1989 Loma Prieta and Northridge earthquakes showed that reactivation of existing deep-seated landslides also occurs (Spittler et al., 1990; Barrows et al., 1995).

A combination of geologic conditions leads to landslide vulnerability. These include high seismic potential; rapid uplift and erosion resulting in steep slopes and deeply incised canyons; highly fractured and folded rock; and rock with inherently weak components, such as silt or clay layers. The orientation of the slope with respect to the direction of the seismic waves (which can affect the shaking intensity) can also control the occurrence of landslides.

Several areas in Glendale have been identified as vulnerable to seismically induced slope failure (see Plate 1-3). The mountainous region along the northern reaches of the City (the San Gabriel Mountains) is susceptible to slope failure due to the steep terrain. The crystalline bedrock that crops out in the northern and central portions of the San Rafael Hills is locally highly fractured and weathered. In steep areas, strong ground shaking can cause slides or rockfalls in this material. Slope failures can also occur in the western and central portions of the City, in the Verdugo Mountains, where locally steep terrain is combined with fractured igneous and metamorphic rock units. Numerous small landslides can be expected to occur in these areas in response to an earthquake on the Sierra Madre, the Verdugo or other nearby faults. For a more detailed assessment of potential slope instability in the Glendale area, refer to Section 2.4.1 of this report.

MITIGATION OF SEISMICALLY INDUCED SLOPE FAILURE

Existing slopes that are to remain adjacent to or within developments should be evaluated for the geologic conditions mentioned above. In general, slopes steeper than about 15 degrees are most susceptible, however failures can occur on flatter slopes if unsupported weak rock units are exposed in the slope face. For suspect slopes, appropriate geotechnical investigation and slope stability analyses should be performed for both static and dynamic (earthquake) conditions. For deeper slides, mitigation typically includes such measures as buttressing slopes or regrading the slope to a different configuration. Protection from rockfalls or surficial slides can often be achieved by protective devices such as barriers, rock fences, retaining structures, catchment areas, or a combination of the above. The runout area of the slide at the base of the slope, and the potential bouncing of rocks must also be considered. If it is not feasible to mitigate the unstable slope conditions, building setbacks should be imposed.

In accordance with the SHMA, all development projects within a State-delineated Seismic Hazard Zone for seismically induced landsliding must be evaluated by a State-licensed engineering geologist and/or civil engineer (for landslide investigation and analysis, this typically requires both). In order to assist in the implementation of the SHMA, the State has published specific guidelines for evaluating and mitigating seismically induced landslides (CGS, previously CDMG, 1997). More recently, the Southern California Earthquake Center (SCEC, 2002) sponsored the publication of the "Recommended Procedures for Implementation of DMG Special Publication 117." These procedures are expected to be adopted by the Los Angeles County and other cities and counties in California in the next year or so, pending some slight revisions and further discussions among the geotechnical community.

1.7.4 Deformation of Sidehill Fills

Sidehill fills are artificial fill wedges typically constructed on natural slopes to create roadways or level building pads. Deformation of sidehill fills was noted in earlier earthquakes, but this phenomenon was particularly widespread during the Northridge earthquake. Older, poorly engineered road fills were most commonly affected, but in localized areas, building pads of all ages experienced deformation. The deformation was usually manifested as ground cracks at the cut/fill contacts, differential settlement in the fill wedge, and bulging of the slope face. The amount of displacement on the pads was generally 8 cm or less, but this resulted in minor to severe property damage (Stewart et al., 1995). This phenomenon was most common in relatively thin fills (9 m or less) placed near the tops or noses of narrow ridges (Barrows et al., 1995).

MITIGATION OF SIDEHILL FILL DEFORMATION

Hillside grading designs should be evaluated during site-specific geotechnical investigations to determine if there is a potential for this hazard. There are currently no proven engineering standards for mitigating sidehill fill deformation, consequently current published research on this topic should be reviewed by project consultants at the time of their investigation. It is thought that the effects of this hazard on structures may be reduced by the use of post-tensioned foundations, deeper overexcavation below finish grades, deeper overexcavation on cut/fill transitions, and/or higher fill compaction criteria.

1.7.5 Ridgetop Fissuring and Shattering

Linear, fault-like fissures occurred on ridge crests in a relatively concentrated area of rugged terrain in the Santa Cruz Mountains during the Loma Prieta earthquake. Shattering of the surface soils on the crests of steep, narrow ridgelines occurred locally in the 1971 San Fernando earthquake, but was widespread in the 1994 Northridge earthquake. Ridgetop shattering (which leaves the surface looking as if it was plowed) by the Northridge earthquake was observed as far as 22 miles away from the epicenter. In the Sherman Oaks area, severe damage occurred locally to structures located at the tops of relatively high (greater than 100 feet), narrow (typically less than 300 feet wide) ridges flanked by slopes steeper than about 2.5:1 (horizontal:vertical). It is generally accepted that ridgetop fissuring and shattering is a result of intense amplification or focusing of seismic energy due to local topographic effects (Barrows et al., 1995).

Ridgetop shattering can be expected to occur in the topographically steep portions of the San Gabriel Mountains north of Glendale, in the Verdugo Mountains, and locally in the San Rafael Hills. These areas are for the most part undeveloped, so the hazard associated with ridgetop shattering is relatively low. However, above ground storage tanks, reservoirs and utility towers are often located on top of ridges, and during strong ground shaking, these can fail or topple over, with the potential to cause widespread damage to development downslope (storage tanks and reservoirs), or disruptions to the lifeline systems (utility towers).

MITIGATION OF RIDGETOP FISSURING AND SHATTERING

Projects located in steep hillside areas should be evaluated for this hazard by an Engineering Geologist. Although it is difficult to predict exactly where this hazard may occur, avoidance of development along the tops of steep, narrow ridgelines is probably the best mitigation measure. For large developments, recontouring of the topography to reduce the conditions conducive to ridgetop amplification, along with overexcavation below finish grades to remove and recompact weak, fractured bedrock might reduce this hazard to an acceptable level.

1.7.6 Seiches

Reservoirs, lakes, ponds, swimming pools and other enclosed bodies of water are subject to potentially damaging oscillations (sloshing), or seiches. This hazard is dependent upon specific earthquake parameters (e.g. frequency of the seismic waves, distance and direction from the epicenter), as well as site-specific design of the enclosed bodies of water, and is thus difficult to predict.

MITIGATION OF SEICHES

The degree of damage to small bodies of water, such as to swimming pools, would likely be minor. However, property owners downslope from pools that could seiche during an earthquake should be aware of the potential hazard to their property should a pool lose substantial amounts of water during an earthquake. Site-specific design elements, such as baffles, to reduce the potential for seiches is warranted in tanks and in open reservoirs or ponds where overflow or failure of the structure may cause damage to nearby properties. Damage to water tanks in recent earthquakes, such as the 1992 Landers-Big Bear sequence and the 1994 Northridge, resulted from seiching. As a result, the American Water Works Association (AWWA) Standards for Design of Steel Water Tanks (D-100) provide new criteria for seismic design (Lund, 1994).

1.8 Vulnerability of Structures to Earthquake Hazards

This section assesses the earthquake vulnerability of structures and facilities common in the Glendale area. This analysis is based on past earthquake performance of similar types of buildings in the U.S. The effects of design earthquakes on particular structures within the city are beyond the scope of this study. However, utilizing a recent standardized methodology developed for the Federal Emergency Management Agency (FEMA), general estimates of losses are provided in Section 1.9 of this report.

Although it is not possible to prevent earthquakes from occurring, their destructive effects can be minimized. Comprehensive hazard mitigation programs that include the identification and mapping of hazards, prudent planning and enforcement of building codes, and expedient retrofitting and rehabilitation of weak structures can significantly reduce the scope of an earthquake disaster.

With these goals in mind, the State Legislature passed Senate Bill 547, addressing the identification and seismic upgrade of Unreinforced Masonry (URM) buildings. In addition, the law encourages identification and mitigation of seismic hazards associated with other types of potentially hazardous buildings, including pre-1971 concrete tilt-ups, soft-stories, mobile homes, and pre-1940 homes.

1.8.1 Potentially Hazardous Buildings and Structures

Most of the loss of life and injuries due to an earthquake are related to the collapse of hazardous buildings and structures. FEMA (1985) defines a hazardous building as “any inadequately earthquake resistant building, located in a seismically active area, that presents a potential for life loss or serious injury when a damaging earthquake occurs.” Building codes have generally been made more stringent following damaging earthquakes.

Building damage is commonly classified as either structural or non-structural. Structural damage impairs the building's support. This includes any vertical and lateral force-resisting systems, such as frames, walls, and columns. Non-structural damage does not affect the integrity of the structural support system, but includes such things as broken windows, collapsed or rotated chimneys, unbraced parapets that fall into the street, and fallen ceilings.

During an earthquake, buildings get thrown from side to side and up and down. Given the same acceleration, heavier buildings are subjected to higher forces than lightweight buildings. Damage occurs when structural members are overloaded, or when differential movements between different parts of the structure strain the structural components. Larger earthquakes and longer shaking duration tend to damage structures more. The level of damage can be predicted only in general terms, since no two buildings undergo the exact same motions, even in the same earthquake. Past earthquakes have shown us, however, that some types of buildings are far more likely to fail than others.

Unreinforced Masonry Buildings - Unreinforced masonry buildings (URMs) are prone to failure due to inadequate anchorage of the masonry walls to the roof and floor diaphragms, lack of steel reinforcing, the limited strength and ductility of the building materials, and sometimes, poor construction workmanship. Furthermore, as these buildings age, the bricks and mortar tend to deteriorate, making the buildings even weaker.

In response to the 1986 URM Law, Glendale issued Chapter 58 of the City Code requiring all URMs in the City to be identified (see Section 1.3.6). In the year 2000, the City of Glendale reported to the Seismic Safety Commission that 703 URMs had been identified in the City. Of these, only 1 building (the Casa de Adobe de San Rafael) was considered of historical significance. By 2000, all 703 building owners had been notified about the hazards of URM construction, and 491 of the URMs had been retrofitted in accordance with the provisions of Chapter 58. Two more buildings had retrofit permits issued, but the work had not yet begun. Finally, another 206 URMs had been demolished or were slated for demolition, leaving only four buildings for which mitigation plans were not yet available (Seismic Safety Commission, 2000). In 2002, City records show that retrofitting had not yet begun at only two buildings, and that one other building was being retrofitted.

Soft-Story Buildings - Of particular concern are soft-story buildings (buildings with a story, generally the first floor, lacking adequate strength or toughness due to too few shear walls). Apartments above glass-fronted stores, and buildings perched atop parking garages are common examples of soft-story buildings. Collapse of a soft story and "pancaking" of the remaining stories killed 16 people at the Northridge Meadows apartments during the 1994 Northridge earthquake (EERI, 1994). There are many other cases of soft-story collapses in past earthquakes. The City of Glendale Engineering Section has identified approximately 520 buildings in the City that are of soft-story construction.

Wood-Frame Structures - Structural damage to wood-frame structures often results from an inadequate connection between the superstructure and the foundation. These buildings may slide off their foundations, with consequent damage to plumbing and electrical connections. Unreinforced masonry chimneys may also collapse. These types of damage are generally not life threatening, although they may be costly to repair. Wood frame buildings with stud walls generally perform well in an earthquake, unless they have no foundation or have a weak foundation constructed of unreinforced masonry or poorly reinforced concrete. In these cases, damage is generally limited to cracking of the stucco, which dissipates much of the earthquake's induced energy. The collapse of wood frame structures, if it happens, generally does not generate heavy debris, but rather, the wood and plaster debris can be cut or broken into smaller pieces by hand-held equipment and removed by hand in order to reach victims (FEMA, 1985).

Pre-Cast Concrete Structures - Partial or total collapse of buildings where the floors, walls and roofs fail as large intact units, such as large pre-cast concrete panels, cause the greatest loss of life and difficulty in victim rescue and extrication (FEMA, 1985). These types of buildings are common not only in southern California, but abroad. Casualties as a result of collapse of these structures in past earthquakes, including Mexico (1985), Armenia (1988), Nicaragua (1972), El Salvador (1986 and 2001), the Philippines (1990) and Turkey (1999) add to hundreds of thousands. In southern California, many of the parking structures that failed during the Northridge earthquake, such as the Cal-State Northridge and City of Glendale Civic Center parking structures, consisted of pre-cast concrete components (EERI, 1994).

Collapse of this type of structure generates heavy debris, and removal of this debris requires the use of heavy mechanical equipment. Consequently, the location and extrication of victims trapped under the rubble is generally a slow and dangerous process. Extrication of trapped victims within the first 24 hours after the earthquake becomes critical for survival. In most instances, however, post-earthquake planning fails to quickly procure equipment needed to move heavy debris. The establishment of Heavy Urban Search and Rescue teams, as recommended by FEMA (1985), has improved victim extrication and survivability. Buildings that are more likely to fail and generate heavy debris need to be identified, so that appropriate mitigation and planning procedures are defined prior to an earthquake.

Tilt-up Buildings - Tilt-up buildings have concrete wall panels, often cast on the ground, or fabricated off-site and trucked in, that are tilted upward into their final position. Connections and anchors have pulled out of walls during earthquakes, causing the floors or roofs to collapse. A high rate of failure was observed for this type of construction in the 1971 San Fernando and 1987 Whittier Narrows earthquakes. Tilt-up buildings can also generate heavy debris.

Reinforced Concrete Frame Buildings - Reinforced concrete frame buildings, with or without reinforced infill walls, display low ductility. Earthquakes may cause shear failure (if there are large tie spacings in columns, or insufficient shear strength), column failure (due to inadequate rebar splices, inadequate reinforcing of beam-column joints, or insufficient tie anchorage), hinge deformation (due to lack of continuous beam reinforcement), and non-structural damage (due to the relatively low stiffness of the frame). A common type of failure observed following the Northridge earthquake was confined column collapse (EERI, 1994), where infilling between columns confined the length of the columns that could move laterally in the earthquake.

Multi-Story Steel Frame Buildings - Multi-story steel frame buildings generally have concrete floor slabs. However, these buildings are less likely to collapse than concrete structures. Common damage to these types of buildings is generally non-structural, including collapsed exterior curtain wall (cladding), and damage to interior partitions and equipment. Overall, modern steel frame buildings have been expected to perform well in earthquakes, but the 1994 Northridge earthquake broke many welds in these buildings, a previously unanticipated problem.

Older, pre-1945 steel frame structures may have unreinforced masonry such as bricks, clay tiles and terra cotta tiles as cladding or infilling. Cladding in newer buildings may be glass, infill panels or pre-cast panels that may fail and generate a band of debris around the building exterior (with considerable threat to pedestrians in the streets below). Structural damage may occur if the structural members are subject to plastic deformation which can cause permanent displacements. If some walls fail while others remain intact, torsion or soft-story problems may result.

Mobile Homes - Mobile homes are prefabricated housing units that are placed on isolated piers, jackstands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes are usually plywood, and outside surfaces are covered with sheet metal. Mobile homes typically do not perform well in earthquakes. Severe damage occurs when they fall off their supports, severing utility lines and piercing the floor with jackstands.

Combination Types - Buildings are often a combination of steel, concrete, reinforced masonry and wood, with different structural systems on different floors or different sections of the building. Combination types that are potentially hazardous include: concrete frame buildings without special reinforcing, precast concrete and precast-composite buildings, steel frame or concrete frame buildings with unreinforced masonry walls, reinforced concrete wall buildings with no special detailing or reinforcement, large capacity buildings with long-span roof structures (such as theaters and auditoriums), large unengineered wood-frame buildings, buildings with inadequately anchored exterior cladding and glazing, and buildings with poorly anchored parapets and appendages (FEMA, 1985). Additional types of potentially hazardous buildings may be recognized after future earthquakes.

In addition to building types, there are other factors associated with the design and construction of the buildings that also have an impact on the structures' vulnerability to strong ground shaking. Some of these conditions are discussed below:

Building Shape - A building's vertical and/or horizontal shape can also be important. Simple, symmetric buildings generally perform better than non-symmetric buildings. During an earthquake, non-symmetric buildings tend to twist as well as shake. Wings on a building tend to act independently during an earthquake, resulting in differential movements and cracking. The geometry of the lateral load-resisting systems also matters. For example, buildings with one or two walls made mostly of glass, while the remaining walls are made of concrete or brick, are at risk. Asymmetry in the placement of bracing systems that provide a building with earthquake resistance, can result in twisting or differential motions.

Pounding - Site-related seismic hazards may include the potential for neighboring buildings to "pound", or for one building to collapse onto a neighbor. Pounding occurs when there is little clearance between adjacent buildings, and the buildings "pound" against each other as they deflect during an earthquake. The effects of pounding can be especially damaging if the floors of the buildings are at different elevations, so that, for example, the floor of one building hits a supporting column of the other. Damage to a supporting column can result in partial or total building collapse.

1.8.2 Essential Facilities

Critical facilities are those parts of a community's infrastructure that must remain operational after an earthquake. Critical facilities include schools, hospitals, fire and police stations, emergency operation centers, and communication centers. Plate 1-4 shows the locations of the City's fire stations, police stations, schools, and other critical facilities. A vulnerability assessment for these facilities involves comparing the locations of these facilities to the hazardous areas identified in the City, including active and potentially active faults (Plate 1-2), liquefaction-susceptible areas (Plate 1-3), unstable slope areas (Plates 1-3 and 2-4), potential dam failure inundation areas (Plate 3-3), fire hazard zones (Plate 4-2), and sites that generate hazardous materials (Plate 5-1).

High-risk facilities, if severely damaged, may result in a disaster far beyond the facilities themselves. Examples include power plants, dams and flood control structures, freeway interchanges, bridges, and industrial plants that use or store explosives, toxic materials or petroleum products.

High-occupancy facilities have the potential of resulting in a large number of casualties or crowd-control problems. This category includes high-rise buildings, large assembly facilities, and large multifamily residential complexes.

Dependent-care facilities, such as preschools and schools, rehabilitation centers, prisons, group care homes, and nursing homes, house populations with special evacuation considerations.

Economic facilities, such as banks, archiving and vital record-keeping facilities, airports, and large industrial or commercial centers, are those facilities that should remain operational to avoid severe economic impacts.

It is crucial that critical facilities have no structural weaknesses that can lead to collapse. For example, the Federal Emergency Management Agency (FEMA, 1985) has suggested the following seismic performance goals for **health care facilities**:

- The damage to the facilities should be limited to what might be reasonably expected after a destructive earthquake and should be repairable and not be life-threatening.
- Patients, visitors, and medical, nursing, technical and support staff within and immediately outside the facility should be protected during an earthquake.

- Emergency utility systems in the facility should remain operational after an earthquake.
- Occupants should be able to evacuate the facility safely after an earthquake.
- Rescue and emergency workers should be able to enter the facility immediately after an earthquake and should encounter only minimum interference and danger.
- The facility should be available for its planned disaster response role after an earthquake.

1.8.3 Lifelines

Lifelines are those services that are critical to the health, safety and functioning of the community. They are particularly essential for emergency response and recovery after an earthquake. Furthermore, certain critical facilities designed to remain functional during and immediately after an earthquake may be able to provide only limited services if the lifelines they depend on are disrupted. Lifeline systems include water, sewage, electrical power, communication, transportation (highways, bridges, railroads, and airports), natural gas, and liquid fuel systems. The improved performance of lifelines in the 1994 Northridge earthquake, relative to the 1971 San Fernando earthquake, shows that the seismic codes upgraded and implemented after 1971 have been effective. Nevertheless, the impact of the Northridge quake on lifeline systems was widespread and illustrates the continued need to study earthquake impacts, to upgrade substandard elements in the systems, to provide redundancy in systems, to improve emergency response plans, and to provide adequate planning, budgeting and financing for seismic safety.

Some of the observations and lessons learned from the Northridge earthquake are summarized below (from Savage, 1995; Lund, 1996).

- Several electrical transmission towers were damaged or totally collapsed. Collapse was generally due to foundation distress in towers that were located near ridge tops where amplification of ground motion may have occurred. One collapse was the result of a seismically induced slope failure at the base of the tower.
- Damage to above ground water tanks typically occurred where piping and joints were rigidly connected to the tank, due to differential movement between the tank and the piping. Older steel tanks not seismically designed under current standards buckled at the bottom (called "elephant's foot"), in the shell, and on the roof. Modern steel and concrete tanks generally performed well.
- Significant damage occurred in water treatment plants due to sloshing in large water basins.
- A number of facilities did not have an emergency power supply or did not have enough power supply capacity to provide their essential services.
- Lifelines within critical structures, such as hospitals and fire stations, may be vulnerable. For instance, rooftop mechanical and electrical equipment is not generally designed for seismic forces. During the Northridge quake, rooftop equipment failed causing malfunctions in other systems.
- A 70-year old crude oil pipeline leaked from a cracked weld, spreading oil for 12 miles down the Santa Clara River.
- A freight train carrying sulfuric acid was derailed causing an 8,000-gallon acid spill and a 2,000-gallon diesel spill from the locomotive.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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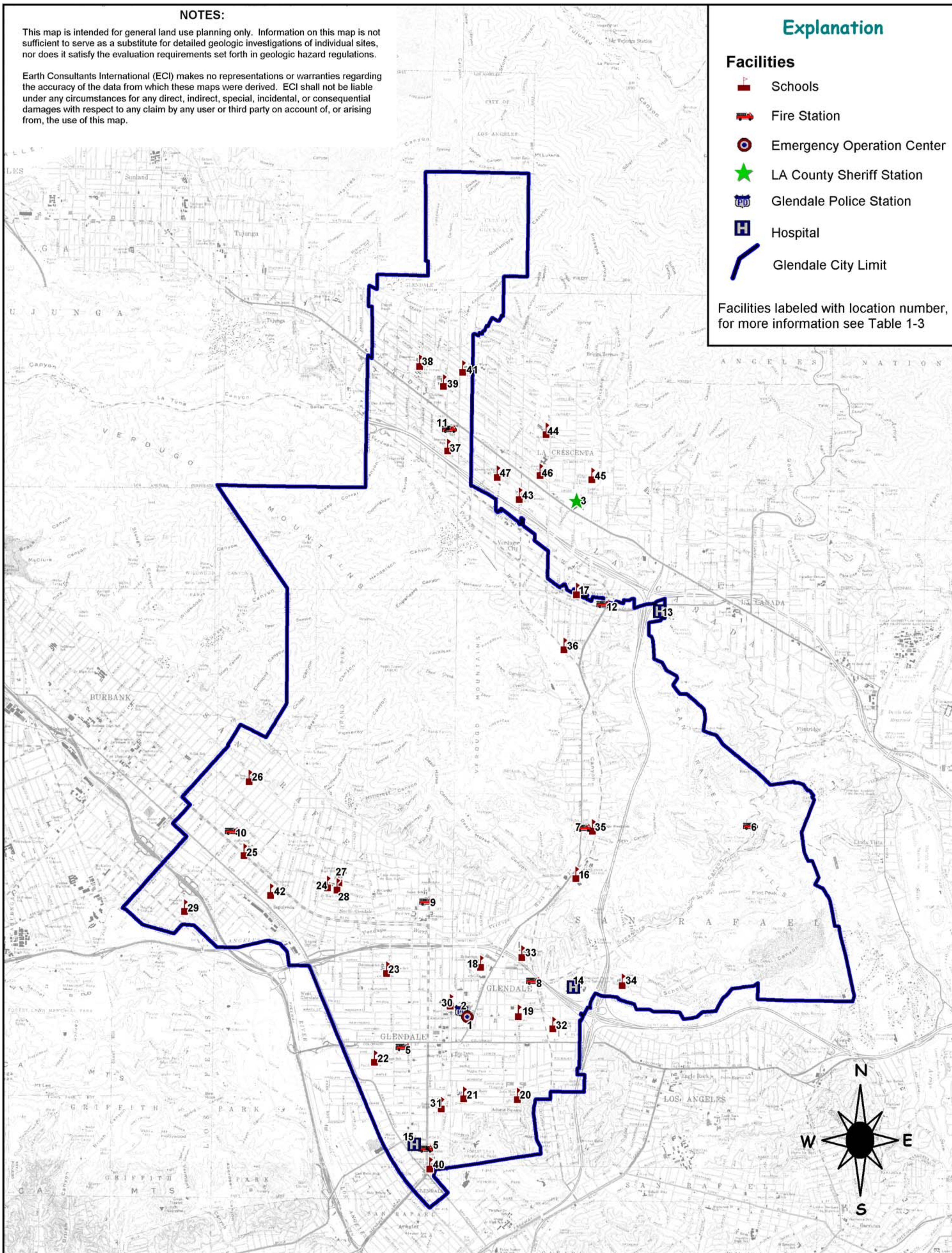

Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: City of Glendale Planning Department data

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Critical Facilities Map

Glendale, California

Plate 1-4

The above list is by no means a complete summary of the earthquake damage, but it does highlight some of the issues pertinent to the Glendale area. All lifeline providers should make an evaluation of the seismic vulnerability within their systems a priority. The evaluation should include a plan to fund and schedule the needed seismic mitigation.

1.9 HAZUS Earthquake Scenario Loss Estimations for the City of Glendale

HAZUS-99TM is a standardized methodology for earthquake loss estimation based on a geographic information system (GIS). A project of the National Institute of Building Sciences, funded by the Federal Emergency Management Agency (FEMA), it is a powerful advance in mitigation strategies. The HAZUS project developed guidelines and procedures to make standardized earthquake loss estimates at a regional scale. With standardization, estimates can be compared from region to region. HAZUS is designed for use by state, regional and local governments in planning for earthquake loss mitigation, emergency preparedness, response and recovery. HAZUS addresses nearly all aspects of the built environment, and many different types of losses. The methodology has been tested against the experience of several past earthquakes, and against the judgment of experts. Subject to several limitations noted below, HAZUS can produce results that are valid for the intended purposes.

Loss estimation is an invaluable tool, but must be used with discretion. Loss estimation analyzes casualties, damage and economic loss in great detail. It produces seemingly precise numbers that can be easily misinterpreted. Loss estimation's results, for example, may cite 4,054 left homeless by a scenario earthquake. This is best interpreted by its magnitude. That is, an event that leaves 4,000 people homeless is clearly more manageable than an event causing 40,000 homeless people; and an event that leaves 400,000 homeless would overwhelm a community's resources. However, another loss estimation that predicts 7,000 people homeless should probably be considered equivalent to the 4,054 result. Because HAZUS results make use of a great number of parameters and data of varying accuracy and completeness, it is not possible to assign quantitative error bars. Although the numbers should not be taken at face value, they are not rounded or edited because detailed evaluation of individual components of the disaster can help mitigation agencies ensure that they have considered all the important options.

The more community-specific the data that are input to HAZUS, the more reliable the loss estimation. HAZUS provides defaults for all required information. These are based on best-available scientific, engineering, census and economic knowledge. The loss estimations in this report have been tailored to Glendale by using a map of soil types for the City. HAZUS relies on 1990 Census data, but for the purposes of this study, we replaced the population by census tract data that came with the software with the 2000 Census data. Other modifications made to the data set before running the analyses include:

- updated the database of critical facilities, including the number and location of the fire and police stations in the City,
- revised the number of beds available in the three major hospitals in Glendale to better represent their current patient capacity, and
- upgraded the construction level for most unreinforced masonry buildings in the City to better represent the City's retrofitting efforts of the last decade.
- As useful as HAZUS seems to be, the loss estimation methodology has some inherent uncertainties. These arise in part from incomplete scientific knowledge concerning earthquakes and their effect upon buildings and facilities, and in part from the approximations and simplifications necessary for comprehensive analyses.

Users should be aware of the following specific limitations:

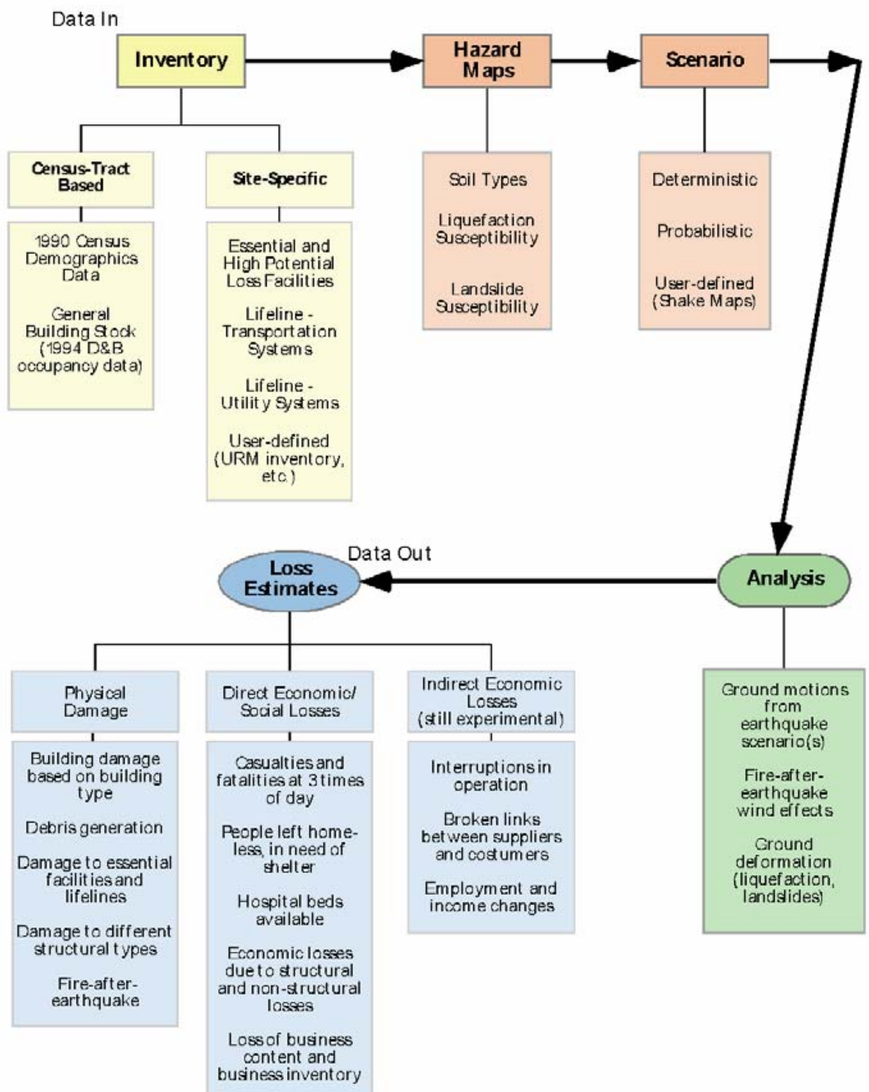
- HAZUS is driven by statistics, and thus is most accurate when applied to a region, or a class of buildings or facilities. It is least accurate when considering a particular site, building or facility.
- Losses estimated for lifelines may be less than losses estimated for the general building stock.
- Losses from smaller (less than M 6.0) damaging earthquakes may be overestimated.
- Pilot and calibration studies have not yet provided an adequate test concerning the possible extent and effects of landsliding.
- The indirect economic loss module is new and experimental. While output from pilot studies has generally been credible, this module requires further testing.
- The databases that HAZUS draws from to make its estimates are often incomplete or outdated (as discussed above, efforts were made to improve some of the datasets used for the analysis, but for some estimates, the software still relies on 1990 census tracts data and 1994 DNB economic reports). This is another reason the loss estimates should not be taken at face value.

1.9.1 Methodology, Terminology and Input Data Used in the Earthquake Loss Estimations for the City

The flow chart in Figure 1-4 illustrates the modules (or components) of a HAZUS analysis. The HAZUS software uses population data by census tract and general building stock data from Dunn & Bradstreet (DNB).

Essential facilities and lifeline inventory are located by latitude and longitude. However, the HAZUS inventory data for lifelines and utilities were developed at a national level and where specific data are lacking, statistical estimations are utilized. Specifics about the site-specific inventory data used in the models are discussed further in the paragraphs below. Other site-specific data used include soil types and liquefaction susceptible zones. The user then defines the earthquake scenario to be modeled, including the magnitude of the earthquake, and the location of the epicenter. Once all these data are input, the software calculates the loss estimates for each scenario.

The loss estimates include physical damage to buildings of different construction and occupancy types, damage to essential facilities and lifelines, number of after-earthquake fires and damage due to fire, and the amount of debris that is expected. The model also estimates the direct economic and social losses, including casualties and fatalities for three different times of the day, the number of people left homeless and number of people that will require shelter, number of hospital beds available, and the economic losses due to damage to the places of businesses, loss of inventory, and (to some degree) loss of jobs. The indirect economic losses component is still experimental; the calculations in the software are checked against actual past earthquakes, such as the 1989 Loma Prieta and 1994 Northridge earthquake, but indirect losses are hard to measure, and it typically takes years before these monetary losses can be quantified with any degree of accuracy. Therefore, this component of HAZUS is still considered experimental.



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Generalized Flow Chart Summarizing the HAZUS Methodology

Figure 1-4

Critical Facilities: HAZUS breaks critical facilities into two groups: essential facilities and high potential loss (HPL) facilities. Essential facilities provide services to the community and should be functional after an earthquake. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. The essential facility module in HAZUS determines the expected loss of functionality for these facilities. The damage probabilities for essential facilities are determined on a site-specific basis (i.e., at each facility). Economic losses associated with these facilities are computed as part of the analysis of the general building stock. Data required for the analysis include occupancy classes (current building use) and building structural type, or a combination of essential facilities building type, design level and construction quality factor. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

Transportation and Utility Lifelines: HAZUS divides the lifeline inventory into two systems: transportation and utility lifelines. The transportation system includes seven components: highways, railways, light rail, bus, ports, ferry and airports. The utility lifelines include potable water, wastewater, natural gas, crude and refined oil, electric power and communications. If site-specific lifeline utility data are not provided for these analyses, HAZUS performs a statistical calculation based on the population served.

General Building Stock Type and Classification: HAZUS provides damage data for buildings based on these structural types:

- Concrete
- Mobile Home
- Precast Concrete
- Reinforced Masonry Bearing Walls
- Steel
- Unreinforced Masonry Bearing Walls
- Wood Frame

and based on these occupancy (usage) classifications:

- Residential
- Commercial
- Industrial
- Agriculture
- Religion
- Government and
- Education

Building Damage Classification - Loss estimation for the general building stock is averaged for each census tract. Building damage classifications range from slight to complete. As an example, the building damage classification for wood frame buildings is provided below. Wood-frame structures comprise the City's most numerous building type.

<u>**Wood, Light Frame**</u>:

- Slight Structural Damage: Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
- Moderate Structural Damage: Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by

small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.

- Extensive Structural Damage: Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of “room-over-garage” or other “soft-story” configurations; small foundations cracks.
- Complete Structural Damage: Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Incorporation of Historic Building Code Design Functions - Estimates of building damage are provided for “High”, “Moderate” and “Low” seismic design criteria. Buildings of newer construction (e.g., post-1973) are best designated by “High.” Buildings built after 1940, but before 1973, are best represented by “Moderate.” If built before about 1940 (i.e., before significant seismic codes were implemented), “Low” is most appropriate. A large percentage of buildings in the City of Glendale fall in the “Moderate” and “High” seismic design criteria.

Fires Following Earthquakes - Fires following earthquakes can cause severe losses. In some instances, these losses can outweigh the losses from direct damage, such as collapse of buildings and disruption of lifelines. Many factors affect the severity of the fires following an earthquake, including but not limited to: ignition sources, types and density of fuel, weather conditions, functionality of water systems, and the ability of fire fighters to suppress the fires.

A complete fire-following-earthquake model requires extensive input about the readiness of local fire departments and the types and availability (functionality) of water systems. The fire following earthquake model presented here is simplified. With better understanding of fires that will be garnered after future earthquakes, forecasting capability will undoubtedly improve. For additional information regarding this topic, refer to Section 4.6.

Debris Generation - HAZUS estimates two types of debris. The first is debris that falls in large pieces, such as steel members or reinforced concrete elements. These require special treatment to break into smaller pieces before they are hauled away. The second type of debris is smaller and more easily moved with bulldozers and other machinery and tools. This type includes brick, wood, glass, building contents and other materials.

Estimating Casualties - Casualties are estimated based on the assumption that there is a strong correlation between building damage (both structural and non-structural) and the number and severity of casualties. In smaller earthquakes, non-structural damage will most likely control the casualty estimates. In severe earthquakes where there will be a large number of collapses and partial collapses, there will be a proportionately larger number of fatalities. Data regarding earthquake-related injuries are not of the best quality, nor are they available for all building types. Available data often have insufficient information about the type of structure in which the casualties occurred and the casualty-generating mechanism. HAZUS casualty estimates are based on the injury classification scale described in Table 1-3.

Table 1-3: Injury Classification Scale

Injury Severity Level	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization.
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life-threatening status.
Severity 3	Injuries which pose an immediate life-threatening condition if not treated adequately and expeditiously. The majority of these injuries are the result of structural collapse and subsequent entrapment or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured.

In addition, HAZUS produces casualty estimates for three times of day:

- Earthquake striking at 2:00 a.m. (population at home)
- Earthquake striking at 2:00 p.m. (population at work/school)
- Earthquake striking at 5:00 p.m. (commute time).

Displaced Households/Shelter Requirements - Earthquakes can cause loss of function or habitability of buildings that contain housing. Displaced households may need alternative short-term shelter, provided by family, friends, temporary rentals, or public shelters established by the City, County or by relief organizations such as the Red Cross or Salvation Army. Long-term alternative housing may require import of mobile homes, occupancy of vacant units, net emigration from the impacted area, or, eventually, the repair or reconstruction of new public and private housing. The number of people seeking short-term public shelter is of most concern to emergency response organizations. The longer-term impacts on the housing stock are of great concern to local governments, such as cities and counties.

Economic Losses - HAZUS estimates structural and nonstructural repair costs caused by building damage and the associated loss of building contents and business inventory. Building damage can cause additional losses by restricting the building's ability to function properly. Thus, business interruption and rental income losses are estimated. HAZUS divides building losses into two categories: (1) direct building losses and (2) business interruption losses. Direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. Business interruption losses are associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

Earthquakes may produce indirect economic losses in sectors that do not sustain direct damage. All businesses are forward-linked (if they rely on regional customers to purchase their output) or backward-linked (if they rely on regional suppliers to provide their inputs) and are thus potentially vulnerable to interruptions in their operation. Note that indirect losses are not confined to immediate customers or suppliers of damaged enterprises. All of the successive rounds of customers of customers and suppliers of suppliers are affected. In this way, even limited physical earthquake damage causes a chain reaction, or ripple effect, that is transmitted throughout the regional economy.

1.9.2 HAZUS Scenario Earthquakes for the Glendale Area

Five specific scenario earthquakes were modeled using the HAZUS loss estimation software available from FEMA: earthquakes on the San Andreas, Sierra Madre, Verdugo, Raymond and Hollywood faults (see Table 1-4).

Table 1-4: HAZUS Scenario Earthquakes for the City of Glendale

Fault Source	Magnitude	Description
San Andreas - Mojave Segment	7.1	A large earthquake that ruptures the Mojave segment of the San Andreas fault is modeled because of its high probability of occurrence, even though the epicenter would not be too close to the City.
Sierra Madre	7.2	Likely worst-case scenario for the Glendale area. The 7.2 magnitude earthquake modeled is at the lower range of the size of earthquakes that researchers now believe this fault is capable of generating.
Verdugo	6.7	Possible worst-case scenario for Glendale. Although this earthquake is not as large as the one estimated on the Sierra Madre fault, this fault extends through an extensively developed area, and therefore has the potential to cause significant damage to buildings and infrastructure.
Raymond	6.5	Maximum magnitude earthquake on the Raymond fault. This fault near the southern portion of the City could cause significant damage in the southern and eastern portions of Glendale, and in the San Rafael Hills.
Hollywood	6.4	Maximum magnitude earthquake on the Hollywood fault would cause extensive damage in Hollywood, West Hollywood, and in the southwestern portion of Glendale. This fault could break together with the Santa Monica faults, generating a stronger, more damaging earthquake than the one presented herein.

Four of the five earthquake scenarios modeled for this study are discussed in the following sections. An earthquake on the San Andreas fault is discussed because it has the highest probability of occurring in the not too distant future, even though the loses expected from this earthquake are not the worst possible for Glendale. An earthquake on the San Andreas fault has traditionally been considered the “Big One,” the implication being that an earthquake on this fault would be devastating to southern California. However, there are several other seismic sources that, given their location closer to the Los Angeles metropolitan area, have the potential to be more devastating to the region, even if the causative earthquake is smaller in magnitude than an earthquake on the San Andreas fault. The 7.1 magnitude San Andreas earthquake modeled for this study would result from the rupture of the Mojave segment of the fault. This segment is thought to have more than a 40 percent probability of rupturing in the next 30 years. A larger-magnitude earthquake on the San Andreas fault would occur if more than one segment of the fault ruptures at the same time. If all three southern segments of the San Andreas fault break together, an earthquake of at least magnitude 7.8 would result.

The Sierra Madre and Verdugo scenarios are also presented here because both of these faults have the potential to cause significant damage in the City. As discussed in Section 1.5.5, the Sierra Madre fault appears to have last ruptured more than 8,000 years ago, and may be near the end of its strain accumulation cycle. Given that recent studies suggest that the Sierra Madre fault can generate earthquakes of magnitude 7.2 to 7.5 (instead of the 7.0 used by the California Geological Survey), a lower-bound 7.2 magnitude earthquake was chosen for the scenario and loss estimation analysis. The earthquake history and recurrence interval of the Verdugo fault are unknown, and as a result, the probability of future earthquakes on this fault cannot be quantified with any degree of certainty. What it is certain is that if, and when this fault breaks, the City of Glendale will be impacted. HAZUS helps to quantify the damage expected.

The Raymond and Hollywood faults would both cause about the same amount of damage in Glendale. The Raymond fault appears to break more often than the Hollywood fault, and as a result, one could argue that it has a higher probability of rupturing again in the future. However, since the Hollywood fault appears to have last ruptured several thousand years ago, it may actually be closer to rupture. Since both faults are located immediately south of Glendale, the damage patterns can be expected to be very similar (directivity of fault breakage can have a substantial impact on the damage potential, but the damage analyses conducted for this study are not designed to be sensitive to this issue).

1.9.3 Inventory Data Used in the HAZUS Loss Estimation Models for Glendale

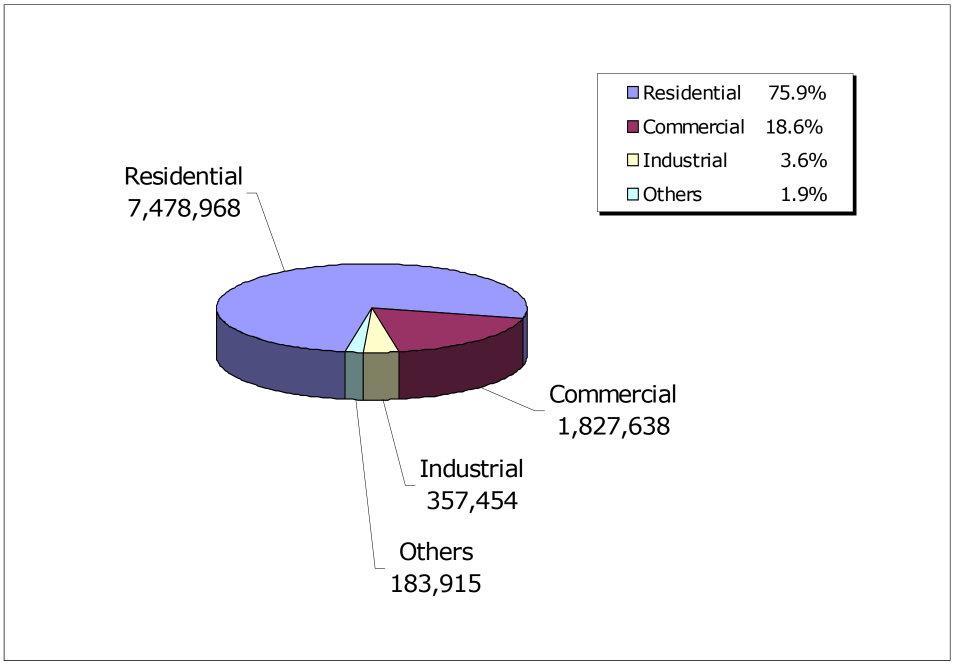
As mentioned previously, the population data used for the Glendale analyses were modified using the recently available 2000 Census data. The general building stock and population inventory data conform to census tract boundaries, and the census tract boundaries generally conform to the City limits, with minor exceptions. The region studied is 30 square miles in area and contains 28 census tracts. There are over 68,000 households (1990 Census Bureau data – the 2000 Census lists 74,000 households) in the region, with a total population of 194,000 (based on 2000 Census Bureau data). There are an estimated 33,000 buildings in the region with a total building replacement value (excluding contents) of $9.85 billion (1994 dollars). Approximately 96 percent of the buildings (and 76 percent of the building value) are associated with residential housing (see Figure 1-5). In terms of building construction types found in the region, wood-frame construction makes up 94 percent of the building inventory. The remaining percentage is distributed between the other general building types. The replacement value of the transportation and utility lifeline systems in the City of Glendale is estimated to be nearly $3.26 billion and $245 million (1994 dollars), respectively.

The HAZUS inventory of unreinforced masonry (URM) buildings includes more URMs than those now present in the City, since many URMs have been demolished since 1994. Therefore, the URM numbers in the HAZUS output are somewhat overstated. However, far more URMs in Glendale have been retrofitted than demolished, and the database used for the HAZUS analyses accounts for this: the seismic design criteria for most URMs in the City were upgraded from low to moderate to reflect the retrofitting efforts that have been accomplished in the late 1990s and early 2000s. It is important to note, however, that retrofitting is typically designed to keep buildings from collapsing, but that structural damage to the building is still possible and expected.

Changes were made to the HAZUS hospital inventory for Glendale, specifically, to the number of beds available. In all cases, the number of beds at all hospitals has increased since

1990, based on recent bed counts published by each of the three main hospitals in the City: Glendale Adventist Medical Center has 450 beds, Glendale Memorial Hospital and Health Center has 334 beds, and Verdugo Hills Hospital has 158 beds, for a total hospital capacity of 942 beds. At least one of these hospitals (Glendale Memorial) is currently enlarging its facilities to serve an even larger number of patients. The new hospital wing is being built to the seismic standards of the Office of the State Architect in accordance with State law.

Figure 1-5
Building Inventory, by Occupancy Type, in the Glendale Area
(values shown are in millions of dollars)



Regarding critical facilities, the HAZUS database for Glendale includes 70 schools or school facilities, including school district offices, private schools, and community colleges. The City's emergency operations center in the basement of City Hall is also included. The database was modified to include the two police stations and nine fire stations that serve the City. The locations of these facilities are shown on Plate 1-4.

1.9.4 Estimated Losses Associated with the Earthquake Scenarios

HAZUS loss estimations for the City of Glendale based on four of the earthquake scenarios modeled are presented concurrently below. For the complete master reports for these scenarios, refer to Appendix C. These scenarios include earthquakes on the San Andreas, Sierra Madre, Verdugo and Raymond faults. Of the five earthquake scenarios modeled for the City, the results indicate that the San Andreas fault earthquake will pose the least damage to the Glendale, although this fault may have the highest probability of rupturing in the near-future.

The Sierra Madre and Verdugo earthquake scenarios are the worst-case scenarios for the City. The losses are similar, but the damaged areas will be different, as the faults transect different sections of the City. Since the Sierra Madre fault is a reverse fault, it has the potential to generate stronger ground accelerations than the predominantly left-lateral strike slip Verdugo fault (reverse faults typically generate stronger ground accelerations, distributed over a broader geographic area than strike-slip faults). However, the stronger seismic shaking will be experienced north of the fault, in the sparsely populated San Gabriel Mountains. Landsliding and rock collapse can be expected to result in road closures in the mountains, and some damage to the dams north of the area can be anticipated. The areas adjacent to and immediately south of the Sierra Madre fault will also experience damage.

The losses anticipated as a result of either the Raymond or Hollywood fault causing an earthquake are also similar. These events would pose the next worst-case scenario for Glendale. Directivity of the seismic waves, as discussed earlier in this chapter, will determine, at least to some extent, where and how much damage will be experienced in the area as a result of earthquakes on either the Hollywood or Raymond faults. However, seismologists still do not have the tools to predict where, when, and how a fault will break, and HAZUS does not consider these issues in the loss estimation analysis.

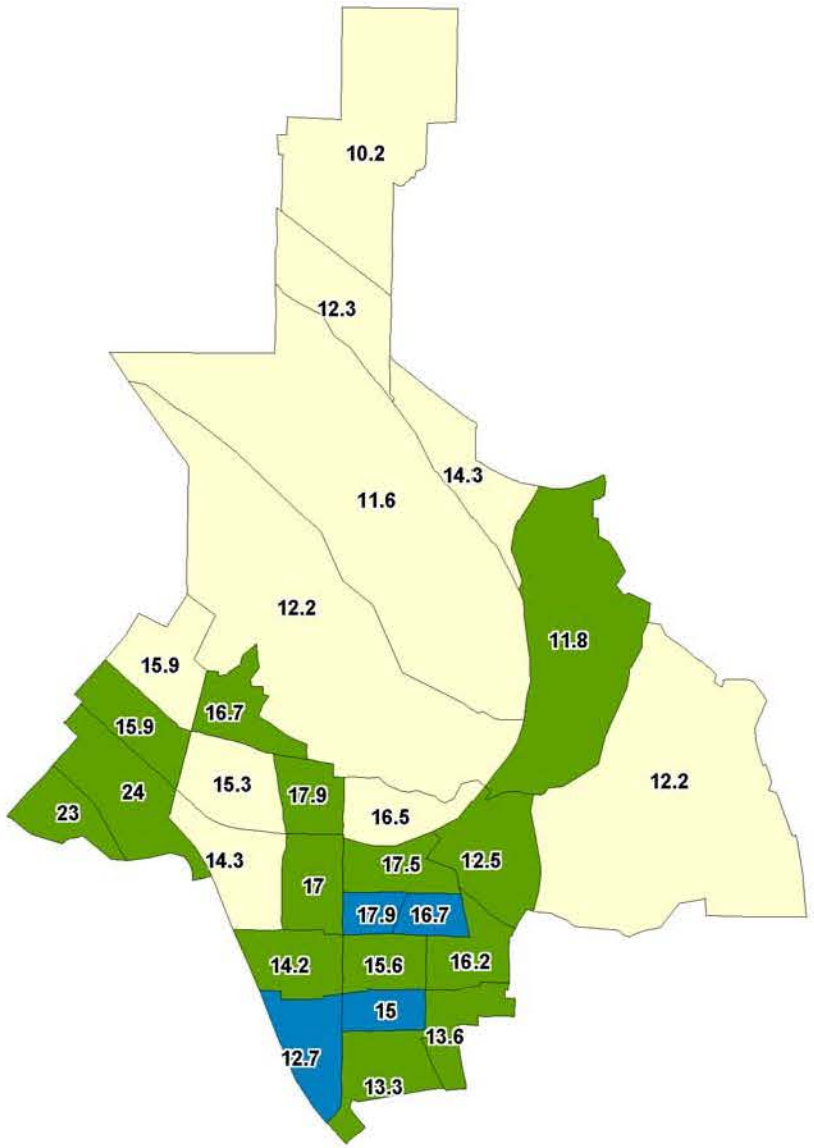
Building Damage - HAZUS estimates that between approximately 350 and 5,000 buildings will be at least moderately damaged in response to the earthquake scenarios presented herein, with the lower number representative of damage as a result of an earthquake on the San Andreas fault, and the higher number representing damage as a result of an earthquake on either the Verdugo or Sierra Madre fault. These figures represent about 1 to 15 percent of the total number of buildings in the study area. An estimated 0 to 55 buildings will be completely destroyed. Table 1-5 summarizes the expected damage to buildings by general occupancy type, while Table 1-6 summarizes the expected damage to buildings in Glendale, classified by construction type.

The data presented in Tables 1-5 and 1-6 show that most of the buildings damaged will be residential, with wood-frame structures experiencing mostly slight to moderate damage. The Verdugo and Sierra Madre fault earthquake scenarios both have the potential to cause at least slight damage to more than 50 percent of the residential structures in Glendale, and moderate to complete damage to as much as 16 percent of the residential stock. The distribution and severity of the damage caused by these earthquakes to the residential buildings in the City is illustrated in Plate 1-5. As mentioned before, an earthquake on the Sierra Madre fault would cause more damage in the northern section of the City than an earthquake on either the Verdugo or Raymond faults. The Raymond (and Hollywood) faults have the potential to cause significant damage to the residential stock of Glendale, but the damage would not be as severe as that caused by either the Sierra Madre or Verdugo faults. The San Andreas fault scenario is anticipated to cause slight to moderate damage to about 10 percent of the residential buildings in the City.

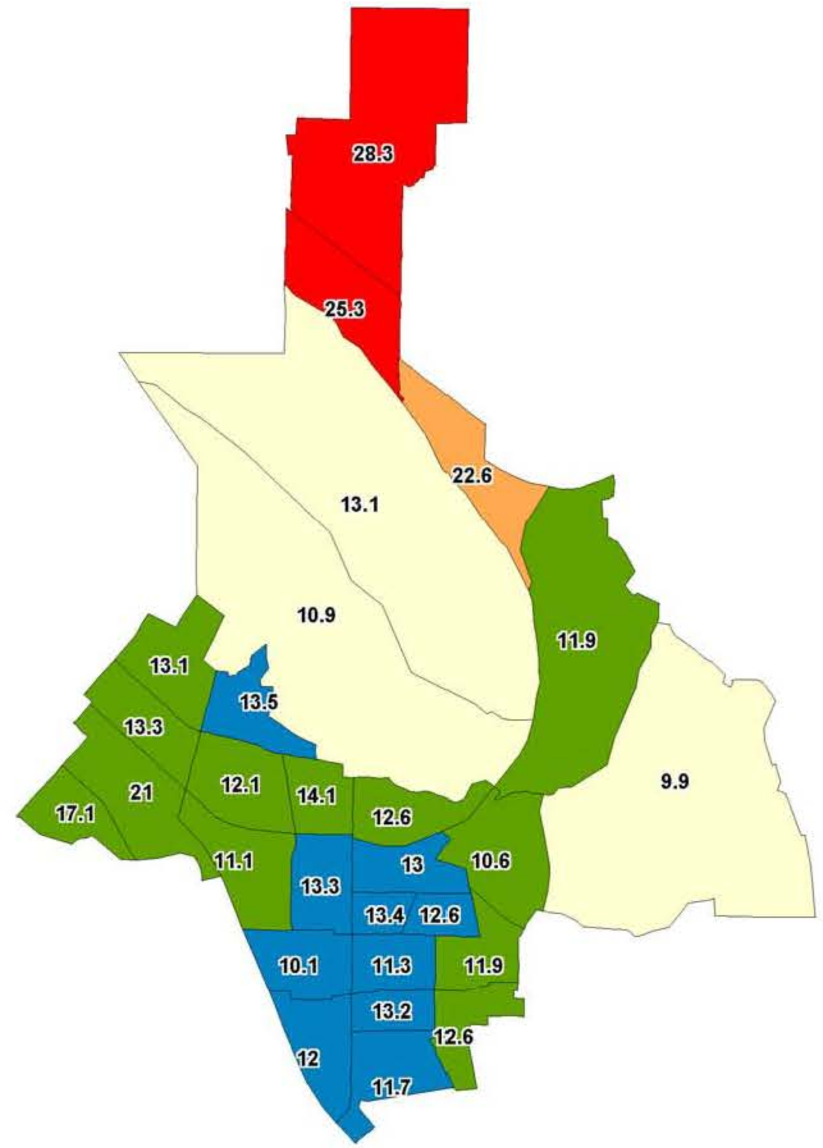
Table 1-5: Number of Buildings Damaged, by Occupancy Type

Scenario	Occupancy Type	Slight	Moderate	Extensive	Complete	Total
San Andreas	Residential	2,859	308	0	0	3,167
	Commercial	86	25	0	0	111
	Industrial	23	10	1	0	34
	Agriculture	0	0	0	0	0
	Religion	3	0	0	0	3
	Government	0	0	0	0	0
	Education	0	0	0	0	0
	Total	2,971	343	1	0	3,315
Sierra Madre	Residential	11,362	4,166	387	51	15,966
	Commercial	276	257	68	2	603
	Industrial	65	71	24	2	162
	Agriculture	2	2	0	0	4
	Religion	18	14	2	0	34
	Government	1	0	0	0	1
	Education	5	2	0	0	7
	Total	11,729	4,512	481	55	16,777
Verdugo	Residential	11,656	4,153	330	20	16,159
	Commercial	285	272	82	5	644
	Industrial	66	73	24	2	165
	Agriculture	2	1	0	0	3
	Religion	18	15	2	0	35
	Government	1	0	0	0	1
	Education	5	1	0	0	6
	Total	12,033	4,515	438	27	17,013
Raymond	Residential	10,026	2,949	186	4	13,165
	Commercial	271	224	50	0	545
	Industrial	62	60	16	2	140
	Agriculture	2	0	0	0	2
	Religion	17	11	1	0	29
	Government	1	0	0	0	1
	Education	4	1	0	0	5
	Total	10,383	3,245	253	6	13,887

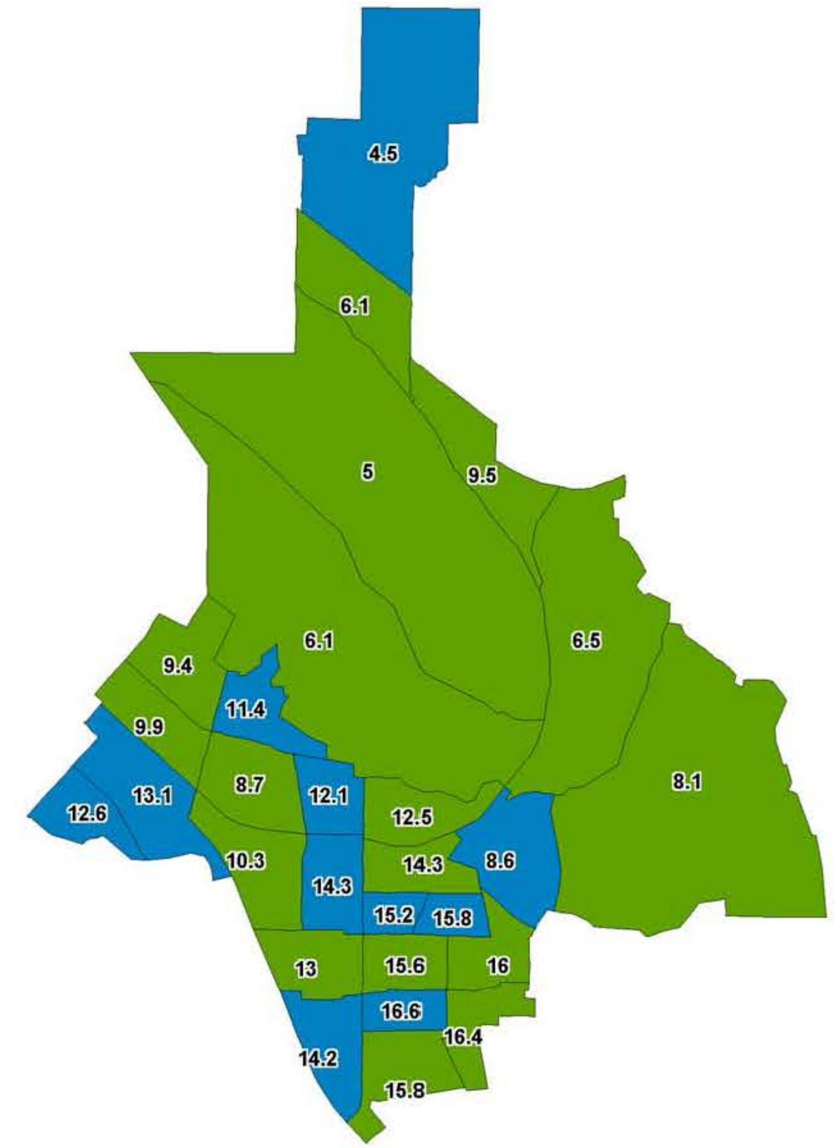
Although the numbers presented in Table 1-5 only hint at it, the commercial and industrial structures will also be impacted. The Sierra Madre and Verdugo earthquakes have the potential to damage about 10 percent and 14 percent of the commercial and industrial buildings, respectively, in the City. The distribution and severity of damage to the commercial structures in the City as a result of earthquakes on the Verdugo, Sierra Madre and Raymond faults is illustrated in Plate 1-6. All three earthquakes shown on Plate 1-6 are anticipated to cause damage in the commercial district of the City, but an earthquake on the Verdugo fault would be the most severe, given the fault's location through the heart of Glendale.



Magnitude 6.7 Earthquake on Verdugo Fault



Magnitude 7.2 Earthquake on Sierra Madre Fault



Magnitude 6.5 Earthquake on Raymond (Hill) Fault

EXPLANATION

Number of Buildings Damaged by Census Tract
(labeled with percentage of damaged buildings in census tract)

- 0-100
- 101-200
- 201-300
- 301-400
- 401 and greater

Sources: Federal Emergency Management Agency, HAZUS 99-SR2

*more than 50% of the residential structure has undergone moderate, extensive and/or complete damage

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Date: July, 2003

Residential Buildings With At Least Moderate Damage > 50%*

(Based on Three Earthquake Scenarios)

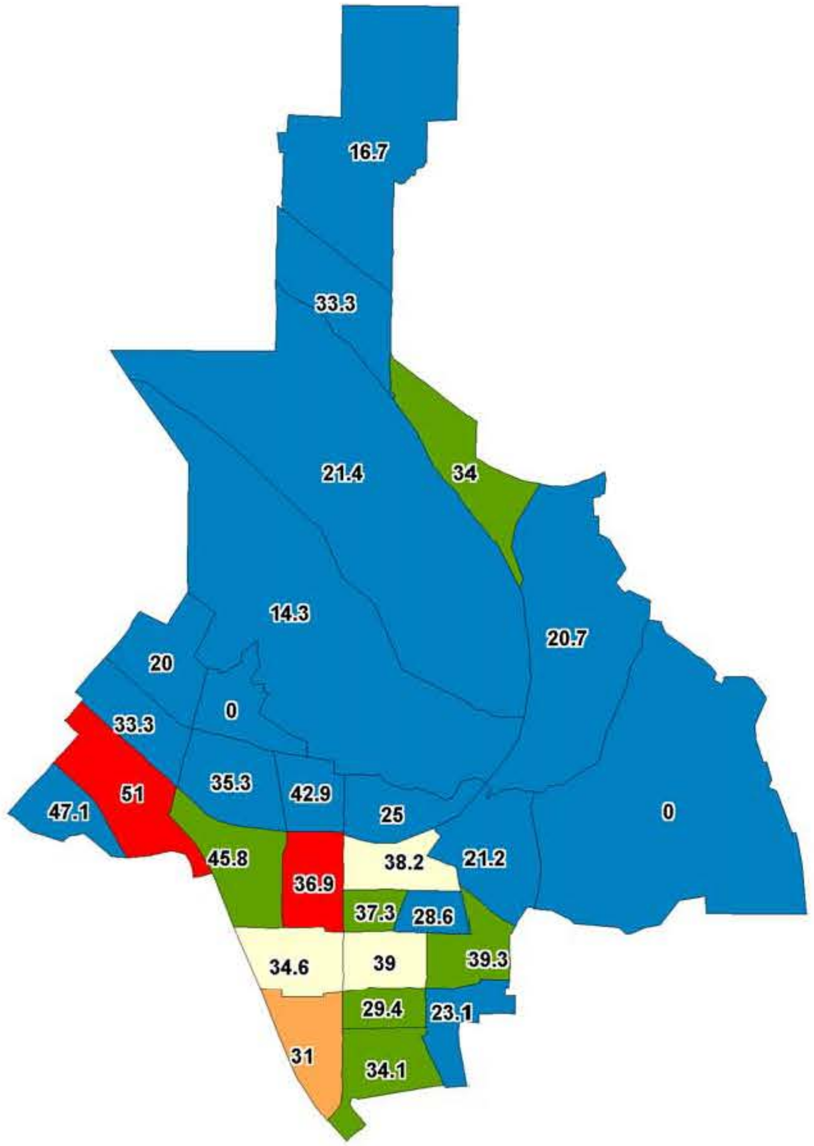
Glendale, California

Plate 1-5

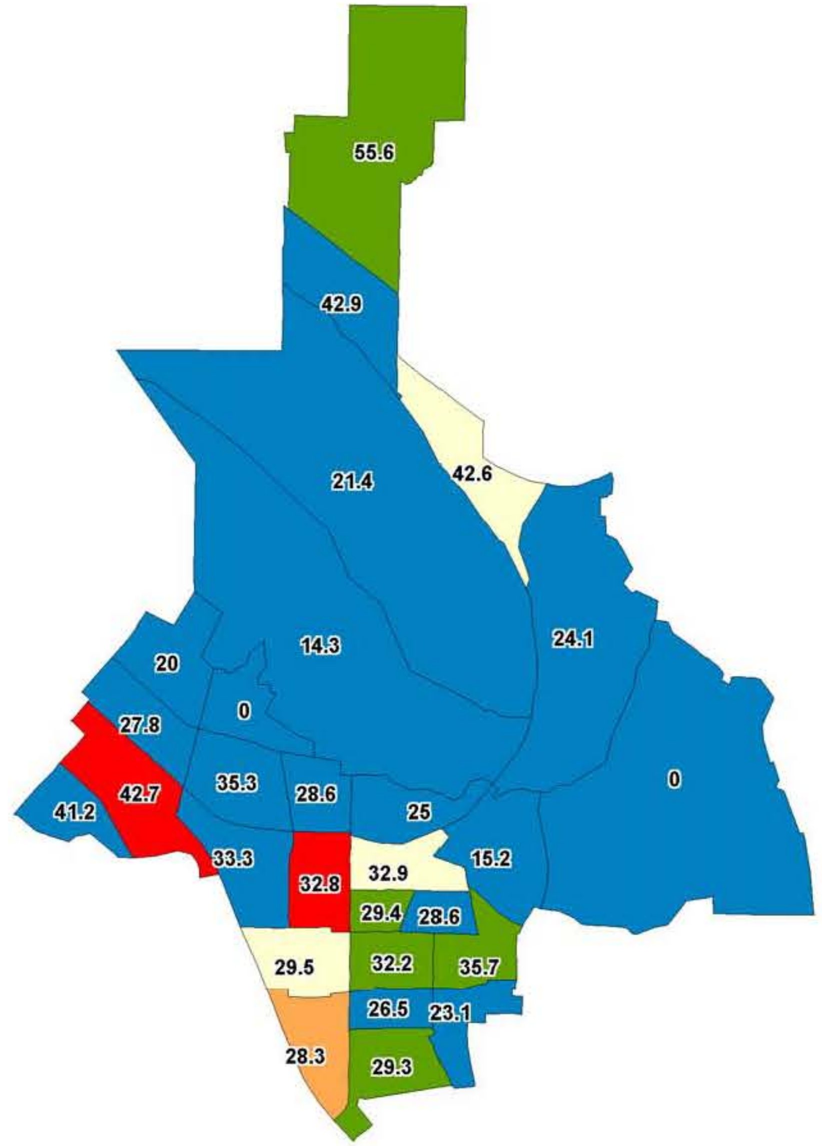
Table 1-6: Number of Buildings Damaged, by Construction Type

Scenario	Structure Type	Slight	Moderate	Extensive	Complete	Total
San Andreas	Concrete	26	2	0	0	28
	Mobile Homes	10	5	0	0	15
	Precast Concrete	18	7	0	0	25
	Reinforced Masonry	40	19	0	0	59
	Steel	23	8	0	0	31
	URM	23	5	0	0	28
	Wood	2,831	290	0	0	3,121
	Total	2,971	336	0	0	3,307
Sierra Madre	Concrete	103	103	25	0	231
	Mobile Homes	8	25	12	2	47
	Precast Concrete	59	83	22	2	166
	Reinforced Masonry	149	167	57	0	373
	Steel	73	106	34	0	213
	URM	39	50	11	1	101
	Wood	11,298	3,978	315	44	15,635
	Total	11,729	4,512	476	49	16,766
Verdugo	Concrete	106	111	31	1	249
	Mobile Homes	11	23	11	0	45
	Precast Concrete	60	91	29	2	182
	Reinforced Masonry	157	185	67	0	409
	Steel	74	106	38	0	218
	URM	39	55	12	1	107
	Wood	11,586	3,944	250	10	15,790
	Total	12,033	4,515	438	14	17,000
Raymond	Concrete	103	94	21	0	218
	Mobile Homes	12	20	4	0	36
	Precast Concrete	60	72	20	0	152
	Reinforced Masonry	142	142	45	0	329
	Steel	74	89	24	0	187
	URM	43	43	7	0	93
	Wood	9,949	2,785	126	0	12,860
	Total	10,383	3,245	247	0	13,875

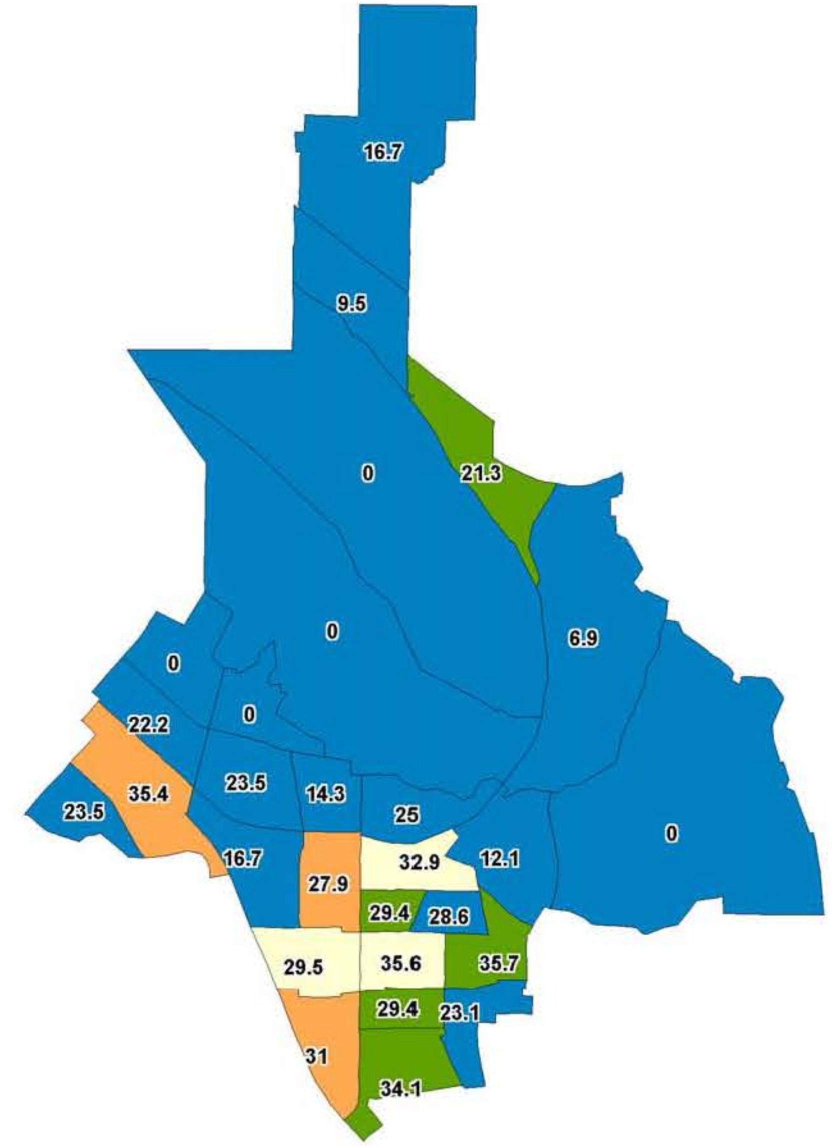
The HAZUS output shows that URMs in Glendale will suffer slight to extensive damage, but that very few are likely to be completely destroyed. This is anticipated to reduce the number of casualties significantly. The numbers show that by retrofitting its URMs, Glendale has already reduced significantly its vulnerability to seismic shaking.



Magnitude 6.7 Earthquake on Verdugo Fault



Magnitude 7.2 Earthquake on Sierra Madre Fault



Magnitude 6.5 Earthquake on Raymond (Hill) Fault

EXPLANATION

Number of Buildings Damaged by Census Tract
(labeled with percentage of damaged buildings in census tract)

- 0-10
- 11-20
- 21-30
- 31-40
- 41 and greater

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Federal Emergency Management Agency, HAZUS 99-SR2

*more than 50% of the residential structure has undergone moderate, extensive and/or complete damage

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Project Number: 2103
Date: July, 2003

Commercial Buildings With At Least Moderate Damage > 50%

(Based on Three Earthquake Scenarios)

Glendale, California

Plate 1-6

Significantly, reinforced masonry, concrete and steel structures are not expected to perform well, with hundreds of these buildings in Glendale experiencing at least moderate damage during an earthquake on the Sierra Madre or Verdugo faults. These types of structures are commonly used for commercial and industrial purposes, and failure of some of these structures explains the casualties anticipated during the middle of the day in the non-residential sector (see Table 1-7). These types of buildings also generate heavy debris that is difficult to cut through to extricate victims.

Casualties - Table 1-7 provides a summary of the casualties estimated for these scenarios. The analysis indicates that the worst time for an earthquake to occur in the City of Glendale is during maximum non-residential occupancy (at 2 o'clock in the afternoon, when most people are in their place of business and schools are in session). The Verdugo fault earthquake scenario is anticipated to cause the largest number of casualties, followed closely by an event on the Sierra Madre fault.

Essential Facility Damage - The loss estimation model calculates the total number of hospital beds in Glendale that will be available after each earthquake scenario.

A maximum magnitude earthquake on the Verdugo fault is expected to impact the local hospitals such that only 38 percent of the hospital beds (358 beds) would be available for use by existing patients and injured persons on the day of the earthquake. One week after the earthquake, about 57 percent of the beds are expected to be back in service. After one month, 82 percent of the beds are expected to be operational.

Similarly, on the day of the Sierra Madre earthquake, the model estimates that only 378 hospital beds (40 percent) will be available for use by patients already in the hospital and those injured by the earthquake. After one week, 59 percent of the beds will be back in service. After thirty days, 83 percent of the beds will be available for use.

An earthquake on the Raymond fault is only expected to be slightly better regarding the availability of hospital beds. The model estimates that only 391 hospital beds (42 percent) will be available on the day of the earthquake. After one week, 60 percent of the hospital beds are expected to be available for use, and after one month, 84 percent of the beds are expected to be operational.

An earthquake on the San Andreas fault is not expected to cause significant damage to the hospitals in Glendale: On the day of the earthquake, the model estimates that 86 percent of the beds will be available for use; after one week, 93 percent of the beds will be available for use; and after 30 days, 98 percent of the beds will be operational.

Given that the models estimate a maximum of about 100 people in the Glendale area will require hospitalization after an earthquake on either the Verdugo or Sierra Madre faults (see Table 1-7), the hospitals in the City, even with the reduced number of beds that the model projects will be available, are anticipated to handle the local demand. However, nearby cities, such as Pasadena, which have limited medical care resources available, are anticipated to have a higher number of casualties. Glendale's hospitals will most likely provide a regional service to other nearby communities, taking in patients that other hospitals outside the City cannot handle because of damage to their own facilities, or due to excess demand for medical care.

Table 1-7: Estimated Casualties

Type and Time of Scenario			Level 1: Medical treatment without hospitalization	Level 2: Hospitalization but not life threatening	Level 3: Hospitalization and life threatening	Level 4: Fatalities due to scenario event
San Andreas	2AM (maximum residential occupancy)	Residential	15	1	0	0
		Non-Residential	1	0	0	0
		Commute	0	0	0	0
		Total	16	1	0	0
	2PM (max educational, industrial, and commercial)	Residential	4	1	0	0
		Non-Residential	24	2	0	0
		Commute	0	0	0	0
		Total	28	3	0	0
	5PM (peak commute time)	Residential	4	0	0	0
		Non-Residential	9	1	0	0
		Commute	0	0	0	0
		Total	13	1	0	0
Sierra Madre (M7.2)	2AM (maximum residential occupancy)	Residential	165	24	2	4
		Non-Residential	9	2	0	1
		Commute	0	0	0	0
		Total	175	26	2	4
	2PM (max educational, industrial, and commercial)	Residential	43	6	1	1
		Non-Residential	337	71	9	19
		Commute	0	0	0	0
		Total	380	78	10	20
	5PM (peak commute time)	Residential	51	7	1	1
		Non-Residential	122	26	3	7
		Commute	0	1	1	0
		Total	173	34	5	8
Verdugo	2AM (maximum residential occupancy)	Residential	179	27	2	5
		Non-Residential	11	2	1	1
		Commute	0	0	0	0
		Total	189	29	3	6
	2PM (max educational, industrial, and commercial)	Residential	47	7	1	1
		Non-Residential	378	82	11	22
		Commute	0	0	0	0
		Total	425	89	12	23
	5PM (peak commute time)	Residential	56	8	1	2
		Non-Residential	140	31	4	8
		Commute	1	1	1	0
		Total	197	40	6	10
Raymond	2AM (maximum residential occupancy)	Residential	131	17	2	3
		Non-Residential	7	1	0	0
		Commute	0	0	0	0
		Total	138	18	2	3
	2PM (max educational, industrial, and commercial)	Residential	35	5	0	1
		Non-Residential	244	47	6	11
		Commute	0	0	0	0
		Total	279	52	6	12
	5PM (peak commute time)	Residential	42	5	0	1
		Non-Residential	90	17	2	4
		Commute	0	0	1	0
		Total	132	23	3	5

HAZUS also estimates the damage to other critical facilities in the City, including schools, fire and police stations, and the emergency operations center. According to the model, an earthquake on the Mojave segment of the San Andreas fault is not going to damage any of the schools, fire or police stations, or the City's emergency operations center. All of these facilities would be fully functional the day after the earthquake.

An earthquake on the Sierra Madre fault is anticipated to cause at least moderate damage to seven schools in the City, and none of the schools and school district offices in Glendale are expected to be more than 50 percent operational the day after the earthquake. Most of the schools with more than 50 percent moderate damage are located in the northern portion of the City, as illustrated in Plate 1-7. The model also indicates that although none of the other critical facilities will experience more than slight damage, none of them would be more than fully operational the day after the earthquake.

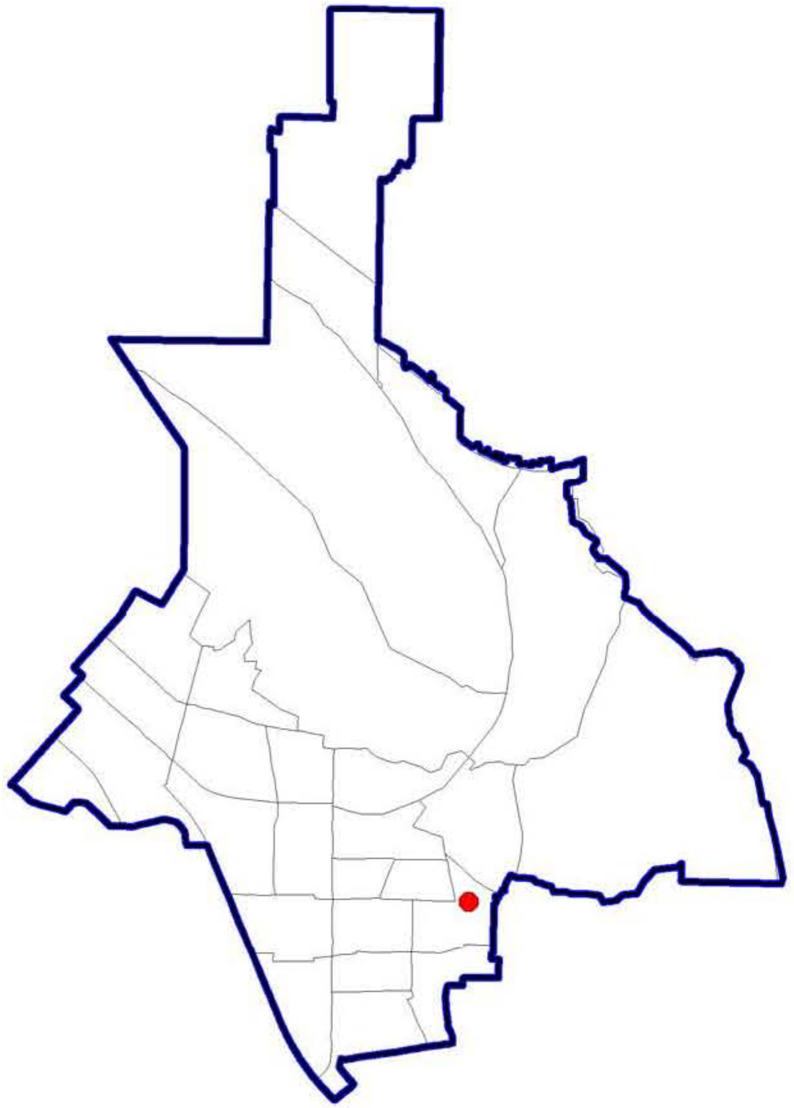
An earthquake on the Verdugo fault is anticipated to cause at least moderate damage to one school in the City – Glendale High (see Plate 1-7), which according to the HAZUS inventory, also houses the Glendale Cosmetology School. The model indicates that none of the other critical facilities in the City will experience more than slight damage, but with the exception of one hospital, none of the critical facilities (including fire stations and the emergency operations center) will be more than 50 percent functional the day after the earthquake.

An earthquake on the Raymond fault is expected to also damage Glendale High. Damage to the other critical facilities in the City is expected to be less severe than that caused by earthquakes on either the Sierra Madre or Verdugo faults, but few facilities are expected to be more than 50 percent operational the day after the earthquake.

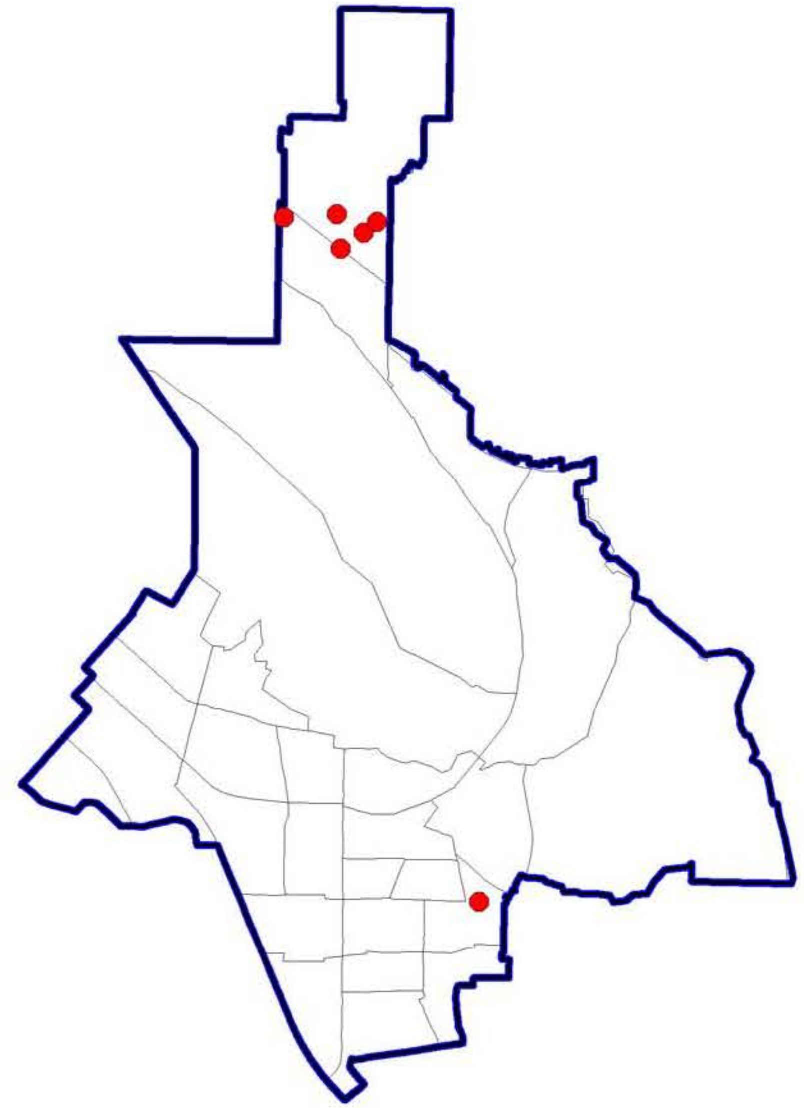
Economic Losses - The model estimates that total building-related losses in the City of Glendale will range from $83 million for an earthquake on the San Andreas fault, to $853 million for an earthquake on the Verdugo fault. Approximately 20 percent of these estimated losses would be related to business interruption in the city. By far, the largest loss would be sustained by the residential occupancies that make up as much as 60 percent of the total loss. Table 1-8 below provides a summary of the estimated economic losses anticipated as a result of each of the earthquake scenarios considered herein.

Table 1-8: Estimated Economic Losses

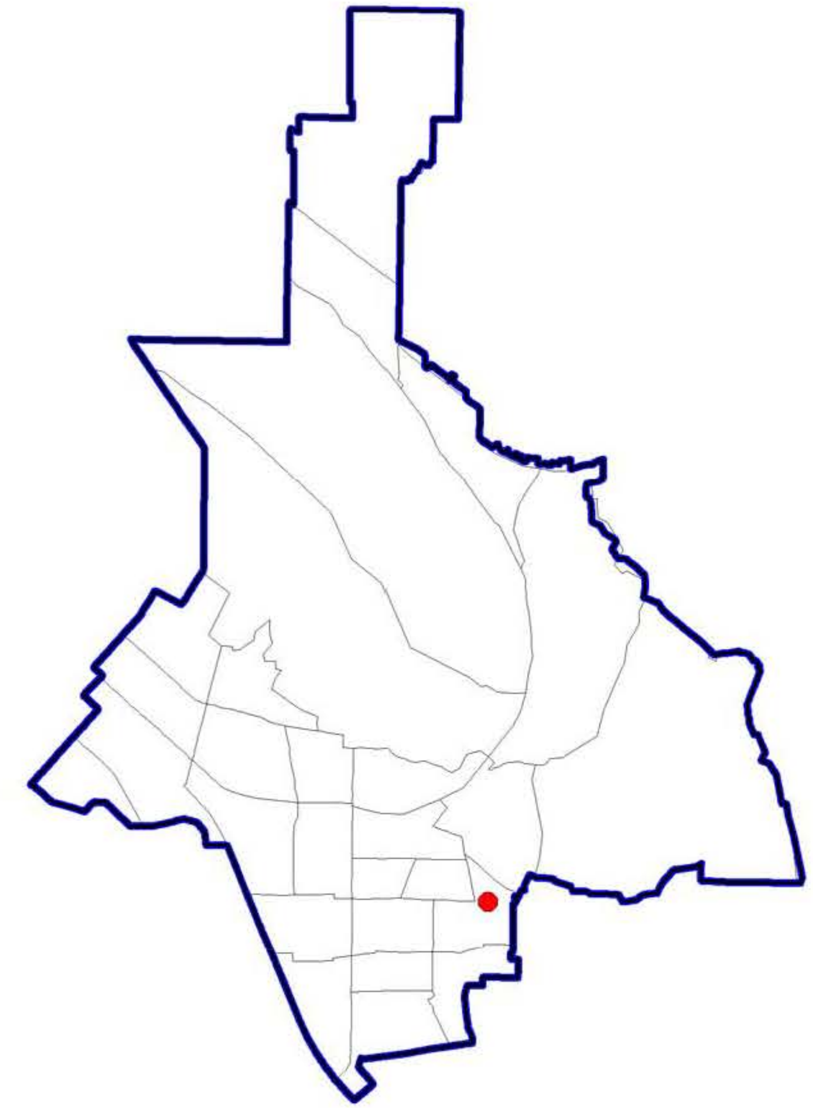
Scenario	Property Damage	Business Interruption	Total
San Andreas	$69.8 Million	$13.5 Million	$83.3 Million
Sierra Madre	$639.7 Million	$158.2 Million	$797.8 Million
Verdugo	$680.4 Million	$72.7 Million	$853.0 Million
Raymond	$560.1 Million	$127.6 Million	$687.7 Million



Magnitude 6.7 Earthquake on Verdugo Fault



Magnitude 7.2 Earthquake on Sierra Madre Fault



Magnitude 6.5 Earthquake on Raymond (Hill) Fault

Sources: Federal Emergency Management Agency, HAZUS 99-SR2

EXPLANATION

● Location of school with at least moderate damage

*more than 50% of the school structures have undergone moderate, extensive and/or complete damage

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Project Number: 2103
Date: July, 2003

Schools With At Least Moderate Damage > 50%*

(Based on Three Earthquake Scenarios)

Glendale, California

Plate 1-7

Shelter Requirement - HAZUS estimates that approximately 1,300 households in Glendale may be displaced due to the Verdugo earthquake modeled for this study (a household contains four people, on average). About 980 people will seek temporary shelter in public shelters. The rest of the displaced individuals are anticipated to seek shelter with family or friends. An earthquake on the Sierra Madre fault is anticipated to displace nearly 1,200 households, with approximately 900 people seeking temporary shelter. An earthquake on the San Andreas fault is not expected to displace any households.

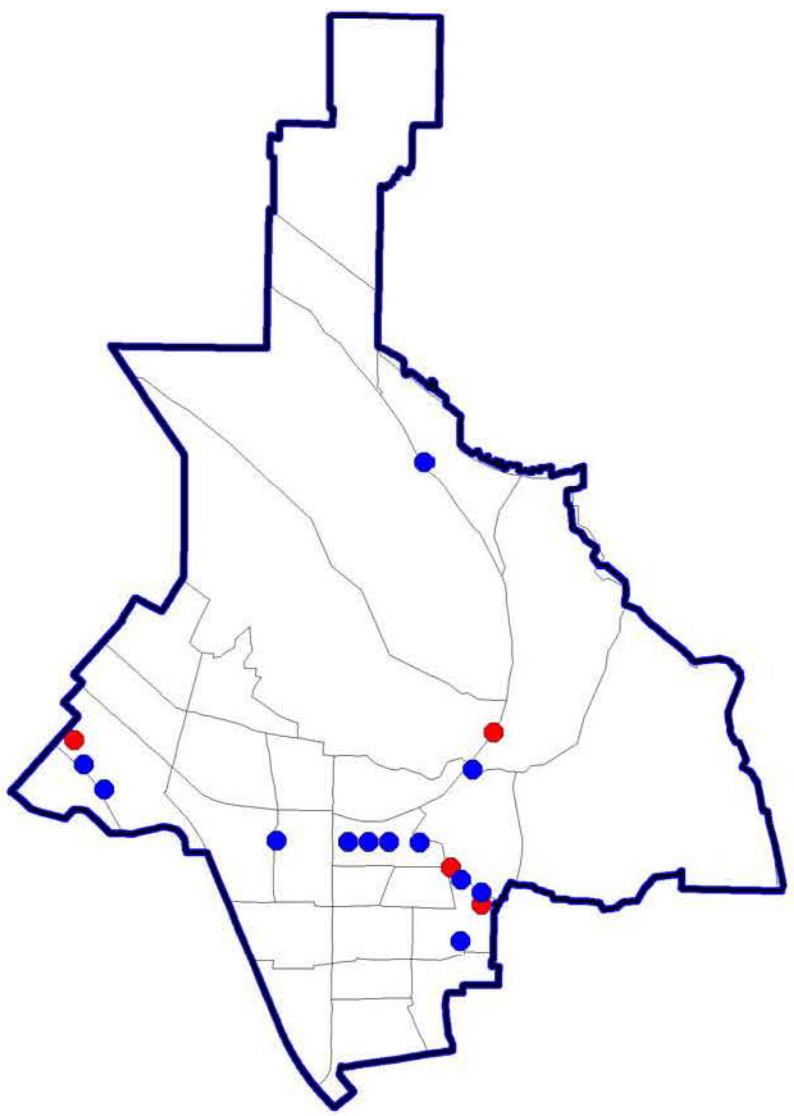
Table 1-9: Estimated Shelter Requirements

Scenario	Displaced Households	People Needing Short-Term Shelter
San Andreas - Mojave Segment	0	0
Sierra Madre	1,179	886
Verdugo	1,303	980
Raymond	945	738

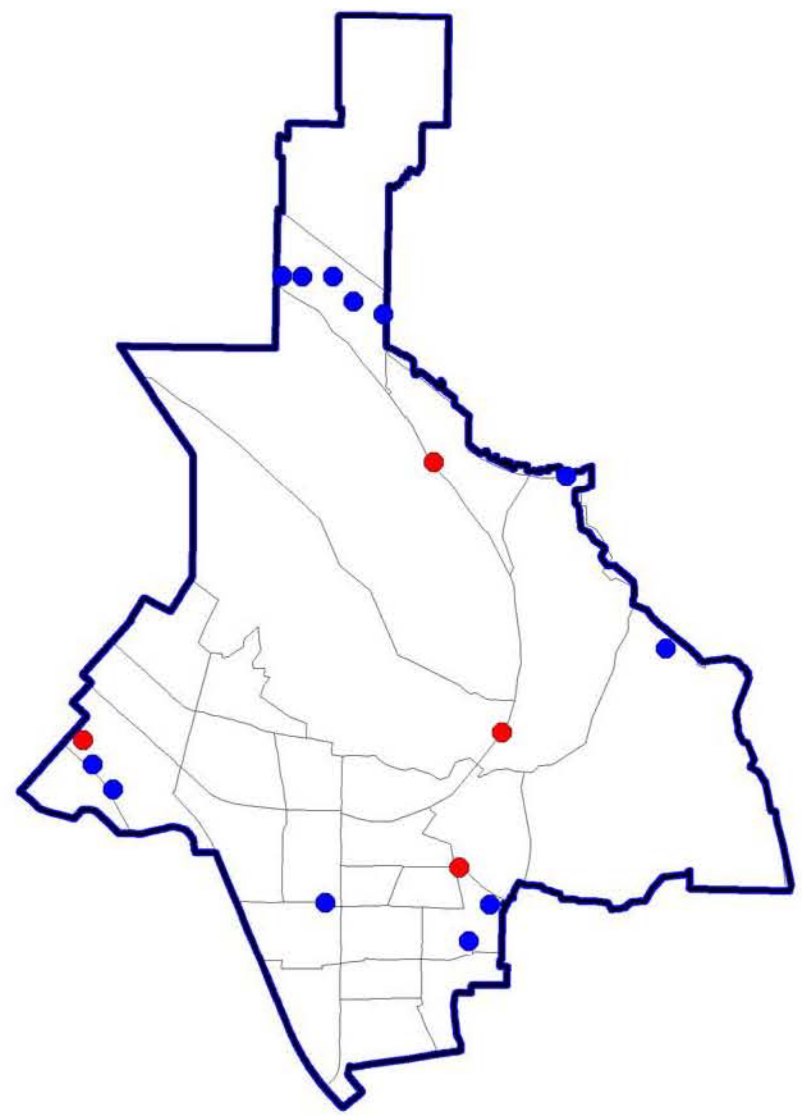
Transportation Damage – Damage to transportation systems in the City of Glendale is based on a generalized inventory of the region as described in Table 1-10. Road segments are assumed to be damaged by ground failure only; therefore, the numbers presented herein may be low given that, based on damage observed from the Northridge and San Fernando earthquakes, strong ground shaking can cause considerable damage to bridges. Economic losses due to bridge damage are estimated at between $0.8 million (for an earthquake on the San Andreas fault) to $24.4 million for an earthquake on the Sierra Madre fault.

The San Andreas fault earthquake scenario estimates that only 1 of the 143 bridges in the study area will experience at least moderate damage, but this bridge is expected to be more than 50 percent functional by the next day. The San Andreas earthquake scenario indicates that the Burbank airport will experience some economic losses, but that its functionality will not be impaired.

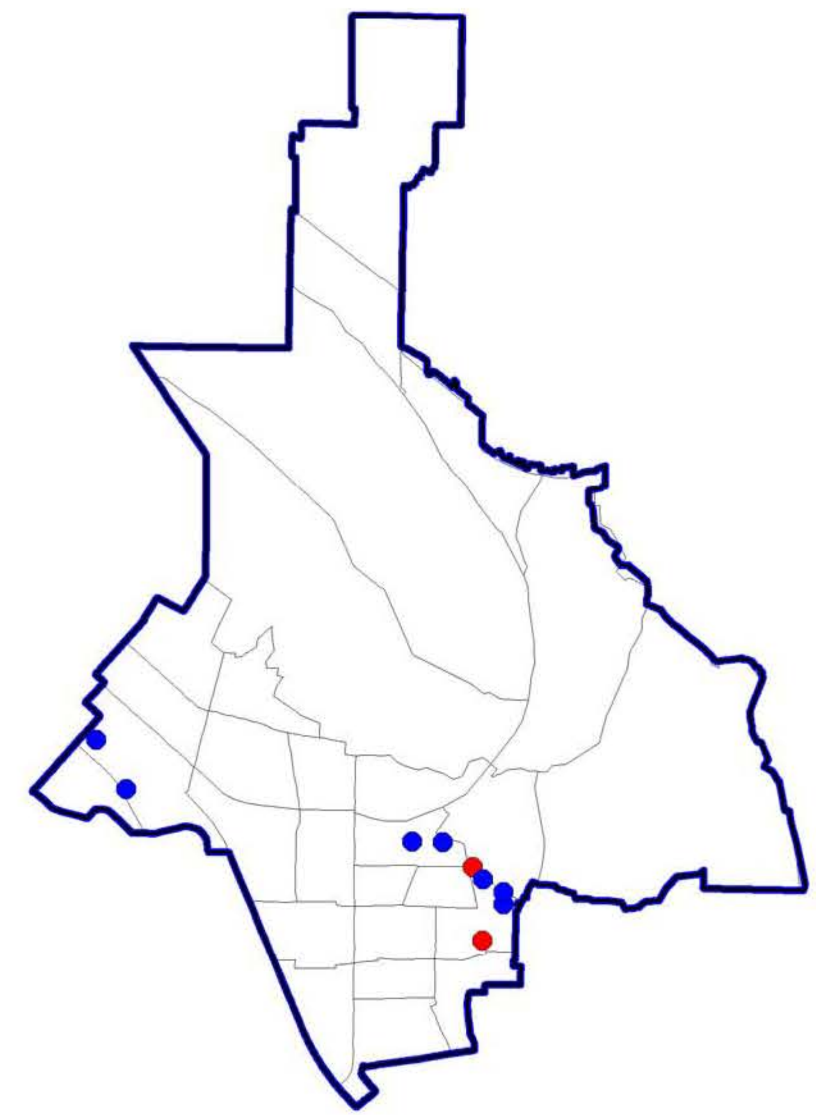
Alternatively, an earthquake on the Sierra Madre fault is expected to damage about 27 bridges in the Glendale area, with 5 of them considered to be completely damaged. Temporary repairs are expected to make all but 2 of the bridge locations more than 50 percent functional one day after the earthquake. Seven days after the earthquake, all bridge locations would be more than 50 percent functional. The Burbank airport is expected to incur losses of about $1.8 million, but the airport will be functional. The Sierra Madre fault earthquake scenario is the worst-case for the transportation system in the City. The damage to bridges as a result of earthquakes on the Sierra Madre, Verdugo and Raymond faults is illustrated in Plate 1-8.



Magnitude 6.7 Earthquake on Verdugo Fault



Magnitude 7.2 Earthquake on Sierra Madre Fault



Magnitude 6.5 Earthquake on Raymond (Hill) Fault

Sources: Federal Emergency Management Agency, HAZUS 99-SR2

EXPLANATION

Bridge Damage

- ● At least Moderate Damage
- ● Complete Damage

Earth Consultants International

Project Number: 2103
Date: July, 2003

Bridge Damage

(Based on Three Earthquake Scenarios)

Glendale, California

Plate 1-8

A maximum magnitude earthquake on the Verdugo fault is modeled to damage about 25 bridges in the City, with 4 of them considered completely damaged. However, as before, all but 2 of the bridge locations are expected to be functional by the next day. The Raymond and Hollywood fault earthquake scenarios model some damage to the Glendale transportation system, but less than that caused by either the Sierra Madre or Verdugo earthquakes discussed above.

Table 1-10: Expected Damage to Transportation Systems

Scenario	System		Segments in Inventory	Replacement Value for All Segments in Inventory	With At Least Moderate Damage	With Complete Damage	Economic Loss ($M)	>50 percent Functional after 1 Day
San Andreas	Highway	Major Roads	5	$2.8 Billion	0	0	0	5
		Bridges	143	$419 Million	1	0	0.8	143
	Railways	Tracks	2	$19 Million	0	0	0	2
	Airport	Facilities	4	$8 Million	0	0	0.3	4
Sierra Madre	Highway	Major Roads	5	$2.8 Billion	0	0	0	5
		Bridges	143	$419 Million	27	5	24.4	143
	Railways	Tracks	2	$19 Million	0	0	0	2
	Airport	Facilities	4	$8 Million	2	0	1.8	4
Verdugo	Highway	Major Roads	5	$2.8 Billion	0	0	0	5
		Bridges	143	$419 Million	25	4	23.3	141
	Railways	Tracks	2	$19 Million	0	0	0	2
	Airport	Facilities	4	$8 Million	1	0	1.7	4
Raymond	Highway	Major Roads	5	$2.8 Billion	0	0	0	5
		Bridges	143	$419 Million	13	2	12.1	143
	Railways	Tracks	2	$19 Million	0	0	0	2
	Airport	Facilities	4	$8 Million	1	0	1.6	4

Utility Systems Damage - The HAZUS inventory for the Glendale area does not include specifics regarding the various lifeline systems in the City, therefore, the model estimated damage to the potable water and electric power using empirical relationships based on the number of households served in the area. The results of the analyses regarding the functionality of the potable water and electric power systems in the City for the four main earthquakes discussed herein are presented in Table 1-11. According to the models, all of the earthquake scenarios will impact the electric power systems; thousands of households in the City are expected to not have electric power even three days after an earthquake on any of the faults discussed in this report. An earthquake on either the Sierra Madre or Verdugo fault is anticipated to leave as many as 9,000 households without electricity for more than one week.

The potable water system is anticipated to do better, but nearly 8,000 households are expected to be without water for at least 3 days after the earthquake. These results suggest that the City will have to truck in water into some of the residential neighborhoods in the northern portion of the City until the damages to the system are repaired. Residents are advised to have drinking water stored in their earthquake emergency kits, enough to last all members of the household (including pets) for at least 3 days.

Table 1-11: Expected Performance of Potable Water and Electricity Services

Scenario	Utility	Number of Households without Service*				
		Day 1	Day 3	Day 7	Day 30	Day 90
San Andreas	Potable Water	0	0	0	0	0
	Electricity	10,215	1,440	69	0	0
Sierra Madre	Potable Water	16,145	7,933	0	0	0
	Electricity	45,389	26,431	9,695	376	0
Verdugo	Potable Water	11,060	4,189	0	0	0
	Electricity	45,250	26,154	9,449	332	0
Raymond	Potable Water	4,334	52	0	0	0
	Electricity	43,850	24,845	8,868	322	0

*Based on Total Number of Households = 68,186.

Fire Following Earthquake - HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area as a result of an earthquake. For the earthquake scenarios ran for Glendale, HAZUS estimates between 3 and 11 ignitions immediately following an earthquake, with the San Andreas fault earthquake scenario triggering 3 ignitions, and the Verdugo and Sierra Madre faults triggering 11 ignitions each. The Raymond and Hollywood faults are both expected to trigger 10 ignitions in the City. The burnt area resulting from these ignitions will vary depending on wind conditions. Normal wind conditions of about 10 miles per hour (mph) are expected to result in burn areas of between 1.9 and 6.7 percent of the region's total area. If Santa Ana wind conditions are present at the time of the earthquake, the burnt areas can be expected to be significantly larger.

The fires triggered by an earthquake on the San Andreas fault are anticipated to displace as few as 30 people (if the winds are low), and as many as 308 people (if 30 mph winds are blowing through the area at the time). The fires triggered by the other earthquake scenarios are expected to impact between 116 and 354 people (if winds are low), and as many as 2,047 to 2,919 people (if 30 mph winds are present). Additional information regarding fires after earthquakes and the resultant losses estimated for the City of Glendale are provided in Chapter 4, Section 4.6.

Debris Generation - The model estimates that a total of 620 – 1,710 thousand tons of debris will be generated. Of the total amount, brick and wood comprise 28 percent of the total, with the remainder consisting of reinforced concrete and steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 25,000 – 69,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquakes modeled.

1.10 Reducing Earthquake Hazards in the City of Glendale

This section identifies and discusses the opportunities available for seismic upgrading of existing development and capital facilities, including potentially hazardous buildings and other critical facilities. Many of the issues and opportunities available to the City apply to both new development and redevelopment and infilling. Issues involving rehabilitation and strengthening of existing development are decidedly more complex given the economic and societal impacts inherent to these issues.

Prioritizing rehabilitation and strengthening projects requires that the City consider where its resources would be better spent to reduce earthquake hazards in the existing development, and how the proposed mitigation programs can be implemented so as not to cause undue hardship on the community. Rehabilitation programs should target, on a priority basis, potentially hazardous buildings, critical facilities, and high-risk lifeline utilities.

Recent earthquakes, with their relatively low loss of life, have demonstrated that the best mitigation technique in earthquake hazard reduction is the constant improvement of building codes with the incorporation of the lessons learned from past earthquakes. The most recent building codes (UBC 1997; CBC 1998, 2001) are a prime example in incorporation of lessons and further reduction of the earthquake hazard. However, while new building codes reduce the hazard, increases in population leading to building in vulnerable areas and the aging of the existing building stock work toward increasing the earthquake hazard of a given region.

1.10.1 1997 Uniform Building Code Impacts on the City of Glendale

Two significant changes were incorporated into the 1997 Uniform Building Code (UBC – which is the basis for the 1998 and 2001 California Building Code) that impact the City of Glendale. The first change is a revision to soil types and amplification factors, and the second change is the incorporation of the proximity of earthquake sources in UBC seismic zone 4, which includes the City of Glendale. These changes represent the most significant increases in ground shaking criteria in the last 30 years. The new soil effects are based on observations made as a result of the Mexico City, Loma Prieta and other earthquakes, and impact all buildings in the City of Glendale. In addition, in the current code, soil effects impact buildings of short predominant period of ground shaking (low-rises), whereas in the past, only long-period structures (high-rises) were influenced by UBC requirements. The new ground-shaking basis for code design is now more complicated, however, because of the wide range of soil types and the close proximity of seismic sources. For the City of Glendale, these code changes are warranted. Due to the proximity of the Sierra Madre, Verdugo, Raymond and Hollywood fault systems, the entire area is impacted by the near-source design factors. The 1997 UBC contains detailed descriptions of the incorporation of these new parameters; only a summary is provided below.

Soil Types and Soil Amplification Factors: The seismic design response spectra are defined in terms of two site seismic coefficients Ca and Cv. These coefficients are determined as a function of the following parameters:

- Seismic Zone
- Soil Type, and
- Near Source Factors (UBC Zone 4 only)

The UBC outlines six soil types based on the average soil properties for the top 100 feet of the soil profile. Site-specific evaluation by the project's geotechnical engineer is required to classify the soil profile underlying proposed projects. The soil type parameters are intended to be used by project engineers with Tables 16-S and 16-T of the 1997 UBC. A general description of the 1997 UBC soil types are outlined in Table 1-12, and the soil types in the City of Glendale are illustrated in Plate 1-9.

Table 1-12: UBC Soil Profile Types

Soil Profile Type	Soil Profile Name/ Generic Description	Average Soil Properties for the Upper 100 Feet		
		Shear Wave Velocity (feet/second)	Standard Penetration Test (blows/foot)	Undrained Shear Strength (psf)
SA	Hard Rock	>5,000		
SB	Rock	2,500 to 5,000		
SC	Very dense soil and soft rock	1,200 to 2,500	>50	>2,000
SD	Stiff soil profile	600 to 1,200	15 to 50	1,000 to 2,000
SE	Soft soil profile	<600	<15	<1,000
SF	Soil requiring site-specific evaluation.			

Near- Source Factors: The Glendale area is subject to near-source design factors given the proximity of several active fault systems. These parameters, new to the 1997 Uniform Building Code (UBC), address the proximity of potential earthquake sources (faults) to the site. These factors were present in earlier versions of the UBC for implementation into the design of seismically isolated structures, but are now included for all structures. The adoption into the 1997 code of all buildings in UBC zone 4 was a result of the observation of more intense ground shaking than expected near the fault ruptures at Northridge in 1994, and again one year later at Kobe, Japan. The 1997 UBC also includes a near-source factor that accounts for directivity of fault rupture. The direction of fault rupture was observed to play a significant role in distribution of ground shaking at Northridge and Kobe. For Northridge, much of the earthquake energy was released into the sparsely populated mountains north of the San Fernando Valley, while at Kobe, the rupture direction was aimed at the city and was a contributing factor in the extensive damage. However, the rupture direction of a given source cannot be predicted, and as a result, the UBC requires a general increase in estimating ground shaking of about 20 percent to account for directivity.

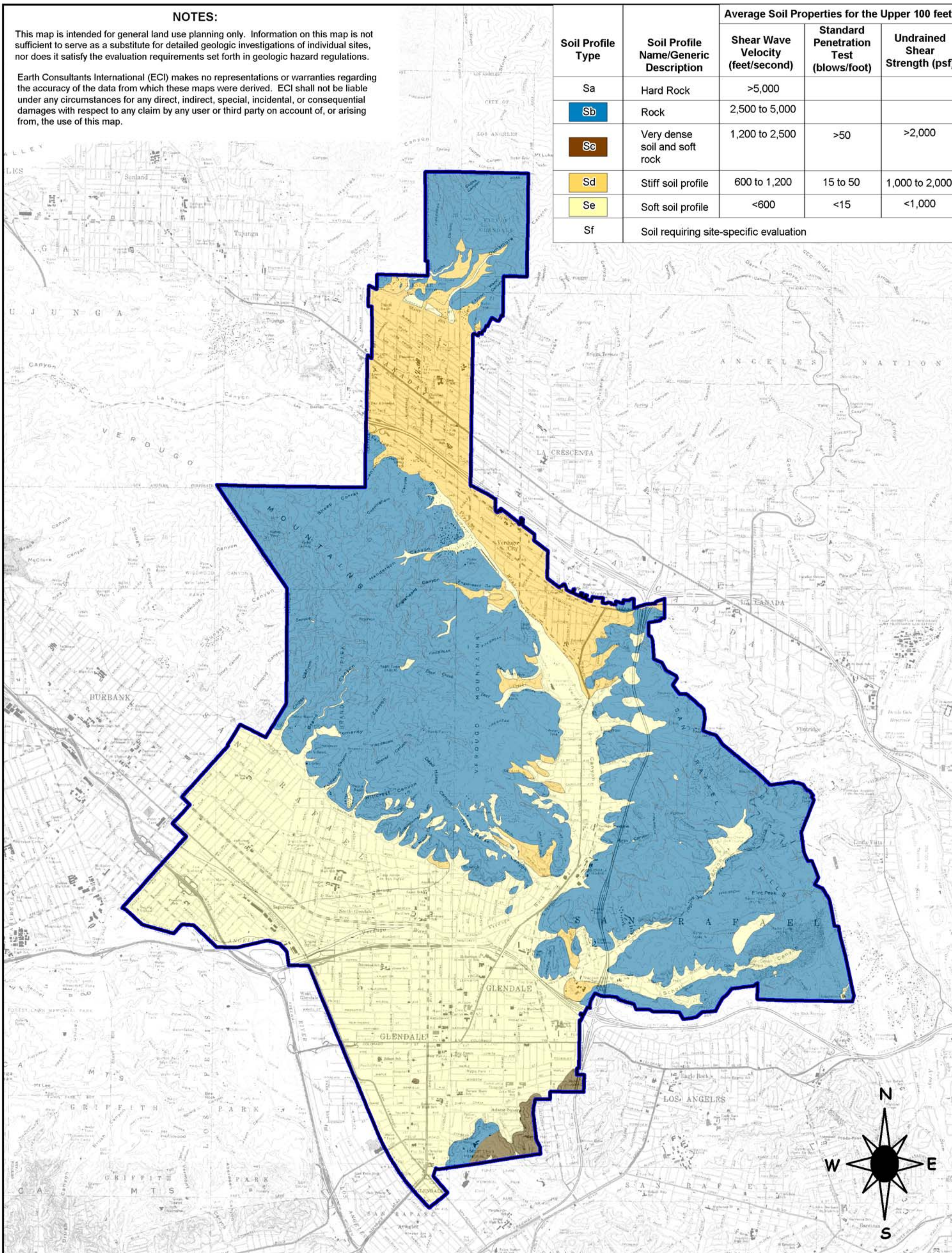
Seismic Source Type: Near source factors also include a classification of seismic sources based on slip rate and maximum magnitude potential. These parameters are used in the classification of three seismic source types (A, B and C) summarized on Table 1-13.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Soil Profile Type	Soil Profile Name/Generic Description	Average Soil Properties for the Upper 100 feet		
		Shear Wave Velocity (feet/second)	Standard Penetration Test (blows/foot)	Undrained Shear Strength (psf)
Sa	Hard Rock	>5,000		
Sb	Rock	2,500 to 5,000		
Sc	Very dense soil and soft rock	1,200 to 2,500	>50	>2,000
Sd	Stiff soil profile	600 to 1,200	15 to 50	1,000 to 2,000
Se	Soft soil profile	<600	<15	<1,000
Sf	Soil requiring site-specific evaluation			



Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Glendale City Boundary

Base Map: USGS Topographic Map from Sure!MAPS RASTER

Sources: Based on data from Dibblee (1989a, 1989b, 1991a, 1991b, 2002) and Byer (1968).

Earth Consultants International

Project Number: 2103

Date: July, 2003

Engineering Soil Types in Accordance with 1997 Uniform Building Code

Glendale, California

Plate 1-9

Table 1-13: Seismic Source Type

Seismic Source Type	Seismic Source Description	Seismic Source Definition	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/yr.)
A	Faults that are capable of producing large magnitude events and which have a high rate of seismicity.	M > 7.0 and	SR > 5
B	All faults other than Types A and C.		
C	Faults which are not capable of producing large magnitude earthquakes and which have a relatively low rate of seismic activity.	M < 6.5	SR < 2

Type A faults are highly active and capable of producing large magnitude events. Most segments of the San Andreas fault are classified as Type A. The Type A slip rate (>5 mm/yr) is common only to tectonic plate boundary faults. Type C seismic sources are considered to be sufficiently inactive and not capable of producing large magnitude events such that potential ground shaking effects can be ignored. Type B sources include most of the active faults in California and include all faults that are neither Type A nor C. The 1997 UBC requires that the locations and characteristics of these faults be established based on reputable sources such as the California Geological Survey (CGS – previously known as the California Division of Mines and Geology - CDMG) and the U.S. Geological Survey (USGS). The CGS classifies the Sierra Madre, Verdugo, Raymond, and Hollywood faults as Type B faults.

To establish near-source factors for any proposed project in the City of Glendale, the first step is to identify and locate the known active faults in the region. The International Conference of Building Officials (ICBO) has provided an Atlas of the location of known faults for California to accompany the 1997 UBC. The rules for measuring distance from a fault are provided by the 1997 UBC. The criteria for determining distance to vertical faults, such as the San Andreas, are relatively straightforward. However, the distance to thrust faults and blind thrust faults is assumed as 0 for anywhere above the dipping fault plane to a depth of 10 kilometers. This greatly increases the areal extent of high ground shaking parameters, but is warranted based on observations of ground shaking at Northridge.

Summary: Seismic codes have been undergoing their most significant changes in history. These improvements are a result of experience in recent earthquakes, as well as extensive research under the National Earthquake Hazard Reduction Program (NEHRP). Inclusion of soil and near-field effects in the 1997 UBC represents a meaningful and impactive change put forth by the geoscience community. Seismic codes will continue to improve with new versions of the building code, and as new data are obtained from both past and future earthquakes.

1.10.2 Retrofit and Strengthening of Existing Structures

The UBC is not retroactive, and past earthquakes have shown that many types of structures are potentially hazardous. Structures built before the lessons learned from the 1971 Sylmar earthquake are particularly susceptible to damage during an earthquake, including unreinforced masonry (URM) structures, pre-cast tilt-up concrete buildings, soft-story structures, unreinforced concrete buildings, as well as pre-1952 single-family structures. Other potentially hazardous buildings include irregular-shaped structures and mobile homes. Therefore, while the earthquake hazard mitigation improvements associated with the current building codes address new construction, the retrofit and strengthening of existing structures requires the adoption of ordinances. The City of Glendale has adopted an ordinance aimed at retrofitting unreinforced masonry buildings (URMs).

Other potentially hazardous buildings, such as pre-1971 concrete tilt-up structures, can be inventoried next. Potentially hazardous buildings can be identified and inventoried following the recommendations set forth in publications such as "Rapid Visual Screening of Buildings for Potential Seismic Hazards: Handbook and Supporting Documentation" and "A Handbook for Seismic Evaluation of Existing Buildings and Supporting Documentation", both prepared by the Applied Technology Council in Redwood City, California, and supplied by the Federal Emergency Management Agency (FEMA publications 154 and 155, and 175 and 178, respectively). The Glendale Building Department has already inventoried the soft-story buildings in the City, but this inventory needs to be kept current and in a digital file that can be improved and modified as necessary.

The building inventory phase of a seismic hazard mitigation program should accurately record the potentially hazardous buildings in an area. To do so, a GIS system is invaluable. The data base should include information such as the location of the buildings, the date and type of construction, construction materials and type of structural framing system, structural conditions, number of floors, floor area, occupancy and relevant characteristics of the occupants (such as whether the building houses predominantly senior citizens, dependent care or handicapped residents, etc.), and information on structural elements or other characteristics of the building that may pose a threat to life.

Once buildings are identified as potentially hazardous, a second, more thorough analysis may be conducted. This step may be carried out by local officials, such as the City's building department, or building owners may be required to submit a review by a certified structural engineer that has conducted an assessment of the structural and non-structural elements and general condition of the building, and has reviewed the building's construction documents (if available). The nonstructural elements should include the architectural, electrical and mechanical systems of the structure. Cornices, parapets, chimneys and other overhanging projections should be addressed too, as these may pose a significant threat to passersby, and to individuals who, in fear, may step out of the building during an earthquake. State of repair of buildings should also be noted, including cracks, rot, corrosion, and lack of maintenance, as these conditions may decrease the seismic strength of a structure. Occupancy should be noted as this factor is very useful in prioritizing the buildings to be abated for seismic hazards.

For multi-story buildings, large occupancy structures, and critical facilities, the seismic analysis of the structure should include an evaluation of the site-specific seismic environment (e.g., response spectra, estimates of strong ground motion duration, etc.), and an assessment of the building's loads and anticipated deformation levels. The resulting data should be weighted against acceptable levels of damage and risk chosen by the City for that particular structure. Once these guidelines are established, mitigation techniques available (including demolition, strengthening and retrofitting, etc.) should be evaluated, weighted, and implemented.

With the inventory and analysis phases complete, a retrofit program can be implemented. Although retrofit buildings may still incur severe damage during an earthquake, the mitigation results in a substantial reduction of casualties by preventing collapse. The societal and economic implications of rehabilitating existing buildings are discussed in many publications, including “Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings - A Handbook and Supporting Report”, “Typical Costs for Seismic Rehabilitation of Existing Buildings: Summary and Supporting Documentation,” (FEMA Publications 174 and 173, and 156 and 157, respectively). Another appropriate source is the publication prepared by Building Technology, Inc. entitled “Financial Incentives for Seismic Rehabilitation of Hazardous Buildings - An Agenda for Action (Report and Appendices).”

The City of Glendale should set a list of priorities by which strengthening of the buildings identified as hazardous will be established and conducted. Currently, there are no Federal or State mandated criteria established to determine the required structural seismic resistance capacity of structures. Retrofitting to meet the most current UBC standards may be cost-prohibitive, and therefore, not feasible. The City may develop its own set of criteria, however, this task should be carried out following a comprehensive development and review process that involves experienced structural engineers, building officials, insurance representatives, and legal authorities. Selection of the criteria by which the structural seismic resistance capacity of structures will be measured may follow a review of the performance during an earthquake of similar types of buildings that had been retrofit prior to the seismic event. Upgrading potentially hazardous buildings to, for example, 1973 standards may prove inefficient if past examples show that similar buildings retrofit to 1973 construction codes performed poorly during a particular earthquake, and had to be demolished anyway. Issues to be addressed include justification for strengthening a building to a performance level less than the current code requirements, the potential liabilities and limitations on liability, and the acceptable damage to the structure after strengthening (FEMA, 1985).

The mitigation program established by the City could be voluntary or mandatory. Voluntary programs to encourage mitigation of potentially hazardous buildings have been implemented with various degrees of success in California. Incentives that have been used to engender support among building owners include tax waivers, tax credits, and waivers from certain zoning restrictions. Other cities have required a review by a structural engineer when the building is undergoing substantial improvements.

1.11 Summary

Since it is not possible to prevent an earthquake from occurring, local governments, emergency relief organizations, and residents are advised to take action and develop and implement policies and programs aimed at reducing the effects of earthquakes. Individuals should also exercise prudent planning to provide for themselves and their families in the aftermath of an earthquake.

Earthquake Sources:

- The City of Glendale is located in an area where several active faults have been mapped. At least two active faults extend through portions of the City: the Sierra Madre fault along its northern limits, and the Verdugo fault through its central portion. The Raymond and Hollywood faults are generally mapped just south of the City’s boundaries, except for the easternmost portion of the Hollywood fault, which actually extends into the southern portion of the City. Given the location of these faults in and near the City, the 1997 Uniform Building

Code requires that Glendale incorporate near-source factors into the design of new buildings. In addition to the faults above, the Elysian Park, Santa Monica, Newport-Inglewood, San Gabriel, Oakridge and several other fault zones have the potential to generate earthquakes that would cause strong ground shaking in Glendale.

- Geologists, seismologists, engineers and urban planners typically use maximum magnitude and maximum probable earthquakes to evaluate the seismic hazard of a region, the assumption being that if we plan for the worst-case scenario, smaller earthquakes that are more likely to occur can be dealt with more effectively.
- A number of historic earthquakes have caused significant ground shaking in Glendale. The 1971 Sylmar and 1994 Northridge earthquakes caused significant damage in the City.

Design Earthquake Scenarios:

- Both the Sierra Madre and Verdugo faults have the potential to generate earthquakes that would be described as worst-case for the City of Glendale. The segment of the Sierra Madre fault that extends through the northern reaches of the City is thought capable of generating an earthquake of magnitude between 7.0 and 7.5. In this report, a magnitude 7.2 earthquake was modeled to obtain loss estimates for the City. A magnitude 7.5 earthquake would cause even higher losses than those presented here. Based on its known length, the Verdugo fault is thought capable of generating an earthquake as large as magnitude 6.7. This estimate of the size of the earthquake that the Verdugo fault is thought capable of generating has not been confirmed through field studies of the fault's previous surface-rupturing events (paleoseismic studies).
- A maximum magnitude earthquake on the Mojave segment of the San Andreas was also considered as a likely earthquake scenario given that this fault is thought to have a relatively high probability of rupturing in the not too distant future. The loss estimation model indicates that the damage caused by an earthquake on the San Andreas fault to the City of Glendale is small compared to the other earthquakes modeled, but not insignificant. Damages of about $83 million were estimated for Glendale if the segment of the San Andreas fault closest to the City breaks in a magnitude 7.1 earthquake. If more than one segment of the fault breaks in the same earthquake, the size of it will be larger, and the damage in Glendale can be anticipated to be more severe.

Fault Rupture and Secondary Earthquake Effects:

- Several active and potentially active faults are known to extend into or across the City, including traces of the Sierra Madre fault, the Verdugo fault, the eastern extension of the Hollywood fault, and the western extension of the Eagle Rock and Sycamore Canyon faults. A fault hazard management zone has been defined around some of these faults – it is proposed that geological studies to evaluate the potential for surface fault rupture should be required in these zones prior to development or redevelopment. A portion of the Sierra Madre fault (the Rowley fault) is zoned under the Alquist-Priolo Earthquake Fault Zoning Act, so geological evaluations to locate the fault are mandated by State law if developments or re-developments amounting to more than 50 percent of the original value of the structure are proposed within this zone. In early aerial photographs of the area, the Verdugo fault appears to have strong geomorphic expression along most of its trace, but unfortunately most of the fault zone is now covered with buildings and roads. This makes it difficult to locate and study the fault. However, given its potential to cause an earthquake that would break the surface, which would cause extensive damage to the buildings and infrastructure built across the traces of the fault, the City should consider implementing a program designed to locate and characterize the fault. Once this is done, structures located across the fault can be moved, strengthened, or demolished. Lots impacted by the fault can be purchased by the City and converted into open space or other suitable land use.

- Currently, shallow ground water levels (< 50 feet from the ground surface) are known to occur along that portion of the Verdugo Wash and its tributaries located north of the Verdugo fault, and in areas near the Los Angeles River. Shallow ground water perched on bedrock may be present seasonally in the canyons draining the south flank of the Verdugo Mountains, especially in the portions of the canyons north of the trace of the Verdugo fault. Seasonal fluctuations in groundwater levels, and the introduction of residential irrigation requires that site-specific investigations be completed to support these generalizations in areas mapped as potentially susceptible to liquefaction.
- Those portions of Glendale that may be susceptible to seismically induced settlement are generally the floodplains and larger drainages that are underlain by late Quaternary alluvial sediments (similar to the liquefaction-susceptible areas). Sites near the base of the San Gabriel and Verdugo Mountains and the San Rafael Hills, at the valley margins, may be particularly vulnerable as a result of differential settlement at the bedrock-alluvial contact.
- The northern and western portions of the Glendale area are most vulnerable to seismically induced slope failure, due to the steep terrain. Some areas in the San Rafael Hills are also susceptible to earthquake-induced slope instability.
- The California Geological Survey (CGS) has completed mapping in the Glendale area under the Seismic Hazards Mapping Act. Geological studies in accordance with the guidelines prepared by the CGS should be followed in those areas identified as having a liquefaction or slope-instability hazard.

Earthquake Vulnerability:

- Most of the loss of life and injuries that occur during an earthquake are related to the collapse of hazardous buildings and structures, or from non-structural components (contents) of those buildings.
- Inventory of potentially hazardous structures, such as concrete tilt-ups, pre 1971- reinforced masonry, and pre-1952 wood-frame buildings, is recommended.
- Most damage in the City is expected to be to wood-frame residential structures, which amount to more than 95 percent of the building stock in the City. Two of the earthquake scenarios modeled for this study suggest that as much as 50 percent of the residential buildings in the City will experience at least some damage. However, the damage to residential structures, although costly, is not expected to cause a large number of casualties.
- The loss estimation models indicate that some of the school buildings in the City are likely to be damaged during an earthquake. Glendale High School consistently received poor marks in the HAZUS analyses. Several schools in the northern portion of the City are expected to experience at least moderate damage as a result of an earthquake on the Sierra Madre fault. Given that the Glendale Unified School District, rather than the City, is responsible for the safety of the school buildings discussed in this report, it is recommended that the City provide the School District with the results of these analyses for the District to use as appropriate.

Given the HAZUS results, it would be prudent for the District to conduct a structural assessment of these schools, and prioritize their structural strengthening.

Earthquake Hazard Reduction:

- The best mitigation technique in earthquake hazard reduction is the constant improvement of building codes with the incorporation of the lessons learned from each past earthquake. This is especially true in areas not yet completely developed, but it is not the most practical option for cities like Glendale, where most of the land is already developed. Nevertheless, for new development, or re-development, where this involves more than 50 percent of the original cost of the structure, the adoption and implementation of the most current building code adopted by the City is warranted. The recent building codes incorporate two significant changes that impact the City of Glendale. The first change is a revision to soil types and amplification factors, and the second change is the incorporation of the proximity of earthquake sources in UBC seismic zone 4. However, since the City of Glendale is mostly developed, and building codes are generally not retroactive, the adoption of the most recent building code is not going to improve the existing building stock, unless actions are taken to retrofit the existing structures. Retrofitting existing structures to the most current building code is in most cases not practicable and cost-prohibitive. However, specific retrofitting actions, even if not to the latest code, that are known to improve the seismic performance of structures should be attempted.
- All of the Glendale area is subject to near-source design factors because the City is traversed by two active fault systems, and located near at least two other potentially significant seismic sources. These parameters, new to the 1997 Uniform Building Code (UBC) and the 1998 and 2001 California Building Codes (CBC), address the proximity and the potential of earthquake sources (faults) to the site.
- While the earthquake hazard mitigation improvements associated with the 1997 UBC address new construction, the retrofit and strengthening of existing structures requires the adoption of ordinances. The City of Glendale has adopted an ordinance aimed at retrofitting unreinforced masonry buildings (URMs). Similar ordinances can be adopted for the voluntary or mandatory strengthening of wood-frame residential buildings, pre-cast concrete buildings, and soft-story structures, among others. Although retrofitted buildings may still incur severe damage during an earthquake, their mitigation results in a substantial reduction of casualties by preventing collapse.
- Adoption of new building codes does not mitigate local secondary earthquake hazards such as liquefaction and ground failure. Therefore, these issues are best mitigated at the local level. Avoiding areas susceptible to earthquake-induced liquefaction, settlement or slope instability is generally not feasible. The best alternative for the City is to require "special studies" within these zones for new construction, as well as for significant redevelopment, and require implementation of the subsequent engineering recommendations for mitigation.

CHAPTER 2: GEOLOGIC HAZARDS

2.1 Physiographic Setting

The City of Glendale is located at the southeasternmost edge of the San Fernando Valley, in an area characterized by sharp contrasts in terrain. Distinct topographic features separate the City into four specific areas. From north to south these include 1) the steeply rising range front of the San Gabriel Mountains, 2) the gently south-dipping but elevated alluvial fan surface known as the La Cañada Valley at the base of the San Gabriel Mountains, 3) the lower but not less impressive bedrock highlands of the Verdugo Mountains and the San Rafael Hills, and 4) the even more gently south-dipping alluvial surface (piedmont) at the base of the Verdugo Mountains. Farther south, just outside the City limits, is the northeastern end of the Santa Monica Mountains, which are locally referred to as the Hollywood Hills. The Los Angeles River hugs the north side of the Hollywood Hills as it flows easterly through the area; when it reaches the eastern end of the hills, the river veers south to flow through the "Narrows" and the City of Los Angeles on its way to the Pacific Ocean. The two heavily populated alluvial surfaces at the base of the Verdugo and San Gabriel Mountains are linked by the south-trending canyon carved by the Verdugo Wash that separates the Verdugo Mountains on the west from the San Rafael Hills on the east.

Elevations in the southern part of the City range from about 420 feet above mean sea level at the southernmost point to about 800 feet at the base of the Verdugo Mountains. Mount Verdugo reaches an elevation of 3,126 feet, while the top of Flint Peak in the San Rafael Hills sits at an elevation of 1,889 feet. In the San Gabriel Mountains, the highest point within the City is at an elevation of about 4,800 feet.

The steep southern flank of the San Gabriel Mountains is deeply incised by gorges and canyons that drain south into the La Cañada Valley, where they have been channelized, conveying their flows south to Verdugo Wash. The three canyons that are located mostly within City limits include Ward, Dunsmore, and Cooks. Several other streams draining the San Gabriel Mountains that are also channelized through the La Crescenta area and into the northern portion of Glendale; these include the Eagle Canyon, Pickens, Hills and Winery Canyon channels. Refer to Chapter 3 and Plate 3-1 for additional information and the location of these landforms. Nearly all the tributaries flowing northerly and easterly out of the Verdugo Mountains and westerly out of the San Rafael Hills also empty into Verdugo Wash. South of the mountains, Verdugo Wash turns to the west-southwest and joins the Los Angeles River near the junction of Highway 134 with the 5 Freeway (Interstate 5). Drainage from the southwestern slope of the Verdugo Mountains flows directly across the alluvial fan and into the Los Angeles River. As discussed further in Chapter 3, Verdugo Wash has been confined to a man-made channel through most of Glendale to reduce the potential for it to flood the City.

2.2 Geologic Setting

The physical features described above reflect geologic and climatic processes that have effected this region in the last few million years. The most striking geologic features of the Glendale area are the Verdugo and San Gabriel Mountains, which form a dramatic backdrop to the southern and northern portions, respectively, of the City. These rugged, geologically young mountains are part of the Transverse Ranges Province of southern California. The characteristic features that define this province are a series of predominantly east-west trending mountain ranges and their intervening valleys. The ranges encompass the northern part of Los Angeles County as well as parts of Riverside, San Bernardino, Ventura, and Santa Barbara counties, and extend offshore, forming submarine canyons and ridges, in addition to the Channel Islands.

The San Gabriel Mountains are located in the central part of the Transverse Ranges, where they rise abruptly to heights of more than 7,000 feet above the valley floor (several peaks are more than 9,000 feet high and Mount Baldy is the highest at 10,064 feet). Bounded by the San Andreas fault system on the north and the Sierra Madre fault zone on the south, the mountains are essentially a large block of the Earth's crust that has been squeezed up and thrust over the valley floor by north-south compression along the Big Bend portion of the San Andreas tectonic plate boundary. Tectonic forces that initiated the rise of the mountains are thought to have started about 3.5 million years ago, at a time when scientists now believe there was a change in the relative motion of the Pacific and North American tectonic plates from strike-slip (slipping horizontally past one another) to transpressive (oblique movement that is a combination of strike-slip and compression). Uplift of the mountains accelerated in mid-Pleistocene time, about 500,000 years ago, and continues today (Wright, 1991). The current rate of uplift, in the context of geologic time, is one of the fastest in the world.

Displacements on faults at the northern edge of the Los Angeles Basin, in the San Fernando and San Gabriel Valleys, are mainly of the thrust or thrust-oblique type, causing older geologic units to be pushed up along a series of faults that dip northward beneath the mountains they have formed (see Plate 1-2). The most dramatic example of this in the Glendale area is the Sierra Madre fault zone, which has thrust ancient crystalline rocks onto and over younger sediments filling the valley. The Verdugo Mountains are also a prominent feature on the Glendale skyline. These mountains are separated from the San Gabriel mountain front by the La Cañada Valley ("cañada" is the Spanish word for valley, gorge, or ravine), but are composed of crystalline rocks similar to those exposed in the San Gabriel Mountains (Jennings et al., 1977; Dibblee, 1989a, 1991a, 1991b). During the mid Miocene (approximately 15 million years ago), the Glendale area was a region of low relief, but the same tectonic forces that gave rise to the San Gabriel Mountains also thrust the basement rocks up to form the present Verdugo Mountains (R.T. Frankian & Associates, 1968). This uplift is thought to have occurred along the Verdugo fault, which is identified by the juxtaposition of Cretaceous quartz diorite bedrock against Quaternary alluvial fan deposits along the southwestern front of the Verdugo range. Some researchers have suggested that vertical separation on this fault may be at least 3,300 feet (1,000 m) (Tsutsumi and Yeats, 1999). Not only was the bedrock uplifted, but it seems that the entire bedrock block was tilted to the north, as evidenced by the consistently north- to northeast-dipping fabric of the rock exposed in the Verdugo Mountains. More recently, the Verdugo fault is thought to be primarily a strike-slip fault (Walls et al., 1998; Dolan, personal communication, 2002).

Also in recent years, researchers have discovered that the Los Angeles metropolitan area is underlain by a series of deep-seated, low-angle thrust faults. When these faults do not reach the surface, they are called "blind thrusts". Faults of this type are thought to be responsible for the uplift of many of the low hills in the Los Angeles Basin, such as the Elysian Park, Repetto, and Montebello Hills (Dolan et al., 2001). Previously undetected blind thrust faults were responsible for the M5.9 Whittier Narrows earthquake in 1987, and the destructive M6.7 Northridge earthquake in 1994.

Strike-slip faults are also present in the northern Los Angeles basin, and where they have been most recently active, they have deformed the landscape and altered drainage patterns. An example of such faulting near the Glendale area is the Raymond fault, a predominantly left-lateral fault that is responsible for the string of low hills and knolls that disrupt the gently sloping valley floor near the southeastern edge of the City (Weaver and Dolan, 2000). The Raymond fault is an active structure that is thought to have been the source of the 1988 Pasadena earthquake (Jones et al., 1990). The relationship between the two styles of fault movement (thrust and strike-slip) is complex and not well understood. Consequently, it is currently one of the focus points in the ongoing research for a greater understanding of earthquake hazards in the Los Angeles basin (Dolan et al., 2001).

The San Rafael Hills are the southeastern extension of the Verdugo Mountains and are similarly separated from the San Gabriel Mountains by the La Cañada Valley. In their central and northern parts, the San Rafael Hills are composed of crystalline rocks similar to those exposed in the San Gabriel and Verdugo Mountains. However, the Eagle Rock fault, which traverses the southern part of the hills, forms the geologic boundary between crystalline rocks to the north and Miocene-age sedimentary rocks forming the low hills to the south.

The La Cañada Valley and the valley south of the Verdugo Mountains are infilled with alluvial fan sediments shed off the rising mountains. As a result, the composition of these alluvial deposits reflects that of the rocks eroded by the various streams emanating from the mountains. Multiple generations of overlapping alluvial fans are present, with older sediments occurring at depth, and younger deposits occurring near the top of the section. Deposition is still ongoing, and as a result, the alluvial sediments exposed at the ground surface are very young. As discussed in Section 1.7, and covered further in this chapter, the age of these alluvial sediments controls to some extent the engineering properties of the materials, and also determines their susceptibility to liquefaction, settlement, and other seismic and geotechnical hazards. Remnants of older surfaces are present locally near the base of the mountains, north of the Sierra Madre fault, where movement on the fault has elevated the alluvial deposits above the area of active deposition. Older alluvial sediments also occur locally in the Verdugo Mountains and San Rafael Hills, on the sides of canyons.

2.3 Geologic Units

The general distribution of geologic units that are exposed at the surface in the Glendale area is shown on the Geologic Map (Plate 2-1). In the numerous geologic maps that have been published over the years for this area, there are inconsistencies in the nomenclature used for faults and geologic formations. In the section that follows, the characteristics of each unit are discussed using the names published by Dibblee (1989a, 1989b, 1991a, 1991b, 2002). Descriptions of the units, as well as some of their engineering characteristics, are compiled from R.T. Frankian & Associates (1968), Lamar (1970), Morton (1973), Crook et al. (1987), Dibblee (1989a, 1989b, 1991a, 1991b, 2002), and the California Geological Survey (CDMG, 1998a, 1998b, 1998c). The units are described, from the youngest to the oldest, in the following sections. Fault names are those published primarily by Weber (1980), Dibblee (1989a, 1989b, 1991a, 1991b), Yerkes (1997), Yerkes and Graham (1997), and Envicom (1975).

2.3.1 Surficial Sediments

Researchers use the degree of soil development on surfaces, stratigraphic position, degree of stream incision, relative uplift, and mineral composition to estimate the age of alluvial deposits. If organic materials, such as charcoal, are found in the deposits, then the age of these sediments can be determined with more certainty using radiocarbon dating techniques. Other absolute age dating techniques for sediments, such as optical thermoluminescence, are slowly becoming more commonplace. The age estimates given below for the alluvial units in Glendale are based on a combination of techniques that different researchers have used to interpret the geologic history of the area.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Fault lines on the map are used solely to approximate the fault location. The width and location of the faults should not be used in lieu of site-specific investigations, evaluation, and design.

Detailed geologic investigations, including trenching studies, may make it possible to refine the location and activity status of a fault. All faults may not be shown. This map should be amended as new data become available and are validated.

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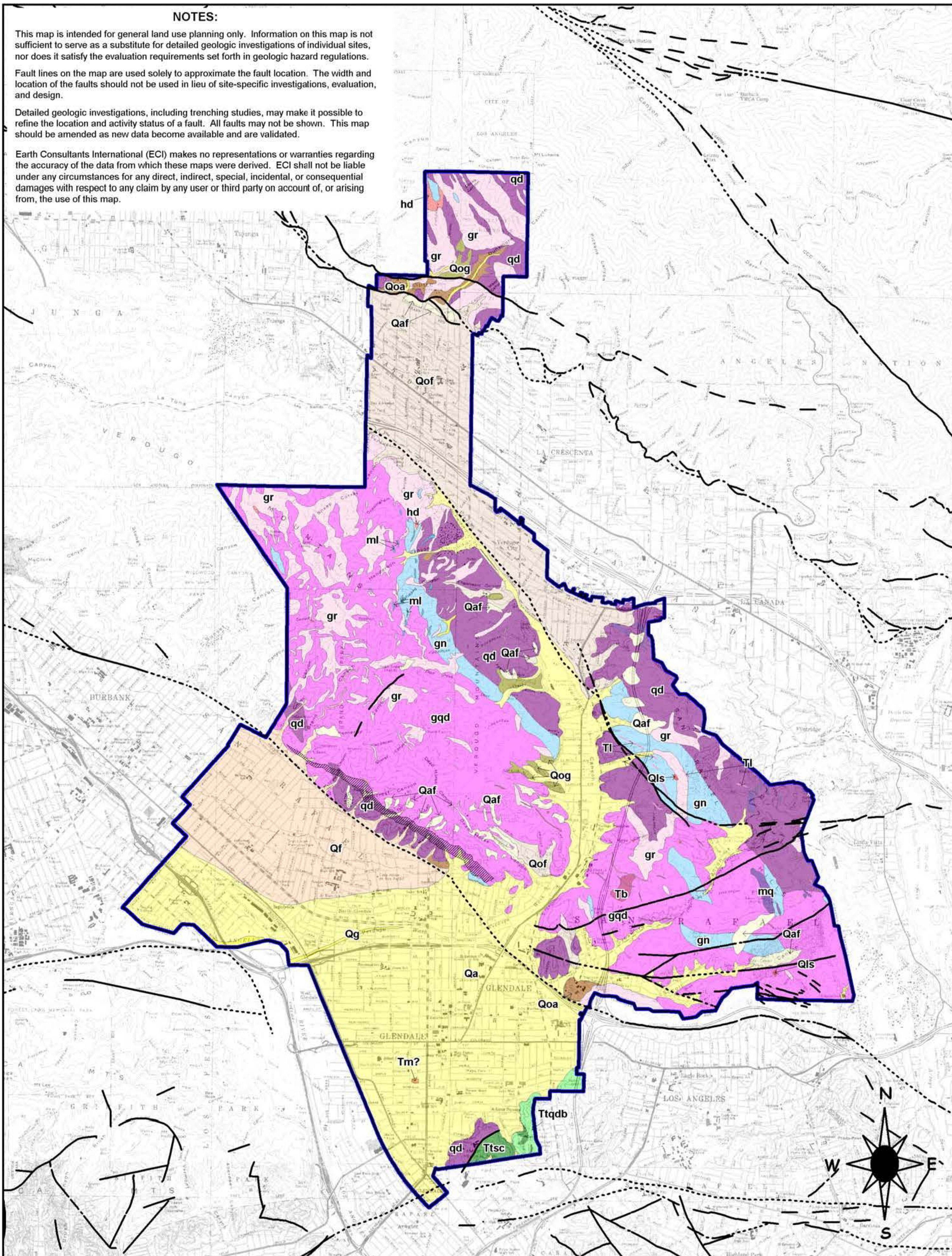

Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Weber, 1980; Dibblee, 1989a, 1989b, 1991a, 1991b, 2002; Rubin, 1992; Yerkes, 1997; Yerkes and Graham, 1997; Byer, 1968.

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Date: July, 2003

Geologic Map

Glendale, California

Plate 2-1

SYMBOLS

Fault; solid where location known, dashed where approximate, dotted where concealed, hatchured where defined as zone, (for more information refer to Plate 1-2).

Glendale City Boundary

Geologic Contact

GEOLOGIC UNIT DESCRIPTIONS

Quaternary

Holocene

Surficial Sediments

Qaf	Artificial fill
Qg	Stream channel deposits of gravel, sand and silt.
Qa	Alluvium; unconsolidated floodplain deposits of silt, sand and gravel.
Qf	Alluvial Fan
Qls	Mapped Landslide

Pleistocene

Older Dissected Surficial Sediments

Qoa	Remnants of older weakly consolidated alluvial deposits of gravel, sand and silt.
Qof	Alluvial fan gravel and sand derived from San Gabriel Mountains; includes some Qg and Qa in northern areas.
Qog	Elevated remnants of alluvial gravel and fanglomerate deposits, weakly indurated; in San Gabriel Mountain foothills partly weathered reddish; in that area may locally include Pacoima and Saugus Formation of Smith (1986).

Tertiary

Miocene

Monterey Formation

Tm?	White-weathering, thin bedded, platy siliceous and semi siliceous rocks.

Topanga(?) Formation

Ttqdb	Gray to brown breccia, massive to vaguely bedded, composed of angular detritus and a few rounded cobbles and boulders, all of biotite horblende quartz diorite.
Ttsc	Light gray to brown, semi-friable sandstone, and interbedded brown sandy to silty shale, semisiliceous shale, and pebble-cobble conglomerate of quartz diorite detritus; Luisian(?) stage.

Dike Rocks

Tb	Thin dikes of black to brown, fine-grained basaltic to andesitic intrusive rocks.
Tl	Thin dikes of light gray latite porphyry.

Mesozoic

Granitic Rocks

gr	Gray-white, medium- to fine-grained massive granitic rock mostly of quartz monzonite and granodiorite composition; composed essentially of quartz, plagioclase feldspar (oligoclase), K-feldspar (mostly microline) and minor biotite.

Quartz Diorite

qd	Gray, medium-grained quartz diorite to diorite, massive, non-gneissoid quartz diorite composed essentially of plagioclase feldspar (oligoclase-andesine, hornblende, biotite, and minor quartz); incoherent where weathered.
gqd	Gray, medium-grained quartz diorite to diorite, massive to gneissoid quartz diorite, composed essentially of plagioclase feldspar (oligoclase-andesine, hornblende, biotite, and minor quartz); incoherent where weathered.

Paleozoic or Older

Hornblende-Diorite

hd	Dark gray, massive to locally gneissoid, medium-grained diorite-gabbro composed m of hornblende and plagioclase feldspar (andesine); locally includes lenses of hornbl biotite-rich layered gneiss.

Precambrian (?)

Siliceous Metamorphic Rocks

mq	Gray, banded fine-grained siliceous rock; probably metaquartzite or metachert.

Gneissic Rocks

gn	Gray banded biotite-rich quartz plagioclase gneiss; in part contorted, migmatized wit quartz diorite (qd) and complexly intruded or injected by leucogranitic rocks (gr).
ml	Small lenses of white layered marble and associated clac-silicate rocks.

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Explanation of Geologic Map

Plate
2-1a

The youngest and most widely exposed alluvial units in the Glendale area consist of Holocene (about 10,000 years old and younger) channel and floodplain deposits derived from the Verdugo Mountains and the San Rafael Hills, and from the Hollywood Hills south and west of the Glendale area. The sediments have been transported from the base of the slopes to the piedmont surfaces by the streams that drain these highlands, that is, the tributaries to Verdugo Wash and Verdugo Wash itself. A large portion of the City is situated on these young deposits.

Older fan deposits form as an elevated, moderately to highly dissected surface near the San Gabriel Mountains range front, in the La Cañada Valley area. Limited exposures of this unit are also present as isolated terraces above active stream channels within the San Gabriel and Verdugo Mountains, and within deeply incised drainage channels where they are visible in the sidewalls below the younger units. Even older alluvial deposits occur locally on the uplifted side (north) of the active Sierra Madre thrust fault. The estimated age for these older sediments in the San Gabriel Mountains is about 200,000+ years (Crook et al., 1987).

Artificial Fill (map symbol Qaf) – Artificial fill occurs in small patches at the base of the San Gabriel Mountains and within canyons of the Verdugo Mountains and San Rafael Hills. The deposits in the San Gabriel and Verdugo Mountains consist primarily of engineered fill that has been compacted and is suitable for development. This type of fill lines the bottom of canyons and is used for residential developments, road beds, and flood control structures. Interstate Highway 210 is also built on engineered fill where it passes through the northern portion of Verdugo Canyon. In the San Rafael Hills, artificial fill that has been compacted to lower densities (not suitable for building foundations) is used for the Scholl Canyon Golf Course and Scholl Canyon Park. Many other areas of artificial fill, too small to show on the geologic map, are present in the City.

Holocene Alluvium (map symbols Qg and Qa) – This group includes modern stream channel and fan deposits (Qg), as well as slightly older floodplain deposits (Qa). Within the City of Glendale, the youngest alluvial unit (Qg) has been mapped in and immediately adjacent to the channel of the Los Angeles River, and in the lower-most reaches of the Verdugo Wash, just before it empties into the Los Angeles River. These sediments are not present in the central and upper reaches of the Verdugo Wash because sediment deposition in this area is now largely contained by the debris basins and man-made channels that have been built in the last about 50 to 70 years. The Qg deposits consist of unconsolidated, poorly sorted, white to gray, silt, sand and gravel. These deposits lack development of a soil profile at or near the ground surface, indicating their youthfulness. Their density has been described as very loose to loose.

The older (Qa) unit is the most extensive deposit in the study area, underlying most of southern Glendale, the Verdugo Wash canyon, and the central and lower reaches of several of the tributaries to Verdugo Wash. Qa deposits also underlie the small uplifted valley that dissects the southern part of the San Rafael Hills. In most areas, this unit consists of fluvial and alluvial fan deposits of unconsolidated, gray to olive brown, silt, fine to coarse sand, and gravel. Mid to late Holocene in age (approximately 5,000 years old and younger), these deposits have been slightly elevated above the modern drainage courses. The gravels are typically subangular to rounded, and are generally unweathered. Soil development in this unit is limited to a poorly developed A horizon. In the southern portion of the San Rafael Hills, this deposit consists primarily of silty and clayey sand with interbedded clay. The density of these deposits has been described as loose to medium dense.

The oldest Holocene unit (Qf) consists of alluvial fan deposits shed off the Verdugo Mountains and deposited at the base of the range front. This unit consists primarily of pale yellowish brown sandy layers with lesser amounts of matrix-supported pebble- to cobble-sized gravel. The compositions of the clasts include granite, quartz diorite, schist, crystalline limestone, and quartzite. These sediments are generally unconsolidated and show minimal soil development, as evidenced by a few buried A horizons and some possible buried B horizons (Dolan and Tucker, 1999).

***Pleistocene Dissected Alluvium (map* symbols: Qoa, Qof and Qog**) – The youngest Pleistocene unit that crops out in the study area (Qoa) consists of uplifted remnant alluvial fan deposits. Small patches of Qoa, approximately 1/2 acre in area, are located on both sides of Verdugo Wash, on the north side of the Verdugo fault, and at the San Gabriel range front, on the uplifted (north) side of the Sierra Madre fault zone. These alluvial fan deposits are characterized by weakly consolidated deposits of gravel, sand, and silt.

The next oldest unit (Qof) underlies most of the developed area of north Glendale and consists of mid-Pleistocene alluvial fan deposits shed from the San Gabriel Mountains and dissected by modern drainages. These deposits consist primarily of yellowish brown to pale brown silt, sand, and silty sand with little to no clay. The alluvium has been described as dense and weakly to moderately well consolidated. Near the mountain front, these deposits consist of crudely bedded sand and gravel with large boulders. Where undisturbed, this unit has a poorly to moderately developed soil profile which includes an A horizon and textural B horizon.

Most of the oldest alluvial deposits (Qog) have been removed by erosion or concealed by deposition of younger sediments. Exposures are limited to a few remnants uplifted above the bottom of Verdugo Canyon at the eastern end of the Verdugo Mountains. This unit consists of red to yellow, poorly consolidated to well-consolidated fine to coarse sand, silty sand, and gravel. Clay content varies from low to high. This unit has been extensively dissected by both large and small drainages, and typically has a well developed soil profile. Gravels within the unit are highly weathered.

Landslide Debris (map symbol Qls) - Three small landslides (Qls) of probable Holocene age have been mapped on the slopes of the Verdugo Mountains and the San Rafael Hills (see Plates 2-1 and 2-4). Because the bedrock in these areas is highly fractured and weathered, the slides consist of small blocks and rock fragments rather than large cohesive masses. The Qls deposits are discussed in more detail in the landslide hazards section below (Section 2.4.1).

2.3.2 Bedrock Units

Within Glendale, areas of high relief are underlain primarily by a complex assemblage of crystalline rocks created from multiple episodes of igneous intrusion and metamorphism deep within the Earth's crust. This association represents a long history of such events, and includes some of the oldest rocks (dating back to the Precambrian age) in southern California. The contacts between rock types are approximate and somewhat variable in geologic maps published over the years, reflecting the difficulty of mapping in rugged, brush-covered terrain, as well as identifying rock types that are highly shattered, sheared, and crushed. Many map units include more than one rock type, and the predominant rock type has typically been used to characterize the unit. One unit, the leucocratic granodiorite, occurs as dikes and irregular-shaped lenses intruding into the various different units southwest of the South Branch of the San Gabriel fault. The youngest bedrock unit consists of sedimentary rock formed from deep marine deposits that encroached onto the area where Glendale is now located prior to uplift of the present Verdugo and San Gabriel Mountains.

Topanga Formation (map symbol: Ttqdb and Ttsc) - The Miocene age Topanga Formation underlies the low hills at the southern edge of the City. This sedimentary rock unit is separated from the crystalline rocks of the San Rafael Hills by the Raymond fault. In the Glendale area, the Topanga Formation consists of two primary components: a light gray to brown sandstone interbedded with a lesser amount of shale and conglomerate (Ttsc), and a massive to vaguely bedded breccia with lenses of silty shale and sandstone (Ttqdb). Bedding character is typically crudely developed to massive in the conglomerate beds, whereas it is well developed in the finer grained sequences. Sedimentary structures within the deposits have led scientists to believe these sediments were deposited in a deep marine environment with a not too distant source (Lamar, 1970). This unit is folded, and bedding dips generally in the range of 20 to 30 degrees to the west and north, although both flatter and steeper dips have been measured locally (Dibblee, 1989a, 1989b).

Dike Rocks (map symbol: Tb and Tl) – These units occur as widely scattered, tabular bodies of igneous rock within older rocks of the Verdugo Mountains and the San Rafael Hills. The dikes typically formed by intrusion of magma into fractures and joints of the existing rocks. In the Glendale area, the dikes are fine-grained and consist of brown to black rocks of basaltic and andesitic composition (Tb), as well as pale gray rocks composed of light-colored minerals (Tl). The dikes are thought to be late Miocene in age, or older.

Leucocratic Granitic Rocks (map symbol: gr) – This unit includes light colored, fine- to medium-grained rocks composed primarily of quartz, plagioclase and potassium feldspars, with minor biotite. It occurs as bands and patches across the base of the San Gabriel Mountains, and as intrusive dikes into the older quartz diorite rock within the Verdugo Mountains and San Rafael Hills. This unit is exposed at a few sites along Verdugo and Sycamore Canyons. This unit is thought to be Cretaceous or Jurassic in age, but may be older.

Quartz Diorite (map symbol: qd and gqd) - Sometimes referred to as the Wilson Diorite, this unit is the most widespread bedrock type in the Glendale area. The bulk of the Verdugo Mountains and the San Rafael Hills are comprised of quartz diorite. The color of the rock is typically a light gray to light brown, and the minerals that form the rock include plagioclase feldspar, hornblende, biotite and quartz. The texture is generally medium grained and the structure is massive (qd). In the central part of the San Rafael Hills, just north of Highway 134, at the southeastern margin of Glendale, the mineral grains are aligned, giving the rock a distinct banding or "foliation" (qqd). This is called a "gneissoid" texture due to its similarity to gneiss, a relatively common metamorphic rock. The foliation gives the rock a somewhat layered structure, and in this area, that structure dips 60 to 70 degrees to the east and northeast. A similar structure is observed in the Verdugo Mountains, except that the foliation dips steeply to the east, and the orientation changes from northwesterly in the southern part of the mountains, to northerly in the northern part of the range (R.T. Frankian & Associates, 1968). The contact between the massive and foliated units is gradational. This rock is highly fractured and generally deeply weathered, making it friable (grains disaggregate easily) near the surface. This unit is approximately 122 million years old, based on actual dating of bedrock samples, and is therefore early Cretaceous in age (Larsen, 1958).

Hornblende Diorite-Gabbro (map symbol: hd) – Within City limits, this rock type crops out in a few small isolated areas in the northern part of Hahamongna Watershed Park. The rock is medium-grained and massive, but locally has a gneissoid structure. The rock is dark gray in color because it is rich in dark minerals such as hornblende and biotite.

Siliceous Metamorphic Rocks (map symbol: mq) – These rocks are rare within the City, occurring only locally in a few small isolated areas in the San Rafael Hills. As described by Smith (1986), this unit consists of medium gray, fine-grained to microcrystalline, banded, siliceous rock, probably metachert. It is estimated to be Paleozoic in age, but may be as old as Precambrian.

Gneissic Rocks (map symbol: gn and ml) – These are the oldest and most lithologically complex rocks that crop out in the Glendale area. The rocks are exposed as irregular patches in the San Rafael Hills and the Verdugo Mountains, and consist primarily of quartzofeldspathic gneiss (gn). Small lenses of white, layered marble and calc-silicate (ml) occur within these rocks in the central portion of the Verdugo Mountains. These rocks are complexly intruded by younger granitic rocks. The gneissic rocks are generally well-banded, and moderately to well-foliated. The foliation dips primarily to the northeast at 30 to 80 degrees (Dibblee, 1991a, 1991b).

2.4 Geologic Hazards in the Glendale Area

2.4.1 Landslides and Slope Instability

Nearly half of the land in Glendale consists of steep hillslopes and rugged mountains. These areas have for the most part been preserved in their near natural state, while most of the development in the City occurs in the flat to gently sloping alluvial surfaces at the base of the mountains. However, some development (primarily residential) is present in and adjacent to steep hillsides. These areas include the canyons within the Verdugo Mountains and the San Rafael Hills, and the alluvial fans situated at the front of the San Gabriel and Verdugo Mountains (see Plate 2-2). Such areas are locally vulnerable to slope instability, particularly in winters of heavy rainfall and in winters following wildfires.

Careful land management in hillside areas can reduce the economic and social losses caused by slope failures. This generally includes land use zoning to restrict development in unstable areas, grading codes for earthwork construction, geologic and soil engineering investigations and reviews, construction of drainage structures, and where warranted, placement of warning systems. Other important factors are risk assessments (including susceptibility maps), a concerned local government, and an educated public.

TYPES OF SLOPE FAILURES

Slope failures occur in a variety of forms and there is usually a distinction made between gross failures (sometimes also referred to as "global" failures) and surficial failures. Gross failures include deep-seated or relatively thick slide masses, such as landslides, whereas surficial failures can range from minor soil slips to destructive debris flows. Slope failures can occur on natural or man-made slopes. Most failures of man-made slopes occur on older slopes, many of which were built at slope gradients steeper than those allowed by today's grading codes. Although infrequent, failures can also occur on newer graded slopes, generally due to poor engineering or poor construction. Slope failures often occur as elements of interrelated natural hazards in which one event triggers a secondary event, such earthquake-induced landsliding, fire-flood sequences, or storm-induced mudflows.

Gross Instability

Landslides - Landslides are movements of relatively large land masses, either as nearly intact bedrock blocks, or as jumbled mixes of bedrock blocks, fragments, debris, and soil. The type of movement is generally described as translational (slippage on a relatively planar, dipping layer), rotational (circular-shaped failure plane) or wedge (movement of a wedge-shaped block from between intersecting planes of weakness, such as fractures, faults and bedding).

The potential for slope failure is dependent on many factors and their interrelationships. Some of the most important factors include slope height, slope steepness (Plate 2-2), shear strength and orientation of weak layers in the underlying geologic unit (see Plate 2-3), as well as pore water pressures. Joints and shears, which weaken the rock fabric, allow water to enter the bedrock mass leading to deeper weathering of the rock, along with increased pore pressures and increased weight of the landmass. Water also increases the plasticity of weak clays lining the joints or shears, forming planes of weakness along which the landmass can fail. Ultimately, all of these conditions can cause the slope to fail.

For engineering of earth materials, these factors are combined in calculations to determine if a slope meets a minimum safety standard. The generally accepted standard is a factor of safety of 1.5 or greater (where 1.0 is equilibrium, and less than 1.0 is failure). Although existing landslides are not widespread in the Glendale area, it is probable that many of the steeper hillsides do not meet the minimum factor of safety, and slope stabilization may be needed if development reaches these areas. Natural slopes, graded slopes, or graded/natural slope combinations must meet these minimum engineering standards where they impact planned homes, subdivisions, or other types of developments. Slopes adjacent to areas where the risk of economic losses from landsliding is small, such as parks and mountain roadways, are often allowed a lesser factor of safety. From an engineering perspective, landslides are generally unstable (may be subject to reactivation), and may be compressible, especially around the margins, which are typically highly disturbed and broken. The headscarp area above the landslide mass is also unstable, since it is typically oversteepened, cracked, and subject to additional failures.

Surficial Instability

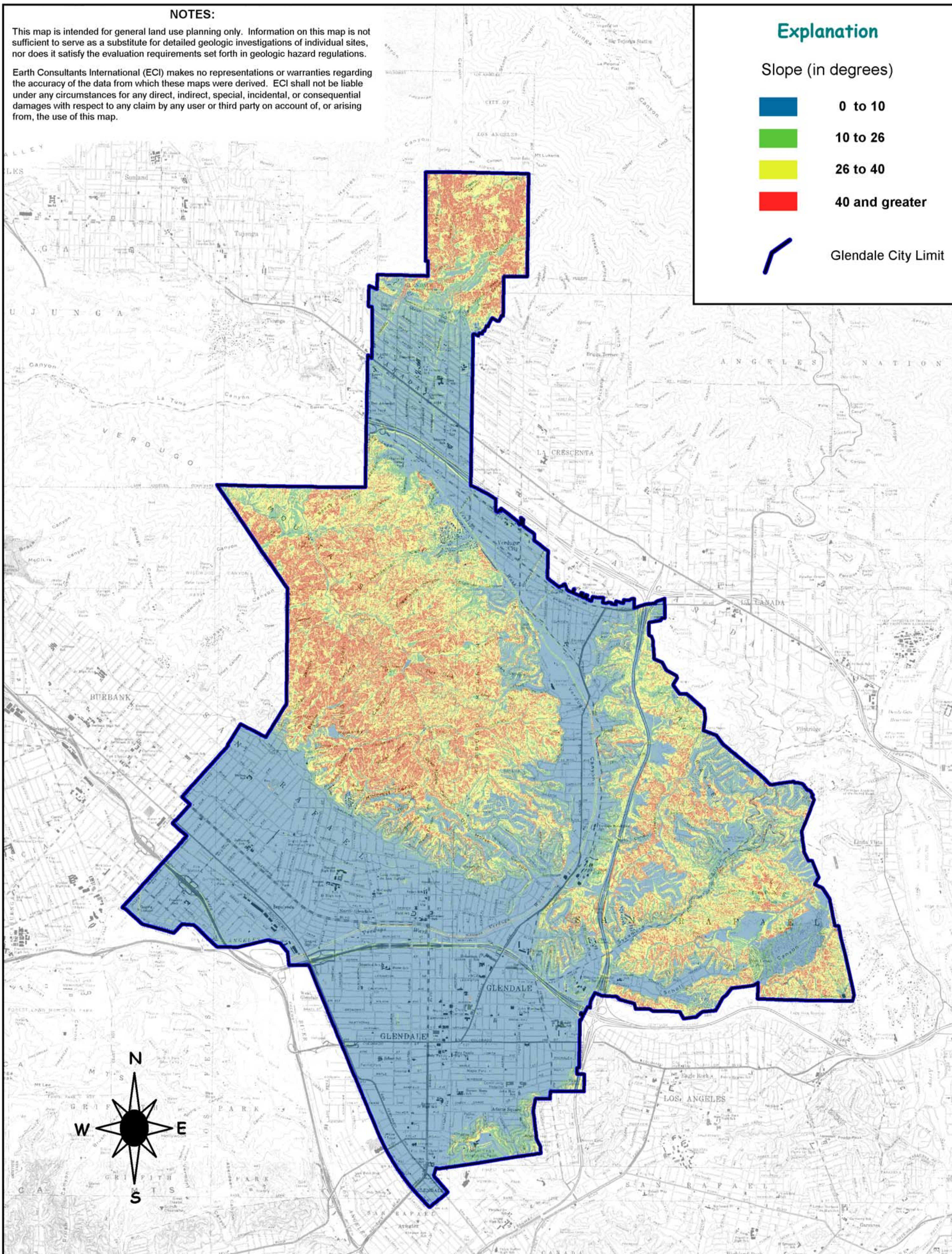
Slope Creep - Slope creep in general involves deformation and movement of the outer soil or rock materials in the face of the slope, due to the forces of gravity overcoming the shear strength of the material. Soil creep is the imperceptibly slow and relatively continuous downslope movement of the soil layer on moderate to steep slopes. Creep is most common in soils that develop on fine-grained bedrock units. Rock creep is a similar process, and involves permanent deformation of the outer few feet of the rock surface, resulting in folding and fracturing. Rock creep is most common in highly fractured, fine-grained rock units, such as siltstone and claystone, but also occurs in highly fractured crystalline rock. In fact, studies of prehistoric landslides in the San Gabriel Mountains suggest that creep can weaken steep rock slopes to the point where toppling failure (essentially a large slide consisting of angular blocks of rock) can occur (Rodgers et al., 1992).

Creep also occurs in graded fill slopes. This process is thought to be related to the alternate wetting and drying of slopes constructed with fine-grained, expansive soils. The repeated expansion and contraction of the soils at the slope face leads to loosening and fracturing of the soils, thereby leaving the soils susceptible to creep. While soil creep is not catastrophic, it can cause damage to structures and improvements located at the top of the slope.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.



Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: Derived from City of Glendale Digital Terrain Model

Earth Consultants International

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Date: July, 2003

Slope Distribution Map

Glendale, California

Plate 2-2

NOTES:

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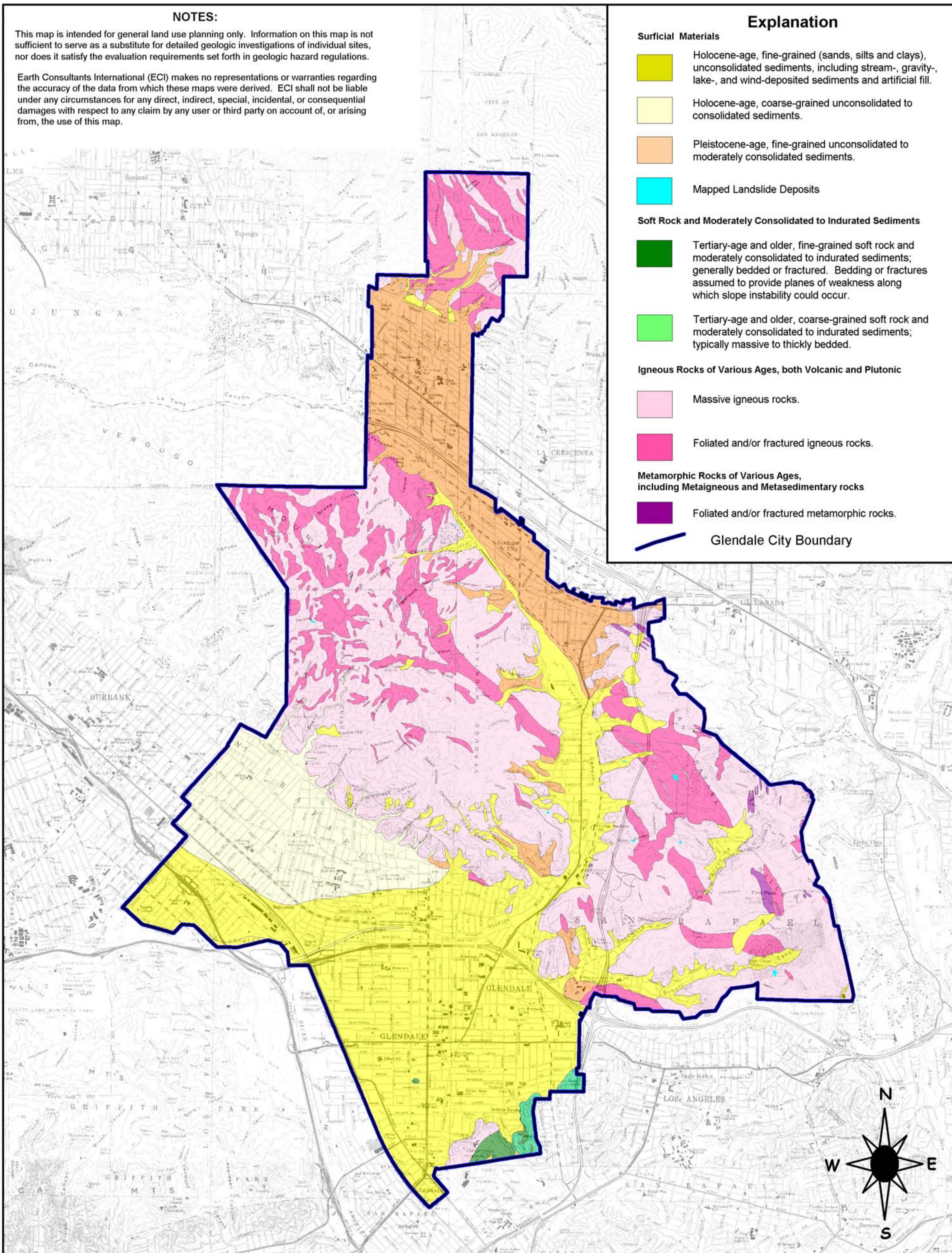


Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Based on data from Dibblee (1989a, 1989b, 1991a, 1991b, 2002) and Byer (1968).

Earth Consultants International

Project Number: 2103
Date: July, 2003

Engineering Geologic Materials Map
Glendale, California

Plate 2-3

Soil Slip - This type of failure is generated by strong winter storms, and is widespread in the steeper slope areas, particularly after winters with prolonged and/or heavy rainfall. Failure occurs on canyon sideslopes, and in soils that have accumulated in swales, gullies and ravines. Slope steepness has a strong influence on the development of soil slips, with most generated on slopes with gradients of between 27 and 56 degrees (Campbell, 1975).

Earth flow - This type of slope failure is a persistent, slow-moving, lobe-shaped slump that typically comes to rest on the slope not far below the failure point. Earth flows commonly form in fine-grained soils (clay, silt and fine sand), and are mobilized by an increase in pore water pressure caused by infiltration of water during and after winter rains. Earth flows occur on moderate to steep slopes with gradients of between 15 and 35 degrees (Keefer and Johnson, 1983).

Rockfall – Rockfalls are free-falling to tumbling masses of bedrock that have broken off steep canyon walls or cliffs. The debris from repeated rockfalls typically collects at the base of extremely steep slopes in cone-shaped accumulations of angular rock fragments called talus. Rockfalls can happen wherever fractured rock slopes are oversteepened by stream erosion or man's activities.

Debris Flow - This type of failure is the most dangerous and destructive of all types of slope failure. A debris flow (also called mudflow, mudslide, and debris avalanche) is a rapidly moving slurry of water, mud, rock, vegetation and debris. Larger debris flows are capable of moving trees, large boulders, and even cars. This type of failure is especially dangerous as it can move at speeds as fast as 40 feet per second, is capable of crushing buildings, and can strike with very little warning. As with soil slips, the development of debris flows is strongly tied to exceptional storm periods of prolonged rainfall. Failure occurs during an intense rainfall event, following saturation of the soil by previous rains.

A debris flow most commonly originates as soil slip in the rounded, soil-filled "hollow" at the head of a drainage swale or ravine. The rigid soil mass is deformed into a viscous fluid that moves down the drainage, incorporating into the flow additional soil and vegetation scoured from the channel. Debris flows also occur on canyon walls, often in soil-filled swales that do not have topographic expression. The velocity of the flow depends on the viscosity, slope gradient, height of the slope, roughness and gradient of the channel, and the baffling effects of vegetation. Even relatively small amounts of debris can cause damage from inundation and/or impact (Ellen and Fleming, 1987; Reneau and Dietrich, 1987). Recognition of this hazard led FEMA to modify its National Flood Insurance Program to include inundation by "mudslides" (FEMA, 2001).

Watersheds that have been recently burned typically yield greater amounts of soil and debris than those that have not burned. Erosion rates during the first year after a fire are estimated to be 15 to 35 times greater than normal, and peak discharge rates range from 2 to 35 times higher. These rates drop abruptly in the second year, and return to normal after about 5 years (Tan, 1998). In addition, debris flows in burned areas are unusual in that they can occur in response to small storms and do not require a long period of antecedent rainfall. These kinds of flows are common in small gullies and ravines during the first rains after a burn, and can become catastrophic when a severe burn is followed by an intense storm season (Wells, 1987). The United States Geological Survey (USGS), as part of its National Landslide Hazards Program, is currently developing tools and methodologies to identify and quantify slope stability hazards posed by burned watersheds. Such tools will help communities with emergency planning and in dealing with post-fire rehabilitation (USGS, 2001).

OCCURRENCE OF SLOPE FAILURES IN THE GLENDALE AREA

Evidence of past slope failures are found throughout the mountain and foothill regions of the City of Glendale. The crystalline rock of the San Gabriel Mountains, weakened by fracturing, shearing, and crushing along numerous fault zones, particularly near the range front, combined with the moderate to extremely steep slopes that have resulted from rapid uplift of the mountains, are important elements that create the setting for the development of slope failures. Similar conditions are present in the Verdugo Mountains and the San Rafael Hills, where rocks are highly weathered and slope gradients of 30 degrees or steeper are common.

Significantly, however, areas of gross instability such as large deep-seated landslides have not been mapped in the Glendale area, primarily because the highly fractured crystalline rocks that underlie the San Gabriel and Verdugo Mountains and the San Rafael Hills rarely fail as large cohesive units. All of the landslides mapped within City limits are relatively small in area, and limited to the Verdugo Mountains and San Rafael Hills. The larger of these landslides are shown on Plates 2-2 and 2-4. Numerous other smaller landslides have also occurred in the area, but their size is too small to show on the maps that accompany this report. Large prehistoric landslides have been mapped in the San Gabriel Mountains just to the east of the City, but not in the Glendale area. The distribution of existing landslides in the Glendale area and vicinity was compiled from various publications, including Morton and Streitz, (1969), Crook et al. (1987), and Dibblee, (1989a, 1989b, 1991a, 1991b, 2002).

Areas of surficial instability are common along the steep slopes and canyons the San Gabriel Mountains, Verdugo Mountains and San Rafael Hills. Unfortunately detailed maps showing previous sites of surficial slope failures, such as small landslides, slumps, soil slips, and rockfalls have not been compiled or published for the Glendale area. However, an unpublished engineering geology report records several talus rockfalls on steep slopes and roadcuts in the Verdugo Mountains (R. T. Frankian & Associates, 1968). The common occurrence of rockfalls can also be inferred by the abundant talus at the base of steep slopes and in canyons of the San Gabriel Mountains.

The Southern California Area Mapping Project (SCAMP), a cooperative effort between the US Geological Survey (USGS) and the California Geological Survey (CGS), has produced a series of Debris-Flow Occurrence Maps, at a scale of 1:100,000, that predict in a general way areas that will be prone to debris flows in normally vegetated hillsides (SCAMP, 2001). The maps are based on their studies of recent El Nino events, specifically relating the relationships between rainfall thresholds, terrain, and past debris flow events. Their studies indicate that in upland areas underlain by sedimentary rock and fractured crystalline rock (such as that found in the mountains of Glendale), essentially all past debris flows have occurred on slopes with gradients of 26 degrees or steeper. The mapped debris flow susceptibility areas in the San Gabriel Mountains include most slopes steeper than 26 degrees, but do not include the heads of the large alluvial fans at the base of the mountains because the flood control dams and debris basins that have been built in these areas are thought to be adequate to contain flows from unburned areas.

However, flows can overwhelm flood control structures during periods of extreme rainfall on a recently burned hillside. For instance, during winters of exceptional rainfall (such as 1934, 1969, 1978, and 1980), debris flows caused widespread property damage and loss of life in communities in and near the base of the San Gabriel Mountains, with areas below burned watersheds receiving the bulk of the damage. For example, in November 1933, there was a large fire in the Montrose-La Crescenta area that burned more than 5,000 acres. Then, on January 1, 1934, intense rainfall fell on the same area that had burned. La Crescenta and Glendale received the brunt of the damage. Several people died, swept away by debris-laden flows that overtopped the canyons in the area. Streets were clogged with debris, and several bridges were washed out (see Plate 3-2). In 1978, several canyons within burned watersheds near the Glendale area overtopped their debris basins (Davis, 1980). These canyons include Zachau Canyon located north of Sunland, Shields Canyon north of La Crescenta, and Rubio Canyon north of Altadena. In 1980, the Rubio basin again overflowed, partially inundating one home and threatening several others (Davis, 1980). Therefore, if the right conditions are met, such as high rainfall within burned watersheds, the possibility that debris flows will overtop basins in the Glendale area cannot be precluded.

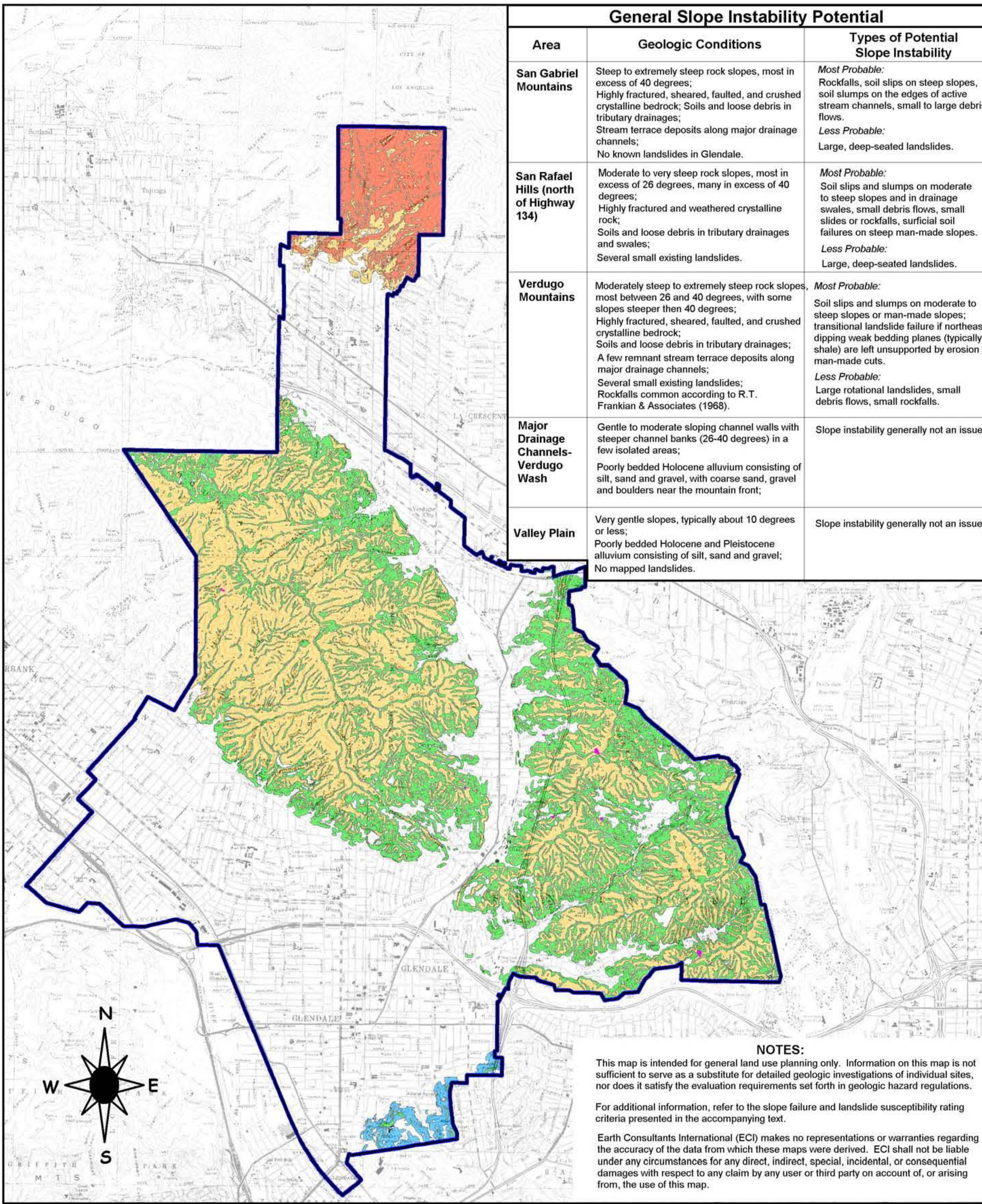
A recent detailed study of burned watersheds (including in the San Gabriel Mountains during and after the 1997-1998 winter rains) indicate that less than half of the drainage basins produced debris flows, although the debris flows that did occur were most frequently in response to the initial heavy rainfall. In addition to rainfall and slope steepness, the study highlights the many other factors that contribute to the formation of post-fire debris flows, including the underlying rock type, the shape of the drainage basin, and the presence or absence of water-repellent soils. The goal of these studies is a better understanding of the processes and conditions that generate this hazard, an understanding that is needed in order for communities to make appropriate decisions on public safety and slope mitigation (Cannon, 2001).

SUSCEPTIBILITY TO SLOPE FAILURE

The City's mountain and foothill areas are vulnerable to the types of slope instability mentioned above. Steep-sided slopes along Verdugo Wash and other incised drainages may also be locally susceptible to slope instability. Table 2-1 below is a general summary of the geologic conditions in various parts of the City that provide the environment for slope instability to occur. These conditions usually include such factors as terrain steepness, rock or soil type, condition of the rock (such as degree of fracturing and weathering), internal structures within the rock (such as bedding, foliation, faults) and the prior occurrence of slope failures. Catalysts that ultimately allow slope failures to occur in vulnerable terrain are most often water (heavy and prolonged rainfall), erosion and undercutting by streams, man-made alterations to the slope, or seismic shaking. The summary in Table 2-1 was derived from the Geologic Map (Plate 2-1), the Slope Distribution Map (Plate 2-2), and the Engineering Materials Map (Plate 2-3). The information in Table 2-1 was then used to prepare the Slope Instability Map for Glendale (Plate 2-4).

Table 2-1: General Slope Instability Potential within the City of Glendale

Area	Geologic Conditions	Types of Potential Slope Instability
San Gabriel Mountains	Steep to extremely steep rock slopes, most in excess of 40 degrees; Highly fractured, sheared, faulted, and crushed crystalline bedrock; Soils and loose debris in tributary drainages; Stream terrace deposits along major drainage channels; No known landslides in Glendale.	*Most Probable:* Rockfalls, soil slips on steep slopes, soil slumps on the edges of active stream channels, small to large debris flows. *Less Probable:* Large, deep-seated landslides.
San Rafael Hills (north of Highway 134)	Moderate to very steep rock slopes, most in excess of 26 degrees, many in excess of 40 degrees; Highly fractured and weathered crystalline rock; Soils and loose debris in tributary drainages and swales; Several small existing landslides.	*Most Probable:* Soil slips and slumps on moderate to steep slopes and in drainage swales, small debris flows, small slides or rockfalls, surficial soil failures on steep man-made slopes. *Less Probable:* Large, deep-seated landslides.
Verdugo Mountains	Moderately steep to extremely steep rock slopes, most between 26 and 40 degrees, with some slopes steeper then 40 degrees; Highly fractured, sheared, faulted, and crushed crystalline bedrock; Soils and loose debris in tributary drainages; A few remnant stream terrace deposits along major drainage channels; Several small existing landslides; Rockfalls common according to R.T. Frankian & Associates (1968).	*Most Probable:* Soil slips and slumps on moderate to steep slopes and in drainage swales, small debris flows, small slides or rockfalls, surficial soil failures on steep man-made slopes. *Less Probable:* Large, deep-seated landslides.
Major Drainage Channels – Verdugo Wash	Gentle to moderate sloping channel walls with steeper channel banks (26-40 degrees) in a few isolated areas; Poorly bedded Holocene alluvium consisting of silt, sand and gravel, with coarse sand, gravel and boulders near the mountain front; No mapped landslides.	Slope instability generally not an issue.
Valley Plain	Very gentle slopes, typically about 10 degrees or less; Poorly bedded Holocene and Pleistocene alluvium consisting of silt, sand and gravel; No mapped landslides.	Slope instability generally not an issue.



General Slope Instability Potential

Area	Geologic Conditions	Types of Potential Slope Instability
San Gabriel Mountains	Steep to extremely steep rock slopes, most in excess of 40 degrees; Highly fractured, sheared, faulted, and crushed crystalline bedrock; Soils and loose debris in tributary drainages; Stream terrace deposits along major drainage channels; No known landslides in Glendale.	*Most Probable:* Rockfalls, soil slips on steep slopes, soil slumps on the edges of active stream channels, small to large debris flows. *Less Probable:* Large, deep-seated landslides.
San Rafael Hills (north of Highway 134)	Moderate to very steep rock slopes, most in excess of 26 degrees, many in excess of 40 degrees; Highly fractured and weathered crystalline rock; Soils and loose debris in tributary drainages and swales; Several small existing landslides.	*Most Probable:* Soil slips and slumps on moderate to steep slopes and in drainage swales, small debris flows, small slides or rockfalls, surficial soil failures on steep man-made slopes. *Less Probable:* Large, deep-seated landslides.
Verdugo Mountains	Moderately steep to extremely steep rock slopes, most between 26 and 40 degrees, with some slopes steeper then 40 degrees; Highly fractured, sheared, faulted, and crushed crystalline bedrock; Soils and loose debris in tributary drainages; A few remnant stream terrace deposits along major drainage channels; Several small existing landslides; Rockfalls common according to R.T. Frankian & Associates (1968).	*Most Probable:* Soil slips and slumps on moderate to steep slopes or man-made slopes; transitional landslide failure if northeast dipping weak bedding planes (typically shale) are left unsupported by erosion or man-made cuts. *Less Probable:* Large rotational landslides, small debris flows, small rockfalls.
Major Drainage Channels- Verdugo Wash	Gentle to moderate sloping channel walls with steeper channel banks (26-40 degrees) in a few isolated areas; Poorly bedded Holocene alluvium consisting of silt, sand and gravel, with coarse sand, gravel and boulders near the mountain front;	Slope instability generally not an issue.
Valley Plain	Very gentle slopes, typically about 10 degrees or less; Poorly bedded Holocene and Pleistocene alluvium consisting of silt, sand and gravel; No mapped landslides.	Slope instability generally not an issue.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

For additional information, refer to the slope failure and landslide susceptibility rating criteria presented in the accompanying text.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Derived from Dibblee, 1989a, 1989b, 1991a, 1991b, 2002; Byer, 1968 and United States Geological Survey 10-meter Digital Elevation Model.

Scale: 1:64,000

1 0 1 2 3 Kilometers

0.5 0 0.5 1 1.5 Miles

EXPLANATION

Mapped Landslides (small isolated areas in the Verdugo Mountains and the San Rafael Hills.)

Glendale City Boundary

Slope Instability Rating

- Very High
- High
- Moderate
- Low

CITY OF GLENDALE CALIFORNIA

Earth Consultants International

Project Number: 2103
Date: July, 2003

Slope Instability Map

Glendale, California

Plate 2-4

MITIGATION OF SLOPE INSTABILITY IN FUTURE DEVELOPMENT

All proposed projects require a site-specific geotechnical evaluation of any slopes that may impact the future use of the property. This includes existing slopes that are to remain, and any proposed graded slopes. The investigation typically includes borings to collect geologic data and soil samples, laboratory testing to determine soil strength parameters, and engineering calculations. Numerous soil engineering methods are available for stabilizing slopes that pose a threat to development. These methods include designed buttresses (replacing the weak portion of the slope with engineered fill); reducing the height of the slope; designing the slope at a flatter gradient; and adding reinforcements such as soil cement or layers of geogrid (a tough polymeric net-like material that is placed between the horizontal layers of fill). Most slope stabilization methods include a subdrain system to remove excessive ground water from the slope area. If it is not feasible to mitigate the slope stability hazard, building setbacks are typically imposed.

For debris flows, assessment of this hazard for individual sites should focus on structures located or planned in vulnerable positions. This generally includes canyon areas; at the toes of steep, natural slopes; and at the mouth of small to large drainage channels. Mitigation of soil slips, earthflows, and debris flows is usually directed at containment (debris basins), or diversion (impact walls, deflection walls, diversion channels, and debris fences). A system of baffles may be added upstream to slow the velocity of a potential debris flow. Other methods include removal of the source material, placing subdrains in the source area to prevent pore water pressure buildup, or avoidance by restricting building to areas outside of the potential debris flow path.

There are numerous methods for mitigating rock falls. Choosing the best method depends on the geological conditions (i.e., slope height, steepness, fracture spacing, bedding orientation), safety, type and cost of construction repair, and aesthetics. A commonly used method is to regrade the slope. This ranges from locally trimming hazardous overhangs, to completely reconfiguring the slope to a more stable condition, possibly with the addition of benches to catch small rocks. Another group of methods focuses on holding the fractured rock in place by draping the slope with wire mesh, or by installing tensioned rock bolts, tie-back walls, or even retaining walls. Shotcrete is often used on the slope face to prevent raveling in highly fractured rock, but its primary purpose is to offer surface protection only. A third type of mitigation includes catchment devices at the toe of the slope, such as ditches, walls, or combinations of both. Designing the width of the catchment structure requires analysis of how the rock will fall. For instance, the slope gradient and roughness of the slope determines if rocks will fall, bounce, or roll to the bottom. Rock slope stabilization may also include the addition of drains in order to reduce water pressure within the slope (Wyllie and Norrish, 1996).

MITIGATION OF SLOPE INSTABILITY IN EXISTING DEVELOPMENT

There are a number of options for management of potential slope instability in developed hillsides.

- Complete a detailed survey and assessment of existing developments in areas recognized to be vulnerable to potential slope failures (for instance, the Verdugo Mountains, the San Rafael Hills, and at the base of the San Gabriel Mountains).

- Protect existing development and population where appropriate by physical controls such as drainage, slope-geometry modification, protective barriers, and retaining structures.
- Implement monitoring or warning systems. For instance in the San Francisco Bay area, the USGS, in cooperation with the National Weather Service, operated a system for real-time warnings for storm-related slope failures (Keefer et al., 1987). Using a combination of tracking storm systems, measuring actual rainfall with a network of rain gauges, and comparing thresholds for the initiation of debris flows, they were able to issue Flash Flood/Debris Watches during the most intense storms (Wilson, 1997). This would be especially valuable for developments adjacent to burned watersheds.
- Post warning signs in areas of potential slope instability
- Encourage homeowners to use landscaping methods that help stabilize the hillsides.
- Incorporate recommendations for potential slope instability into geologic and soil engineering reports for additions and new grading.
- Educate the public about slope stability, including the importance of maintaining drainage devices. USGS Fact Sheet FS-071-00 (May, 2000) and the CGS Note 33 (November, 2001) provide public information on landslide and mudslide hazards. These are available on the internet (see Appendices A and B).

2.4.2 Collapsible Soils

In soil engineering terminology, collapse occurs when saturated soils undergo a rearrangement of their grains and a loss of cementation, resulting in substantial and rapid settlement under relatively low loads. An increase in surface water infiltration, such as from irrigation, or a rise in the groundwater table, combined with the weight of a building or structure, can initiate rapid settlement and cause foundations and walls to crack. In the Glendale area, the most likely occurrence of collapsible soils is at the bottoms of the modern drainage channels, such as the Verdugo Wash, and at the base of the mountains, where talus and other loose sediments that were deposited rapidly by gravity have accumulated.

MITIGATION OF COLLAPSIBLE SOILS

The potential for soils to collapse should be evaluated on a site-specific basis as part of the geotechnical studies for development. If the soils are determined to be collapsible, the hazard can be mitigated by several different measures or combination of measures, including excavation and recompaction, or pre-saturation and pre-loading of the susceptible soils in-place to induce collapse prior to construction. After construction, infiltration of water into the subsurface soils should be minimized by proper surface drainage design, which directs excess runoff to catch basins and storm drains, and away from the building foundations.

2.4.3 Expansive Soils

Fine-grained soils, such as silts and clays, may contain variable amounts of expansive clay minerals. These minerals can undergo significant volumetric changes as a result of changes in moisture content. The upward pressures induced by the swelling of expansive soils can have significant harmful effects upon structures and other surface improvements.

Most of the Glendale area is underlain by alluvial units that are composed primarily of granular soils (silty sand, sand, and gravel). Such units are typically in the low to moderately low range for expansion potential. However, every sedimentary unit in the area contains lenses or layers of fine-grained soils (clays and silty clays) that are typically in the moderate to highly expansive range. Such sediments are most likely to be found in the more distal parts of the alluvial fans, in the southern part of the City.

Expansive clay can also be found within fault and fracture zones in the highly sheared crystalline bedrock of the San Gabriel and Verdugo Mountains and in the San Rafael Hills. These tabular and lensoidal zones of clay often form due to alteration of bedrock during fault movement. Clay can also be deposited along bedrock fractures by ground water. The clay zones lining faults and fractures can be up to several feet thick.

Potentially expansive layers, including clay zones along faults and fractures, may be exposed at the surface by erosion, or may be uncovered during grading, in cuts made for developments. In some cases, engineered fills may be expansive and cause damage to improvements if such soils are incorporated into the fill near the finished surface. Structures placed directly on clay beds or clay-rich zones may experience structural distress as a result of expansion of the clay minerals in a vertical (upward) direction.

MITIGATION OF EXPANSIVE SOILS

The best defense against this hazard in new developments is to avoid placing expansive soils near the surface. If this is unavoidable, building areas with expansive soils are typically "presaturated" to a moisture content and depth specified by the soil engineer, thereby "pre-swelling" the soil prior to constructing the structural foundation or hardscape. This method is often used in conjunction with strong foundations that can resist small ground movements without cracking. Good surface drainage control is essential for all types of improvements, both new and old. Property owners should be educated about the importance of maintaining relatively constant moisture levels in their landscaping. Excessive watering, or alternating wetting and drying, can result in distress to improvements and structures.

2.4.4 Ground Subsidence

Ground subsidence is the gradual settling or sinking of the ground surface with little or no horizontal movement. Most ground subsidence is man-induced. In the areas of southern California where significant ground subsidence has been reported (such as Antelope Valley, Murrieta, and Wilmington, for example) this phenomenon is usually associated with the extraction of oil, gas or ground water from below the ground surface.

Ground-surface effects related to regional subsidence can include earth fissures, sinkholes or depressions, and disruption of surface drainage. Damage is generally restricted to structures sensitive to slight changes in elevations, such as canals, levees, underground pipelines, and drainage courses; however, significant subsidence can result in damage to wells, buildings, roads, railroads, and other improvements. Subsidence has largely been brought under control in affected areas by good management of local water supplies, including reducing pumping of local wells, importing water, and use of artificial recharge (Johnson, 1998; Stewart et al., 1998).

No regional subsidence as a result of groundwater pumping has been reported in the literature for the Glendale area. However, the thick alluvial deposits underlying the City may be susceptible to subsidence should rapid groundwater withdrawal occur beneath this portion of the groundwater basin in response to an increasing population.

MITIGATION OF GROUND SUBSIDENCE

Subsidence prevention requires a regional approach to groundwater conservation and recharge. In the Antelope Valley, some the measures that have been proposed or implemented to manage subsidence (Galloway et al., 1998) include:

- Increase use of reclaimed water, storm water, and imported water;
- Implement artificial recharge programs;
- Determine the safe yields of the groundwater basins, so that the available supplies can be balanced with groundwater extraction;
- Monitor the groundwater and publish annual reports on basin conditions;
- Protect groundwater quality;
- Reduce long-term water demand with specific programs of water conservation;
- Acquire additional imported water supplies; and
- Encourage water conservation through public education.

2.4.5 Radon Gas

Radon is a colorless, odorless, radioactive gas. The most common source of indoor radon is uranium in the soil or rock on which homes are built. As uranium naturally breaks down, it releases radon gas, which enters homes through dirt floors, cracks in concrete walls and floor, floor drains, and sumps. Exposure to radon becomes a concern if the radon becomes trapped in buildings and concentrations build up indoors. Sometimes radon enters homes through well water. In a small number of homes, the building materials can give off radon too, although building materials rarely cause radon problems by themselves.

Health Effects and Risk from Exposure to Radon - There are no immediate symptoms associated with exposure to radon. The main health effect associated with exposure to elevated levels of radon is an elevated risk of developing lung cancer. The EPA estimates that radon causes about 14,000 deaths per year in the United States, although this number could range from 7,000 to 30,000 deaths per year (http://www.epa.gov/iaq/pubs/insidest.html).

Radon Potential - The United States Environmental Protection Agency (EPA) and the United States Geological Survey (USGS) have evaluated the radon potential in the United States and have developed maps to assist national, state and local organizations to target their resources and to assist building code officials in deciding whether radon-resistant features are applicable and justifiable in new construction. These maps can be viewed at the following website: http://www.epa.gov/iaq/radon/zonemap.html.

Each county in the United States is assigned to one of three zones based on radon potential. The zone designations are based on the average short-term radon measurement that can be expected to be measured in a building without the implementation of radon control methods. The Zone 1 designation indicates the highest potential for radon gas, Zone 2 a moderate potential, and Zone 3 a low potential. However, the EPA notes that these maps are not intended to be used to determine if a home in a given zone should be tested for radon. Homes with elevated levels of radon have been found in all three zones and therefore, the EPA recommends that all homes be tested regardless of geographic location. Any home may have a radon problem, including new or old homes, well-sealed or drafty homes, and homes with or without basements. The EPA also recommends consulting the EPA Map of Radon Zones document (EPA-402-R-93-071) before using the website map. EPA regional radon contacts are listed on the following website: http://www.epa.gov/iaq/regionia.html.

Table 2-2: Radon Health Risk If You Smoke or If You Have Never Smoked

RADON RISK IF YOU SMOKE			
Radon Level	If 1,000 people who smoked were exposed to this level over a lifetime …	The risk of cancer from radon exposure compares to …	WHAT TO DO: Stop smoking and …
20 pCi/L	About 135 people could get lung cancer	100 times the risk of drowning.	Fix your home.
10 pCi/L	About 71 people could get lung cancer	100 times the risk of dying in a home fire.	Fix your home.
8 pCi/L	About 57 people could get lung cancer		Fix your home.
4 pCi/L	About 29 people could get lung cancer	100 times the risk of dying in an airplane crash.	Fix your home.
2 pCi/L	About 15 people could get lung cancer	2 times the risk of dying in a car crash.	Consider fixing between 2 and 4 pCi/L.
1.3 pCi/L	About 9 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult.)
0.4 pCi/L	About 3 people could get lung cancer	(Average outdoor radon level).	(Reducing radon levels below 2 pCi/L is difficult.)
Note: If you are a former smoker, your risk may be lower.			

RADON RISK IF YOU HAVE NEVER SMOKED			
Radon Level	If 1,000 people who never smoked were exposed to this level over a lifetime …	The risk of cancer from radon exposure compares to …	WHAT TO DO:
20 pCi/L	About 8 people could get lung cancer	The risk of being killed in a violent crime.	Fix your home.
10 pCi/L	About 4 people could get lung cancer		Fix your home.
8 pCi/L	About 3 people could get lung cancer	10 times the risk of dying in an airplane crash.	Fix your home.
4 pCi/L	About 2 people could get lung cancer	The risk of drowning.	Fix your home.
2 pCi/L	About 1 person could get lung cancer	The risk of dying in a home fire.	Consider fixing between 2 and 4 pCi/L.
1.3 pCi/L	Less than 1 person could get lung cancer	(Average indoor radon level).	(Reducing radon levels below 2 pCi/L is difficult.)
0.4 pCi/L	Less than 1 person could get lung cancer	(Average outdoor radon level).	(Reducing radon levels below 2 pCi/L is difficult.)
Note: If you are a former smoker, your risk may be higher.			

Source: http://www.epa.gov/cgi-bin/epaprintonly.cgi

The EPA Map of Radon Zones and other indoor air quality publications can be ordered from the following sources:

- IAQ INFO
  P.O. Box 37133
  Washington, D.C. 20013-7133
  1-800-438-4318 or 703-356-4020
  iaqinfo@aol.com

- EPA's National Service Center for Environmental Publications (NSCEP)
  http://www.epa.gove/ncepihom/

- U.S. Environmental Protection Agency
  National Center for Environmental Publications (NSCEP)
  P.O. Box 42419
  Cincinnati, OH 42419
  1-800-490-9198 or 513-489-8695 (FAX)

Radon and Real Estate - The Environmental Protection Agency (EPA) has developed a number of tools and resources to be used by the real-estate community. There is a new video, *Breathing Easy: What Home Buyers and Sellers Should Know about Radon Gas*. It gives information on how to best include radon in residential real estate transactions. The video covers the radon science, the lung cancer risk, home inspection, building a new radon-resistant home, testing and fixing a home, disclosure, State radon offices, hotline and web resources, and key radon numbers (e.g., EPA's action level and the U.S. indoor and outdoor averages). The video was developed for use by homebuyers and sellers, and real estate sales agents and brokers. Home inspectors, mortgage lenders, other real estate practitioners, and radon services providers will also find the video helpful. Single copies of the video are free from IAQ-Info (1-800-438-4318) in VHS format [ask for EPA 402-V-02-003 TRT 13.10]; copies in CD-ROM and DVD formats will also be available soon.

The following resources are also available from the EPA:

- Revised Home Buyer's and Seller's Guide to Radon (EPA Publication 402-K-00-008, updated in July, 2000). This publication is also available in Spanish (www.epa.gov/iaq/pubs/hmbyguidsp.html);
- Financing Residential Radon Mitigation Costs: the HUD 203(k) Mortgage Insurance Program;
- American Society of Home Inspectors (ASHI) Radon Mitigation System Inspection Checklist; and
- How to Find a Qualified Radon Service Professional in Your Area.

Hazard Analysis and Mitigation - The County of Los Angeles, and therefore the City of Glendale, are located in Zone 2, which has a "Moderate Potential" for radon gas (http://www.epa.gov/iaq/radon/zonemap/california.htm). Zone 2 counties have a predicted average indoor radon screening level between 2 and 4 pCi/L (picoCuries per liter). However, you cannot predict radon levels based on state, local and neighborhood radon measurements. Testing is the only way to know if you are at risk from radon. The EPA and the Surgeon General recommend testing all homes below the third floor for radon (http://www.epa.gov/iaq/radon/pubs/hmbyguid.html). In addition, the EPA recommends that homebuyers and sellers do the following:

- If you are buying or selling your home, have it tested for radon.
- For a new home, ask if radon-resistant construction features were used and if the house has been tested.
- Fix the home if the radon level is 4 pCi/L, or higher.
- Radon levels less than 4 pCi/L still pose a risk, and in many cases, may be reduced.
- Prevent device interference when conducting a radon test.

California law requires professional providers of radon services to be certified. It is strongly recommended to hire a disinterested third-party to assure the validity of the testing. The State of California maintains a list of certified providers of radon services and one of the groupings for certification is "testers." Certified Radon Testers conduct radon measurements in residential structures, commercial structures, and occupational settings.

The California Department of Health Services Radon program is currently offering free short-term radon test kits available for persons interested in determining the radon level in the indoor air of their homes. These radon test kits can be used to screen your home prior to offering it for sale to determine if the radon levels may be an issue or a concern. In order to obtain a free short-term radon test, you can contact the phone numbers or addresses below, providing your name, address and phone number. The Radon Program staff will send you informational materials and a test kit. It is important to note however, that the test kits are NOT to be used for determining the radon levels in your home as part of a real estate transaction.

For more information regarding radon, or if you have questions regarding radon in the State of California, contact:

Radon Program, http://www.dhs.ca.gov/radon
Department of Health Services
Environmental Management Branch
601 North 7th Street, MS 396
P.O. Box 942732
Sacramento, CA 94234-7320
Fax (916) 324-1380
Radon Hotline 1-(800)-745-7236

How to Find a Qualified Radon Service Professional in Your Area - Contact your **State Radon Contact** (http://www.epa.gov/iaq/whereyoulive.html) to determine the requirements, if any, associated with providing radon measurement and or radon mitigations/reductions in your State. Some States maintain lists of contractors available in their state or they have proficiency programs or requirements of their own.

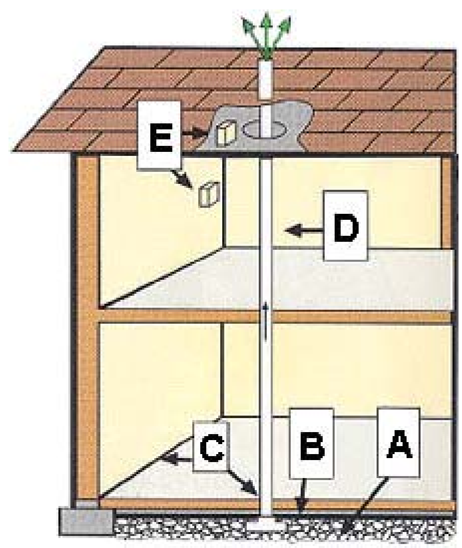
Inspection Checklist - The American Society of Home Inspectors (ASHI) along with the EPA's Indoor Environments Division have created a **Radon Mitigation System Inspection**

Checklist (**http://www.epa.gov/iaq/radon/images/ashicklst.pdf**). The main purpose of this checklist is to educate home inspection clients about radon, and to encourage radon testing and mitigation when radon levels of 4pCi/L or more are found. The *Checklist* promotes radon awareness, testing and mitigation for people who are having their home or prospective home, inspected. The *Checklist* has seven inspection elements and should take under 15 minutes to complete. Inspectors can easily integrate it into a general home inspection. The inspection results indicate whether the home has a mitigation system, and if so, whether the system is active or passive. It also encourages the consumer to verify that indoor radon levels are below 4 pCi/L, and to consult a qualified mitigator if the inspection notes any apparent deficiencies.

Radon Mitigation - If your radon test result is 4 pCi/L or higher, the EPA recommends that action be taken to reduce the indoor radon level. Various methods can be used to reduce radon in homes. One method is sealing cracks and openings in the foundation. However, the EPA does not recommend the use of sealing alone to limit radon entry, as it has not been shown to lower radon levels significantly or consistently. For most homes, a system with a vent pipe and fan is used, however the correct system depends on home design and other factors. The EPA provides techniques for reducing radon in its publication "Consumer's Guide to Radon Reduction." The basic elements are:

Figure 2-1: Radon Construction Mitigation

<table>
<tr><td>A. Gas Permeable Layer

This layer is placed beneath the slab or flooring system to allow the soil gas to move freely underneath the house. In many cases, the material used is a 4-inch layer of clean gravel.</td><td rowspan="3">
</td></tr>
<tr><td>B. Plastic Sheeting

Plastic sheeting is placed on top of the gas permeable layer and under the slab to help prevent the soil gas from entering the home. In crawlspaces, the sheeting is placed over the crawlspace floor.</td></tr>
<tr><td>C. Sealing and Caulking

All openings in the concrete foundation floor are sealed to reduce soil gas entry into the home.</td></tr>
<tr><td colspan="2">D. Vent Pipe

A 3- or 4-inch gas-tight or PVC pipe (commonly used for plumbing) runs from the gas permeable layer through the house to the roof to safely vent radon and other soil gases above the house.</td></tr>
<tr><td colspan="2">E. Junction Box

An electrical junction box is installed in case an electric venting fan is needed later.</td></tr>
</table>

Source: http://www.epa.gov/iag/radon/construc.html

2.5 Summary

The City of Glendale is situated on the alluvial surfaces and mountainous regions of the southeastern San Fernando Valley. The alluvial surfaces blanket the flanks and fill the intervening valleys and drainages between the San Gabriel Mountains and the Verdugo Mountains, and between the Verdugo Mountains, the San Rafael Hills and the eastern extension of the Santa Monica Mountains (locally known as the Hollywood Hills). Geologic units within the City consist of poorly or crudely stratified sand, silt, and gravel in the lowlands, with dense crystalline rock forming most of the hillsides. The hills in the southeastern portion of the City are composed of stratified sedimentary rocks, typically sandstone, conglomerate and shale.

The City's hillsides are vulnerable to slope instability due primarily to the fractured, crushed and weathered condition of the bedrock, and the steep terrain. Oversteepened slopes along the large drainage channels are also locally susceptible. The probability of large bedrock landslides occurring is relatively low, therefore the source of potential losses due to slope instability arises primarily from the occurrence of smaller slope failures in the form of small slides, slumps, soil slips, debris flows and rockfalls. The initiation of such failures is generally tied to a preceding event, such as wildfire, heavy winter storms, seismic activity, or man's activities.

Although the mountainous terrain within the San Gabriel Mountains has been dedicated to parks and recreation, residential development is present within the steep slopes of the Verdugo Mountains and the San Rafael Hills. The Uniform Building Code and the City's hillside grading ordinance provide standards by which slope stability in new developments (including the required geologic and soils investigations) can be effectively managed, provided these requirements are strictly enforced. This process should include geotechnical third-party review by a California-registered engineering geologists and soil engineers. The majority of the City's buildable hillsides are already developed. Some of the older structures in these areas were built prior to development of modern grading codes, regulations and practices, and may therefore be at risk, especially if located at the top or the toe of steep slopes (generally those steeper than 26 degrees), at the mouth of gullies, swales or ravines. Structures built in areas adjacent to or in potential wildfire areas are particularly susceptible to slope damage during wet winters following wildland fires.

Both the USGS and the CGS are currently conducting significant research that focuses on the conditions and processes that lead to destructive slope failures. This includes methodology for analysis of slopes and drainage basins, and the development of susceptibility maps. Detailed maps prepared by either of these agencies showing the prior occurrence of slope failures in the Glendale area, as well as local susceptibility, are not yet available. Plate 2-2 shows the slope instability areas identified for the Safety Element update, based on slope angle and soil and rock conditions.

The alluvial deposits in floors of major drainage channels are susceptible to liquefaction (see Section 1.7) and possibly collapse. For mitigation measures that can be implemented to reduce the liquefaction hazard, refer to Chapter 1. In areas proposed for development, site-specific studies need to be conducted to evaluate the settlement potential of the underlying soils. These geotechnical studies should evaluate the collapse potential of the entire soil column within the effective depth of infiltration of irrigation water, instead of only the near-surface soils.

Some of the geologic units in the Glendale area have fine-grained components that are moderately to highly expansive. These units are generally present in all the low-lying areas within Glendale, where fine-grained sequences within the alluvial fans are more likely to be present. Expansive materials are also present in clay-lined fault and fracture zones throughout the highly sheared crystalline rock of the

San Gabriel and Verdugo Mountains and the San Rafael Hills. These fine-grained units may not be present at the surface but may be exposed during grading. The presence of potentially expansive soils should be assessed for every project, on a lot-by-lot basis, with engineering solutions implemented as needed.

There are no immediate symptoms associated with exposure to radon gas. The main health effect associated with exposure to elevated levels of radon gas is an elevated risk of developing lung cancer. Testing is the only way to know if you are at risk from radon gas. The California Department of Health Services (DHS) and the United States Environmental Protection Agency have programs to increase public awareness of radon risks, radon testing and mitigation of radon gas risks. Their websites provide a wealth of information. It is recommended that City of Glendale residents, buyers and sellers of residential property, realtors and business owners contact these governmental agencies for additional information and resources. It is also recommended that the City of Glendale play a more active role in educating its residents about the hazards posed by radon gas and the sources of radon gas information and resources available.

CHAPTER 3: FLOOD HAZARDS

Safety Elements of General Plans must assess the impact of flooding from storm activity such as the 100-year and 500-year flood events. Smaller-scale flooding generally associated with overburdened storm drain and canal systems may also damage property and hinder emergency activities such as fire department access or evacuation. Therefore, small-scale flooding is also addressed if there are available data. The State of California Government Code Section 65302 (g) also requires local governments to assess the potential impact that failure of dams or other water retention structures might have on their community. This chapter reviews published flood data and a directory of dams showing inundation limits in the Glendale area. The results of this study indicate that several areas in Glendale may be impacted by the catastrophic failure of reservoirs and water tanks.

Floods are natural and recurring events that only become hazardous when man encroaches onto floodplains, modifying the landscape and building structures in the areas meant to convey excess water during floods. Unfortunately, floodplains have been alluring to populations for millennia since they provide level ground and fertile soils suitable for agriculture, access to water supplies, and transportation routes. These benefits come with a price – flooding is one of the most destructive natural hazards, responsible for more deaths per year than any other geologic hazard. Furthermore, average annual flood losses (in dollars) have increased steadily over the last decades as development in floodplains has increased.

The City of Glendale and surrounding areas are, like most of southern California, subject to unpredictable seasonal rainfall. Most years, the scant winter rains are only enough to turn the hills green for a few weeks, but every few years the region is subjected to periods of intense and sustained precipitation that result in flooding. Flood events that occurred in 1969, 1978, 1980, 1983, 1992, 1995, and 1998 have caused an increased awareness of the potential for public and private losses as a result of this hazard, particularly in highly urbanized parts of floodplains and alluvial fans. As the population in Los Angeles County increases, there will be increased pressure to build on flood-prone areas, and in areas upstream of already developed areas. With increased development, there is also an increase in impervious surfaces, such as asphalt. Water that used to be absorbed into the ground becomes runoff to downstream areas. If the storm drain systems are not designed or improved to convey these increased flows, areas that may have not flooded in the past may be subject to flooding in the future. This is especially true for developments at the base of the mountains and downstream from canyons that have the potential to convey mudflows.

3.1 Storm Flooding

3.1.1 Hydrologic Setting

The City of Glendale is drained by the south-, southwest-, and west-flowing Verdugo Wash and its tributaries. The Verdugo Wash ultimately drains onto the larger Los Angeles River at the City's western boundary. Several streams are tributary to the Verdugo Wash (see Plate 3-1). From north to south, in the City of Glendale, these include Cooks Canyon, Dunsmore Canyon, and Ward Canyon. Streams or channels that flow out of the San Gabriel Mountains, through the La Crescenta and La Cañada – Flintridge areas and into Verdugo Wash include Shields Canyon, Eagle Canyon, Pickens Canyon, Hall Beckley Canyon, and Winery Canyon. Several streams emanate from the north and east sides of the Verdugo Mountains and make their way into Verdugo Wash as well. These include, again from north to south, La Tuna, Las Barras, Sheep Corral, Cunningham, Henderson, Engleheard, Deer and Dead Horse Canyons.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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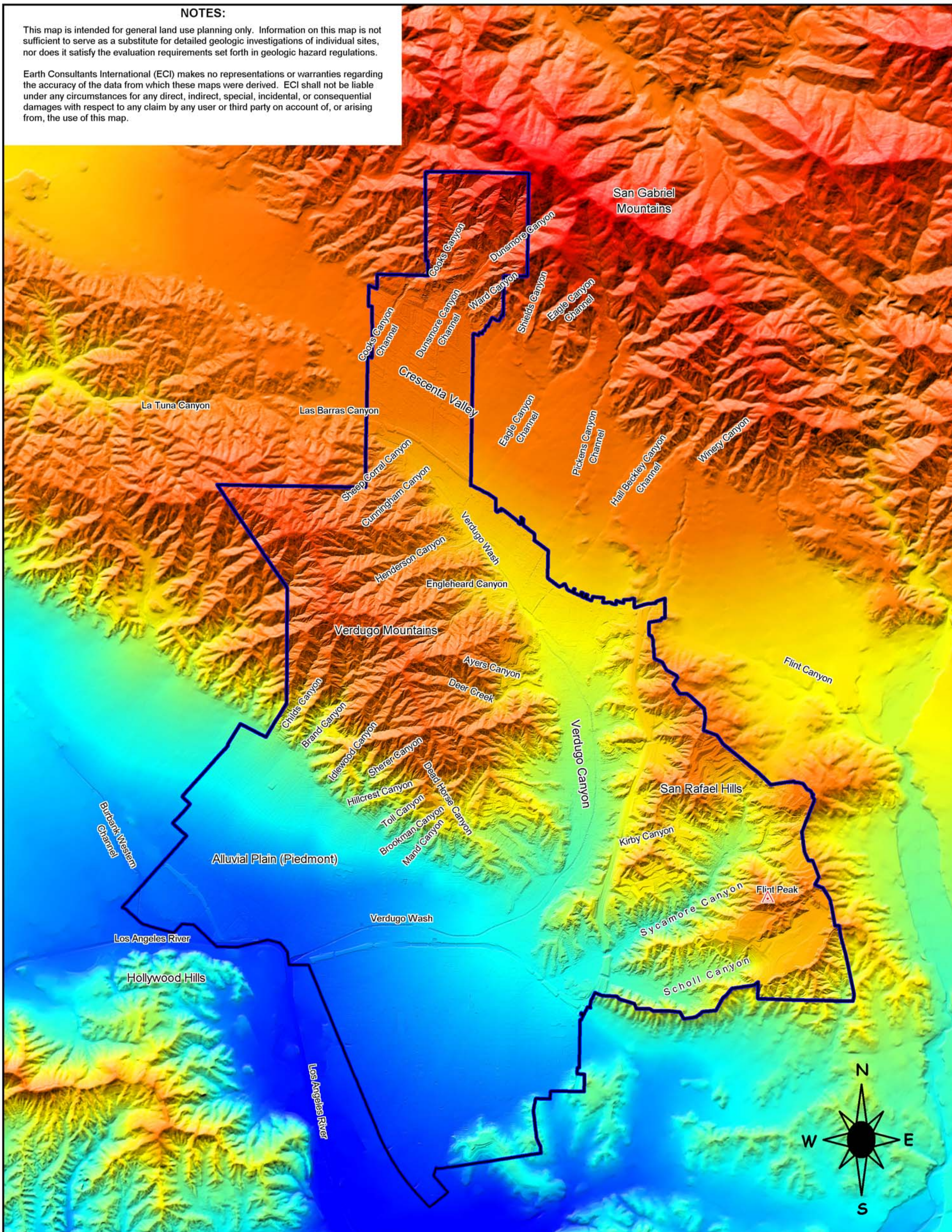


Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

EXPLANATION

Elevation in Feet

200 400 600 800 1000 1200 1400

Glendale City Limit

Base Map: USGS 10-m Digital Elevation Model and City of Glendale Digital Terrain Model based on 1-foot and 2-foot elevation contour data.

Earth Consultants International

Project Number: 2103

Date: July, 2003

Geomorphic Map

Glendale, California

Plate 3-1

In the western portion of the City, the Burbank Western Channel extends through a small portion of Glendale on the channel's final stretch before emptying into the Los Angeles River. Other canyons draining off the south flank of the Verdugo Mountains include, from west to east, Childs, Brand, Idlewood, Sherer, Hillcrest, Toll, Brookman and Mand Canyons.

Several small and two large canyons drain the western and southwestern portions of the San Rafael Hills. Most of the small canyons in the northwestern portion of the San Rafael Hills are unnamed, except for Kirby Canyon. The two large ones are Sycamore Canyon and Scholl Canyon. There are also a few unnamed streams in the San Rafael Hills whose headwaters are in Glendale but drain to the east, toward Arroyo Seco.

Several of the canyons in the San Gabriel and Verdugo Mountains have debris basins that were built for flood protection purposes. Most of the streams off the San Gabriel Mountains also have been channelized through the La Cañada Valley, also for flood-protection purposes. Similarly, Verdugo Wash is channelized through Glendale.

3.1.2 Meteorological Setting

Average yearly precipitation in the downtown Glendale area is about 17 to 18 inches (see Table 3-1), while rainfall in the northern reaches of the City is better represented by rainfall data for the La Crescenta area (Table 3-2). These tables show that areas closer to the San Gabriel Mountains receive higher precipitation rates, on average, than areas farther south from the mountains.

Table 3-1: Average Annual Rainfall by Month for the Glendale Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	3.9	3.8	2.5	1.5	0.2	0.1	0.0	0.0	0.3	0.4	2.0	3.0	**17.6**

Data based on 40 complete years between 1941 and 1971.
Source: http://www.worldclimate.com/

Table 3-2: Average Annual Rainfall by Month for the La Crescenta Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	4.5	5.4	4.0	1.7	0.4	0.1	0.0	0.2	0.5	0.8	2.3	3.6	**23.5**

Data based on data from 60 complete years between 1931 and 1995.
Source: http://www.worldclimate.com/

Not only does rainfall vary significantly from one location to the next, often within short distances, but rainfall in southern California is extremely variable from year to year. For example, in the 1999-2000 water year, the County of Los Angeles Department of Public Works rain gage station at Brand Park recorded 10.72 inches of rain for the year, while the rain gage at Scholl Landfill reported 17.62 inches of rain during the same period (http://www.dpw.co.la.us/wrd/report/9900/precip/stations.cfm). Data reviewed for this study also suggest that southern California has experienced more wet years in the last 20 to 30 years than in the 50 years prior.

There are three types of storms that produce precipitation in southern California: winter storms, local thunderstorms, and summer tropical storms. These are described below.

Winter storms are characterized by heavy and sometimes prolonged precipitation over a large area. These storms usually occur between November and April and are responsible for most of the precipitation recorded in southern California. This is illustrated by the data on Tables 3-1 and 3-2. The storms originate over the Pacific Ocean and move eastward (and inland). The mountains, such as the San Gabriel and San Bernardino Mountains, form a rain shadow, slowing down or stopping the eastward movement of this moisture. A significant portion of the moisture is dropped on the mountains as snow. If large storms are coupled with snowmelt from these mountains, large peak discharges can be expected in the main watersheds at the base of the mountains. Some of the severe winter storm seasons that have historically impacted the southern California area have been related to El Niño events.

El Niño is the name given to a phenomenon that starts every few years, typically in December or early January, in the southern Pacific off the western coast of South America, but whose impacts are felt worldwide. Briefly, warmer than usual waters in the southern Pacific are statistically linked with increased rainfall in both the southeastern and southwestern United States, droughts in Australia, western Africa and Indonesia, reduced number of hurricanes in the Atlantic Ocean, and increased number of hurricanes in the Eastern Pacific. Two of the largest and most intense El Niño events on record occurred during the 1982-83 and 1997-98 water years. [A water year is the 12-month period from October 1 through September 30 of the second year. Often a water year is identified only by the calendar year in which it ends, rather than by giving the two years, as above.] These are also two of the worst storm seasons reported in southern California.

Local thunderstorms can occur at any time, but usually cover relatively small areas. These storms are usually prevalent in the higher mountains during the summer (FEMA, 1986). Tropical rains are infrequent, and typically occur in the summer or early fall. These storms originate in the warm, southern waters off Baja California, in the Pacific Ocean, and move northward into southern California.

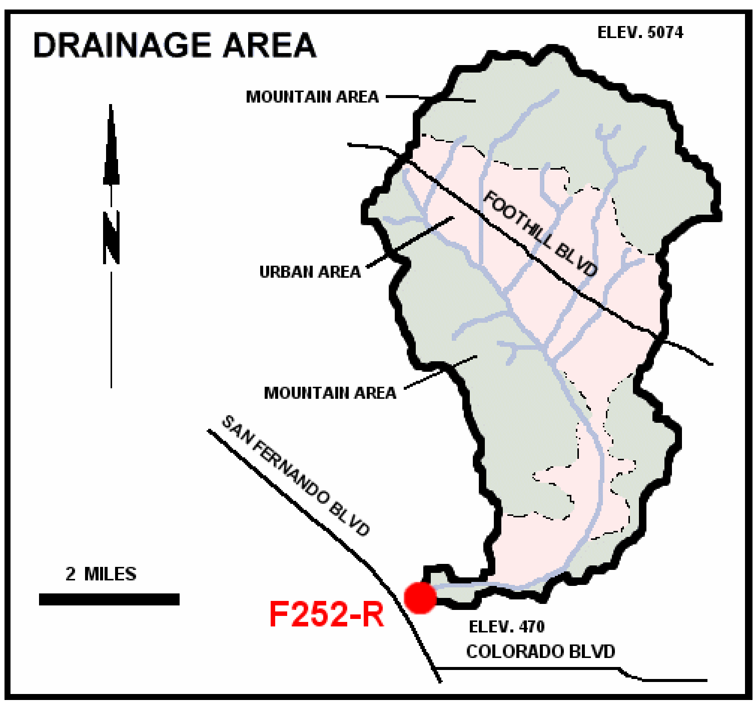
3.1.3 Historical Flows and Past Floods

The streams in the Glendale area are typical of the majority of the streams that emanate from the San Gabriel and San Bernardino Mountains in southern California. Stream flow is negligible other than during and immediately after rains because climate and basin characteristics are not conductive to continuous flow. In the Los Angeles Basin, including the Glendale area, flooding is difficult to predict, and thus plan for, because as mentioned previously, rainfall in the area is extremely variable. It can be said that floods of consequence to the City of Glendale are typically of the flash flood type, of short duration, but with high peak volumes and high velocities. This type of flooding occurs in response to the local geology and geography and the built environment (human-made structures). The mountains in and north of the City consist of rock that is predominantly impervious to water so little precipitation infiltrates the ground; rainwater instead flows along the surface as runoff. When a major storm moves in, water collects rapidly and runs off quickly, making a steep, rapid descent from the mountains onto the alluvial fans and ultimately into Verdugo Wash.

The U.S. Geological Survey does not maintain any stream gages on the Verdugo Wash, but the County of Los Angeles Public Works Department has over the years manned at least one, and occasionally two, stream gages in the Verdugo Wash drainage area. One of these, Gage Station F252-R on Estelle Avenue, near the southwestern end of the Verdugo Wash, has been operated continuously since December 2, 1935 (its location is shown on Figure 3-1), although sporadic measurements date back to 1928. These provide a relatively long-term record of flow discharge and peak flows that can be used to describe the flooding history and future flooding potential of the Glendale area. The drainage area for Station F252-R, which is 26.80 square miles in size, is shown on Figure 3-1.

Records show that maximum daily peak flows in the lower reaches of Verdugo Wash are typically less than about 400 cubic feet per second (cfs), with many years actually measuring peaks of considerably less than 100 cfs (see Table 3-3). However, maximum daily peak flows have occasionally exceeded 1,000 cfs (in 1937-38, 1942-43, 1965-66, 1968-69, 1977-78, 1982-83, 1994-95, 1995-96, and 1996-97). Notice that in the decades between 1930 and 1990, maximum daily peak flows exceeding 1,000 cfs generally occurred only once in a decade, but that in the 1990s, there were three consecutive years when this channel had maximum daily peak flows exceeding 1,000 cfs (and in the 1997-98 water year, the maximum daily peak flow was 966 cfs, also high for the area). The highest peak flow recorded at this stream gage is for the water year of 1968-69, with a maximum daily peak flow of 1,850 cfs. However, there are two years for which there are no records, in 1933-34, and 1983-84. As discussed further below, the lack of data for 1933-34 is probably the result of the gage being washed out during the worst flood recorded for Verdugo Wash. Similarly, the winter storms in 1983-84 caused considerable damage in southern California, and could be related to the lack of data for the stream gage in Verdugo Wash for the 1983-84 water year.

Figure 3-1: Drainage Area for Stream Gaging Station F252-R in Glendale



Source: Los Angeles County Department of Public Works, at
http://www.dpw.co.la.us/wrd/runoff/dispimg.cfm?showimg=graphics/d252.gif

Table 3-3: Peak Flow Records for Station F252-R at Estelle Avenue in Glendale

	Maximum	Minimum	Mean		Date	cfs
1928-29	15.0	0.0	*	140*	4/4	56*
1929-30	14.0	0.0	0.4	274.0*	5/3	80
1930-31	8.4	+	0.2	145.0	4/26	46
1931-32	39.0	0.1	1.0	713.0	2/9	145
1932-33	42.0	0.1	0.4	295.0	1/19	391
1933-34	No Record					
1934-35	85.0*	0.0	*	620.0	1/5	1,020*
1935-36	33.0	0.0	0.6	463.0	3/30	1,100*
1936-37	*	0.0	*	1,560	12/27	768
1937-38	1,500.0	0.0	7.5	5,450	3/2	4,400E
1938-39	78.0	0.0	2.0	1,420	1/5	520
1939-40	60.0	+	2.0	1,430	1/8	533
1940-41	357.0	+	10.2	7,370	2/19	1,120
1941-42	81.0	0.8	3.0	2,160	12/10	440
1942-43	1,020.0	0.3	12.0	8,690	1/23	3,570
1943-44	998.0	0.2	7.0	5,040	2/12	3,160
1944-45	181.0	0.6	2.8	2,010	2/2	1,520
1945-46	135.0	0.3	2.7	1,930	12/22	816
1946-47	234.0	0.0	2.7	1,940	12/25	1,860
1947-48	41.0	0.0	0.5	382.0	3/24	573
1948-49	35.0	0.0	0.6	433.0	12/16	202
1949-50	69.0	0.0	0.9	638.0	2/6	467
1950-51	41.0	0.0	0.5	383.0	1/11	960
1951-52	422.0	0.0	7.8	5,630	1/16	2,920
1952-53	100.0	0.0	1.3	968.0	11/15	1,520
1953-54	227.0	0.0	2.7	1,920	2/13	1,300
1954-55	134.0	0.0	2.0	1,480	1/18	784
1955-56	550.0	0.0	2.5	1,840	1/26	1,940
1956-57	184.0	0.0	1.9	1,400	2/23	2,960
1957-58	236.0	0.0	5.2	3,770	2/19	1,700
1958-59	232.0	0.0	2.0	1,440	2/16	2.080
1959-60	56.0	0.0	1.2	862.0	2/11	533
1969-61	98.0	+	0.9	667.0	11/5	676
1961-62	592.0	0.0	6.8	4,830	2/12	1,880
1962-63	370.0	+	2.0	1,460	2/9	2,180
1963-64	192.0	0.0	2.1	1,510	1/21	1,640
1964-65	249.0	+	3.8	2,780	4/8	1,480
1965-66	1,030.0	0.1	12.2	8,830	12/29	3,480
1966-67	422.0	0.5	10.4	7,530	1/22	3,230
1967-68	606.0	0.2	9.3	6,730	3/8	3,460
1968-69	1,850	1.8	36.1	26,120	1/25	5,050
1969-70	261.0	2.0	8.4	6,090	2/28	2,500
1970-71	931.0	1.8	10.6	7,690	11/29	5,330
1971-72	476.0	1.2	14.8	4,570	12/24	1,960
1972-73	897.0	1.0	12.8	9,280	1/18	4,010
1973-74	671.0	1.8	10.2	7,380	1/7	2,390
1974-75	373.0	0.7	7.7	5,590	12/4	3,390

Table 3-3 (Continued)

	Maximum	Minimum	Mean		Date	cfs
1975-76	180.0	0.5	6.4	4,560	3/1	1,190
1976-77	210.0	0.3	6.0	4,318	1/23	2,100
1977-78	1,700.0	+	34.2	24,739	2/10	9,820
1978-79	*	*	*	*	3/27	*
1979-80	440.0	1.2	18.1	13,000	2/16	6,420
1980-81	266.0	1.5	12.0	8,706	1/29	2,870
1981-82	333.0	1.0	12.5	9,083	4/1	1,960
1982-83	1,260.0	2.0	37.0	26,750	3/1	6,714
1983-84	No Record					
1984-85	279.0	1.0	9.2	6,686	12/19	2,430
1985-86	437.0	1.2	12.1	8,737	3/8	1,620
1986-87	158.0	1.5	5.0	3,635		ND
1987-88	688.0	2.3	19.3	14,042	2/1	4,150
1988-89	301.0	0.3	9.1	6,262	12/16	1,700
1989-90	474.0	+	5.7	4,120	2/17	1,820
1990-91	544.0	0.2	11.1	8,017		ND
1991-92	636.0	0.0	20.1	14,621	2/10	4,110
1992-93	733.0	1.7	32.5	23,520	6/5	4,320
1993-94	265.0	0.0	10.4	7,543	11/30	2,220
1994-95	1,710.0	1.0	46.5	33,700	1/10	4,460
1995-96	1,260.0	0.8	18.6	13,520	2/21	3,460
1996-97	1,140.0	1.9	23.3	16,860	12/22	3,010
1997-98	966.0	3.9	22.3	16,150	2/7	5,550
1998-99	117.0	3.6	10.0	7,250	11/28	1,390
1999-2000	289.0	2.9	11.7	8,470	2/16	2,700

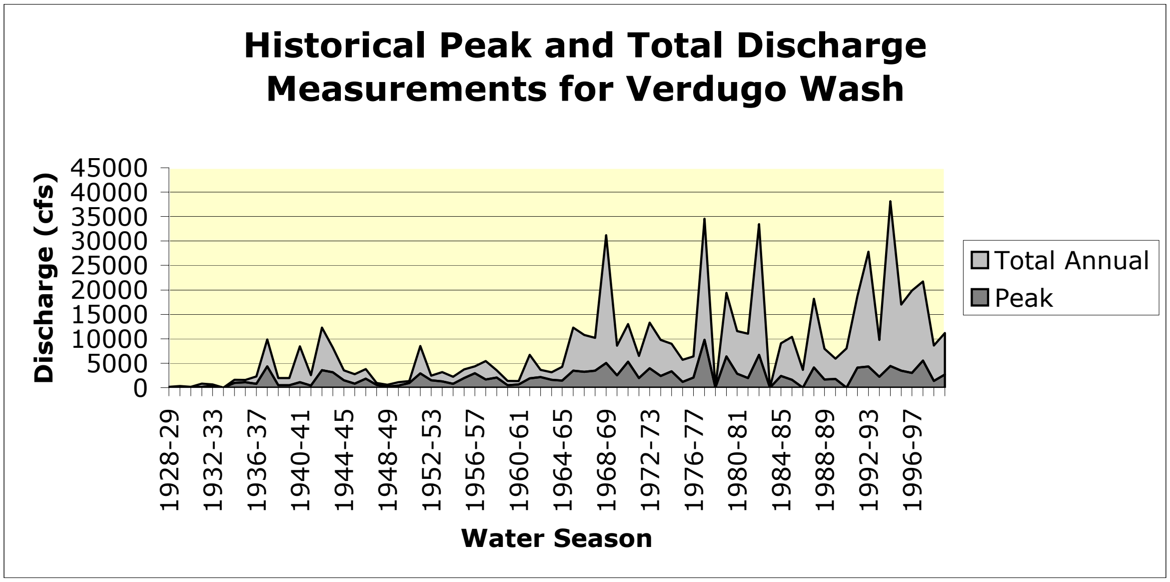
* = Record Incomplete E = Estimate ND = Not Determined
\+ = Less than 0.05 acre-feet or less than 0.05 cfs, but greater than 0
Source: http://www.dpw.co.la.ca.us/wrd/report/9900/runoff/peak.cfm

Figure 3-2 illustrates the total annual and peak annual discharge measurements for Verdugo Wash. The graph clearly illustrates that the annual discharges in the last decades, since the late 1960s, are overall higher than the measurements for the previous four decades. The annual peak discharge measurements also have increased in the last few decades, but not as much as the total annual measurements. This may indicate that the climate indeed has been wetter in the last few decades, or it could mean that with increased development in the Verdugo drainage area, the Verdugo Wash receives more runoff.

Several canyons near the Glendale area have flooded in the past, impacting developments within the canyons or areas downstream. For example, during the storms of 1969, the Verdugo Hills and the City proper were impacted by debris flows and flood flows when tributary streams reportedly overtopped their debris basins, causing damage (Waananen, 1969).

The most severe flood recorded in Glendale occurred in 1934. Intense precipitation on New Year's Eve, 1933 occurred locally in the La Canada Flintridge area, causing the Verdugo Wash to swell and overflow its then natural channel. Extensive areas of the drainage basin had burned earlier, in November 1933, causing large amounts of debris. The debris was carried by the storm waters down the mountains, and into the alluvial valleys, where several roads were choked. Damage was not confined to Verdugo Wash, but extended to several of the canyons draining the eastern and southern flanks of the Verdugo Mountains, and also in Sycamore and Scholl Canyons. Several people died, several bridges were washed out, and erosion and sedimentation damaged property. The damage caused by this storm was carefully documented by an unknown official or employee of the City. The map showing the damage is reproduced here, as Plate 3-2. Verdugo Wash and most of its tributaries through the La Crescenta area were channelized in response to the 1934 flood.

Figure 3-2:



Source: Los Angeles County Department of Public Works, Annual Hydrological Report 1999-2000, at http://www.dpw.co.la.us/wrd/report

3.1.4 National Flood Insurance Program

The Federal Emergency Management Agency (FEMA) is mandated by the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 to evaluate flood hazards. To promote sound land use and floodplain development, FEMA provides Flood Insurance Rate Maps (FIRMs) for local and regional planners. Flood risk information presented on FIRMs is based on historic, meteorological, hydrologic, and hydraulic data, as well as topographic surveys, open-space conditions, flood control works, and existing development.

Rainfall-runoff and hydraulic models are utilized by the FIRM program to analyze flood potential, adequacy of flood protective measures, surface-water and groundwater interchange characteristics, and the variable efficiency of mobile (sand bed) flood channels. It is important to realize that FIRMs only identify potential flood areas based on the conditions at the time of the study, and do not consider the impacts of future development.

NOTES:

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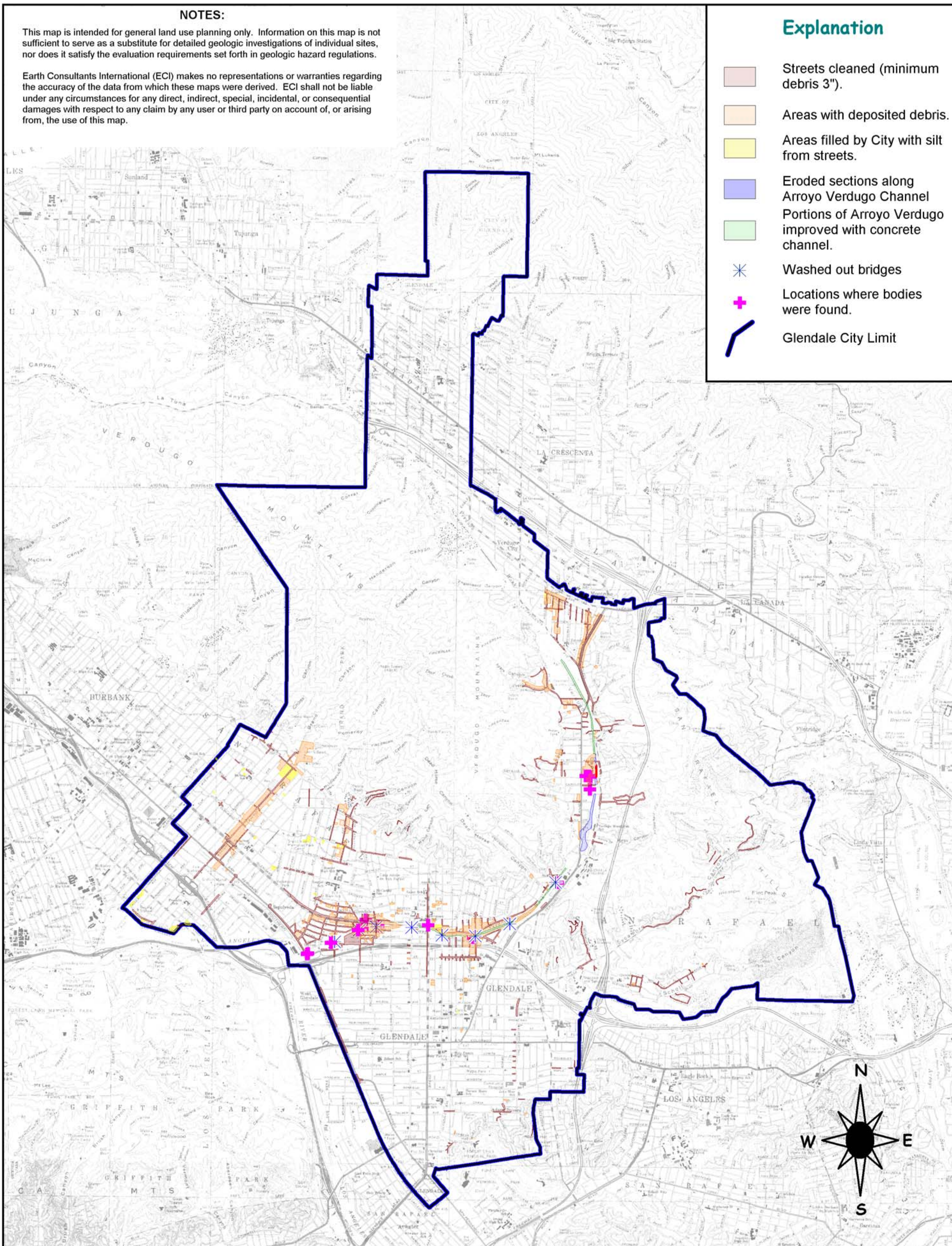

Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: Flood Map prepared by the City of Glendale (undated), provided by the Glendale Planning Department

CITY OF GLENDALE CALIFORNIA

Earth Consultants International

Project Number: 2103
Date: July, 2003

Damage Caused by the January 1, 1934 Flood

Glendale, California

Plate 3-2

To prepare FIRMs that illustrate the extent of flood hazards in a flood-prone community, FEMA conducts engineering studies referred to as Flood Insurance Studies (FISs). Using information gathered in these studies, FEMA engineers and cartographers delineate Special Flood Hazard Areas (SFHAs) on FIRMs. SFHAs are those areas subject to inundation by a "**base flood**" which FEMA sets as a 100-year flood. A **100-year flood** is defined by looking at the long-term average period between floods of a certain size, and identifying the size of flood that has a 1 percent chance of occurring during any given year. This base flood has a 26 percent chance of occurring during a 30-year period, the length of most home mortgages. However, a recurrence interval such as "100 years" represents only the long-term average period between floods of a specific magnitude; rare floods can in fact occur at much shorter intervals or even within the same year.

On May 7, 1976 the Federal Insurance Administration (FIA) issued a Flood Hazard Boundary map for the City of Glendale. However, this map was rescinded by FIA on November 15, 1979, because information provided to them indicated "that for all practical purposes no part of the community would be inundated by the base flood; that is, a flood having a one percent chance of being equaled or exceeded in any given year." (letter from Gloria M. Jimenez, FIA, stamped November 29, 1979). In addition, the Federal Emergency Management Agency, in a letter to the City of Glendale, dated August 31, 1984 "determined that no Special Flood Hazard Areas exist, at this time, within the corporate limits of your community. Therefore, no map will be published."

The base flood is a regulatory standard used by the National Flood Insurance Program (NFIP) as the basis for insurance requirements nationwide. The Flood Disaster Protection Act requires owners of all structures in identified SFHAs to purchase and maintain flood insurance as a condition of receiving Federal or federally related financial assistance, such as mortgage loans from federally insured lending institutions.

The base flood is also used by Federal agencies, as well as most county and State agencies to administer floodplain management programs. The goals of floodplain management are to reduce losses caused by floods while protecting the natural resources and functions of the floodplain. The basis of floodplain management is the concept of the "**floodway**". FEMA defines this as the channel of a river or other watercourse, and the adjacent land areas that must be kept free of encroachment in order to discharge the base flood without cumulatively increasing the water surface elevation more than a certain height. The intention is not to preclude development, but to assist communities in managing sound development in areas of potential flooding. The community is responsible for prohibiting encroachments into the floodway unless it is demonstrated by detailed hydrologic and hydraulic analyses that the proposed development will not increase the flood levels downstream.

The NFIP is required to offer federally subsidized flood insurance to property owners in those communities that adopt and enforce floodplain management ordinances that meet minimum criteria established by FEMA. The National Flood Insurance Reform Act of 1994 further strengthened the NFIP by providing a grant program for State and community flood mitigation projects. The act also established the Community Rating System (CRS), a system for crediting communities that implement measures to protect the natural and beneficial functions of their floodplains, as well as managing the erosion hazard. *The City of Glendale has participated as a regular member in the NFIP since August 31, 1984 (City ID No. – 065030) however, there are no FIRM maps for the City, and Glendale is not currently listed in FEMA's CRS of cities*. Since the City is a participating member of the NFIP, flood insurance is available for individuals to purchase voluntarily. There is, however, a 30-day wait period after the policy is issued before the coverage becomes effective.

3.1.5 Bridge Scour

Scour at highway bridges involves sediment-transport and erosion processes that cause streambed material to be removed from the bridge vicinity. Nationwide, several catastrophic collapses of highway and railroad bridges have occurred due to scouring and a subsequent loss of support of foundations. This has led to a nationwide inventory and evaluation of bridges (Richardson and others, 1993).

Scour processes are generally classified into separate components, including pier scour, abutment scour, and contraction scour. ***Pier scour*** occurs when flow impinges against the upstream side of the pier, forcing the flow in a downward direction and causing scour of the streambed adjacent to the pier. ***Abutment scour*** happens when flow impinges against the abutment, causing the flow to change direction and mix with adjacent main-channel flow, resulting in scouring forces near the abutment toe. ***Contraction scour*** occurs when flood-plain flow is forced back through a narrower opening at the bridge, where an increase in velocity can produce scour. ***Total scour*** for a particular site is the combined effects from all three components. Scour can occur within the main channel, on the flood plain, or both. While different materials scour at different rates, the ultimate scour attained for different materials is similar and depends mainly on the duration of peak stream flow acting on the material (Lagasse and others, 1991).

The State of California participates in the bridge scour inventory and evaluation program; however, to date, we have not found any records to indicate that the bridges in the Glendale area have been evaluated. Nevertheless, since the Verdugo Wash is channelized in the City, the potential for bridge scour to occur along the Verdugo Wash is considered low to nil. The most significant, although unlikely concern regarding bridge scour is if unusually high surface water flows in the Sycamore and Scholl Canyons were to reach the Glendale (2) Freeway, impacting the bridges at Chase Drive and Glenoaks Boulevard.

3.1.6 Existing Flood Protection Measures

(The information in this section was provided by the City of Glendale Engineering Department in a memo dated April 17, 2003).

Most storm drains within the City are maintained by the County of Los Angeles. For other problem areas, the City has provided the County a “Drainage Deficiency Report” for their evaluation. It is anticipated that the Los Angeles County Department of Public Works will address these conditions as funds become available.

During the past 80 years, the Los Angeles County Department of Public Works (LACDPW) and the US Army Corps of Engineers have constructed several detention or debris basins in the San Gabriel Mountains, in or above Glendale, including debris basins in Cooks, Dunsmore, Shields, Eagle, Pickens and Hall Beckley Canyons (se Plates 3-1). At least three other debris basins have been built in the Verdugo Mountains, above the populated areas of the City. The LACDPW also has made channel alterations consisting primarily of concrete side-slopes and linings for most of the major channels in the area. These flood control structures are presently owned and operated by the LACDPW, which has jurisdiction over the watercourses in the Glendale area, as well as the regional flood control system in the Los Angeles County. All of these structures help regulate flow in the Verdugo Channel, holding back some of the flow during intense rainfall periods that could otherwise overwhelm the storm drain system in the area.

Verdugo Wash Flood Control Channel: The City of Glendale is primarily served by the Verdugo Wash Flood Control Channel. This Channel was designed for a 100-year capital storm to carry the storm water run-off from the hillsides at the northern portion of the City (La Crescenta), and outlets into the Los Angeles River. Other tributaries of the Verdugo Wash include: Halls Canyon Channel, Pickens Canyon Channel, Eagle Shields Canyon Channel, Cooks Canyon Channel and the Dunsmuir Canyon Channel. A debris basin was also constructed across the Verdugo Wash Channel downstream from all the tributary channels to filter debris that could potentially clog the channel and reduce its capacity.

These storm drain facilities provide the City with adequate protection from a major storm except some isolated minor localized inundation. This type of localized inundation may mean that on major storms, a portion of the street may be flooded but the water level will be contained within the curbs. No flooding of private properties occurs unless there is a backup of local storm drains.

Localized Inundation: Another area that could potentially be subjected to localized inundation is the area at the terminus of Woodland Avenue. This street was cut with the construction of the Verdugo Wash, and is now a dead-end residential street that is serving only 12 residential homes. A lateral of the Verdugo Wash Channel was also constructed which terminated at the terminus of Woodland Avenue. Because of grade, three (3) 36-inch flap gates were installed at the end of that lateral. Under severe storm conditions, the flap gates would close and runoff from the street will be retained within the street temporarily until the flow can be taken into the channel.

Sycamore Canyon Channel: The eastern portion of the City is served by the Sycamore Canyon Channel. This channel was built during the 1930's. Although many developments have occurred within its drainage area, it is generally adequate for storm water protection, except for a small portion of the "Adams Hill Area", where there is a dip on Cottage Grove Avenue, between Palmer Street and Green Street. This dip acts as drainage channel, and during heavy rains, this dip may be subjected to minor flooding. However, private properties are not adversely affected.

3.1.7 Future Flood Protection

As development projects in the hillsides of Glendale are considered, it is important that hydrologic studies be conducted to assess the impact that increased development may have on the existing development down gradient. These studies should quantify the effects of increased runoff and alterations to natural stream courses. Such constraints should be identified and analyzed in the earliest stages of planning. If any deficiencies are identified, the project proponent needs to prove that these can be mitigated to a satisfactory level prior to proceeding forward with the project, in accordance with CEQA guidelines. Mitigation measures typically include flood control devices such as catch basins, storm drain pipelines, culverts, detention basins, desilting basins, velocity reducers, as well as debris basins for protection from mud and debris flows.

The methodology for analysis and design is set forth in several manuals published by the Los Angeles County Department of Public Works (LACDPW). Future responsibilities for operation of regional flood control facilities will be with the LACDPW, while the local storm drain network outside of the regional system will be with the City of Glendale. Therefore, both agencies must be involved in the planning and approval of mitigation measures, to assure compatibility.

Across the United States, substantial changes in the philosophy, methodology and mitigation of flood hazards are currently in the works. For example:

- Some researchers have questioned whether or not the current methodology for evaluating average flood recurrence intervals is still valid, since we are presently experiencing a different, warmer and wetter climate. Even small changes in climate can cause large changes in flood magnitude (Gosnold et al., 2000).

- Flood control in undeveloped areas should not occur at the expense of environmental degradation. Certain aspects of flooding are beneficial and are an important component of the natural processes that affect regions far from the particular area of interest. For instance, lining major channels with concrete reduces the area of recharge to the ground water, and depletes the supply of sand that ultimately would be carried to the sea to replenish our beaches. Thus there is a move to leave nature in charge of flood control. The advantages include lower cost, preservation of wildlife habitats and improved recreation potential.

- Floodway management design in land development projects can also include areas where stream courses are left natural or as developed open space, such as parks or golf courses. Where flood control structures are unavoidable, they are often designed with a softer appearance that blends in with the surrounding environment.

- Environmental legislation is increasingly coming in conflict with flood control programs. Under the authority of the Federal Clean Water Act and the Federal Endangered Species Act, development and maintenance of flood control facilities has been complicated by the regulatory activities of several Federal agencies including the U.S. Army Corps of Engineers, the Environmental Protection Agency, and the U.S. Fish and Wildlife Service. For instance, FEMA requires that Los Angeles County and its incorporated cities maintain the carrying capacity of all flood control facilities and floodways. However, this requirement can conflict with mandates from the U.S. Fish and Wildlife Service regarding maintaining the habitat of endangered or threatened species. Furthermore, the permitting process required by the Federal agencies is lengthy, and can last several months to years. Yet, if the floodways are not permitted to be cleared of vegetation and other obstructing debris in a timely manner, future flooding of adjacent areas could develop. Zappe (1997) argues that reform of environmental laws is necessary to ease the burden on local governments, and ensure the health and safety of the public. In particular, Zappe calls for a categorical exemption from the Federal laws for routine maintenance and emergency repair of all existing flood control facilities.

3.1.8 Flood Protection Measures for Property Owners

Property owners can make modifications to their houses to reduce the impact of flooding. FEMA has identified several flood protection measures that can be implemented by property owners to reduce flood damage. These include: installing waterproof veneers on the exterior walls of buildings; putting seals on all openings, including doors, to prevent the entry of water; raising electrical components above the anticipated water level improvements; and installing backflow valves that prevent sewage from backing up into the house through the drainpipes. Obviously, these changes vary in complexity and cost, and some need to be carried out only by a professional licensed contractor. For additional information and ideas, refer to the FEMA webpage at www.fema.gov. Structural modifications require a permit from the City's Building Department. Refer to them for advice regarding whether or not flood protection measures would be appropriate for your property.

3.2 Seismically Induced Inundation

3.2.1 Dam Inundation

Seismically induced inundation refers to flooding that results when water retention structures (such as dams) fail due to an earthquake. Statutes governing dam safety are defined in Division 3 of the California State Water Code (California Department of Water Resources, 1986). These statutes empower the California Division of Dam Safety to monitor the structural safety of dams that are greater than 25 feet in dam height or have more than 50 acre-feet in storage capacity.

Dams under State jurisdiction are required to have inundation maps that show the potential flood limits in the remote, yet disastrous possibility a dam is catastrophically breached. Inundation maps are prepared by dam owners to help with contingency planning; these inundation maps in no way reflect the structural integrity or safety of the dam in question. Dam owners are also required to prepare and submit emergency response plans to the State Office of Emergency Services, the lead State agency for the State dam inundation-mapping program. Areas in Glendale within the dam inundation areas identified by the State are shown on Plate 3-3.

The City of Glendale is required by State law to have in place emergency procedures for the evacuation and control of populated areas within the limits of dam inundation. In addition, recent legislation requires real estate disclosure upon sale or transfer of properties in the inundation area (AB 1195 Chapter 65, June 9, 1998; Natural Hazard Disclosure Statement).

Seven dams located in the Glendale area fall under State jurisdiction. These dams are owned by the City of Glendale and retain small reservoirs in the Verdugo Mountains and San Rafael Hills. From west to east they include the 10th and Western, Brand Park, and Diederich dams in the Verdugo Mountains, and the East Glorietta, Chevy Chase 1290, Glenoaks and Chevy Chase 980 dams in the San Rafael Hills.

(For security purposes, the locations of dams and reservoirs are not included in this document. In order to obtain this information please send a written request to the Planning Department, 633 East Broadway, Room 103.)

There are several other, smaller debris basins in the Glendale area that are not subject to State regulations because they are too small. These debris basins, and other flood control improvements, such as canals, culverts, and levees, may crack and suffer structural damage during an earthquake, especially in areas prone to ground failure, such as that due to liquefaction or slope instability. These facilities could pose an inundation hazard to areas downstream if they contain water at the time of the seismic event, or if they are not repaired prior to the next winter storm season.

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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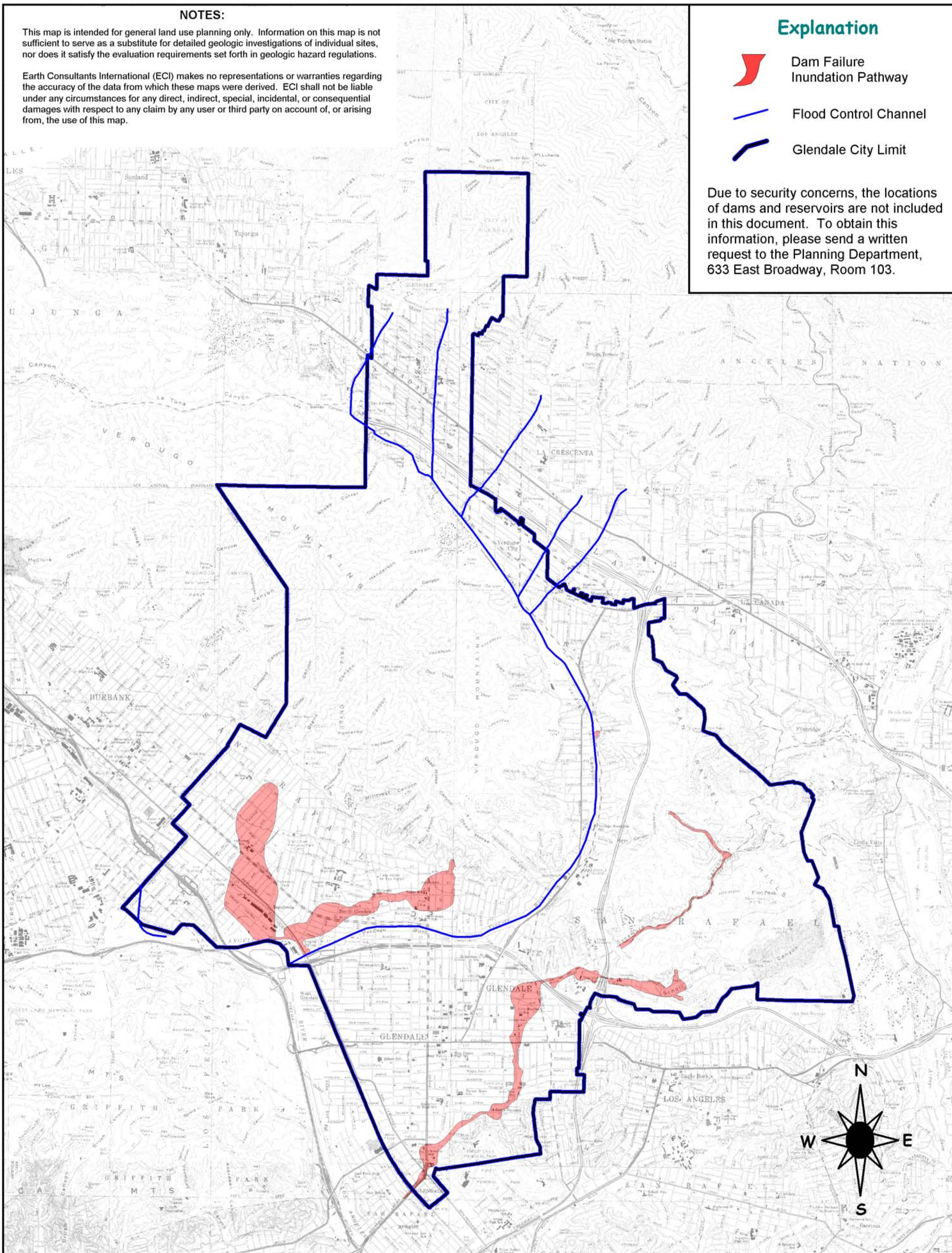

Explanation

Dam Failure Inundation Pathway

Flood Control Channel

Glendale City Limit

Due to security concerns, the locations of dams and reservoirs are not included in this document. To obtain this information, please send a written request to the Planning Department, 633 East Broadway, Room 103.

Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: California Governors Office of Emergency Services (OES); City of Glendale Planning Department

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Date: July, 2003

Dam Inundation Pathways

Glendale, California

Plate 3-3

3.2.2 Inundation From Above-Ground Storage Tanks

(For security purposes, the locations of above-ground storage tanks are not included in this document. In order to obtain this information please send a written request to the Planning Department, 633 East Broadway, Room 103.)

Seismically induced inundation can also occur if strong ground shaking causes structural damage to aboveground water tanks. If a tank is not adequately braced and baffled, sloshing water can lift a water tank off its foundation, splitting the shell, damaging the roof, and bulging the bottom of the tank (elephants foot) (EERI, 1992). Movement can also shear off the pipes leading to the tank, releasing water through the broken pipes. These types of damage occurred during southern California's 1992 Landers, 1992 Big Bear, and 1994 Northridge earthquakes. The Northridge earthquake alone rendered about 40 steel tanks non-functional (EERI, 1995), including a tank in the Santa Clarita area that failed and inundated several houses below. As a result of lessons learned from recent earthquakes, new standards for design of steel water tanks were adopted in 1994 (Lund, 1994). The new tank design includes flexible joints at the inlet/outlet connections to accommodate movement in any direction. Flexible joints have been installed at most of Glendale's larger steel tanks.

There are thirteen steel water storage tanks in the City of Glendale. Tanks located near the fault hazard management zones (identified in Chapter 1 of this report) are especially vulnerable to rupture due to ground deformation, strong ground shaking and even surface fault rupture. While most water tanks in the Glendale area are not located near fault management zones, three tanks near the base of the San Gabriel Mountains, are located within the State mandated Alquist-Priolo Earthquake Fault Zone for the Sierra Madre fault. Because these water tanks have a heightened risk of rupturing catastrophically during an earthquake on the Sierra Madre fault, their inundation paths should be identified to evaluate whether or not habitable structures are located within the floodway. The evaluation should also address whether these water reservoirs are self-contained. In the event of a catastrophic breakage, will the water be contained within the site, or will it be discharged to a storm drain or channel or will it pose a hazard to properties downstream?

Because the entire City of Glendale is susceptible to strong seismic ground motion, all water tanks should incorporate new earthquake resistant designs, including flexible pipe joints. Many water tanks have already been retrofitted with these improvements; however, the Glendale Heights, Allen, San Luis Rey, and especially Cooks Canyon water tanks still need to be updated.

Water lost from tanks during an earthquake can significantly reduce the water resources available to suppress earthquake-induced fires. Damaged tanks and water mains can also limit the amount of water available to residents. Furthermore, groundwater wells can be damaged during an earthquake, also limiting the water available to the community after an earthquake. Therefore, it is of paramount importance that the water storage tanks in the area retain their structural integrity during an earthquake, so water demands after an earthquake can be met. In addition to evaluating and retrofitting to meet current standards, this also requires that the tanks be kept at near full capacity as much as practical.

3.3 Summary of Issues and Planning Opportunities

According to the Federal Emergency Management Agency, the City of Glendale is not vulnerable to flooding associated with the Verdugo Wash and its tributaries, or the Los Angeles River. Although there are no FIRM maps for the Glendale area, FEMA does provide National Flood Insurance for property owners in the City of Glendale. Many of the claims that FEMA processes are for structures located outside the 100-year flood zone. FEMA's National Flood Insurance Program (FEMA, 2001) also includes inundation by "mudslides," coverage that may be of interest to property owners at the base of the San Gabriel and Verdugo Mountains, or the San Rafael Hills, especially if near the mouth of a small canyon or drainage.

Future planning for new developments must consider the impact on flooding potential as well as the impact of flood control structures on the environment, both locally and regionally. Flood control should not be introduced in undeveloped areas at the expense of environmental degradation. Land development planning should consider leaving watercourses natural wherever possible, or developing them as parks, nature trails, golf courses or other types of recreation areas that could withstand inundation.

Several of the reservoirs and water tanks in the City are located within or adjacent to a fault zone. If an earthquake occurs on either the Sierra Madre or Verdugo faults, several reservoirs and water tanks may be damaged. The catastrophic release of water from these tanks has the potential to impact large areas in the City, including critical facilities located within the inundation zones. Critical facilities should not be permitted in floodplains unless they are elevated above the projected inundation depths and/or otherwise protected. Two of the largest reservoirs in the City, have the potential to inundate several facilities that use or store hazardous materials. Facilities using, storing, or otherwise involved with substantial quantities of onsite hazardous materials should not be permitted within these inundation zones unless all standards of elevation, anchoring, double containment and flood proofing have been satisfied, and the hazardous materials are stored in watertight containers that will not float.

Above-ground water storage tanks in the City of Glendale need to be reviewed, and retrofitted as necessary, to prevent them from rupturing catastrophically during an earthquake, which could have severe consequences on down slope structures and properties. Retrofitting measures should be in accordance with the latest water tank design guidelines, which were amended based on experience in recent southern California earthquakes. The evaluation should also address whether or not a water reservoir is self-contained, so that in the event of catastrophic breakage, the water is contained within the site.

CHAPTER 4: FIRE HAZARDS

4.1 Wildland Fires

Due to its weather, topography and native vegetation, the entire southern California area is at risk from wildland fires. The extended droughts characteristic of California's Mediterranean climate result in large areas of dry vegetation that provide fuel for wildland fires. Furthermore, the native vegetation typically has a high oil content that makes it highly flammable. The area is also intermittently impacted by Santa Ana (or Santana) winds, the hot, dry winds that blow across southern California in the spring and late fall. These winds often fan and help spread fires in the region. Combine these conditions with the fact that more people than ever are living and playing in wildland areas, and the potential for major wildland fires to occur increases even further. In fact, the wildfire risk in the United States has increased in the last few decades with the increasing encroachment of residences and other structures into the wildland environment and the enduring drought conditions that have affected some regions. Between 1990 and 1999 inclusive, there were on average 106,347 wildfires annually in the United States, for a combined average annual burn of nearly 3.65 million acres of brush (htpp://nifc.gov/fireinfo/1999/highlites.html). These fires are for the most part caused by people: between 1988 and 1997, human-induced fires burned nearly eight times more acreage than fires caused by lightning.

A wildfire that consumes hundreds to thousands of acres of vegetated property can overwhelm local emergency response resources. Under the right wind conditions, multiple ignitions can develop as a result of the wind transport of burning cinders (called brands) over distances of a mile or more. Wildfires in those areas where the wildland approaches or interfaces with the urban environment (referred to as the urban-wildland interface or UWI) can be particularly dangerous and complex, posing a severe threat to public and firefighter safety, and causing devastating losses of life and property. This is because when a wildland fire encroaches onto the built environment, ignited structures can then sustain and transmit the fire from one building to the next. This is what happened at three of the most devastating fires in California: the Oakland Hills/Berkeley Tunnel fire of October 1991, the Laguna fire of 1970 in northern San Diego County, and the Laguna Beach fire of 1993. In the Oakland Hills fire, 25 lives were lost, and 2,900 structures were damaged for a total of $1.7 billion in insured losses. The September 1970 fire, which started as a result of downed power lines, burned 175,425 acres, destroyed 382 structures and killed 5 people. The Laguna Beach fire of 1993 burned 14,437 acres and destroyed 441 homes, but thankfully no lives were lost. It is clear that continuous planning, preparedness, and education are required to reduce the fire hazard potential, and to limit the destruction caused by wildfires.

Fires usually last only a few hours or days, but their effects can last much longer, especially in the case of intense fires that develop in areas where large amounts of dry, combustible vegetation have been allowed to accumulate. If wildland fires are followed by a period of intense rainfall, debris flows off the recently burned hillsides can develop. Flood control facilities may be severely taxed by the increased flow from the denuded hillsides and the resulting debris that washes down. If the flood control structures are overwhelmed, widespread damage can ensue in areas down gradient from these failed structures. This happened in several communities in and near the base of the San Gabriel Mountains during the winters of 1934, 1969, 1978, and 1980, with areas below burned watersheds receiving the bulk of the damage. In November 1933, there was a large fire in the Montrose-La Crescenta area that burned more than 5,000 acres. Then, on January 1, 1934, the recently burned watershed experienced an exceptionally intense rainstorm. Debris-laden flows that overtopped canyons impacted the La Crescenta and Glendale areas. Streets were clogged with debris, several bridges were washed out, and several people died (see Chapters 2 and 3).

However, this does not need to happen if remedial measures following a wildfire are taken in anticipation of the next winter. Studies (Cannon, 2001) suggest that in addition to rainfall and slope steepness, other factors that contribute to the formation of post-fire debris flows include the underlying rock type, the shape of the drainage basin, and the presence or absence of water-repellant soils (during a fire, the organic material in the soil may be burned away or decompose into water-repellent substances that prevents water from percolating into the soil.)

Other effects of wildfires are economical and social. Homeowners who lose their house to a wildfire may not be able to recover financially and emotionally for years to come. Recreational areas that have been affected may be forced to close or operate at a reduced scale. In addition, the buildings that are destroyed by fire are usually eligible for re-assessment, which reduces income to local governments from property taxes.

The impact of wildland fire on plant communities is generally beneficial, although it often takes time for plant communities to re-establish themselves. If a grassland area has been burned, it will re-sprout the following spring. A chaparral community, however, takes three to five years to recover. Oak woodland, which has had most of the seedlings and saplings destroyed by fire, will require at least five to ten years for a new crop to start.

Regardless of the comments above, we should not forget that wildland fire is a natural process. In the past, the presumption has been that all wildfire is bad, and that it should therefore be extinguished promptly. This has caused fire-dependent plant communities to grow more densely, which ultimately weakens the plants in their struggle for living space and increases their destruction by pests and disease. Dead and dying plants add fuel for fire. In addition, the absence of fire has altered or disrupted the cycle of natural plant succession and wildlife habitat in many areas (http://www.nps.gov/gosp/resource/fire_nps.htm). Consequently, land management agencies are now committed to finding ways, such as prescribed burning, to reintroduce fire into natural ecosystems. Future efforts to reduce this hazard need to consider ways of managing wildland fire to benefit the natural environment, while reducing the potential for structural fires in the built environment. Policies developed to manage the fire hazard will be successful if a balance between both goals is obtained.

4.1.1 Wildland Fire Susceptibility Mapping

Wildfires have been part of the natural ecosystem in the rolling hillsides and mountains of southern California for thousands of years. Some of the plants native to this area actually require periodic burning to germinate and recycle nutrients that enrich the soils. Researchers have also determined that Native Americans in California used fire to reduce fuel load and improve their ability to hunt and forage. It is thought that as much as 12 percent of the State was burned every year by the various tribes (Coleman, 1994). In the early 20th Century, as development started to encroach onto the foothills, wildfires came to be unacceptable as they posed a hazard with the potential loss of property and even life. As a result, in the early 1920s, the fire service began to prevent wildfires from occurring. Unfortunately, over time, this led to an increase in fuel loads. Wildfires that impact areas with fuel buildup are more intense and significantly more damaging to the ecosystem than periodic, low-intensity fires.

The fire hazard of an area is typically based on the combined input of several parameters. Some of these conditions include:

- fuel loading (that is, type of vegetation, its density, and moisture content),
- topography (slope),

- weather,
- dwelling density and accessibility,
- building construction (with emphasis on combustible roof coverings),
- wildfire history, and
- whether or not there are local mitigation measures in place that help reduce the zone's fire rating (such as an extensive network of fire hydrants, fire-rated construction materials, fuel modification zones, fire sprinklers in structures, etc.).

Since the early 1970s, several fire hazard assessment systems have been developed for the purpose of quantifying the severity of the hazard in a given area. Those that have been developed in California are described further below. Early systems characterized the fire hazard of an area based on a weighted factor that typically considered fuel, weather and topography. More recent systems rely on the use of Geographic Information System (GIS) technology to integrate the factors listed above to map the hazards, and to predict fire behavior and the impact on watersheds.

HUD Study System: In April 1973, the California Department of Forestry and Fire Prevention (CDF) published a study funded by the Department of Housing and Urban Development (HUD) under an agreement with the Governor's Office of Planning and Research (Helm et al., 1973). As is often the case, the study was conducted in response to a disaster: during September and October 1970, 773 wildfires burned more than 580,000 acres of California land. The HUD mapping process relied on information obtained from US Geological Survey (USGS) 15- and 7.5-minute quadrangle maps on fuel loading (vegetation type and density) and slope, and combined it with fire weather information to determine the Fire Hazard Severity of an area.

California Department of Forestry and Fire Protection – State Responsibility Areas System: Legislative mandates passed in 1981 (Senate Bill 81, Ayala, 1981) and 1982 (Senate Bill 1916, Ayala, 1982) that became effective on July 1, 1986, required the CDF to develop and implement a system to rank the fire hazards in California. Areas were rated as moderate, high or very high based primarily on fuel types. Thirteen different fuel types were considered using the 7.5-minute quadrangle maps by the US Geological Survey as base maps (Phillips, 1983). Areas identified as having a fire hazard were referred to as **State Responsibility Areas** (SRAs) (Public Resources Code Section 4125). These are non-federal lands covered wholly or in part by timber, brush, undergrowth or grass, for which the State has the primary financial responsibility of preventing and suppressing fires.

Bates Bill Process: The Bates Bill (Assembly Bill 337, September 29, 1992) was a direct result of the great loss of lives and homes in the Oakland Hills Tunnel Fire of 1991. Briefly, the California Department of Forestry and Fire Protection (CDF), in cooperation with local fire authorities was tasked to identify Very High Fire Hazard Severity Zones (VHFHSZs) in Local Responsibility Areas (LRAs). To accomplish this, the CDF formed a working group comprised of state and local representatives that devised a point system that considers fuel (vegetation), slope, weather, and dwelling density. To qualify as a VHFHSZ, an area has to score ten or more points in the grading scale.

Once the boundaries of a VHFHSZ have been delineated, the CDF notifies the local fire authorities that are responsible for fire prevention and suppression within that area. Since the State is not financially responsible for Local Responsibility Areas, local jurisdictions have final say regarding whether or not an area should be included in a VHFHSZ (Government Code Section 51178). As a result, although several areas in California have adopted the State-developed fire hazard maps, many local jurisdictions did not acknowledge the Bates system, and developed their own maps instead. Local jurisdictions that do not follow the Bates system are required to follow at a minimum the model ordinance developed by the State Fire Marshal for mitigation purposes. The City of Glendale is one of the cities that has developed its own fire hazard maps and has adopted stringent hazard mitigation programs that have often been years ahead of State regulations. This will be discussed further in the following sections of this report.

California Fire Plan: The 1996 California Fire Plan is a cooperative effort between the State Board of Forestry and Fire Protection and the CDF (California Board of Forestry, 1996). This system ranks the fire hazard of the wildland areas of the State using four main criteria: fuels, weather, assets at risk, and level of service (which is a measure of Fire Department's success in initial-attack fire suppression). The California Fire Plan uses GIS data layers to conduct the initial evaluations, and local CDF Ranger Units are then tasked with field validation of the initial assessment. The final maps use a Fire Plan grid cell with an area of approximately 450 acres, which represents 1/81 of the area of a 7.5-minute quadrangle map (called Quad 81). The fire hazard of an individual cell is ranked as moderate, high or very high. This system is expected to replace the current State Responsibility Areas process, but at the time of this writing, the California Fire Plan has not been implemented. For additional information regarding this system refer to http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/FirePlan.asp.

FireLine System: The Insurance Services Office (ISO) developed a program used by the insurance industry to identify those areas where the potential loss due to wildfire is greatest (ISO, 1997). ISO retained Pacific Meridian Resources of Emeryville, California to develop the FireLine software, which uses satellite-imagery interpretation to evaluate the factors of fuel types, slope and roads (access) to develop the risk rating. Most insurance companies that provide insurance services to homeowners in California now use this system. This software is only available through ISO. Updated versions of this system are being developed that include the factors of elevation, aspect, and relative slope position.

National Fire Plan: Funding for the National Fire Plan was authorized by Congress in October 2000 in response to the wildfires of that year. The plan is a cooperative effort of the US Department of Agriculture's Forest Service, the Department of the Interior, and the National Association of State Foresters. National Fire Plan maps show communities that are within the vicinity of federal lands that are at high risk from wildland fire. The plan uses hazardous fuel reduction treatment techniques (including prescribed fire alone, mechanical treatment alone, mechanical treatment plus prescribed fire, and other/wildland fire use, such as allowing lightning-caused fires to burn) to reduce the impact of wildland fire on communities within the urban-wildland interface. For additional information refer to http://www.fireplan.gov/.

FARSITE, BehavePlus and FlamMap: These are PC-based computer programs that can be used by local fire managers to calculate potential fire behavior in a given area using GIS data inputs for terrain and fuels. The purpose of these models is to predict fire behavior. Data inputs that can be used in the analyses include elevation, slope, aspect, surface fuel, canopy cover, stand height, crown base height and crown bulk density.

The oldest of these models is the BEHAVE Fire Behavior Prediction and Fuel Modeling System (Burgan and Rothermel, 1984; Burgan, 1987; Andrews, 1986; Andrews and Chase, 1989; Andrews and Bradshaw, 1991) that has been used since 1984. A newer version of it is referred to as the BehavePlus Fire Modeling System (Andrews and Bevins, 1999). This software is undergoing additional updates to make it more user- friendly and provide additional fire modeling capabilities. FARSITE (Finney, 1995, 1998) "simulates the growth and behavior of a fire as it spreads through variable fuel and terrain under changing weather conditions" (http://fire.org/cgi-bin/nav.cgi?pages=JFSP&mode=9). This software can be used to project the growth of ongoing wildfires and prescribed fires, and can be used as a planning tool for fire suppression and prevention, and fuel assessment. The FlamMap fire behavior mapping and analysis system is still under preparation, although a prototype has been released and is being used for the Tahoe Basin project (http://fire.org/cgi-bin/nav.cgi?pages=JFSP&mode=11). FlamMap combines elements of the two older models. The Glendale Fire Department is considering the use of some of these computer models to simulate fire conditions and predict fire behavior in the fire hazard areas of the City.

Brian Barrette's Structural Vulnerability System: This system starts with the State Responsibility Area fire hazard severity rating described above, but also includes structural elements as rating factors (Barrette, 1999). The structural elements considered include roofing, siding, vegetation clearance, roads and signage, chimneys, structural accessories, water supply, and the location of the structure in relation to the surrounding conditions. This system is intended for use in assessing individual parcels, and is therefore not likely to be used by agencies, as it is time- and personnel-intensive. However, the system is easy to use and can therefore be used by individual homeowners or insurance companies to determine whether or not a specific property has a high fire hazard and is therefore a good candidate for specific fire hazard mitigation measures.

4.1.2 Wildland Fire Susceptibility in the Glendale Area

Several historical fires have impacted the Glendale area and vicinity over the years. In fact, as shown on Plate 4-1, the entire northern two-thirds of the City have burned at some time in the last 125 years. Historical records kept by the City and the County of Los Angeles indicate that significant acreage was impacted by fires in 1878, 1927, 1933, 1964, 1975, and 1980. The most recent wildland fire in the area occurred in September 2002 (see Figure 4-1). The worst fire in the City's history, however, is the College Hills fire of June 1990, which burned 100 acres and destroyed 64 homes in the foothills of the San Rafael Hills.

Figure 4-1: September 2002 Fire in Glendale

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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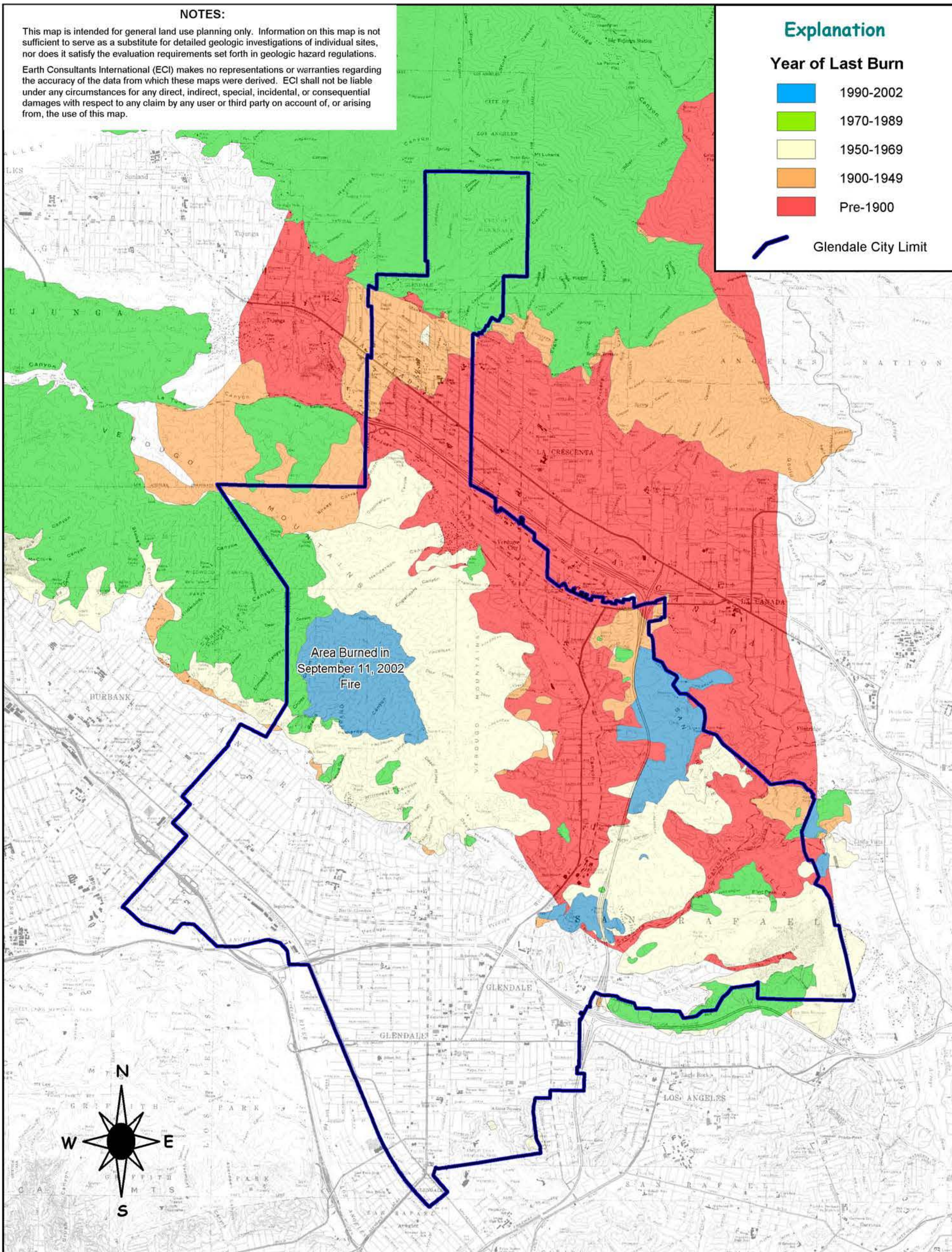

Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: City of Glendale Fire and Los Angeles County Fire Departments

This map shows areas in Glendale that have burned between 1878 and 2002 based on maps prepared by the City of Glendale Fire and Los Angeles County Fire Departments.

Earth Consultants International

Project Number: 2103
Date: July, 2003

Historical Wildland Fire Map of the Glendale Area

Plate 4-1

- **Climate**: The Glendale area typically has mild, wet winters that lead to an annual growth of grasses and plants. This vegetation dries out during the hot summer months and is exposed to Santa Ana wind conditions in the fall. During Santa Ana conditions, winds in excess of 40 miles per hour (mph) are typical; gusts in excess of 100 mph may occur locally. Santa Ana winds are generally consistent in their direction, but when combined with winds generated from burning vegetation, the wind direction generally becomes extremely erratic. This can stress fire-fighting resources and reduce fire-fighting success.

- **Geography and Topography**: Although Glendale is a highly urbanized community, there are several large areas in the City that consist of undeveloped, grass- and chaparral-covered hillsides and mountains. The Verdugo Mountains, located in the western section of the City, are more than 2,300 feet higher in elevation than the valley floor. Similarly, at their highest point, the San Rafael Hills rise more than 1,200 feet above the alluvial plain in the eastern section of the City. The San Gabriel Mountains to the north have an elevation gain of as much as 2,700 feet within City limits. The rough topography that characterizes these areas not only facilitates the spread of fire but also impedes or hinders responding fire-fighting personnel and equipment. Traffic congestion in the urban areas and long travel distances and narrow, winding roads in the hillsides and mountains can also hinder fire department response to the urban-wildland interface areas. Thus, enhanced onsite protection for structures and people in or adjacent to these undeveloped areas is absolutely necessary, with property owners assuming responsibility for maintenance of their properties and adhering to construction standards that make their houses more fire-resistant.

Figure 4-2: Slopes Burnt During the September 9-11, 2002 Fire in Glendale

- **Geology**: Several major earthquake-generating faults affect the region, including the Verdugo, Sierra Madre, Raymond, and Hollywood fault systems. A moderate earthquake on any of these faults could trigger multiple fires, disrupt lifeline services (such as the water supply), and trigger other geologic hazards, such as landslides or rock-falls, which could block roads and hinder disaster response.

In addition to the natural conditions described above, some hillside areas in the City have a historical legacy of narrow roads, difficult access, insufficient water supplies, and non-rated flammable building construction. Furthermore, an increasing number of people use the surrounding undeveloped areas for recreation purposes, and as a result there is an increased potential for fires to be accidentally or purposely set in the difficult-to-reach portions of the City.

Given the above conditions, it is not surprising that the Glendale Fire Department rates almost two-thirds of the City as highly susceptible to wildland fires. The High Fire Hazard Areas in the City defined by the Glendale Fire Department are shown on Plate 4-2. These areas are based on vegetation, access, zoning and topography.

Notice that the Glendale Fire Department, consistent with the Bates Bill process described above, does not classify the fire hazard of an area as low, medium, high or extreme, but rather, a property is either in the fire hazard area, or it is not. [The City's High Fire Hazard Area includes all areas with a medium, high or extreme brush fire hazard as delineated in the City's 1975 Safety Element.] The reason for this yes - no approach is that California State law requires that fire hazard areas be disclosed in real estate transactions; that is, real-estate sellers are required to inform prospective buyers whether or not a property is located within a wildland area that could contain substantial fire risks and hazards [Assembly Bill 6; Civil Code Section 1103(c)(6)].

Real estate disclosure requirements typically ask two "yes or no" questions concerning fire hazards. The questions are formatted as follows:

THIS REAL PROPERTY LIES WITHIN THE FOLLOWING HAZARDOUS AREA(S):

- A VERY HIGH FIRE HAZARD SEVERITY ZONE pursuant to Section 51178 or 51179 of the Government Code. (The owner of this property is subject to the maintenance requirements of Section 51182 of the Government Code.) [Note that the Fire Hazard Areas in the City of Glendale are, for the purposes of real-estate disclosure purposes equivalent to the State's Very High Fire Hazard Severity Zones, however, the City rather than the State defines maintenance requirements.]

- A WILDLAND AREA THAT MAY CONTAIN SUBSTANTIAL FOREST FIRE RISKS AND HAZARDS pursuant to Section 4125 of the Public Resources Code. (The owner of this property is subject to the maintenance requirements of Section 4291 of the Public Resources Code. Additionally, it is not the State's responsibility to provide fire protection services to any building or structure located within the wildlands unless the Department of Forestry and Fire Protection has entered into a cooperative agreement with a local agency for those purposes pursuant to Public Resources Code Section 4142.) [Given that there are no State Responsibility Areas within the City of Glendale, this question is not applicable in the City of Glendale.]

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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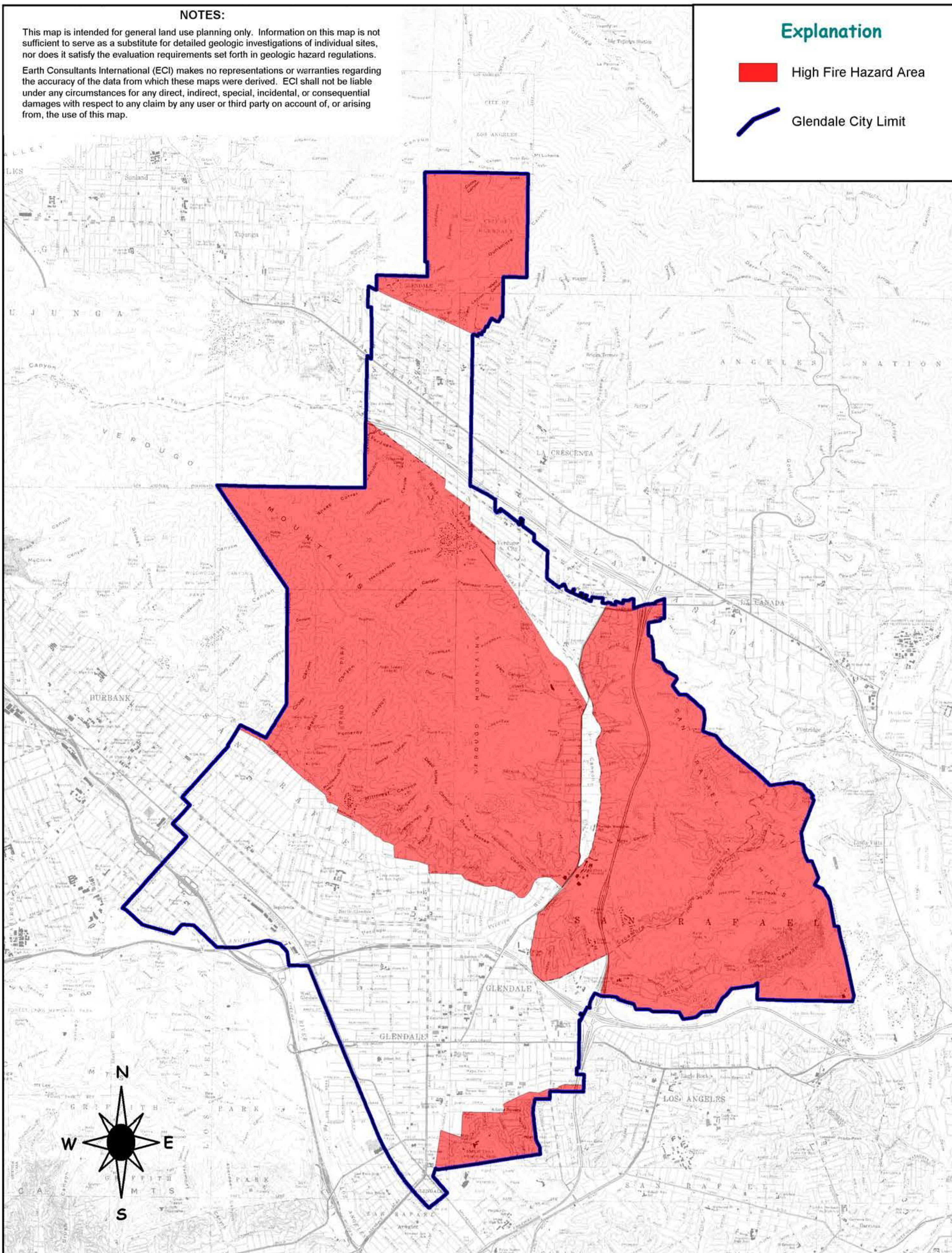


Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: City of Glendale Fire Department

Earth Consultants International

Project Number: 2103
Date: July, 2003

High Fire Hazard Areas

Glendale, California

Plate 4-2

Real-estate disclosure requirements are important because in California the average period of ownership for residences is only five years (Coleman, 1994). This turnover creates an information gap between the several generations of homeowners in fire hazard areas. Uninformed, new homeowners may attempt landscaping or structural modifications that could be a detriment to the fire-resistant qualities of the structure, with negative consequences. Appropriate landscaping and fire-resistive structural requirements in fire hazards areas are discussed in detail in the next sections.

4.1.3 Hazard Mitigation

Hazard mitigation programs in fire hazard areas currently include fire prevention, vegetation management, legislated construction requirements, and public awareness. Each of these programs is described further below.

4.1.3.1 Fire Prevention*:* Fire prevention aims to reduce the incidence and extent of fire by preventing wildfires from occurring in the first place. Over the years, a variety of fire prevention programs have been developed and implemented by federal, state, and local agencies. These programs typically include education, engineering, patrolling, code enforcement, and signing (Greenlee and Sapsis, 1996). Smokey Bear is one of the best-known characters that both children and adults recognize, attesting to the success of public education programs aimed at fire prevention. Quantitative studies show that fire losses arising from human fires, especially those caused by children, have dropped substantially over the last 30 years or so, in some cases by as much as 80 percent (Greenlee and Sapsis, 1996). Therefore, fire prevention is a well-understood program with a high degree of success. However, as discussed above, by preventing fire from occurring, fuel loads are allowed to increase, with the potential for high intensity fires and resultant damage. Therefore, fire prevention needs to be complemented with a variety of other programs that will guarantee long-term success in reducing the losses resulting from fires.

Fire Prevention can include limiting access to fire hazard areas during certain times of the year. Although not apparent from Plate 4-2, the wildfire susceptibility of an area changes throughout the year, and from one year to the next, in response to local variations in precipitation, temperature, vegetation growth, and other conditions. When the fire danger in a High Fire Hazard Zone is deemed to be of special concern, local authorities can rely on increased media coverage and public announcements to educate the local population about being fire safe. For example, to reduce the potential for wildfires during fire season, the City of Glendale can opt to close hazardous fire areas to public access during at least part of the year. By monitoring site-specific wildfire susceptibility of a region, the Fire Department can establish regional prevention priorities that help reduce the risk of wildland fire ignition and spread, and help improve the allocation of suppression forces and resources, which can lead to faster control of fires in areas of high concern.

Restricted public access to hiking trails in and around the City of Glendale during the fire season may help reduce the opportunity for human-caused wildfires in the area. Continued use of signs during high and extreme fire conditions along the freeways and roads that cut through the wildland areas in the City and adjacent areas can also help reduce the fire hazard by alerting and educating motorists and residents.

The City of Glendale has a variety of fire prevention programs in place. Routine (annual or bi-annual) fire prevention inspections are conducted on a citywide basis by the Fire Department for residential, commercial, and industrial-type occupancies. The Fire

Prevention Bureau of the City's Fire Department inspects all new and existing public assemblies, educational facilities, institutions and hospitals, high-rise buildings, hazardous materials occupancies, malls and large retail centers, and all new residential dwellings (Glendale Fire Department, 1994). The inspections are conducted for the purpose of enforcing the Fire Code and hazardous materials regulations, for Fire Department personnel from within that jurisdictional area to become familiar with the premises (this is helpful in the event that they need to respond to a fire or emergency), and to instruct occupants about fire prevention methods and procedures. The Neighborhood Services Section of the Community Development Department provides assistance with the inspection of single-family residential dwellings as part of a community-wide beautification program. All personnel that conduct these surveys have received training in hazard recognition from the Fire Department.

Glendale's Fire Prevention Bureau is comprised of several different units, each with specific responsibilities. Fire Prevention Bureau members have the powers of a peace officer in enforcing the City's Fire Code. The responsibilities of each unit are described further below:

- Fire Code Inspection – conducts inspections of all new and existing structures.
- Development Plan Review – reviews proposed developments for conformance with fire protection requirements including fire-resistive construction, landscaping, emergency access, available fire flow, and built-in fire detection and suppression systems.
- Fire Investigation and Arson – investigates fire cause and origin, administers aggressive code enforcement, and analyzes cost recovery for negligent or malicious acts causing fire. All members of this unit have full police powers as set in California Penal Code Section 832 (Section 103.2.2.3 of the City's Building and Safety Code).
- Vegetation Management – reviews existing properties for compliance with fuel management requirements; administers and enforces the weed abatement and brush clearance program, and contracts for fire hazard reduction measures, including fuel breaks, fire roads, and non-compliant parcels.
- Hazardous Materials and Waste Management – administers hazardous materials disclosure laws and legislation, as well as conducts inspection of underground storage tanks and facilities that use or store hazardous materials for environmental compliance.
- Public Education – provides public fire safety education for groups or individuals on the hazards associated with the urban-wildland interface area.

4.1.3.2 Vegetation Management: Although, as discussed above, wildland fire is a significant potential hazard in large portions of Glendale, there are several management tools that can be implemented to reduce this hazard to manageable levels. Experience and research have shown that **vegetation management** is an effective means of reducing the wildland fire hazard in southern California. As a result, in areas identified as susceptible to wildland fire, jurisdictions typically require property owners to use a combination of maintenance approaches aimed at reducing the amount and continuity of the fuel (vegetation) available.

Fuel or vegetation treatments often used include mechanical, chemical, biological and other forms of biomass removal (Greenlee and Sapsis, 1996) or **hazard reduction** within a given distance from habitable structures. The intent is to create a defensible space that slows the rate and intensity of the advancing fire, and provides an area at the urban-wildland interface where firefighters can set up to suppress the fire and save the threatened structures. Defensible space is defined as an area, either ***natural*** or man-made, where plant materials and natural fuels have been treated, cleared, or modified. However, removal of the native vegetation and maintenance of a wide strip of bare ground is not aesthetically acceptable and it increases the potential for water runoff and soil erosion. Native vegetation can be replaced with a green belt of low-lying, vegetation, but the increased use of water and maintenance requirements can make this option undesirable.

Another approach used in some areas of southern California is referred to as **fuel modification.** This method places emphasis on the space near structures that provides natural landscape compatibility with wildlife, water conservation and ecosystem health. Immediate benefits of this approach include improved aesthetics, increased health of large remaining trees and other valued plants, and enhanced wildlife habitat. **Fuel modification is used in the City of Glendale.**

In 1993, the City of Glendale adopted a Hillside Development Plan that provides guidelines regarding landscaping and vegetation modification to promote fire safety while protecting the visual quality of the hillsides (City of Glendale, 1993). The landscape guidelines provide lists of plants (referred to as plant palettes) that are drought tolerant and help control erosion to be used on engineered slopes. By using these plants instead of non-native species, the visual contrast between the natural hillsides and the engineered slopes can be diminished, making the man-made slopes resemble more closely the adjacent natural slopes. Two plant palettes are available: the naturalizing palette, which includes plants to be used on that portion of the engineered slopes closer to the natural hillsides; and the ornamental palette, to be used on that section of the slope closer to structures, adjacent to the ornamental vegetation. On large enough slopes, both plant palettes can be blended along a 150-foot wide interface. For the most recent version of the plant palettes acceptable in Glendale, request a copy from the City's Planning Department.

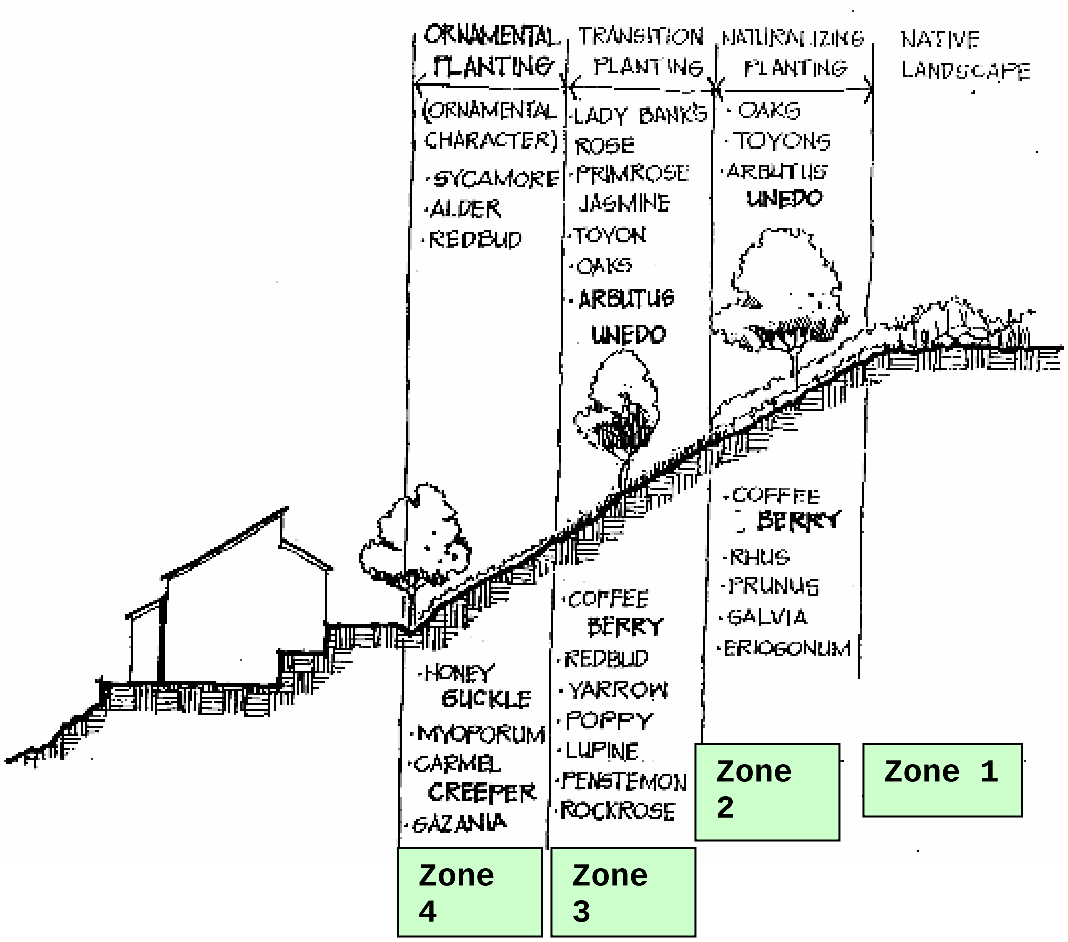
The Fire Zone Management Guidelines portion (Section 8.0) of Glendale's Landscape Guidelines Plan outlines the methods by which the two plant palettes discussed above are to be used around all flammable structures in the urban-wildland interface. A minimum buffer distance of 100 feet is required around all structures; in some cases, at the discretion of the City's Fire Chief, this buffer distance may be increased to 200 feet. Within this buffer distance, the City requires four distinct Fire Management Zones to be established. Each of these zones is described further below and shown graphically on Figures 4-3 and 4-4.

- **Zone 1:** Zone 1 includes the natural, ungraded slope and continues to the edge of the engineered slope. Existing vegetation in this zone needs to be thinned selectively to reduce the fuel volume and lower the intensity of any fire that may approach buildings. Foliage mass reduction is accomplished by removing large shrubby plants and dense groupings. The thinning of these plants needs to be conducted in such a way as to create a natural appearance and not expose excess soil areas that would then be susceptible to erosion.

- **Zone 2**: Zone 2 is the next zone inward from the natural, ungraded terrain, where low, slow-burning plantings should predominate. The volume of vegetation in this zone needs to be reduced and replaced with fire-resistant plant materials from both the naturalizing and ornamental plant palettes. Their low growth and limited foliage mass can diminish the intensity of wildfires, and prevent erosion of the slope.

- **Zone 3**: This zone can vary between 20 and 25 feet in width, depending upon the degree of fire risk in the area, and consists of fire-retardant plantings. This zone is referred to as the fire buffer zone or maximum fire prevention edge, and includes plants from both the ornamental and naturalizing palettes that require regular irrigation and weed control. Although some drought tolerant plants may be acceptable in this area, higher water and maintenance demands actually help achieve the maximum fire barrier. The plants in this zone are typically ground covers and plants with low fuel volumes.

Figure 4-3: Glendale's Hillside Planting Zones
(from the City of Glendale Landscape Guidelines for Hillside Development)



- **Zone 4:** This zone is the area immediately surrounding the structure where ornamental plantings are preferred. The plants in this zone should be carefully selected and placed. The amount of tall trees should be limited. Foliage should be thinned and dead branches and vegetation removed from those areas next to the building.

These standards require property owners in fire hazard areas, especially at the urban-wildland interface, to conduct maintenance, modifying or removing non-fire-resistive vegetation around their structures to reduce the fire danger. This affects any person who owns, leases, controls, operates, or maintains a building or structure in, upon, or adjoining the UWI area. An example of vegetation management is shown on Figure 4-4.

Figure 4-4: Example of Vegetation Management at the Urban-Wildland Interface
(Residential community in southern California that uses fuel modification to reduce its fire hazard. Note selective thinning of vegetation in the slope below the structures. Closer to the structures, there is a zone of fire-resistive ornamental plants that are irrigated. The vegetation in the foreground is in its natural state.)

Specific maintenance actions that can be undertaken by property owners in the fire hazard areas include:

- Remove all dead vegetation and keep grasses and weeds maintained within 100 feet of any building and within 10 feet of any roadway. These provisions are part of an amendment to the Hazardous Vegetation Ordinance adopted in 1990. In extreme cases, clearance up to 200 feet from a structure and 50 feet from a roadway may be required by the Fire Department.
- Grasses and other vegetation located more than 30 feet from any building and less than 18 inches in height may be maintained where necessary to prevent erosion. Large trees and shrubs in that area should be at least 18 feet apart.
- Remove leafy foliage, dead wood, combustible ground cover, twigs, or branches within 3 feet of the ground from mature trees located within 100 feet of any building or within 10 feet of any roadway.
- Remove dead limbs, branches, and other combustible matter from trees or other growing vegetation adjacent to or overhanging any structure.
- Remove any portion of a tree that extends within 10 feet of a chimney or stovepipe.
- Trim and maintain all vegetation away from the curb line up to a height of 13.5 feet to accommodate emergency vehicles.
- Maintain 5 feet vertical clearance between roof surfaces and any overhanging portions of trees.
- Property owners in the urban-wildland interface area can request that the Fire Department conduct a comprehensive fire safety survey of their homes and property. The Fire Department inspects the residences for compliance with applicable regulations, and prepares a report for use by the homeowner to reduce its fire hazard. Implementation of

the recommended mitigation measures may help the homeowner obtain a reduction in the cost of fire insurance.

Prescribed Fire: As discussed previously, before modern settlement began, the area experienced small but frequent wildfires that impacted primarily the grasses and low-lying bushes, without severely damaging the tree stands. As man-made structures were built in these fire-susceptible areas, there was a strong effort to suppress fires, since these would threaten the structures and people living there. As a result, dense stands of vegetation have accumulated locally in the outlying areas, while increasingly larger numbers of people have moved into the urban-wildland interface. Over time, fire suppression and increasing populations have produced these results:

- Increased losses to life, property, and resources.
- Difficulty of fire suppression, increased safety problems for firefighters, and reduced productivity by fire crews on perimeter lines.
- Longer periods between recurring fires for many vegetation types by a factor of 5 or more.
- Increased volume of fuel per acre.
- Increased fire intensities.
- Increased taxpayer costs and property losses.

Recognition of these problems has led to vegetation management programs such as those described above, and in some areas, prescribed fires. A prescribed fire is deliberately set under carefully controlled and monitored conditions. The purpose is to remove brush and other undergrowth that can fuel uncontrolled fires. Prescribed fire is used to alter, maintain or restore vegetative communities, achieve desired resource conditions, and to protect life and property that would be degraded by wildland fire. Prescribed fire is only accomplished through managed ignition and should be supported by planning documents and appropriate environmental analyses.

Since 1981, prescribed fire has been the primary means of fuel management in Federal and State owned lands. Approximately 500,000 acres — an average of 30,000 acres a year — have been treated with prescribed fire under the vegetation management program throughout the State. In the past, the typical vegetation management project targeted large wildland areas. Now, increasing development pressures (with increased populations) at the urban-wildland interface often preclude the use of large prescribed fires. Many still find the notion of "prescribed fire" difficult to accept since for the last 100 years or so, humans have attempted to suppress and fight fires. Prescribed fire also carries a risk, as recent experiences in New Mexico and Arizona have shown. The Cerro Grande fire began when a prescribed burn escaped, destroying several hundred homes in Los Alamos, New Mexico and burning more than 50,000 acres. It is likely that this fire will lead to revisions in the guidelines for performing prescribed burns. Furthermore, a recent program review by the CDF has identified needed changes, with focus on citizen and firefighter safety, and the creation of wildfire safety and protection zones.

Prescribed fire is not presently being used in the City of Glendale to mitigate the wildland fire hazard. However, the cities of Glendale and La Canada Flintridge have entered into a cooperative agreement with Los Angeles County Fire Department to conduct prescribed fires in the Descanso Gardens area. This effort will include open space areas within the City of Glendale at the north end of the San Rafael Hills. The proposed plan has been approved by all parties involved and is ready to be implemented as soon as all conditions for a safe prescribed fire are met.

Hazard Abatement Notices: Each spring, the Glendale Fire Department mails information and hazard brush pamphlets to approximately 4,500 residences located in designated High Fire Hazard Areas. The purpose of this mailing is to remind and inform property owners of their specific responsibility to mitigate hazardous vegetation conditions. The mailing is followed-up, commencing May 1, by Fire Department fire company inspections of residences and lots to ensure compliance. Fire department personnel are assigned inspection districts throughout the City. Fire Department personnel survey the hillside areas and issue notices of violation for hazardous vegetation on an annual basis. If abatement work is not completed in a timely manner, a "Notice to Abate Fire Hazard" is sent and a compliance inspection is conducted 30 days later. If abatement is still not satisfactory a "Notice of Intention to Abate Public Nuisance" is sent, and a final inspection made after 15 days to ensure compliance. If voluntary compliance is not achieved, the Fire Department may abate the hazardous vegetation using an approved contractor, and charge the owner or impose a lien on the property.

At this time, per an agreement between Glendale and the County of Los Angeles, the Los Angeles County Agricultural Commissioner provides for weed abatement on non-compliant improved properties and approximately 800 vacant lots in the City of Glendale.

4.1.3.3 Legislated Construction Requirements in Fire Hazard Areas: Building construction standards for such items as roof coverings, fire doors, and fire resistant materials help protect structures from external fires *and* contain internal fires for longer periods. That portion of a structure most susceptible to ignition from a wildland fire is the **roof**, due to the deposition of burning cinders or brands. Burning brands are often deposited far in advance of the actual fire by winds. Roofs can also be ignited by direct contact with burning trees and large shrubs (Fisher, 1995). The danger of combustible wood roofs, such as wooden shingles and shakes, has been known to fire fighting professionals since 1923, when California's first major urban fire disaster occurred in Berkeley. It was not until 1988, however, that California was able to pass legislation calling for, at a minimum, Class C roofing in fire hazard areas. Then, in the early 1990s, there were several other major fires, including the Paint fire of 1990 in Santa Barbara, the 1991 Tunnel fire in Oakland/Berkeley, and the 1993 Laguna Beach fire, whose severe losses were attributed in great measure to the large percentage of combustible roofs in the affected areas. In 1995-1996 new roofing materials standards were approved by the California legislature for Very High Fire Hazard Severity Zones.

Significantly, the City of Glendale has been at the forefront of the State on this issue since the early 1980s. Specifically, in 1984, Glendale adopted a Fire Safe Roofing Ordinance that required a minimum Class B roof covering for all new and re-roof applications City-wide. In 1989, Glendale adopted legislation (the Fire Safe Roofing Code) that amended the City's roofing requirements to ban the installation of wood roof material City-wide, and to upgrade the minimum classification from B to A in the high fire hazard areas. Today, Glendale requires all new roofs and re-roofs amounting to more than 25 percent of the original roof area to be done in Class A roof covering.

So what do these Classes A, B and C mean? To help consumers determine the fire resistance of the roofing materials they may be considering, roofing materials are rated as to their fire resistance into three categories that are based on the results of test fire conditions that these materials are subjected to under rigorous laboratory conditions, in accordance with test method ASTM-E-108 developed by the American Society of Testing Materials. The rating classification provides information regarding the capacity of the roofing material to resist a fire that develops outside the building on which the roofing material is installed (The Institute for Local Self Government, 1992). The three ratings are as follows:

Class A: Roof coverings that are effective against **severe** fire exposures. Under such exposures, roof coverings of this class:
- Are not readily flammable;
- Afford a high degree of fire protection to the roof deck;
- Do not slip from position; and
- Do not produce flying brands.

Class B: Roof coverings that are effective against **moderate** fire exposures. Under such exposures, roof coverings of this class:
- Are not readily flammable;
- Afford a moderate degree of fire protection to the roof deck;
- Do not slip from position; and
- Do not produce flying brands.

Class C: Roof coverings that are effective against **light** fire exposures. Under such exposures, roof coverings of this class:
- Are not readily flammable;
- Afford a measurable degree of fire protection to the roof deck;
- Do not slip from position; and
- Do not produce flying brands.

Non-Rated Roof coverings have not been tested for protection against fire exposure. Under such exposures, non-rated roof coverings:
- May be readily flammable;
- May offer little or no protection to the roof deck, allowing fire to penetrate into attic space and the entire building; and
- May pose a serious fire brand hazard, producing brands that could ignite other structures a considerable distance away.

Attic ventilation openings are also a concern regarding the fire survivability of a structure. Attics require significant amounts of cross-ventilation to prevent the degradation of wood rafters and ceiling joists. This ventilation is typically provided by openings to the outside of the structure, but these openings can provide pathways for burning brands and flames to be deposited within the attic. Therefore, it is important that all ventilation openings be properly screened to prevent this. Additional prevention measures that can be taken to reduce the potential for ignition of attic spaces are to "use non-combustible exterior siding materials and to site trees and shrubs far enough away from the walls of the house to prevent flame travel into the attic even if a tree or shrub does torch" (Fisher, 1995).

The type of **exterior wall construction** used can also help a structure survive a fire. Ideally, exterior walls should be made of non-combustible materials such as stucco or masonry. During a wildfire, the dangerous active burning at a given location typically lasts about 5 to 10 minutes (Fisher, 1995), so if the exterior walls are made of non-combustible or fire-resistant materials, the structure has a better chance of surviving. For the same reason, the type of **windows** used in a structure can also help reduce the potential for fire to impact a structure. Single-pane, annealed glass windows are known for not performing well during fires; thermal radiation and direct contact with flames cause these windows to break because the glass under the window frame is protected and remains cooler than the glass in the center of the window. This differential thermal expansion of the glass causes the window to break. Larger windows are more susceptible to fracturing when exposed to high heat than smaller windows. Multiple-pane windows, and tempered glass windows perform much better than single-pane windows, although they do cost more. Fisher (1995) indicates that in Australia, researchers have noticed that the use of metal screens helps protect windows from thermal radiation. Some homeowners may consider the use of exterior, heavy-duty metal blinds that are dropped down into position, at least on the windows in the exposed portion of the structure facing the wildland area.

Fire **sprinklers** are very effective at controlling structural fires, saving property and lives. In 1988, Glendale passed an ordinance requiring automatic fire sprinklers in existing structures four stories or more in height, and since 1989, the City of Glendale has required all new one- and two-family structures to have fire sprinklers. Fire sprinklers can help contain a fire that starts inside a structure from becoming a potential incendiary source, impacting other nearby structures and brush. Fire sprinklers are not likely to protect a structure from an external wildland fire, however. Sprinklers permanently mounted on the roof have been suggested as a defensive measure, but most authorities argue against the value of external sprinklers as a viable alternative to fire-resistant roofing materials (http://www.fs.fed.us/psw/publications/documents/gtr-050/struct.html).

The City of Glendale has adopted the California Building and Fire Codes with local additions and amendments (City Ordinance 5329 - Glendale Building and Safety Code, Volume I, Section 715 which deals with construction requirements in fire hazard areas, and Volume VI, which pertains to fire and life-safety requirements). These additions and amendments make the Glendale Building and Safety Code more restrictive than the minimum State Code / model ordinance. For specific requirements regarding roofing standards (non-combustible Class A roofs), construction materials and standards including fire resistive siding and eaves, the orientation and placement of window glazing, sprinklers, etc., contact the Fire Prevention Bureau and Building Section of the City of Glendale.

4.1.3.4 Access: Fires at the urban-wildland interface tend to move quickly, with most of the damage or losses generally occurring in the first few hours after the fire starts (Coleman, 1994). Therefore, access to the urban-wildland interface for the purposes of emergency response is critical. This requires streets that meet minimum access and egress requirements so that they can be traversed by fire apparatus. The Glendale Municipal Code includes minimum width standards for local streets and width and length standards for cul-de-sacs. The Glendale Fire Code (Volume VI, Article 10, Section 10.207) requires an all-weather surface roadway with a minimum width of 20 feet (without parking) that can support loads of 55,000 pounds, minimum 13-feet 6-inches of vertical clearance, a grade that does not exceed 12 percent, and an approved turnaround when in excess of 150 feet in length. Chapter 28, Section 28-59 of the Municipal Code stipulates that any local street or cul-de-sac street that is abutted by more than ten residences shall be no less than 24 feet wide from curb to curb, within a 28-foot wide dedication. The length of cul-de-sacs is regulated based on the number of dwelling units and distance from the point of dual access, but the maximum distance for dead-end or no-outlet streets is 2,600 feet. In fire hazard areas, easy access for fire equipment shall be provided.

Unfortunately, many streets in the hillside areas of Glendale are of insufficient width because they were built prior to the development of the current standards. Several other roads are non-compliant because they are dead-end streets more than 1/2-mile long, or do not have a turnaround at their end. There are several non-compliant residential streets off of East Chevy Chase Drive, and in the southeastern corner of the City, off of Adams Street. Several other roads in the eastern and southern Verdugo Mountains are also narrow and do not have proper turnarounds. The streets that do not meet Glendale's Municipal Code requirements are shown on Plate 4-3.

Although not shown on the map, the City's Fire Department also considers the east end of Glenoaks Boulevard, east of the Glendale Freeway as a potentially hazardous road because it does not have a secondary outlet. A wildland fire, earthquake or another disaster in the area could place a substantial number of people at risk of not being able to evacuate this neighborhood if and when necessary.

Figure 4-5: Firefighters putting out the September 2002 "Mountain Incident" Fire in Glendale

4.1.3.5 Public Awareness: Individuals can make an enormous contribution to fire hazard reduction and need to be educated about their important role. The Glendale Fire Department has several outreach programs aimed at providing fire safety education to the public. These presentations are given to local schools, service clubs and associations, homeowners groups, the Chamber of Commerce, Board of Realtors, businesses and other professional organizations. The Jr. Fire Program, which is more than 50 years old, sends firefighters into all of the 5th grade classes in the area to teach fire safety and awareness. A picnic at the end of the school year is held to honor those students that demonstrated exceptional participation in the program. Every October, the Fire Department also contracts with a theater group to present fire safety programs to all elementary schools in Glendale.

NOTES:

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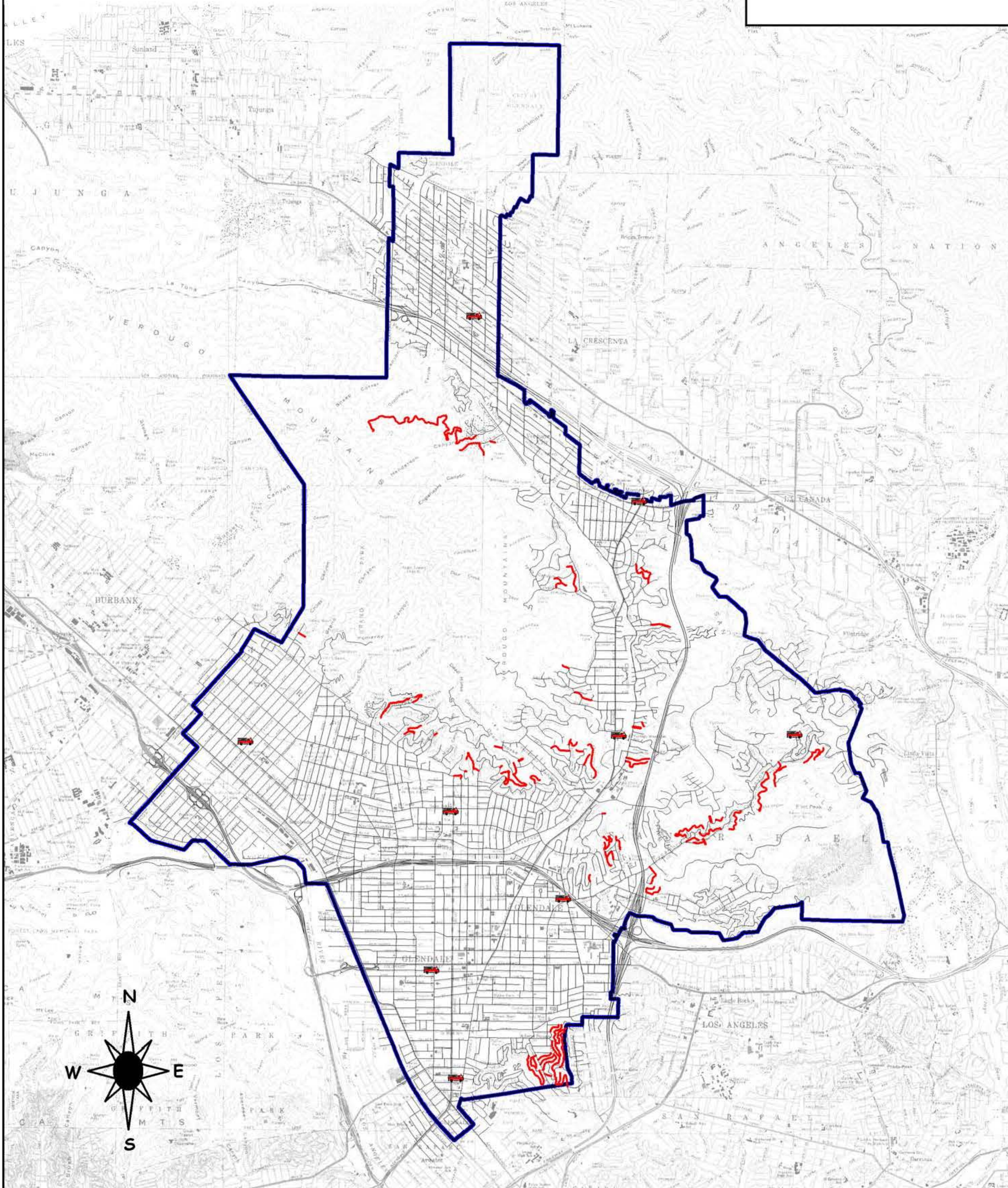
Explanation

Fire Station

Non-compliant Road



Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: City of Glendale Planning Department

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Project Number: 2103
Date: July, 2003

Non-compliant Roads in the City of Glendale

Plate 4-3

One of the most recent public education tools used by the Fire Department is the Fire Safety Trailer, which is operated in conjunction with the Burbank and Pasadena Fire Departments. The trailer provides a scaled version of a house, where children can learn and practice life-saving procedures. These and many other public education and outreach programs that the Fire Department offers are described in the Fire Department's effective web site (http://fire.ci.glendale.ca.us/). This web site is also an education tool that residents can refer to for additional information regarding how to deal with fire and other natural and man-made hazards.

The Fire Department has also prepared and distributes informational brochures to hillside property owners. The brochures describe mitigation measures that can be implemented to reduce the fire hazard, and describe how property owners can help themselves to prevent loss of property or life as a result of a wildland fire. In addition to the specific requirements in the Municipal Code mentioned in the sections above regarding appropriate landscaping and construction materials, there are other steps that homeowners can take to reduce the risk of fire on their property. Some of these are listed below. This list is not all-inclusive, but provides a starting point and framework to work from.

- Mow and irrigate your lawn regularly.
- Dispose of cuttings and debris promptly, according to local regulations.
- Store firewood away from the house.
- Be sure the irrigation system is well maintained.
- Use care when refueling garden equipment and provide regular maintenance for your garden equipment.
- Store and use flammable liquids properly.
- Dispose of smoking materials carefully.
- Do not light fireworks (in accordance with the Municipal Code).
- Become familiar with local regulations regarding vegetation clearing, disposal of debris, and fire safety requirements for equipment.
- Follow manufacturers' instructions when using fertilizers and pesticides.
- Keep the gutters, eaves, and roof clear of leaves and other debris.
- Occasionally inspect your home, looking for deterioration, such as breaks and spaces between roof tiles, warping wood, or cracks and crevices in the structure.
- Use non-flammable metal when constructing a trellis and cover it with high-moisture, non-flammable vegetation.
- Install automatic seismic shut-off valves for the main gas line to your house. Information for approved devices, as well as installation procedures, is available from the Southern California Gas Company.

Figure 4-6: Command Post During the September 2002 "Mountain Incident" Fire in Glendale

4.2 Structural Fires in Urban Areas

Glendale's permanent residential population is currently about 200,000. Since the 1970s, multiple family units (apartments and condominiums) have been the predominant housing type in the City, with most of these units located in the City's flatland areas. Many of these multiple-family units are high-rise and mid-rise buildings that have special fire protection needs. Such buildings are required to have fire and life safety systems in place, including automatic fire sprinklers and smoke detectors, in conformance with the City's Building and Safety Code.

Single-family units predominate in the hillside areas. The majority of Glendale's residential stock dates from between 1940 and 1969 (54 percent), but more than 18 percent of the homes were constructed prior to 1940 (City of Glendale 1998-2005 Housing Element). Since the City's fire sprinkler ordinance for all new residences and businesses was adopted in 1986 (with 1989 amendments), there are many older single-family units that are not sprinklered, unless the sprinklers have been added as part of additions, alterations or repairs to the structure.

In order to quantify the structural fire risk in a community, it is necessary for the local fire departments to evaluate all occupancies based upon their type, size, construction type, built-in protection (such as internal fire sprinkler systems) and risk (high-occupancy versus low-occupancy) to assess whether or not they are capable of controlling a fire in the occupancy types identified. Simply developing an inventory of the number of structures present within a fire station's response area is not sufficient, as those numbers do not convey all the information necessary to address the community's fire survivability. In newer residential areas where construction includes fire-resistant materials and internal fire sprinklers, most structural fires can be confined to the building or property of origin. In older residential areas where the building materials may not be fire-rated, and the structures are not fitted with fire sprinklers, there is a higher probability of a structural fire impacting adjacent structures, unless there is ample distance between structures, there are no strong winds, and the Fire Department is able to respond in a timely manner.

The major urban conflagrations of yesteryear in large cities were often the result of closely built, congested areas of attached buildings with no fire sprinklers, no adequate fire separations, no Fire Code enforcement, and narrow streets. In the past, fire apparatus and water supplies were often inadequate in many large cities, and many fire departments were comprised of volunteers. Many of these conditions no longer apply to the cities of today. Nevertheless, major earthquakes can result in fires and the loss of water supply, as it occurred in San Francisco in 1906, and more recently in Kobe, Japan in 1995. Several structural fires, many as a result of broken gas mains, also occurred in southern California near the epicenter of the Northridge earthquake of 1994. For additional information regarding the Northridge Earthquake, refer to Section 4.5 below. Although the threat that existed in San Francisco was and is far greater than that in Glendale, there are some sections of Glendale where, due to ground failure as a result of either fault rupture or liquefaction, breaks in the gas mains and the water distribution system could lead to a significant fire-after-earthquake situation. The potential surface fault rupture areas in the City are shown on Plate 1-2 and the liquefactions susceptible areas are shown on Plate 1-3 (in Chapter 1 of this document).

4.2.1 Structural Target Fire Hazards and Standards of Coverage

Fire departments quantify and classify structural fire risks to determine where a fire resulting in large losses of life or property is more likely to occur. Structures at risk are known as Target Hazards and are catalogued utilizing the following criteria:

- The size, height, location and type of occupancy;
- The risk presented by the occupancy (probability of a fire and the consequence if one occurs);
- The unique hazards presented by the occupancy (such as the occupant load, the types of combustibles therein and any hazardous materials);
- Potential for loss of life;
- The presence of fire sprinklers and proper construction;
- Proximity to exposures;
- The estimated dollar value of the occupancy;
- The needed fire flow versus available fire flow; and
- The ability of the on-duty forces to control a fire therein.

Target Hazards encompass all significant community structural fire risk inventories. Typically, fire departments identify the major target hazards and then perform intensive pre-fire planning, inspections and training to address the specific fire problems in that particular type of occupancy (for example, training to respond to fires in facilities that handle hazardous materials is significantly different than training to respond to a fire in a high-occupancy facility such as a mall, auditorium or night club). Typically, the most common target hazard due to the life-loss potential, 24-hour occupancy, risk and frequency of events, is the residential occupancy, however, the consequences of residential fires can be high or low, depending on the age, location, size, and occupancy load, among other factors. Four classifications of risk are considered, as follows:

- <u>High Probability/High Consequences</u> (Example: multi-family dwellings, single-family residential homes in the older sections of the City, hazardous materials occupancies, shopping centers).
- <u>Low Probability/High Consequences</u> (Example: hospitals; senior housing projects, group homes, and other assisted projects; shopping malls such as the Glendale

Galleria; industrial occupancies, large office complexes and newer upscale homes in the high fire hazard area).

- High Probability/Low Consequences (Example: detached single-family dwellings in the non-vegetated, flatland areas of town).
- Low Probability/Low Consequences (Example: newer detached single-family dwellings in non-vegetated areas and small office buildings).

In order to address the Fire Department's capability to respond effectively to the structural fire risk in Glendale, "Standards of Coverage" need to be determined based upon the various risks. Those risks are: Single-family detached residential, multi-family attached residential, commercial and industrial. Some of these risks exist in various areas throughout the City, rather than in well-defined separate areas. For example, residential areas adjoining and intermixed with commercial areas occur in the older portions of the City, such as between the Verdugo Mountains on the north and Glenoaks Boulevard on the south, and especially within the inverted triangle defined by Glendale Avenue on the east, Glenoaks Boulevard on the north, and San Fernando Road on the west. Similarly, in the Montrose Business District and surrounding areas adjacent to Honolulu Avenue, there is also significant intermix of residential and commercial space. Given these combined risks within the same geographic areas, it is appropriate for the Glendale Fire Department to have fire stations within or near these areas. For the location and distribution of the fire stations in the City of Glendale, refer to Plate 4-3 and especially Plate 4-4.

4.2.2 Model Ordinances and Fire Codes

Effective fire protection cannot be accomplished solely through the acquisition of equipment, personnel and training. The area's infrastructure also must be considered, including adequacy of nearby water supplies, transport routes and access for fire equipment, addresses, and street signs, as well as maintenance. To that end, the City of Glendale has adopted the 2001 California Fire Code with City amendments and some changes referring to the adopted document as Volume VI of the 2002 Building and Safety Code of the City of Glendale. The City's Fire Chief is authorized and directed to enforce the provisions of the Fire Code throughout the City (Section 101.2.1. of Volume VI of the City's Building and Safety Code). These provisions include construction standards in new structures and remodels, road widths and configurations designed to accommodate the passage of fire trucks and engines, and requirements for minimum fire flow rates for water mains. The construction requirements are a function of building size, type, material, purpose, location, proximity to other structures, and the type of fire suppression systems installed. For building construction standards refer to the City's Building and Safety Code.

4.3 Fire Suppression Capabilities

The Glendale Fire Department is responsible for fire suppression on all lands within the City of Glendale. The Department constantly monitors the fire hazard in the City, and has ongoing programs for investigation and alleviation of hazardous situations. Fire fighting resources in the immediate Glendale area are provided by Glendale Fire Department Station Nos. 21, 22, 23, 24, 25, 26, 27, 28, and 29. The Fire Department is comprised of 12 fire companies with nine engine companies and three truck companies. The Department also staffs four rescue ambulances. These data are summarized by fire station on Table 4-1 below. The locations of the fire stations are shown on Plates 4-3 and 4-4. Staffing at these stations is as follows: 4 crew per each ladder truck and engine company, and 2 firefighter paramedics per rescue ambulance. The Glendale Fire Department is a member of the

Verdugo Fire Communications Center (VFCC) that provides dispatch services to nine cities, including Glendale. Additional information regarding the VFCC is provided in Section 4.4.1.

Fire Stations 26 and 29 are no longer adequate for the Fire Department's needs due to the buildings' age, physical condition and size. Efforts are ongoing to find adequate alternative locations for these two stations. The preferred alternatives are expected to be located south of the 134 Freeway.

Table 4-1: Fire Stations and Facilities in the City of Glendale

Fire Station No.	Street Address	Fire Companies and Ambulances		
		Engine Companies	*Ladder Truck Companies*	*Rescue Ambulances*
21	421 Oak Street	1	1	1
22	1201 S. Glendale Ave.	1	0	0
23	3303 E. Chevy Chase Drive	1	0	0
24	1734 Canada Blvd.	1	0	0
25	353 N. Chevy Chase Drive	1	0	1
26	1145 N. Brand Blvd.	1	1	1
27	1127 Western Ave.	1	0	0
28	4410 New York Ave.	1	0	0
29	2465 Honolulu Ave.	1	1	1
Facility		**Street Address**		
Fire Mechanical Maintenance		210 E. Palmer Avenue		
Verdugo Fire Communications Center		421 Oak Street		
Fire Prevention Bureau		420 Harvard Street		
Fire Training		541 W. Chevy Chase Drive		
Environmental Management Center		780 Flower Street		

For emergencies, dial 911.

According to the VFCC (2002), there were 14,158 incidents reported for Glendale in 2002. The twenty-year (1983-2002) history of Glendale incidents is summarized on Figure 4-7. The number of incidents reported has nearly doubled in that time period, reflective of the population growth that this area has experienced in the last 20 years. Table 4-2 shows that the number of medical emergencies compared to fire calls has increased over time; in 1983, fire calls amounted to 26 percent of the incidents reported, while in 2002, the figure was 12.6 percent. Significantly, 49.5 percent of the fire incidents that the Fire Department responded to in 2002 were for fire alarms, so the actual number of true fire incidents was actually smaller.

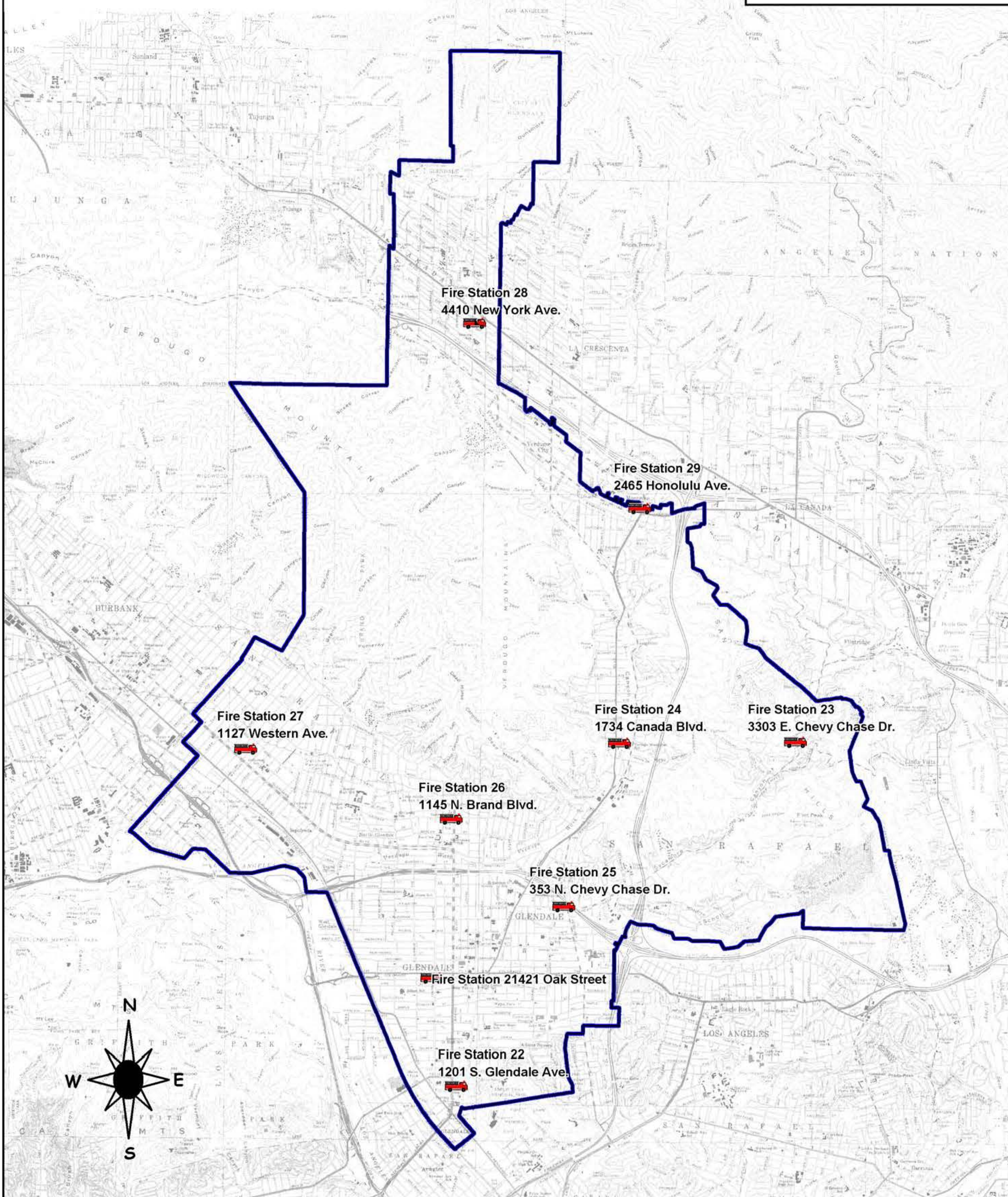
NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Explanation

Fire Station



Scale: 1:60,000

1000 0 1000 2000 3000

Meters

5000 0 5000 10000 15000

Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER

Source: City of Glendale Planning Department

Earth Consultants International

Project Number: 2103

Date: July, 2003

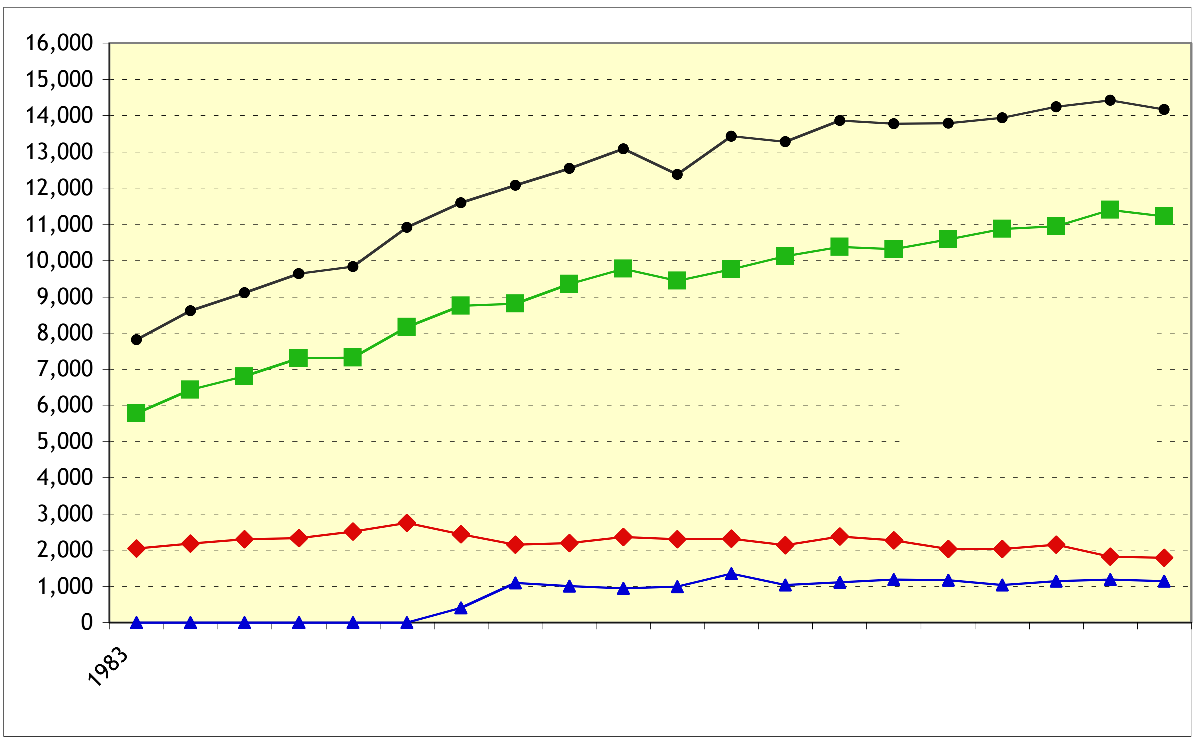
Fire Station Location Map

Glendale, California

Plate 4-4

In 2002, 79 percent of the responses were medical emergency calls, while in 1980, they amounted to 74 percent of the calls. That medical emergency calls far outnumber fire calls is typical of most communities. These medical emergencies are handled primarily by the four fire stations in the City with rescue ambulances (Fire Stations 21, 25, 26, and 29), and other neighboring fire stations that are part of the Verdugo system that staff rescue ambulances. In 2002, assuming that all medical emergencies were handled by the four local fire stations with rescue ambulances, each fire station responded to an average of 2,806 medical emergencies, or an average of 7.7 medical calls per day. This amount of medical responses could be an issue if engine companies provide support to the rescue ambulances by responding to medical aid calls, and this impacted the fire department's response to structural fire calls. If the number of medical emergency responses continue to increase, and this is found to have an impact on the availability of fire-fighting personnel and equipment, it may be prudent to add another rescue ambulance and support squad vehicle and increase staffing at the fire station in the area of the City with the highest rate of medical incidents.

Figure 4-7:
20-Year History of Incidents in the City of Glendale Responded to by the Fire Department



Source: Verdugo Fire Communications Center 2002 Annual Report

In 2002, vehicle fires exceeded any other type of fires reported in the City (11 percent of the fire incidents). Miscellaneous outside fires, illegal burning, refuse fires, brush fires, and other vegetation fires combined also add to about 11 percent of the fire incidents. Although wildland fires do not occur very often, they do have the potential to involve a substantial portion of the fire department's forces, and often, additional help is requested from other jurisdictions. Since fires comprise a small percentage of the fire department responses, it could be argued that fighting fires nowadays is a "seldom used skill," and that this can lead to an increase in firefighter injuries. It could also be argued that this could result in fires larger than those that occurred in past years, when fire departments were accustomed to responding to more severe structural fires due to the absence of sprinkler systems, poor construction, and lack of ongoing Code enforcement. Glendale Fire Department personnel, however, participate in extensive, almost daily training exercises on a variety of subjects and specialties, such as fire prevention, mechanical maintenance, emergency response, and brush fires, to name a few. Several Fire Officer Certification classes are also offered on a regular basis, including EMT-D certification of all firefighters, and defibrillator program (in excess of minimum EMT certification).

The National Fire Protection Association (NFPA Standard 1710, 2001) recommends that in 90 percent of the time, fire departments respond to fire calls within 5 minutes of receiving the call. These time recommendations are based on the demands created by a structural fire: It is critical to attempt to arrive and intervene at a fire prior to the fire flashing over the entire room or building of origin, which results in total destruction, and flashover can occur within 3 to 5 minutes after ignition. Response time is generally defined as 1 minute to receive and dispatch the call, 1 minute to prepare to respond in the fire station or field, and 3 minutes driving time. The 90 percent figure is stated as a goal to be achieved. Regular management audits by the Fire Chief should be conducted to reveal if the goal is being met. In many communities it is difficult to exceed the 90 percent figure in a cost-effective manner due to the following limiting factors:

- Low staffing
- Insufficient equipment available
- Fire stations located too far from area impacted by fire, or insufficient number of fire stations to service the area
- Access obstructions
- Traffic-calming devices and median strips on major highways and roadways
- Traffic congestion
- Weather
- Multiple alarms
- Delayed response
- Winding access roads in the hillsides
- Road grades
- Gated communities
- Multiple story buildings or large buildings where it takes time to reach the source of the fire after arrival at the occupancy.

The Verdugo Fire Communications Center (2002) reports that in Glendale, during 2002, the Fire Department arrived on-scene in less than 5 minutes from receiving the dispatch in 80.4 percent of the responses, and in less than 6 minutes in 91 percent of the responses. In Glendale, response times vary as a result of traffic density, the time of day or night, road conditions, emergency unit availability and the City's geographical layout. In some communities with traffic congestion, traffic-signal actuation devices (Opticom) are being installed at critical intersections with traffic lights and on all fire apparatus to improve the driving time response. The use of these devices is being evaluated at this time in Glendale.

In addition to these components, there is another component called "set up" time. This is the time it takes firefighters to get to the source of a fire and get ready to fight the fire. This may range from 2 minutes at a small house fire to 15 minutes or more at a large or multi-story occupancy, such as an apartment complex or condominium, industrial park, shopping mall or hospital.

Structural fire response requires numerous critical tasks to be performed simultaneously. The number of firefighters required to perform the tasks varies based upon the risk. Obviously, the number of firefighters needed at a maximum high-risk occupancy, such as a shopping mall or large industrial occupancy would be significantly higher than for a fire in a lower-risk occupancy. Given the large number of firefighters that are required to respond to a high-risk, high-consequence fire, fire departments increasingly rely on automatic and mutual aid agreements to address the fire suppression needs of their community. If additional resources are needed due to the intensity or size of the fire, a second alarm may be requested. The second alarm results in the response of at least another two engine companies and a ladder truck. Additional fire units may be requested via automatic and mutual aid agreements.

4.3.1 Automatic and Mutual Aid Agreements

Although the Glendale Fire Department is tasked with the responsibility of fire prevention and fire suppression in Glendale, in reality, fire departments and other agencies team up and work together during emergencies. These teaming arrangements are handled through automatic and mutual aid agreements.

The California Disaster and Civil Defense Master Mutual Aid Agreement (California Government Code Section 8555-8561) states: "Each party that is signatory to the agreement shall prepare operational plans to use within their jurisdiction, and outside their area." These plans included fire and non-fire emergencies related to natural, technological, and war contingencies. The State of California, all State agencies, all political subdivisions, and all fire districts signed this agreement in 1950.

Section 8568 of the California Emergency Services Act, (California Government Code, Chapter 7 of Division 1 of Part 2) states that "the State Emergency Plan shall be in effect in each political subdivision of the State, and the governing body of each political subdivision shall take such action as may be necessary to carry out the provisions thereof." The Act provides the basic authorities for conducting emergency operations following the proclamations of emergencies by the Governor or appropriate local authority, such as a City Manager. The provisions of the act are further reflected and expanded on by appropriate local emergency ordinances. The act further describes the function and operations of government at all levels during extraordinary emergencies, including war (www.scesa.org/cal_govcode.htm). Therefore, local emergency plans are considered extensions of the California Emergency Plan.

Glendale has automatic aid agreements with the adjacent cities of Burbank, Pasadena, and Los Angeles, and with the County of Los Angeles. These agreements obligate the departments to help each other under pre-defined circumstances. **Automatic aid** agreements obligate the nearest fire company to respond to a fire regardless of the jurisdiction. **Mutual aid** agreements obligate fire department resources to respond outside of their district upon request for assistance.

The Glendale Fire Department is party to an agreement that authorizes calls for emergency response to be dispatched through the **Verdugo Joint Fire Communications Center**, which coordinates 33 different stations in the region. This "region" includes stations not only from Glendale, but also from Burbank, Pasadena, San Marino, South Pasadena, Monrovia, Arcadia, Sierra Madre and San Gabriel. The Verdugo Joint Fire Communications Center is located on the third floor of Fire Station 21 in Glendale, at 412 Oak Street. Dialing 911 in any of the cities served by the Verdugo Fire Communications Center connects the caller to police or California Highway Patrol dispatchers, who determine the nature of the emergency, and transfer fire and paramedic calls to the Verdugo Communications Center. A dispatcher at Verdugo enters the pertinent details into the computer for transmittal via radio to the fire station that is dispatched for that particular incident. Emergency personnel are on the road within 1 to 2 minutes of receiving the call, and remain in constant radio contact with the Verdugo Communications Center as additional details are received.

Numerous other agencies are available to assist the City if needed. Several Federal agencies have roles in fire hazard mitigation, response, and recovery, including: the Fish and Wildlife Service, National Park Service, US Forest Service, Natural Resource Conservation Service, Office of Aviation Services, National Weather Service, and National Association of State Foresters. The State Office of Emergency Services can be called upon for further aid if necessary, as can Federal agencies, including the Department of Agriculture, the Department of the Interior, and, in extreme cases, the Department of Defense. Private companies and individuals may also assist.

4.3.2 Standardized Emergency Management System (SEMS)

The SEMS law refers to the Standardized Emergency Management System described by the Petris Bill (Senate Bill 1841; California Government Code Section 8607, made effective January 1, 1993) that was introduced by Senator Petris following the 1991 Oakland fires. The intent of the SEMS law is to improve the coordination of State and local emergency response in California. It requires all jurisdictions within the State of California to participate in the establishment of a standardized statewide emergency management system.

When a major incident occurs, the first few moments are absolutely critical in terms of reducing loss of life and property. First responders must be sufficiently trained to understand the nature and the gravity of the event to minimize the confusion that inevitably follows catastrophic situations. The first responder must then put into motion relevant mitigation plans to further reduce the potential for loss of life and property damage, and to communicate with the public. According to the State's Standardized Emergency Management System, local agencies have primary authority regarding rescue and treatment of casualties, and making decisions regarding protective actions for the community. This on-scene authority rests with the local emergency services organization and the incident commander.

Depending on the type of incident, several different agencies and disciplines may be called in to assist with emergency response. Agencies and disciplines that can be expected to be part of an emergency response team include medical, health, fire and rescue, police, public works, and coroner. The challenge is to accomplish the work at hand in the most effective manner, maintaining open lines of communication between the different responding agencies to share and disseminate information, and to coordinate efforts.

Emergency response in every jurisdiction in the State of California is handled in accordance with SEMS, with individual City agencies and personnel taking on their responsibilities as defined by the City's Emergency Plan. This document describes the different levels of emergencies, the local emergency management organization, and the specific responsibilities of each participating agency, government office, and City staff.

The framework of the SEMS system is the following:

- Incident Command System – a standard response system for all hazards that is based on a concept originally developed in the 1970s for response to wildland fires
- Multi-Agency Coordination System – coordinated effort between various agencies and disciplines, allowing for effective decision-making, sharing of resources, and prioritizing of incidents
- Master Mutual Aid Agreement and related systems – agreement between cities, counties and the State to provide services, personnel and facilities when local resources are inadequate to handle and emergency
- Operational Area Concept – coordination of resources and information at the county level, including political subdivisions within the county; and
- Operational Area Satellite Information System - a satellite-based communications system with a high-frequency radio backup that permits the transfer of information between agencies using the system.

The SEMS law requires the following:

- Jurisdictions must attend training sessions for the emergency management system.
- All agencies must use the system to be eligible for funding for response costs under disaster assistance programs.
- All agencies must complete after-action reports within 120 days of each declared disaster.

4.3.3 ISO Rating for the City of Glendale

The Insurance Services Office (ISO) provides rating and statistical information for the insurance industry in the United States (insurance carriers use this information to establish insurance rates in different parts of the country). To do so, ISO evaluates a community's fire protection needs and services, and assigns each community evaluated a Public Protection Classification (PPC) rating. The rating is developed as a cumulative point system, based on the community's fire-suppression delivery system, including fire dispatch (operators, alarm dispatch circuits, telephone lines available), fire department (equipment available, personnel, training, distribution of companies, etc.), and water supply (adequacy, condition, number and installation of fire hydrants). Insurance rates are based upon this rating. The worst rating is a Class 10. The best is a Class 1. The City of Glendale is rated as a Class 1, and therefore has the distinction of being one of only 44 communities in the United States that have achieved this rating at this time.

4.4 Earthquake-Induced Fires

A large portion of the structural damage caused by the great San Francisco earthquake of 1906 was the result of fires rather than ground shaking. More recently and closer to home, the moderately sized, M 6.7 Northridge earthquake caused 15,021 natural gas leaks that resulted in three street fires, 51 structural fires (23 of these caused total ruin) and the destruction by fire of 172 mobile homes. In one incident, the earthquake severed a 22-inch gas transmission line and a motorist ignited the gas while attempting to restart his stalled vehicle. Response to this fire was impeded by the earthquake's rupture of a water main; five nearby homes were destroyed. Elsewhere, one mobile home fire started when a downed power line ignited a ruptured transmission line. In many of the destroyed mobile homes, fires erupted when inadequate bracing allowed the homes to slip off their foundations, severing gas lines and igniting fires. There was a much greater incidence of mobile home fires (49.1 per thousand) than other structure fires (1.1 per thousand).

The California Division of Mines and Geology (Toppozada and others, 1988) published in 1988 a study that identified projected damages in the Los Angeles area as a result of an earthquake on the Newport-Inglewood fault. The earthquake scenario estimated that thousands of gas leaks would result from damage to pipelines, valves and service connections. This study prompted the Southern California Gas Company to start replacing their distribution pipelines with flexible plastic polyethylene pipe, and to develop ways to isolate and shut off sections of supply lines when breaks are severe. Nevertheless, as a result of the 1994 Northridge earthquake, the Southern California Gas Company reported 35 breaks in its natural gas transmission lines and 717 breaks in distribution lines. About 74 percent of its 752 leaks were corrosion related. Furthermore, in the aftermath of the earthquake, 122,886 gas meters were closed by customers or emergency personnel. Most of the leaks were small and could be repaired at the time of service restoration.

History indicates that fires following an earthquake have the potential to severely tax the local fire suppression agencies, and develop into a worst-case scenario. Earthquake-induced fires can place extraordinary demands on fire suppression resources because of multiple ignitions. The principal causes of earthquake-related fires are open flames, electrical malfunctions, gas leaks, and chemical spills. Downed power lines may ignite fires if the lines do not automatically de-energize. Unanchored gas heaters and water heaters are common problems, as these readily tip over during strong ground shaking (State law now requires new and replaced gas-fired water heaters to be attached to a wall or other support).

Many factors affect the severity of fires following an earthquake, including ignition sources, types and density of fuel, weather conditions, functionality of the water systems, and the ability of firefighters to suppress the fires. Casualties, debris and poor access can all limit fire-fighting effectiveness. Water availability in Los Angeles County following a major earthquake will most likely be curtailed due to damage to the water distribution system — broken water mains, damage to the aqueduct system, damage to above-ground reservoirs, etc. (see Chapter 1 – Seismic Hazards, and Chapter 3 – Flooding Hazards).

4.4.1 Earthquake-Induced Fire Scenarios for the Glendale Area using HAZUS

HAZUS™ is a standardized methodology for earthquake loss estimation based on a geographic information system (GIS). The user can run the program to estimate the damage and losses that an earthquake on a specific fault would generate in a specific geographic area, such as a city. Detailed information on this methodology is covered in Sections 1.8 and 1.9 of Chapter 1. One of the HAZUS components is earthquake-induced fire loss estimation.

Loss estimation is a new methodology, and our understanding of fires following earthquakes is limited. An accurate, fire-following-earthquake evaluation possibly requires extensive knowledge of the level of readiness of local fire departments, as well as the types and availability (functionality) of water systems, among other data. Although these parameters are not yet considered in the fire-after-earthquake module, preliminary results obtained from this HAZUS component are encouraging.

Current data suggest that about 70 percent of all earthquake-induced fire ignitions occur immediately after an earthquake since many fires are discovered within a few minutes after an earthquake. The remaining ignitions occur about an hour to a day after the earthquake. A typical cause of the delayed ignitions is the restoration of electric power. When power is restored, short circuits caused by the earthquake become energized and can start fires. Also, items that have overturned or fallen onto stove tops, etc., can ignite. If no one is present at the time electric power is restored, ignitions can develop into fires requiring fire department response.

HAZUS loss estimations were made for earthquake scenarios on the San Andreas, Sierra Madre, Verdugo, Raymond and Hollywood faults (refer to Chapter 1 for additional information on each of these earthquake scenarios). Four of the five scenarios are summarized below. Two wind speeds were used for each earthquake scenario. A value of 10 mph was used to model normal wind conditions. A speed of 30 miles per hour (mph) was assigned to evaluate fire spread as a result of Santa Ana winds. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area that each earthquake scenario is likely to generate.

Note that the HAZUS loss estimation does not consider effects of reduced water pressure due to breaks in the water distribution system. These are expected to be widespread where ground failure occurs, and could further reduce functionality at some stations.

Table 4-2: Earthquake-Induced Fire Losses in Glendale based on HAZUS Scenario Earthquakes

Earthquake Scenario (refer to Chapter 1 for additional information)	**No. of Ignitions**		**Population Displaced At a Wind Speed of**		**Building Value Burnt At a Wind Speed of (US$ millions)**	
	10 mph	30 mph	10 mph	30 mph	10 mph	30 mph
San Andreas	3	3	30	308	0.14	1.59
Sierra Madre	11	11	116	2,047	5.6	99.8
Verdugo	11	11	142	2,295	7.1	116
Raymond	10	10	354	2,224	16.6	106
Hollywood	10	10	244	2,919	11.3	151.8

Table 4-2 shows that earthquakes on the Sierra Madre, Verdugo, Raymond and Hollywood faults have the potential to cause significant fire-after-earthquake losses in the City of Glendale. The HAZUS results show that wind speeds definitely have an impact on the damage extent. The Hollywood fault fire-after-earthquake scenario is modeled as the worst case for the City of Glendale if Santa Ana wind conditions are present at the time of the earthquake, with the Verdugo and Raymond fault earthquakes coming in second. Rupture of the Verdugo and Sierra Madre faults, given their location across developed portions of the City and surrounding communities, is anticipated to cause many breaks in the gas and water distribution systems. Therefore, retrofitting those pipe sections across and near the mapped trace of these faults with flexible plastic polyethylene pipe and flexible joints should be a priority.

The Glendale Fire Department has procedures in place to follow immediately after an earthquake. In accordance with their Earthquake Response Plan, immediately after an earth tremor, fire apparatus and other response vehicles are taken out of the stations and parked outside. Personnel from each station then drive around their district to assess the damage, if any, and provide assistance as needed.

At the time of this writing, the Glendale Fire Department was in the process of re-establishing an Urban Search and Rescue (USAR) program, with emphasis on trench, confined space, water, technical rope, and some limited shoring rescue. The Department has acquired a USAR apparatus and has a full complement of new confined space hose and fittings, and a winch system that allows them to put a two-line rope system in place, off the apparatus, in less than two minutes. They also have the only "Victim Locator" in the Verdugo system. Certification training is ongoing, with monthly training drills. The emphasis of the monthly drills is rotated among the different disciplines of USAR so that each discipline is covered four times a year. The Department also plans to drill together with the Burbank and Pasadena USAR teams at least once a year.

4.5 Summary of Findings

The City of Glendale includes brush-covered areas of significant topographic relief in the Verdugo and San Gabriel Mountains and the San Rafael Hills that are susceptible to wildland fires. In fact, Glendale's Fire Department places nearly two-thirds of the City in the high fire hazard area. The historical record supports this mapping: since the late 1800s, the entire northern two-thirds of the City have burned at least once. The most recent wildland fire in Glendale occurred in September 2002.

Although large areas of the Verdugo Mountains and San Rafael Hills are undeveloped, there are many, mostly single-family, residential neighborhoods that have been developed in the canyons, and at the base or edges of the hillsides, within the high fire hazard area. In these areas, referred to as the urban-wildland interface, the wildland fire hazard is of significant concern. This is especially true for those older residential areas in the hillsides that are reached by narrow roads that do not meet the current fire safety standards for access and egress of fire apparatus. Many roads in the hillsides are also dead-end roads that are too long, do not have appropriate turnarounds at their end, have no secondary access, or service many more residential units than what is recommended. These roads should be improved to provide access to emergency vehicles, with the retrofit prioritized so that roads that provide access to the largest number of residences are retrofitted first. Of the roads with no secondary access, Glenoaks Boulevard in the San Rafael Hills poses by far the most serious concern regarding accessibility, as this is the only way out for hundreds of residents. In the event of a disaster, it may not be possible to evacuate this area, with the potential for multiple loss of life. Establishing a secondary outlet from Glenoaks Canyon should be a priority for the City.

To reduce the wildland fire hazard, especially at the urban-wildland interface, the City of Glendale has adopted an aggressive fuel modification ordinance that requires property owners to maintain a defensible space around their properties. The defensible space consists of a buffer zone 100 feet wide (the City's Fire Chief may require the buffer zone to be 200 feet wide in some areas) where the native vegetation is thinned and/or replaced with City-approved, drought-tolerant and fire-resistant ornamental plants. The Fire Department conducts annual inspections of residences and lots in the City to ensure compliance with the fuel modification ordinance, and issues notices of violation where appropriate. If voluntary compliance is not achieved, the Fire Department contracts with the Los Angeles County Agricultural Commissioner for weed abatement in non-compliant properties and vacant lots. Glendale should continue to require property owners to conduct maintenance on their properties to reduce the fire danger in accordance with the City's Building and Fire Safety Code. The single most important mitigation measure for a single-family residence is to maintain a fire-safe landscape, thereby creating a defensible space around the structure.

In addition to vegetation management to reduce the fire hazard, the City of Glendale has adopted several ordinances that require the use of fire-resistant construction materials that protect structures from fire damage. Most of the City-adopted ordinances have become effective years ahead of the rest of California, setting an example for other communities, and are also more stringent than California Fire Code requirements. These include Class A roof coverings for all new roofs and re-roofs amounting to more than 25 percent of the original roof area, and fire sprinklers in all new one- and two-family structures. The Class A roof-covering ordinance first applied only to structures within the high fire hazard area, but is now enforced Citywide.

Most development in Glendale occurs in the flatlands, where the predominant housing type is multiple-family units (apartments and condominiums) that have special fire protection needs. To that end, City ordinances require all of mid-rise and high-rise buildings to have fire and life safety systems in place, including automatic fire sprinklers and smoke detectors. The specific construction requirements are contained in the Glendale Building and Safety Code (Volume I, Section 715 which deals with construction requirements in fire hazard areas, and Volume VI, which pertains to fire and life-safety requirements).

Fire incidents comprise only 12.6 percent of the total number of incidents that the Glendale Fire Department responds to in a yearly basis (medical emergencies make up about 79 percent of the calls based on 2002 figures), and structural fires amount to about 5 percent of these fire calls. Therefore, structural fires in the City do not occur very often, due in great part to the various fire prevention programs that the Fire Department has in place, and the prompt reply to fire calls by fire fighting personnel. The only concern is that a large percentage of the single-family residential structures in the City were built before 1986, when the first fire sprinkler ordinance in Glendale was adopted. If the Fire Department determines that a large percentage of the few structural fires in the City occur in non-sprinklered structures, homeowners should be encouraged to retrofit their residences to add sprinklers.

Some of the fire prevention programs that the City uses include fire prevention inspections on a yearly or bi-yearly basis to a variety of buildings, including residential, commercial and industrial, with emphasis on multiple-occupancy structures (both high probability/high consequences and high probability/low consequences risk assets). Glendale's Fire Prevention Bureau also reviews all proposed development plans for conformance with fire protection requirements, and has an extensive public education and awareness program aimed at various groups, including school children. These programs are clearly working and should therefore be continued.

The Glendale Fire Department has nine fire stations distributed throughout the City. Dispatch calls are received through the Verdugo Fire Communications Center, and most calls in the City are responded to within 5 to 6 minutes of the dispatch center receiving the call. Improving these already excellent response times is generally difficult, especially in a city like Glendale, where traffic is intense at several times throughout the day, there are many structures accessed by long, winding roads in areas of significant topographic relief, and the City's layout is not geometric. The last two conditions are difficult to modify. However, if review of the data indicates that the response time is a function primarily of congestion during peak traffic hours, there are several methods that can be used to improve the firefighters' response time, including traffic signal pre-emption devices installed at critical intersections and elimination of traffic calming devices such as speed humps and speed bumps.

As discussed above, normal, day-to-day fire conditions in the developed portions of the City are readily manageable with the resources at hand. In fact, the Glendale Fire Department has an excellent fire-suppression delivery system that has earned the City an Insurance Services Office (ISO) rating of Class 1, the best possible. If the Glendale Fire Department requires assistance from neighboring fire departments, it can request so via the automatic aid agreements that the City has in place with the cities of Burbank, Pasadena, and Los Angeles, and with the County of Los Angeles. If these resources are still not sufficient, the City can request assistance from other jurisdictions in accordance with the provisions of the California Mutual Aid Agreement (California Government Code Section 8555-8561). As the City grows, and the infrastructure ages, however, the City should regularly re-evaluate specific fire hazard areas, conducting periodic Fire Station location and Resource studies to ensure that the Fire Department can continue to provide the level of service expected. This includes reviewing the adequacy of the water supplies (fire flow) on a regular, possibly yearly basis.

After-earthquake fires have the potential to severely impact a community, especially if gas transmission lines break due to ground rupture (surface fault rupture, liquefaction, landsliding, or other geologic conditions that results in ground deformation). Several faults in the area have the potential to cause extensive earthquake-induced fire damage. According to loss-estimation models the Raymond, Hollywood and Verdugo faults have the potential to cause the most fire damage in Glendale. Because the effects of an earthquake are regional, earthquake-induced fires can occur throughout a community and adjacent areas, immediately taxing the regional fire suppression system. The rupture of water mains, and the failure of water storage facilities that result in insufficient water or water pressure to fight the fires can also hinder fire suppression. The Verdugo and Sierra Madre faults may rupture the ground surface during an earthquake, causing many breaks in the gas and water distribution systems. This would be especially serious if the Verdugo fault broke, since many of the reservoirs in the City are on the north side of the this fault, and breakage of the distribution pipes would limit the amount of water available to fight fires in the extensively developed southern portion of Glendale. Therefore, retrofitting of the pipe sections across and near the mapped traces of these faults with flexible pipe and joints should be a priority.

The Glendale Fire Department conducts training exercises that simulate natural and man-made disasters. City staff, as well as elected officials, should participate in earthquake-induced fire-scenario exercises based on this study's HAZUS loss estimates, using the adopted emergency management system (SEMS). They are also re-starting their Urban Search and Rescue (USAR) program that will specialize in techniques that other USAR teams from neighboring cities are not emphasizing, so as to not duplicate efforts. Support for this program should be maintained.

CHAPTER 5: HAZARDOUS MATERIALS MANAGEMENT

5.1 Introduction

A high standard of living has driven society's increasing dependence on chemicals. Hydrocarbon fuels that power the transportation industry, chlorine used to clean our drinking water, and pesticides used in the agricultural sector to grow our foods are all chemicals used on a daily basis and in large quantities. This demand requires the manufacturing, transportation and storage of chemicals. As we will discuss throughout this chapter, these activities provide opportunities for the release of chemicals into the environment, often with negative consequences. As our dependence on chemicals has increased, scientists have discovered that exposure to many of these substances is hazardous to human health and to the environment. As a result, beginning in the late 1960's, Federal, State, and local regulations have been implemented to dictate the safe use, storage, and transportation of hazardous materials and wastes. These regulations help to minimize the public's risk of exposure to hazardous materials.

The United States Environmental Protection Agency (EPA) defines a hazardous waste as a substance that 1) may cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness; and 2) that poses a substantial present or potential future hazard to human health or the environment when it is improperly treated, stored, transported, disposed of or otherwise managed. Hazardous waste is also ignitable, corrosive, explosive, or reactive (U.S. EPA 40 CFR 260.10). A material may also be classified as a hazardous material if it contains defined amounts of toxic chemicals. The EPA has developed a list of specific hazardous substances that are in the forms of solids, semi-solids, liquids, and gases. Producers of such substances include private businesses, Federal, State, and local government agencies. The EPA regulates the production and distribution of commercial and industrial chemicals to protect human health and the environment. The EPA also prepares and distributes information to further the public's knowledge about these chemicals and their effects, and provides guidance to manufacturers in pollution prevention measures, such as more efficient manufacturing processes and the recycling of used materials.

The State of California defines hazardous materials as substances that are toxic, ignitable or flammable, reactive, and/or corrosive. The State also defines an extremely hazardous material as a substance that shows high acute or chronic toxicity, carcinogenity (causes cancer), bioaccumulative properties (accumulates in the body's tissues), persistence in the environment, or water reactivity (California Code of Regulations, Title 22).

This chapter discusses some of the hazards associated with the use, generation, storage, and transport of hazardous wastes and materials in the City of Glendale, with emphasis on the impact these substances can have on the air we breathe or the drinking water supply. There are hundreds of Federal, State and local programs that regulate the use, storage and transportation of hazardous materials. Some of these programs are discussed in this chapter. However, the environmental regulatory scene is in a constant state of flux as new findings are published and new or modified methods for studying and cleaning contaminants are developed. Therefore, for recent updates, the reader is encouraged to contact the Glendale or Los Angeles County Fire Departments, the Department of Health Services, and/or the Environmental Protection Agency (EPA). This chapter also addresses the potential for hazardous materials to be released during a natural disaster, such as an earthquake, since these events have the potential to cause multiple releases of hazardous materials at the same time, taxing the local emergency response agencies.

5.2 Air Quality

Each one of us breathes about 3,400 gallons of air every day. Unfortunately, our air is contaminated on a daily basis by human activities such as driving cars, burning fossil fuels, and manufacturing chemicals. Natural events, such as wildfires, windstorms, and volcanic eruptions also degrade air quality. Nevertheless, during the last three decades, the United States has made impressive strides in improving and protecting air quality despite substantial economic expansion and population growth. However, as any resident of the Los Angeles metropolitan area can attest, additional improvements in air quality can and should be made.

5.2.1 National Ambient Air Quality Standards

The Clean Air Act requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The EPA uses two types of national air quality standards: Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly, and secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

National Ambient Air Quality Standards have been set for six principal pollutants called "criteria" pollutants. These pollutants include:

- Carbon monoxide (CO)
- Particulate matter (PM10)
- Lead (Pb)
- Nitrogen dioxide (NO2)
- Ground-level ozone (O3)
- Sulfur dioxide (SO_2)

For each of these pollutants, the EPA tracks two kinds of air pollution trends: air concentrations based on actual measurements of pollutant concentrations in the ambient (outside) air at selected monitoring sites throughout the country, and emissions based on engineering estimates of the total tons of pollutants released into the air each year. The standards or allowable concentrations for these six pollutants are known as National Ambient Air Quality Standards (NAAQS). These are listed in Table 5-1.

Peak air quality statistics for the six principal pollutants measured in the Los Angeles-Long Beach metropolitan area for the year 2000 are listed in Table 5-2. The data show that the peak values for ozone and particulate matter exceed the national ambient air quality standards for those pollutants (values shown in bold), while all other pollutants are below the national standards. Ozone and particulate matter are discussed in detail below.

Ozone is an odorless, colorless gas that occurs naturally in the Earth's upper atmosphere – 10 to 30 miles above the Earth's surface – where it forms a protective layer that shields us from the sun's harmful ultraviolet rays. Man-made chemicals are gradually destroying this beneficial ozone. In the Earth's lower atmosphere, near ground level, ozone is formed when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources react chemically in the presence of sunlight. Ozone at ground level is a harmful pollutant. Ozone pollution is a concern during the summer months, when the weather conditions needed to form it – lots of sun and hot temperatures – normally occur.

Table 5-1: National Ambient Air Quality Standards

	In parts per million*	In mg/m³ or µg/m³	
Carbon Monoxide			
8-hour average (U.S.) 8-hour average (CA)	≥9.5 >9.0		Primary
1-hour average (U.S.) 1-hour average (CA)	>35 >20		Primary
Nitrogen Dioxide			
AAM (U.S.) 1-hour average (CA)	>0.0534 >0.25		Primary and Secondary
Ozone			
1-hour average (U.S.) 1-hour average (CA)	>0.12 >0.09		Primary and Secondary
8-hour average	*>0.08*		*Primary and Secondary*
Lead			
Quarterly average (U.S.) Monthly average (CA)		>1.5 $\mu g/m^3$ ≥1.5 $\mu g/m^3$	Primary and Secondary
Particulate (PM 10)			
AAM (U.S.) AGM (CA)		>50 $\mu g/m^3$ >30 $\mu g/m^3$	Primary and Secondary
24-hour average (U.S.) 24-hour average (CA)		>150 $\mu g/m^3$ >50 $\mu g/m^3$	Primary and Secondary
Particulate (PM 2.5)			
AAM (U.S.)		>15 $\mu g/m^3$	Primary and Secondary
24-hour average (U.S.)		*>65* $\mu g/m^3$	*Primary and Secondary*
Sulfur Dioxide			
AAM (U.S.)	>0.03		Primary
24-hour average (U.S.) 24-hour average (CA)	>0.14 >0.045		Primary
3-hour average (U.S.) 1-hour average (CA)	>0.50 >0.25		Secondary

* Parts per million, ppm, of air, by volume
AAM = Annual Arithmetic Mean; AGM = Annual Geometric Mean
PM 10 refers to particles with diameters of 10 micrometers or less.
PM 2.5 refers to particles with diameters of 2.5 micrometers or less.
The ozone 8-hour standard and the PM 2.5 standards are included for information only, since a 1999 Federal court ruling blocked implementation of these standards, and the issue has not yet been resolved.
mg/m^3 = milligrams per cubic meter; $\mu g/m^3$ = micrograms per cubic meter
U.S. = Federal (or National) Standard; CA = California Standard

Roughly one out of every three people in the United States is at a higher risk of experiencing ozone-related health effects. Sensitive people include children and adults who are active outdoors, people with respiratory disease, such as asthma, and people with unusual sensitivity to ozone. People of all ages who are active outdoors are at increased risk because, during physical activity, ozone penetrates deeper into the parts of the lungs that are more vulnerable to injury. Ozone can irritate the respiratory system, causing coughing, throat irritation, and/or an uncomfortable sensation in the chest, and aggravating asthma. Ozone can also reduce lung function, making it more difficult to breathe deeply and vigorously, and can increase susceptibility to respiratory infections.

The term "particulate matter" (PM) includes both solid particles and liquid droplets found in air. Many man-made and natural sources emit PM directly or emit other pollutants that react in the atmosphere to form PM. These solid and liquid particles come in a wide range of sizes. Particles less than 10 micrometers in diameter tend to pose the greatest health concern because they can be inhaled into and accumulate in the respiratory system. Particles less than 2.5 micrometers in diameter are referred to as "fine" particles. Sources of fine particles include all types of combustion (motor vehicles, power plants, wood burning, etc.) and some industrial processes. Particles with diameters between 2.5 and 10 micrometers are referred to as "coarse." Sources of coarse particles include crushing or grinding operations, and dust from paved or unpaved roads.

Both fine and coarse particles can accumulate in the respiratory system and are associated with numerous health effects. Coarse particles can aggravate respiratory conditions such as asthma. Exposure to fine particles is associated with several serious health effects, including premature death. Adverse health effects have been associated with exposures to PM over both short periods (such as a day) and longer periods (a year or more).

Table 5-2: Year 2000 Peak Air Quality Statistics for Criteria Pollutants in the Los Angeles-Long Beach Metropolitan Area

Pollutant	National Air Quality Standard	Peak Concentration in Los Angeles-Long Beach Area
Carbon Monoxide		
8-hour average	9 ppm	**10 ppm**
Nitrogen Dioxide		
Annual Arithmetic Mean	0.053 ppm	0.044 pp
Ozone		
1-hour average	0.12 ppm	**0.17 ppm**
8-hour average	0.08 ppm	**0.11 ppm**
Lead		
Quarterly maximum	1.5 μg/m^3	0.06 μg/m^3
Particulate (PM10)		
Annual arithmetic mean	50 μg/m^3	46 μg/m^3
24-hour average	150 μg/m^3	93 μg/m^3
Particulate (PM2.5)		
Annual arithmetic mean	15 μg/m^3	**23.9 μg/m^3**
24-hour average	65 μg/m^3	**83 μg/m^3**
Sulfur Dioxide		
Annual arithmetic mean	0.03 ppm	0.003 ppm
24-hour average	0.14 ppm	0.010 ppm

ppm = parts per million
μg/m^3 = micrograms per cubic meter
Source: http://www.epa.gov/airtrends

5.2.2 *Air Quality Index*

There are two indicators that are typically used to assess the air quality of a given area. These indicators are the Air Quality Index and the quantity of pollutant emissions. In 1976, EPA developed the Pollutant Standards Index (PSI), which was a consistent and easy to understand way of stating air pollutant concentrations and associated health implications. In June 2000, the EPA updated the index and renamed it Air Quality Index (AQI). EPA's AQI provides accurate, timely, and easily understandable information about daily levels of air pollution. The Index provides a uniform system for measuring pollution levels for five major air pollutants regulated under the Clean Air Act.

The AQI is reported as a numerical value between 0 and 500, which corresponds to a health descriptor like "good," or "unhealthy" (see Table 5-3). AQI values are reported daily in the local news media (TV, radio, internet (http://www.epa.gov/airnow), and newspapers) serving metropolitan areas with populations exceeding 200,000. The AQI converts daily measured pollutant concentration in a community's air to the numerical value and color code. The most important number on the scale is 100. An AQI level in excess of 100 means that a pollutant is in the "unhealthy for sensitive groups" range for that day. An AQI level at or below 100 means that a pollutant reading is in the satisfactory range with respect to the National Ambient Air Quality Standard (NAAQS).

Table 5-3: Air Quality Index (a measure of community-wide air quality)

Index Values	Levels of Health Concern	Cautionary Statements
0-50	Good	None
51-100*	Moderate	Unusually sensitive people should consider limiting prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.
201 - 300	Very Unhealthy	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
301 - 500	Hazardous	Everyone should avoid all outdoor exertion

Source: http://www.epa.gov/airnow/aqibroch/aqi.html#8

The EPA determines, on a daily basis, the index value for each of the measured pollutants, and reports the highest figure as the AQI value for the day. The pollutant with the highest daily value is identified as the Main Pollutant. The pollutants indexed by the AQI are the criteria pollutants discussed earlier. The Clean Air Act directs the EPA to regulate criteria pollutants because of their impact on human health and the environment. The standards or allowable concentrations for these six pollutants are known as National Ambient Air Quality Standards (NAAQS).

The South Coast Air Quality Management District (SCAQMD) has provided NAAQS air quality data for the Los Angeles, Orange, Riverside, and San Bernardino counties. The most recent year for which these data are available is 1999. The last column in Table 5-4 provides the number of days that Criteria Air Pollutant concentrations for the area around Glendale were in excess of federal and state standards for the year 1999.

Table 5-4: Air Quality in the Glendale Area in 1999

Pollutant	Measurement Location	# Days in excess
Ozone	Eastern San Fernando Valley	9*
Carbon Monoxide	Eastern San Fernando Valley	0**
Nitrogen Dioxide	Eastern San Fernando Valley	0***
PM10	Eastern San Fernando Valley	35‡
PM2.5	Eastern San Fernando Valley	1‡

* 8-hour average federal standard
** 8-hour average state standard
*** 1-hour average state standard
‡ 24-hour average federal standard
Source: http://www.aqmd.gov

Historical data for the years 1991-2000 show that the Los Angeles-Long Beach metropolitan area has more days with AQI values for ozone over 100 than most other monitored metropolitan areas in the United States. The values do show that there have been substantial improvements – in 1991, AQI values for ozone greater than 100 were measured 126 days out of that year, while in 2000, the number of days had decreased to 46.

Facilities that release emissions into the air are required to obtain a permit to do so from the EPA. The more recent data available indicate that there are approximately 180 facilities permitted to release emissions into the air in Glendale. These facilities include a variety of businesses such as restaurants, dry cleaners, tire shops, welding shops, car repair shops, hospitals, and industrial and manufacturing facilities. The South Coast Air Quality Management District (SCAQMD) is the local agency responsible for monitoring and enforcing air quality control with emphasis on emissions from stationary sources, such as the permitted facilities mentioned before. To reduce air emissions, SCAQMD staff conducts periodic inspections of permitted facilities to ensure continued compliance with Federal and State requirements, and provide training to help business owners understand these requirements and keep up with new rules. If necessary, SCAQMD takes enforcement action to bring businesses into compliance.

5.3 Drinking Water Quality

Most people in the United States take for granted that the water that comes out of their kitchen taps is safe to drink. In most areas, this is true, thanks to the efforts of hundreds of behind-the-scene individuals that continually monitor the water supplies for contaminants, in accordance with the drinking water standards set by the EPA. Primary authority for EPA water programs was established by the 1986 amendments to the Safe Drinking Water Act (SDWA) and the 1987 amendments to the Clean Water Act (CWA).

The National Primary Drinking Water Standard protects drinking water quality by limiting the levels of specific contaminants that are known to occur or have the potential to occur in water and can adversely affect public health. All public water systems that provide service to 25 or more individuals are required to satisfy these legally enforceable standards. Water purveyors must monitor for these contaminants on fixed schedules and report to the EPA when a Maximum Contaminant Level (MCL) has been exceeded. MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. Drinking water supplies are tested for a variety of contaminants, including organic and inorganic chemicals (minerals), substances that are known to cause cancer (carcinogens), radionuclides (such as uranium and radon), and microbial contaminants. The contaminants for which the EPA has established MCLs are listed at http://www.epa.gov/safewater/mcl.html. Changes to the MCL list are typically made every three years, as the EPA adds new contaminants or, because, based on new research or new case studies, there are reasons to issue revised MCLs for some contaminants.

One of the contaminants checked for on a regular basis is the coliform count. Coliform is a group of bacteria primarily found in human and animal intestines and wastes. These bacteria are widely used as indicator organisms to show the presence of such wastes in water and the possible presence of pathogenic (disease-producing) bacteria. Pathogens in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems. One of the fecal coliform bacteria that water samples are routinely tested for is Escherichia coli (E. coli). To fail the monthly Total Coliform Report (TCR), the following must occur:

- For systems testing more than 40 samples, more than five percent of the samples test positive for Total Coliform, or
- For those systems testing less than 40 samples, more than one sample tests positive for Total Coliform.

Two water agencies provide retail drinking water to the residents of the City of Glendale. The two agencies are:

- Glendale Water and Power (96 percent of the City) and
- Crescenta Valley Water District (4 percent of the City)

As shown above, Glendale Water and Power (GWP) is the agency that provides water to the majority of the residents of the Glendale. Approximately 70 percent of the water distributed is bought from the Metropolitan Water District (MWD); the remaining approximately 30 percent comes from eleven groundwater wells in the Glorietta well field located within the City. Water from the wells is blended with MWD water and distributed to City residents by GWP. GWP sends approximately 3,500 water samples annually to a certified water quality laboratory to analyze for compliance with federal and state drinking water regulations (Glendale, 2000).

Neither of these two agencies is listed in the EPA Safe Drinking Water Violation Report for Los Angeles County, found at http://www.epa.gov/enviro/html/sdwis/sdwis_ov.html. This means that the water provided by these agencies has not failed the total coliform report, nor has it exceeded the maximum contaminant levels for the contaminants routinely tested. However, some of the ground water beneath the City of Glendale has high levels of nitrates. This water is mixed with other water to reduce the concentration of nitrates to levels below the EPA-mandated water quality standards. For additional information regarding this, refer to Section 5.4.2.

One facility in the Glendale area has EPA permits to discharge to local water sources. This facility is listed in Table 5-5.

Table 5-5: Facility with EPA Permits to Discharge to Water in the Glendale Area

NPDES ID	EPA Facility ID	Facility Name	Address
CAP000033	CAD008337099	Drilube Co.	711 W. Broadway

Source: http://www.epa.gov/enviro/html/pcs/pcs_querry_java.html

One of the products most often used as a disinfectant by swimming pool, drinking water and wastewater facilities is chlorine, making chlorine one of the most prevalent extremely hazardous substances. Chlorine is typically found in the form of a colorless to amber-colored liquid, or as a greenish-yellow gas with a characteristic odor. The liquid solutions are generally very unstable, reacting with acids to release chlorine gas (such as bleach mixed with vinegar or toilet bowl cleaner containing hydrochloric acid). Mixing bleach with other products is the largest single source of inhalation exposure reported to poison control centers (http://www.emedicine.com/EMERG/topic851.htm). Chlorine gas is heavier than air and therefore stays close to the ground, where it can impact individuals. Exposure to chlorine gas generally impacts the respiratory system, with cough, shortness of breath, chest pain, and burning sensation in the throat reported as the most common symptoms. Respiratory distress can occur at even low concentrations of less than 20 parts per million (ppm). At high concentrations (> 800 parts per million – ppm) chlorine gas is lethal.

Chlorine pellets and chlorine solutions can be found at supermarkets, hardware stores and other locations that sell pool supplies. Bleach solutions can be found in almost every household and in commercial and industrial facilities, including hotels, hospitals, medical and veterinary facilities, etc. Proper storage and usage practices are required at all of these locations to reduce or eliminate the potential for a toxic release of chlorine. Chlorine is used by the City at some of its water storage facilities to disinfect the water. At these facilities, proper operations and maintenance procedures are followed to prevent equipment and process failures that could lead to the unauthorized release of chlorine at concentrations that could impact the surrounding areas. These facilities maintain a comprehensive program of personnel training, security enforcement and equipment monitoring to reduce the risk of an accidental or intentional (terrorist) release.

5.4 Regulations Governing Hazardous Materials and Glendale's Environmental Profile

Various Federal and State programs regulate the use, storage, and transportation of hazardous materials. These will be discussed in this chapter as they pertain to the City of Glendale and its management of hazardous materials. The goal of the discussions presented herein is to provide information that can be used to reduce or mitigate the danger that hazardous substances may pose to City of Glendale residents and visitors.

Although several of these programs are summarized below, this is not meant to be an all-inclusive list. Hazardous materials management is extensively legislated, and the laws governing hazardous waste management are complex and diverse. Several of the agencies involved in this process are identified below. Additional information can be obtained from their web pages.

5.4.1 National Pollutant Discharge Elimination System (NPDES)

"Out of sight, out of mind" has traditionally been a common approach to dealing with trash, sediment, fertilizer-laden irrigation water, used motor oil, unused paint and thinner, and other hazardous substances that people dump into the sewer or storm drains. What we often forget is that these substances eventually make their way into the rivers and oceans, where they can sicken surfers and swimmers, and endanger wildlife. The Clean Water Act of 1972 originally established the National Pollutant Discharge Elimination System (NPDES) to control wastewater discharges from various industries and wastewater treatment plants, known as "point sources." Point sources are defined by the EPA as discrete conveyances such as pipes or direct discharges from businesses or public agencies. Then, in 1987, the Water Quality Act amended the NPDES permit system to include "nonpoint source" pollution (NPS pollution). NPS pollution refers to the introduction of bacteria, sediment, oil and grease, heavy metals, pesticides, fertilizers and other chemicals into our rivers, bays and oceans from less defined sources. These pollutants are washed away from roadways, parking lots, yards, farms, and other areas by rain and dry-weather urban runoff, entering the storm drains, and ultimately the area's streams, bays and ocean. NPS pollution is now thought to account for most water quality problems in the United States. Therefore, strict enforcement of this program at the local level, with everybody doing his or her part to reduce NPS pollution, can make a significant difference.

The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point and nonpoint sources that discharge pollutants into waters of the United States. The City of Glendale is a member of the Los Angeles County Stormwater Program. This program regulates and controls storm water and urban runoff into the Los Angeles River, San Gabriel River, Santa Clara River, tributaries to these rivers, and ultimately, the Pacific Ocean. The Los Angeles County Stormwater Program is the local enforcer of the NPDES program. In the Glendale Area, NPDES permits are filed with the California Regional Water Quality Control Board, Los Angeles Region. This permit was required by all counties with a storm drain system that serves a population of 100,000 or more. On October 29, 1999, Phase II of NPDES was signed into law. Under this phase of NPDES, areas with 50,000 or more residents, and construction sites one acre or more in size, must file for and obtain an NPDES permit. Under NPDES, the local regulator is responsible for the following control measures:

- Public education and outreach on storm water impacts,
- Public involvement/participation,
- Illicit discharge detection and elimination,
- Construction of site storm water runoff control,
- Post-construction storm water management in new development and redevelopment, and
- Pollution prevention/good housekeeping for municipal operations.

The NPDES permit area that includes Glendale is 3,100 square miles in area, with a population of 11.4 million. In conformance with the Federal requirements listed above, one of the major tasks of the Los Angeles County Stormwater Program is to educate the local population about keeping the water that flows into our rivers and ocean clean by eliminating discharges of hazardous materials into storm drains and other point sources. Signs are typically painted by storm drains that drain to the local rivers and ultimately into the Pacific Ocean to encourage people from not disposing motor oil or other potentially hazardous substances into the drains. Displays are often presented in local libraries, and presenters visit elementary and high schools.

5.4.2 *Comprehensive Environmental Response, Compensation and Liability Act*

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) is law developed to protect the water, air, and land resources from the risks created by past chemical disposal practices. This act is also referred to as the Superfund Act, and the sites listed under it are referred to as Superfund sites.

According to the EPA, there are nine Superfund sites in the Glendale area, three of which are active (see Table 5-6). The other six are "archive" Superfund sites, meaning they are listed on the "archive" or "No Further Remedial Action Planned (NFRAP)" database and have been removed and archived from the inventory of Superfund sites. Archive status indicates that to the best of the EPA's knowledge, the EPA has completed its assessment of the site and has determined that no immediate or long-term risks to human health or to the environment are associated with the site, or that no further steps will be taken to list that site on the National Priority List (NPL).

Table 5-6: CERCLIS Sites in the Glendale Area

Facility Name	Facility Address	EPA ID	Status
PRC-Desoto Inter. (California Zonolite Co.), (W.R. Grace & Co.)	5430-5454 San Fernando Rd.	CAN000905637	Not on NPL, preliminary assessment ongoing
San Fernando Valley (Area 2)	Crystal Springs Wellfield Area	CAD980894901	On Final NPL
San Fernando Valley (Area 3)	Glorietta Wellfield	CAD980894984	On Final NPL
Air Products & Chemicals Inc.	6505 San Fernando Rd.	CAD982005282	NFRAP
Drilube Co.	711 W. Broadway	CAD008337099	NFRAP
Glendale Public Service Department	800 Air Way	CAD980735864	NFRAP
Newell	940 Allen Ave.	CAD982339400	NFRAP
Pacific Airmotive #1	6265 San Fernando Rd.	CAD980636567	NFRAP
Pacific Airmotive #2	926 S. Brand Blvd.	CAD980636575	NFRAP

Source: http://www.epa.gov/superfund/sites/arcsites/index/htm

Of the three sites listed as active Superfund sites, only two are actually on the NPL: The San Fernando Valley (Area 2) and San Fernando Valley (Area 3) are portions of the larger San Fernando groundwater basin where groundwater is contaminated with chlorinated volatile organic compounds (VOCs) and nitrate. Area 2 is an area of contaminated groundwater covering approximately 6,680 acres near the Crystal Springs Well Field. Prior to the discovery of groundwater contamination, the aquifer had provided drinking water to over 800,000 residents in the area. In 1980, concentrations of trichloroethylene (TCE) and perchloroethylene (PCE) were found to be above the Federal Maximum Contaminant Levels (MCLs) and State Action Levels (SALs) in several production wells in the area. In order to protect the public, water suppliers have provided the area with alternate drinking water supplies, including imported water or ground water mixed with imported water. Contaminated water in Area 2 is currently being treated using the pump-and-treat method.

San Fernando Valley Area 3 is part of the Verdugo groundwater sub-basin and covers an area of approximately 4,400 acres. The ground water in the area is minimally contaminated with VOCs in small isolated areas in concentrations near or below the maximum allowable levels. PCE, the most prevalent of the organic contaminants in the area, is found near the Glorietta Well Field at concentrations of less than 1.1 ppb (parts per billion). The MCL for PCE is 5 ppb, so these concentrations are well below the EPA-mandated limits. Nitrate contamination of ground water in excess of the 45 ppm (parts per million) State-mandated MCL has been detected near the Glorietta Well Field. Drinking water providers have taken steps to ensure the quality of the drinking water provided to the public. The City of Glendale blends ground water containing nitrate with imported water prior to distribution to customers. The blending of ground water and imported water ensures that nitrate levels are in the 22-28 ppm range. Treatment for VOC contamination has not been a concern due to the low concentrations present.

5.4.3 Emergency Planning and Community Right-To-Know Act (EPCRA)

The primary purpose of the Federal Emergency Planning and Community Right-To-Know Act (EPCRA) is to inform communities and citizens of chemical hazards in their areas. Sections 311 and 312 of EPCRA require businesses to report to State and local agencies the locations and quantities of chemicals stored on-site. These reports help communities prepare to respond to chemical spills and similar emergencies. This reduces the risk to the community as a whole.

EPCRA mandates that Toxic Release Inventory (TRI) reports be made public. The Toxics Release Inventory (TRI) is an EPA database that contains information on toxic chemical releases and other waste management activities reported annually by certain industry groups as well as federal facilities. This inventory was established in 1986 under the EPCRA and expanded by the Pollution Prevention Act of 1990. Sites on the TRI database are known to release toxic chemicals into the air. The EPA closely monitors the emissions from these facilities to ensure that their annual limits are not exceeded. TRI reports provide accurate information about potentially hazardous chemicals and their uses to the public in an attempt to give the community more power to hold companies accountable and to make informed decisions about how such chemicals should be managed.

Section 313 of EPCRA requires manufacturers to report the release to the environment of any of more than 600 designated toxic chemicals. These reports are submitted to the EPA and State agencies. The EPA compiles these data into an on-line, publicly available national digital TRI. These data are readily available on the EPA website at http://www.epa.gov. Facilities are required to report releases of toxic chemicals to the air, soil, and water. They are also required to report off-site transfers of waste for treatment or disposal at separate facilities. Pollution prevention measures and activities, and chemical recycling must also be reported. All reports must be submitted on or before July 1 of every year and must cover all activities that occurred at the facility during the previous year.

Facilities with ten or more full-time employees that meet the following criteria are required to report their activities to the EPA and the regulatory State agencies:

- That manufacture or process over 25,000 pounds of any of approximately 600 designated chemicals or twenty-eight chemical categories specified in regulations, or
- use more than 10,000 pounds of any designated chemical or category, or

- are engaged in certain manufacturing operations in the industry groups specified in the U.S. Government Standard Industrial Classification Codes (SIC) 20 through 39, or
- are a Federal facility.

The seven facilities in the City of Glendale listed in the Toxic Release Inventory are summarized in Table 5-7.

Table 5-7: Toxic Release Inventory of Facilities in the Glendale Area

Facility Name	EPA ID	Chemicals
Automation Plating Corp.	CAD008342784	Cyanide compounds, hydrochloric acid aerosols, nitric acid, sodium hydroxide (solution), sulfuric acid, zinc (fume or dust)
California Offset Printers	CAD981397425	1,1,1-trichloroethane
Drilube Co.	CAD008337099	Tetrachloroethylene, chlorine
GCC Corp.	CAD059240663	1,1,1-Trichloroethane, phosphoric acid, nitric acid, sulfuric acid aerosol, toluene, xylene (mixed isomers), sodium hydroxide (solution)
Librascope Corp.	CA0001913250	Freon 113
PRC-Desoto Intl. Inc. Courtaulds Aerospace Inc. Chem	000007647616 CAD008237596	Methyl ethyl ketone, toluene, manganese compounds, chromium compounds, antimony compounds, 1,1,1-trichloroethane, methylenebis(phenylisocyanate), xylene (mixed isomers), toluene-2,4-disocyanate, decabromodiphenyl oxide
Products Research & Chemical, Corp.	000007647616	Data not available

Source: Hazus 99SR-2 Data and http://www.epa.gov/enviro/html/tris/tris_query.html

5.4.4 Resources Conservation and Recovery Act

The Resources Conservation and Recovery Act (RCRA) is the principal Federal law that regulates the generation, management, and transportation of hazardous materials and other wastes. Hazardous waste management includes the treatment, storage, or disposal of hazardous waste. Treatment is defined as any process that changes the physical, chemical, or biological character of the waste to make it less of an environmental threat. Treatment can include neutralizing the waste, recovering energy or material resources from the waste, rendering the waste less hazardous, or making the waste safer to transport, dispose of, or store. Storage is defined as the holding of waste for a temporary period of time. The waste is treated, disposed of, or stored at a different facility at the end of each storage period. Disposal is the permanent placement of the waste into or on the land. Disposal facilities are usually designed to contain the waste permanently and to prevent the release of harmful pollutants to the environment.

Many types of businesses can be producers of hazardous waste. Small businesses like dry cleaners, auto repair shops, medical facilities or hospitals, photo processing centers, and metal plating shops are usually generators of small quantities of hazardous waste. Small-quantity generators are facilities that produce between 100 and 1,000 kilogram (Kg) of hazardous waste per month. Since many of these facilities are small, start-up businesses that come and go, the list of small-quantity generators in a particular area changes significantly over time. Often, a facility remains, but the name of the business changes with new ownership. For these reasons, small-quantity generators in the Glendale area are not listed in this report, but EPA data indicate that there are approximately 250 small-quantity generators of hazardous materials in the City. The general distribution of these sites by census tract is shown on Plate 5-1.

Larger businesses are sometimes generators of large quantities of hazardous waste. These include chemical manufacturers, large electroplating facilities, and petroleum refineries. The EPA defines a large-quantity generator as a facility that produces over 1,000 Kg of hazardous waste per month. Large-quantity generators are fully regulated under RCRA. The registered large-quantity generators in the City of Glendale are listed in Table 5-8. The general location of these sites is shown on Plate 5-1.

Table 5-8:
EPA-Registered Large-Quantity Generator (LQG) Facilities in the Glendale Area

Facility Name	EPA ID
Scholl Canyon Landfill	CA0000927426
PRC-Desoto International Inc., (Courtaulds Aerospace)	CAD008237596
Drilube	CAD008337099
Automation Plating Corp.	CAR000002089 CAD008342784

Source: *The National Biennial RCRA Hazardous Waste Report (Based on 1999 Data): List of Large Quantity Generators in the United States.*

5.4.5 Hazardous Materials Disclosure Program

Both the Federal Government and the State of California require all businesses that handle more than a specified amount of hazardous materials or extremely hazardous materials, termed a reporting quantity, to submit a business plan to its local Certified Unified Program Agency (CUPA). The CUPA with responsibility for the City of Glendale is the Glendale City Fire Department. The preparation, submittal and implementation of a business plan, on a yearly basis, is required if a business uses, stores, or manufactures an extremely hazardous material in any amount, or a hazardous material exceeding the reportable quantity of:

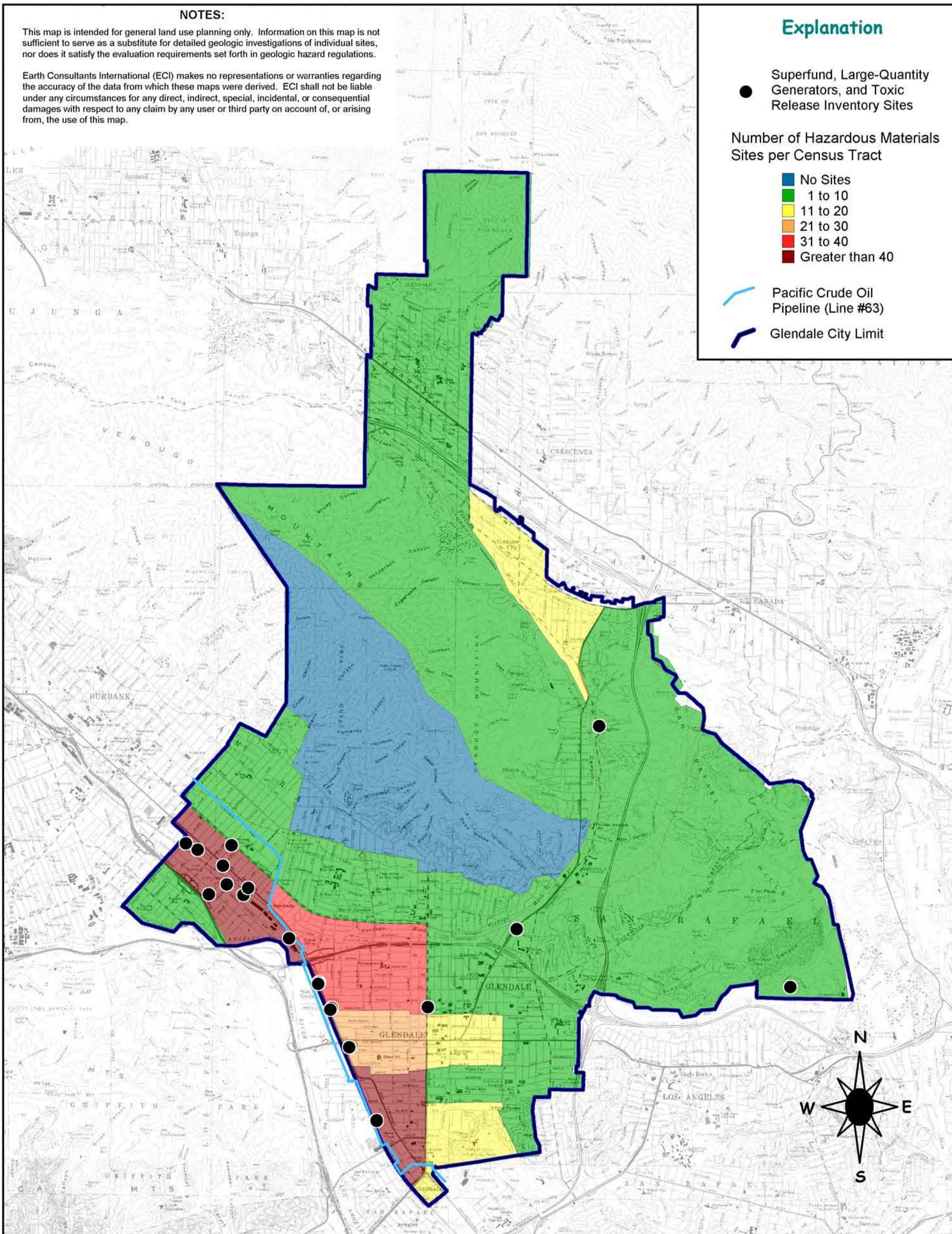
- 5 gallons or more of a liquid;
- 50 pounds or more of a solid; and/or
- 50 cubic feet or more of a gas at standard temperature and pressure.

The full business plan must include an inventory of the hazardous materials used in the facility, and emergency response plans and procedures to be used in the event of a significant or threatened significant release of a hazardous material. The plan must include the Material Safety Data Sheet (MSDS) for each hazardous and potentially hazardous substance used. MSDSs summarize, among other things, the physical and chemical properties of the substances, and their health impacts. The plan also requires immediate notification to all appropriate agencies and personnel of a release, identification of local emergency medical assistance appropriate for potential accident scenarios, contact information for all company emergency coordinators of the business, a listing and location of emergency equipment at the

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.



Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: Environmental Protection Agency 2002; Federal Emergency Management Agency HAZUS, 1999.

Hazardous materials listings include: US Environmental Protection Agency, California Environmental Protection Agency, and Toxic Release Inventory. Some sites are included in more than one list, and may therefore be counted more than once.

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Hazardous Materials Site Map

Glendale, California

Plate 5-1

business, an evacuation plan, and a training program for business personnel. Businesses that use, store, or manufacture hazardous materials below the reportable quantities listed above are required to submit an abbreviated business plan on a yearly basis with the local administering agency. The abbreviated business plan consists of emergency contact names and telephone numbers, as well as a chemical inventory list.

Business plans are designed to be used by responding agencies, such as the Glendale City Fire Department and the Los Angeles County Fire Department during a release to allow for a quick and accurate evaluation of each situation for an appropriate response. Business plans are also used during a fire to quickly assess the types of chemical hazards that fire-fighting personnel may have to deal with, and to make decisions as to whether or not the surrounding areas need to be evacuated. The Glendale Fire Department, Environmental Management Center (EMC), currently reviews annually submitted business plans.

5.4.6 Hazardous Materials Incident Response

There are thousands of different chemicals available today, each with its own unique physical characteristics; what might be an acceptable mitigation practice for one chemical could be totally inadequate for another. Therefore it is essential that agencies responding to a hazardous material release have as much available information as possible regarding the type of chemical released, the amount released, and its physical properties to effectively and quickly evaluate and contain the release. The EPA-required business plans are an excellent resource for this type of information. Other sources of information are knowledgeable facility employees present onsite.

In 1986, Congress passed the Superfund Amendments and Reauthorization Act (SARA). Title III of this legislation requires that each community establish a Local Emergency Planning Committee (LEPC). This committee is responsible for developing an emergency plan that outlines steps to prepare for and respond to chemical emergencies in that community. This emergency plan must include the following:

- an identification of local facilities and transportation routes where hazardous materials are present;
- the procedures for immediate response in case of an accident (this must include a community-wide evacuation plan);
- a plan for notifying the community that an incident has occurred;
- the names of response coordinators at local facilities; and
- a plan for conducting exercises to test the plan.

The plan is reviewed by the State Emergency Response Commission (SERC) and publicized throughout the community. The LEPC is required to review, test, and update the plan each year. The Glendale Fire Office of Emergency Services is the City entity that is charged with the coordination of the City's disaster operations.

5.4.7 Hazardous Material Spill/Release Notification Guidance

All significant releases or threatened releases of hazardous materials, including oil, require emergency notification to several government agencies. The State of California, Governor's Office of Emergency Services (OES) has developed a Hazardous Material Spill/Release Notification Guidance to guide the public, industry, and other government entities in the reporting process for hazardous materials accidents. This Guidance can be found at the OES website (http://www.oes.ca.gov/) under the Hazardous Materials Unit link.

To report all significant releases or threatened releases of hazardous materials, first call 911 (or the local emergency response agency), and then call the Governor's Office of Emergency Services (OES) Warning Center at 1-800-852-7550. In addition, written Follow-Up Reports may be required by some agencies.

The Hazardous Material Spill/Release Notification Guidance summarizes pertinent emergency notification requirements and applies to all significant releases of hazardous materials. Refer to the Safe Drinking Water and Toxic Enforcement Act of 1986, better known as Proposition 65, and §9030 of the California Labor Code for additional reporting requirements.

Requirements for immediate notification of all significant spills or threatened releases cover: Owners, Operators, Persons in Charge, and Employers. Notification is required regarding significant releases from: facilities, vehicles, vessels, pipelines and railroads. Under Health and Safety Code §25507, State law requires Handlers, any Employees, Authorized Representatives, Agents or Designees of handlers to, upon discovery, immediately report any release or threatened release of hazardous materials. Federal law requires, under the Emergency Planning and Community-Right-to-Know Act (SARA Title III) (EPCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) (CERCLA), that all Owners, Operators, and Persons in Charge report all releases that equal or exceed federal reporting quantities.

State law requires, at a minimum, the following information during the notification of a spill or threatened release:

- Identity of caller
- Location, date and time of spill, release, or threatened release
- Substance and quantity involved
- Chemical name (if known, it should be reported; also if the chemical is extremely hazardous)
- Description of what happened.

Federal law requires the following additional information during the notification of spills (CERCLA chemicals) that exceed federal reporting requirements:

- Medium or media impacted by the release
- Time and duration of the release
- Proper precautions to take
- Known or anticipated health risks
- Name and phone number for more information

In the event of a release/spill, at a minimum, the following government agencies must be notified:

- Local Emergency Response agency (9-1-1 or Local Fire Department)
- The Certified Unified Program Agency (CUPA) (Glendale City Fire Department: 818-548-4030)
- Governor's Office of Emergency Services Warning Center (1-800-852-7550 or 916-845-8911)

- California Highway Patrol (CHP) (9-1-1), only if the spill/release occurred on a highway.

In addition to these agencies, one or more of the following agencies may need to be notified, depending on the specifics of the incident:

- National Response Center (1-800-424-8802) if the spill equals or exceeds CERCLA Federal reportable quantities
- United States Coast Guard (Marine Safety Office LA/Long Beach: 310-732-7380) if the spill occurred in a waterway
- California Occupational Safety and Health Administration (Cal/OSHA) (Van Nuys Enforcement District Office: 818-901-5403) if serious injuries or harmful exposures to workers occurred during the spill
- Department of Toxic Substances Control (DTSC) (Glendale Regional Office: 818-551-2800) if the release is from a hazardous waste tank system or from a secondary containment system
- Department of Conservation, Division of Oil Gas and Geothermal Resources (DOGGR) (District 1, Cypress Office: 714-816-6847) in the case of an oil or gas release at a drilling site
- Public Utilities in the case of a natural gas pipeline release

For further information on the requirements for emergency notification of a hazardous chemical release, refer to the following statutes:

- Health and Safety Code §25270.7, 25270.8, 25507
- Vehicle Code §23112.5
- Public Utilities Code §7673, (PUC General Orders #22-B, 161)
- Government Code §51018, 8670.25.5 (a)
- Water Code §13271, 13272
- California Labor Code §6409.1 (b)10
- Title 42, U.S. Code §9603, 11004

The new California Accidental Release Prevention Program (CalARP) became effective on January 1, 1997, in response to Senate Bill 1889. The CalARP replaced the California Risk Management and Prevention Program (RMPP). Under the CalARP, the Governor's Office of Emergency Services (OES) must adopt implementing regulations and seek delegation of the program from the EPA.

The CalARP program is proactive because it requires businesses to prepare Risk Management Plans (RMPs), which are detailed engineering analyses of:

- the potential accident factors present at a business; and
- the mitigation measures that can be implemented to reduce this accident potential.

In most cases, local governments have the lead role for working directly with businesses in this program. The Glendale Fire Department, Environmental Management Center (EMC) is designated as the administering agency for hazardous materials for the City of Glendale.

5.5 Leaking Underground Storage Tanks (LUST)

Leaking underground storage tanks (LUSTs) are one of the greatest environmental concerns of the past several decades. In California, regulations aimed at protecting against UST leaks have been in place since 1983, one year before the Federal Resource Conservation and Recovery Act (RCRA) was amended to add Subtitle I requiring UST systems to be installed in accordance with standards that address the prevention of future leaks. The Federal regulations are found in the Code of Federal Regulations (CFR), parts 280-281. The State law and regulations are found in the California Health and Safety Code, Chapter 6.7, and the California Code of Regulations (CCR) Title 23, commonly referred to as the "California Underground Storage Tank Regulations." Federal and state programs include leak reporting and investigation regulations, and standards for clean up and remediation. UST cleanup programs exist to fund the remediation of contaminated soil and groundwater caused by leaking tanks. California's program is more stringent than the Federal program, requiring that all tanks be double walled, and prohibiting gasoline delivery to non-compliant tanks. The State Water Resources Control Board (SWRCB) has been designated the lead regulatory agency in the development of UST regulations and policy.

The State of California now requires replacement of older tanks with new double-walled, fiberglass tanks with flexible connections and monitoring systems. Many older tanks were single-walled steel tanks that leaked as a result of corrosion and detached fittings. Extensive Federal and State legislation addresses LUSTs, including replacement and cleanup. UST owners were given a ten-year period to comply with the new requirements, and the deadline came due on December 22, 1998. However, many UST owners did not act by the deadline, so the State granted an extension for the Replacement of Underground Storage Tanks (RUST) program to January 1, 2002. The California Regional Water Quality Control Board (CRWQCB), in cooperation with the Office of Emergency Services, maintains an inventory of LUSTs in a statewide database.

According to the State Water Resources Control Board's (SWRCB) Leaking Underground Storage Tank (LUST) database (LUSTIS, 2001*)*, 55 LUST cases have been reported in the Glendale area. Of these, only 25 are still considered "active" cases, either under investigation or remediation. These active sites are listed in Table 5-9. Note that it is likely that clean up at many of these facilities has been completed or deemed unnecessary by the regional office of the SWRCB.

Table 5-9 shows that most underground storage tank leaks in the Glendale area have impacted only the surrounding soil. Only one site (Interstate Brands Corporation, 6841 San Fernando Rd.) in Glendale reportedly impacted a groundwater aquifer used for drinking water as a result of a leak from an underground storage tank. A remediation plan has been submitted to the lead agency for this case, but according to the database, remedial actions have not been started at this location.

5.6 Glendale Fire Department, Environmental Management Center and Glendale Fire Office of Emergency Services

A project of the Environmental Management Center (EMC) is to coordinate hazardous material planning and appropriate response efforts with city departments, as well as local, and State agencies. The Office of Emergency Services for Glendale is tasked with coordinating the City's disaster operations. The goal of these agencies is to improve public and private sector readiness, and to mitigate local impacts resulting from natural or technological emergencies. Both agencies are branches of the Glendale Fire Department that deals with the planning for and response to the natural and technological disasters in the City of Glendale.

The EMC is also charged with the responsibility of conducting compliance inspections for regulated facilities in the City. These facilities handle hazardous material, generate or treat a hazardous waste and/or operate an underground storage tank. All new installations of underground storage tanks require an inspection, along with the removal, of the old tanks.

Table 5-9: Sites in the Glendale Area with Leaking Underground Storage Tanks

Facility Name	Address	Case No.	Case Type	Status	Date Reported
500 North Brand Partnership	550 Brand Blvd N	R-10794	S	0	3/7/1986
Al Sal Oil #6	1501 Glenoaks Blvd W	I-10622	S	3b	8/14/1998
Brand Mobil	1100 Brand Blvd N	912070016	S	5c	11/1/1998
California Car Wash	3940 San Fernando Rd	912040089	S	3b	5/1/2000
Exxon #7-3678	825 Central St N	R-11989	S	3b	5/6/1992
Fueling Station Brock Bus Line	722 Wilson Ave W	113.0203	O	7	8/22/1995
Gay's Automotive & Towing	418 Glenoaks Blvd E	R-10555	S	0	9/19/1997
Glendale Adventist Med. Ctr.	1509 Wilson Terrace	912060061	S	5C	3/12/1990
Highland Arco	5800 San Fernando Rd	912020034	S	3A	3/1/2000
Hovik's Auto Repair	1020 E Chevy Chase Drive	912050025	O	3B	6/24/1998
Interstate Brands Corporation	6841 San Fernando Rd	915200025	A	5R	2/24/1987
Mcnamara & Peepe	1619 Glendale Drive	1NHU527	U	1	9/23/1994
Mobil #11-816	301 Verdugo Rd S	912050034	S	1	8/30/1991
Mobil #11-GHW	250 Glendale Ave S	R-11158	S	5C	4/30/1991
Mobil #11-JPL	3200 Foothill Blvd	912140016	S	1	4/4/1996
Mobil #11-KNL	800 Pacific Ave N	912030043	S	5C	5/14/1986
Mobil #18-GGL	900 Glenoaks Blvd W	912020025	O	5C	9/1/1987
Mobil #18-KR4	700 Glendale Ave N	912060016	S	3A	10/3/1983
Octo #1	1118 Glendale Ave N	912060070	O	5C	11/30/1998
Patrick's Texaco	2527 Canada Blvd	912080016	S	5R	5/8/1998
Products Research & Chemical Co.	5430 San Fernando Rd	R-10470	O	0	7/31/1996
Shell	350 Glendale Ave N	R-10603	S	1	11/10/1989
Shell	625 Pacific Ave N	912030034	S	0	6/11/1986
Texaco	401 Glendale Ave N	R-11012	S	3B	9/4/1991
Thrifty #013	3680 San Fernando Rd	912040070	O	5C	12/30/1986

Source: http://www.swrcb.ca.gov/cwphome/lustis/index.html

Abbreviations Used for Case Type: **S** = Soil Only; **O** = ground water not used for drinking water; **U** = undefined; **A** = aquifer used for drinking water supply.
Abbreviations Used for Status: **0** = No action taken; **1** = Leak being confirmed; **3A** = Preliminary Site Assessment Workplan Submitted; **3B** = Preliminary Site Assessment Underway; **5C** = Pollution Characterization Underway; **5R** = Remediation Plan Submitted; **7**= Remedial Action Under Way.

5.7 Household Hazardous Waste and Recycling

According to FEMA (1999), most victims of chemical accidents are injured at home. These accidents usually result from ignorance or carelessness in using flammable or combustible materials. In an average city of 100,000 residents, 23.5 tons of toilet bowl cleaner, 13.5 tons of liquid household cleaners, and 3.5 tons of motor oil are discharged into city drains each month (FEMA, 1999)

The Glendale Fire Department Environmental Management Center (EMC) is tasked with administering a household hazardous waste collection plan for the City of Glendale in accordance with the California Integrated Solid Waste Management Act of 1989 (AB 939). The EMC is located at 780 Flower Street.

A variety of household toxics are accepted. Acceptable wastes include used motor oil, used oil filters, pesticides, pool chemicals, paints, and items found in most homes. The EMC also runs a curbside used oil collection program. In this program, the EMC collects used motor oil and used oil filters from residents' homes. Over 6,300 gallons of used motor oil have been collected in this program, which is available to over 1,600 households citywide. The City of Glendale, like other California cities, has also implemented a recycling program. This program helps reduce the amount of waste that is being taken to the landfill sites.

5.8 Oil Fields

A review of the map "Oil, Gas, and Geothermal Fields in California, 2001" published by the California Department of Conservation, Division of Oil and Gas indicates that there are no current or abandoned oil fields in the Glendale area. The map is available in pdf format from the Division of Oil and Gas website at: http://www.consrv.ca.gov/dog/. Some of the concerns typically associated with oil fields, especially when they are abandoned and redeveloped (such as oil-impacted soils that need to be treated or disposed of offsite), are therefore not a concern in Glendale.

5.9 Hazard Analysis

The primary concern associated with a hazardous materials release is the short and/or long term effect to the public from exposure to the hazardous material, especially when a toxic gas is involved. The best way to reduce the liability for a hazardous material release is through stringent regulations governing the storage, use, manufacturing, and handling of hazardous materials.

The Glendale Fire Department and the County of Los Angeles Fire Department use modified versions of the 1997 Uniform Fire Code (UFC), which identify proper usage, storage, handling and transportation requirements for hazardous materials. Risk minimization criteria include secondary containment, segregation of chemicals to reduce reactivity during a release, sprinkler and alarm systems, monitoring, venting and auto shutoff equipment, and treatment requirements for toxic gas releases.

The "Significant Hazardous Materials Sites" in the City of Glendale included in Table 5-10, and shown on Plate 5-1, were compiled from the data reported in the sections above. The list includes facilities that are identified in the following State and/or Federal databases:

- Superfund-Active or Archived Sites (CERCLIS)
- RCRA/RCRIS-EPA Registered Large Quantity Generators
- Toxic Release Inventories (TRIs)

Notice that most of the Superfund sites have been archived and deemed to no longer pose a threat to the environment; they are included herein because the sites are still on the Federal Superfund Sites list. Other sites may be undergoing clean-up or remediation. There are a variety of techniques currently being used by the environmental remediation industry to clean up the soils and water. Therefore, some of the sites identified below may be taken off future lists issued by the appropriate Federal or

State agency. Furthermore, and more importantly, the lists included in this section of the Safety Element are snapshots in time, and are often based on EPA data that date back to the 1990s. Facilities that use, store, generate or transport hazardous materials are expected to come and go; so these lists, or comparable lists, should be updated at least once a year.

Table 5-10: Significant Hazardous Materials Sites in Glendale

Facility Name	Facility ID	Source
Air Products & Chemicals Inc.	CAD982005282	CERCLIS
Automation Plating Corp.	CAD008342784, CAR000002089, CAD008342784	TRI, LQG
California Offset Printers	CAD981397425	TRI
Drilube Co.	CAD008337099	TRI, LQG, CERCLIS
GCC Corp.	CAD059240663	TRI
Glendale Public Service Department	CAD980735864	CERCLIS
Librascope Corp.	CA0001913250	TRI
Newell	CAD982339400	CERCLIS
Pacific Airmotive #1	CAD980636567	CERCLIS
Pacific Airmotive #2	CAD980636575	CERCLIS
PRC DeSoto Intl. Inc., Courtaulds Aerospace Inc. Chem, California Zonolite Co., W.R. Grace & Co.	000007647616, CAD008237596, CAN000905637,	TRI, LQG, CERCLIS
Products Research & Chemical, Corp.	000007647616	TRI
San Fernando Valley (Area 2)	CAD980894901	CERCLIS
San Fernando Valley (Area 3)	CAD980894984	CERCLIS
Scholl Canyon Landfill	CA0000927426	LQG

5.9.1 *Earthquake-Induced Releases of Hazardous Materials*

Isolated unauthorized releases of hazardous materials can occur at any time, but earthquakes have the potential to cause several linked incidents at the same time, generating worst-case scenarios for emergency response personnel. Strong seismic shaking can lead to the release of hazardous materials by damaging storage facilities and transport infrastructure. During an earthquake, chemical storage tanks could buckle or, if improperly secured and fastened could easily be punctured and/or tipped over. Improperly segregated chemicals could react forming a toxic gas cloud. Pipelines are especially vulnerable to damage as they can be pulled apart or ruptured by strong ground motion. Natural gas lines pose a significant hazard due to the high number lines in urban environments and because gas leaks from ruptured lines can lead to secondary fires. Train derailment during an earthquake can also lead to significant hazardous materials release.

As a result of the 1994 Northridge earthquake, 134 locations reported hazardous materials problems and 60 emergency hazardous materials responses were required. The majority of these events occurred where structural damage was minimal or absent (Perry and Lindell, 1995). The earthquake caused 1,377 breaks in the natural gas piping system and half a dozen leaks in a 10-inch crude oil pipeline (Hall, 1994).

A train derailment in the Northridge earthquake included a train with 29 cars and one locomotive. One of 13 tankcars spilled an estimated 2,000 gallons of sulfuric acid, and 1,000 gallons of diesel fuel spilled from the locomotive. According to the California Public Utilities Commission (1994), it is standard operating procedure to stop all trains within one hundred miles of the epicenter of a magnitude 6.0 or greater earthquake. The stoppage of trains in the area of the 1994 Northridge earthquake took approximately 14 minutes to implement.

The 1987 Whittier Narrows earthquake, a significantly smaller event than the Northridge earthquake, caused 22 hazardous materials situations, including the collapse of a large chlorine tank that forced an evacuation in Santa Fe Springs. The Whittier Narrows earthquake also caused over 1,400 natural gas leaks, three of which caused subsequent fires.

A key point to remember regarding the management of hazardous materials spills in the aftermath of an earthquake is that it is substantially more difficult to respond to a spill immediately after an earthquake than it is to do so during non-earthquake conditions. Hazardous materials response teams responding to an earthquake-induced release have to deal with potential structural and non-structural problems of the buildings housing the hazardous materials, potential leaks of natural gas from ruptured pipes, and/or downed electrical lines or equipment that could create sparks and cause a fire. When two hazards with potentially high negative consequences intersect, the challenges of managing each are greatly increased. During an earthquake response, hazardous materials emergencies become an additional threat that must be integrated into the response management system.

5.9.2 Chemical Fires

Chemical substances are often unstable under high temperatures. Other chemicals are reactive to water or oxygen, and can self-ignite if exposed to water or air. For example, sulfuric acid, one of the most abundant and widely distributed chemicals produced in the U.S., is highly reactive when exposed in its concentrated form to water. Other substances if mixed together can also generate a fire. Therefore, when dealing with chemical fires it is important to know what type of chemicals are present in the area and where they are held. It is also important to note that when dealing with chemical fires, time is critical: the longer chemicals are exposed to extreme heat, the more likely they are to react violently, increasing the severity of the fire. Fire fighters can better respond to a situation with the appropriate equipment if they have the information needed to make these decisions immediately available to them. This is what the business plans and the Material Safety Data Sheets (MSDS) discussed in Section 5.4.5 are intended to provide.

Firefighters recognize four main different types of fires:

- Class A fires involve ordinary materials like paper, lumber, cardboard, and some types of plastics.
- Class B fires involve flammable or combustible liquids such as gasoline, kerosene, and common organic solvents.
- Class C fires involve energized electrical equipment, such as appliances, switches, panel boxes, power tools, and hot plates. Water is a particularly dangerous extinguishing medium for class C fires because of the risk of electrical shock.
- Class D fires involve combustible metals, such as magnesium, titanium, potassium and sodium, as well as pyrophoric organometallic reagents such as alkyllithiums,

Grignards and diethylzinc. These materials burn at high temperatures and will react violently with water, air, and/or other chemicals.

It is not uncommon for fires to be a combination of the types discussed above. Therefore, it is typically recommended that fire extinguishers obtained for household and office use have an ABC rating, which means that they have the capacity to fight Class A, B and C fires.

Common types of extinguishers include:

- Water extinguishers, which are suitable for class A (paper etc.) fires, but not for class B, C and D fires, because the water can make the flames spread.
- Dry chemical extinguishers, which are useful for class ABC fires and are the best all around choice. They have an advantage over CO2 extinguishers because they leave a blanket of non-flammable material on the extinguished material that reduces the likelihood of re-ignition. There are two kinds of dry chemical extinguishers:
  - Type BC fire extinguishers contain sodium or potassium bicarbonate, and
  - Type ABC fire extinguishers contain ammonium phosphate.
- CO2 (carbon dioxide) extinguishers are for class B and C fires. They don't work very well on class A fires because the material usually re-ignites. CO2 extinguishers have an advantage over dry chemical in that they leave behind no harmful residue -- a good choice for an electrical fire on a computer or other delicate instrument. Note that CO2 is a bad choice for flammable metal fires such as Grignard reagents, alkyllithiums and sodium metal because CO2 reacts with these materials. CO2 extinguishers are not approved for class D fires.
- Metal/Sand Extinguishers are for flammable metals (class D fires) and work by simply smothering the fire.

Not only is it imperative to control chemical fires as soon as possible, but two main "by-products" of these types of fires require special attention, including special handling and evacuation procedures. These "by-products" include the "smoke plume" and water run-off from the fire-extinguishing process. The smoke plume has the potential to pose a severe hazard to those exposed to it: chemicals in the vapor phase can be mildly to extremely toxic if inhaled, depending on the chemicals involved. Smoke inhalation is a hazard in itself, but when chemicals are part of the smoke, it can have severe negative impacts on the health of those nearby, including fire-fighting personnel and individuals not evacuated in time to prevent them from inhaling the smoke. Soot from some types of fires can also cause chemical burns on skin. Therefore, depending on the types of chemicals involved in the fire, an evacuation of the immediate area and especially of those areas down-wind should be conducted.

If water is used to fight a fire, the runoff could include chemicals or substances that pose a hazard to the environment. Therefore, the runoff should be contained to prevent it from flowing into the storm drains. Containing the water runoff from a fire is difficult but possible. Special equipment is available to do so, but only a few fire response units have the equipment and necessary training. Fire Station #27 has been designated as the Hazardous Materials (HAZMAT) Unit headquarters for the City of Glendale. This station is responsible for the deployment of the necessary equipment to contain runoff from a chemical fire. All of the other units located throughout the City of Glendale have been trained as First Response

Units and can deal with the fire aspect of a chemical fire, but they lack the equipment available at Station 27. The next closest unit able to handle a chemical fire is located in Burbank.

5.9.3 Hazards Overlays

Plate 5-1 was used as an overlay to the other plates prepared for this Technical Background Report to assess the natural hazards vulnerability of the significant hazardous materials sites. The intent was to identify whether some of these sites are located in areas at risk of being impacted by the natural hazards discussed in previous chapter. This analysis indicates that no Significant Hazardous Materials sites are located within a Fault Hazard Management Zone. Given the City's location between the Sierra Madre (Rowley) fault zone to the north, the Verdugo fault through the center, and the Raymond and Hollywood faults to the south, the entire City is susceptible to strong to very strong ground motions. Due to the large quantities of hazardous materials used at the Significant Hazardous Materials facilities, strong ground shaking poses a special concern that needs to be addressed.

Several of the Significant Hazardous Materials sites are located within a liquefaction susceptible area and one facility (Scholl Canyon Landfill is in an area susceptible to slope movement in response to seismic activity. The facilities in the liquefaction susceptible zones include: Newell, Automation Plating Corp., Air Products & Chemicals Inc., GCC Corp., Librascope Corp., Pacific Airmotive #1, and San Fernando Valley (Area 2). Two of the sites (Pacific Airmotive #1 and San Fernando Valley (Area 2), are located within the dam inundation pathway zones identified in Chapter 3. No Significant Hazardous Materials sites are located in or near a high fire hazard area.

The City of Glendale has dozens of schools, as shown on Plate 1-4. These schools are distributed over most of the non-mountainous regions of the City, and a few are located within 1/2-mile of the significant hazardous materials sites identified herein. The Toxic Release Inventory sites are of most concern in this regard, since emissions into the air have the potential to impact a large geographical area. If any of the chemicals that these facilities have the potential to release into the air are toxic, evacuation of the surrounding area may be required. Since schools have special evacuation needs, these Significant Hazardous Materials sites should be required to prepare Risk Management Plans (RMPs) that identify the procedures by which the surrounding critical facilities will be evacuated, should it become necessary during an accidental release of hazardous materials. Alternatively, the schools in the immediate vicinity of the significant hazardous materials sites should consider implementing, as part of their School Safety Plans mandated by Senate Bill 187 (the Safe School Act of 1997), procedures for evacuation should a chemical spill occur in the area.

Some of the significant hazardous materials sites are located at or near the City's boundaries. These facilities may be located within a short distance of critical facilities located immediately adjacent but outside City limits that have not been identified herein. Similarly, there may be facilities located immediately outside City limits that use, store, or generate hazardous materials that could pose a risk to critical facilities within Glendale. Unauthorized releases of hazardous materials do not respect jurisdictional boundaries. Therefore, Risk Management Plans prepared by these facilities should address all critical facilities within a given radius, such as 1/2-mile or 1-mile from the hazardous materials site, so as to identify potential impact areas not within City limits.

5.10 Summary of Findings

The primary concern associated with a hazardous materials release is the short and/or long term effect to the public from exposure to the hazardous material. The best way to reduce the liability for a hazardous material release is through stringent regulation governing the storage, use, manufacturing and handling of hazardous materials. These regulations are typically issued by the EPA, but various local agencies are tasked with the responsibility of monitoring those facilities that use, store, transport, and dispose hazardous materials for compliance with the Federal guidelines, or if applicable, with more stringent State guidelines. Some of these programs and regulations, and the local enforcement agency, are summarized below, as they pertain to the City of Glendale.

National Pollutant Discharge Elimination System (NPDES): The City of Glendale participates in the Los Angeles County Stormwater Program, the local enforcing agency of the National Pollutant Discharge Elimination System. NPDES permits are filed with the California Regional Water Quality Control Board, Los Angeles Region. On October 29, 1999, Phase II of NPDES was signed into law. Under this phase of NPDES, areas with 50,000 or more residents, and construction sites one acre or more in size, must file for and obtain an NPDES permit.

Superfund Sites: According to the EPA, there are nine Superfund sites in the City of Glendale, six of which are "archive" or No Further Remedial Action Planned (NFRAP) sites. Of the three sites designated as active Surperfund sites, two are on the National Priority List (NPL). The NFRAP sites have been remediated to levels below National Priority List levels, but this does not guarantee that these sites have been completely remediated. The NPL sites still need to be remediated, while the active Superfund site not on the NPL is still undergoing preliminary assessment studies.

Hazardous Waste Sites: According to the data available, there are four large-quantity generators and approximately 250 small-quantity generators in the Glendale area. These numbers are not expected to change much, since the City is almost fully developed, and significant additional growth is not anticipated. Many of the small-generators are expected to change name with time, as these businesses come and go, or are taken over by new ownership. The City's Fire Department should maintain a list, updated at least once a year, and preferably more often, showing the small generators in Glendale. This database should include the types of chemicals and quantities produced by these facilities.

Toxic Release Inventory: According to the EPA records, there are seven facilities in the Glendale area that are listed in the Toxics Release Inventory (TRI). These are sites that are known to release toxic chemicals into the air. The EPA closely monitors the emissions from these facilities to ensure that their annual limits are not exceeded. The EPA also issues permits to facilities that emit chemicals, both toxic and non-toxic, into the atmosphere. The EPA records list more than 170 facilities in the Glendale area that are permitted to release chemicals into the atmosphere.

Leaking Underground Storage Tanks: According to data from the State Water Resources Control Board, 55 underground storage tank leaks have been reported in the Glendale area, 25 of which are still listed as active in the database. The data indicate that only one leak has impacted a potable groundwater source. The Glendale Fire Department, Environmental Management Center (EMC) provides oversight and conducts inspections of all underground tank removals and installation of new ones.

Air Quality: Data from the South Coast Air Quality District show that in 1999 in the San Fernando Valley area, which includes the City of Glendale, the ozone levels were above the Federal standards for only 9 days, above the PM-2.5 levels for only 1 day, and only above the PM-10 levels for 35 days. Air quality criteria are expected to become even more stringent, as the results of recent studies that indicate that air quality in the southern California area is still poor. With increased enforcement, the concentrations of these air pollutants are expected to decrease further.

Water Quality: Two water agencies provide retail drinking water to the Glendale area. The two agencies are: Glendale Water and Power and the Crescenta Valley Water District. Both of these agencies rely on significant supplies from the Metropolitan Water District. Neither of these agencies is listed on the EPA Safe Drinking Water Violation Report. Well water that has high levels of nitrates is mixed with water from the Metropolitan Water District to reduce the nitrate concentrations to acceptable levels.

Hazardous Materials Disclosure Program: Both the Federal government and the State of California require all businesses that handle more than a specified amount of hazardous materials or extremely hazardous materials to submit a business plan to a regulating agency. Annually submitted business plans are currently reviewed by the Glendale Fire Department.

Household Hazardous Waste: The City of Glendale participates in a Household Hazardous Waste (HHW) collection program set up by the Glendale Fire Department, Environmental Management Center in accordance with the California Integrated Solid Waste Management Act of 1989. The Environmental Management Center is located at 780 Flower Street. The City also provides a recycling program in which recyclable materials are collected by the refuse collection agency. It is clear that outreach and education programs that encourage recycling and conservation are in place.

Hazards Overlays: In the older sections of Glendale, businesses and residential areas are often within short distances of each other, or they co-exist. This gives the City a strong sense of community, a quality unique to the older cities of southern California. Most “planned” communities that have sprung elsewhere in the last decades do not provide for this desirable mix of uses within short, walking distances of each other. Unfortunately, there are also some disadvantages to this development pattern - facilities that generate, use, or store hazardous materials are often located near residential areas or near critical facilities, with the potential to impact these areas if hazardous materials are released into the environment at concentrations of concern.

There are four large-quantity and more than 250 small-quantity generators of hazardous materials in the City. Given these numbers, it is impressive that the actual number of unauthorized releases of hazardous materials into the environment is fairly small, as documented in the Federal and State databases reviewed. There are eight sites that have released hazardous materials of concern into the air – the EPA monitors these facilities closely to reduce the potential of future emissions at concentrations above the acceptable limits.

Eight of the significant hazardous materials sites are located within or adjacent to a liquefaction susceptible area, or an unstable slope area. Furthermore, two of the sites are located within or adjacent to a dam inundation area. The one concern that applies to all sites is that the City of Glendale is susceptible to high to very high ground motions as a result of an earthquake on several nearby seismic sources, including but not limited to, the Sierra Madre, Verdugo, Raymond or Hollywood faults. Therefore, all sites should provide for, at a minimum, secondary containment of hazardous substances, including segregation of reactive chemicals, in accordance with the most recent Uniform Fire Code and City of Glendale Fire Department amendments to the code.

CHAPTER 6: OTHER SAFETY ISSUES

6.1 Introduction

This chapter covers safety issues that did not fit the theme of the previous chapters, but that nevertheless require discussion. These are also safety issues that the State does not require to be covered in Safety Elements, but that the City of Glendale considers of sufficient importance as to be included in its Safety Element. Specifically, issues covered herein include terrorism and civil unrest, crime, major accident response, dangerous plants and animals, and disease and vector control. The data used in this study are based entirely on openly published information. No confidential information was sought or obtained, nor was any used.

6.2 Terrorism and Civil Unrest

6.2.1 Definitions

Webster's dictionary defines **terrorism** as the "use of force or threats to demoralize, intimidate, and subjugate, especially as a political weapon or policy." Terrorists rely on stealth and surprise to accomplish their means and to cause a feeling of uncertainty and hopelessness. The targets chosen are typically high-profile places that are likely to attract the most public attention, usually as a result of media coverage. This assures that the terrorist group's cause or objective becomes known. This is also why terrorist groups often issue public announcements taking responsibility for their actions. In an effort to cause as much damage as possible, terrorists may use or threaten to use nuclear, biological or chemical substances. These are referred to as Weapons of Mass Destruction, or WMDs.

While a terrorist attack is typically meant to generate as much publicity as possible, the planning and delivery phases of the attack need to be conducted in secrecy. This is the greatest weakness in the world of terrorism. Secrecy obscures terrorist plans from the outside world and introduces an element of uncertainty on the part of the target. This creates a perception of risk. However, to preserve secrecy, terrorist teams generally consist of a limited number of people. Consequently, most terrorist acts may take months, or even years to plan and execute. If a terrorist attack in the planning stages is detected, it loses its cover, forcing the terrorist group to abort its plans. Also, fear of detection may throw terrorists off-balance and cause them to make mistakes and get caught. Therefore, *detection* is the most powerful solution for terrorist attacks and the greatest fear in the terrorists' minds. The ability to detect and intercept a group's plans is the single most important weapon to prevent terrorism. The more that terrorist secrecy is breached, the more effective the counter-terrorism efforts become. *Prevention* is also a key element of a successful counter-terrorism strategy and planning. The other three crucial planning and mitigation elements are *preparedness, response, and recovery*.

Civil disturbances typically develop in response to an unpopular policy or act issued or made by the group in power, either the policy makers, or those that enforce these procedures, such as the police. Civil disturbances can also develop in response to perceived or real racial or social inequality, and deep-seated political or religious differences. Civil disturbances can include minor infractions, such as disturbing the peace or assembling illegally, to major offenses such as looting, robbery and possession of stolen property, assault, arson, brandishing of weapons, and even murder. Civil disturbances can become as large as the Los Angeles riots in April 1992, which caused significant destruction of property and loss of life.

6.2.2 Hazard Analysis

6.2.2 Hazard Analysis

The September 11, 2001 events, more than any other acts before or since, made Americans realize that U.S. soil is not immune to terrorism. Although most terrorist acts to date on American soil have occurred on the East Coast, California has many potential targets. There are several reasons for this: California is the fifth largest economy in the world, home to several economically and politically sensitive assets, and is a symbol of industrial strength and technological prowess with its vast military production, well-known and attended entertainment venues, world-renowned educational institutions, and numerous airports and harbors. The State's border with Mexico is frequently breached and its extensive international sea border makes California even more attractive as a potential terrorist target. Glendale is an integral part of southern California. Therefore, the potential for crime, terrorism and civil unrest need to be assessed within this *regional* context.

The consultant and City staff worked together to identify specific high-risk facilities in Glendale that could be targets of terrorist attack. These facilities, for obvious security reasons, are not identified herein, but the list of the facilities, and their locations, were issued to the Glendale Police Department. The sites were evaluated according to their economic and civic importance – high-occupancy businesses and City facilities that provide critical services were given a high rating and placed on a list of potential targets. Although several potential targets were identified in the City, this study suggests that within a regional context, as part of southern California, Glendale has a relatively low level of risk – other high-profile neighboring communities are at higher risk of being targeted for terrorist or civil unrest acts. Nevertheless, with effective prevention and mitigation strategies in place, Glendale can reduce its risk even further.

6.2.3 Hazard Response

The State of California has prepared and published as an addendum to the State Emergency Plan a document entitled *California Terrorism Response Plan*. This document identifies and describes how the State and local governments are to plan for and respond to terrorism incidents. The tasks and responsibilities of emergency management are based on two terms: Crisis Management and Consequence Management. Crisis Management refers to the response to people committing an act of terrorism. Consequence Management refers to the response to the potential or actual effects of terrorism. According to the *California Terrorism Response Plan* (2001), local government has primary responsibility for responding to an incident for the purpose of protecting public health and safety (Consequence Management). All responses to terrorism incidents need to be conducted in accordance with the State's Standardized Emergency Management System (SEMS). The Federal government is responsible for the law enforcement aspects of a terrorism incident that relate to identifying, apprehending and neutralizing the terrorists and their weapons (Crisis Management). These tasks are handled by the Federal Bureau of Investigation (FBI), with assistance from other agencies as necessary. Consequence management support at the Federal level is provided by the Federal Emergency Management Agency (FEMA), now part of the Department of Homeland Security.

In the City of Glendale, the Glendale Fire and Police Departments are responsible for responding to terrorist attacks and civil disturbances. The Glendale Police Department maintains the list of assets in the City that are considered potential terrorist and/or civil disturbance targets. The Glendale Police Department has a detailed program specifically designed for crowd control issues that was first implemented in the late 1980s. The tactical response unit, which specializes in civil disorder incidences, is referred to as the Tactical

Operation Support Squad (TOSS). This unit has been trained to act as a distinct team, responding to civil unrest and unusual events that require a tactical law enforcement presence, such as during earthquakes, catastrophic fires, and flooding conditions. More recently, the Police Department formed a special weapons unit called Special Response Team (SRT). This group is trained to handle unique situations, including acts of terrorism. The Intelligence Unit of the Police Department has been expanded to deal with issues relating to terrorism and organized crime, and the Police Department employs a Crisis Negotiation Team.

In addition to the *TOSS Manual*, there are several other planning documents that have been developed at the City level that outline specific procedures to be followed during civil unrest, and more recently, terrorist attacks. The Special Services Bureau maintains plans dealing with civil unrest. The Strategic Planning Element (SPE) maintains the *First Responder Contingencies and Plans For Regional and Local Area Terrorist Retaliation Attacks Resulting From US War on Terrorism* to counter terrorism. This document was developed after the September 11, 2001 attacks.

If an event exceeds the capabilities of the Glendale Police Department, additional resources are available. The Glendale Police Department participates in the Los Angeles County Mutual Aid Response Plan – if necessary, assistance can be obtained from the Los Angeles County Sheriff's Office. Mutual aid agreements and appropriate partnerships to address terrorism and disaster preparedness have been developed and are in place. At the State level, the National Guard would be deployed to help if the situation exceeds the capabilities of the local jurisdictions. Anticipating the possibility that the police facilities in the City could be a target, the Glendale Police Department has developed contingency plans that include the use of redundant facilities from which, if necessary, they can continue operating without interruption.

The California Office of Emergency Services (OES) has established the State Standing Committee on Terrorism (SSCOT). This group has the responsibility of: 1) monitoring terrorist trends and activities, 2) determining the potential impact area in the event that a terrorist threat is carried out, 3) planning for the coordinated and comprehensive emergency response to an event, and 4) providing timely guidance to State organizations or agencies responding to a specific threat or event. In the Los Angeles area, 44 members representing several government agencies and disciplines formed the Terrorism Working Group (TWG) in 1996. This group meets regularly to develop plans, procedures and systems related to terrorism issues. As a subgroup of the TWG, the Terrorism Early Warning Group provides intelligence estimates derived from open sources of information.

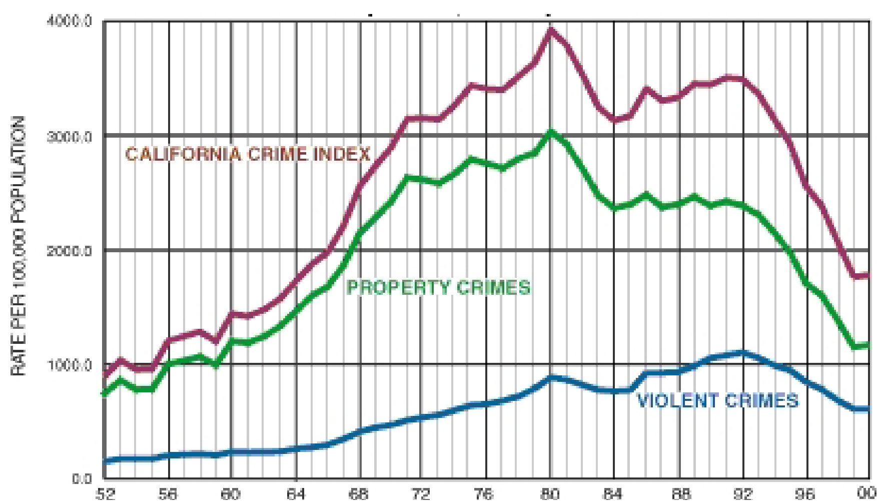
Consistent with the division of responsibilities as indicated in the *California Terrorism Response Plan*, the Glendale Police Department does not have the responsibility or the internal capabilities to assess terrorist threats locally. Furthermore, the number of implicit or explicit terrorist threats that they receive is not sufficient to justify a staff position or a tracking system at the City. Therefore, any threats received at the local level are forwarded to the California Anti-Terrorism Information Center (CATIC) for assessment. CATIC was established in response to the World Trade Center and Pentagon attacks on September 11, 2001, and is under the jurisdiction of the State's Department of Justice, Office of the Attorney General. CATIC acts as a clearinghouse for threats received statewide. Threats are evaluated and relevant information is then sent to the appropriate Federal, State and local jurisdictions, including the local police departments, if appropriate. Additional specific information on how these various agencies need to operate to maintain continuous communication and to coordinate their activities for effective response is spelled out in two documents prepared by the Office of Emergency Services: *Local Planning Guidance on Terrorism Response* (1998), and the *California Terrorism Response Plan* (2001). Updates to these documents can be expected on a regular basis as new information on how to plan for and respond to terrorism threats and attacks are developed.

6.3 Crime

In the last twenty years, significant changes have occurred in California's economic patterns, with a transition from primarily an industrial, blue-collar economy to a more diversified, increasingly technologically oriented one. California is now the undisputed center of innovation and technology in the world, and the export leader in the United States. Glendale, as the third most populous city in Los Angeles County, is representative of the social, cultural and economic diversity that characterizes and energizes southern California. For example, eighty different languages are spoken in Glendale schools; every rung on the socio-economic ladder is represented as well. Glendale is renowned as a financial district and retail center, and home to many entertainment industry studios, companies and theatres, and a well-established industrial park. The City has a variety of restaurants and nightspots, and is also the home of countless local small businesses.

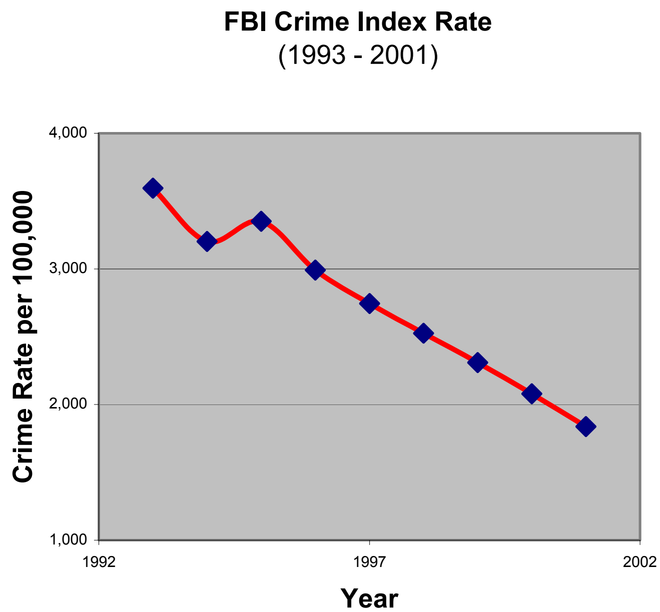
The changes in the local economy have had a profound effect on the crime picture. In the last twenty years, the crime rate in California has decreased drastically to almost one-half the rate of the 1980 peak (see Figure 6-1). Consistent with statewide trends, between 1993 and 2001, Glendale experienced a drastic drop in its crime rate to nearly one-half the values for 1992 (see Figure 6-2). This declining trend appears to be reversing, with preliminary figures for 2002 showing a moderate increase. Nevertheless, when compared to the five surrounding southern California counties and the State, the City of Glendale has one of the lowest crime rates (see Figure 6-3).

**Figure 6-1: Crime Index in California for the Years 1952-2000
(by category, per 100,000 population)**



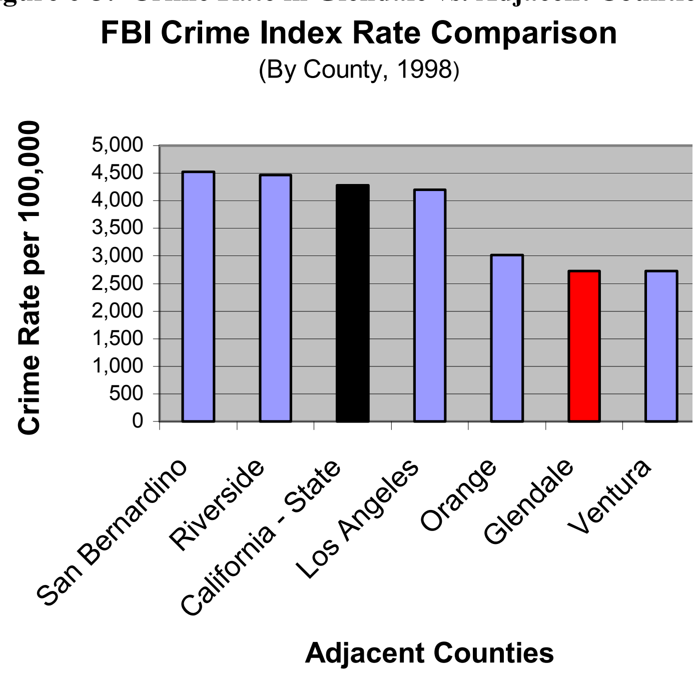
(Source: California Attorney General's Office)

Figure 6-2: Crime Trends in the City of Glendale for Years 1993-2001



(Source: Glendale Police Department)

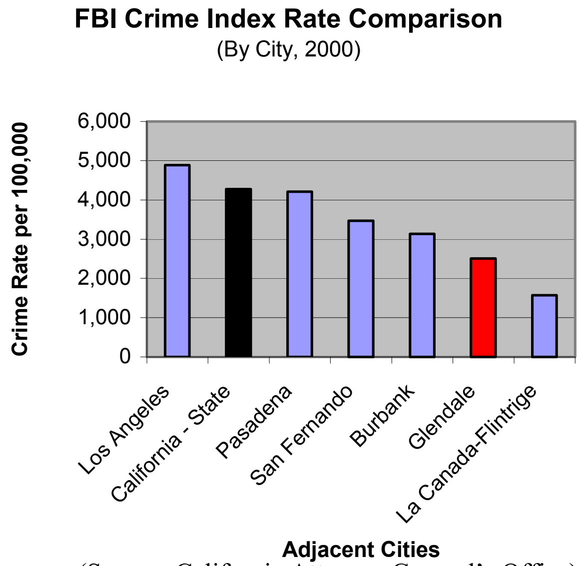
Figure 6-3: Crime Rate in Glendale vs. Adjacent Counties



(Source: California Attorney General's Office)

When compared to the five neighboring cities, Glendale has the second lowest crime rate, also significantly lower than its largest neighbor, the City of Los Angeles. This comparison is shown on Figure 6-4. In fact, Glendale is considered one of the safest cities with a population of more than 100,000.

Figure 6-4: Crime Rate in Glendale and Neighboring Cities



(Source: California Attorney General's Office)

Crime rates within Glendale vary significantly, with some census tracts experiencing substantially higher crime rates than the rest. The Crime Index by census tract in the City ranges from a low of 700 crimes for every 100,000 people in the area, to a high of over 7,000 crimes for every 100,000 people. For example, the northern, residential sections of Glendale, with substantially lower population densities, exhibit lower crime rates than the southern census tracts. On the other hand, census tracts with the highest crime rates lie in a relatively small area where critical risk factors, such as higher population density and accessibility, come together. This is the triangular area fully surrounded by the Golden State, Ventura, and Glendale Freeways, in addition to several major arteries, such as the San Fernando Road, cutting across it. Plate 6-1 shows a detailed distribution of crime by census tract within the City.

A revealing crime distribution pattern emerges within this triangular area. Namely, the highest crime areas have two things in common:

1. They are immediately adjacent to the Glendale Galleria; and
2. They have the highest population densities in the City.

There are several factors that can contribute to the crime risk in any city, including Glendale. The crime factors listed below can result in elevated levels of risk when present together in a relatively confined geographic area.

- High Population Density
- Population Instability
- Age Distribution
- Family Conditions
- Economic Conditions
- Housing-Stock Conditions
- Architectural Practices
- Street Layout and Accessibility
- Organized Crime Potential
- Gang Potential
- Crime Reporting Practices
- Ethnic Tensions
- Commercial and Industrial Enterprises Density, and
- Operational Skills and Capabilities of the Local Police Department

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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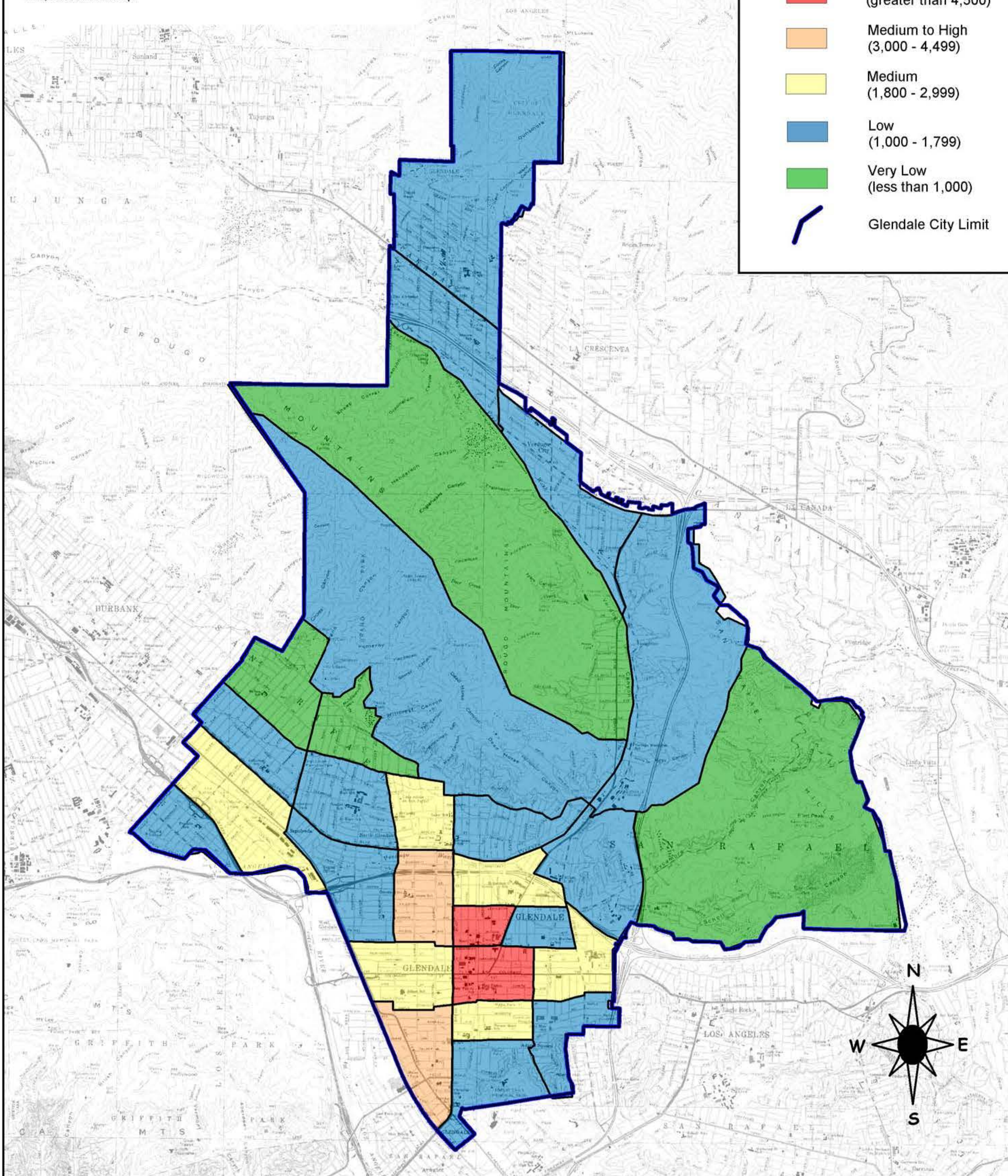


Explanation

Crime Rate per 100,000

- High (greater than 4,500)
- Medium to High (3,000 - 4,499)
- Medium (1,800 - 2,999)
- Low (1,000 - 1,799)
- Very Low (less than 1,000)
- Glendale City Limit

Scale: 1:60,000

1000 0 1000 2000 3000 Meters

5000 0 5000 10000 15000 Feet

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: US Census Bureau 1990, using population estimates as of 12/31/99. Crime data provided by the Glendale Police Department for the year 1999.

Earth Consultants International

Project Number: 2103
Date: July, 2003

Crime Rate per 100,000 by Census Tract

Glendale, California

Plate 6-1

Crime analysis is conducted by the Glendale Police Department on a continuous basis. Crime statistics are collected daily and scrutinized regularly. Based on these data, the Police Department indicates that property crimes in Glendale far outnumber crimes against persons. The data also show that, as in other commerce centers, white-collar crimes, such as fraud and identity theft, have increased in the last few years in Glendale. Like many diverse communities, Glendale experiences a certain amount of culturally based organized crime. Changes in the frequency, pattern, or type of crime are addressed by the Police Department. For example, the street-gang situation in Glendale is addressed on a daily basis, primarily by the Gang Unit. The Police Department utilizes a variety of programs and affirmative policing, forming partnerships with community groups, businesses, schools and other government agencies, to fight crime. The community as a whole has zero tolerance for criminal activity.

6.4 Major Accident Response

When a major accident or terrorist attack occurs, the first few moments are absolutely critical in terms of reducing loss of life and property. First responders must be sufficiently trained to understand the nature and the gravity of the event to minimize the confusion that inevitably follows catastrophic situations. The first responder must then put into motion relevant mitigation plans to further reduce the potential for loss of lives and property damage, and to communicate with the public. According to the State’s Standardized Emergency Management System, local agencies have primary authority regarding rescue and treatment of casualties, and making decisions regarding protective actions for the community. This on-scene authority rests with the local emergency services organization and the incident commander.

Depending on the type of accident or terrorist attack, several different agencies and disciplines may be called in to assist with emergency response. Agencies and disciplines that can be expected to be part of an emergency response team include medical, health, fire and rescue, police, public works, and coroner. The challenge is to accomplish the work at hand in the most effective manner, maintaining open lines of communication between the different responding agencies to share and disseminate information, and to coordinate efforts.

In the City of Glendale, emergency response is handled in accordance with SEMS, with individual City agencies and personnel taking on their responsibilities as defined by the City’s *Emergency Plan*. This document describes the different levels of emergencies, the local emergency management organization, and the specific responsibilities of each participating agency, government office, and City staff. As required by the State, training and exercises are conducted on a regular basis.

6.5 Dangerous Animals

In the last 20 years or so, there has been an increase in the number of incidences of wild animal encounters all over southern California. This is attributed to our increased encroachment onto the relatively undeveloped areas left in the region, and the highly adaptable nature of some of these animals. In the Verdugo Mountains and San Rafael Hills areas of Glendale, and in the San Gabriel Mountains in the northern portion of the City, the wild animal population includes coyotes, opossums, deer, rabbits, bats, raccoons, squirrels, skunks, rattlesnakes, and possibly mountain lions, bobcats, and bears. Some of these animals, such as coyotes, mountain lions, bobcats, and rattlesnakes, can harm humans or pets, while others, like deer and bats can be carriers of diseases. Some of these animals will be discussed further below.

The City of Glendale contracts with the Pasadena Humane Society (PHS) for animal control. The PHS provides to citizens, at nominal fees, humane traps that can be used to trap small animals. The PHS also deals with feral cats, stray dogs, and provides vector control services for Glendale (http://www.phsspca.org/animalcontrol/animal_control.htm).

6.5.1 Coyotes

Coyotes (*Canis latrans*) are medium-sized animals that belong to the dog family. Coyotes are known for their distinctive voice consisting of howls, high-pitched yaps and occasional dog-like barks. In the wild, their diet consists mainly of rodents, insects, reptiles, amphibians, fruits, and birds, although a pack of coyotes can tackle a prey as large as an adult deer (www.countyofsb.org/agcomm/coyote.htm). Thousands of coyotes are believed to roam the mountains and hillsides of Los Angeles County. Coyotes are highly adaptable and easily become urbanized, surviving on garbage, pet food that is left outside, and even small pets.

Coyote attacks on humans are rare, but they do occur. Typically, between 12 and 15 coyote attacks are reported every year in California, although most of these are not serious. In 1979, however, a coyote attempted to take a 13-month child from an Agoura yard, and in 1981, a 3-year old girl in Glendale was killed in her yard by a coyote (http://www.losangelesalmanac.com/topics/environment/ev15c.htm). This is the only known human death in California caused by a coyote. Most often, coyotes are known for attacking pets, usually domestic cats and small dogs. The Los Angeles Zoo has had trouble with coyotes eating the zoo exhibits. For example, in 1987, coyotes killed 53 flamingoes at the zoo, and also victimized the penguins. In 1995, coyotes again killed flamingoes and an Andean Condor at the zoo. As a result of the 1995 attacks, the zoo installed a 6-1/2 mile perimeter fence.

The easy access to water, food and shelter makes urban and suburban areas attractive to coyotes. A study of coyotes in Glendale and Claremont conducted by William Wirtz of Pomona College indicated that a high percentage (78 percent) of the coyotes in Glendale include garbage in their diet, while only about 25 percent of the coyotes in Claremont do so (http://www.lalc.k12.ca.us/uclasp/urban_science/urban_bestiary/coyote.htm). The reason for this difference in habits seems to be two-fold: 1) Claremont has a City ordinance that requires residents to use garbage cans that cannot be opened easily, which forces coyotes to look elsewhere for dinner, and 2) in Glendale, some people used to leave food outside for coyotes, which made these animals become more opportunistic, less fearsome of humans, and more likely to roam through residential neighborhoods. As a result, packs of coyotes are often reported in the residential areas of Glendale. The City is contracting with Los Angeles County for a coyote abatement program.

The Southern California Veterinary Medical Association (as quoted in http://www.losangelesalmanac.com/topics/Environment/ev15c.htm) has issued the following guidelines regarding coyotes and pets:

- In coyote areas, keep small pets indoors and don't let them out at night unsupervised. Most coyote attacks occur at night.
- Obey leash law and don't let pets roam. Roaming pets are more likely to be hit by cars, attacked by coyotes, or poisoned.
- Report coyote encounters to authorities. Coyote sightings and encounters are mapped by agencies. When sightings increase, authorities may issue community alerts.

- Coyotes eat a wide variety of food. Pick up pet food left outside and take it inside at night to avoid attracting unwanted guests. Remove fallen fruit, especially avocados, from yards. Store trash in containers with tight lids.
- An enclosed backyard does not provide safety for small dogs unless fencing is sufficiently high. Low fencing allows pets to escape and stray animals to enter the yard. Coyotes and cats can scale fences looking for food.
- Clear brush and dense weeds around the yard since these can provide shelter for coyotes and the rodents they hunt.
- If you see a coyote stalking your pet, yell and throw rocks at the coyote. Take your pet indoors.

6.5.2 Mountain Lions

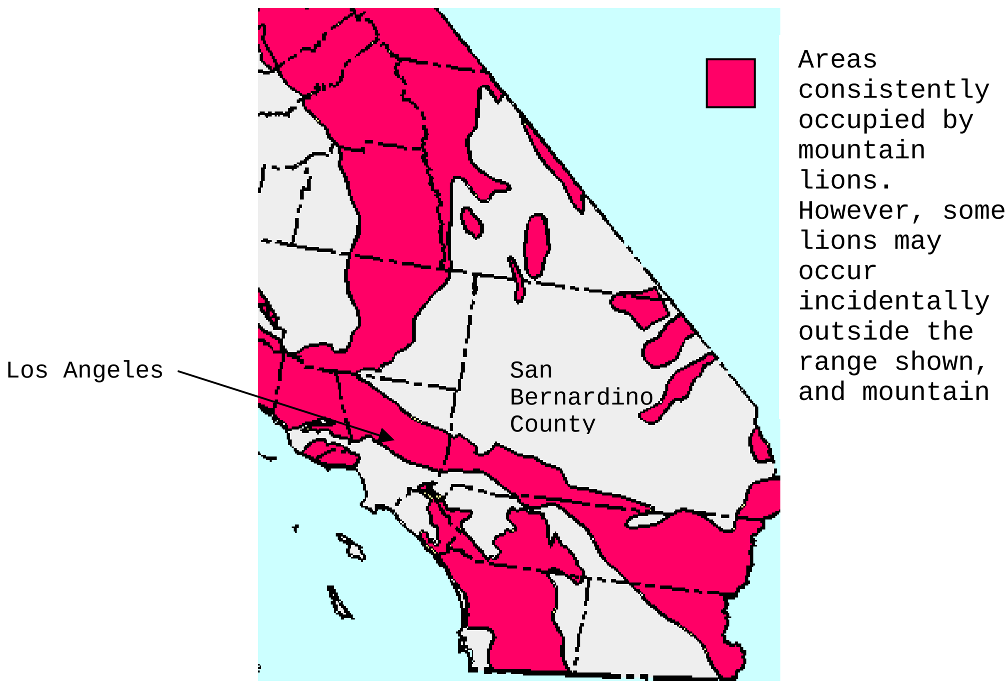
Mountain lions (*Felis concolor*; also known as pumas, panthers or cougars) are tawny-colored cats with black-tipped ears and tails. Adult male mountain lions can weigh between 130 and 150 pounds, and stretch 8 feet from their nose to the tip of their tail. Female pumas are generally smaller, usually between 65 and 90 pounds in weight, and about 7 feet long. Mountain lions are powerful hunters that usually hunt alone, and at night. Their preferred prey is deer, but they will also hunt small game and on occasion, unfortunate stray pets. A lion's hunting grounds or home range may vary between 25 and nearly 300 square miles (http://www.dfg.ca.gov/lion/; http://www.basecamp.cnchost.com/mntlions.htm).

Mountain lions are elusive and generally avoid humans. The number of mountain lions in the southern California area is unknown. However, in 1990 Californians approved Proposition 117 banning trophy hunting of the California mountain lion, and making mountain lions a specially protected mammal (http://www.mountainlion.org/habitat/prop117guide.htm). As a result of this legislation, the overall mountain lion population in California is thought to be increasing – between 4,000 and 6,000 mountain lions are thought to now live in California. However, in some areas mountain lion populations are thought to be doomed due to habitat loss and fragmentation. This is the case in the Santa Ana and Santa Monica mountains, and in the Chino Hills. In the mountainous areas of Beverly Hills, Studio City, Tarzana, and Chatsworth, naturalists estimate that there are about a dozen mountain lions left (http://www.losangelesalmanac.com/topics/Environment/ev15c.htm); their numbers in these areas are also probably decreasing. Mountain lions are also known to live in the San Gabriel Mountains north of Pasadena and Glendale. Information regarding the presence of mountain lions in the Verdugo Mountains, if any, was not readily available. The mountain lion range in southern California is shown on Figure 6-5.

The data indicate that mountain lion sightings in the last ten years have increased. Researchers attribute this to: 1) an increased awareness about mountain lions since the passing of Proposition 117; 2) encroachment of humans, especially hikers and bikers, into mountain lion habitat with an increased potential for sightings; and 3) loss of mountain lion habitat due to urban growth has resulted in an increased density of lions in parks and natural preserves. Researchers have suggested that, however, many of these reports are not correct, and that as many as 80 percent of these sightings are actually deer, bobcats, dogs, or even domestic cats.

Although the actual number of sightings has been questioned, there seems to have been a recent increase in mountain lion attacks. In 1991, Paul Beier, a wildlife ecologist, reported that in the 101 years between January 1890 and December 1990, 53 mountain lion attacks on humans had occurred in all of the United States and Canada, amounting to an average of two attacks per year. Between 1990 and 1993, however, eleven attacks were reported; four of these occurred in California. One of the more recent attacks occurred on March 20, 1995, when a cyclist was bitten and cut by a female mountain lion near Mount Lowe, in the San Gabriel Mountains north of Pasadena. The cyclist fought off the lion with rocks. The lion was subsequently tracked and killed by personnel from the California Department of Fish and Game. Most recently, on February 20, 2003, it was reported that a mountain lion crashed into a sliding glass door at a home on Starfall Drive (located in the northern portion of La Crescenta, in the San Gabriel Mountains), while apparently attempting to catch the homeowners' cat that was inside. The lion was reported to be approximately 6 feet long, 3 feet high, and at least 150 pounds. Sheriff's deputies and officials from the Department of Fish and Game tried to capture the lion, but were unsuccessful (http://www.dailynews.com/Stories/0,1413,200%257E20954%257E1194193,00.html)

Figure 6-5: Mountain Lion Range in Southern California



(Modified from http://www.dfg.ca.gov/lion/index.html)

Researchers stress that the probability of being attacked by a mountain lion is very small. Nevertheless, to reduce the possibility of being attacked by a mountain lion while hiking in the local mountains, researchers and experienced hikers suggest the following:

- Hike in groups, but do not take your dog along. Do not hike after dark or early in the morning, before dawn.
- If you encounter a mountain lion, make yourself look as big as possible. If you have children with you, pick them up and put them on your shoulders to look even bigger.
- Aggressively defend your position. Shout and wave your arms or flap your jacket. Do not crouch, and especially, DO NOT run. This is more likely to cause the mountain lion to attack. If the lion attacks, fight back.

- If camping, do not leave food outside, and do not let pets roam. Do not let children wander alone, especially in brushy or wooded areas. Do not feed the wildlife, as this can attract mountain lions and bears to the area.
- Refer all mountain lion attacks or sightings to the Park Ranger or the local office of the Department of Fish and Game.

If you live in mountain lion country, follow these guidelines:

- Deer-proof your landscape.
- Landscape for safety – remove dense and/or low lying vegetation that could provide good hiding places for mountain lions.
- Install outdoor lighting to keep the perimeter of your house well lit at night, especially along walkways.
- Keep pets and livestock secure.
- Do not feed pets outside.
- Keep a close watch on children when playing outside.

6.5.3 Bears

Southern California used to be home to grizzly bears, but these bears were hunted to extinction. The last known grizzly bear in Los Angeles County was shot and killed in either 1897 (Storer and Tevis, 1955) or 1916. In fact, by 1933, bears of any sort were extinct in the mountains of southern California, so in that year, in an attempt to reintroduce bears to the Los Angeles area, rangers from Yosemite National Park introduced 11 American Black Bears (*Ursus americanus*) to the San Gabriel Mountains near Crystal Lake. Since then, black bears have made a comeback, with the black bear population in California estimated at between 16,000 and 24,000. Between about 150 and 500 black bears are now thought to roam in the Los Angeles National Forest.

The black bear is a smaller and much less aggressive cousin of the grizzly. The name black bear is a misnomer, as most black bears west of the Mississippi River are actually cinnamon brown or gray. Black bears also come in many other shades, even white and bluish gray, usually with a patch of white on the chest called a blaze. The males are much larger than females, with males weighing in at between 200 and 600 pounds, and standing nearly six feet tall when upright. Females usually weigh between approximately 100 and 400 pounds. Black bears have non-retractable curved claws that are about one inch long. These claws allow bears to be excellent climbers.

In the wild, bears prefer forests and wooded terrain. Their diet is about 75 percent vegetarian, typically consisting of berries, plants, nuts, roots, fruit, and honey. Bears in parks, however, have learned that people and food go together, and either beg for food, or get into garbage cans and improperly stored food containers. Bears can do a substantial amount of property damage; even more troublesome, bears that become accustomed to people may become bold and aggressive. Bears in the San Gabriel Mountains are known to occasionally come down from the mountains and into developed areas, usually in search of food. As with coyotes, bears are opportunistic, and eat almost anything. Some black bears have actually become famous for their penchant to go dipping in hot tubs in peoples' backyards. The most famous of these was Samson, the "Hot Tub Bear", a local celebrity in the City of Monrovia, who lived his last six years in a made-to-order enclosure, complete with hot tub, at the Orange County Zoo.

Bears have an acute sense of smell, and are attracted to anything smelly including garbage and ripe fruit. In bear country, people are recommended to follow these guidelines (http://www.395.com/generalinfo/blackbear.shtml):

- Deodorize garbage cans with bleach or ammonia.
- Double-bag garbage to help contain odors.
- Separate "wet garbage" and keep it in an air or odor-tight container. Use a garbage disposal whenever possible. Freeze bones, fat and poultry skin until garbage pick-up day.
- Keep barbecue grills clean.
- Pick up fallen fruit, and pick ripe fruit off trees on a daily basis.
- Put away pet food and bird feeders at night.
- Close windows at night on accessible ground floors and decks.
- Don't leave food in or near a window sill or on a counter near an open window.
- Block access to potential hibernation spaces like crawl spaces under decks and buildings.
- Install bear-proof garbage and compost containers.
- Request bear-proof garbage bins for your neighborhood or apartment complex.

When visiting or hiking in bear country follow these guidelines:

- Make noise while hiking to avoid an encounter with a bear. Keep a close watch on children. If you do see a bear, do not approach it. Give it plenty of room to pass by. Do not pick up or approach a bear cub.
- Do not run from a bear. Instead, stand and face the animal. Make eye contact without staring. If you have small children with you, pick them up.
- Make yourself appear larger, stand up, raise your arms and open your jacket. Yell at the bear, bang pots or use whatever is available to make noise. Bear attacks have been avoided or injuries reduced when the victims fought back.
- If camping, bring the minimum amount of food and toiletries needed. Store food, toiletries and scented items in bear-proof containers. Do not keep food in your tent. Keep a clean camp at all times. Keep cooking utensils clean. Properly dispose of wash water and food waste away from your camping area.
- Report all bear attacks or aggressive bears to the Department of Fish and Game.

6.5.4 Raccoons

Raccoons are usually found along water courses or near wooded areas, but are also known to adapt well to suburban areas and parks. Raccoons are primarily nocturnal, and are only occasionally seen during the day. These animals will eat almost anything, and can use their hands to pry off garbage can lids and open pet food containers. Raccoons are also known to use pet doors to go into garages or houses where pet food is available to them. In campgrounds, raccoons are well known for getting into garbage cans and stealing campers' food.

Raccoons are cute-looking, and therefore people often cannot resist feeding them. However, as discussed above, this has the potential to attract other unwelcomed guests that are less lovable and far more dangerous. Raccoons themselves are very strong, and can inflict severe wounds on pets and people who try to grab them.

6.5.5 Ground Squirrels

California ground squirrels live in open spaces, and are common along roadsides and in fields or well-grazed pastures (Jameson and Peeters, 1988). These animals are diurnal and strictly ground-dwelling. Their diet includes seeds, berries, and leaves of grasses, forbs and wood plants, bulbs, tubers, and carrion.

The burrowing activities and food preferences of ground squirrels can cause substantial problems for ranchers, farmers, and homeowners. Burrowing by ground squirrels can cause significant distress to slopes, with the potential for erosion and even failure. Many species of ground squirrels carry fleas that can transmit the bacterium responsible for plague (see Section 6.7.2 below).

6.5.6 Bees, Wasps, Hornets, and Yellow Jackets

Bees, wasps, hornets, and yellow jackets can and will sting people, especially if provoked. Most bees, except for Africanized honey bees, tend to be more docile than wasps, hornets, or yellow jackets, and do not attack unless threatened or hurt. Furthermore, when a bee stings, its barbed stinger is ripped out of its abdomen along with the venom sac. As a result, the bee dies. Wasps, hornets and yellow jackets, on the other hand, are capable of repeated attacks. Bees can be recognized by their hairy and usually thick bodies, while wasps, hornets, and yellow jackets have more slender, nearly hairless, bodies. Some bees, such as honeybees, live in colonies, while others, like carpenter bees and bumblebees, live in individual nest holes, either in wood or in the ground.

Although their venom can be quite painful, bee, wasp, and hornet stings rarely kill a person unless the individual is allergic to that particular toxin. Avoidance is the best tactic for self-protection. Watch out for flowers or fruit that the bees may be eating. Be careful of meat-eating yellow jackets when cleaning fish or game, or when barbequing or eating outside. The average person has a relatively minor and temporary reaction to a bee sting and recovers in a few hours, when the pain and headache go away. Those who are allergic to bee venom, however, can have severe reactions, including anaphylactic shock, coma, and death. If antihistamine medicine is not available and a substitute cannot be found, an allergy sufferer in a survival situation is in grave danger. An individual allergic to bee venom needs to be treated immediately.

Glendale is on the watch list for Africanized Honey Bee (AHB) infestation, as is the entire Los Angeles County. Although not an issue at this time, the Los Angeles County considers AHB a potentially serious future problem if it goes unchecked. The Los Angeles County has discontinued the AHB abatement program due to budgetary reasons, but there are efforts to restart it. The County would provide AHB services for Glendale.

6.5.7 Spiders

In the Western United States, the only spider that is known to be poisonous is the black widow spider, a small, dark spider often with hourglass-shaped white, red or orange spots on their abdomens. A black widow spider bite is not fatal, but it can cause a large, painful lesion. Black widow spiders are often found in woodpiles and storage areas, but they can be found everywhere, even inside well-maintained homes. They are generally not aggressive, but will bite if disturbed.

6.5.8 Snakes

There are more than 20 different snake species common to southern California, but of these, only rattlesnakes are venomous. Of the six rattlesnake species in southern California, three are more likely to be found in Los Angeles County, including portions of Glendale. These are the Speckled, Western Diamondback and Southern Pacific rattlesnakes (http://www.werc.usgs.gov/fieldguide; http://health.ucsd.edu/poison/snakes.asp). These rattlesnakes are common to the rocky hillsides and outcrops common in Glendale. The Southern Pacific and Speckled rattlesnakes are fairly common, nervous species that may aggressively defend their position when encountered. They should not be handled. Many other non-poisonous snake species common to the area are also nervous and will bite if disturbed.

All snake bites should initially be treated as if they are poisonous, even though in nearly 20 percent of rattlesnake bites, the snake does not inject venom (http://health.ucsd.edu/poison/snakes.asp). The effect of a poisonous bite depends on the size and health of the victim, location of the bite, the amount of venom injected, and the size and type of snake. The venom of a rattlesnake causes damage to the tissue surrounding the bite, and also affects the blood clotting system. Symptoms associated with rattlesnake venom injection include pain, swelling and discoloration of the bitten area, tingling around the mouth, nausea and vomiting, weakness and dizziness, sweating and/or chills. Death from rattlesnake bites is extremely rare if the victims receive prompt medical treatment, therefore, a rattlesnake bite victim should be transported to a medical facility immediately. It is preferable to transport the victim to a medical facility rather than trying to provide first-aid care in the field. Making incisions in the fang marks, attempting to suck out the venom or applying a tourniquet are all considered ineffective and even dangerous.

6.6 Dangerous Plants

Many plants are poisonous or capable of causing highly allergic reactions. Other plants have physical defenses, such as thorns or spines, which can cause injury. There are no identifying characteristics common to all poisonous plants, but as a general rule of thumb, plants with a bitter taste, unusual or strong smell, milky sap, or red seeds or berries may be poisonous. Therefore, it is best is to know the plants common to your area or yard. If contact with a poisonous plant is an issue, those plants should be removed. Poisonous plants should not be placed in compost piles, or in burn piles (as in wood used for firewood or for barbeques), as the fumes from poisonous plants can be highly toxic. The Open Space and Conservation Element of the City of Glendale's General Plan provides an assessment of existing vegetation communities in the Verdugo and San Gabriel Mountains, and in the San Rafael Hills.

Poison oak may be present along hiking trails, in hilly areas, and especially along streams or dry creek beds, and is commonly found in the mountains of Glendale. Poison oak can cause an allergic reaction and skin rash in some individuals; a few people are especially sensitive to poison oak, and seem to develop increased sensitivity every time they come in contact with the plant. Extreme cases require immediate hospitalization. Specially prepared creams that act as a barrier on the skin for protection against poison oak are commercially available and may minimize the potential for development of skin rash if exposure occurs. If you are exposed to poison oak, wash the exposed areas thoroughly with soap and water immediately.

Oleander, which is common in many homes, and along roads, forming living fences, is poisonous when ingested, although the taste is reportedly so disagreeable that it is difficult to consume enough of it to become sick. Small children, however, may be sensitive to small amounts of this plant.

Young children, usually babies that are crawling, or toddlers, are at most risk of eating poisonous plants, since kids at this stage tend to put many things in their mouth. Therefore, to reduce the likelihood of young children ingesting a poisonous plant, a few basic rules should be followed:

- Known poisonous plants or dangerous plants should be fenced off or removed from the area where children play. There are several common ornamental plants that are poisonous. Many of these plants are identified in Table 6-1.
- Teach toddlers and older children not to eat anything straight from a plant or bush without first checking with an adult.
- Keep the Poison Control Center phone number near the phone, and maintain a bottle of ipecac syrup in your medical aid kit.

Symptoms of poisoning from plants can include:

- skin rashes
- vomiting
- stomach cramps
- irregular heart beat
- burning or stinging around and inside the mouth, and
- convulsions

The type and severity of symptoms will vary according to the type of plant eaten, the amount swallowed and the size of the individual.

If you suspect that a child or an individual has touched or eaten something poisonous, the following first aid measures can help:

- For skin contact - gently wash the skin with clear running water. If a rash develops, consult a doctor.
- For eye contact - irrigate the eye with clear running water for 20 minutes. If burning or stinging develop, consult a doctor, or report to the nearest hospital.
- For swallowed plants - remove any remaining plants and wash out the person's mouth. Monitor the individual. If the person is having difficulty breathing, is unconscious or having convulsions, immediately call 911 and the poison control center. Taking an identifying piece of the plant to the hospital or doctor can be helpful.

Table 6-1: Poisonous Plants Common in Ornamental Gardens
[Table 6-1 is not meant to be all-inclusive.
For additional information regarding poisonous plants in the local area,
refer to the local poison control service or agricultural extension office.]

Plant Name	Poisonous Parts	Symptoms
Aconite (Monkshood; Friar's Cap; Garden Wolfsbane)	Roots; leaves; seeds	Nausea; vomiting; slow pulse; burning sensation in the mouth, throat and skin; collapse; nervous excitement.
Autumn Crocus (Star of Bethlehem)	Bulbs	Vomiting and nervous excitement.
Baneberry	Roots; sap; berries	Vomiting; rapid pulse; diarrhea.
Berberis	Berries	Nausea; vomiting; diarrhea.
Broom	All parts are poisonous, but only in large amounts	Burning sensation in the mouth; nausea, vomiting; diarrhea.
Castor Oil Plant, Castor Bean, Rosary Pea	Seeds	Fatal. A single seed has caused death. One or two seeds are near the lethal dose for adults.
Cherry (both wild and cultivated)	Pits, if broken and swallowed; twigs, foliage	Headache; difficulty in breathing; vomiting; lack of coordination; dilation of the pupils; unconsciousness. Can be fatal. Contains a compound that releases cyanide when eaten.
Daffodil, Narcissus, Hyacinth	Bulbs	Nausea; vomiting; diarrhea. May be fatal.
Daphne	Bark; leaves; berries	Burning sensation in the mouth and stomach; severe cramps. A few berries can kill a child.
Deadly Nightshade (Belladonna)	Roots; leaves; seeds	Dry mouth; dilation of the pupils; irregular heartbeat; nausea; vomiting; coma.
Dieffenbachia (Dumb Cane, Elephant Ear)	All parts	Intense burning and irritation of the mouth and tongue. Death can occur if the tongue swells so much that it blocks the air passage.
Elderberry	Leaves; bark.	Headache; difficulty in breathing; nausea; vomiting; lack of coordination; dilation of the pupils; unconsciousness.
Foxglove / Digitalis	Leaves; seeds	Dizziness; nausea; vomiting; slow pulse; irregular heartbeat and pulse, digestive upset, mental confusion. May be fatal.
Hellebore	Roots; leaves; seeds	Salivation; abdominal pain; clammy skin; coma.
Hemlock	All parts	Burning sensation in the mouth; slow pulse; paralysis; coma; fatal.
Holly	Berries	Nausea; vomiting; diarrhea; drowsiness.
Hydrangea	All parts are poisonous	Headache; difficulty in breathing; vomiting; lack of coordination; dilation of the pupils; unconsciousness.
Iris	Underground stems	Severe, but not usually serious digestive upset.
Jasmine	Berries	Fatal. Digestive disturbance and nervous symptoms.
Laburnum	All parts are poisonous	Burning sensation in mouth; nausea; continual vomiting; diarrhea; collapse; delirium; convulsions; coma.
Lantana (Lantana Camara, Red Sage)	Unripe berries and leaves	Vomiting and diarrhea, dilated pupils, respiratory distress. Affects lungs, kidneys, heart and nervous system. Dermatitis can occur. Can be fatal.

Plant Name	Poisonous Parts	Symptoms
Larkspur	Leaves, seeds, young plant	Tingling sensation in mouth; agitation, severe depression; digestive upset. May be fatal.
Lily of the Valley (May Lily)	Roots, leaves, flowers, fruit	Irregular pulse and heartbeat, nausea, vomiting, dizziness; mental confusion.
Lupin	Seeds	Difficulty in breathing; paralysis, convulsions.
Mistletoe	All parts, but mostly berries	Nausea, vomiting, diarrhea, slow pulse. Both children and adults have died from eating berries.
Oleander	Leaves, branches	Extremely poisonous. Affects the heart, severe digestive upset. Can be fatal.
Rhododendron, Laurels, Azaleas	All parts	Burning of the mouth, numbness and tingling, nausea, vomiting, diarrhea, depression, difficulty breathing, prostration and coma. Can be fatal.
Rhubarb	Leaf blade	Fatal if large amounts of raw or cooked leaves can cause convulsions, and coma.
Wisteria	Seeds, pods	Mild to severe digestive upset.
Yew	All parts of plant are poisonous; foliage more toxic than berries	Abdominal pain, nausea, vomiting, diarrhea, difficulty breathing. Can be fatal. Death can occur suddenly without warning symptoms.

6.7 Disease and Vector Control

Viruses, bacteria, fungus, parasites and other living organisms can cause diseases in human beings and domesticated animals. Diseases transmitted from animals to humans are common. Therefore, contact with unfamiliar insects, plants, and animals should be generally avoided, unless trained to do so. Some arthropods and insects have the potential to transmit a variety of diseases. For example, ticks are known to be carriers of Lyme disease, Rocky Mountain spotted fever, babesiosis, and encephalitis. Mosquitoes can transmit malaria and encephalitis. Infectious and parasitic diseases can also result from exposure to contaminated water, sewage, insects, or infected people. Some of these conditions of relevance in the United States include Lyme disease, plague, encephalitis, and rabies. These diseases will be discussed further below.
Sale of illegal animals is also a concern. Several Salmonella incidences linked to reptiles, such as iguanas and turtles, have been reported in Los Angeles County. The United States has a ban on pet turtles less than four inches in length.

6.7.1 Lyme Disease

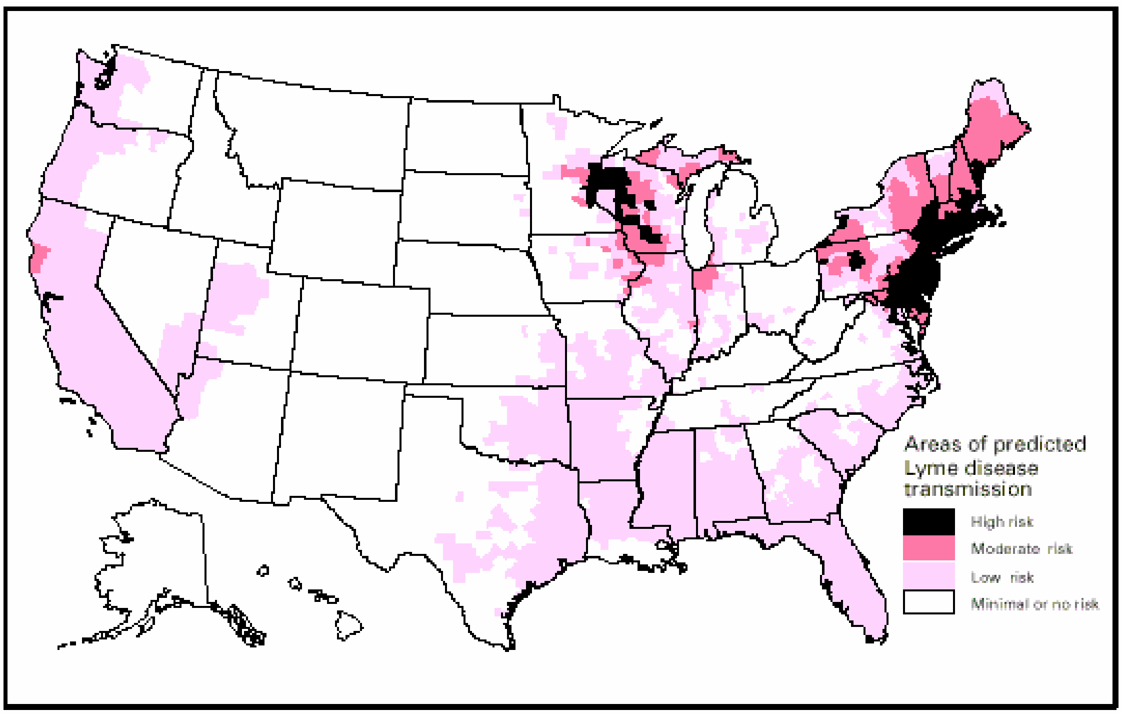
Lyme disease was first recognized in the United States in 1975, after several children were diagnosed with juvenile rheumatoid arthritis in and near Lyme, Connecticut. Scientists assigned to the case discovered that the disease is caused by a corkscrew-shaped bacterium called *Borrelia burgdorferi* that is passed to humans through the bite from a tick. The bacterium is carried by the deer tick in the eastern and central United States, and by the Western black-legged tick on the Pacific Coast. Since 1975, reports of Lyme disease have increased dramatically, and the disease has become an important public-health problem in some areas of the United States – in 1999, 16,273 cases of Lyme disease were reported to the Centers for Disease Control and Prevention, with more than 90 percent of all cases reported in the Northeast, mid-Atlantic and upper Midwest states. Few cases are actually reported in California, and these are typically in the northern part of the state. The risk of Lyme disease transmission in most of California is considered low (see Figure 6-6).

The first sign of Lyme disease is often a circular or "bulls-eye" like rash at the site of the tick bite. This rash often first appears several weeks after being bitten. The rash then usually progresses to other parts of the body. The disease can be easily cured at this stage with antibiotics, so it is important to pay attention to these symptoms and request medical assistance. If left untreated, Lyme disease can be extremely debilitating, causing pain and swelling of the joints, chronic arthritis, and in some people, neurological damage. There is a Lyme-disease vaccine (LYMErix) that is available for people who live in endemic areas or that are at high risk of contracting the disease.

6.7.2 Plague

Plague is an infectious disease of animals and humans caused by the bacterium *Yersinia pestis*. These bacteria are often carried by fleas that live on rats, mice, squirrels and other rodents, on deer, and even domestic animals. In the Western United States, the California ground squirrel and its fleas are the most common source of plague. Some recent cases of plague developed from contact with domestic cats and dogs that brought plague-infected fleas into the home. The disease is transmitted from animal to animal, and from animal to human by the bites of fleas infected with the bacterium. Although occurring less frequently, infection can also occur as a result of direct contact with tissue or body fluids of a plague-infected animal, or by inhaling droplets expelled by coughing. Plague can be transmitted from human to human.

Figure 6-6: Approximate Distribution of Predicted Lyme Disease Risk in the United States



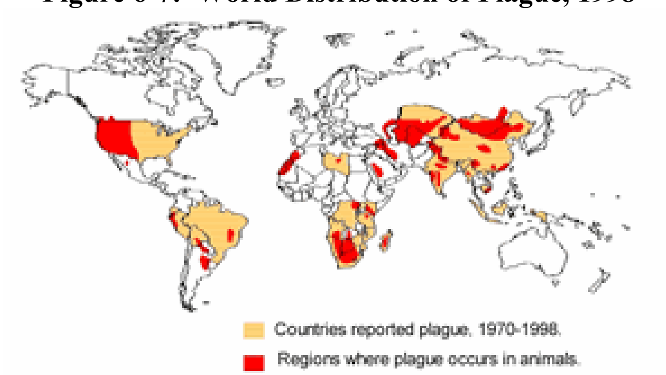
The actual risk in any given area may differ from that shown here, and the risk may change from year to year. More detailed information is best obtained from State and local health authorities.
[Figure obtained from the Centers for Disease Control and Prevention web site at http://www.cdc.gov/].

Plague was responsible for the death of millions of people in the Middle Ages, and outbreaks of this disease still occur in some rural communities and cities all around the world. In the

United States, the last urban epidemic of plague occurred in Los Angeles in 1924-1925 (http://www.cdc.gov/ncidod/dvbid/plague/index.htm). Since then, human plague in the United States has occurred as scattered cases in primarily rural areas, with ten to 15 cases reported annually. Human plague in the United States most often occurs in northern New Mexico, northern Arizona, southern Colorado, California, southern Oregon and western Nevada. The 1998 world distribution of plague is shown on Figure 6-7. Plague is considered a plausible threat if used as a biological weapon. Several countries, including the United States and the Soviet Union, reportedly developed techniques to disseminate plague as an aerosol, with the potential to infect hundreds of thousands if spread over a large urban area (http://jama.ama-assn.org/issues/v283n17/ffull/jst90013.html).

Onset of plague usually occurs two to six days after a person is exposed. Plague is often, but not always, characterized by a very painful, usually swollen, and often hot-to-the-touch lymph node called a bubo. Other symptoms include fever, and extreme exhaustion. The fever, headache and general illness may be present for a day or so before the onset of the swollen lymph nodes. The disease spreads rapidly, so prompt diagnosis and treatment with antibiotics is critical for survival. As soon as a diagnosis of suspected plague is made, the patient should be isolated, and local and State health departments should be notified.

Figure 6-7: World Distribution of Plague, 1998



(From http://www.cdc.gov/ncidod/dvbid/plague/index.htm)

Attempts to eliminate wild rodent plague are costly and futile. Therefore, the Centers for Disease Control and Prevention (http://www.cdc.gov/ncidod/dvbid/plague/index.htm) recommends environmental management and public health education as the two main preventive measures directed at reducing the threat of infection in humans in high-risk areas. Environmental management consists primarily of controlling rodent populations in both urban and rural areas; monitoring for human plague cases, and for plague in rodents; and the use of insecticides to control rodent fleas. In the Western United States, where plague is widespread in wild rodents, the following prevention measures should be considered:

- Eliminating food and shelter for rodents in and around homes, work places, and recreation areas by making buildings rodent-proof, and by removing brush, rock piles, junk, and food sources (such as pet food), from properties.
- Surveying for plague activity in rodent populations by public health workers or by citizens reporting to local health departments if sick or dead rodents found.

- Using appropriate and licensed insecticides to kill fleas during wild animal plague outbreaks to reduce the risk to humans.
- Treating pets (dogs and cats) for fleas in a regular and consistent manner.

6.7.3 Arboviral Encephalitides

Arboviruses are viruses that are transmitted between susceptible vertebrate hosts by blood-feeding arthropods, including mosquitoes and ticks. Many of the viruses that cause encephalitis have a variety of different vertebrate hosts, and some are transmitted by more than one vector. There are five main agents of encephalitis in the United States: Eastern equine encephalitis, Western equine encephalitis, St. Louis encephalitis, La Crosse encephalitis, and West Nile encephalitis. All of these are transmitted by mosquitoes. Another virus called Powassan that is transmitted by ticks is responsible for some cases of encephalitis in the northern United States. Of the five mosquito-born cases above, the Western equine encephalitis, the St. Louis encephalitis, and the West Nile Encephalitis are known to occur in California. The Western equine encephalitis virus was first isolated in 1930 in California from the brain of a horse with the disease. This virus still remains an important cause of encephalitis in horses and humans in North America. Humans infected with this virus are either asymptomatic, or exhibit mild, non-specific symptoms that include a sudden onset of fever, headache, nausea, vomiting, anorexia, and malaise. Advanced cases may experience altered mental status, weakness and signs of meningeal irritation. Children, especially infants less than one year old, are affected more severely than adults. The mortality rate for this disease is about three percent.

St. Louis encephalitis is the most-common mosquito-transmitted human pathogen in the United States. The virus is known to be distributed throughout the lower 48 states, but periodic epidemics of this disease have occurred only in the Midwest and Southeast. An average of about 193 cases are reported every year, but less than one percent of the viral infections are clinically apparent, so the actual number of infected people is probably much larger. Symptoms range from a mild fever and headache to meningoencephalitis, with an overall case to fatality ratio of between five and 15 percent. Children are usually affected less than adults, but those kids that do get the disease have a higher rate of encephalitis. The elderly have the highest risk of severe disease and death.

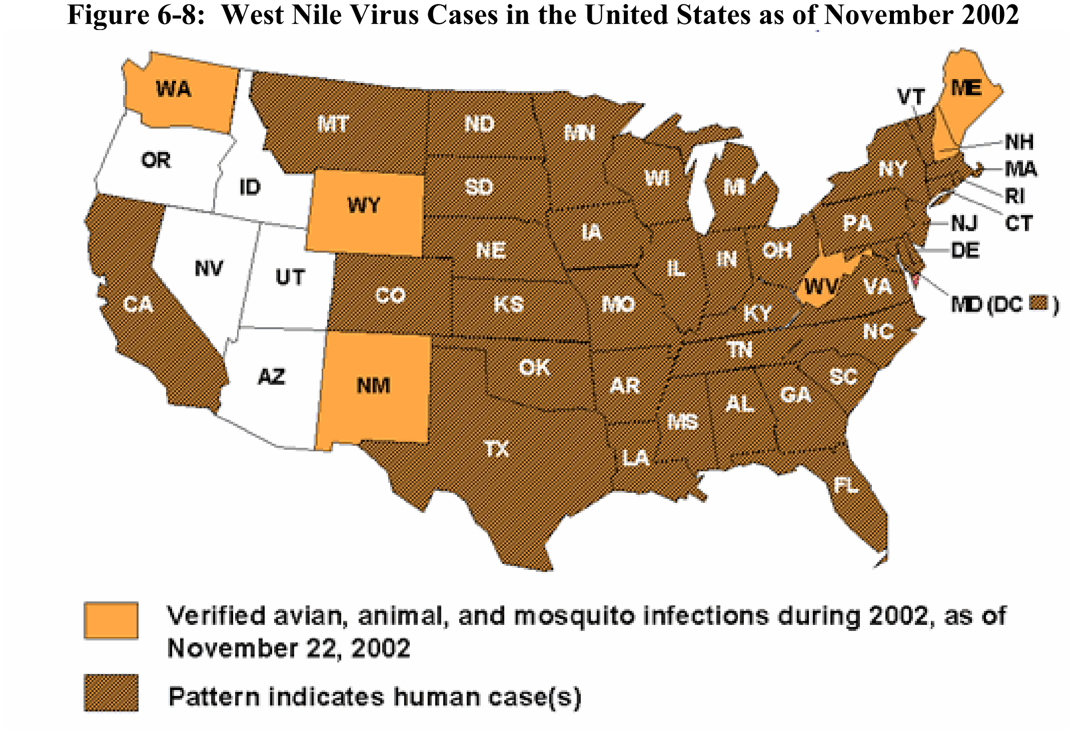
The virus responsible for West Nile encephalitis is, among others, closely related to the St. Louis encephalitis virus. West Nile encephalitis (WNE) was first isolated in the West Nile Province of Uganda in 1937. Epidemics of this virus-caused disease, impacting both humans and horses, have occurred in Israel, Europe and South Africa in the 1950s, 1960s and 1970s. The first outbreak of this disease in the United States occurred in New York City and neighboring counties in August and September of 1999. It is unknown how this virus was introduced in the United States, but international travel by infected persons or import of infected birds is suspected. The virus is typically transmitted to humans, birds, and other mammals by mosquito bites. Infected birds are the reservoir hosts – an infected bird is bitten by a mosquito and the virus is passed on to the mosquito as a blood-meal. The mosquito then bites another bird, animal or human, passing on the virus. At least 138 species of birds have been found to carry the West Nile virus. The bird hosts are only infectious for one to four days after exposure, after which they develop life-long immunity, become ill, or die. Although an unusually large number of dead birds is considered a sign that West Nile virus is present in an area, most infected birds actually do survive.

Most people infected with the West Nile virus do not develop any illness. About 20 percent of those people who do become infected develop relatively mild symptoms that include fever, headache and body aches. A skin rash on the trunk of the body and swollen lymph glands may develop in some. Only about 1 in 150 people infected with the virus will develop a severe infection, typically encephalitis or meningitis. The symptoms of severe infection include high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness and paralysis. It takes between 3 and 14 days from infection for symptoms of the disease to appear. As of January 15, 2003, 3,949 cases of West Nile virus infection have been clinically documented in humans in the United States; 254 of these people died. The disease has been reported in 40 states; only one non-fatal case has been reported in California. The distribution of West Nile virus in the United States is shown on Figure 6-8.

6.7.4 Rabies

Rabies is a preventable viral disease of mammals that can be transmitted to humans through the bite from a rabid animal. Rabies used to be relatively common in the early 1900s, with approximately 100 human deaths as a result of rabies reported every year. In the last ten years or so, the Centers for Disease Control and Prevention have reported one to two cases of human deaths due to rabies every year; these are usually people who did not seek medical attention because they were unaware that they had been bit. This significant decrease in the number of human cases has come about as a result of an extensive public health education campaign that includes the required vaccination of all domestic animals. As a result, more than 90 percent of all rabies cases reported are now related to wild animals rather than domestic animals. The main wild carriers of rabies include raccoons, skunks, bats and foxes.

Figure 6-8: West Nile Virus Cases in the United States as of November 2002



(Figure from http://www.cdc.gov/ncidod/dvbid/westnile/)

The rabies virus affects the central nervous system. Early symptoms of rabies in humans are nonspecific, consisting of fever, headache, and general malaise. As the disease progresses, neurological symptoms appear. These may include insomnia, anxiety, confusion, slight or partial paralysis, excitation, hallucinations, agitation, hypersalivation, difficulty swallowing, and fear of water (hydrophobia). Death usually occurs within days of the onset of symptoms. The acute period of the disease typically ends after two to ten days. Once the clinical signs of rabies appear, the disease is nearly always fatal (http://www.cdc.gov/ncidod/dvrd/rabies/Introduction/intro.htm).

There is no treatment for rabies once the symptoms of the disease appear. Therefore, people who are bit by rabid or potentially rabid animals need to obtain medical help immediately. The rabies vaccine regimen provides immunity to rabies when administered shortly after exposure. Vaccines can also be administered for protection before an exposure occurs. Approximately 40,000 people in the United States receive post-exposure treatment annually.

The Pasadena Humane Society (PHS) considers rabies in wild animals a high-risk problem. The PHS keeps a close tab on rabbits and bats as carriers of the disease.

6.7.5 Hantavirus Pulmonary Syndrome

An outbreak of an unexplained illness was first noticed in May 1993 in the Four Corners region, where several young Native Americans died as a result of this condition. The symptoms included fever, muscle aches, headache, and cough, progressing rapidly to severe lung disease that simulated acute respiratory distress syndrome. Laboratory findings by the Centers for Disease Control and Prevention showed that the illness is caused by a previously unknown virus that has since been isolated and named Sin Nombre Virus (SNV), and the condition is called hantavirus pulmonary syndrome (HPS). Symptoms include, from most frequent to less frequent, fever, chills, headache, muscular pain, nausea and vomiting, abdominal pain, diarrhea, cough, shortness of breath, dizziness, joint pain, back or chest pain, and sweats. Coughing does not usually start before approximately the seventh day. Once the pulmonary phase begins, the disease progresses rapidly, requiring hospitalization. The disease can be treated successfully with antibiotics.

Available data indicate that the common deer mouse is the main host, but the virus can also be found in pinion mice, brush mice, and western chipmunks. Human infection may occur when infective saliva or excreta are inhaled as aerosols produced directly from the animal. Transmission may also occur when dried materials contaminated by rodent excreta are disturbed, directly introduced into broken skin, introduced into the eyes, or possibly ingested in contaminated food or water. Persons can also be infected after being bitten by rodents.

As of January 2003, 331 cases of HPS have been reported in the United States, in 31 states. Thirty-five of those cases occurred in California.

6.8 Summary of Findings

With the September 11, 2001 events, the threat of terrorism on United States' soil has become real for most people. California is considered a significant potential terrorist target given its worldwide recognition as an economic, cultural and technological power. Since Glendale is an integral part of southern California, its potential as a terrorist target needs to be considered. A regional analysis suggests, however, that other neighboring communities have a higher terrorist risk. Nevertheless, the Glendale Police Department has modified and developed a variety of programs and procedures to deal effectively with civil unrest and terrorist attacks. These programs should be continued and improved upon as new data and procedures designed to deal with these issues become available or are developed and proven to be of significant value. This includes holding annual or bi-annual practice scenarios that involve all divisions of city government responsible for responding to this type of emergency.

In accordance with the California Terrorism Response Plan, the City's Police and Fire Departments have primary responsibility for protecting the public health and safety (Consequence Management) should a terrorist attack or civil disturbance event occur in the City. If an event exceeds the capabilities of the Glendale Police Department, additional local resources at the county, State and national levels are available through mutual aid agreements and partnerships with various organizations. The Federal Government, through local offices of the Federal Bureau of Investigation (FBI), is responsible for identifying, apprehending, and neutralizing the terrorists and their weapons (Crisis Management). Any terrorist threats received at the local or State level are assessed by the California Anti-Terrorism Information Center. Threats are evaluated and relevant information is then sent to the appropriate agencies at all levels, as deemed necessary.

Crime in California has decreased drastically in the last twenty years, to levels nearly one-half the rate of the 1980 peak. Consistent with statewide trends, crime in Glendale has also decreased, with levels in 2001 nearly one-half the rate of 1992. The data suggest however, that in 2002 there was a moderate increase in the crime rate in Glendale. Nevertheless, Glendale has one of the lowest crime rates in the southern California area, and is one of the safest California cities with a population of more than 100,000. Crime rates within Glendale, as in most other cities, vary significantly by census tract. The highest crime rates in Glendale are reported in the area adjacent to the Glendale Galleria and in those census tracts with the highest population densities in the City. Property crimes in Glendale far outnumber crimes against persons. Police statistics also show that white-collar crimes, such as fraud and identity theft have increased in the last few years. The Glendale Police Department utilizes a variety of programs to fight crime. The community as a whole has zero tolerance for criminal activity. The City's Police Department should continue to monitor their case load to identify any shifts in the types, numbers or locations of crimes in the City. This would allow the Police Department to respond to these changes effectively and thereby continue to provide the quality of service that the community expects.

Major accident response in the City of Glendale is handled in accordance with the State's Standardized Emergency Management System (SEMS), which defines the specific responsibilities of the various City agencies and City staff in the event of an emergency. This document identifies and describes the procedures to be taken by the local emergency management organization, including communication among the various response teams. Training and exercises are conducted regularly in accordance with State requirements. The City's Emergency Plan should be reviewed annually or bi-annually to ensure that the information contained therein, such as telephone numbers, and personnel assignments are correct and current.

The City of Glendale includes and abuts some of the last fairly undeveloped territory available in Los Angeles County, where the wild animal population includes coyotes, opossums, deer, rabbits, bats, raccoons, squirrels, skunks, rattlesnakes, mountain lions, bobcats and bears. This provides Glendale residents with the opportunity to sight in their own backyard coyotes, rattlesnakes and other wild animals; several of these animals may also be seen along the various nature trails that criss-cross the local mountains. Although most wild animals avoid contact with humans, residents and hikers have the responsibility of limiting contact with these animals, many of which can be carriers of disease or can be dangerous if they feel threatened.

Coyotes are very common in this area of Los Angeles County. These animals are highly adaptable and easily become urbanized, surviving on garbage, pet food left outside, fruit and vegetables in orchards and gardens, and even small pets. Packs of coyotes are known to roam some of Glendale's neighborhoods, in part because residents used to leave food outside for these animals. Using garbage cans that cannot be opened easily, and removing food left outside for coyotes can help dissuade coyotes from roaming the area. The City may consider providing residents in and near the hillside areas with trash receptacles that cannot be easily opened or knocked over. Although unusual, coyote attacks do occur. The only known human death in California caused by a coyote occurred in Glendale in 1981, when a 3-year old girl was killed in her yard by a coyote. Therefore, residents in the hillside areas of the City are cautioned about leaving unsupervised small children and pets in their yards. New residents could be provided with brochures that describe the local fauna, including potential hazards. These flyers could be issued during the process of, for example, signing up for utilities with the appropriate local utility providers. Information about how to live peacefully with the local animal population could also be provided on the City's web page.

Mountain lions are known to live in the San Gabriel Mountains north of the City. These animals are elusive and generally avoid humans, but two mountain lion encounters have been reported in the local mountains since 1995. Although the probability of being attacked by a mountain lion is remote, there are several actions that hikers, cyclists and residents can take to reduce their exposure. The local San Gabriel Mountains are also home to American Black Bears, a misnomer since most bears in this area are cinnamon brown or gray in color. Bears are also generally elusive in the wild, but do adapt well to living near humans. Most of the recommendations suggested to reduce the potential encounter with a mountain lion also apply to an encounter with a black bear. Informational flyers at the entrance to trailheads that describe the potentially dangerous animals and plants that may be encountered in the local hillsides and mountains, including tips on how to evade or fight off an attack can be used to educate the individuals that chose to hike or bike in the area.

Of the six rattlesnake species known to live in California, three are known to be found in Los Angeles County, generally in rocky hillsides and rock outcrops such as those common in Glendale. The Southern Pacific and Speckled rattlesnakes are known to aggressively defend their position when encountered. These snakes should not be handled, and is best to give them a wide berth if found in the wild. Many other non-poisonous snakes are common to the area, and some of these will also bite if disturbed. All snake bites should be treated initially as if they are poisonous. The best course of action is to transport the victim immediately to a health care facility. Making incisions in the fang marks, attempting to suck out the venom or applying a tourniquet are all considered ineffective and even dangerous measures.

Bites from bees, wasps, hornets, yellow jackets and black widow spiders can be very painful but are not fatal, unless the individual is allergic to that particular toxin. Avoidance is the best tactic for self-protection. Watch out for bees, wasps and yellow jackets when preparing food or eating outside, and be careful when moving or working around woodpiles and storage areas where black widow spiders are commonly found. Individuals with known allergic reactions to bee venom should have antihistamine medicine readily available, especially when outdoors. If a person allergic to bee venom is bitten, and antihistamine medication is not available, the victim should be transported immediately to a medical facility for treatment. Glendale is on the watch list for Africanized Honey Bee (AHB) infestation, but AHBs are not considered a major threat at this time. The City should monitor for any reports of AHBs in the Los Angeles County, and if there are an increased number of cases, should consider establishing an AHB abatement program.

Raccoons, ground squirrels, rabbits, deer and bats can be carriers of diseases, such as rabies and plague. Only one to two human deaths due to rabies occur in the United States every year; these are usually people who did not seek medical attention because they were unaware that they had been bitten. If detected early, rabies can be treated, but once the clinical signs of rabies appear, the disease is nearly fatal. Ground squirrels and their fleas are the most common source of plague in the western United States, although flea-infested domestic cats and dogs have also been know to transmit this disease. Today, plague can be treated and cured with antibiotics, provided that it is diagnosed promptly. Vaccinating domestic animals and treating them to control flea infestations are effective means of controlling rabies and plague. The City should continue to encourage residents to have their pets vaccinated for rabies and provide information about the benefits of flea control as a method for preventing the spread of dangerous diseases.

Deer are typically the hosts to ticks that carry and transmit Lyme disease, a debilitating condition that causes pain and swelling of the joints, chronic arthritis and even neurological damage. If the disease is diagnosed early, it can be cured with antibiotics. In southern California, Lyme disease is not common.

The three different kinds of mosquito-transmitted encephalitis known to occur in the western United States are the Western equine, St. Louis and West Nile encephalitis, but overall only a few encephalitis cases in humans have been reported in California. Most people exposed to any of these viruses do not develop any illness, or report only minor symptoms, such as mild fever, headache and body aches. Young children, seniors and people with compromised immune systems are more likely to be severely impacted, developing encephalitis or meningitis. Local and national agencies keep track of bird mortalities and reports of encephalitis cases diagnosed in the area, and issue public alerts as needed. The City should continue to monitor for unusual numbers of dead rodents or birds and report these sightings to the appropriate County agencies, especially during the summer, when these viral illnesses are more common.

Deer mice, pinion mice, brush mice and western chipmunks are the main hosts to the virus that causes hantavirus pulmonary syndrome (HPS), a condition that can result in severe respiratory distress in advanced cases. The disease can be treated successfully with antibiotics. This disease was first reported in the Four Corners region of the Southwest in 1993; by 2003, 331 cases of HPS have been reported in the United States. Thirty-five of those cases occurred in California. Good housekeeping to deter the presence of rodents in and around residences, sheds and gardens can help decrease the potential for people to become in contact with rodents or their excreta, which are the main mode of human infection. The City should continue to enforce those sections of the City Code regarding rodent control (City Code Sections 8.48.010 et seq.).

Many landscaping and native plants are poisonous or capable of causing highly allergic reactions. Toddlers and infants are at most risk of eating poisonous plants since young kids tend to put things into their mouths. In households with young children, poisonous plants should be removed or fenced to reduce the potential for accidental poisoning. A list of common poisonous plants is provided in this report; additional information can be obtained from local poison control centers or a local agricultural extension office. Some people are sensitive to poison oak, a plant common in the mountains of Glendale. Sensitivity is generally manifested as a skin rash; in extreme cases, people who have come in contact with poison oak leaves or roots may require hospitalization. Oleander, common along many roads and used as a living fence in many parts of southern California, is poisonous if ingested. Poisonous plants should never be placed in compost piles or used for burning, such as wood used for firewood or barbeques.

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APPENDIX A
REFERENCES

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Appendix A
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APPENDIX B
USEFUL WEB SITES

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Appendix B
USEFUL WEB SITES

Geologic Hazards in General

http://geohazards.cr.usgs.gov/
USGS Hazard Team website. Hazard information on commonly recognized hazards such as earthquakes, landslides, and volcanoes. Contains maps and slide shows.

http://www.usgs.gov/themes/hazard.html
A webpage by the USGS on hazards such as hurricanes, floods, wildland fire, wildlife disease, coastal storms and tsunamis, and earthquakes. Also has information on their Hazard Reduction Program.

http://www.consrv.ca.gov/dmg/index.htm
Homepage for the California Geologic Survey (formerly the Division of Mines and Geology). Information their publications (geologic reports and maps), programs (seismic hazard mapping, Alquist-Priolo Earthquake Fault Study Zone maps); and other brochures (asbestos, natural hazard disclosure).

http://www.oes.ca.gov/
California Governor's Office of Emergency Services website. Contains information on response plans regarding natural disasters (earthquakes), terrorist attacks, and electrical outages, and information on past emergencies.

Geologic Maps

http://wrgis.wr.usgs.gov/wgmt/scamp/scamp.html
Homepage for the Southern California Aerial Mapping Project(SCAMP), which is the USGS' program to update geologic maps of Southern California at a 1:100,000 scale and release these in a digital GIS format.

Seismic Hazards, Faults, and Earthquakes

http://www.consrv.ca.gov/dmg/shezp/schedule.htm
Shows the current list of seismic hazard maps available from the California Geologic Survey. These can be downloaded in a .pdf format.

http://www.scecdc.scec.org.
Southern California Earthquake data center (hosted by SCEC, USGS, and Caltech. Shows maps and data for recent earthquakes in Southern California and worldwide. Catalogs of historic earthquakes.

http://www.consrv.ca.gov/dmg/geohaz/eq_chron.htm
List of California earthquakes (date, magnitude, latitude longitude, description of damage)

http://geohazards.cr.usgs.gov/eq/html/canvmap.html
Website at the USGS Earthquake Hazard's Program that lists seismic acceleration maps available for downloading.

http://www.seismic.ca.gov/
Homepage of the California Seismic Safety Commission. Contains information on California earthquake legislation, safety plans, and programs designed to reduce the hazards from earthquakes. Includes several publications of interest, including "The Homeowner's Guide to Earthquake Safety." Also contains a catalog of recent California earthquakes.

Landslides and Debris Flows

http://landslides.usgs.gov/index.html
USGS Landslide webpage. Links to their publications, recent landslide events, and bibliographic databases.

http://www.consrv.ca.gov/dmg/shezp/index.htm
California Geologic Survey website on Seismic Hazard maps.

http://vulcan.wr.usgs.gov/Glossary/Lahars/framework.html
USGS Volcanic Observatory website list of links regarding mudflows, debris flows, and lahars.

http://www.fema.gov/library/landslif.htm
Federal Emergency Management Agency (FEMA) fact sheet website about landslides and mudflows.

Flooding, Dam Inundation, and Erosion (Note: the information on some of these web sites may no longer be available – data have been removed due to safety concerns).

http://vulcan.wr.usgs.gov/Glossary/Sediment/framework.html
US Geological Survey Volcanic Observatory website list of links regarding sediment and erosion.

http://www.usace.army.mil/public.html#Regulatory
US Army Corps of Engineers website regarding waterway regulations.

http://crunch.tec.army.mil/nid/webpages/nid.cfm
National Inventory of Dams.

http://www.spl.usace.army.mil/resreg/htdocs/Briefing_main.html
US Army Corps of Engineers website about reservoirs in the Los Angeles District.

http://www.fema.gov/fema/nfip.htm
FEMA website about the National Flood Insurance Program.

http://ceres.ca.gov/planning/nhd/dam_inundation.html
Dam inundation information provided by the California Office of Emergency Services

Fire Hazards

http://osfm.fire.ca.gov/FFLaws.html
Site that pertains to California laws about fires and firefighters

http://www.fire.ca.gov/
California Department of Forestry and Fire Protection's Web Site.

http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/FirePlan.asp
California Fire Plan.

http://www.fireplan.gov
National Fire Plan.

http://fire.ci.glendale.ca.us/main.html
City of Glendale Fire Department web site.

http://nfpa.org/
National Fire Protection Association Web Site.

http://firewise.org/
Site dedicated to providing information to homeowners about becoming firewise in the urban/wildland interface.

http://www.fema.gov/
Federal Emergency Management Agency Web Site; includes general information on how to prepare for wildfire season, current fire events, etc.

http://www.usfa.fema.gov/
U.S. Fire Administration Web Site.

http://www.iso.com
Insurance Services Office Web Site.

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APPENDIX C
HAZUS EARTHQUAKE SCENARIO REPORTS

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HAZUS 99-SR2: Earthquake Scenario Report for the City of Glendale

Earthquake Scenario: Magnitude 6.7 Earthquake on the Verdugo Fault

Disclaimer:

The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

- California

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 30 square miles and contains 28 census tracts. There are over 68 thousand households in the region and has a total population of 194,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 33 thousand buildings in the region with a total building replacement value (excluding contents) of 9,848 million dollars (1994 dollars). Approximately 96% of the buildings (and 76% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 3,258 and 245 million dollars (1994 dollars), respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 33,000 buildings in the region which have an aggregate total replacement value of 9,848 million dollars (1994 dollars). Figure 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

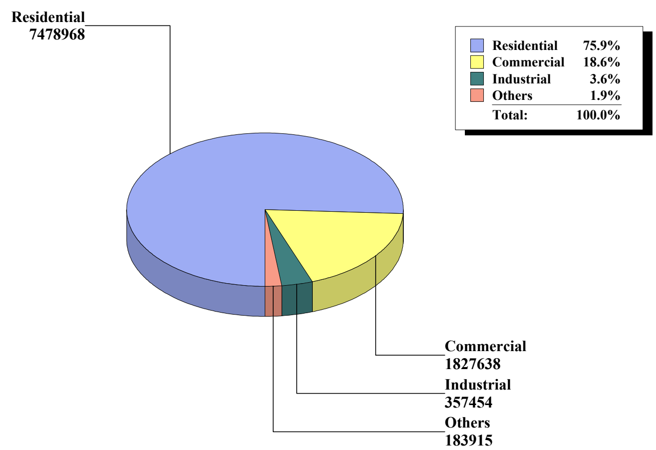

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 94% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilites into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 3 hospitals in the region with a total bed capacity of 942 beds. There are 70 schools, 9 fire stations, 2 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 4 of the dams are classified as 'high hazard'. The inventory also includes 470 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in Tables 2 and 3.

The total value of the lifeline inventory is over 3,290 million dollars. This inventory includes over 281 kilometers of highways, 143 bridges, 0 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component		# locations/ # Segments	Replacement value (millions of dollars)
Highway	Major Roads		5	2,813
	Bridges		143	419
	Tunnels		0	0
		Subtotal		3,232
Railways	Rail Tracks		2	19
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		19
Light Rail	Rail Tracks		0	0
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		0
Bus	Facilities		0	0
Ferry	Facilities		0	0
Port	Facilities		0	0
Airport	Facilities		4	8
	Runways		0	0
		Subtotal		8
		Total		**3,258**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	87.5
	Subtotal		87.5
Waste Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	52.5
	Subtotal		52.5
Natural Gas	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	35.0
	Subtotal		35.0
Oil Systems	Pipelines	0	0.0
	Facilities	0	0.0
	Subtotal		0.0
Electrical Power	Facilities	0	0.0
	Distribution Lines	*NA*	26.2
	Subtotal		26.2
Communication	Facilities	16	32.0
	Distribution Lines	*NA*	11.7
	Subtotal		43.7
	Total		**244.9**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	Verdugo Fault 6.7Mw
Type of Earthquake	Source event
Fault Name	
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-118.253
Latitude of Epicenter	34.117
Earthquake Magnitude	6.4
Depth (Km)	0
Rupture Length (Km)	17
Rupture Orientation (degrees)	0
Attenuation Function	Project 97 West Coast

Building Damage

Building Damage

HAZUS estimates that about 7,330 buildings will be at least moderately damaged. This is over 22.254% of the total number of buildings in the region. There are an estimated 165 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	12,411	97.31	12,326	97.13	6,054	93.60	681	79.00	140	84.85
Commercial	259	2.03	274	2.16	312	4.82	138	16.01	20	12.12
Industrial	58	0.45	64	0.50	80	1.24	36	4.18	5	3.03
Agriculture	2	0.45	2	0.00	1	0.02	0	0.00	0	0.00
Religion	18	0.14	18	0.00	18	0.28	7	0.81	0	0.00
Government	1	0.01	1	0.00	1	0.02	0	0.00	0	0.00
Education	5	0.04	5	0.04	2	0.03	0	0.00	0	0.00
Total	**12,754**		**12,690**		**6,468**		**862**		**165**	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	132	1.0	110	0.9	125	1.9	47	5.5	3	1.9
Mobile Homes	4	0.0	9	0.1	26	0.4	9	1.0	0	0.0
Precast Concrete	87	0.7	48	0.4	104	1.6	49	5.7	6	3.8
RM*	266	2.1	148	1.2	230	3.6	90	10.4	4	2.6
Steel	138	1.1	66	0.5	127	2.0	48	5.6	0	0.0
URM*	15	0.1	32	0.3	62	1.0	28	3.2	6	3.8
Wood	12,112	95.0	12,277	96.7	5,794	89.6	591	68.6	137	87.8

*Note:

RM Reinforced Masonry
URM Unreiforced Masonry

Essential Facility Damage

Before the earthquake, the region had 942 hospital beds available for use. On the day of the earthquake, the model estimates that only 233 hospital beds (25%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 44% of the beds will be back in service. By 30 days, 72% will be operational.

Table 6: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Least Moderate Damage > 50%	Complete Damage > 50%	Functionality > 50% at day 1
Hospitals	3	2	0	1
Schools	70	27	0	0
EOCs	1	0	0	0
Police Stations	2	0	0	0
Fire Stations	9	0	0	0

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

			Number of Locations			
System	**Component**	**Locations/ Segments**	**With at Least Mod. Damage**	**With Complete Damage**	**With Functionality > 50 % After Day 1**	**After Day 7**
Highway	**Roads**	5			5	5
	Bridges	143	25	6	136	142
	Tunnels	0	0	0	0	0
Railways	**Tracks**	0			2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	**Tracks**	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	**Facilities**	0	0	0	0	0
Ferry	**Facilities**	0	0	0	0	0
Port	**Facilities**	0	0	0	0	0
Airport	**Facilities**	4	2	0	3	4
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8 through10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

		# of Locations			
System	**Total #**	**With at Least Moderate Damage**	**With Complete Damage**	**with Functionality > 50 % After Day 1**	**with Functionality > 50 % After Day 7**
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	16	11	1	16	16
Total	**17**	**11**	**1**	**16**	**16**

Table 9 : Expected Utility System Pipeline Damage

System	**Total Pipelines Length (kms)**	**Number of Leaks**	**Number of Breaks**
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	0	0	0
Total	**0**	**0**	**0**

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	**Number of Households without Service**				
		At Day 1	**At Day 3**	**At Day 7**	**At Day 30**	**At Day 90**
Potable Water	68,186	15,715	8,193	10	0	0
Electric Power	68,186	57,478	45,336	25,592	3,977	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 20 ignitions that will burn about 10 sq. mi (27.4% of the region's total area.) The model also estimates that the fires will displace about 1,400 people and burn about 60 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.70 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 32% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 28,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 2,932 households to be displaced due to the earthquake. Of these, 2,302 people (out of a total population of 194,000) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level 1: Injuries will require medical attention but hospitalization is not needed.

Severity Level 2: Injuries will require hospitalization but are not considered life-threatening

Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.

Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum, and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	Residential	345	62	6	11
	Non-Residential	15	4	1	1
	Commute	0	0	0	0
	Total	360	66	7	12
2 PM	Residential	93	17	2	3
	Non-Residential	565	134	20	39
	Commute	0	1	1	0
	Total	658	152	22	42
5 PM	Residential	111	20	2	4
	Non-Residential	207	49	7	14
	Commute	1	1	2	0
	Total	319	71	11	18

Economic Loss

The total economic loss estimated for the earthquake is 1,456 million dollars, which represents 11 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 1,407 million dollars. 18% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 63% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Structural	76.2	44.6	8.7	3.9	**133.5**
	Non-Structural	525.9	151.4	28.5	14.5	**720.2**
	Content	170.0	89.5	21.8	8.1	**289.4**
	Inventory	N/A	1.3	3.1	0.0	**4.4**
	Subtotal	772.0	286.9	62.1	26.5	**1,147.5**
Business Interruption Loss	Wage	2.3	43.2	1.4	1.1	**48.0**
	Income	1.1	35.8	0.8	0.3	**38.0**
	Rental	49.7	20.3	1.0	0.7	**71.6**
	Relocation	57.0	35.4	4.3	5.5	**102.2**
	Subtotal	110.1	134.7	7.5	7.6	**259.8**
	Total	882.1	421.5	69.6	34.1	**1,407.3**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Roads	2,812.8	0.0	0.0
	Bridges	419.0	33.5	8.0
	Tunnels	0.0	0.0	0.0
	Subtotal	3,231.8	33.5	1.0
Railways	Tracks	18.5	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	18.5	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	0.0	0.0	0.0
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities			
		0.0	0.0	0.0
Airport	Facilities	8.0	2.9	36.6
	Runways	0.0	0.0	0.0
	Subtotal	8.0	2.9	36.6
		3,258.3	**36.4**	**1.1**

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	87.5	*NA*	*NA*
	Subtotal	87.5	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	52.5	*NA*	*NA*
	Subtotal	52.5	0.0	0.0
Natural Gas	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	35.0	*NA*	*NA*
	Subtotal	35.0	0.0	0.0
Oil Systems	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.00
Electrical Power	Facilities	0.0	0.0	0.0
	Distribution Lines	26.2	*NA*	*NA*
	Subtotal	26.2	0.0	0.0
Communication	Facilities	32.0	11.7	36.4
	Distribution Lines	11.7	*NA*	*NA*
	Subtotal	43.7	11.7	36.4
	Total	**244.9**	**11.7**	**17.4**

Appendix A: County Listing for the Region

California
- Los Angeles

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
California					
	Los Angeles	194,000	7,480	2,370	9,850
State Total		*194,000*	*7,480*	*2,370*	*9,850*
Region Total		**194,000**	**7,480**	**2,370**	**9,850**

HAZUS 99-SR2: Earthquake Scenario Report for the City of Glendale

Earthquake Scenario: Magnitude 7.2 Earthquake on the Sierra Madre Fault

Disclaimer:

The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

- California

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 30 square miles and contains 28 census tracts. There are over 68 thousand households in the region and has a total population of 194,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 33 thousand buildings in the region with a total building replacement value (excluding contents) of 9,848 million dollars (1994 dollars). Approximately 96% of the buildings (and 76% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 3,258 and 245 million dollars (1994 dollars), respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 33,000 buildings in the region which have an aggregate total replacement value of 9,848 million dollars (1994 dollars). Figure 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

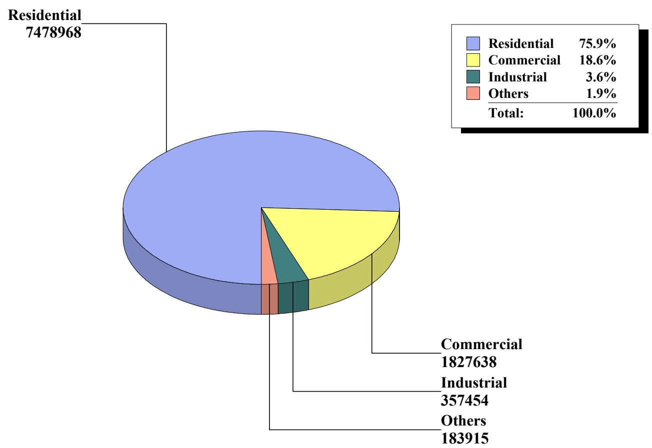

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 94% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilites into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 3 hospitals in the region with a total bed capacity of 942 beds. There are 70 schools, 9 fire stations, 2 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 4 of the dams are classified as 'high hazard'. The inventory also includes 470 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in Tables 2 and 3.

The total value of the lifeline inventory is over 3,290 million dollars. This inventory includes over 281 kilometers of highways, 143 bridges, 0 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component		# locations/ # Segments	Replacement value (millions of dollars)
Highway	Major Roads		5	2,813
	Bridges		143	419
	Tunnels		0	0
		Subtotal		3,232
Railways	Rail Tracks		2	19
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		19
Light Rail	Rail Tracks		0	0
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		0
Bus	Facilities		0	0
Ferry	Facilities		0	0
Port	Facilities		0	0
Airport	Facilities		4	8
	Runways		0	0
		Subtotal		8
		Total		**3,258**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	87.5
	Subtotal		87.5
Waste Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	52.5
	Subtotal		52.5
Natural Gas	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	35.0
	Subtotal		35.0
Oil Systems	Pipelines	0	0.0
	Facilities	0	0.0
	Subtotal		0.0
Electrical Power	Facilities	0	0.0
	Distribution Lines	*NA*	26.2
	Subtotal		26.2
Communication	Facilities	16	32.0
	Distribution Lines	*NA*	11.7
	Subtotal		43.7
	Total		**244.9**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	Sierra Madre Fault 7.2Mw
Type of Earthquake	Source event
Fault Name	
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-118.257
Latitude of Epicenter	34.2373
Earthquake Magnitude	7.2
Depth (Km)	0
Rupture Length (Km)	57
Rupture Orientation (degrees)	0
Attenuation Function	Project 97 West Coast

Building Damage

Building Damage

HAZUS estimates that about 4,993 buildings will be at least moderately damaged. This is over 15.136% of the total number of buildings in the region. There are an estimated 55 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	15,718	96.96	11,362	96.87	4,166	92.33	387	80.46	51	92.73
Commercial	376	2.32	276	2.35	257	5.70	68	14.14	2	3.64
Industrial	78	0.48	65	0.55	71	1.57	24	4.99	2	3.64
Agriculture	2	0.48	2	0.00	2	0.04	0	0.00	0	0.00
Religion	25	0.15	18	0.00	14	0.31	2	0.42	0	0.00
Government	1	0.01	1	0.00	0	0.00	0	0.00	0	0.00
Education	10	0.06	5	0.04	2	0.04	0	0.00	0	0.00
Total		**16,210**		**11,729**		**4,512**		**481**		**55**

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	187	1.2	103	0.9	103	2.3	25	5.3	0	0.0
Mobile Homes	1	0.0	8	0.1	25	0.6	12	2.5	2	4.1
Precast Concrete	126	0.8	59	0.5	83	1.8	22	4.6	2	4.1
RM*	361	2.2	149	1.3	167	3.7	57	12.0	0	0.0
Steel	168	1.0	73	0.6	106	2.3	34	7.1	0	0.0
URM*	43	0.3	39	0.3	50	1.1	11	2.3	1	2.0
Wood	15,324	94.5	11,298	96.3	3,978	88.2	315	66.2	44	89.8

*Note:
RM Reinforced Masonry
URM Unreiforced Masonry

Essential Facility Damage

Before the earthquake, the region had 942 hospital beds available for use. On the day of the earthquake, the model estimates that only 378 hospital beds (40%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 59% of the beds will be back in service. By 30 days, 83% will be operational.

Table 6: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Least Moderate Damage > 50%	Complete Damage > 50%	Functionality > 50% at day 1
Hospitals	3	0	0	0
Schools	70	8	0	0
EOCs	1	0	0	0
Police Stations	2	0	0	0
Fire Stations	9	0	0	0

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

				Number of Locations		
System	**Component**	**Locations/ Segments**	**With at Least Mod. Damage**	**With Complete Damage**	**With Functionality > 50 % After Day 1**	**After Day 7**
Highway	**Roads**	5			5	5
	Bridges	143	22	5	141	143
	Tunnels	0	0	0	0	0
Railways	**Tracks**	0			2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	**Tracks**	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	**Facilities**	0	0	0	0	0
Ferry	**Facilities**	0	0	0	0	0
Port	**Facilities**	0	0	0	0	0
Airport	**Facilities**	4	2	0	4	4
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8 through10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

System	Total #	# of Locations: With at Least Moderate Damage	# of Locations: With Complete Damage	# of Locations: with Functionality > 50 % After Day 1	# of Locations: with Functionality > 50 % After Day 7
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	16	7	0	16	16
Total	**16**	**7**	**0**	**16**	**16**

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	0	0	0
Total	**0**	**0**	**0**

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service: At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	68,186	16,145	7,933	0	0	0
Electric Power	68,186	45,389	26,431	9,695	376	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 11 ignitions that will burn about 0 sq. mi (3% of the region's total area.) The model also estimates that the fires will displace about 100 people and burn about 10 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.70 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 32% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 16,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 1,179 households to be displaced due to the earthquake. Of these, 886 people (out of a total population of 194,000) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level 1: Injuries will require medical attention but hospitalization is not needed.

Severity Level 2: Injuries will require hospitalization but are not considered life-threatening

Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.

Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum, and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	**Residential**	165	24	2	4
	Non-Residential	9	2	0	1
	Commute	0	0	0	0
	Total	175	26	2	4
2 PM	**Residential**	43	6	1	1
	Non-Residential	337	71	9	19
	Commute	0	0	0	0
	Total	380	78	10	20
5 PM	**Residential**	51	7	1	1
	Non-Residential	122	26	3	7
	Commute	0	1	1	0
	Total	173	34	5	8

Economic Loss

The total economic loss estimated for the earthquake is 832 million dollars, which represents 6 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 798 million dollars. 20% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 60% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
	Structural	44.0	28.7	6.2	2.7	**81.5**
Building	**Non-Structural**	284.3	88.3	17.6	8.9	**399.1**
Loss	**Content**	91.4	47.7	12.9	4.5	**156.5**
	Inventory	N/A	0.7	1.8	0.0	**2.6**
	Subtotal	419.6	165.5	38.5	16.1	**639.7**
	Wage	1.2	28.2	1.0	0.8	**31.2**
Business	**Income**	0.5	23.9	0.6	0.2	**25.2**
Interruption	**Rental**	24.7	13.5	0.7	0.5	**39.3**
Loss	**Relocation**	32.2	23.4	3.2	3.7	**62.5**
	Subtotal	58.6	88.9	5.5	5.2	**158.2**
	Total	478.2	254.4	44.1	21.3	**797.8**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Roads	2,812.8	0.0	0.0
	Bridges	419.0	24.4	5.8
	Tunnels	0.0	0.0	0.0
	Subtotal	3,231.8	24.4	0.8
Railways	Tracks	18.5	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	18.5	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	0.0	0.0	0.0
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities			
		0.0	0.0	0.0
Airport	Facilities	8.0	1.8	22.2
	Runways	0.0	0.0	0.0
	Subtotal	8.0	1.8	22.2
		3,258.3	**36.4**	**0.8**

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	87.5	*NA*	*NA*
	Subtotal	87.5	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	52.5	*NA*	*NA*
	Subtotal	52.5	0.0	0.0
Natural Gas	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	35.0	*NA*	*NA*
	Subtotal	35.0	0.0	0.0
Oil Systems	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.00
Electrical Power	Facilities	0.0	0.0	0.0
	Distribution Lines	26.2	*NA*	*NA*
	Subtotal	26.2	0.0	0.0
Communication	Facilities	32.0	7.2	22.5
	Distribution Lines	11.7	*NA*	*NA*
	Subtotal	43.7	7.2	22.5
	Total	**244.9**	**7.2**	**10.7**

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California
- Los Angeles

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
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	Los Angeles	194,000	7,480	2,370	9,850
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Region Total		**194,000**	**7,480**	**2,370**	**9,850**

HAZUS 99-SR2: Earthquake Scenario Report for the City of Glendale

Earthquake Scenario: Magnitude 6.4 Earthquake on the Hollywood Fault

Disclaimer:

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The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

- California

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 30 square miles and contains 28 census tracts. There are over 68 thousand households in the region and has a total population of 194,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 33 thousand buildings in the region with a total building replacement value (excluding contents) of 9,848 million dollars (1994 dollars). Approximately 96% of the buildings (and 76% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 3,258 and 245 million dollars (1994 dollars), respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 33,000 buildings in the region which have an aggregate total replacement value of 9,848 million dollars (1994 dollars). Figure 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

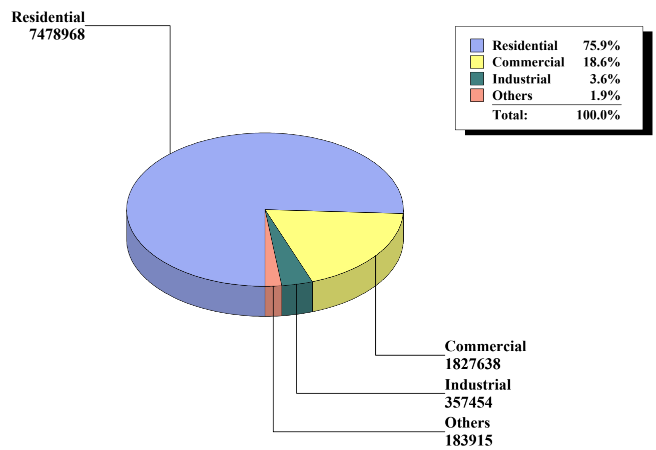

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 94% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilites into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 3 hospitals in the region with a total bed capacity of 942 beds. There are 70 schools, 9 fire stations, 2 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 4 of the dams are classified as 'high hazard'. The inventory also includes 470 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in Tables 2 and 3.

The total value of the lifeline inventory is over 3,290 million dollars. This inventory includes over 281 kilometers of highways, 143 bridges, 0 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component	# locations/ # Segments	Replacement value (millions of dollars)
Highway	Major Roads	5	2,813
	Bridges	143	419
	Tunnels	0	0
		Subtotal	3,232
Railways	Rail Tracks	2	19
	Bridges	0	0
	Tunnels	0	0
	Facilities	0	0
		Subtotal	19
Light Rail	Rail Tracks	0	0
	Bridges	0	0
	Tunnels	0	0
	Facilities	0	0
		Subtotal	0
Bus	Facilities	0	0
Ferry	Facilities	0	0
Port	Facilities	0	0
Airport	Facilities	4	8
	Runways	0	0
		Subtotal	8
		Total	**3,258**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	87.5
	Subtotal		87.5
Waste Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	52.5
	Subtotal		52.5
Natural Gas	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	35.0
	Subtotal		35.0
Oil Systems	Pipelines	0	0.0
	Facilities	0	0.0
	Subtotal		0.0
Electrical Power	Facilities	0	0.0
	Distribution Lines	*NA*	26.2
	Subtotal		26.2
Communication	Facilities	16	32.0
	Distribution Lines	*NA*	11.7
	Subtotal		43.7
	Total		**244.9**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	Hollywood Fault 6.4Mw
Type of Earthquake	Source event
Fault Name	Hollywood Fault
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-118.253
Latitude of Epicenter	34.117
Earthquake Magnitude	6.4
Depth (Km)	0
Rupture Length (Km)	17
Rupture Orientation (degrees)	0
Attenuation Function	Project 97 West Coast

Building Damage

Building Damage

HAZUS estimates that about 3,120 buildings will be at least moderately damaged. This is over 9.482% of the total number of buildings in the region. There are an estimated 1 building that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	19,344	96.94	9,452	96.45	2,598	90.11	170	71.73	0	0.00
Commercial	461	2.31	264	2.69	215	7.46	49	20.68	0	0.00
Industrial	98	0.49	62	0.63	58	2.01	16	6.75	1	0.00
Agriculture	4	0.49	1	0.00	0	0.00	0	0.00	0	0.00
Religion	32	0.16	17	0.00	11	0.38	2	0.84	0	0.00
Government	4	0.02	1	0.00	0	0.00	0	0.00	0	0.00
Education	12	0.06	3	0.03	1	0.03	0	0.00	0	0.00
Total	**19,985**		**9,800**		**2,883**		**237**		**1**	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	207	1.0	104	1.1	88	3.1	18	8.1	0	0.0
Mobile Homes	15	0.1	13	0.1	18	0.6	4	1.8	0	0.0
Precast Concrete	142	0.7	61	0.6	70	2.4	18	8.1	0	0.0
RM*	436	2.2	136	1.4	128	4.4	35	15.7	0	0.0
Steel	205	1.0	72	0.7	81	2.8	21	9.4	0	0.0
URM*	57	0.3	42	0.4	39	1.4	6	2.7	0	0.0
Wood	18,923	94.7	9,372	95.6	2,459	85.3	121	54.3	0	0.0

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry

Essential Facility Damage

Before the earthquake, the region had 942 hospital beds available for use. On the day of the earthquake, the model estimates that only 425 hospital beds (45%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 63% of the beds will be back in service. By 30 days, 85% will be operational.

Table 6: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Least Moderate Damage > 50%	Complete Damage > 50%	Functionality > 50% at day 1
Hospitals	3	0	0	1
Schools	70	2	0	8
EOCs	1	0	0	0
Police Stations	2	0	0	0
Fire Stations	9	0	0	3

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

			Number of Locations			
System	**Component**	**Locations/ Segments**	**With at Least Mod. Damage**	**With Complete Damage**	**With Functionality > 50 % After Day 1**	**After Day 7**
Highway	**Roads**	5			5	5
	Bridges	143	9	1	143	143
	Tunnels	0	0	0	0	0
Railways	**Tracks**	0			2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	**Tracks**	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	**Facilities**	0	0	0	0	0
Ferry	**Facilities**	0	0	0	0	0
Port	**Facilities**	0	0	0	0	0
Airport	**Facilities**	4	1	0	4	4
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8 through10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

		# of Locations			
System	**Total #**	**With at Least Moderate Damage**	**With Complete Damage**	**with Functionality > 50 % After Day 1**	**with Functionality > 50 % After Day 7**
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	16	5	0	16	16
Total	**16**	**5**	**0**	**16**	**16**

Table 9 : Expected Utility System Pipeline Damage

System	**Total Pipelines Length (kms)**	**Number of Leaks**	**Number of Breaks**
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	0	0	0
Total	**0**	**0**	**0**

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	**Number of Households without Service At Day 1**	**At Day 3**	**At Day 7**	**At Day 30**	**At Day 90**
Potable Water	68,186	1,562	0	0	0	0
Electric Power	68,186	41,248	22,007	7,295	224	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 10 ignitions that will burn about 0 sq. mi (4.8% of the region's total area.) The model also estimates that the fires will displace about 200 people and burn about 10 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.31 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 32% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 13,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 831 households to be displaced due to the earthquake. Of these, 665 people (out of a total population of 194,000) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level 1: Injuries will require medical attention but hospitalization is not needed.

Severity Level 2: Injuries will require hospitalization but are not considered life-threatening

Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.

Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum, and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	**Residential**	119	15	1	2
	Non-Residential	6	1	0	0
	Commute	0	0	0	0
	Total	125	16	1	2
2 PM	**Residential**	32	4	0	1
	Non-Residential	219	41	5	10
	Commute	0	0	0	0
	Total	251	45	5	10
5 PM	**Residential**	38	5	0	1
	Non-Residential	82	16	2	4
	Commute	0	0	0	0
	Total	120	21	3	5

Economic Loss

The total economic loss estimated for the earthquake is 644 million dollars, which represents 5 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 628 million dollars. 19% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 59% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	Structural	31.4	21.7	4.7	1.8	**59.6**
	Non-Structural	222.7	72.5	15.1	6.8	**317.0**
	Content	73.8	42.7	11.7	3.8	**131.9**
	Inventory	N/A	0.7	1.7	0.0	**2.3**
	Subtotal	327.8	137.5	33.1	12.5	**510.9**
Business Interruption Loss	Wage	0.9	20.8	0.8	0.5	**23.0**
	Income	0.4	17.3	0.4	0.1	**18.3**
	Rental	19.1	10.3	0.6	0.3	**30.2**
	Relocation	21.9	18.2	2.6	2.6	**45.3**
	Subtotal	42.3	66.6	4.4	3.6	**116.8**
	Total	370.0	204.1	37.5	16.1	**627.7**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Roads	2,812.8	0.0	0.0
	Bridges	419.0	9.2	2.2
	Tunnels	0.0	0.0	0.0
	Subtotal	3,231.8	9.2	0.3
Railways	Tracks	18.5	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	18.5	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	0.0	0.0	0.0
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities			
		0.0	0.0	0.0
Airport	Facilities	8.0	1.5	18.5
	Runways	0.0	0.0	0.0
	Subtotal	8.0	1.5	18.5
		3,258.3	**10.7**	**0.3**

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	87.5	*NA*	*NA*
	Subtotal	87.5	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	52.5	*NA*	*NA*
	Subtotal	52.5	0.0	0.0
Natural Gas	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	35.0	*NA*	*NA*
	Subtotal	35.0	0.0	0.0
Oil Systems	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.00
Electrical Power	Facilities	0.0	0.0	0.0
	Distribution Lines	26.2	*NA*	*NA*
	Subtotal	26.2	0.0	0.0
Communication	Facilities	32.0	5.2	16.3
	Distribution Lines	11.7	*NA*	*NA*
	Subtotal	43.7	5.2	16.3
	Total	**244.9**	**5.2**	**7.8**

Appendix A: County Listing for the Region

California
- Los Angeles

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
California					
	Los Angeles	194,000	7,480	2,370	9,850
State Total		*194,000*	*7,480*	*2,370*	*9,850*
Region Total		**194,000**	**7,480**	**2,370**	**9,850**

HAZUS 99-SR2: Earthquake Scenario Report for the City of Glendale

Earthquake Scenario: Magnitude 6.5 Earthquake on the Raymond Fault

Disclaimer:

The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

- California

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 30 square miles and contains 28 census tracts. There are over 68 thousand households in the region and has a total population of 194,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 33 thousand buildings in the region with a total building replacement value (excluding contents) of 9,848 million dollars (1994 dollars). Approximately 96% of the buildings (and 76% of the building value) are associated with residential housing.

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Building Inventory

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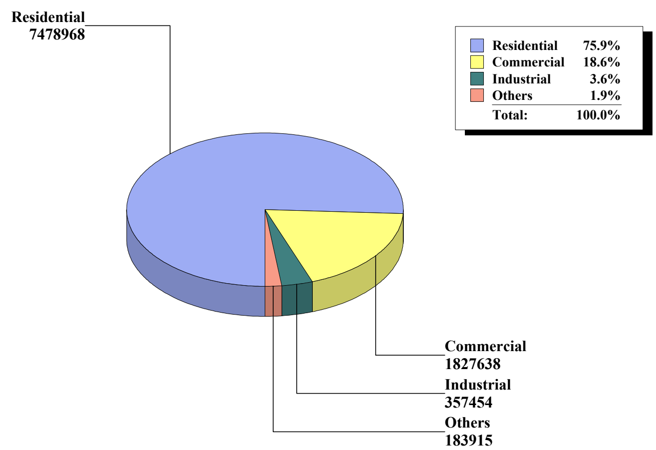

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 94% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilites into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 3 hospitals in the region with a total bed capacity of 942 beds. There are 70 schools, 9 fire stations, 2 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 4 of the dams are classified as 'high hazard'. The inventory also includes 470 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in Tables 2 and 3.

The total value of the lifeline inventory is over 3,290 million dollars. This inventory includes over 281 kilometers of highways, 143 bridges, 0 kilometers of pipes.

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	Bridges	143	419
	Tunnels	0	0
		Subtotal	3,232
Railways	Rail Tracks	2	19
	Bridges	0	0
	Tunnels	0	0
	Facilities	0	0
		Subtotal	19
Light Rail	Rail Tracks	0	0
	Bridges	0	0
	Tunnels	0	0
	Facilities	0	0
		Subtotal	0
Bus	Facilities	0	0
Ferry	Facilities	0	0
Port	Facilities	0	0
Airport	Facilities	4	8
	Runways	0	0
		Subtotal	8
		Total	**3,258**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	87.5
	Subtotal		87.5
Waste Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	52.5
	Subtotal		52.5
Natural Gas	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	35.0
	Subtotal		35.0
Oil Systems	Pipelines	0	0.0
	Facilities	0	0.0
	Subtotal		0.0
Electrical Power	Facilities	0	0.0
	Distribution Lines	*NA*	26.2
	Subtotal		26.2
Communication	Facilities	16	32.0
	Distribution Lines	*NA*	11.7
	Subtotal		43.7
	Total		**244.9**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	Raymond Fault 6.5Mw
Type of Earthquake	Source event
Fault Name	Raymond Fault
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-118.222
Latitude of Epicenter	34.1218
Earthquake Magnitude	6.5
Depth (Km)	0
Rupture Length (Km)	21
Rupture Orientation (degrees)	0
Attenuation Function	Project 97 West Coast

Building Damage

Building Damage

HAZUS estimates that about 3,498 buildings will be at least moderately damaged. This is over 10,642% of the total number of buildings in the region. There are an estimated 6 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	18,397	96.92	10,026	96.56	2,949	90.88	186	73.52	4	66.67
Commercial	439	2.31	271	2.61	224	6.90	50	19.76	0	0.00
Industrial	95	0.50	62	0.60	60	1.85	16	6.32	2	33.33
Agriculture	4	0.50	2	0.00	0	0.00	0	0.00	0	0.00
Religion	32	0.17	17	0.00	11	0.34	1	0.40	0	0.00
Government	4	0.02	1	0.00	0	0.00	0	0.00	0	0.00
Education	11	0.06	4	0.04	1	0.03	0	0.00	0	0.00
Total	**18,982**		**10,383**		**3,245**		**253**		**6**	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	198	1.0	103	1.0	94	2.9	21	8.5	0	0.0
Mobile Homes	12	0.1	12	0.1	20	0.6	4	1.6	0	0.0
Precast Concrete	140	0.7	60	0.6	72	2.2	20	8.1	0	0.0
RM*	407	2.1	142	1.4	142	4.4	45	18.2	0	0.0
Steel	193	1.0	74	0.7	89	2.7	24	9.7	0	0.0
URM*	51	0.3	43	0.4	43	1.3	7	2.8	0	0.0
Wood	17,981	94.7	9,949	95.8	2,785	85.8	126	51.0	0	0.0

*Note:
RM Reinforced Masonry
URM Unreiforced Masonry

Essential Facility Damage

Before the earthquake, the region had 942 hospital beds available for use. On the day of the earthquake, the model estimates that only 391 hospital beds (42%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 60% of the beds will be back in service. By 30 days, 84% will be operational.

Table 6: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Least Moderate Damage > 50%	Complete Damage > 50%	Functionality > 50% at day 1
Hospitals	3	0	0	1
Schools	70	2	0	1
EOCs	1	0	0	0
Police Stations	2	0	0	0
Fire Stations	9	0	0	1

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

			Number of Locations			
System	**Component**	**Locations/ Segments**	**With at Least Mod. Damage**	**With Complete Damage**	**With Functionality > 50 % After Day 1**	**After Day 7**
Highway	**Roads**	5			5	5
	Bridges	143	11	2	143	143
	Tunnels	0	0	0	0	0
Railways	**Tracks**	0			2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	**Tracks**	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	**Facilities**	0	0	0	0	0
Ferry	**Facilities**	0	0	0	0	0
Port	**Facilities**	0	0	0	0	0
Airport	**Facilities**	4	1	0	4	4
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8 through10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

		# of Locations			
System	Total #	With at Least Moderate Damage	With Complete Damage	with Functionality > 50 % After Day 1	with Functionality > 50 % After Day 7
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	16	6	0	16	16
Total	**16**	**6**	**0**	**16**	**16**

Table 9 : Expected Utility System Pipeline Damage

System	Total Pipelines Length (kms)	Number of Leaks	Number of Breaks
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	0	0	0
Total	**0**	**0**	**0**

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	Number of Households without Service At Day 1	At Day 3	At Day 7	At Day 30	At Day 90
Potable Water	68,186	4,334	52	0	0	0
Electric Power	68,186	43,850	24,845	8,868	322	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 10 ignitions that will burn about 0 sq. mi (6.7% of the region's total area.) The model also estimates that the fires will displace about 400 people and burn about 20 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.34 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 32% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 14,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 945 households to be displaced due to the earthquake. Of these, 738 people (out of a total population of 194,000) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level 1: Injuries will require medical attention but hospitalization is not needed.

Severity Level 2: Injuries will require hospitalization but are not considered life-threatening

Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.

Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum, and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	**Residential**	131	17	1	3
	Non-Residential	7	1	0	0
	Commute	0	0	0	0
	Total	138	18	2	3
2 PM	**Residential**	35	5	0	1
	Non-Residential	244	47	6	11
	Commute	0	0	0	0
	Total	279	52	6	12
5 PM	**Residential**	42	5	0	1
	Non-Residential	90	17	2	4
	Commute	0	0	1	0
	Total	132	23	3	5

Economic Loss

The total economic loss estimated for the earthquake is 708 million dollars, which represents 5 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 688 million dollars. 19% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 60% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	**Structural**	34.2	23.6	4.9	2.0	**64.6**
	Non-Structural	246.7	78.4	15.8	7.4	**348.4**
	Content	81.9	46.2	12.2	4.2	**144.6**
	Inventory	N/A	0.7	1.7	0.0	**2.5**
	Subtotal	362.8	149.0	34.7	13.6	**560.1**
Business Interruption Loss	**Wage**	1.0	22.6	0.8	0.6	**25.0**
	Income	0.5	19.0	0.5	0.1	**20.1**
	Rental	20.9	11.1	0.6	0.4	**33.0**
	Relocation	24.2	19.8	2.7	2.8	**49.6**
	Subtotal	46.6	72.6	4.5	3.9	**127.6**
	Total	409.4	221.5	39.2	17.5	**687.7**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Roads	2,812.8	0.0	0.0
	Bridges	419.0	12.1	2.9
	Tunnels	0.0	0.0	0.0
	Subtotal	3,231.8	12.1	0.4
Railways	Tracks	18.5	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	18.5	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	0.0	0.0	0.0
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities			
		0.0	0.0	0.0
Airport	Facilities	8.0	1.5	20.6
	Runways	0.0	0.0	0.0
	Subtotal	8.0	1.6	20.6
		3,258.3	**10.7**	**0.3**

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	87.5	*NA*	*NA*
	Subtotal	87.5	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	52.5	*NA*	*NA*
	Subtotal	52.5	0.0	0.0
Natural Gas	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	35.0	*NA*	*NA*
	Subtotal	35.0	0.0	0.0
Oil Systems	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.00
Electrical Power	Facilities	0.0	0.0	0.0
	Distribution Lines	26.2	*NA*	*NA*
	Subtotal	26.2	0.0	0.0
Communication	Facilities	32.0	6.2	19.5
	Distribution Lines	11.7	*NA*	*NA*
	Subtotal	43.7	6.2	19.5
	Total	**244.9**	**6.2**	**9.3**

Appendix A: County Listing for the Region

California
- Los Angeles

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
California					
	Los Angeles	194,000	7,480	2,370	9,850
State Total		*194,000*	*7,480*	*2,370*	*9,850*
Region Total		**194,000**	**7,480**	**2,370**	**9,850**

HAZUS 99-SR2: Earthquake Scenario Report for the City of Glendale

Earthquake Scenario: Magnitude 7.1 Earthquake on the San Andreas Fault

Disclaimer:

The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific earthquake. These results can be improved by using enhanced inventory, geotechnical, and observed ground motion data.

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General Description of the Region

HAZUS is a regional earthquake loss estimation model that was developed by the Federal Emergency Management Agency and the National Institute of Building Sciences. The primary purpose of HAZUS is to provide a methodology and software application to develop earthquake losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

The earthquake loss estimates provided in this report was based on a region that includes 1 county(ies) from the following state(s):

- California

Note:
Appendix A contains a complete listing of the counties contained in the region.

The geographical size of the region is 30 square miles and contains 28 census tracts. There are over 68 thousand households in the region and has a total population of 194,000 people (1990 Census Bureau data). The distribution of population by State and County is provided in Appendix B.

There are an estimated 33 thousand buildings in the region with a total building replacement value (excluding contents) of 9,848 million dollars (1994 dollars). Approximately 96% of the buildings (and 76% of the building value) are associated with residential housing.

The replacement value of the transportation and utility lifeline systems is estimated to be 3,258 and 245 million dollars (1994 dollars), respectively.

Building and Lifeline Inventory

Building Inventory

HAZUS estimates that there are 33,000 buildings in the region which have an aggregate total replacement value of 9,848 million dollars (1994 dollars). Figure 1 presents the relative distribution of the value with respect to the general occupancies. Appendix B provides a general distribution of the building value by State and County.

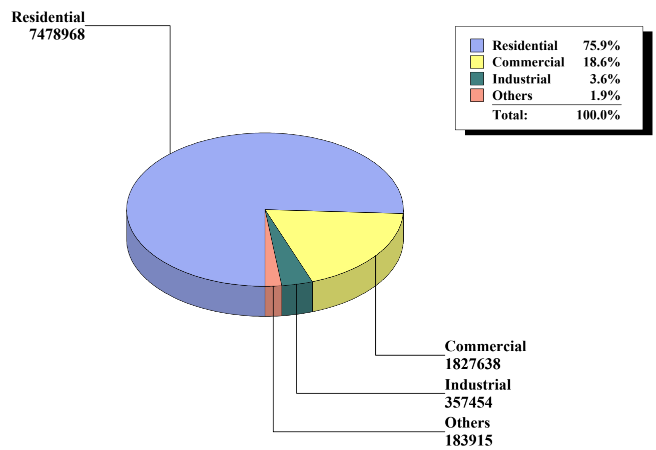

Figure 1: Building Exposure by Occupancy Type
(Thousands of dollars)

In terms of building construction types found in the region, wood frame construction makes up 94% of the building inventory. The remaining percentage is distributed between the other general building types.

Critical Facility Inventory

HAZUS breaks critical facilities into two (2) groups: essential facilities and high potential loss (HPL) facilities. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

For essential facilities, there are 3 hospitals in the region with a total bed capacity of 942 beds. There are 70 schools, 9 fire stations, 2 police stations and 1 emergency operation facilities. With respect to HPL facilities, there are 8 dams identified within the region. Of these, 4 of the dams are classified as 'high hazard'. The inventory also includes 470 hazardous material sites, 0 military installations and 0 nuclear power plants.

Transportation and Utility Lifeline Inventory

Within HAZUS, the lifeline inventory is divided between transportation and utility lifeline systems. There are seven (7) transportation systems that include highways, railways, light rail, bus, ports, ferry and airports. There are six (6) utility systems that include potable water, wastewater, natural gas, crude & refined oil, electric power and communications. The lifeline inventory data is provided in Tables 2 and 3.

The total value of the lifeline inventory is over 3,290 million dollars. This inventory includes over 281 kilometers of highways, 143 bridges, 0 kilometers of pipes.

Table 2: Transportation System Lifeline Inventory

System	Component		# locations/ # Segments	Replacement value (millions of dollars)
Highway	Major Roads		5	2,813
	Bridges		143	419
	Tunnels		0	0
		Subtotal		3,232
Railways	Rail Tracks		2	19
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		19
Light Rail	Rail Tracks		0	0
	Bridges		0	0
	Tunnels		0	0
	Facilities		0	0
		Subtotal		0
Bus	Facilities		0	0
Ferry	Facilities		0	0
Port	Facilities		0	0
Airport	Facilities		4	8
	Runways		0	0
		Subtotal		8
		Total		**3,258**

Table 3: Utility System Lifeline inventory

System	Component	# Locations / Segments	Replacement value (millions of dollars)
Potable Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	87.5
	Subtotal		87.5
Waste Water	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	52.5
	Subtotal		52.5
Natural Gas	Pipelines	0	0.0
	Facilities	0	0.0
	Distribution Lines	*NA*	35.0
	Subtotal		35.0
Oil Systems	Pipelines	0	0.0
	Facilities	0	0.0
	Subtotal		0.0
Electrical Power	Facilities	0	0.0
	Distribution Lines	*NA*	26.2
	Subtotal		26.2
Communication	Facilities	16	32.0
	Distribution Lines	*NA*	11.7
	Subtotal		43.7
	Total		**244.9**

Earthquake Scenario

HAZUS uses the following set of information to define the earthquake parameters used for the earthquake loss estimate provided in this report.

Scenario Name	San Andreas Fault 7.1Mw
Type of Earthquake	Source event
Fault Name	San Andreas
Historical Epicenter ID #	NA
Probabilistic Return Period	NA
Longitude of Epicenter	-118.091
Latitude of Epicenter	34.5428
Earthquake Magnitude	7.1
Depth (Km)	0
Rupture Length (Km)	67.92
Rupture Orientation (degrees)	0
Attenuation Function	Project 97 West Coast

Building Damage

Building Damage

HAZUS estimates that about 344 buildings will be at least moderately damaged. This is over 1.044% of the total number of buildings in the region. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS technical manual. Table 4 below summaries the expected damage by general occupancy for the buildings in the region. Table 5 summaries the expected damage by general building type.

Table 4: Expected Building Damage by Occupancy

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Residential	28,420	95.89	2,859	96.23	308	89.80	0	0.00	0	0.00
Commercial	884	2.98	86	2.89	25	7.29	0	0.00	0	0.00
Industrial	224	0.76	23	0.77	10	2.92	1	0.00	0	0.00
Agriculture	8	0.76	0	0.00	0	0.00	0	0.00	0	0.00
Religion	58	0.20	3	0.00	0	0.00	0	0.00	0	0.00
Government	17	0.06	0	0.00	0	0.00	0	0.00	0	0.00
Education	26	0.09	0	0.00	0	0.00	0	0.00	0	0.00
Total	**29,637**		**2,971**		**343**		**1**		**0**	

Table 5: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	388	1.3	26	0.9	2	0.6	0	0.0	0	0.0
Mobile Homes	31	0.1	10	0.3	5	1.5	0	0.0	0	0.0
Precast Concrete	266	0.9	18	0.6	7	2.1	0	0.0	0	0.0
RM*	675	2.3	40	1.3	19	5.7	0	0.0	0	0.0
Steel	348	1.2	23	0.8	8	2.4	0	0.0	0	0.0
URM*	115	0.4	23	0.8	5	1.5	0	0.0	0	0.0
Wood	27,814	93.8	2,831	95.3	290	86.3	0	0.0	0	0.0

*Note:
RM Reinforced Masonry
URM Unreiforced Masonry

Essential Facility Damage

Before the earthquake, the region had 942 hospital beds available for use. On the day of the earthquake, the model estimates that only 811 hospital beds (86%) are available for use by patients already in the hospital and those injured by the earthquake. After one week, 93% of the beds will be back in service. By 30 days, 98% will be operational.

Table 6: Expected Damage to Essential Facilities

		# Facilities		
Classification	Total	Least Moderate Damage > 50%	Complete Damage > 50%	Functionality > 50% at day 1
Hospitals	3	0	0	3
Schools	70	0	0	70
EOCs	1	0	0	1
Police Stations	2	0	0	2
Fire Stations	9	0	0	9

Transportation and Utility Lifeline Damage

Table 7 provides damage estimates for the transportation system.

Table 7: Expected Damage to the Transportation Systems

			Number of Locations			
System	**Component**	**Locations/ Segments**	**With at Least Mod. Damage**	**With Complete Damage**	**With Functionality > 50 % After Day 1**	**After Day 7**
Highway	**Roads**	5			5	5
	Bridges	143	1	0	143	143
	Tunnels	0	0	0	0	0
Railways	**Tracks**	0			2	2
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Light Rail	**Tracks**	0			0	0
	Bridges	0	0	0	0	0
	Tunnels	0	0	0	0	0
	Facilities	0	0	0	0	0
Bus	**Facilities**	0	0	0	0	0
Ferry	**Facilities**	0	0	0	0	0
Port	**Facilities**	0	0	0	0	0
Airport	**Facilities**	4	0	0	4	4
	Runways	0	0	0	0	0

Note: Roadway segments, railroad tracks and light rail tracks are assumed to be damaged by ground failure only. If ground failure maps are not provided, damage estimates to these components will not be computed.

Tables 8 through10 provide information on the damage to the utility lifeline systems. Table 8 provides damage to the utility system facilities. Table 9 provides estimates on the number of leaks and breaks by the pipelines of the utility systems. For electric power and potable water, HAZUS performs a simplified system performance analysis. Table 10 provides a summary of the system performance information.

Table 8 : Expected Utility System Facility Damage

		# of Locations			
System	**Total #**	**With at Least Moderate Damage**	**With Complete Damage**	**with Functionality > 50 % After Day 1**	**After Day 7**
Potable Water	0	0	0	0	0
Waste Water	0	0	0	0	0
Natural Gas	0	0	0	0	0
Oil Systems	0	0	0	0	0
Electrical Power	0	0	0	0	0
Communication	16	1	0	16	16
Total	**16**	**1**	**0**	**16**	**16**

Table 9 : Expected Utility System Pipeline Damage

System	**Total Pipelines Length (kms)**	**Number of Leaks**	**Number of Breaks**
Potable Water	0	0	0
Waste Water	0	0	0
Natural Gas	0	0	0
Oil	0	0	0
Total	**0**	**0**	**0**

Table 10: Expected Potable Water and Electric Power System Performance (Level 1)

	Total # of Households	**Number of Households without Service At Day 1**	**At Day 3**	**At Day 7**	**At Day 30**	**At Day 90**
Potable Water	68,186	0	0	0	0	0
Electric Power	68,186	10,215	1,440	69	0	0

Induced Earthquake Damage

Fire Following Earthquake

Fires often occur after an earthquake. Because of the number of fires and the lack of water to fight the fires, they can often burn out of control. HAZUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area. For this scenario, the model estimates that there will be 3 ignitions that will burn about 0 sq. mi (1.9% of the region's total area.) The model also estimates that the fires will displace about 0 people and burn about 0 million dollars of building value.

Debris Generation

HAZUS estimates the amount of debris that will be generated by the earthquake. The model breaks the debris into two general categories: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

The model estimates that a total of 0.03 million tons of debris will be generated. Of the total amount, Brick/Wood comprises 44% of the total, with the remainder being Reinforced Concrete/Steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 1,000 truckloads (@25 tons/truck) to remove the debris generated by the earthquake.

Social Impact

Shelter Requirement

HAZUS estimates the number of households that are expected to be displaced from their homes due to the earthquake and the number of displaced people that will require accommodations in temporary public shelters. The model estimates 0 households to be displaced due to the earthquake. Of these, 0 people (out of a total population of 194,000) will seek temporary shelter in public shelters.

Casualties

HAZUS estimates the number of people that will be injured and killed by the earthquake. The casualties are broken down into four (4) severity levels that describe the extent of the injuries. The levels are described as follows;

Severity Level 1: Injuries will require medical attention but hospitalization is not needed.

Severity Level 2: Injuries will require hospitalization but are not considered life-threatening

Severity Level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.

Severity Level 4: Victims are killed by the earthquake.

The casualty estimates are provided for three (3) times of day: 2:00 AM, 2:00 PM and 5:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residential occupancy load is maximum, the 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum, and 5:00 PM represents peak commute time.

Table 11 provides a summary of the casualties estimated for this earthquake

Table 11: Casualty Estimates

		Level 1	Level 2	Level 3	Level 4
2 AM	**Residential**	15	1	0	0
	Non-Residential	1	0	0	0
	Commute	0	0	0	0
	Total	15	1	0	0
2 PM	**Residential**	4	0	0	0
	Non-Residential	24	2	0	0
	Commute	0	0	0	0
	Total	28	3	0	0
5 PM	**Residential**	4	0	0	0
	Non-Residential	9	1	0	0
	Commute	0	0	0	0
	Total	13	1	0	0

Economic Loss

The total economic loss estimated for the earthquake is 86 million dollars, which represents 1 % of the total replacement value of the region's buildings. The following three sections provide more detailed information about these losses.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake.

The total building-related losses were 83 million dollars. 16% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies which made up over 55% of the total loss. Table 12 below provides a summary of the losses associated with the building damage.

Table 12: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss	**Structural**	4.4	2.9	0.8	0.3	**8.3**
	Non-Structural	28.6	10.4	2.7	1.0	**42.8**
	Content	8.8	6.6	2.2	0.6	**18.3**
	Inventory	N/A	0.1	0.3	0.0	**0.4**
	Subtotal	41.8	20.0	6.1	1.9	**69.8**
Business Interruption Loss	**Wage**	0.0	2.3	0.1	0.1	**2.6**
	Income	0.0	2.3	0.1	0.0	**2.4**
	Rental	1.7	1.3	0.1	0.0	**3.1**
	Relocation	2.2	2.4	0.5	0.3	**5.4**
	Subtotal	4.0	8.3	0.8	0.4	**13.5**
	Total	45.8	28.3	6.8	2.3	**83.3**

Transportation and Utility Lifeline Losses

For the transportation and utility lifeline systems, HAZUS computes the direct repair cost for each component only. There are no losses computed by HAZUS for business interruption due to lifeline outages. Tables 13 & 14 provide a detailed breakdown in the expected lifeline losses.

Table 13: Transportation System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Highway	Roads	2,812.8	0.0	0.0
	Bridges	419.0	0.8	0.2
	Tunnels	0.0	0.0	0.0
	Subtotal	3,231.8	0.8	0.0
Railways	Tracks	18.5	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	18.5	0.0	0.0
Light Rail	Tracks	0.0	0.0	0.0
	Bridges	0.0	0.0	0.0
	Tunnels	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.0
Bus	Facilities	0.0	0.0	0.0
Ferry	Facilities	0.0	0.0	0.0
Port	Facilities			
		0.0	0.0	0.0
Airport	Facilities	8.0	1.5	3.3
	Runways	0.0	0.0	0.0
	Subtotal	8.0	1.6	3.3
		3,258.3	**1.1**	**0.0**

Table 14: Utility System Economic Losses
(Millions of dollars)

System	Component	Inventory Value	Economic Loss	Loss Ratio (%)
Potable Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	87.5	*NA*	*NA*
	Subtotal	87.5	0.0	0.0
Waste Water	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	52.5	*NA*	*NA*
	Subtotal	52.5	0.0	0.0
Natural Gas	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Distribution Lines	35.0	*NA*	*NA*
	Subtotal	35.0	0.0	0.0
Oil Systems	Pipelines	0.0	0.0	0.0
	Facilities	0.0	0.0	0.0
	Subtotal	0.0	0.0	0.00
Electrical Power	Facilities	0.0	0.0	0.0
	Distribution Lines	26.2	*NA*	*NA*
	Subtotal	26.2	0.0	0.0
Communication	Facilities	32.0	0.9	2.9
	Distribution Lines	11.7	*NA*	*NA*
	Subtotal	43.7	0.9	2.9
	Total	**244.9**	**0.9**	**1.4**

Appendix A: County Listing for the Region

California
- Los Angeles

Appendix B: Regional Population and Building Value Data

State	County Name	Population	Building Value (millions of dollars)		
			Residential	Non-Residential	Total
California					
	Los Angeles	194,000	7,480	2,370	9,850
State Total		*194,000*	*7,480*	*2,370*	*9,850*
Region Total		**194,000**	**7,480**	**2,370**	**9,850**

APPENDIX D
GLOSSARY

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Appendix D
GLOSSARY

Acceleration – The rate of change for a body's magnitude, direction, or both over a given period of time.

Active fault - For implementation of Alquist-Priolo Earthquake Fault Zoning Act (APEFZA) requirements, an active fault is one that shows evidence of, or is suspected of having experienced surface displacement within the last 11,000 years. APEFZA classification is designed for land use management of surface rupture hazards. A more general definition (National Academy of Science, 1988), states "a fault that on the basis of historical, seismological, or geological evidence has the finite probability of producing an earthquake" (see potentially active fault).

Adjacent grade – Elevation of the natural or graded ground surface, or structural fill, abutting the walls of a building. See *highest adjacent grade* and *lowest adjacent grade*.

Aftershocks - Minor earthquakes following a greater one and originating at or near the same place.

Aggradation – The building up of earth's surface by deposition of sediment.

Alluvium - Surficial sediments of poorly consolidated gravels, sand, silts, and clays deposited by flowing water.

Anchor – To secure a structure to its footings or foundation wall in such a way that a continuous load transfer path is created and so that it will not be displaced by flood, wind, or seismic forces.

Aplite – A light-colored igneous rock with a fine-grained texture and free from dark minerals. Aplite forms at great depths beneath the earth's crust.

Appurtenant structure – Under the *National Flood Insurance Program*, a structure which is on the same parcel of property as the principal *structure* to be insured and the use of which is incidental

Argillic – Alteration in which certain minerals of a rock or sediments are converted to clay.

Armor – To protect slopes from *erosion* and *scour* by *flood* waters. Techniques of armoring include the use of riprap, gabions, or concrete.

Artesian – An adjective referring to ground water confined under hydrostatic pressure. The water level in wells drilled into an **artesian** aquifer (also called a confined aquifer) will stand at some height above the top of the aquifer. If the water reaches the ground surface the well is a "flowing" **artesian** well.

Attenuation – The reduction in amplitude of a wave with time or distance traveled.

A zone – Under the *National Flood Insurance Program*, area subject to inundation by the *100-year flood* where wave action does not occur or where waves are less than 3 feet high, designated Zone A, AE, A1-A30, A0, AH, or AR on a *Flood Insurance Rate Map* (FIRM).

Base flood – *Flood* that has as 1-percent probability of being equaled or exceeded in any given year. Also known as the *100-year flood*.

Base Flood Elevation (BFE) – Elevation of the *base flood* in relation to a specified datum, such as the *National Geodetic Vertical Datum* or the *North American Vertical Datum*. The Base Flood Elevation is the basis of the insurance and *floodplain management* requirements of the *National Flood Insurance Program*.

Basement – Under the *National Flood Insurance Program*, any area of a building having its floor subgrade on all sides. (Note: What is typically referred to as a "walkout basement," which has a floor that is at or above grade on at least one side, is not considered a basement under the *National Flood Insurance Program*.)

Bedding - The arrangement of a sedimentary rock in beds or layers of varying thickness and character.

Bedrock - Designates hard rock that is in its natural intact position and underlies soil or other unconsolidated surficial material.

Bench - A grading term that refers to a relatively level step excavated into earth material on which fill is to be placed.

Biotite – A general term to designate all ferromagnesian micas.

Blind thrust fault - A thrust fault is a low-angle reverse fault (top block pushed over bottom block). A "blind" thrust fault refers to one that does not reach the surface.

Breakaway wall – Under the *National Flood Insurance Program*, a wall that is not part of the structural support of the building and is intended through its design and construction to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system. Breakaway walls are required by the *National Flood Insurance Program* regulations for any enclosures constructed below the *Base Flood Elevation* beneath elevated buildings in *Coastal High Hazard Areas* (also referred to as *V zones*). In addition, breakaway walls are recommended in areas where *flood* waters flow at high velocities or contain ice or other debris.

Building code – Regulations adopted by local governments that establish standards for construction, modification, and repair of buildings and other structures.

Built-up roof covering – Two or more layers of felt cemented together and surfaced with a cap sheet, mineral aggregate, smooth coating, or similar surfacing material.

Cast-in-place concrete – Concrete that is poured and formed at the construction site.

Cladding – Exterior surface of the building envelope that is directly loaded by the wind.

Clay - A rock or mineral fragment having a diameter less than 1/256 mm (4 microns, or 0.00016 in.). A clay commonly applied to any soft, adhesive, fine-grained deposit.

Claystone - An indurated clay having the texture and composition of shale, but lacking its fine lamination. A massive mudstone in which clay predominates over silt.

Code official – Officer or other designated authority charged with the administration and enforcement of the code, or a duly authorized representative, such as a building, zoning, planning, or *floodplain management* official.

Column foundation – Foundation consisting of vertical support members with a height-to-least-lateral-dimension ratio greater than three. Columns are set in holes and backfilled with compacted material. They are usually made of concrete or masonry and often must be braced. Columns are sometimes known as posts, particularly if the column is made of wood.

Concrete Masonry Unit (CMU) – Building unit or block larger than 12 inches by 4 inches by 4 inches made of cement and suitable aggregates.

Conglomerate - A coarse-grained sedimentary rock composed of rounded to subangular fragments larger than 2 mm in diameter set in a fine-grained matrix of sand or silt, and commonly cemented by calcium carbonate, iron oxide, silica or hardened clay. The consolidated equivalent of gravel.

Connector – Mechanical device for securing two or more pieces, parts, or members together, including anchors, wall ties, and fasteners.

Consolidation - Any process whereby loosely aggregated, soft earth materials become firm and cohesive rock. Also the gradual reduction in volume and increase in density of a soil mass in response to increased load or effective compressive stress, such as the squeezing of fluids from pore spaces.

Contraction joint – Groove that is formed, sawed, or tooled in a concrete structure to create a weakened plane and regulate the location of cracking resulting from the dimensional change of different parts of the structure. See *Isolation joint*.

Corrosion-resistant metal – Any nonferrous metal or any metal having an unbroken surfacing of nonferrous metal, or steel with not less than 10 percent chromium or with not less than 0.20 percent copper.

Coseismic rupture - Ground rupture occurring during an earthquake but not necessarily on the causative fault.

Cretaceous – The final period of the Mesozoic era (before the Tertiary period of the Cenozoic era), thought to have occurred between 136 and 65 million years ago.

Dead load – Weight of all materials of construction incorporated into the building, including but not limited to walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, *cladding*, and other similarly incorporated architectural and structural items and fixed service equipment. See *Loads*.

Debris – (Seismic) The scattered remains of something broken or destroyed; ruins; rubble; fragments. (Flooding, Coastal) Solid objects or masses carried by or floating on the surface of moving water.

Debris impact loads –Loads imposed on a structure by the impact of floodborne debris. These loads are often sudden and large. Though difficult to predict, debris impact loads must be considered when structures are designed and constructed. See *Loads*.

Debris flow - A saturated, rapidly moving saturated earth flow with 50 percent rock fragments coarser than 2 mm in size which can occur on natural and graded slopes.

Debris line – Line left on a structure or on the ground by the deposition of debris. A debris line often indicates the height or inland extent reached by *flood* waters.

Deck – Exterior floor supported on at least two opposing sides by an adjacent structure and/or posts, piers, or other independent supports.

Deflected canyons - A relatively spontaneous diversion in the trend of a stream or canyon caused by any number of processes, including folding and faulting.

Deformation - A general term for the process of folding, faulting, shearing, compression, or extension of rocks.

Design flood – The greater of either (1) the *base flood* or (2) the *flood* associated with the *flood hazard area* depicted on a community's flood hazard map, or otherwise legally designated.

Design Flood Elevation (DFE) – Elevation of the *design flood*, or the flood protection elevation required by a community, including wave effects, relative to the *National Geodetic Vertical Datum*, *North American Vertical Datum*, or other datum.

Development – Under the *National Flood Insurance Program*, any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations or storage of equipment or materials.

Differential settlement – Non-uniform settlement; the uneven lowering of different parts of an engineered structure, often resulting in damage to the structure. Sometimes included with liquefaction as ground failure phenomenon.

Dike – A tabular shaped, igneous intrusion that cuts across bedding of the surrounding rock.

Diorite – A group of igneous rocks that form at great depth beneath the earth's crust. These rocks are intermediate in composition between acidic and basic rocks.

Dynamic analysis - A complex earthquake-resistant engineering design technique (UBC - used for critical facilities) capable of modeling the entire frequency spectra, or composition, of ground motion. The method is used to evaluate the stability of a site or structure by considering the motion from any source or mass, such as that dynamic motion produced by machinery or a seismic event.

Earth flow - Imperceptibly slow-moving surficial material in which 80 percent or more of the fragments are smaller than 2 mm, including a range of rock and mineral fragments.

Earthquake - Vibratory motion propagating within the Earth or along its surface caused by the abrupt release of strain from elastically deformed rock by displacement along a fault.

Earth's crust - The outermost layer or shell of the Earth.

Effective Flood Insurance Rate Map (FIRM) – See *Flood Insurance Rate Map*.

Enclosure – That portion of an elevated building below the *Design Flood Elevation (DFE)* that is partially or fully surrounded by solid (including breakaway) walls.

Encroachment – Any physical object placed in a floodplain that hinders the passage of water or otherwise affects the flood flows.

Engineering geologist - A geologist who is certified by the State as qualified to apply geologic data, principles, and interpretation to naturally occurring earth materials so that geologic factors affecting planning, design, construction, and maintenance of civil engineering works are properly recognized and used. An engineering geologist is particularly needed to conduct investigations, often with geotechnical engineers, of sites with potential ground failure hazards.

Epicenter - The point at the Earth's surface directly above where an earthquake originated.

Erodible soil – Soil subject to wearing away and movement due to the effects of wind, water, or other geological processes during a flood or storm or over a period of years.

Erosion – Under the *National Flood Insurance Program*, the process of the gradual wearing away of landmasses. In general, erosion involves the detachment and movement of soil and rock fragments, during a flood or storm or over a period of years, through the action of wind, water, or other geologic processes.

Erosion analysis – Analysis of the short- and long-term *erosion* potential of soil or strata, including the effects of wind action, *flooding* or *storm surge*, moving water, wave action, and the interaction of water and structural components.

Expansive soil - A soil that contains clay minerals that take in water and expand. If a soil contains sufficient amount of these clay minerals, the volume of the soil can change significantly with changes in moisture, with resultant structural damage to structures founded on these materials.

Fault - A fracture (rupture) or a zone of fractures along which there has been displacement of adjacent earth material.

Fault segment - A continuous portion of a fault zone that is likely to rupture along its entire length during an earthquake.

Fault slip rate - The average long-term movement of a fault (measured in cm/year or mm/year) as determined from geologic evidence.

Federal Emergency Management Agency (FEMA) – Independent agency created in 1979 to provide a single point of accountability for all Federal activities related to disaster mitigation and emergency preparedness, response and recovery. FEMA administers the *National Flood Insurance Program*.

Federal Insurance Administration (FIA) – The component of the *Federal Emergency Management Agency* directly responsible for administering the flood insurance aspects of the *National Flood Insurance Program*.

Feldspar – The most widespread of any mineral group; constitutes ~60% of the earth's crust. Feldspars occur as components of all kinds of rocks and, on decomposition, yield a large part of the clay of a soil.

Fill – Material such as soil, gravel, or crushed stone placed in an area to increase ground elevations or change soil properties. See *structural fill*.

Five (500)-year flood – *Flood* that has as 0.2-percent probability of being equaled or exceeded in any given year.

Flood - A rising body of water, as in a stream or lake, which overtops its natural and artificial confines and covers land not normally under water. Under the *National Flood Insurance Program*, either (a) a general and temporary condition or partial or complete inundation of normally dry land areas from:

(1) the overflow of inland or tidal waters,
(2) the unusual and rapid accumulation or runoff of surface waters from any source, or
(3) mudslides (i.e., mudflows) which are proximately caused by flooding as defined in (2) and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, as when the earth is carried by a current of water and deposited along the path of the current,

or (b) the collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding as defined in (1), above.

Flood-damage-resistant material – Any construction material capable of withstanding direct and prolonged contact (i.e., at least 72 hours) with floodwaters without suffering significant damage (i.e., damage that requires more than cleanup or low-cost cosmetic repair, such as painting).

Flood elevation – Height of the water surface above an established elevation datum such as the *National Geodetic Vertical Datum*, *North American Vertical Datum*, or *mean sea level*.

Flood hazard area – The greater of the following: (1) the area of special flood hazard, as defined under the *National Flood Insurance Program*, or (2) the area designated as a flood hazard area on a community's legally adopted flood hazard map, or otherwise legally designated.

Flood insurance – Insurance coverage provided under the National Flood Insurance Program.

Flood Insurance Rate Map (FIRM) – Under the *National Flood Insurance Program*, an official map of a community, on which the *Federal Emergency Management Agency* has delineated both the special hazard areas and the risk premium zones applicable to the community. (Note: The latest FIRM issued for a community is referred to as the *effective FIRM* for that community.)

Flood Insurance Study (FIS) – Under the *National Flood Insurance Program*, an examination, evaluation, and determination of *flood* hazards and, if appropriate, corresponding *water surface elevations*, or an examination, evaluation, and determination of mudslide (i.e., mudflow) and/or flood-related erosion hazards in a community or communities. (Note: The *National Flood Insurance Program* regulations refer to Flood Insurance Studies as "flood elevation studies.")

Flood-related erosion area or flood-related erosion prone area – A land area adjoining the shore of a lake or other body of water, which due to the composition of the shoreline or bank and high water levels or wind-driven currents, is likely to suffer *flood*-related *erosion* damage.

Flooding – See *Flood*.

Floodplain – Under the *National Flood Insurance Program*, any land area susceptible to being inundated by water from any source. See *Flood*.

Floodplain management – Operation of an overall program of corrective and preventive measures for reducing *flood* damage, including but not limited to emergency preparedness plans, flood control works, and *floodplain management regulations*.

Floodplain management regulations – Under the *National Flood Insurance Program*, zoning ordinances, subdivision regulations, building codes, health regulations, special purpose ordinances (such as floodplain ordinance, grading ordinance, and erosion control ordinance), and other applications of police power. The term describes such state or local regulations, in any combination thereof, which provide standards for the purpose of *flood* damage prevention and reduction.

Footing – Enlarged base of a foundation wall, pier, post, or column designed to spread the load of the structure so that it does not exceed the soil bearing capacity.

Footprint – Land area occupied by a structure.

Freeboard – Under the *National Flood Insurance Program*, a factor of safety, usually expressed in feet above a *flood* level, for the purposes of *floodplain management*. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the heights calculated for a selected size flood and floodway conditions, such as the hydrological effect of urbanization of the watershed.

Geomorphology - The science that treats the general configuration of the Earth's surface. The study of the classification, description, nature, origin and development of landforms, and the history of geologic changes as recorded by these surface features.

Geotechnical engineer - A licensed civil engineer who is also certified by the State as qualified for the investigation and engineering evaluation of earth materials and their interaction with earth retention systems, structural foundations, and other civil engineering works.

Grade beam – Section of a concrete slab that is thicker than the slab and acts as a footing to provide stability, often under load-bearing or critical structural walls. Grade beams are occasionally installed to provide lateral support for vertical foundation members where they enter the ground.

Grading - Any excavating or filling or combination thereof. Generally refers to the modification of the natural landscape into pads suitable as foundations for structures.

Granite – Broadly applied, any completely crystalline, quartz-bearing, plutonic rock.

Ground failure - Permanent ground displacement produced by fault rupture, differential settlement, liquefaction, or slope failure.

Ground rupture - Displacement of the earth's surface as a result of fault movement associated with an earthquake.

Highest adjacent grade – Elevation of the highest natural or regarded ground surface, or structural fill, that abuts the walls of a building.

Holocene – An epoch of the Quaternary period spanning from the end of the Pleistocene to the present time (10,000 years).

Hornblende – The most common mineral of the amphibole group. It is a primary constituent in many intermediate igneous rocks.

Hydrocompaction - Settlement of loose, granular soils that occurs when the loose, dry structure of the sand grains held together by a clay binder or other cementing agent collapses upon the introduction of water.

Hydrodynamic loads – Loads imposed on an object, such as a building, by water flowing against and around it. Among these loads are positive frontal pressure against the structure, drag effect along the sides, and negative pressure on the downstream side.

Hydrostatic loads – Loads imposed on a surface, such as a wall or floor slab, by a standing mass of water. The water pressure increases with the square of the water depth.

Igneous – Type of rock or mineral that formed from molten or partially molten magma.

Intensity - A measure of the effects of an earthquake at a particular place. Intensity depends on the earthquake magnitude, distance from the epicenter, and on the local geology.

Isolation joint – Separation between adjoining parts of a concrete structure, usually a vertical plane, at a designated location such as to interfere least with the performance of the structure, yet such as to allow relative movement in three directions and avoid formation of cracks elsewhere in the concrete and through which all or part of the bonded reinforcement is interrupted. See *Contraction joint*.

Jetting (of piles) – Use of a high-pressure stream of water to embed a pile in sandy soil. See *pile foundation*.

Joist – Any of the parallel structural members of a floor system that support, and are usually immediately beneath, the floor.

ka – thousands of years before present.

Lacustrine flood hazard area – Area subject to inundation by *flooding* from lakes.

Landslide - A general term covering a wide variety of mass-movement landforms and processes involving the downslope transport, under gravitational influence, of soil and rock material en masse.

Lateral force - The force of the horizontal, side-to-side motion on the Earth's surface as measured on a particular mass; either a building or structure.

Lateral spreading - Lateral movements in a fractured mass of rock or soil which result from liquefaction or plastic flow or subjacent materials.

Left-lateral fault – A strike-slip fault across which a viewer would see the block on the opposite side of the fault move to the left.

Lifeline system - Linear conduits or corridors for the delivery of services or movement of people and information (e.g., pipelines, telephones, freeways, railroads)

Lineament – Straight or gently curved, lengthy features of earth's surface, frequently expressed topographically as depressions or lines of depressions, scarps, benches, or change in vegetation.

Liquefaction - Changing of soils (unconsolidated alluvium) from a solid state to weaker state unable to support structures; where the material behaves similar to a liquid as a consequence of earthquake shaking. The transformation of cohesionless soils from a solid or liquid state as a result of increased pore pressure and reduced effective stress.

Live loads – *Loads* produced by the use and occupancy of the building or other structure. Live loads do not include construction or environmental loads such as wind load, snow load, rain load, earthquake load, flood load, or dead load. See *Loads*.

Load-bearing wall – Wall that supports any vertical load in addition to its own weight. See *Non-load-bearing wall*.

Loads – Forces or other actions that result from the weight of all building materials, occupants and their possessions, environmental effects, differential movement, and restrained dimensional changes. Permanent loads are those in which variations over time are rare or of small magnitude. All other loads are variable loads.

Lowest adjacent grade (LAG) – Elevation of the lowest natural or re-graded ground surface, or structural fill, that abuts the walls of a building. See *Highest adjacent grade*.

Lowest floor – Under the *National Flood Insurance Program*, the lowest floor of the lowest enclosed area (including basement) of a structure. An unfinished or *flood*-resistant enclosure, usable solely for parking of vehicles, building access, or storage in an area other than a basement is not considered a building's lowest floor, provided that the enclosure is not built so as to render the structure in violation of *National Flood Insurance Program* regulatory requirements.

Lowest horizontal structural member – In an elevated building, the lowest beam, *joist*, or other horizontal member that supports the building. *Grade beams* installed to support vertical foundation members where they enter the ground are not considered lowest horizontal structural members.

Ma – millions of years before present.

Magnitude - A measure of the size of an earthquake, as determined by measurements from seismograph records.

Major earthquake - Capable of widespread, heavy damage up to 50+ miles from epicenter; generally near Magnitude range 6.5 to 7.0 or greater, but can be less, depending on rupture mechanism, depth of earthquake, location relative to urban centers, etc.

Manufactured home – Under the *National Flood Insurance Program*, a *structure*, transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when attached to the required utilities. The term “manufactured home” does not include a “recreational vehicle.”

Masonry – Built-up construction of combination of building units or materials of clay, shale, concrete, glass, gypsum, stone, or other approved units bonded together with or without mortar or grout or other accepted methods of joining.

Maximum Magnitude Earthquake (Mmax) - The highest magnitude earthquake a fault is capable of producing based on physical limitations, such as the length of the fault or fault segment.

Maximum Probable Earthquake (MPE) - The design size of the earthquake expected to occur within a time frame of interest, for example within 30 years or 100 years, depending on the purpose, lifetime or importance of the facility. Magnitude/frequency relationships are based on historic seismicity, fault slip rates, or mathematical models. The more critical the facility, the longer the time period considered.

Metamorphic rock – A rock whose original mineralogy, texture, or composition has been changed due to the effects of pressure, temperature, or the gain or loss of chemical components.

Mean sea level (MSL) – Average height of the sea for all stages of the tide, usually determined from hourly height observations over a 19-year period on an open coast or in adjacent waters having free access to the sea. See *National Geodetic Vertical Datum*.

Metal roof panel – Interlocking metal sheet having a minimum installed weather exposure of 3 square feet per sheet.

Metal roof shingle – Interlocking metal sheet having an installed weather exposure less than 3 square feet per sheet.

Mitigation – Any action taken to reduce or permanently eliminate the long-term risk to life and property from natural hazards.

Mitigation Directorate – Component of *Federal Emergency Management Agency* directly responsible for administering the flood hazard identification and *floodplain management* aspects of the *National Flood Insurance Program*.

Moderate earthquake - Capable of causing considerable to severe damage, generally in the range of Magnitude 5.0 to 6.0 (Modified Mercalli Intensity <VI), but highly dependent on rupture mechanism, depth of earthquake, and location relative to urban center, etc.

National Flood Insurance Program (NFIP) – Federal program created by Congress in 1968 that makes *flood* insurance available in communities that enact and enforce satisfactory *floodplain management regulations*.

National Geodetic Vertical Datum (NGVD) – Datum established in 1929 and used as a basis for measuring flood, ground, and structural elevations, previously referred to as Sea Level Datum or *Mean Sea Level*. The *Base Flood Elevations* shown on most of the *Flood Insurance Rate Maps* issued by the *Federal Emergency Management Agency* are referenced to NGVD or, more recently, to the *North American Vertical Datum*.

Naturally decay-resistant wood – Wood whose composition provides it with some measure of resistance to decay and attack by insects, without preservative treatment (e.g., heartwood of cedar, black locust, black walnut, and redwood).

Near-field earthquake - Used to describe a local earthquake within approximately a few fault zone widths of the causative fault which is characterized by high frequency waveforms that are destructive to above-ground utilities and short period structures (less than about two or three stories).

New construction – For the purpose of determining flood insurance rates under the *National Flood Insurance Program*, *structures* for which the start of construction commenced on or after the effective date of the initial *Flood Insurance Rate Map* or after December 31, 1974, whichever is later, including any subsequent improvements to such structures. (See *Post-FIRM structure*.) For *floodplain management* purposes, new construction means *structures* for which the *start of construction* commenced on or after the effective date of a *floodplain management regulation* adopted by a community and includes any subsequent improvements to such structures.

Non-coastal A zone – The portion of the *Special Flood Hazard Area* in which the principal source of *flooding* is runoff from rainfall, snowmelt, or a combination of both. In non-coastal A zones, *flood* waters may move slowly or rapidly, but waves are usually not a significant threat to buildings. See *A zone* and *coastal A zone*. (Note: the *National Flood Insurance Program* regulations do not differentiate between non-coastal A zones and *coastal A zones*.)

Non-load-bearing wall – Wall that does not support vertical loads other than its own weight. See *Load-bearing wall*.

North American Vertical Datum (NAVD) – Datum used as a basis for measuring flood, ground, and structural elevations. NAVD is used in many recent *Flood Insurance Studies* rather than the *National Geodetic Vertical Datum*.

Oblique – reverse fault – A fault that combines some strike-slip motion with some dip-slip motion in which the upper block, above the fault plane, moves up over the lower block.

Offset ridge - A ridge that is discontinuous on account of faulting.

Offset stream - A stream displaced laterally or vertically by faulting.

(One) 100-year flood – See *Base flood*.

Oriented strand board (OSB) – Mat-formed wood structural panel product composed of thin rectangular wood strands or wafers arranged in oriented layers and bonded with waterproof adhesive.

Orthoclase – One of the most common rock-forming minerals; colorless, white, cream-yellow, flesh-reddish, or grayish in color.

Paleoseismic – Pertaining to an earthquake or earth vibration that happened decades, centuries, or millennia ago.

Peak Ground Acceleration (PGA) - The greatest amplitude of acceleration measured for a single frequency on an earthquake accelerogram. The maximum horizontal ground motion generated by an earthquake. The measure of this motion is the acceleration of gravity (equal to 32 feet per second squared, or 980 centimeter per second squared), and generally expressed as a percentage of gravity.

Pedogenic – Pertaining to soil formation.

Pegmatite – An igneous rock with extremely large grains, more than a centimeter in diameter.

Perched ground water - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

Peak flood - The highest discharge or stage value of a flood.

Plagioclase – One of the most common rock forming minerals.

Plutonic – Pertaining to igneous rocks formed at great depth.

Plywood – Wood structural panel composed of plies of wood veneer arranged in cross-aligned layers. The plies are bonded with an adhesive that cures on application of heat and pressure.

Pore pressure - The stress transmitted by the fluid that fills the voids between particles of a soil or rock mass.

Post foundation – Foundation consisting of vertical support members set in holes and backfilled with compacted material. Posts are usually made of wood and usually must be braced. Posts are also known as columns, but columns are usually made of concrete or masonry.

Post-FIRM structure – For purposes of determining insurance rates under the *National Flood Insurance Program*, structures for which the *start of construction* commenced on or after the effective date of an initial *Flood Insurance Rate Map* or after December 31, 1974, whichever is later, including any subsequent improvements to such structures. This term should not be confused with the term *new construction* as it is used in *floodplain management*.

Potentially active fault - A fault showing evidence of movement within the last 1.6 million years (750,000 years according to the U.S. Geological Survey) but before about 11,000 years ago, and that is capable of generating damaging earthquakes.

Precast concrete – Structural concrete element cast elsewhere than its final position in the structure. See *Cast-in-place concrete*.

Pressure-treated wood – Wood impregnated under pressure with compounds that reduce the susceptibility of the wood to flame spread or to deterioration caused by fungi, insects, or marine borers.

Project - A development application involving zone changes, variances, conditional use permits, tentative parcel maps, tentative tract maps, and plan amendments.

Quartzite – A metamorphic rock consisting mostly of quartz.

Quartz monzonite – A plutonic rock containing major plagioclase, orthoclase and quartz; with increased orthoclase it becomes a granite.

Quaternary – The second period of the Cenozoic era, consisting of the Pleistocene and Holocene epochs; covers the last two to three million years.

Resonance - Amplification of ground motion frequencies within bands matching the natural frequency of a structure and often causing partial or complete structural collapse; effects may demonstrate minor damage to single-story residential structures while adjacent 3- or 4-story buildings may collapse because of corresponding frequencies, or vice versa.

Recurrence interval – The time between earthquakes of a given magnitude, or within a given magnitude range, on a specific fault or within a specific area.

Reinforced concrete – *Structural concrete* reinforced with steel bars.

Response spectra - The range of potentially damaging frequencies of a given earthquake applied to a specific site and for a particular building or structure.

Retrofit –Any change made to an existing structure to reduce or eliminate damage to that structure from flooding, *erosion*, high winds, earthquakes, or other hazards.

Revetment – Facing of stone, cement, sandbags, or other materials placed on an earthen wall or embankment to protect it from *erosion* or *scour* caused by *flood* waters or wave action

Right-lateral fault - A strike-slip fault across which a viewer would see the block on the opposite side of the fault move to the right.

Riprap – Broken stone, cut stone blocks, or rubble that is placed on slopes to protect them from *erosion* or *scour* caused by *flood* waters or wave action.

Roof deck – Flat or sloped roof surface not including its supporting members or vertical supports.

Sand boil - An accumulation of sand resembling a miniature volcano or low volcanic mound produced by the expulsion of liquefied sand to the sediment surface. Also called sand blows, and sand volcanoes.

Sandstone - A medium-grained, clastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in a fine-grained matrix and more or less firmly united by a cementing material.

Saturated - Said of the condition in which the interstices of a material are filled with a liquid, usually water.

Scarp – A line of cliffs produced by faulting or by erosion. The term is an abbreviated form of escarpment.

Schist – A metamorphic rock characterized by a preferred orientation in grains resulting in the rock's ability to be split into thin flakes or slabs.

Scour – Removal of soil or fill material by the flow of *flood* waters. The term is frequently used to describe storm-induced, localized conical erosion around pilings and other foundation supports where the obstruction of flow increases turbulence. See *Erosion*.

Sediment - Solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, ice, or that accumulates by other natural agents, such as chemical precipitation from solution. and that forms in layers on the Earth's surface in a loose, unconsolidated form.

Seiche - A free or standing-wave oscillation of the surface of water in an enclosed or semi-enclosed basin (such as a lake, bay, or harbor), that is initiated chiefly by local changes in atmospheric pressure, aided by winds, tidal currents, and earthquakes, and that continues, pendulum-fashion, for a time after cessation of the originating force.

Seismogenic - Capable of producing earthquake activity.

Seismograph - An instrument that detects, magnifies, and records vibrations of the Earth, especially earthquakes. The resulting record is a seismogram.

Shearwall – *Load-bearing wall* or *non-load-bearing wall* that transfers in-plane lateral forces from lateral *loads* acting on a structure to its foundation.

Shoreline retreat – Progressive movement of the shoreline in a landward direction caused by the

Shutter ridge – That portion of an offset ridge that blocks or "shutters" the adjacent canyon.

Silt - A rock fragment or detrital particle smaller than a very fine sand grain and larger than coarse clay, having a diameter in the range of 1/256 to 1/16 mm (4-62 microns, or 0.00016-0.0025 in.). An indurated silt having the texture and composition of shale but lacking its fine lamination is called a siltstone.

Single-ply membrane – Roofing membrane that is field-applied with one layer of membrane material (either homogeneous or composite) rather than multiple layers.

Slope ratio - Refers to the angle or gradient of a slope as the ratio of horizontal units to vertical units. For example, in a 2:1 slope, for every two horizontal units, there is a vertical rise of one unit (equal to a slope angle, from the horizontal, of 26.6 degrees).

Slump - A landslide characterized by a shearing and rotary movement of a generally independent mass of rock or earth along a curved slip surface.

Soil horizon – A layer of soil that is distinguishable from adjacent layers by characteristic physical properties such as structure, color, or texture.

Special Flood Hazard Area (SFHA) – Under the *National Flood Insurance Program*, an area having special *flood*, mudslide (i.e., mudflow) and/or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or *Flood Insurance Rate Map* as Zone A, AO, A1-A30, AE, A99, AH, V, V1-V30, VE, M or E.

Storage capacity - Dam storage measured in acre-feet or decameters, including dead storage.

Strike-slip fault - A fault with a vertical to sub-vertical fault surface that displays evidence of horizontal and opposite displacement.

Structural concrete – All concrete used for structural purposes, including *plain concrete* and *reinforced concrete*.

Structural engineer - A licensed civil engineer certified by the State as qualified to design and supervise the construction of engineered structures.

Structural fill – Fill compacted to a specified density to provide structural support or protection to a *structure*. See *Fill*.

Structure – Something constructed, such as a building, or part of one. For *floodplain management* purposes under the *National flood Insurance Program*, a walled and roofed building, including a gas or liquid storage tank, that is principally above ground, as well as a manufactured home. For insurance coverage purposes under the NFIP, structure means a walled and roofed building, other than a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a *manufactured home* on a permanent foundation. For the latter purpose, the term includes a building while in the course of construction, alteration, or repair, but does not include building materials or supplies intended for use in such construction, alteration, or repair, unless such materials or supplies are within an enclosed building on the premises.

Subsidence - The sudden sinking or gradual downward settling of the Earth's surface with little or no horizontal motion.

Swale – In hillside terrace, a shallow drainage channel, typically with a rounded depression or “hollow” at the head.

Thrust fault – A fault, with a relatively shallow dip, in which the upper block, above the fault plane, moves up over the lower block.

Transform system – A system in which faults of plate-boundary dimensions transform into another plate-boundary structure when it ends.

Transpression – In crustal deformation, an intermediate stage between compression and strike-slip motion; it occurs in zones with oblique compression.

Tsunami – Great sea wave produced by submarine earth movement or volcanic eruption.

Typhoon – Name given to a *hurricane* in the area of the western Pacific Ocean west of 180 degrees longitude.

Unconfined aquifer – Aquifer in which the upper surface of the saturated zone is free to rise and fall.

Unconsolidated sediments - A deposit that is loosely arranged or unstratified, or whose particles are not cemented together, occurring either at the surface or at depth.

Underlayment – One or more layers of felt, sheathing paper, non-bituminous saturated felt, or other approved material over which a steep-sloped roof covering is applied.

Undermining – Process whereby the vertical component of erosion or scour exceeds the depth of the base of a building foundation or the level below which the bearing strength of at the foundation is compromised.

Uplift – Hydrostatic pressure caused by water under a building. It can be strong enough lift a building off its foundation, especially when the building is not properly anchored to its foundation.

Upper bound earthquake – Defined as a 10% chance of exceedance in 100 years, with a statistical return period of 949 years.

Variance – Under the *National Flood Insurance Program*, grant of relief by a community from the terms of a *floodplain management regulation*.

Violation – Under the *National Flood Insurance Program*, the failure of a structure or other development to be fully compliant with the community's *floodplain management regulations*. A *structure* or other *development* without the elevation certificate, other certifications, or other evidence of compliance required in Sections 60.3(b)(5), (c)(4), (c)(10), (d)(3), (e)(2), (e)(4), or (e)(5) of the NFIP regulations is presumed to be in violation until such time as that documentation is provided.

Watershed - A topographically defined region draining into a particular water course.

Water surface elevation – Under the *National Flood Insurance Program*, the height, in relation to the *National Geodetic Vertical Datum* of 1929 (or other datum, where specified), of *floods* of various magnitudes and frequencies in the *floodplains* of coastal or riverine areas.

Water table - The upper surface of groundwater saturation of pores and fractures in rock or surficial earth materials.

X zone – Under the *National Flood Insurance Program*, areas where the *flood* hazard is less than that in the *Special Flood Hazard Area*. Shaded X zones shown on recent *Flood Insurance Rate Maps* (B zones on older maps) designate areas subject to inundation by the *500-year flood*. Un-shaded X zones (C zones on older *Flood Insurance Rate Maps*) designate areas where the annual probability of flooding is less than 0.2 percent.

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