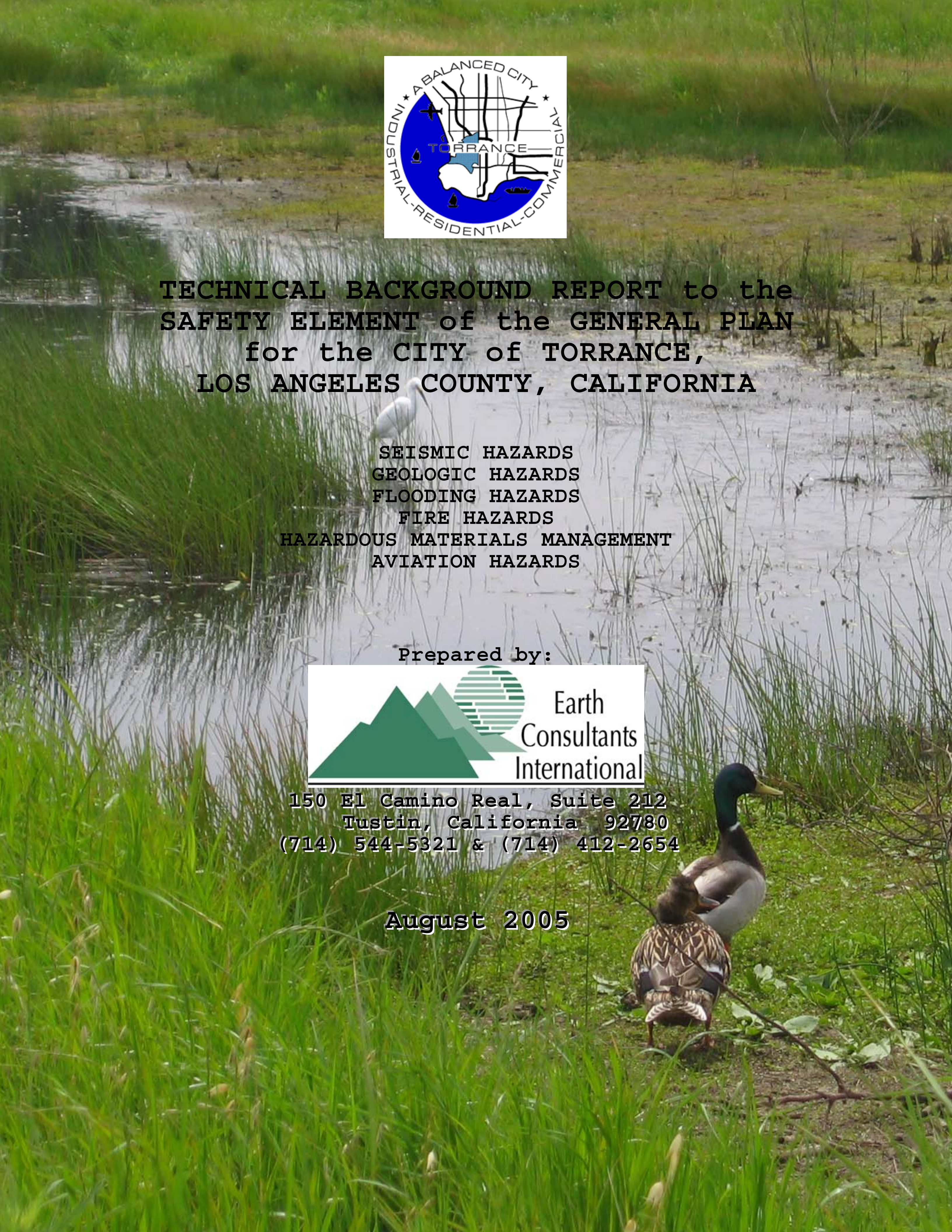
Appendix G
Technical Background Report

This page intentionally left blank.



A BALANCED CITY
TORRANCE
INDUSTRIAL-RESIDENTIAL-COMMERCIAL

TECHNICAL BACKGROUND REPORT to the SAFETY ELEMENT of the GENERAL PLAN for the CITY of TORRANCE, LOS ANGELES COUNTY, CALIFORNIA

SEISMIC HAZARDS
GEOLOGIC HAZARDS
FLOODING HAZARDS
FIRE HAZARDS
HAZARDOUS MATERIALS MANAGEMENT
AVIATION HAZARDS

Prepared by:

Earth Consultants International

150 El Camino Real, Suite 212
Tustin, California 92780
(714) 544-5321 & (714) 412-2654

August 2005

TECHNICAL BACKGROUND REPORT TO THE SAFETY ELEMENT
CITY of TORRANCE, CALIFORNIA

TABLE OF CONTENTS

Section **Page No.**

TABLE OF CONTENTS (Continued)

Section **Page No.**

TABLE OF CONTENTS (Continued)

Section **Page No.**

TABLE OF CONTENTS (Continued)

Section **Page No.**

TABLE OF CONTENTS (Continued)

Section **Page No.**

APPENDICES

FIGURES, TABLES AND PLATES

FIGURES

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

CHAPTER 1: SEISMIC HAZARDS

1.1 Introduction

While Torrance 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, tsunamis and seiches, all of which are discussed below. Earthquakes can also lead to urban fires, reservoir failures, and toxic chemical releases. These man-related 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, M_W 7.1 Loma Prieta earthquake, the traffic was uncommonly light because so many were watching the World Series. The 1994, M_W 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. Torrance 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 to 70 kilometers of the Earth consist of enormous blocks of moving rock, called tectonic plates. There are about a dozen major plates, which slowly collide, separate, and grind past each other. In the uppermost brittle portion of the plates, friction locks the plate edges together, while plastic 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 then released in seismic 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 point where the fault rupture originates is called the focus (or hypocenter). The released energy radiates out in all directions from the rupture surface causing the Earth to vibrate and shake as the waves travel through. This shaking is what we feel in an earthquake.

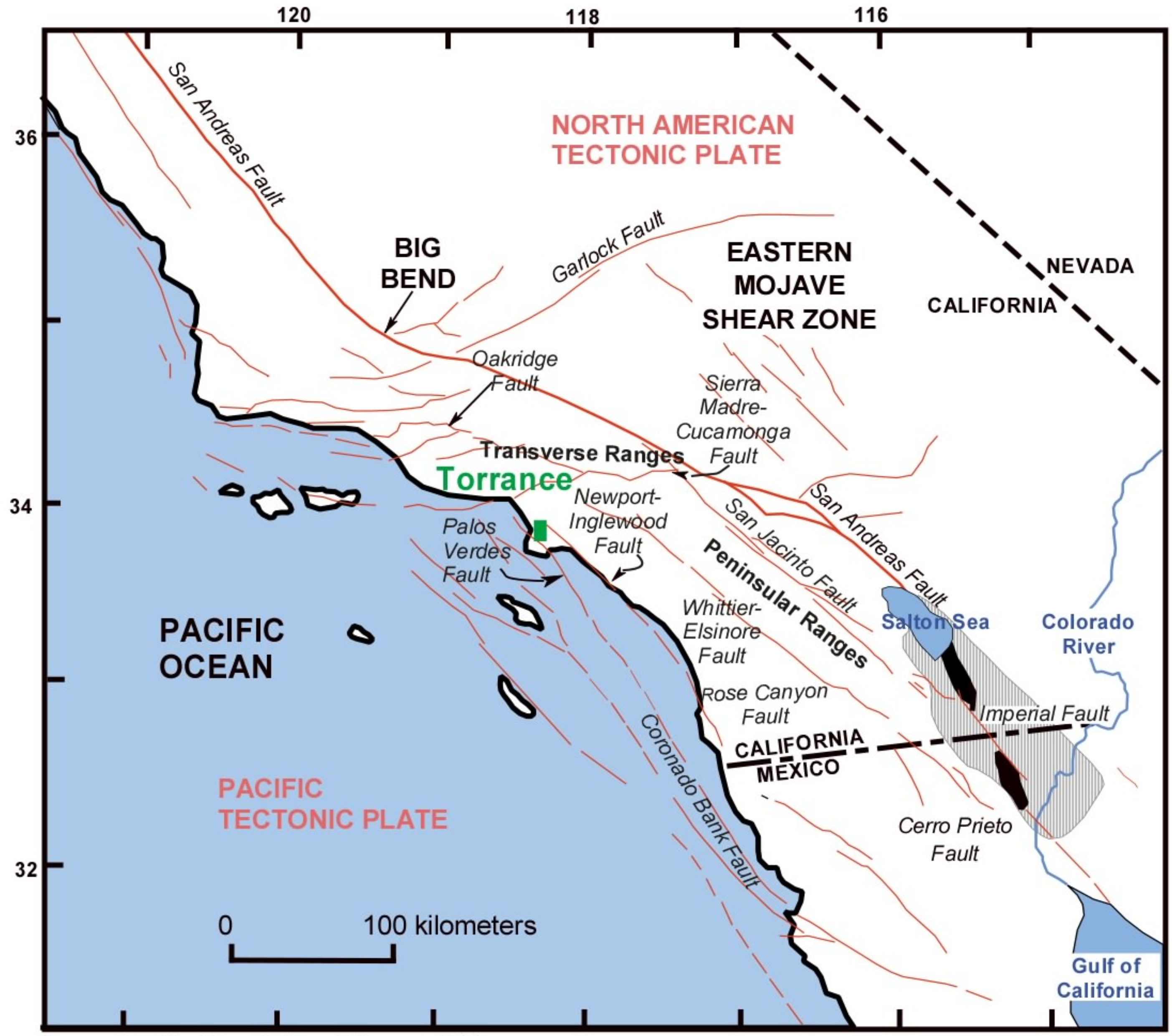
Although faults exist everywhere, most earthquakes occur on or near plate boundaries. Thus, southern California has many earthquakes, because it straddles the boundary between the North American and Pacific plates, and fault rupture accommodates their motion. Torrance is riding on the Pacific Plate, which 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 tens 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, Torrance 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 actually occurs on this fault. The rest is distributed along other faults of the San Andreas system, including the San Jacinto, Whittier-Elsinore, Newport-Inglewood, Palos Verdes, and several offshore faults. To the east of the San Andreas fault, slip is distributed among faults of the Eastern Mojave Shear Zone, including those responsible for the 1992, M_W 7.3 Landers and 1999 M_W 7.1 Hector Mine earthquakes. (M_W 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 Nevada to the Pacific Ocean (see Figure 1-1).

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 trend 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 north of Torrance (Figure 1-1). Near the Big Bend, the two plates do not slide past each other. Instead, they collide, causing localized compression, which results in folding and thrust faulting. Thrust faults meet the surface of the Earth at a low angle, dipping 25 to 35 degrees from 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 opposite 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 is 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 M_W 6.7 San Fernando, the 1987 M_W 5.9 Whittier Narrows, the 1991 M_W 5.8 Sierra Madre, and the 1994 M_W 6.7 Northridge earthquakes.



Source: Modified from Fuis and Mooney, 1990

MAP EXPLANATION

Fault

Onshore Spreading Center

New Crust (late Cenozoic)

Earth Consultants International

Project Number: 2431
Date: July 2005

Regional Fault Map

Figure 1-1

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 previously unknown blind thrust faults.

The city of Torrance is situated in the northern part of the Peninsular Ranges Province, an area that is exposed to risk from multiple earthquake fault zones. The highest risks originate from the Palos Verdes (strike-slip, right-lateral) fault zone, the Puente Hills (blind thrust) fault, the Newport-Inglewood (strike-slip, right-lateral) fault zone, the Elysian Park (blind thrust) fault zone, the Malibu Coast-Santa Monica-Hollywood (strike-slip left-lateral) fault zone, and the Whittier (strike-slip, right-lateral) fault zone (see Figure 1-2). Each of these faults, plus other regional seismic sources, such as the San Andreas fault, will be discussed in more detail in Section 1-5.

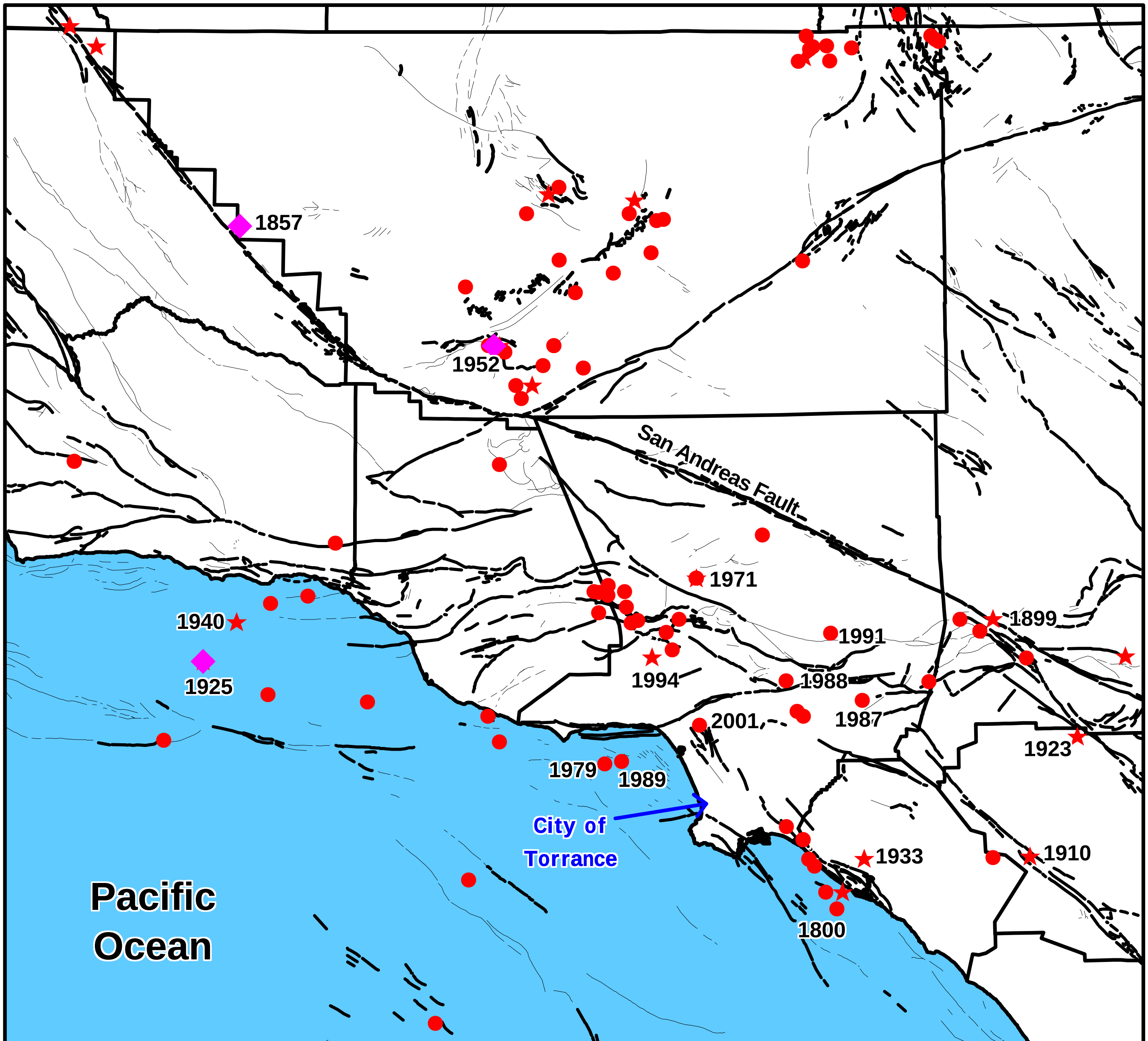
1.2.2 Evaluating Earthquake Hazard Potential

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 (M_w) 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 levels of intensity because intensity effects vary with the location and the 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 (1 inch on paper represents 2,000 feet on the ground). 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.



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

Map Explanation

◆ Magnitude 7+	● Magnitude 5 - 6
★ Magnitude 6 - 7	— Quaternary faults

Earth Consultants International

Project Number: 2431
Date: July, 2005

Regional Seismicity Map

Figure 1-2

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)

The bigger and closer the earthquake, the greater the damage it may generate. 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 allow an estimation of 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 the recurrence interval for a given fault is to excavate a trench across the fault to obtain paleoseismic evidence of earthquakes that have occurred during prehistoric time.

Paleoseismic studies show that faults with higher slip rates often have shorter recurrence intervals between major earthquakes. This makes sense because 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.

The Alquist-Priolo classification is used primarily for residential subdivisions. Different 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 settled 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, M_W 6.9 Kobe, Japan earthquake was not much bigger than the 1994, M_W 6.7 Northridge, California earthquake, but the city of Kobe suffered 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 focused into one location and causes damage in unexpected areas. Focusing of 1989's M_W 7.1 Loma Prieta earthquake waves caused damage in San Francisco's Marina district, some 62 miles (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. The Marina District of San Francisco also serves as an example of site effects. Earthquake motions were greatly amplified in the deep, sediment-filled basin underlying the District compared to the surrounding bedrock areas. 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 to 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. Combined with analyses of slope gradient, land use, and bedrock or soil materials, this information 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 (M_{max}). Other scenarios consider the Maximum Probable Earthquake (M_{PE}) or Design Basis Earthquake (DBE) (1997 Uniform Building Code – UBC; 2001 California Building Code - CBC). The DBE is defined as 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 (2001) 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, expected lifetime of a structure, 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. 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.

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.

As is true for most earthquake-prone regions, many potential earthquake sources pose a threat to Torrance. 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 62-mile (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. As the size of the mainshock increases, there typically is a corresponding increase in the number of aftershocks, the size of the aftershocks, and the size of the area in which they might occur.

On average, the largest aftershock will be 1.2 magnitude units less than the mainshock. Thus, a M_W 6.9 earthquake will tend to produce aftershocks up to M_w 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 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 that 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. As of this writing, there are no Alquist-Priolo Earthquake Fault Zones mapped within city of Torrance limits. If, in the future, the Palos Verdes fault is zoned as an active fault by the State Geologist, then an Alquist-Priolo Earthquake Fault Zone would extend across the southern portion of the city. As discussed further in Section 1.6, a Fault Hazard Management Zone is recommended for this area to encourage the study of the onshore segment of the Palos Verdes fault to conclusively determine whether or not it is an active structure.

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 liquefaction, and 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 Torrance area, the CGS has mapped all three quadrangles that encompass the city: Inglewood, Redondo Beach, and Torrance (CDMG, 1998a, b, c). These maps indicate that liquefaction and earthquake-induced landslides are hazards present locally in some portions of the Torrance 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 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 homes.

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 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, building codes were updated on a fairly regular basis, but adoption of these updates at the county- and city-level was not mandatory. As a result, the building codes used from one community to the next were often not the same. Then in 1980, 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, the legislature amended the State's Health and Safety Code to require local jurisdictions to adopt, as a minimum, 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; although each jurisdiction can require more stringent regulations, issued as amendments to the CBC. 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 used to be updated and republished every three years since the initial action by the legislature.

Then, in 1994, to further the concept of uniformity in building design, the 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 the year 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 California Building Standards Commission, after careful review, chose to continue to adopt the old 1997 UBC for the CBC. The most recent building standard adopted by the legislature and used throughout the State is the 2001 version of the CBC, often with local, more restrictive amendments that are based upon local geographic, topographic or climatic conditions.

As indicated above, the CBC has not been updated since 2001, pending resolution regarding California's adoption of the National Fire Protection Association (NFPA) 5000 building code as the State's next building code. Specifically, on July 29, 2003, the California Building Standards Commission recommended the adoption of the NFPA 5000 code as the basis for California's next building code. However, state agencies that reviewed the proposed building code found it to be incomplete, requiring the adoption of substantial amendments, many transcribed directly from the current CBC, to bring it to the level currently provided by the 2001 CBC. For this and other reasons, including the cost of developing the amendments and training state, county and city officials responsible for the enforcement of the code, on March 8, 2005, the Coordinating Council of the California Building Standards Commission recommended rescission of the 2003 decision to adopt the NFPA 5000, and instead recommended adoption of the latest ICB as the basis for the next CBC. [For more recent information regarding this issue, refer to the California Building Standards Commission website at www.bsc.ca.gov/].

It should be emphasized that the building codes provide minimum requirements. In some cases these requirements may not adequate, particularly in the area of faulting and seismology, where the pool of knowledge is rapidly growing and evolving. Consequently, it is important that geotechnical consultants working in the city, as well as reviewers of their work, keep up to date on current research.

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 potentially 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 Torrance area lies entirely within Seismic Zone 4. Therefore, and in compliance with the Unreinforced Masonry Law, the City inventoried the URMs in its jurisdiction. In the year 2000, Torrance reported to the Seismic Safety Commission that 50 URMs had been identified in the city. Of these, none were considered of historical significance.

Furthermore, by 2000, all 50 building owners had been notified about the hazards of URM construction, and 43 of the URMs had been brought to compliance with the City's mandatory strengthening requirements. The remaining seven buildings were demolished. To encourage URM building owners to strengthen their structures, the City funded a subsidy to pay for the engineering analysis (at $0.50 per square foot) and formed an assessment district (of $679,000.00) for building owners who chose to join (California Seismic Safety Commission, 2000, 2003).

1.4 Notable Earthquakes in the Torrance Area

Figure 1-3 shows the approximate epicenters of some of the earthquakes that have resulted in significant ground shaking in the southern California area, including Torrance, since at least the 1800s. The most significant of these events are described below. Plate 1-1 shows the approximate epicentral locations of historical earthquakes in and around the city. Please note that the locations and magnitudes of pre-1932 earthquakes are approximate since there were no instruments available to measure these parameters before 1932.

1.4.1 Unnamed Earthquake of 1769

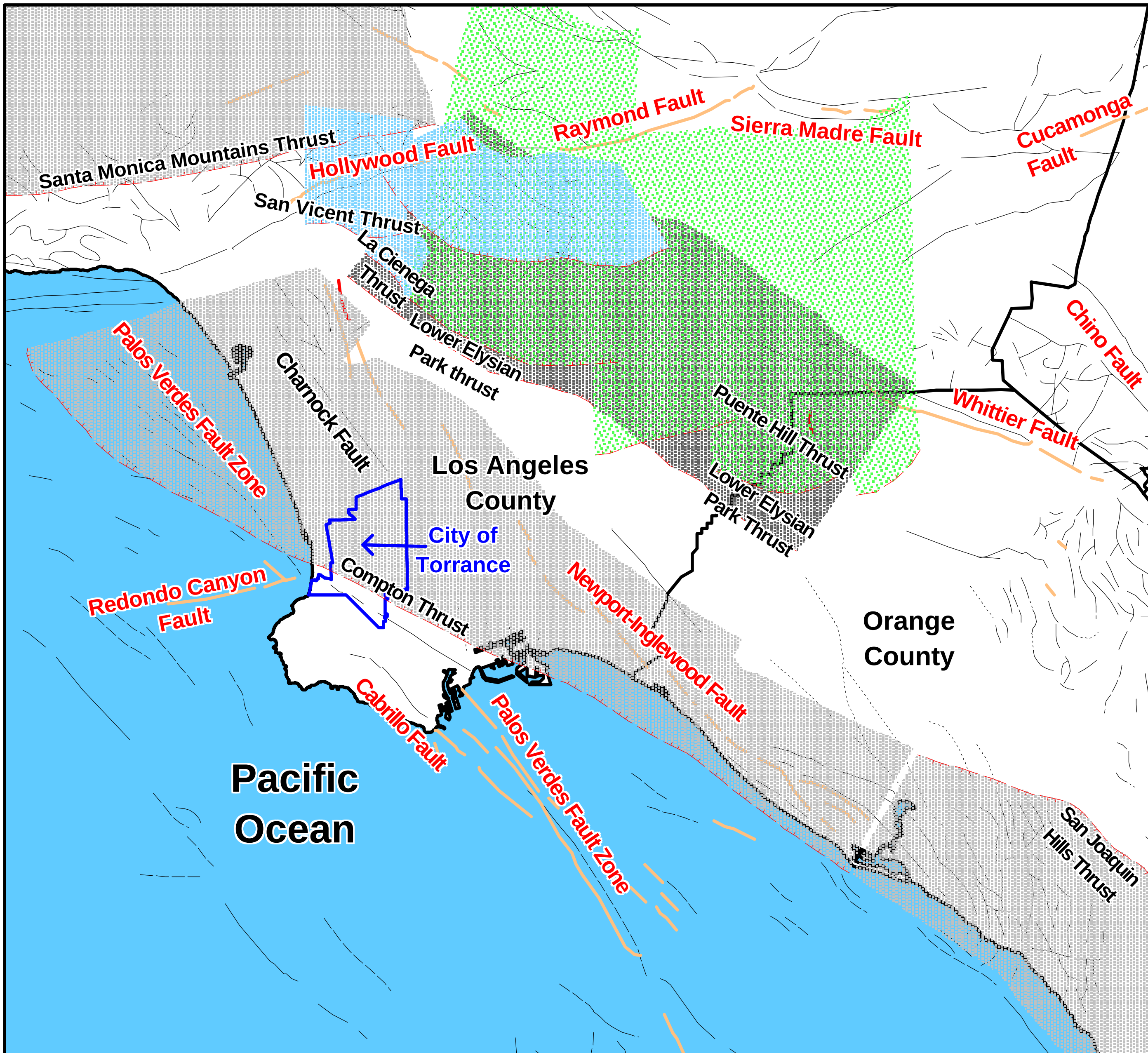
On July 28, 1769 the first recorded earthquake in southern California was noted by the Spanish explorers traveling north with Gaspar de Portola. At the time of the earthquake, the explorers were camped in the present-day city of Orange, on the east bank of the Santa Ana River. Father Juan Crespo, who kept a daily account of the expedition, reported a strong mainshock followed by five days of moderate aftershocks; an estimated magnitude of at least 6.0 has been assigned to the event based on the explorers' account (Teggart, 1911). Recent studies of coastal uplift attributed to the earthquake suggest that it may have had a magnitude as high as 7.3 and that it occurred on a blind fault beneath the San Joaquin Hills (Grant et al., 2002), although this location is still being debated by the paleoseismology community. The Elsinore and Newport-Inglewood faults are also considered possible sources for this earthquake.

1.4.2 Unnamed Earthquake of 1800

An earthquake with an estimated magnitude of 6.5 occurred on November 22, 1800 in the coastal region of southern California. Based on the distribution of damage attributed to the earthquake, the epicenter is thought to have been between Newport Beach and San Diego, and was possibly located offshore (Ellsworth, 1990). The earthquake damaged the mission at San Juan Capistrano and collapsed a barracks in the present-day Old Town district of San Diego (www.sfmuseum.org/alm/quakeso.html).

1.4.3 Wrightwood Earthquake of December 12, 1812

This large earthquake occurred on December 8, 1812 and was felt throughout southern California. Based on accounts of damage recorded at missions in the earthquake-affected area, an estimated magnitude of 7.5 has been calculated for the event (Toppozada et al., 1981). Subsurface investigations and tree ring studies show that the earthquake likely ruptured the Mojave section of the San Andreas fault near Wrightwood, and may have been accompanied by a significant surface rupture between Cajon Pass and Tejon Pass (Jacoby, Sheppard and Sieh, 1988; www.scecdc.scec.org/quakedex.html). The worst damage caused by the earthquake occurred significantly west of the San Andreas fault at San Juan Capistrano Mission, where the roof of the church collapsed, killing 40 people.



Modified from: Shaw et al., 2002; Dolan, Shaw, and Pratt, 2001; and Jennings, 1995

Map Explanation

Blind thrust fault ramp; red hatchures show surface projection or upper edge of thrust ramp, the thrust fault ramps are shown from deepest to shallowest by gray and green shading, respectively.

Fault Showing Evidence of Historic Rupture (Active).

Fault Showing Evidence of Holocene Rupture (Active).

Fault Showing Evidence of Quaternary and Late Quaternary Rupture (Potentially Active).

Earth Consultants International

Project Number: 2431
Date: March, 2005

Local Active and Potentially Active Faults

Figure 1-3

The earthquake also damaged walls and destroyed statues at San Gabriel Mission and damaged missions in the Santa Barbara area. Strong aftershocks caused earthquake-damaged buildings to collapse for several days after the mainshock.

1.4.4 Unnamed Earthquake of December 21, 1812

The Wrightwood earthquake was followed by a strong earthquake on December 21st that caused widespread damage in the Santa Barbara area. The effects of this second earthquake are sometimes attributed to the December 12th event, giving the impression that a single large earthquake caused significant damage from Santa Barbara to San Diego. The second earthquake had an estimated magnitude of 7 and was likely located offshore within the Santa Barbara Channel, although it could have occurred inland in Santa Barbara or Ventura Counties (www.scecdc.scec.org/quakedex.html). The earthquake destroyed the church at the Mission in Santa Barbara, the Mission de Purísima Concepción near present day Lompoc, and the Mission at Santa Inez (www.johnmartin.com/eqs/00000077.htm). The earthquake may have also caused a tsunami that may have traveled up to 1/2 mile inland near Santa Barbara (Toppozada et al., 1981), although more recent review of the data suggests that this tsunami was caused by a submarine landslide (Lander et al., 1993; Greene and Maher, 2000; Borrero et al., 2001).

1.4.5 Unnamed Earthquake of 1855

This earthquake occurred on July 11, 1855 and was felt across southern California from Santa Barbara to San Bernardino. Light to moderate damage was reported in the Los Angeles area, where 26 houses experienced cracked walls and the bell tower of the San Gabriel Mission was knocked down (www.sfmuseum.org/alm/quakeso.html). Because damage was limited primarily to the Los Angeles area, this earthquake is postulated to have occurred on a local fault such as the Hollywood-Raymond, Whittier or Newport-Inglewood faults, or on one of the many blind thrust faults in the area.

1.4.6 Elsinore Earthquake of 1910

This magnitude 6 earthquake occurred on May 15, 1910 at 7:47 A.M. Pacific Standard Time (PST), following two moderate tremors that occurred on April 10 and May 12, 1910. The Elsinore fault is thought to have caused the earthquake, although no surface rupture along this fault was reported. Damage as a result of this earthquake was minor; toppled chimneys were reported in the Corona, Temescal and Wildomar areas. The epicentral location of this earthquake is very poorly defined.

1.4.7 San Jacinto Earthquake of 1918

The magnitude 6.8 San Jacinto earthquake occurred on April 21, 1918 at 2:32 P.M. PST, near the town of San Jacinto. The earthquake caused extensive damage to the business districts of San Jacinto and Hemet, where many masonry structures collapsed, but because it occurred on a Sunday, when these businesses were closed, the number of fatalities and injuries was low. Several people were injured, but only one death was reported. Minor damage as a result of this earthquake was reported outside the San Jacinto area, and the earthquake was felt as far away as Taft (west of Bakersfield), Seligman (Arizona), and Baja California.

Strong shaking cracked the ground, concrete roads, and concrete irrigating canals, but none of the cracks are thought to have been caused directly by surface fault rupture.

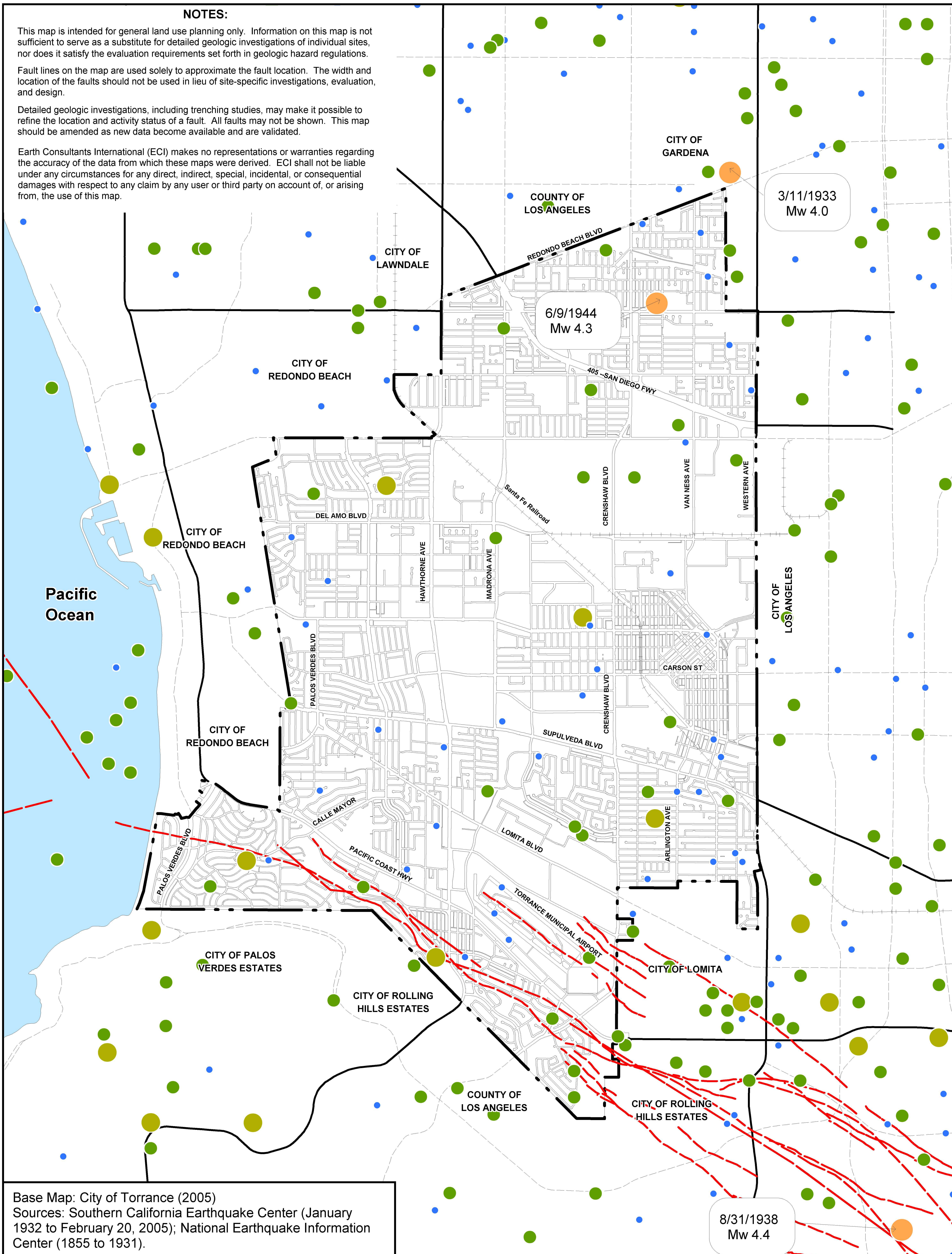
NOTES:

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: City of Torrance (2005)
Sources: Southern California Earthquake Center (January 1932 to February 20, 2005); National Earthquake Information Center (1855 to 1931).

Scale: 1:48,000

1 0 1 2 3 Kilometers

4000 0 4000 8000 12000 Feet

Explanation

Earthquake Magnitude

- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- >2

Fault or lineament, solid where location known, dashed where approximate, dotted where inferred (for more information refer to Plate 1-2).

Torrance City Limit

Earth Consultants International

Project Number: 2431
Date: July, 2005

Historical Seismicity Map (1932-2005)

Torrance, California

Plate 1-1

The shaking also triggered several landslides in mountain areas. The road from Hemet to Idyllwild was blocked in several places where huge boulders rolled down slopes. Two men in an automobile were reportedly swept off a road by a landslide, and would have rolled several hundred feet down a hillside had they not been stopped by a large tree. Two miners were trapped in a mine near Winchester, but they were eventually rescued, uninjured. The earthquake apparently caused changes in the flow rates and temperatures of several springs. Sand craters (due most likely to liquefaction) were reported on one farm, and an area near Blackburn Ranch "sunk" approximately three feet (one meter) during the quake (/www.scecdc.scec.org/quakedex.html).

1.4.8 Long Beach Earthquake of 1933

The M_w 6.4 Long Beach earthquake occurred on March 10, at 5:54 P.M. PST, following a strong foreshock the day before. The earthquake ruptured the Newport-Inglewood fault, and was felt from the San Joaquin Valley to Northern Baja. The epicenter was located on the boundary between Huntington Beach and Newport Beach, although the earthquake was called "the Long Beach earthquake" because the worst damage was focused in the city of Long Beach. In the Torrance area, the earthquake produced Modified Mercalli Intensities of VII-VIII (http://pasadena.wr.usgs.gov/shake/ca/).

The earthquake killed 115 people and caused $40-50 million in property damage (www.scecdc.scec.org/quakedex.html). Primary ground rupture of the Newport-Inglewood fault was not observed, although secondary cracking, minor slumping, and lateral movement of unconsolidated sediments occurred throughout the region. Road surfaces along the shore between Long Beach and Newport Beach were damaged by settlement of road fills that had been placed on marshy land. In urban areas, unreinforced masonry buildings were most severely damaged, especially in areas of artificial fill or water-soaked alluvium. In one part of Compton, most buildings built on unconsolidated sediments and artificial fill were destroyed. In Long Beach, many buildings collapsed, were pushed off their foundations, or had walls or chimneys knocked down. In Newport Beach, 800 chimneys were knocked down at the roofline and hundreds of houses were destroyed (www.anaheimcocom.com/quake.htm). Damage to school buildings was especially severe and led to the passage of the Field and Riley Acts by the State legislature. The Field Act regulates school construction and the Riley Act regulates the construction of buildings larger than two-family dwellings. Many strong aftershocks occurred through March 16th.

1.4.9 Torrance-Gardena Earthquakes of 1941

In 1941, two small earthquakes struck the southern Los Angeles basin, affecting surrounding communities. Although these earthquakes were relatively minor, they occurred close to the surface and caused significant, although localized damage. The magnitude 4.8 Torrance earthquake occurred on October 21st at 10:57 P.M. PST, and was located east of Carson, near the present-day interchange of the 405 and 710 freeways. Shaking up to intensity level VII (see Table 1-1) was reported in the communities of Torrance, Wilmington, Gardena, Lynwood, Hynes and Signal Hill, where walls were cracked and chimneys damaged. In some cases, houses that had not been adequately repaired after the 1933 Long Beach earthquake were damaged again (www.johnmartin.com/eqpapers/00000077.htm). No injuries were reported and damage estimates totaled $100,000 (www.scecdc.scec.org/quakedex.html).

A second earthquake occurred less than a month later, on November 14 at 12:42 A.M. PST, near Wilmington. Shaking during the second earthquake was reportedly stronger than the first, locally reaching intensity level VIII (Table 1-1) and felt as far away as Cabazon, Carpinteria, and San Diego. Gas and water mains burst near the epicenter and storefronts in the business districts of Torrance and Gardena collapsed, crushing parked cars. Damage to local oilfields was significant - well casings and equipment were damaged and a 55,000 gallon oil tank ruptured, flooding nearby streets with oil. Production of several wells was lowered or stopped. No injuries were reported, although damage attributed to the second event totaled one million dollars (www.scecdc.scec.org/quakedex.html).

1.4.10 San Jacinto Fault Earthquake of 1954

This M_W 6.4 earthquake occurred on March 19, 1954, at 1:54 A.M. PST, on the Clark fault segment of the San Jacinto fault, about 30 miles south of Indio. It caused minor damage throughout southern California including cracked plaster walls in San Diego and falling ceiling plaster at Los Angeles City Hall. In the Palm Springs area, a water pipe was damaged and the walls of several swimming pools were cracked. Parts of San Bernardino experienced temporary blackouts because the shaking caused power lines to snap. The earthquake was felt as far away as Ventura County, Baja California, and Las Vegas.

1.4.11 Borrego Mountain Earthquake of 1968

This M_w 6.5 earthquake occurred on the evening of April 8, 1968 at 6:29 P.M. PST. The epicenter was located about 40 miles south of Indio on the Coyote Creek fault, which is a branch of the San Jacinto fault. The earthquake was felt throughout southern California, and as far away as Las Vegas, Fresno and the Yosemite Valley. The earthquake produced minor surface rupture near Ocotillo Wells and triggered minor slip on the Superstition Hills, Imperial and Banning-Mission Creek faults (www.scecdc.scec.org/quakedex.html). Damage was reported throughout southern California, most notably in the Imperial Valley, where several buildings collapsed, and in Anza-Borrego Desert State Park where landslides damaged several vehicles. The earthquake also severed power lines in San Diego, knocked plaster from ceilings in Los Angeles, and the Queen Mary II, which was dry-docked at Long Beach, rocked back and forth on its keel blocks for five minutes. No injuries were reported.

1.4.12 San Fernando (Sylmar) Earthquake of 1971

This magnitude 6.6 earthquake occurred on the San Fernando fault zone, the westernmost segment of the Sierra Madre fault, on February 9, 1971, at 6:00 in the morning local time. The surface rupture caused by this earthquake was nearly 12 miles long, and occurred in the Sylmar-San Fernando area, approximately 33 miles (53 km) north of Torrance. The maximum slip measured at the surface was nearly six 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 that 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 the day. 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 call the Earthquake Fault Zone) Act was passed in 1972.

1.4.13 Oceanside Earthquake of 1986

This magnitude 5.4 earthquake occurred on the morning of July 13, 1986 at 6:47 A.M. Pacific Daylight Time. The epicenter was about 32 miles offshore from Oceanside and occurred on an unidentified fault that may be related to the San Diego Trough or the Palos Verdes-Coronado Bank fault zones (www.scecdc.scec.org/quakedex.html). One death and at least 29 injuries are attributed to this relatively small earthquake, which was felt throughout the coastal communities of southern California. At least 50 buildings were damaged from Newport Beach to San Diego, with damage estimates totaling nearly one million dollars.

1.4.14 Whittier Narrows Earthquake of 1987

The Whittier Narrows earthquake occurred on October 1, 1987, at 7:42 in the morning local time, with its epicenter located approximately 21 miles (34 km) northeast of Torrance (Hauksson and Jones, 1989). This magnitude 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 constructed to meet 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 their foundations, or were houses built over garages with large 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.

1.4.15 Landers Earthquake 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, while a maximum of up to 18 feet 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 five separate faults: Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock faults (Sieh and others, 1993). Other nearby faults also experienced triggered slip and minor surface rupture.

1.4.16 Northridge Earthquake of 1994

On the morning of January 17th, 1994, at 4:31 PST, a M_w 6.7 earthquake struck the San Fernando Valley. This moderate-sized tremor was the most expensive earthquake in United

States history, due primarily to its proximity to the heavily populated northern Los Angeles area. The rupture occurred in the San Fernando Valley on the previously unidentified eastern continuation of the Oak Ridge fault, which is a blind thrust fault and thus does not break the surface. The earthquake produced widespread ground accelerations of 1.0 g, some of the highest ever recorded for an earthquake of its size. The earthquake caused 57 deaths, 1,500 injuries and damaged 12,500 structures, knocking several major freeways out commission for days to months. Although most damage was focused in the northern Los Angeles area, intensities of level VI (Table 1-1) were recorded in the Torrance area, where scattered light to moderate damage was reported.

1.4.17 Hector Mine Earthquake of 1999

Southern California's most recent large earthquake was a widely felt magnitude 7.1. It occurred on October 18, 1999, in a remote region of the Mojave Desert, 47 miles east-southeast of Barstow. Modified Mercalli Intensities of IV (Table 1-1) were reported in the Torrance area (http://pasadena.wr.usgs.gov/shake/ca/). The Hector Mine earthquake is not considered an aftershock of the M 7.3 Landers earthquake of 1992, although Hector Mine occurred on similar, north-northwest trending strike-slip faults within the Eastern Mojave Shear Zone. Geologists documented a 25-mile (40-km) long surface rupture and a maximum right-lateral strike-slip offset of about 16 feet on the Lavic Lake fault.

1.5 Potential Sources of Seismic Ground Shaking

Seismic shaking is the geologic hazard that has the greatest potential to severely impact the Torrance area, given that the city is located near several significant seismic sources (faults) that have the potential to cause moderate to large earthquakes (see Table 1-2). As discussed in Section 1.4 above, some of these faults caused moderate-sized earthquakes in the last century; however, given their length, many are thought capable of generating even larger earthquakes in the future that would cause strong ground shaking in Torrance and nearby communities. The proximity of Torrance to these and other regionally significant seismic sources should encourage City officials to diligently attend to seismic hazard mitigation.

In order to provide a better understanding of the shaking hazard posed by these faults, we conducted a deterministic seismic hazard analysis for City Hall and several other randomly selected points in the city using the software program EQFAULT by Blake (2000a). This analysis estimates the Peak Horizontal Ground Accelerations (PHGA) that could be expected at these locations due to earthquakes occurring on any of the known active or potentially active faults within about 62 miles (100 km). The fault database (including fault locations and earthquake magnitudes of the maximum magnitude and maximum probable earthquakes for each fault) used to conduct these seismic shaking analyses is that used by the California Geological Survey (CGS) and the US Geological Survey (USGS) for the National Seismic Hazard Maps (Peterson and others, 1996; Cao et al., 2003). However, as described further in the text, recent paleoseismic studies suggest that some of these faults, like the Whittier fault, may actually generate even larger earthquakes than those used in the analysis. Where appropriate, this is discussed further below.

PGHA depends on the size of the earthquake, the proximity of the rupturing fault, and local soil conditions. Effects of soil conditions are estimated by use of an attenuation relationship derived empirically from an analysis of recordings of earthquake shaking on similar soils during earthquakes of various sizes and distances. Although most of Torrance is underlain in the shallow subsurface by unconsolidated, and therefore soft, sediments and soils, for these analyses we assumed that all locations selected are underlain by soft rock at a depth of 100 feet (30 meters), and used the attenuation relationship of Campbell and Bozorgnia (2000). Based on the ground shaking analyses described above, those faults that can cause peak horizontal ground accelerations of about 0.1g or greater (Modified Mercalli Intensities greater than VII) in the Torrance area are listed in Table 1-2. For a map showing most of these faults, refer to Figures 1-1 and 1-2. Those faults included in Table 1-2 that have the greatest impact on the Torrance area, or that are thought to have a higher probability of causing an earthquake, are described in more detail in the following pages. The locations of active faults near the city are shown of Figure 1-2. The deterministic analyses conducted indicate that should the onshore Palos Verdes fault or the Puente Hills blind thrust fault rupture, PGHA values of about 1.0g to 1.3g, respectively, could be experienced in Torrance. Shaking at these levels can cause heavy damage to even newer buildings constructed in accordance with the latest building code provisions.

Table 1-2 shows:

- The approximate distance, in kilometers and miles, between the fault and various points in the city of Torrance;
- The maximum magnitude earthquake (M_{max}) each fault is estimated capable of generating;
- The peak ground accelerations (PGA), or intensity of ground motion expressed as a fraction of the acceleration of gravity (g), that could be experienced in different areas of the city of Torrance if the M_{max} occurs on the faults listed; and
- The Modified Mercalli seismic Intensity (MMI) values calculated for various parts in the city.

The peak ground accelerations and intensities summarized in Table 1-2 are shown from largest to lowest for each fault; these should be considered as average values, since different sections of the city are expected to feel and respond to each earthquake differently in response to site-specific conditions. In general, peak ground accelerations and seismic intensity values decrease with increasing distance away from the causative fault. However, local site conditions, such as ridge tops and deep basins, can amplify the seismic waves generated by an earthquake, resulting in localized higher accelerations than those listed here. Please note that the PHGA analyses conducted for this study provide a general indication of relative earthquake risk throughout the city of Torrance. For individual projects however, site-specific analyses that consider the precise distance from a given site to the various faults in the region, as well as the local near-surface soil types, should be conducted. These site-specific analyses should also consider the degree of amplification provided by these soft sediments.

In addition to the ground shaking values calculated using a deterministic analysis, we also conducted a probabilistic analysis of ground motion. Deterministic analyses consider the largest possible earthquake that each of the known faults in the area is thought capable of producing. Probabilistic analyses consider the likelihood of exceeding a certain level of damaging ground motion that could be produced by any or all faults within 62 miles (100 km). For Torrance, we calculated the level of ground motion that has a 10 percent probability of being exceeded in 50 years at City Hall, using two different soil conditions. The results indicate that the city has a 10 percent probability of experiencing ground motions of between about 0.43g (for stiff soils) and 0.52g (for alluvium) in the next 50 years. These probabilistic ground motion values for Torrance are in the moderate to high range for southern California, and are the result of the city's proximity to major fault systems with high earthquake recurrence rates. These levels of shaking can be expected to cause damage, particularly to older and poorly constructed buildings.

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

Fault Name	Distance to Torrance $^{\beta}$ (km)	Distance to Torrance $^{\beta}$ (mi)	Magnitude of M_{max}*	PGA (g) from M_{max}	MMI from M_{max}
Palos Verdes	0 – 10.6	0 – 6.6	7.3	1.1 - 0.6	XII-X
Puente Hills Blind Thrust	0.8 - 10	0.5 – 6.2	7.1	1.3 – 0.6	XII-X
Puente Hills (Coyote Hills segment)	0.8 – 10	0.5 – 6.2	6.6	1.3 – 0.5	XII - X
Puente Hills (Los Angeles segment)	13 – 24	8.3 – 15	6.6	0.3 – 0.15	IX - VIII
Puente Hills (Santa Fe Springs)	16 – 26	10 - 16	6.5	0.3 – 0.13	IX - VIII
Newport-Inglewood (Onshore)	5 – 16	3 - 10	7.1	0.6 – 0.3	X - IX
Elysian Park Thrust	16 – 30	10 - 19	6.7	0.3 – 0.12	IX - VIII
Santa Monica	24 - 31	15 - 19	6.6	0.15 – 0.11	VIII- VII
Malibu Coast	26- 32	16 - 20	6.7	0.13 – 0.11	VIII- VII
Hollywood	26 – 32	16 - 20	6.4	0.13 – 0.09	VIII- VII
Upper Elysian Park	20 - 30	12 - 19	6.4	0.18 – 0.12	VIII - VII
Anacapa-Dume	37 - 42	23 - 26	7.5	0.15 – 0.12	VIII - VII
Whittier	30 - 40	18 - 25	6.8	0.12 – 0.08	VII
Raymond	29 – 39	18 – 24	6.5	0.11 – 0.07	VII - VI
Verdugo	34 - 45	21 - 28	6.9	0.11 – 0.08	VII
San Andreas – 1857 Rupture	76 - 81	47 - 54	7.8	0.08 – 0.07	VII - VI

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

Differences between deterministic and probabilistic PGHA in this area are due to the long recurrence intervals of many of the faults in the analysis. Faults which cause damaging earthquakes at less frequent intervals yield a lower annual likelihood of a damaging earthquake, and thus a lower probabilistic hazard value. Since we do not know when the clock started ticking for most of these faults (i.e., when the last earthquake occurred, nor how close the fault is to failure today), City officials cannot take comfort in the presumed low yearly likelihood of damage, but must be prepared for shaking of at least 0.5g, and preferably even 1.0g. Furthermore, most estimates of regional seismic hazard such as those described herein typically consider only known faults onshore. However, there are several faults offshore that are poorly understood but which are active or potentially active, and therefore have the capacity to cause earthquakes that could cause strong ground shaking in the Los Angeles area, including Torrance. These potential seismic sources include the offshore segment of the Palos Verdes fault, the Thums-Huntington Beach fault, the Cabrillo fault, and others farther west, but still within the San Pedro shelf.

The most significant faults in Table 1-2 are discussed in greater detail below.

1.5.1 Palos Verdes Fault Zone

The Palos Verdes fault zone is located primarily offshore and extends in a southeasterly direction from Santa Monica Harbor to the southern San Pedro Channel (Figure 1-2). The short onshore segment of the fault extends for nine miles (15 km) from Redondo Beach to San Pedro and follows the northeastern flank of the Palos Verdes Hills, along the southern limits of the city of Torrance (see Plate 1-2). Offshore, to the southeast, the fault trends across Los Angeles Harbor, and onto the continental shelf where it splays into two discontinuous sub-parallel strands and continues southeast as the Coronado Bank fault zone. Northwest of Redondo Beach, the fault is thought to end in a horsetail splay in Santa Monica Bay, although some scientists suggest the fault continues northwesterly and joins the Dume fault (Stephenson et al., 1995).

Davis et al. (1989) and Shaw and Suppe (1994) modeled the Palos Verdes fault as a southwest-dipping back thrust above a blind thrust. Calculated vertical rates of deformation for the fault based on uplifted marine terraces range from 0.2 to 0.7 mm/yr (Clarke et al., 1985) to 3 mm/yr (Ward and Valensise, 1994). Recent geomorphic studies, however, indicate the fault has a significant right-lateral component of movement. McNeilan et al. (1996) used an offset channel in the Los Angeles Harbor to derive a right-lateral slip rate of 3 mm/yr.

Based on its length and slip rate, the Palos Verdes is thought capable of generating an earthquake of magnitude 7.3. Given its location relative to the city of Torrance, an earthquake of that size on the Palos Verdes fault could generate strong ground shaking in the city of between about 0.5g and 1.1g. This fault has the potential to cause Modified Mercalli intensities of level XII (the highest level) in the city. Such an earthquake can be expected to cause considerable property damage and loss of life, and should therefore be considered the worst-case scenario for Torrance.

1.5.2 Puente Hills Blind Thrust Fault

In 1999, Shaw and others announced the discovery of a blind thrust fault that extends from northern Orange County to the Los Angeles metropolitan area. The fault does not extend upward to the surface, which is why it is called blind, although it is expressed at the surface by a series of low hills, including the Puente Hills on its eastern end. These hills have risen over the surrounding landscape in response to movement on the underlying fault; Dolan and others (2003) believe that the hills rise 1 to 2 meters (3 to 6 feet) every time the Puente Hills thrust fault breaks in a large magnitude earthquake of M_w 7.2 to 7.5. The Puente Hills thrust fault system consists of three en-echelon faults referred to, from east to west, as the Coyote Hills, Santa Fe Springs and the Los Angeles segments (see Figure 1-3).

Dolan and others' (2003) studies suggest that the fault has experienced four large earthquakes in the past 11,000 years. Smaller earthquakes that rupture only a section of the fault are also possible, as evidenced by the Whittier Narrows earthquake of 1987, which is now attributed to rupture of a small, deep patch of the Santa Fe Springs segment of the Puente Hills thrust. Thrust faults typically generate stronger ground shaking than strike-slip faults, as the ground above the plane of the fault is moved up and over the underlying plane. Ground shaking from earthquakes on these types of faults is also felt over a broader area, tends to last longer, and has more of the lower frequency seismic waves. All of these characteristics are especially damaging to high-rise buildings and large structures, like freeway overpasses. In fact, a 2005 study on the impact that an earthquake on the Puente Hills fault would have on Los Angeles estimates between 3,000 and 18,000 fatalities, and more than $250 billion in total losses (Field et al., 2005). A magnitude 7.1 earthquake on the Puente Hills thrust fault is estimated to generate ground accelerations in the Torrance area of between 0.6g and 1.3g; stronger shaking could be experienced if the fault breaks in a larger magnitude earthquake, as indicated above. If only a section of the fault ruptures, causing a smaller earthquake of magnitude 6.5 to 6.6, ground shaking in Torrance could range from 0.13g to 1.3g (see Table 1-2). These are very strong ground motions; therefore, a large earthquake on the Puente Hills thrust fault should be considered a worst-case scenario in Torrance, similar to an earthquake on the onshore segment of the Palos Verdes fault. According to Dolan and others (2003), this fault last ruptured several thousand years ago, although when exactly is unknown. Therefore, there is the possibility that this fault could rupture again in the not-too-distant future.

1.5.3 Newport-Inglewood Fault Zone

The northwest-trending Newport-Inglewood fault zone (NIFZ) is 145 miles long and extends from Santa Monica south to Newport Beach. At Newport Beach, the fault continues offshore and lines up with a deep submarine canyon (Fischer and Mills, 1991) known as the Newport Submarine Canyon. The offshore segment of the fault joins the Rose Canyon fault, which extends southeasterly through San Diego to the international border. The Newport-Inglewood fault zone is discontinuous, consisting of a series of left-stepping en echelon fault strands up to 4 miles long. Onshore, the fault zone is marked by a series of uplifts and anticlines including Newport Mesa, Huntington Mesa, Bolsa Chica Mesa, Alamitos Heights and Landing Hill, Signal Hill and Reservoir Hill, Dominguez Hills, Rosecrans Hills, and Baldwin Hills (Barrows, 1974). These anticlines are traps for oil and have been drilled successfully since the beginning of the last century. Several studies have identified multiple strands of the onshore segment of the NIFZ that have displaced Holocene-age terraces and sediments, showing that this fault is active (Barrows, 1989; Grant et al., 1997).

The slip rate for the NIFZ is poorly constrained at between 0.3 and 3.5 mm/yr. A study by Woodward-Clyde Consultants in 1979 calculated a slip rate of 0.5 mm/yr for the southern onshore segment of the NIFZ. This is consistent with long-term slip rates of 0.31 – 0.52 mm/yr calculated by Freeman et al. (1992) by correlating stratigraphy on one side of the fault to a best match on the opposite side of the fault. More recent paleoseismic studies by Grant et al. (1997) also suggest a slip rate of between 0.34 and 0.55 mm/yr for the onshore segment. Fischer and Mills (1991) estimated a slightly higher slip rate of between 1.3 and 3.5 mm/yr for the offshore segment of the NIFZ between San Mateo Point and Newport Beach with an earthquake recurrence interval of between 200 and 800 years. Lindvall and

Rockwell (1995) calculated a maximum slip rate of 2 mm/yr for the Rose Canyon fault, the southern continuation of the NIFZ.

Paleoseismic studies by Grant et al. (1997) and Shlemon et al. (1995) have shown that the onshore segment of the NIFZ has had three to five ground rupturing earthquakes in the last 11,700 (+/-700 years). This is consistent with the recurrence interval calculated by Fischer and Mills (1991) for the offshore segment of the NIFZ. The last significant earthquake on the NIFZ was the magnitude 6.3 Long Beach event. This earthquake did not break the ground surface. A magnitude 7.1 earthquake on the onshore segment of the NIFZ could generate peak horizontal ground acceleration in the Torrance area of between about 0.3g and 0.6g, with Modified Mercalli intensity values of between X and IX.

1.5.4 Elysian Park Thrust Fault

The Whittier Narrows earthquake of October 1, 1987 alerted geologists to the presence of blind thrust faults underneath the Los Angeles basin that pose a significant seismic hazard to the region. 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. In 1989, Davis and others used oil field data to construct cross-sections showing the sub surface geology of the basin, and concluded that the Whittier Narrows earthquake occurred on a 12- to 24-mile (20 to 38-km) long thrust ramp they called the Elysian Park thrust fault. They modeled the Elysian Park as a shallow-angle, reverse 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. Davis et al. (1989) estimated a long-term slip rate on the Elysian Park fault 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, arriving at a rate 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 and proposed a new model for what they call the Elysian Park trend. They 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 – see Section 1.5.2).

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 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 (CDMG, 1996; Cao et al., 2003), this fault is still considered a potential seismic source that can affect the region. If this fault caused a magnitude 6.7 earthquake, it is estimated that Torrance would experience peak ground accelerations of between about 0.12g and 0.3g.

1.5.5 Santa Monica Fault

The Santa Monica fault is one segment of the Malibu – Santa Monica – Hollywood fault system; others include the Anacapa - Dume and even the Raymond fault as part of the whole system. The Santa Monica segment is a north-dipping, high angle fault that extends for a distance of approximately 22 miles (35 km), through the communities of Pacific Palisades, Westwood, Beverly Hills and Santa Monica, and offshore. The left-lateral, oblique-slip fault was identified in the subsurface from a review of oil wells; at the surface it forms a gentle escarpment that was first recognized as fault controlled in 1992 (Dolan and Sieh, 1992). Since then, the fault has been trenched at the Veterans Hospital site in Santa Monica, and found to have experienced two to three surface-rupturing events in the last 16,000 to 17,000 years (the most recent event probably occurred between 1,000 and 3,000 years ago); at least six other rupture events have occurred on the fault in the past 50,000 years (Dolan and others, 1995; Dolan and others, 2000). From this trench exposure, Dolan and others (1995) estimated a slip rate on this fault of 1.0-1.5 mm/yr. More recently, Dolan and others (2000) calculated a dip-slip rate of 0.5-0.6 mm/yr. Given its length, the fault is thought capable of generating a magnitude 6.6 earthquake. Such an earthquake would cause peak horizontal ground accelerations of between 0.11g and 0.15g in Torrance.

1.5.6 Malibu Coast Fault

The Malibu Coast fault is a complex zone of reverse and left-stepping, en echelon, left-lateral strike-slip faults that parallel the west-trending coastline in the Malibu area of southern California. The onshore traces of the fault zone are moderately well expressed by an alignment of benches, saddles and linear drainages, but youthful landsliding and erosion make it difficult to determine the fault's recency of activity. The offshore section of the fault zone is not well defined.

The Malibu Coast fault has moved in the late Quaternary, but the timing of the most recent surface-rupturing earthquake on this fault is poorly constrained. Treiman (1994) reports no evidence for Holocene displacement along most of the onshore fault traces. Probable Holocene displacement has been reported on one, and possibly two, secondary faults (Drumm, 1992; Rzonca and others, 1991), but more recent studies suggest that some of these secondary faults have not moved in the past 11,000 years (E. Gath, personal communication, 2005). These data suggest that many of the fault traces onshore are no longer active, or that they move very infrequently. Treiman (1994, 2000a) favors the first alternative, as he has suggested that the slip rate of the fault has diminished from about 1 to 2 mm/yr in the Quaternary to 0.5 mm/yr in the late Quaternary, to nearly zero in the Holocene. Alternatively, the active strands of the fault may have moved southward (and beachward), analogous to several other range-fronting faults, such as the Sierra Madre and Cucamonga faults. Further studies are necessary to resolve these questions.

Nevertheless, the Malibu Coast fault is currently listed in the CGS fault database (Cao et al., 2003), and was therefore included in the analysis. Given its length, the fault is thought capable of generating a magnitude 6.7 earthquake. An earthquake of that size on this fault is estimated to cause ground shaking in the Torrance area of between 0.11g and 0.13g, with Modified Mercalli intensity values in the VII to VIII range.

1.5.7 Hollywood Fault

The Hollywood fault is the eastern 9-mile (14 km) long segment of the Malibu - 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 1.5.11 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 infrequent but 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 M_w ~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 0.09g to 0.13g in Torrance.

1.5.8 Upper Elysian Park Fault

The Upper Elysian Park fault is one of several blind thrust faults that underlie the Los Angeles metropolitan area, such as the Puente Hills and Elysian Park thrust faults discussed above. The Upper Elysian Park blind fault is closest to the surface (Figure 1.3), and extends from about the Silver Lake district to the Whittier Narrows area, a distance of approximately 11 miles (18 km) (Oskin et al. 2000). Repeated movement on this fault has formed several gently rolling, east-west trending hills in downtown Los Angeles that are the surface expression of this fault at depth. These hills are thought to move upward, relative to the surrounding landscape, at a rate of about 23.6 to 33.5 inches (60 to 85 cm) per earthquake event, with these earthquakes occurring about every 2,800 to 3,900 years. Oskin et al. (2000) also estimated that the Upper Elysian Park fault is capable of generating earthquakes of between magnitude 6.2 and 6.5. The CGS (Cao et al., 2003) uses a maximum magnitude earthquake of 6.4 for this fault. Such an earthquake is thought capable of generating peak horizontal ground accelerations in Torrance of between 0.12g and 0.18g, with Modified Mercalli intensity values in the VII to VIII range.

1.5.9 Anacapa-Dume Fault

The Anacapa-Dume fault is an offshore fault that is poorly studied. Some researchers that the Anacapa and Dume faults are separate structures, with the Anacapa fault being a segment of the Malibu Coast fault, and the Dume fault being a possible extension of the

Santa Monica fault. As traditionally mapped, the Anacapa-Dume fault is thought to be a left-lateral oblique fault approximately 47 miles (75 km) long that is receiving slip from both the Palos Verdes and Santa Monica faults, for an average slip rate of 3 ±2 mm/yr (Cao et al. 2003). Given its length, the fault is thought capable of generating a magnitude 7.5 earthquake. Such an earthquake would generate peak horizontal ground accelerations in the Torrance area of about 0.12g to 0.15g, with Modified Mercalli intensities in the VII to VIII range. Future studies of this fault system are likely to modify significantly our current understanding of this fault, which is expected to require a revision to this section of the report.

1.5.10 Whittier Fault

The Whittier fault zone is considered one of the most prominent structural features of the Los Angeles basin. The fault zone extends from the Santa River northwestward to the Whittier Narrows area, a distance of approximately 24 miles (38 km). Southeast of the Santa Ana River, the Whittier fault merges with the Elsinore fault. Much of the movement of the Whittier fault is late Pleistocene and younger, as indicated by tilted, locally overturned and faulted bedrock less than 2 million years old, and faulted alluvium.

No major historical earthquakes have been attributed to the Whittier fault. However, trenching studies have documented recurrent movement of this fault in the last 17,000 years (Gath et al., 1992; Patterson and Rockwell, 1993). Based on radiocarbon dating of faulted and unfaulted alluvium exposed in trenches, the two most recent surface rupturing earthquake events on this fault occurred between 1,400 and 2,200 years ago, and 3,000 and 3,100 years ago, respectively (Patterson and Rockwell, 1993). These values give a minimum recurrence interval of 760 (+640, -274) years (WGCEP, 1995). Since a minimum of at least 1,400 years has passed since the last surface-rupturing event occurred on the Whittier fault, the fault is at or near the end of its cycle and is likely to generate an earthquake in the not too distant future. The Southern California Earthquake Center (1995) determined there is a five percent chance of an earthquake occurring on the Whittier fault by 2024. Based on these trenching studies, the Whittier fault is thought to be moving at a rate of about 2.5 +/- 1 mm/yr.

The Whittier fault is thought capable of producing a magnitude 6.8 maximum magnitude earthquake, although some investigators propose an even larger magnitude 7.1 quake. A magnitude 6.8 earthquake on the Whittier fault is estimated capable of causing horizontal peak ground accelerations in the Torrance area of about 0.08g to 0.12g. A larger 7.1 earthquake would generate even stronger ground shaking.

1.5.11 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 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 (M_L) 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 Torrance area of about 0.07 to 0.11g. 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 Torrance.

1.5.12 Verdugo Fault

The Verdugo fault is a 13 to 19-mile (21 to 30 km) long, southeast-striking fault 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 it.

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. 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).

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 6.9 earthquakes. A magnitude 6.9 earthquake on this fault would generate peak ground accelerations in the Torrance area of about 0.08g to 0.11g.

1.5.13 San Andreas Fault Zone

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 47 miles (76 km) northeast of Torrance.

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 Torrance area as a result of the 1857 earthquake are estimated to have been in the order of 0.07g to 0.08g. 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.

1.5.14 Compton Thrust Fault

The Compton Thrust fault is an inferred blind thrust fault in the southwestern portion of the Los Angeles basin (see Figure 1.3). The fault was interpreted as part of the Compton-Los Alamitos fault system, postulated to extend over 50 miles from Western Santa Monica Bay southeast into northwestern Orange County. Since buried faults do not break the ground surface, they are difficult to study; Shaw and Suppe (1996) used deep seismic data from oil exploration companies to infer this fault at depth below the Los Angeles basin and calculate a slip rate on this fault of 1.4 +/- 0.4 mm/yr. More recently, Mueller (1997) used borehole transects to show that geologic structures and units overlying the fault, including a 1,900 year-old peat deposit and a 15,000 to 20,000 year-old aquifer, are not deformed, indicating that the fault is no longer active. As a result, the California Geological Survey has removed this fault from their active fault database. Consistent with this more recent interpretation, we did not calculate the ground motions that this fault could generate in Torrance, since at this time the geological community does no longer consider this fault a viable seismic source.

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 past about 11,000 years. If an active fault is encountered, structural setbacks from the fault are defined.

The Palos Verdes fault is the only known fault with the potential to generate primary surface rupture in the city of Torrance. The offshore segment of the fault has been mapped in detail from geophysical surveys conducted for the Port of Los Angeles expansion project in the 1990s (Fugro-McClelland, 1993; Fugro West, Inc., 1994; McNeilan et al., 1996). From these surveys, we know that the fault, consisting of several traces over a zone more than 1,000 feet wide, passes under the Vincent Thomas Bridge, and through the channel connecting the West Basin to the Los Angeles Main Channel, on its way onshore near the eastern side of the Palos Verdes Hills. From these and other studies (such as Clarke and Kennedy, 1997; Marlow et al., 2000; Fisher et al., 2004), we know that the Palos Verdes fault exhibits youthful characteristics that indicate recent activity. In fact, charcoal samples collected from cores drilled in the Port of Los Angeles show that sediments that are 7,800 to 8,000 years old are vertically displaced 3 meters (18 feet) by the fault (McNeilan et al., 1996).

The onshore segment of Palos Verdes fault was reviewed in 1978 by the California Geological Survey (CGS) for potential inclusion in an Alquist-Priolo Earthquake Fault Zone. The results of that study indicated that the fault is not sufficiently active and well defined, and as a result the fault was not zoned under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act. Unfortunately, this determination was in great part the result of the Palos Verdes region been extensively developed, with urbanization in some areas dating back to the 1910s and 1920s, obscuring landform features typically used to identify active faults. In some other areas of the Palos Verdes peninsula, the fault zone has also been obscured by active slope processes. More recent investigators however, encouraged by the offshore studies that show the fault has had recent activity, have revisited the onshore segment of the fault. Stephenson and others (1995) and T. Rockwell (one of the

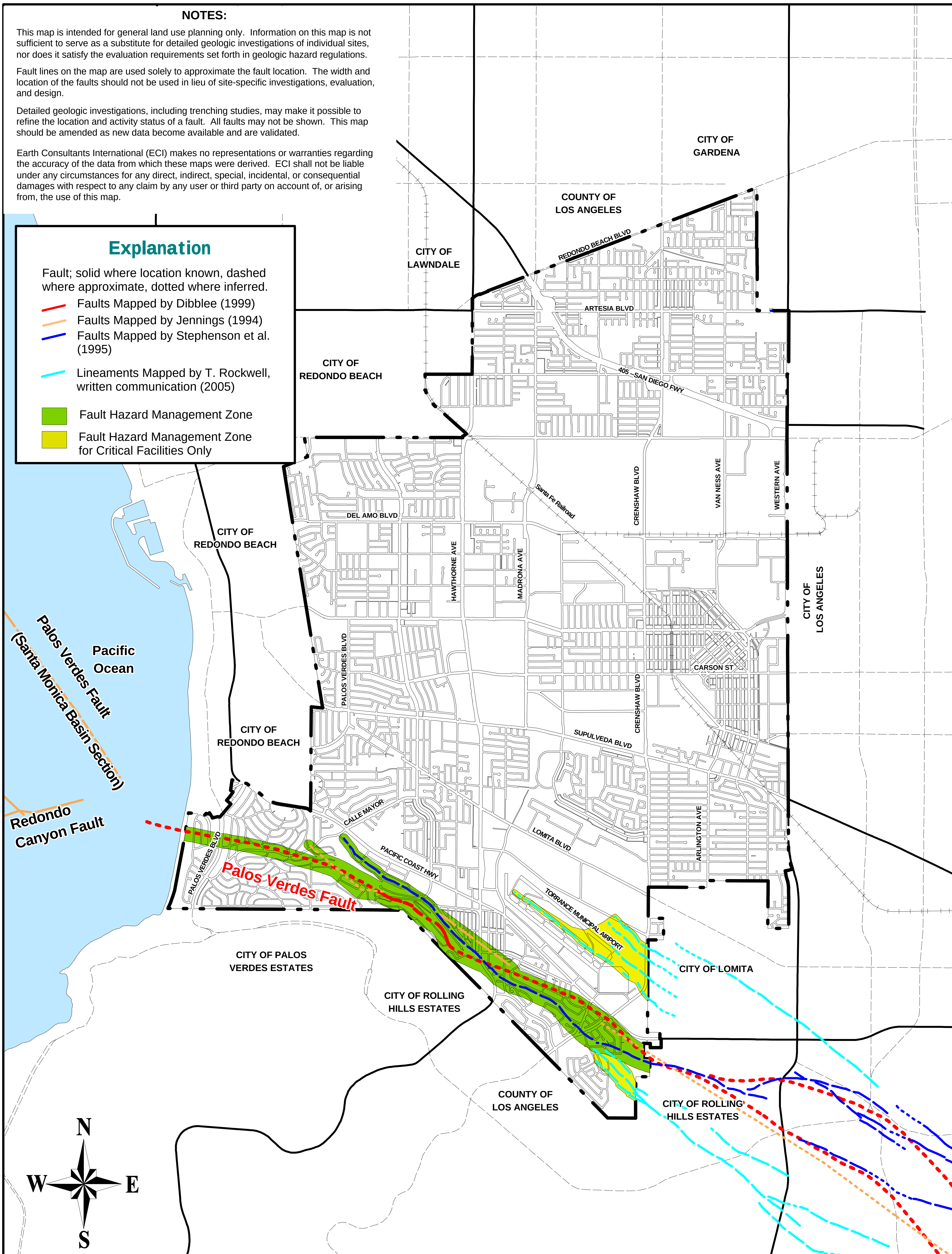
NOTES:

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.

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.



Scale: 1:48,000

1 0 1 2 3

Kilometers

4000 0 4000 8000 12000

Feet

Legend

Torrance City Limit

Base Map: City of Torrance (2005).

Project Number: 2431
Date: July, 2005

Fault Map

Torrance, California

Plate 1-2

main researchers of this fault zone, and co-author of many of the sources cited herein, written communication, 2005) conducted studies of the onshore Palos Verdes fault zone using aerial photo interpretation (of early 20th century photographs) followed by seismic reflection profiles along Gaffey Street and Narbornne Avenue, both to the east of but near Torrance. The aerial photo interpretation indicates there are several northwest-trending lineaments that extend along the base of the Palos Verdes Hills and to the north, in the basin, that could be related to recent faulting (see blue and turquoise lines in Plate 1-2). The seismic profiles were placed so as to investigate these lineaments, and the results indicate that in most cases, the lineaments are associated with faults in the subsurface. Some of these faults, however, appear to extend upward closer to the ground surface, or have a stronger signature in the subsurface than others, suggesting that they are the most recently active traces. These are the faults by Stephenson and others (1995) that are shown in dark blue on Plate 1-2. These are also the fault traces that generally coincide with the accepted "main" Palos Verdes fault, as mapped previously by Jennings (1994) and Dibblee (1999).

As mentioned above, most of the Palos Verdes fault zone has been extensively developed. As a result, there are very few suitable sites not occupied by buildings, infrastructure or utilities where trenching studies could be conducted to study (and refute or confirm) the recency of activity of the Palos Verdes fault. Fault trenching studies have been conducted in the Chandler Quarry in the city of Rolling Hills Estates, to the southeast of Torrance, across some of the secondary faults or lineaments of Rockwell shown on Plate 1-2. These studies confirmed that many of these lineaments are associated with faults, but none of them could be shown to have moved in the past 11,000 years, and were therefore determined to be not active (Earth Consultants International, 2000). These studies however, did not investigate the "main" Palos Verdes fault, as that fault trace was outside the quarry area that was part of the study. Plate 1-2 shows that there are many structures built across the Palos Verdes fault, with the potential for surface fault rupture should this fault break the ground in an earthquake. As a result, the Palos Verdes fault poses a significant surface fault rupture hazard in the area.

1.6.1.1 Mitigation of Primary Fault Rupture

Geologic studies on the Palos Verdes fault suggest that slip per event on this fault could exceed 3.3 meters (10 feet) horizontally, and 0.4 meters (1.3 feet) vertically. Most engineered structures are not designed to withstand this amount of movement, so buildings that straddle the fault will most certainly be damaged beyond repair if and when the fault breaks the surface. 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, given the extensive urbanization present in the area, the opportunity to miss the fault when siting habitable structures has already been lost. During re-development of these lots, geologic studies should be conducted to locate the fault, with structural setbacks established around the active fault traces. However, implementation of this mitigation measure is likely to take decades, if at all, as the replacement of fault-impacted prime real estate with greenbelts or other non-habitable uses is likely to be a unpopular with homeowners.

Furthermore, 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 of a fault is often not an easy or inexpensive task. Nevertheless, given the significant surface fault rupture hazard in the area, we have established a fault hazard management zone around the traces of the Palos Verdes fault that are considered more recently active (green zone in Plate 1-2). This fault hazard management zone is asymmetrical, that is, wider on one side of the fault, consistent with observations of past earthquakes that show that there is more surface deformation and damage on the up-thrown block (in this case, the south side of the fault). The intent of the fault hazard management zone is to require that geologic investigations, which may include fault trenching, be performed if conventional structures designed for human occupancy are proposed within the zone. These studies must evaluate whether or not an active segment of the fault extends across the area of proposed development, following the guidelines for evaluating the hazard of fault rupture presented in Note 49, published by the CGS, which is available on the world wide web at http://www.consrv.ca.gov/CGS/rghm/ap/index.htm. A similar fault hazard management zone has been identified around the presumably less active traces of the Palos Verdes fault (yellow zone in Plate 1-2) to prevent the siting of critical facilities (especially high-risk and high-occupancy facilities, see section 1.9.2) across a fault. In this case, and depending on the type of structure proposed, different criteria for recency of activity (other than the fault having moved at least once in the past about 11,000 years) may apply, depending on the reviewing agency.

Based on the results of these studies, appropriate structural setbacks may be recommended to prevent the siting of the proposed structures directly on top or within a certain distance from the fault. 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 recommended. 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. 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). Since the Palos Verdes fault has a vertical component of movement, deformation of this type could occur in the hillside areas of in Torrance during the next moderate- to large-sized earthquake on the Palos Verdes fault.

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.

1.6.2.1 Mitigation of Secondary Fault Rupture and Ground Deformation

Geotechnical investigations for future development and redevelopment should consider this hazard. The methodology for evaluating these features is similar to that used for evaluating primary fault rupture (CGS Note 49, as discussed in Section 1.6.1.1).

Lazarte et al. (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.

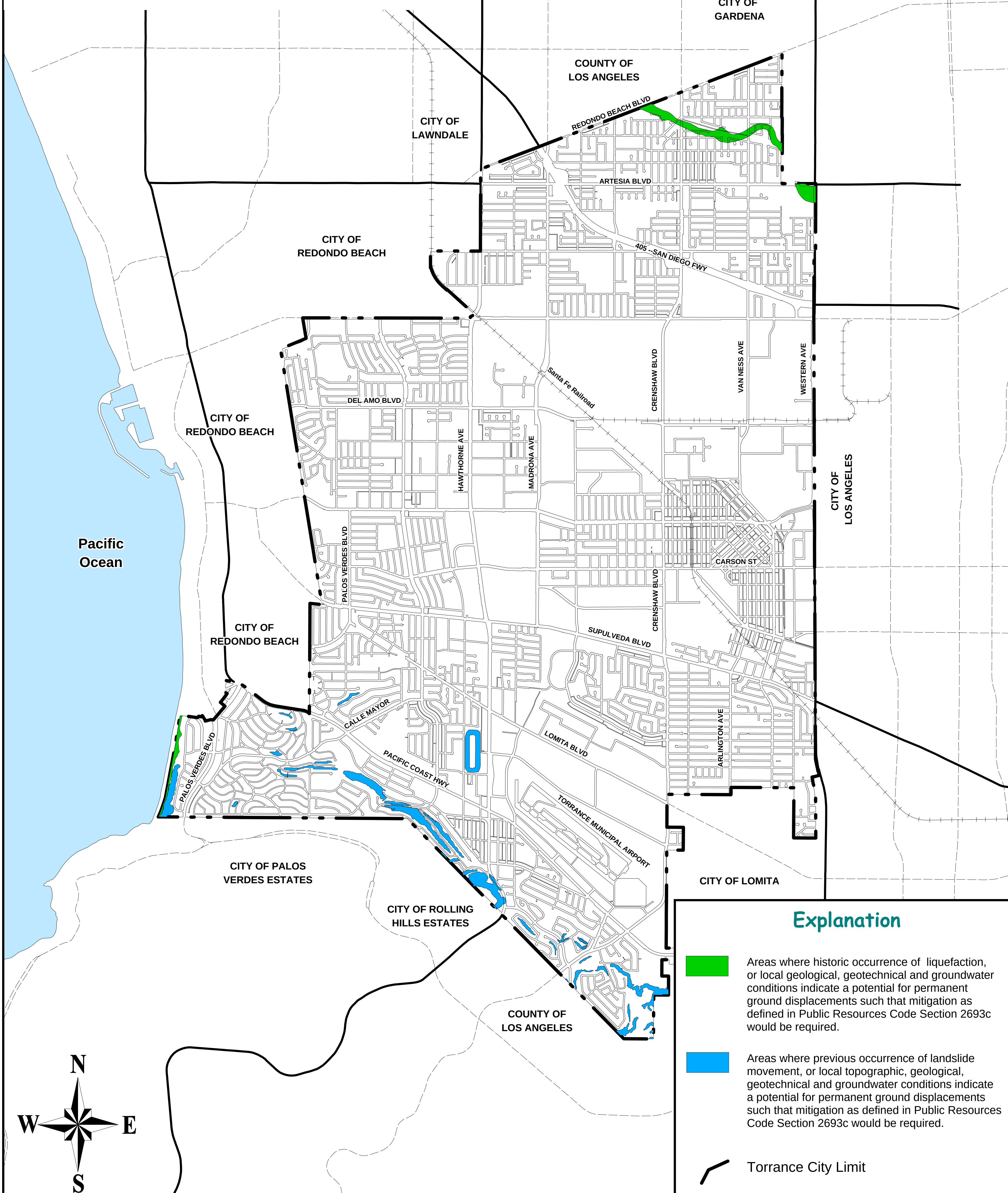
As indicated above, there are three general conditions that need to be met for liquefaction to occur. The first of these – strong ground shaking of relatively long duration – can be expected to occur in the Torrance area as a result of an earthquake on any of several active faults in the region (see Section 1.5 above). The second condition – loose, unconsolidated sediments consisting primarily of silty sand and sand - occurs in scattered areas in Torrance, as mapped by the CDMG (1998). These areas include two irregularly shaped areas to the west and north, respectively of the Torrance Municipal Airport (see yellow zones of young alluvium – map symbol Qa – in Plate 2-2), the area underlying the old channel of Dominguez Creek (also in yellow on Plate 2-2), the beach sand deposits along Torrance Beach (in light green on Plate 2-2), and small alluvial fans at mouth of the several north- to northeast-trending canyons emanating from the Palos Verdes Hills (these areas are too small to map at the scale of Plate 2-2). The third condition – water-saturated sediments within about 50 feet of the surface – occurs only along the old, natural channel of Dominguez Creek, and at the beach, based on a review by the CDMG (1998) of several boreholes in the Torrance area. Therefore, these are the areas with the potential to experience future liquefaction-induced ground displacements. The potentially liquefiable areas are shown on Plate 1-3. Additionally, areas of artificial fill that have been placed on liquefiable soils may also be at risk, but these areas were not mapped for this study. The potential for these areas to liquefy should be evaluated on a case-by-case basis.

Residential or commercial development is not expected to occur in the liquefiable area along the beach. However, structures and improvements (such as roadways, major utility lines, and park improvements) if built in this area could be vulnerable to damage from liquefaction if mitigation measures have not been included in their design. Construction planned for these areas should include liquefaction mitigation measures, weighing the factors of public safety, the impact to the environment, and the risk of economic loss. For instance, a parking lot at the beach may not warrant ground modification measures, especially if the mitigation measures would be destructive to the environment, but a high-pressure gas line would. A considerable part of the city's mapped liquefiable areas (along the channel of Dominguez Creek) are already built upon, mostly with residential and commercial development. It is possible for a nearby moderate to strong earthquake to cause extensive damage to buildings and infrastructure in these areas. Since retrofitting mitigation measures are generally not feasible, the city should be prepared to respond to damage and disruption in the event of an earthquake. Re-developments in this area, however, should conduct liquefaction-susceptibility studies prior to design and construction, in accordance with State guidelines, as discussed in Section 1.7.1.1.

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 ground displacements 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.

Torrance City Limit

Scale: 1:48,000

1 0 1 2 3 Kilometers

4000 0 4000 8000 12000 Feet

Base Map: City of Torrance (2005).

Sources: California Division of Mines and Geology, 1998; (Inglewood, Redondo Beach, and Torrance Quadrangles)

Earth Consultants International

Project Number: 2431
Date: July, 2005

Seismic Hazards Map

Torrance, California

Plate 1-3

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). Lateral spreading was also reported in and around the Port of Los Angeles during both the 1933 and 1994 Earthquakes (CDMG, 1998).

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 degrees (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).

1.7.1.1 Mitigation of Liquefaction

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 involved in the evaluation, and in the implementation of the mitigation measures. Likewise, project review by the local agency must be performed by geologists and engineers with the same credentials and experience. In order to assist project consultants and reviewers in the implementation of the SHMA, the State has published specific guidelines for evaluating and mitigating liquefaction (CDMG, 1997). Furthermore, in 1999, a group sponsored by the Southern California Earthquake Center (SCEC, 1999) published recommended procedures for carrying out the California Geological Survey 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 (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.

The portions of the Torrance area that may be susceptible to seismically induced settlement are those underlain by late Quaternary (Holocene) unconsolidated sediments, including artificial fill, young alluvium, beach sand, and elevated alluvium (see Plate 2-2).

1.7.2.1 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, specially designed deep foundations, 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 1994 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). Numerous landslides have been mapped in the San Joaquin Hills in eastern Newport Beach (Plates 3-1 and 3-4, Chapter 3).

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.

A few steep slopes along the southern and southwestern parts of Torrance have been mapped as vulnerable to seismically induced slope failure (CDMG, 1998 – see the blue zones on Plate 1-3). Some of these are areas where slope instability has been reported in the past. The past occurrence of landslides in some of these areas indicates that without mitigation, slope instability can pose a significant hazard to developments in these areas. Rupture along the Palos Verdes fault could also reactivate existing landslides and cause new slope failures throughout the Palos Verdes Hills. Slope failures can also be expected to occur along stream banks, steep earthen reservoir or debris basin walls, and coastal bluffs, as shown on Plate 1-3.

Ground water conditions at the time of the earthquake play an important role in the development of seismically induced slope failures. For instance, the 1906 San Francisco earthquake occurred in April, after a winter of exceptionally heavy rainfall, and produced many large landslides and mudflows, some of which were responsible for several deaths. The 1987 Loma Prieta earthquake however, occurred in October during the third year of a drought, and slope failures were limited primarily to rock falls and reactivation of older landslides that was manifested as ground cracking in the scarp areas but with very little movement (Griggs et al., 1991).

1.7.3.1 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, 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 and reviewed by State-licensed engineering geologists and/or civil engineers (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 (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."

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 1994 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 about three inches or less, but this resulted in minor to severe property damage (Stewart et al., 1995). This phenomenon was most common in relatively thin fills (about 27 feet or less) placed near the tops or noses of narrow ridges (Barrows et al., 1995). This hazard is expected to occur only in a few local areas of Torrance, in the Palos Verdes Hills.

1.7.4.1 Mitigation of Sidehill 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 Palos Verdes Hills, south of Torrance. Although the impact of ridgetop shattering is considered low within the corporate limits of Torrance, given that the steeper portions of the Palos Verdes hills are located along the hills' southern edge, overlooking the Pacific Ocean, there are some structural concerns associated with ridge-top shattering that need to be considered. Specifically, 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). In Torrance, the Walteria water reservoirs are located near the city's southern boundary, in the hillside areas; given their topographic location, these tanks may be subjected to particularly strong ground motions during an earthquake on a nearby seismic source, with the potential for catastrophic rupture (see Chapter 3).

1.7.5.1 Mitigation of Ridgetop Fissuring and Shattering

Projects located in steep hillside areas should be evaluated for this hazard by a Certified 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

A seiche is defined as a standing wave oscillation in an enclosed or semi-enclosed, shallow to moderately shallow water body or basin. Seiches continue (in a pendulum fashion) after the cessation of the originating force, which can be tidal action, wind action, or a seismic event. Reservoirs, lakes, ponds, swimming pools and other enclosed bodies of water are subject to these potentially damaging oscillations (sloshing). Whether or not seismically induced seiches develop in a water body 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. Seiches are often described by the period of the waves (how quickly the waves repeat themselves), since the period will often determine whether or not adjoining structures will be damaged. The period of a seiche varies depending on the dimensions of the basin. Whether an earthquake will create seiches depends upon a number of earthquake-specific parameters, including the earthquake location (a distant earthquake is more likely to generate a seiche than a local earthquake), the style of fault rupture (e.g., dip-slip or strike-slip), and on the configuration (length, width and depth) of the basin.

Amplitudes of seiche waves associated with earthquake ground motion are typically less than 0.5 m (1.6 feet high), although some have exceeded 2 m (6.6 ft). A seiche in Hebgen Reservoir, caused by an earthquake in 1959 near Yellowstone National Park, repeatedly overtopped the dam, causing considerable damage to the dam and its spillway (Stermitz, 1964). The 1964 Alaska earthquake produced seiche waves 0.3 m (1 ft) high in the Grand Coulee Dam reservoir, and seiches of similar magnitude in fourteen bodies of water in the state of Washington (McGarr and Vorhis, 1968). There are no large bodies of water in Torrance. The Madrona Marsh is too shallow a body of water to develop significant oscillations. Water in swimming pools is known to slosh during earthquakes, but in most cases, the sloshing does not lead to significant damage.

1.7.6.1 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 are 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 Tsunamis

A tsunami is a sea wave caused by any large-scale disturbance of the ocean floor that occurs in a short period of time and causes a sudden displacement of water. Tsunamis can travel across the entire Pacific Ocean basin, or they can be local. For example, an earthquake off the coast of Japan could generate a tsunami that causes substantial damage in Hawaii. These distantly generated tsunamis are also referred to as teletsunamis. Large-scale tsunamis are not single waves, but rather a long train of waves. The most frequent causes of tsunamis are shallow underwater earthquakes and submarine landslides, but tsunamis can also be caused by underwater volcanic explosions, oceanic meteor impacts, and even underwater nuclear explosions. Tsunamis are characterized by their length, speed, low period, and low observable amplitude: the waves can be up to 200 km (125 mi) long from one crest to the next, they travel in the deep ocean at speeds of up to 950 km/hr (600 mi/hr), and have periods of between 5 minutes and up to a few hours (with most tsunami periods ranging between 10 and 60 minutes). Their height in the open ocean is very small, a few meters at most, so they pass under ships and boats undetected (Garrison, 2002), but may pile up to heights of 30 m (100 ft) or more on entering shallow water along an exposed coast, where they can cause substantial damage. The highest elevation that the water reaches as it runs up on the land is referred to as wave runup, uprush, or inundation height (McCulloch, 1985; Synolakis et al., 2002). Inundation refers to the horizontal distance that a tsunami wave penetrates inland (Synolakis et al., 2002).

Earthquake-generated tsunamis have been studied more extensively than any other type. Researchers have found that there is a correlation between the depth and size of the earthquake and the size of the associated tsunami: the larger the earthquake and the shallower its epicenter, the larger the resulting tsunami (Imamura, 1949; Iida, 1963, as reported in McCulloch, 1985). The size of the tsunami is also related to the volume of displaced sea floor (Iida, 1963). Given these correlations, several researchers in the last decades have modeled tsunami runups for various areas along the Pacific Ocean, including in the western United States (Houston, 1980; Brandsma et al., 1978; Synolakis, 1987; Titov and Synolakis, 1998; and many others – refer to http://www.usc.edu/dept/tsunamis/tsupubs).

1.8.1 Notable Tsunamis in the Southern California Area

In the Pacific Basin, most tsunamis originate in six principal regions, all of which have prominent submarine trenches. Of the six regions, only two have produced major tsunami damage along the California coastline in historical times. These are the Aleutian (Gulf of Alaska) region and the region off Chile, in South America (CDMG, 1976). Southern California is generally protected from teletsunamis by the Channel Islands, which deflect east- and northeast-trending waves, and by Point Arguello, which deflects waves coming in from the continental area of Alaska. Tsunamis generated by local earthquakes or landslides have historically posed only a minor, localized risk to southern California. However, the record also shows that the highest sea waves recorded in the southern California area were caused by a locally generated tsunami, the 1812 Santa Barbara event.

Although the historical record for southern California is short, over 30 tsunamis have been recorded in southern California since the early 1800s (see Table 1-3). Given that instrumented tidal measurements in southern California were first made in 1854, wave heights for pre-1854 events are estimated based on historical accounts.

Most records are for the San Diego and Los Angeles areas. Most of the recorded tsunamis produced only small waves between 0.15 and 0.3 m (0.5 – 1 ft) high that did not cause any damage, but six are known to have caused damage in the southern California area. Those six are marked in bold in Table 1-3, and are described further in the text below.

Table 1-3: Historical Tsunami Record for Southern California - 1812 to Present
(Tsunamis that caused damage in southern California are in bold)

Date	Source	Wave Height
December, 1812	**Southern California; earthquake or landslide in Santa Barbara Channel?**	**Santa Barbara: ~2-3 m (6.6-9.8 ft); Ventura: ~2-3 m (6.6-9.8 ft)**
November, 1853	Kurils Islands	Unknown; possibly observed in San Diego
May, 1854	Southern California; possibly same as July or December events	Unknown; observed in San Diego
July, 1854	Unknown; possible meteorological origin	San Diego: ~0.3 m (~1 ft)
December 23, 1854	Japan	San Diego: < 0.1 m (0.3 ft)
December 24, 1854	Japan	San Diego: 0.1 m (0.3 ft)
July, 1855	Southern California; possible offshore landslide caused by earthquake in Los Angeles	Unknown; large waves reported at Point San Juan
April, 1868	Hawaii	San Diego: 0.1 m (0.3 ft)
August, 1868	Chile	San Diego: 0.3 – 0.8 m (0.6-2.6 ft); San Pedro: 1.8 m (5.9 ft)

Date	Source	Wave Height
		Wilmington: 1.8 m (5.9 ft)
August, 1872	Aleutian Islands	San Diego: < 0.1 m (0.3 ft)
May, 1877	Chile	San Pedro: 1 m (3.3 ft); Wilmington: 1 m (3.3 ft); Gaviota: 3.7 m (12.1 ft)
August, 1879	Southern California; possible undersea landslide caused by earthquake in San Fernando area	Unknown; tsunami reported at Santa Monica
December, 1899	Southern California; Underwater landslide generated by earthquake in San Jacinto area?	Unknown; large wave reported along southern California coast
February, 1902	El Salvador-Guatemala	Unknown; large wave reported in San Diego
January, 1906	Ecuador	Unknown; reported in San Diego
August, 1906	Chile	San Diego: 0.1 m (0.3 ft)
May, 1917	South Pacific	Unknown; large waves reported in La Jolla
June, 1917	South Pacific	Unknown; reported in San Diego
April, 1919	South Pacific	Unknown; reported in San Diego
November, 1922	Chile	San Diego: 0.2 m (0.7 ft)
February, 1923	Kamchatka	San Diego: 0.2 m (0.7 ft)
October, 1925	Unknown; possible meteorological origin or submarine volcanic event	Long Beach: 0.34 m (0.1 ft)
January, 1927	**Southern California; possible submarine landslide caused by earthquake in Imperial Valley**	**Unknown; large waves reported along southern California coast**
November, 1927	Central and southern California; offshore earthquake off Point Arguello, possibly on the Hosgri fault	La Jolla: 0.2 – 0.3 m (0.7 – 1 ft); Surf: 1.8 m (5.9 ft) Port San Luis: 1.5 m (4.9 ft)
June, 1928	Southern Mexico	La Jolla: < 0.1 m (0.3 ft)
August, 1930	Southern California; offshore earthquake in Santa Monica Bay	Santa Monica: 0.6 m (1.9 ft)
March, 1933	Japan	Los Angeles: 0.2 m (0.7 ft); Santa Monica < 2.0 m (6.6 ft)
March, 1933	Southern California; Long Beach Earthquake	Long Beach: 0.1 m? (0.3 ft)
August, 1934	**Unknown; possibly caused by earthquake near Balboa, or of meteorological origin (rogue waves?)**	**Newport Beach: 3 m rise (9.8 ft); 9-12 m (30 –39 ft) waves**
April, 1943	Chile	San Diego: 0.1 m (0.3 ft)
December, 1944	Japan	San Diego: < 0.1 m (0.3 ft)
April, 1946	Aleutian Islands	Avila: 1.2 m (3.4 ft)
March, 1957	**Aleutian Islands**	**San Diego: 0.2 – 1.0 m (0.7–3.3 ft)**
May, 1960	**Chile**	**Santa Monica: 1.4 m (4.6 ft)**
May, 1964	**Gulf of Alaska**	**Santa Monica: 1.0 m (3.3 ft)**
February, 1965	Aleutian Islands	Santa Monica: 0.08 m (0.3 ft)
May, 1968	Japan	Santa Monica: 0.2 m (0.7 ft); Long Beach: 0.1 m (0.3 ft)
May, 1971	South Pacific	Los Angeles: 0.05 m (0.2 ft)
November, 1975	Hawaii	La Jolla: 0.1 m (0.3 ft)

Date	Source	Wave Height
June, 1977	South Pacific	Los Angeles: 0.05 m (0.2 ft); Long Beach: 0.12 m (0.4 ft)

Source: Compiled from Lander and Lockridge (1989) and McCulloch (1985)

1.8.1.1 Santa Barbara Tsunami of 1812

A strong earthquake in the Santa Barbara area on December 21st, 1812 produced a tsunami that caused damage in Santa Barbara and Ventura counties and was reported along the coast of southern California. The most likely source for the earthquake is a fault zone in the Santa Barbara Channel, although onshore faults east of Santa Barbara cannot be ruled out.

While some historical accounts suggest the tsunami produced a maximum one-mile runup and wave heights of 15 m (49 ft) at Gaviota, 9 to 10.5 m (29.5 – 34.5 ft) at Santa Barbara and 3.5 m (11.4 ft) at Ventura, contemporary records from the missions at Santa Barbara and Ventura do not mention tsunami runup or damage to nearby coastal communities (Lander and Lockridge, 1989). The mission records describe only a disturbed ocean and fear of tsunami, suggesting that the accounts of high waves, most of which were recorded years after the event, may have been exaggerated (Lander and Lockridge, 1989). For example, an account of "an old trader" printed in the San Francisco Bulletin 52 years after 1812, reported a 1-mile runup in Gaviota. From this account, a 15 m (49 ft) wave height was derived using topographic maps.

Accounts collected by Trask (1856), 44 years after the event, report that waves damaged the lower part of the town of Santa Barbara, half a mile inland. Trask (1856) also recorded reports of a ship damaged by a tsunami wave near San Buenaventura (present day Ventura). This may be the same vessel reported by Los Angeles Star in 1857 to have been swept up a canyon at El Refugio Bay, near Gaviota. A third-hand account of tsunami damage to the mission in Ventura, located 4.5 m (14.8 ft) above sea level, is not corroborated by the mission records (Grauzinis et al., unpublished report). Grauzinis et al. (unpublished, based on data from Soloviev and Go, 1975; McCulloch, 1985; Marine Advisors, 1965; Iida et al., 1967; Wood, 1916; Heck, 1947; Toppozada et al., 1981), conclude that the most reliable historical data support a tsunami height of less than 3 m (9.8 ft) at Santa Barbara and Ventura, 3.5 m (11.4 ft) at El Refugio, and lower elsewhere in southern California. This is roughly consistent with analysis of predicted tidal data for the region by Long (1988) who suggests a wave height of 2 m (6.6 ft) at Santa Barbara and Ventura.

1.8.1.2 Tsunami of January 1927

A magnitude 5.7 earthquake followed by several aftershocks occurred in Imperial Valley, at the border between the United States and Mexico, on January 1, 1927. According to Montandon (1928), sea waves in San Pedro destroyed a seawall or embankment causing about three million dollars in damage (Lander and Lockridge, 1989). However, since the Imperial Valley is far from the coast, and the earthquake was moderate in size, it is doubtful that these two events are related, unless the earthquake triggered a submarine landslide.

1.8.1.3 Possible Tsunami of 1934

On August 21, 1934 large destructive waves were reported along the coast of southern California from Malibu to Laguna Beach. The true source of the waves is not known, however several causative events have been suggested. Although official records show no large earthquakes in the area on the day of the waves, a small, magnitude 3 tremor was reported in the Balboa (Newport Beach) region before the waves struck. Submarine landsliding, volcanic activity, and unusual meteorological conditions (rogue waves?) have also been suggested as possible explanations for the waves. A runup of 270 m (886 ft) inland, 3 m (9.8 ft) above mean high tide level was recorded at Newport Beach, which flooded part of that city to a depth of one meter (3.3 ft). Four people were injured near the channel entrance to Newport Bay, at the western pier. Many houses were destroyed, including a two-story home in Balboa that was detached from its foundation. Part of the pavement on Balboa Peninsula was washed away, temporarily isolating the residents of this area from the mainland. Thousands of tons of debris were tossed onshore. The waves also flooded a moorage in Balboa Island and collapsed part of the breakwater in Long Beach (Lander and Lockridge, 1989).

1.8.1.4 Aleutian Island Tsunami of 1957

A magnitude 8.3 earthquake in the Aleutian Islands on March 9, 1957 generated a small tsunami in the San Diego area that damaged two ships in San Diego Harbor and caused minor damage at La Jolla (McMulloch, 1985; Iida et al., 1967; Salsman, 1959; Joy, 1968). A wave height of up to one meter (3.3 ft) was reported at Shelter Island, off the San Diego coast, although the tide gauge there recorded only a 0.2 m (0.7 ft) wave. No reports of damage were recorded in the Los Angeles area.

1.8.1.5 Chilean Tsunami of 1960

On May 22, 1960, a moment magnitude 9.4 earthquake off the coast of Chile produced a tsunami that damaged coastal communities in southern California between Santa Barbara and San Diego. A wave height of 1.4 m (4.6 ft) was recorded in Santa Monica and the tidal gauge in San Diego was carried away by the tsunami waves (Lander and Lockridge, 1989). Significant damage was recorded in the Los Angeles and Long Beach Harbors, where 30 small craft were sunk and over 300 were set adrift. Over 340 boat slips, valued at $300,000, were also damaged in the area. At Santa Monica, eight small boats were swept away and a runup of 91 m (300 ft) flooded a parking lot along the Pacific Coast Highway. Damage of $20,000 was reported in the Santa Barbara area. At San Diego, two passenger ferries were knocked off course by the waves; the first ferry was pushed against a dock in Coronado, destroying 80 m (260 ft) of the dock, and the second was rammed into a flotilla of anchored destroyers. The waves also rammed a 100-ton dredge into the Mission Bay Bridge, knocking out a 21 m (70 ft) section and sinking a barge at Seaforth Landing (Lander and Lockridge, 1989; Iida et al., 1967; Talley and Cloud, 1962; Joy, 1968).

1.8.1.6 Good Friday Earthquake Tsunami of 1964

On March 28, 1964 a moment magnitude 9.2 earthquake in the Gulf of Alaska produced the largest and most damaging tsunami to ever hit the West Coast. The tsunami killed 16 people in northern California and Oregon and caused $8,000,000 in damage in California. Although damage was primarily focused in coastal areas north of San Francisco, southern California experienced hundreds of thousands of dollars in losses. A wave height of 1 m (3.3 ft) was recorded in Santa Monica. In Los Angeles Harbor, the wave damaged six small-boat slips, pilings, and the Union Oil Company fuel dock. It also scoured the harbor sides, causing, all tolled, $175,000 to $275,000 in damage. The tsunami also destroyed eight docks in the Long Beach Harbor at a loss of $100,000 (Spaeth and Berkman, 1972). Minor damage was also reported elsewhere along the southern California coast.

1.8.2 Tsunami Scenarios for Torrance

Because of the substantial increase in population in the last century and extensive development along the world's coastlines, a large percentage of the Earth's inhabitants live near the ocean. As a result, the risk of loss of life and property damage due to tsunamis has increased substantially. Between 1992 and 2002, tsunamis were responsible for over 4,000 human deaths worldwide (Synolakis et al., 2002). Then, on December 26, 2004, a magnitude 9.3 earthquake off the northwest coast of Sumatra, Indonesia caused tsunamis in the Indian Ocean that resulted in more than 155,000 confirmed fatalities in the region, with another nearly 130,000 missing, and presumed killed, in Indonesia alone. The earthquake and resulting tsunami also displaced more than 1.1 million people in ten countries in South Asia and East Africa, making it the most devastating natural event in recorded history, and increasing overnight the worldwide awareness of tsunamis as a potentially devastating natural hazard.

McCarthy et al. (1993) reviewed the historical tsunami record for California and suggested that the tsunami hazard in the southern California region from the Palos Verdes Peninsula south to San Diego, is moderate. However, as discussed previously, the southern California historical record is very short. Given that the recurrence interval for many of the faults in the world is in the order of hundreds to thousands of years, it is possible that southern California has been impacted by teletsunamis for which we have no record. More significantly, there are several active faults immediately offshore of the southern California area, and any of these could generate a future earthquake that could have a tsunami associated with it. Finally, several submarine landslides and landslide-susceptible areas have been mapped offshore, within 3.5 to 14 km of the coastline (Field and Edwards, 1980; McCulloch, 1985; Clarke et al., 1985). Synolakis et al. (1997) reviewed the McCarthy et al. (1993) study and other data, and concluded that not only do early, pre-1980 methods give tsunami runup results that are more than 50 percent lower than what current inundation models predict, but that there is a need to model near-shore tsunami events. In fact, near-shore tsunamis should be considered worst-case scenarios, as these have the potential to cause high runups that would impact the coastline with almost no warning.

Having recognized the potential hazard, the next step is to quantify it so it can be managed appropriately. Although the record of tsunamis impacting the California coast goes back only to 1812, there are sufficient data from which mathematical models of tsunami runup for the California coast can be developed. Houston and Garcia looked at the worldwide, long-term historical data, and combined it with mathematical models to estimate the predicted, distantly generated, 100-year and 500-year probability tsunami runup elevations for the west coast of the United States (Garcia and Houston, 1975; Houston and Garcia, 1974; 1978; Houston et al., 1975; Houston, 1980; as presented in McCulloch, 1985).

These predictions are used by the Federal Insurance Administration to calculate flood-insurance rates, thus the 100- and 500-year terms risk levels selected, similar to storm flooding. As with flooding, the 100- and 500-year designations do not mean that these tsunamis occur only once every 100 or 500 years, but rather, these terms describe the tsunami that has a 1 percent (for 100-year) or 0.2 percent (for 500-year) probability of occurring in any one year. The 100-year and 500-year tsunami runup elevations are thought to have the potential to cause significant damage to harbors and upland areas, whereas smaller 50-year events may cause damage to boats and harbor facilities, but the onshore damage will be restricted to very low-lying areas. Smaller than 50-year tsunamis may still cause minor damage to unprotected boats and harbor facilities (CDMG, 1976). The 100-year (R_{100}) and 500-year (R_{500}) teletsunami runup heights predicted for the area between Redondo Beach and Malaga Cove are approximately 1.3 and 1.7 meters (4.2 and 5.7 feet), respectively (Houston, 1980, based on Figure 208 in McCulloch, 1985). For various reasons, these predicted tsunami runup height values are to be used only as a guide to quantify the risk of distantly generated tsunamis on the California coastline. Houston (1980) did not have the technology available to quantify the effect that estuaries, the offshore zone where water is 5 to 10 meters deep, and the shoreline have on tsunami runup (C. Synolakis, personal communication, 2002). Furthermore, Houston's (1980) predicted heights are based on mean sea level elevation data, and thus do not show the maximum credible heights that are possible if a tsunami coincides with peak high tide, or with storm-induced high water. Nevertheless, since structures along the coastline in the Torrance Beach area are located on top of the sea-cliff, approximately 100 feet above the beach, a teletsunami is not expected to cause damage to these structures. Furthermore, warnings issued by the Pacific Tsunami Warning Center (PTWC) would be received in ample time to evacuate beach goers from the lower elevations before the teletsunami strikes.

The results provided above, however, are for teletsunami events, and therefore not representative of the runup heights that could be expected from a landslide-induced or fault-rupture induced tsunami occurring immediately offshore. The University of Southern California Tsunami Research Group, under the direction of Costas Synolakis and Jose Borrero, have prepared tsunami inundation models for the southern California area caused by either offshore faulting or submarine landsliding. Their initial models indicate that these locally generated tsunamis are a concern: earthquakes in the Santa Barbara Channel could generate a 2 m (6.6 ft) runup, while an earthquake-induced submarine landslide could generate a runup of as much as 20 m (66 ft) (Borrero et al., 2001). A submarine landslide off the southern Palos Verdes peninsula could also generate tsunami runup of as much as 20 m (66 ft) along that portion of the Palos Verdes peninsula directly north of the landslide failure, with runups of as much as 2 m (6.6 feet) around the northern end of the Palos Verdes peninsula, in the area of Malaga Cove. The tsunami waves would hit the coastline in as little as 10 to 20 minutes after the landslide failure, allowing little time to issue public warnings. The continental shelf in the Santa Monica Bay, immediately offshore of Torrance, although not as steep as that on the south side of the Palos Verdes peninsula, also has sufficient relief to generate submarine landslides. Therefore, although not modeled, a landslide-induced tsunami directly offshore of Torrance is plausible. Runup heights of as much as 20 meters (66 feet) may be possible in the Torrance and Redondo Beach areas, although a Santa Monica Bay-specific scenario would be required to confirm this estimate. Such a scenario has the potential to cause significant casualties along the beach given the short time span between the landslide failure and the appearance of the tsunami. The Paseo de la Playa street near its intersection with Calle Miramar and adjacent areas, could flood in this scenario, impacting several residential structures. Farther south, near Malaga Cove, the runup height would still be too low to directly impact the residences at the top of the slope, but slope stability issues in that area could develop as a result of a direct hit by the tsunami, with the potential for secondary structural damage to the houses above.

1.9 Vulnerability of Structures to Earthquake Hazards

This section assesses the general earthquake vulnerability of structures and facilities common in the Torrance 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.

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.

1.9.1 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, Torrance inventoried its URMs. In the year 2000, the City reported to the Seismic Safety Commission that there were 50 URMs in Torrance, none of which were considered of historical significance. All of the property owners were notified of the type of construction they owned, and of these, 43 buildigns were strengthened to comply with the 1982 Edition of Division 88 of the Los Angeles City Code, the City-mandated mitigation standard for URMs. The remaining seven structures were demolished. To accomplish this, the City funded a subsidy to pay for the engineering analysis of the structures at $0.50 the square foot, and formed an assessment district to encourage owners to strengthen their structures. The assessment district was funded at the $679,000 level, and was available to all URM owners who chose to join (Seismic Safety Commission, 2000, 2003).

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 Torrance should consider conducting an inventory of their soft-stories, and encouraging the structural retrofit of these structures to withstand collapse during an earthquake.

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 un-engineered 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.

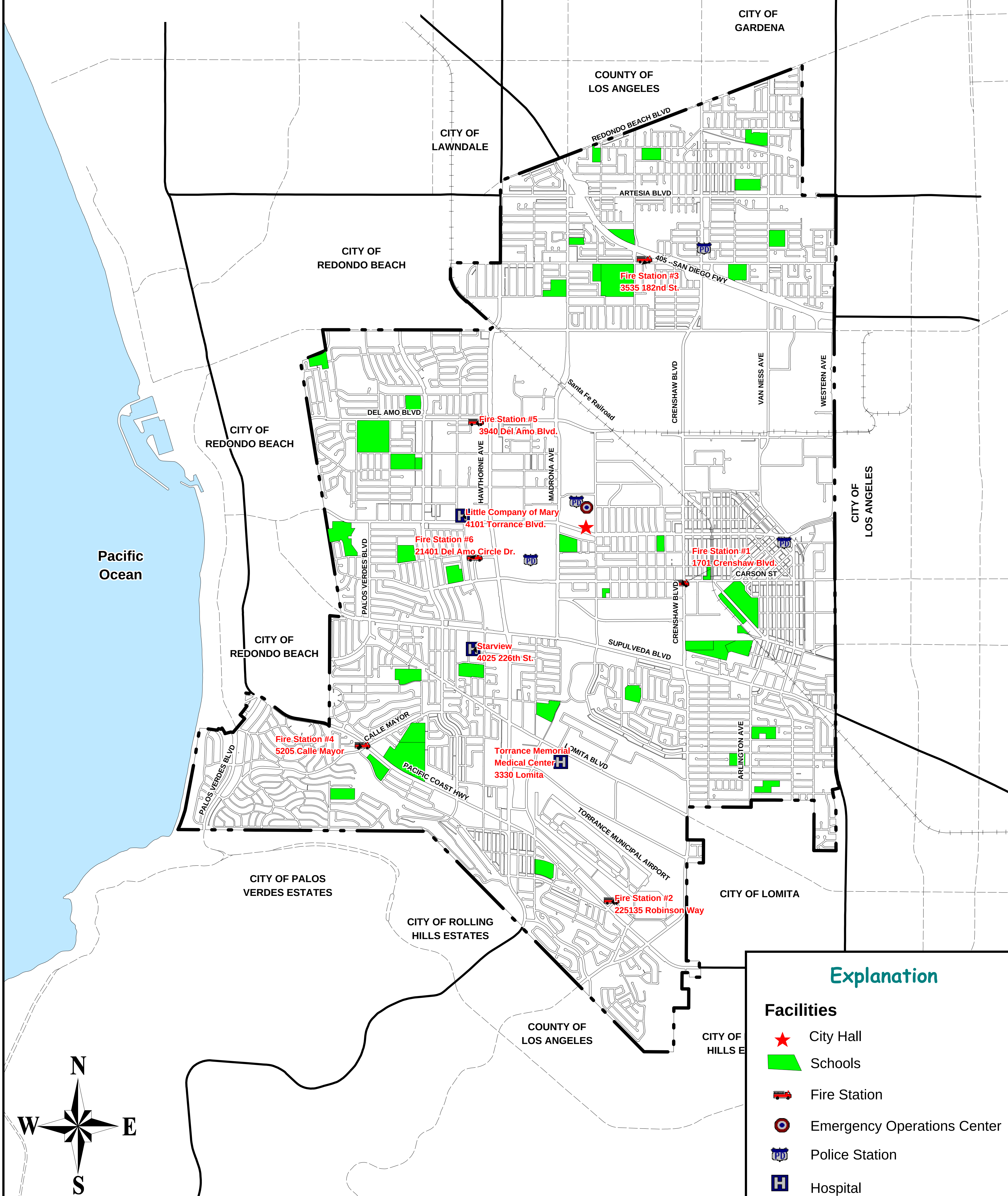
1.9.2 Essential Facilities

Essential facilities are those parts of a community's infrastructure that must remain operational after an earthquake. Buildings that house essential services 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 essential facilities. A vulnerability assessment for these facilities involves comparing their locations to hazardous areas identified in the city, including active and

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: 1:48,000

1 0 1 2 3
Kilometers

4000 0 4000 8000 12000
Feet

Torrance City Limit

Base Map: City of Torrance
Source: Essential Facilities, City of Torrance

Earth Consultants International

Project Number: 2431
Date: July, 2005

Critical Facilities Map

Torrance, California

Plate 1-4

potentially active faults (Plate 1-2), liquefaction-susceptible areas (Plate 1-3), unstable slope areas (Plates 1-3, 2-2 and 2-3), potential flood areas due to either storm events or coastal processes (Plate 3-2), 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, and industrial plants that use or store explosives, toxic materials or petroleum products, such as the ExxonMobil plant.

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, hospitals, 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 essential 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.

1.9.3 Lifelines

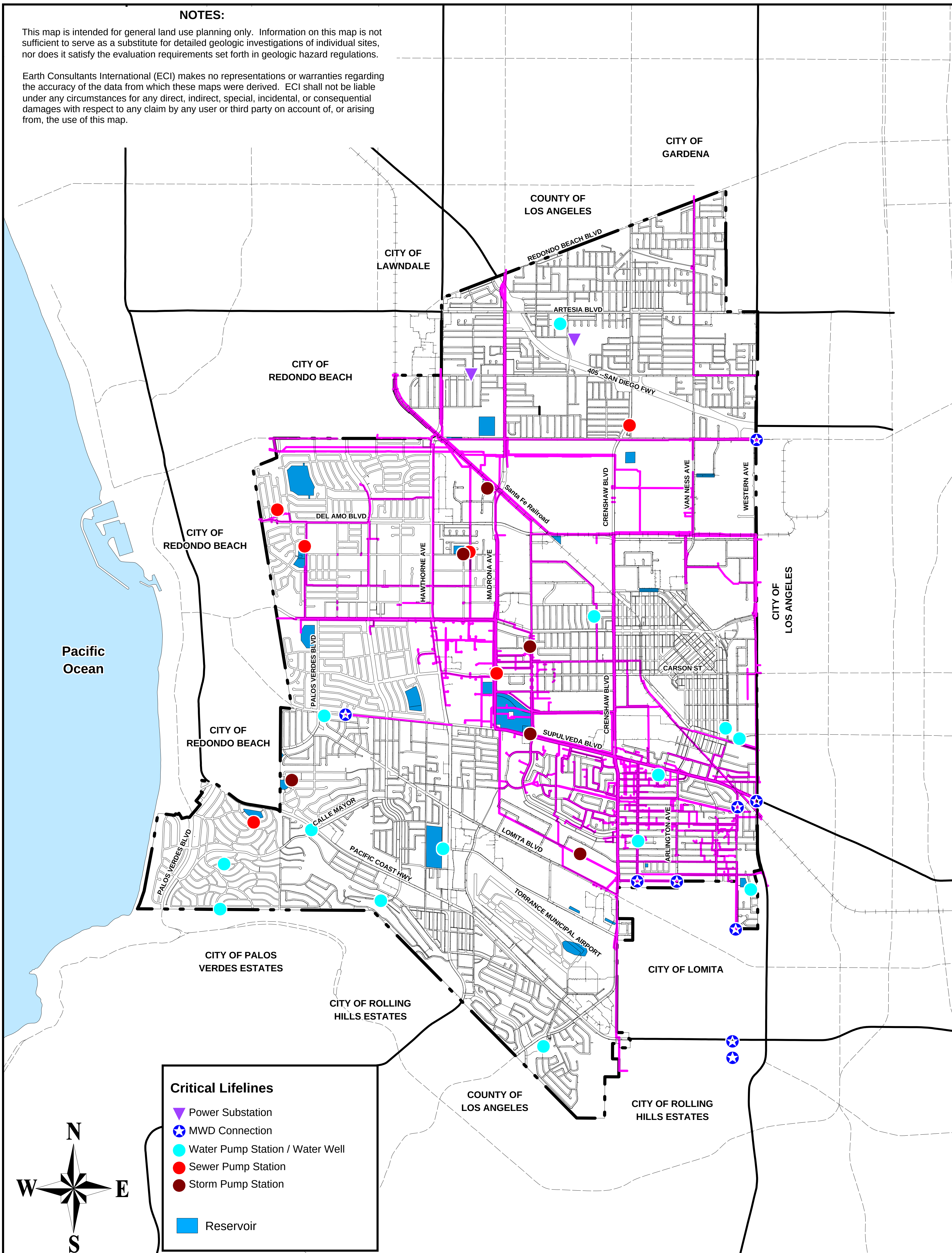
Lifelines are those services that are critical to the health, safety and functioning of the community. They are particularly essential for emergency response and recovery after an earthquake. Furthermore, certain critical facilities designed to remain functional during and immediately after an earthquake 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 lifelines in the city of Torrance are shown in Plate 1-5. This plate does not show all of the pipelines that extend through the city, as there are so many that showing them would make the graphic unusable.

Water supply facilities, such as dams, reservoirs, pumping stations, water treatment plants, and distribution lines are especially critical after an earthquake, not only for drinking water, but to fight fires. Failure of reservoirs during an earthquake is discussed further in Chapter 3.

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.
- The most vulnerable components of pipeline distribution systems were older threaded joints, cast iron valves, cast iron pipes with rigid joints, and older steel pipes weakened by corrosion. In the case of broken water lines, the loss of fire suppression water forced fire departments to utilize water from swimming pools and tanker trucks.
- 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.

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 Torrance 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. Some of the lifelines in the city of Torrance are shown on Plate 1-5, below.



Scale: 1:48,000

1 0 1 2 3 Kilometers

4000 0 4000 8000 12000 Feet

Torrance City Limit

Oil and Gas Lines

Base Map: City of Torrance (2005).
Source: Utilities, City of Torrance (2005).

Earth Consultants International

Project Number: 2431
Date: July, 2005

Utility Lifelines Map

Torrance, California

Plate 1-5

1.10 Reducing Earthquake Hazards in the City of Torrance

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 new development as well as 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. The City can best address rehabilitation issues. However, the hazard evaluation is intended to define the scope of the problem.

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 2001) are prime examples of how incorporating past experience can further reduce of the devastating effects of an earthquake. 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 Torrance

Two significant changes were incorporated into the 1997 Uniform Building Code (UBC – which is the basis for the 2001 California Building Code) that impact the city of Torrance. 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 Torrance. 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 Torrance. 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 Torrance, these code changes are warranted. Due to the proximity of the Palos Verdes, Puente Hills, and Newport-Inglewood 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 C_a and C_v. 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 1-4, and the soil types in the city of Torrance are illustrated in Plate 1-6. Not all soil profile types summarized in Table 1-4 are found in the city of Torrance.

Table 1-4: 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)
S_A	Hard Rock	>5,000		
S_B	Rock	2,500 to 5,000		
S_C	Very dense soil and soft rock	1,200 to 2,500	>50	>2,000
S_D	Stiff soil profile	600 to 1,200	15 to 50	1,000 to 2,000
S_E	Soft soil profile	<600	<15	<1,000
S_F	Soil requiring site-specific evaluation.			

<u>Near- Source Factors</u>*:* The Torrance 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.

<u>Seismic Source Type</u>*:* 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 1-5.

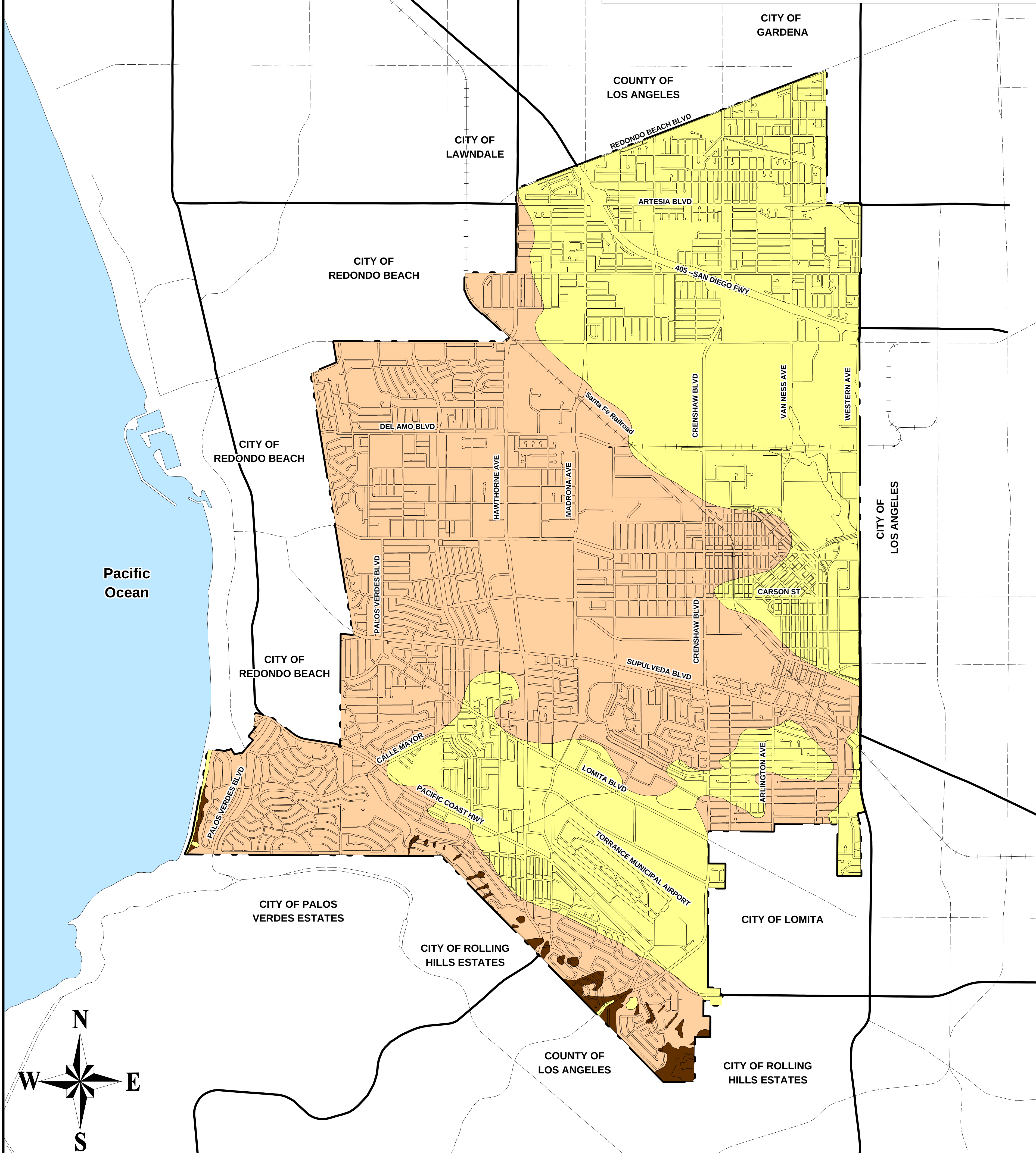
NOTES:

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)
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

Soft types Sa, Sb, and Sf not present in the study area.



Scale: 1:48,000

1 0 1 2 3
Kilometers

4000 0 4000 8000 12000
Feet

Torrance City Boundary

Base Map: City of Torrance (2005).
Sources: Based on data from Dibblee (1999).

A BALANCED CITY · INDUSTRIAL-RESIDENTIAL-COMMERCIAL · TORRANCE

Earth Consultants International

Project Number: 2431
Date: July, 2005

Engineering Soil Types in Torrance, California

(In Accordance with 1997 Uniform Building Code)

Plate 1-6

Table 1-5: Seismic Source Type

Seismic Source Type	Seismic Source Description	Seismic Source Definition	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/yr.)
A	Faults which are capable of producing large magnitude events and which have a high rate of seismicity.	$M \geq 7.0$ and	$SR \geq 5$
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.	$M < 6.5$	$SR \leq 2$

Type A faults are highly active and capable of producing large magnitude events. Most segments of the San Andreas fault, for example, 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 Palos Verdes, Puente Hills and Newport-Inglewood faults as Type B faults (Cao et al., 2003).

To establish near-source factors for any proposed project in the city of Torrance, 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 or near-vertical strike-slip faults, such as the Palos Verdes and Newport-Inglewood, are relatively straightforward. However, the distance to thrust faults and blind thrust faults, such as the Puente Hills fault, 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 Torrance has adopted an ordinance aimed at retrofitting unreinforced masonry buildings (URMs).

Other potentially hazardous buildings, such as pre-1971 concrete tilt-up structures and soft-story buildings, 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 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 database 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 and Safety 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 Torrance 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 active traces of the Palos Verdes fault pass through the southern portion of the city. Torrance is also close to both the Newport-Inglewood and Puente Hills thrust fault. All three of these fault zones are capable of causing severe damage in the city due to strong ground motions. Given the location of these faults in and near the city, the 1997 Uniform Building Code requires that Torrance incorporate near-source factors into the design of new buildings. In addition to the faults above, numerous other active faults, both onshore and offshore, have the potential to generate earthquakes that would cause strong ground shaking in Torrance.

- 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 strong ground shaking in Torrance. The 1933 Long Beach earthquake, and the 1941 Torrance-Gardena earthquakes caused significant damage in the city.

Design Earthquake Scenarios:

- Both the Palos Verdes and the Puente Hills faults have the potential to generate earthquakes that would be described as worst-case for the city of Torrance. The Palos Verdes fault is thought capable of generating an earthquake of magnitude 7.3. The Puente Hills fault is thought capable of generating earthquake of between magnitude 6.5 and 7.1, depending on how many segments of the fault rupture together during a single event. The onshore segment of the Newport-Inglewood fault is thought capable of generating a magnitude 7.1 earthquake. As a comparison, all of these potential earthquakes are larger than the M_w 6.7 Northridge Earthquake, the single most-expensive earthquake yet to impact the United States.

Fault Rupture and Secondary Earthquake Effects:

- Several active and potentially active traces of the Palos Verdes fault have been mapped across the city. An Alquist-Priolo Earthquake Fault Zone has not been yet been designated for the Palos Verdes fault, as its location is not well defined. However, offshore studies have shown that this fault is clearly active, and future mapping of the Palos Verdes fault by the California Geological Survey can be anticipated. This report recommends the establishment of two fault hazard management areas. The first surrounds the trace of the Palos Verdes fault that is thought to be most recently active, based on a review of seismic reflection lines that imaged the fault in the shallow subsurface. This fault hazard management zone is 100 feet wide on the north side of the fault, and 200 feet wide on the south side of the fault, to capture potential ground deformation associated with the now minor, but still possible, component of vertical movement on the fault. All new development in this area should be required to conduct fault evaluation studies following the guidelines of the Alquist-Priolo Act. The second fault hazard management zone is established along potentially less recently active traces of the Palos Verdes fault, and lineaments that have been identified from aerial photographs that could be related to faulting. Fault studies in this area would only be required if a critical facility (high-risk or high-occupancy) is proposed in this area. If and when active traces of the Palos Verdes fault are encountered as a result of these studies, building setbacks should be recommended by the project's engineering geologists.

- The California Geological Survey (CGS) has completed mapping in the Torrance 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. Currently, shallow ground water levels (less than 50 feet from the ground surface) are known to occur only along the coast, in Torrance Beach, and along the pre-channelized drainage of Dominguez Creek. These areas are also underlain by soft, unconsolidated sediments, and as a result, the California Geological Survey has mapped these zones as susceptible to liquefaction. Redevelopment in these areas should conduct liquefaction evaluation studies in accordance with State law.

- The southern and southwestern portions of Torrance are most vulnerable to seismically induced slope failure, due to the steep terrain.

- Those portions of the Torrance area that may be susceptible to seismically induced settlement are the alluvial surfaces and larger drainages that are underlain by late Quaternary alluvial and beach sediments. Sites next to the now channelized Dominguez Creek may be particularly vulnerable.

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, soft-story buildings, and pre-1952 wood-frame buildings, is recommended.

- Most damage in the city is expected to be to wood-frame residential structures. However, the damage to residential structures, although costly, is not expected to cause a large number of casualties.

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. In addition, current building codes should be adopted for re-development projects that involve more than 50 percent of the original cost of the structure. The recent building codes incorporate two significant changes that impact the city of Torrance. 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 Torrance 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 cost-prohibitive and not practicable. 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 Torrance area is subject to near-source design factors because the city is located near three active fault systems (Palos Verdes, Puente Hills thrust and Newport-Inglewood faults). These parameters, new to the 1997 Uniform Building Code (UBC) and the 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 Torrance 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.

- Effective management of seismic hazards in Torrance includes technical review of consulting reports submitted to the City. For projects within seismic hazard zones, State law requires that the City's reviewer be a licensed engineering geologist and/or civil engineer having competence in the evaluation and mitigation of seismic hazards (CCR Title 14, Section 3724). Because of the interrelated nature of geology, seismology, and engineering, most projects will benefit from review by both the geologist and civil engineer. The California Geological Survey has published guidelines to assist reviewers in evaluating site-investigation reports (CDMG, 1997).

CHAPTER 2: GEOLOGIC HAZARDS

2.1 Physiographic Setting

The city of Torrance is located in an area of diverse terrain at the western margin of the Los Angeles Basin, the broad, very gently sloping coastal outwash plain formed by the Los Angeles and San Gabriel Rivers. Just east and northeast of the city's boundary, this plain is interrupted by two of a string of low hills that have been uplifted along the Newport-Inglewood fault zone. These two hills closest to Torrance are the Dominguez and Rosecrans hills (see Plate 2-1). Streams and rivers emanating from the Santa Monica and San Gabriel Mountains have, on their way to the Pacific Ocean, carved gaps in these hills, forming, among others, the Dominguez and Ballona gaps. The Dominguez Gap is south and east of the study area, whereas the Ballona Gap is north of the city, north of the Los Angeles International Airport. To the south of Torrance, the Palos Verdes Hills constitute a block of land uplifted along the Palos Verdes fault zone. The city's southwestern border includes coastal bluffs and beaches at the edge of the Pacific Ocean.

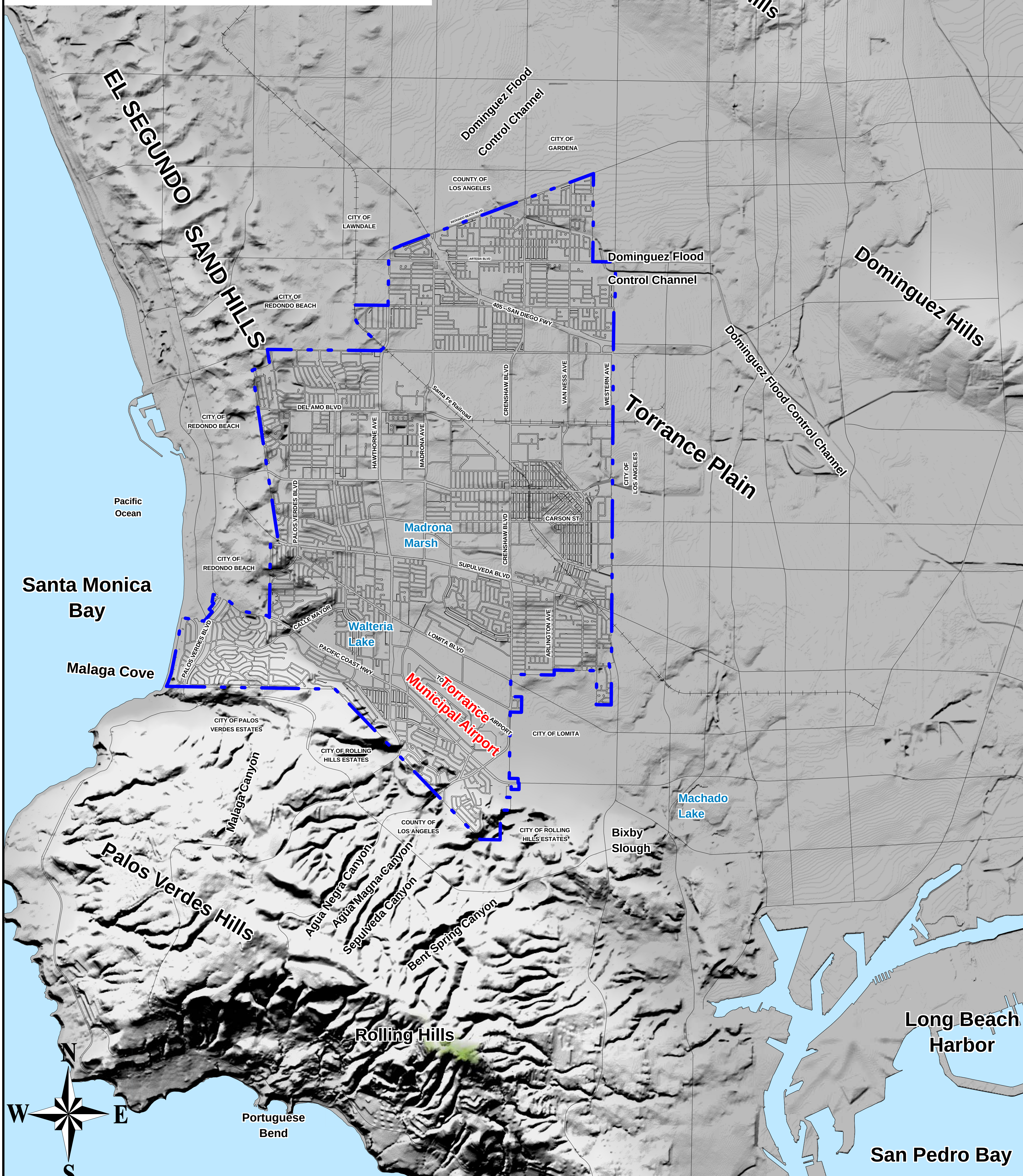
The landscape within the city can best be described by physiographic area, each reflective of its distinct topographic features (see Plate 2-1). The central and western portions of the city encompass the southern part of an area once known as the El Segundo Sand Hills (also known as the El Segundo Sand Dunes). Prior to development, this area consisted of ancient and modern sand dunes that extended from the sea to about four miles inland, with dunes rising to almost 200 feet above sea level, creating a landscape of shallow hills and closed depressions. The northeastern part of the city, as well as the relatively flat area between Lomita Boulevard and Pacific Coast Highway in the south, is part of a physiographic area known as the Torrance Plain. This plain, which parallels the Newport-Inglewood uplift from the Ballona Gap to Wilmington, is a prehistoric flood plain that was intermittently inundated by the sea. Its history of emergence and submergence has been revealed in excavations that have yielded fresh-water fossils, extinct land mammals, and marine fossils (California Department of Water Resources - DWR, 1961). Today, this area is slightly elevated above the modern flood plain, and has been gently dissected by local streams. Hillside areas within the city are confined to coastal bluffs and, at its southern margin, the base of the Palos Verdes Hills. During the last 80 years, the city's natural landscape has been largely altered by dense urban development. Lowland portions of city, including the area of the El Segundo Sand Hills, are now at elevations ranging from about 60 to 100 feet above sea level. The Palos Verdes Hills rise to an elevation of about 1,480 feet; however, the portions of the hills within city limits reach only to about 400 feet above sea level.

Drainage within the city is largely to the east, via storm drains and the Dominguez Flood Control Channel. This channel replaced Dominguez Creek and its tributaries, once a system of braided streams, marshes, and small ponds that eventually reached San Pedro Bay. The portion of the Palos Verdes Hills that borders the city is drained by several north-trending canyons, including, from east to west, Bent Spring, Sepulveda, Agua Magna, Agua Negra and Malaga canyons, as well as numerous smaller, unnamed canyons. Carrying significant amounts of water only during the winter, these streams now flow into storm drain structures. Historical and current drainages in the city are described in more detail in Chapter 3.

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: 1:72,000

2 0 2 4 6 Kilometers

6000 0 6000 12000 18000 Feet

EXPLANATION

Torrance City Limit

Elevation Shading (feet)

0 250 500 750 1000

Base Map: City of Torrance (2005); USGS 7.5-minute Digital Elevation Model.

Earth Consultants International

Project Number: 2431
Date: July, 2005

Physiographic Map of Torrance, California and Surrounding Areas

Plate 2-1

2.2 Geologic Setting

The physical features described in the previous section are a reflection of the geologic and climatic processes that have played upon this region in the last few million years. The city of Torrance lies at the northern end of the Peninsular Ranges, a geologic/geomorphic province characterized by a northwest-trending structural grain aligned with the San Andreas fault and represented by a series of northwest-trending faults, mountain ranges and valleys stretching from the Los Angeles Basin to the Mexican border. Displacements on faults in this region are mainly of the strike-slip type, and where they have been most recently active they have deformed the landscape and altered drainage patterns. Examples of such faulting in the Torrance area are the Newport-Inglewood and Palos Verdes fault zones. Predominantly right-lateral in movement, the location and structure of the Newport-Inglewood fault zone is known primarily from a compilation of surface mapping and deep, subsurface data, driven initially by an interest in oil exploration (all of the hills and mesas along the Newport-Inglewood fault zone have yielded petroleum), and later by a shift toward evaluating earthquake hazards. The fault is an active structure and was the source of the 1933 M6.4 Long Beach earthquake (M stands for magnitude).

The Palos Verdes Hills are the westernmost onshore uplift in the Peninsular Ranges province (Catalina Island is an example of an offshore uplift). The hills are geologically complex, the sedimentary rock layers having been folded and faulted into a dome-like structure with the north and south limbs dipping downward from the center of the hill. This structure is complicated locally by smaller-scale folding and faulting. Near the city's southern boundary, the rock is tilted to the north and northeast, generally in the range of about 15 to 45 degrees. At the base of the hills, within city limits, the major structural feature is the northwest-trending Palos Verdes fault zone, which is continuous for about 60 miles, mostly offshore. This fault zone is a steeply dipping oblique-slip fault, and although it has not been zoned by the state under the provisions of the Alquist-Priolo Earthquake Fault Zone Act, the fault is considered by researchers to be an active structure, capable of producing moderate earthquakes (Dolan et al., 2001; CGS, 2003; SCEC, 2005).

The Los Angeles coastal plain is underlain by a sequence of marine and non-marine sediments that are locally more than 30,000 feet thick. Whereas many of the older sediments have proven to be rich in petroleum, younger sediments, deposited primarily by flooding of ancestral rivers, are water bearing, initially providing water for agriculture, and then, in the last century, for urbanization. Torrance overlies the West Coast Groundwater Basin where the thickness of unconsolidated to semi-consolidated water-bearing sediments is on the order of 1,200 feet (Harris et al., 1992).

In recent years, scientists have discovered that the northern end of the province, where the Los Angeles metropolitan area is located, is underlain by a series of deep-seated, low-angle thrust faults that do not reach the surface (referred to as "blind thrusts"). Faults of this type are thought to be responsible for uplift of many of the low hills in the Los Angeles Basin, such as the Repetto and Montebello Hills. 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. An older blind thrust fault, the Compton Thrust, underlies the Torrance area. These faults, and the hazard that they pose to the area, are described in more detail in Chapter 1.

2.3 Geologic Units

Sediments of late Holocene age (less than about 11,000 years old) are present in remnants of recently active stream channels in the eastern part of the city, in addition to isolated alluvial deposits that occupy the once low-lying depressions in the Torrance Plain. Holocene deposits are also present in the beach strand bounding the southwestern edge of the city. Late Pleistocene (11,000 to about 200,000 years old) deposits are represented by stabilized dune and drift sand that widely blankets the west and central parts of the city. The dune deposits are generally interpreted to be ancient offshore sand bars that have been modified by wind and stream processes since their emergence from the sea at the beginning of Holocene time (DWR, 1961). Pleistocene-age sediments are also present in the form of coalescing alluvial fans emanating from canyons of the Palos Verdes Hills. Buried beneath these deposits are older sediments, largely deep marine to shallow marine in origin, and ranging in age from Miocene (10 to 26 million years old) to mid-Pleistocene (about 300,000 to 500,000 years old). Where uplift has occurred, these older units have been exposed by erosion. Within the city, their presence at the surface is very minor, being limited to isolated areas in coastal bluffs and at the base of the Palos Verdes Hills.

The general distribution of the geologic units that are exposed at the surface is shown on the Geologic Map (Plate 2-2). The names of the geologic units that occur at and near the surface in the Torrance area are based on nomenclature published by Dibblee (1999). The geologic units are described in the next section, from youngest to oldest, including some of their general engineering characteristics. These descriptions have been compiled from various sources, including published regional geologic reports and papers, as well as unpublished consulting reports.

There are many deposits of man-made fill throughout the city, including road and bridge embankments, small canyon fills, and grading associated with leveling of the El Segundo Sand Hills. These deposits vary widely in size, age, and composition, and although some may be significantly extensive, due to the map scale, most of these areas are not shown on the Geologic Map (Plate 2-2).

2.3.1 Young Surficial Deposits

Holocene deposits (sediments that range in age from about 11,000 years ago to the present) within the city generally occupy the low-lying areas, including beaches and stream channels. Being geologically young and subject to active geologic processes, these deposits are typically unconsolidated and have very little, if any, soil development. These young surficial deposits can be sub-divided into four main groups, as described below.

2.3.1.1 Beach Sediments (map symbol: Qs)

Late Holocene beach sand and gravel form a narrow strandline along the western edge of the city, just north of the Palos Verdes Hills. These sediments generally consist of light gray to tan, fine- to coarse-grained sand, but near Malaga Cove, they include deposits of pebbles and cobbles. The beach deposits typically slope gently towards the ocean. Due to their lack of cohesion and sparse vegetation cover, the beach sands are highly vulnerable to erosion. Their permeability is high, and their expansion potential is low.

2.3.1.2 Young Alluvium (map symbol: Qa)

Late Holocene alluvium consists of loamy clays, silty sands, and fine sands filling stream channels and depressions in the Torrance Plain. Such deposits are typically of low density, and contain organic debris. Consequently, they are subject to settlement under loading (for example, under fill embankments or buildings), erosion, and poor slope stability. Their

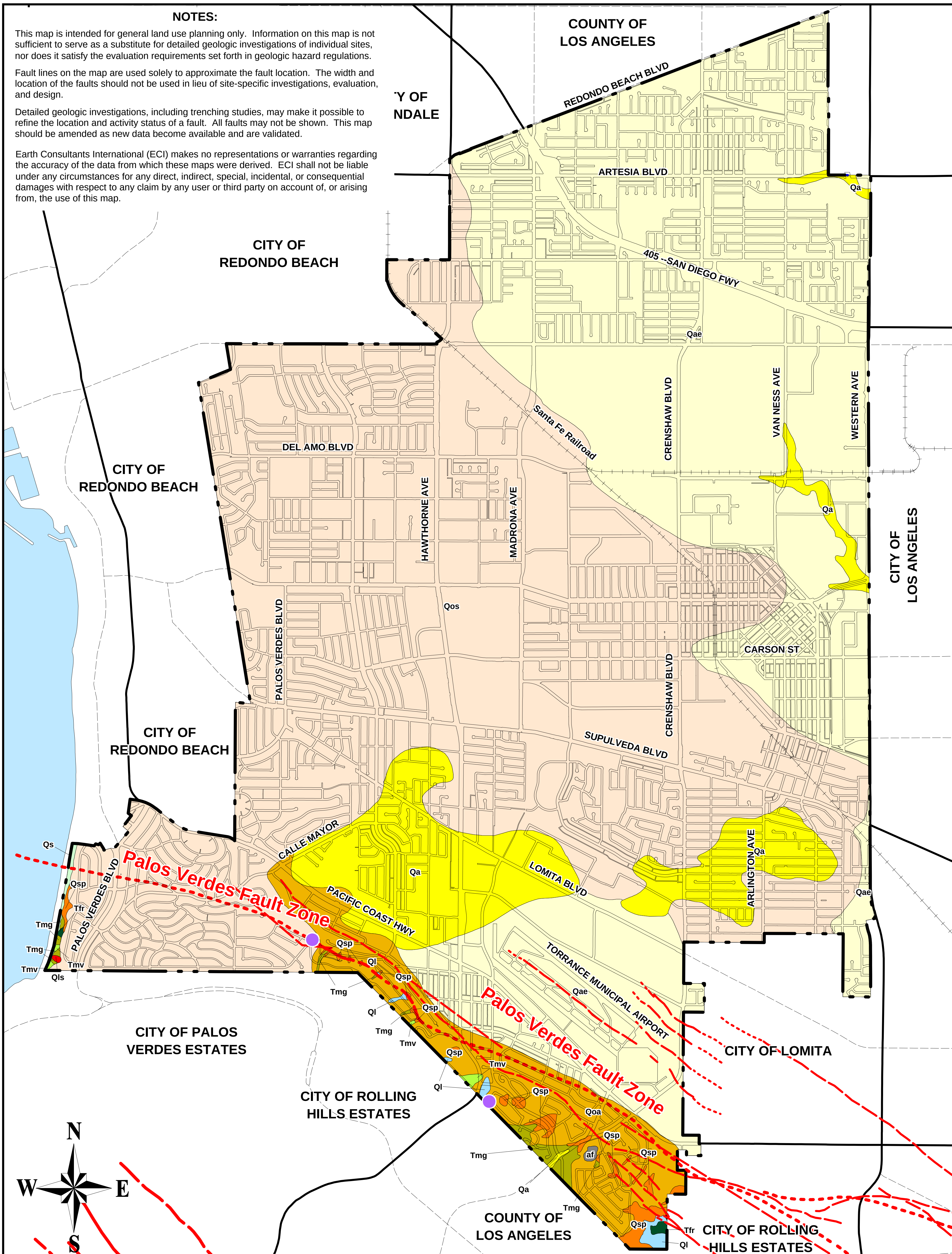
NOTES:

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.



Scale: 1:36,000

Kilometers: 1 0 1 2 3

Feet: 3000 0 3000 6000 9000

Base Map: City of Torrance (2005).
Sources: Faults and Geology, Dibblee (1999).

For the key to map symbols and Geologic Descriptions, See Plate 2-2a.

Earth Consultants International

Project Number: 2431
Date: July, 2005

Geologic Map

Torrance, California

Plate 2-2

SYMBOLS

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

Geologic Contact

Torrance City Boundary

Areas of known slope instability, 1978-2004

GEOLOGIC UNIT DESCRIPTIONS

Period	Epoch	Unit	Description
Quaternary	Holocene	af	**Artificial Fill- Many areas may no be shown.**
Quaternary	Holocene	Qs	**Beach Sediments- Ranging from sand to cobble-boulder gravel.**
Quaternary	Holocene	Qa	**Alluvium- Mostly loamy clay of valleys and flood plains; includes fine sand near Palos Verdes Hills.**
Quaternary	Holocene	Qae	**Elevated Alluvium- Locally dissected, mostly loamy clay of valleys and flood plains; includes fin sand near Palos Verdes Hills**
Quaternary	Holocene	Qls	**Landslide Debris- Mostly of Monterey Shale**
Quaternary	Pleistocene	Qoa	**Older Alluvium- Nonmarine terrace cover sandy loam and loamy clay, includes sand and pebble gravel in Palos Verdes Hills, with pebbles derived mostly form Miocene hard siliceous shale and limestone; includes Palos Verdes Sand**
Quaternary	Pleistocene	Qos	**Older, stabilized dune and drift sand- Mostly unconsolidated fine-grained sand**
Quaternary	Pleistocene	Qsp	**San Pedro Sand- Light gray to reddish-tan sand and pebble gravel, pebbles derived mostly from Miocene hard siliceaous shale and limestone detritus; massive to locally cross-bedded**
Quaternary	Pleistocene	Ql	**Lomita Marl- Gray-white marl and calcareous fine-grained sandstone, gray siltstone, in places with basal gravel of Miocene shale and limestone debris**
Tertiary	Miocene	Tfr	**Fernando Formation- Soft gray siltstone-claystone, locally glauconitic**
Tertiary	Miocene	Tmg	**Malaga Mudstone- Light gray sandstone and dark gray-brown mudstone with diatomaceous strata and limestone concreations**
Tertiary	Miocene	Tmv	**Valmonte Diatomite- Soft, white, punky, laminated diatomaceous shale and mudstone in places up to 125m thick**

A BALANCED CITY · TORRANCE · INDUSTRIAL-RESIDENTIAL-COMMERCIAL

Earth Consultants International

Project Number: 2431
Date: July, 2005

Explanation of Geologic Map

Plate 2-2a

expansion characteristics can range from low to high, depending on the grain size of the deposit.

2.3.1.3 Elevated Alluvium (map symbol: Qae)

This unit consists of fine-grained floodplain deposits, mainly sands, silts, and clays of the Torrance Plain, that have been slightly elevated and incised by modern streams. At the surface, these sediments are unconsolidated; below the upper few feet, they are typically dense to very dense. This alluvium is slightly to moderately susceptible to erosion, and moderately to highly expansive.

2.3.1.4 Landslide Deposits (map symbol: Qls)

The occurrence of landslides in Torrance is rare, and most of the significant slope instability in the city is present on the steep sea cliff above Torrance Beach, and locally in the flanks of the Palos Verdes Hills. Although only one landslide has been mapped in the sea cliff area (in fact the only mapped landslide in the city), most of the Torrance sea cliff shows signs of past instability, including slumping, spalling, and soil slippage, as well as erosion (see Figures 2-1 and 2-2). In this area, headward erosion and slope failure may pose a threat to homes at the top of the bluff, particularly those near the edge. Slope instability has also been reported in the southern portion of the city (City of Torrance Natural Hazard Mitigation Plan, 2004), in the Vista Largo – Via Corona area, and in the Country Hills area (see Plate 2-2).

Figure 2-1: **Sea Cliff Above Torrance Beach Showing Signs of Past Slope Instability.** Note the hummocky topography and steep scarp below the homes.

Landslide deposits consist of broken up fragments of the geologic unit (or units) in which the landslide developed. Landslides in general are unsuitable for support of foundations, being subject to future instability and compressibility.

2.3.2 Older Surficial Deposits

Pleistocene (between about 11,000 and 1.6 million years old) deposits are widespread in the western and central parts of the city, as well as along the north flank of the Palos Verdes Hills. Ranging in age from about 11,000 to one million years old, these deposits are unconsolidated to weakly consolidated, and may have moderate to well-developed weathering profiles. Four separate deposits in this age range are recognized in the Torrance area, as described below.

2.3.2.1 Older Alluvium (map symbol: Qoa)

This unit includes sediments eroded from the Palos Verdes Hills and deposited as alluvial fans along the base of the hills. Consisting of sandy loam and loamy clay with lenses of sand and pebble gravel, these sediments are typically dense below the upper few feet. Induration ranges from poor to well developed. Permeability and expansion potential are highly variable, depending on the composition and degree of soil development. Slope stability is generally good. This unit also includes the Palos Verdes Sand, a shallow marine and terrestrial deposit that contains abundant fossils. The thickest section of Palos Verdes sand known in the Palos Verdes peninsula is exposed in the Chandler Quarry just south of the city.

2.3.2.2 Older Stabilized Dune and Drift Sand (map symbol: Qos)

This unit consists of Late Pleistocene unconsolidated fine- to medium-grained sand, with sandy silt, clay, and gravel near the base. Where deeply weathered and oxidized at the surface, its color typically ranges from yellow to brown; where unweathered, its color ranges from white to gray. These sediments are moderately dense to very dense, but where unweathered (typically starting a few feet below the ground surface) are otherwise similar in characteristics to the beach sand deposits described in Section 2.3.1.1. Except where at the soil zone, their expansion potential is low. Due to a lack of cohesion, particularly in the unweathered portion, their erosion potential is high. Most of these deposits are now covered by dense development and their original surfaces and landforms have been altered by grading.

2.3.2.3 San Pedro Sand (map symbol: Qsp)

The San Pedro Sand is mid-Pleistocene in age and consists of dense, weakly consolidated light gray (unweathered) to reddish tan (weathered) sand and pebble gravel with interbedded sandy silt. Bedding ranges from massive to well stratified and locally cross-bedded. Sand intervals within this unit are susceptible to erosion, have relatively high permeability, poor surficial slope stability, and a low potential for expansion. Fine-grained intervals are more resistant to erosion, have low permeability, and may be expansive. The San Pedro Sand has been folded and faulted; where bedding planes dip flatter than the slope face, there is a potential for slope instability.

2.3.2.4 Lomita Marl (map symbol: Ql)

The Lomita Marl is mid-Pleistocene in age and stratigraphically underlies the San Pedro Sand. This unit consists of fossiliferous grayish-white marl (a mix of calcite and fine-grained sediments) and calcareous fine-grained sandstone, with gravel and gray siltstone. The Lomita Marl sediments are dense to very dense.

2.3.3 Tertiary Sedimentary Rocks

The Palos Verdes Hills are underlain primarily by an assemblage of sedimentary rocks uplifted by multiple episodes of faulting and folding. All of these rocks are marine in origin, having formed from sediments deposited in a deep ocean embayment that encroached into the Los Angeles basin prior to uplift of the region. These sedimentary deposits are described further below.

2.3.3.1 Fernando Formation - (map symbol: Tfr)

Small, isolated patches of the early Pliocene (about 5 to 10 million years old) Fernando Formation are exposed near the base of the Palos Verdes Hills where it consists of gray, semi-consolidated siltstone to claystone. Bedding in the Fernando Formation is generally poorly developed or massive. From an engineering viewpoint, this formation is not compressible, has relatively good gross slope stability, but poor surficial stability, is susceptible to erosion, and is moderately to highly expansive.

The units described below are part of the Miocene-age (10 to 26 million years old) Monterey Formation. The Monterey Formation is widely exposed in the Palos Verdes Hills south of the Palos Verdes fault zone. It also underlies Pleistocene and Holocene deposits that cap the coastal plain, and is exposed in bluffs along the beach. The Monterey Formation consists predominantly of thinly bedded to laminated siliceous siltstone, diatomaceous shale, and clayey siltstone with interbeds of clayey, diatomaceous siltstone and very fine-grained sandstone and diatomite. Locally it contains irregular lenses and thin beds of water-laid tuff (volcanic ash) that is frequently altered to highly plastic clay.

2.3.3.2 Monterey Formation - Malaga Mudstone Member (map symbol: Tmg)

The late Miocene Malaga Mudstone consists of light gray sandstone and dark grayish brown mudstone with interbedded diatomaceous layers and limestone concretions. Permeability of the rock is low, and its expansion potential is high to very high. Although somewhat resistant to erosion, slope stability of this member is generally poor.

2.3.3.3 Monterey Formation – Valmonte Diatomite Member (map symbol: Tmv)

The Valmonte Diatomite is a distinctive unit within the Monterey Formation that consists of white, laminated diatomaceous mudstone and shale. This unit is highly porous, but with low permeability, has poor slope stability, is highly expansive, and is not suitable for fill material.

2.4 Geologic Hazards in the Torrance Area

Geologic hazards are generally defined as surficial earth processes that have the potential to cause loss or harm to the community or the environment. The basic elements involved in the assessment of geologic hazards are climate, geology, soils, topography, and land use.

2.4.1 Landslides and Slope Instability

In Torrance, the hazard of slope instability is locally a concern due to the occurrence of hillsides within and immediately adjacent to the city. Significantly high and steep slope areas are present along sea cliffs and at the base of the Palos Verdes Hills, and smaller slopes are present in the western part of the city. Although only one landslide has been mapped in the sea cliff above Malaga Cove (Dibblee, 1999), slope instability, primarily in the form of soil slips and mudflows, is possible in this area. Similarly, in the northern flank of the Palos Verdes Hills, in the southern part of Torrance, surficial slope instability issues have been reported in the past. For example, in April 1986, there was a major landslide in the Vista Largo - Via Corona area that impacted two houses. The slope was repaired but the houses had to be demolished. Then, in February 1998, a major landslide occurred in the backyards of 24 single-home residential properties on Carolwood Lane and Singingwood Drive. Repair of the hillside was underway as of 2004 (City of Torrance Natural Hazard Mitigation Plan, 2004), with repairs being done for 15 of the 24 impacted properties. Although an active slope failure tends to affect a relatively small area (as compared to a damaging earthquake), and is generally a problem for only a short period of time, the dollar loss can be high. Insurance policies typically do not cover landslide damage, and this can add to the anguish of the affected property owners.

Careful land management in hillside areas can reduce the risk of economic and social losses from slope failures. This generally includes land use zoning to restrict development in unstable areas, grading codes for earthwork construction, geologic and soil engineering investigation and review, 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.

2.4.1.1 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. For man-made slopes, most failures 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 a nearly intact bedrock blocks, or as jumbled mixes of bedrock blocks, fragments, debris, and soils. 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, shear strength and orientation of weak layers in the underlying geologic unit, as well as pore water pressures. Joints and shears, which weaken the rock fabric, allow penetration of water leading to deeper weathering of the rock along with increasing the pore pressures, increasing the plasticity of weak clays, and increasing the weight of the landmass. 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).

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 roadways, are often allowed, at the discretion of the local reviewing agency, 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**

  Surficial slumps and soil slips are too small to map at the scale used in the figures that accompany this report (such as Plate 2-2). However, they are relatively common in hillside areas, typically occurring during winters of particularly heavy and prolonged rainfall. Some of the most common types of surficial slope failure are discussed below.

  Slope Creep - Slope creep in general involves deformation and movement of the outer soil or rock materials in the face of the slope resulting when the gravity forces overcome 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. Soil creep occurs most often in soils developed on fine-grained bedrock units. Rock creep is a similar process, and involves permanent deformation of the outer few feet of the rock face resulting in folding and fracturing. Rock creep is most common in highly fractured, fine-grained rock units, such as siltstone, claystone and shale.

  Creep also occurs in graded fill slopes. This 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 slope creep is not catastrophic, it can cause damage to structures and improvements located at the tops of slopes.

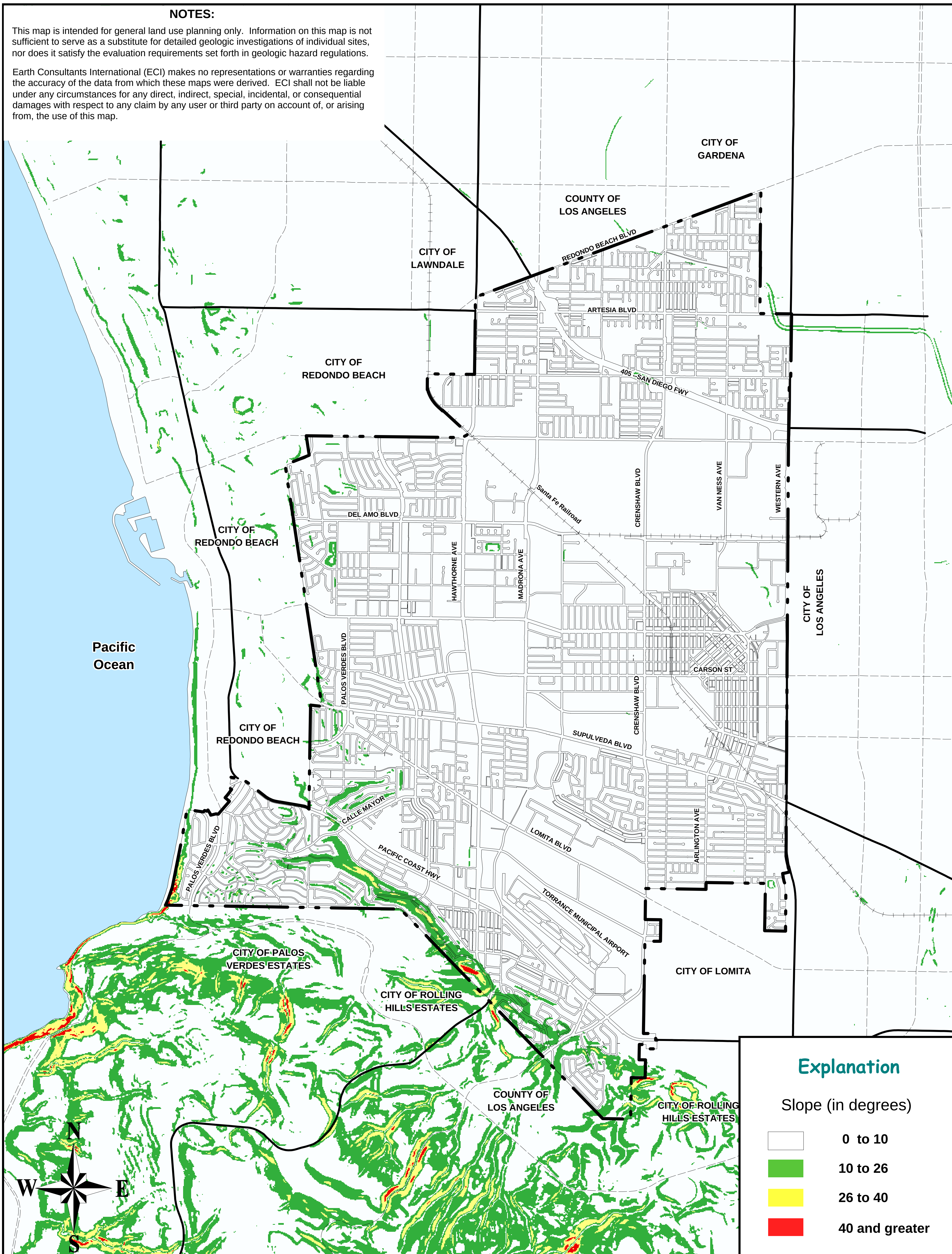
  Soil Slip - This type of failure is generated by strong winter storms, and is widespread in the steeper slope areas, particularly after winters with prolonged and/or heavy rainfall. Failure occurs on canyon sideslopes, and in soils that have accumulated in swales, gullies and ravines. Soil slips can also occur on graded slopes, especially older slopes, and those that are poorly maintained. Slope steepness has a strong influence on the development of soil slips, with most slips occurring on slopes with gradients of between about 27 and 56 degrees (Campbell, 1975). More recently, in a study of the Santa Paula area of Ventura County it was found that about 70 percent of the debris flows generated during winter storms occurred on slopes between 20 and 36 degrees (Morton et al., 2003). For slope gradients in the Torrance area, refer to the Slope Distribution Map (Plate 2-3). Figure 2-2 shows recent soil slippage on the steep slopes of an abandoned quarry pit in at the base of the Palos Verdes Hills.

  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

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

Slope (in degrees)

- 0 to 10
- 10 to 26
- 26 to 40
- 40 and greater

Scale: 1:48,000

1 0 1 2 3 Kilometers

4000 0 4000 8000 12000 Feet

Torrance City Limit

Base Map: City of Torrance (2005).
Source: Derived from USGS 10m Digital Elevation Model

A BALANCED CITY · INDUSTRIAL-RESIDENTIAL-COMMERCIAL · TORRANCE

Earth Consultants International

Project Number: 2431
Date: July, 2005

Slope Distribution Map

Torrance, California

Plate 2-3

pore water pressure caused by infiltration of water during and after winter rains. Earth flows occur on moderate to steep slopes, typically in the range of about 15 to 35 degrees (Keefer and Johnson, 1983).

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.

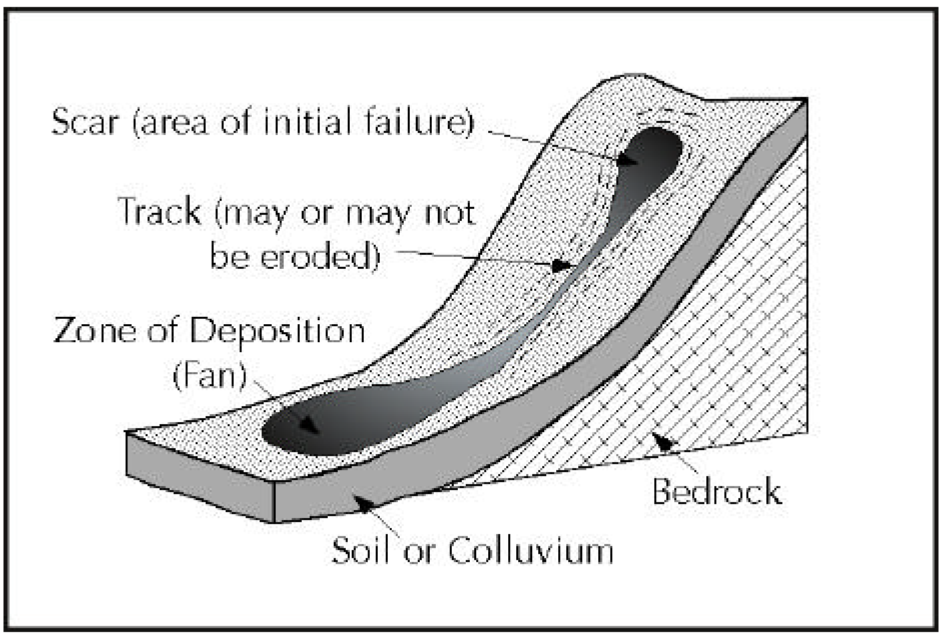
Figure 2-2: **Soil Slippage on a Steep Quarry Slope at the Base of the Palos Verdes Hills.** Note the accumulation of soil debris at the base of the slope. Such failures during intense winter rains are often the catalyst for dangerous debris flows.

A debris flow most commonly originates as a soil slip in the rounded, soil-filled “hollow” at the head of a drainage swale or ravine (see Figure 2-3). 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 the Federal Emergency Management

Agency (FEMA) to modify its National Flood Insurance Program to include inundation by "mudslides."

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 five 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).

Figure 2-3: Sketch of a Typical Debris Avalanche Scar and Track



Modified from:
http://www.consrv.ca.gov/cgs/information/publications/cgs_notes/note_33/index.htm.
Original sketch by Janet K. Smith

Rockfalls – Rockfalls are free-falling to tumbling masses of bedrock and soil 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, wave erosion along sea cliffs, or man's activities.

2.4.1.2 Susceptibility to Slope Failure

Fortunately, past occurrences of slope failures in the city of Torrance have been minor. Nevertheless, developments in hillside areas can be impacted by slope failures, particularly during winters of intense and prolonged rainfall, as the cases on Vista Largo-Via Corona and Carolwood Lane – Singingwood Drive demonstrate. Even if a slope failure does not reach the properties above or below, the visual impact will generally cause alarm to homeowners. The hillside areas of the city are also susceptible to slope failures resulting from strong seismic shaking (see Chapter 1 – Seismic Hazards).

Table 2-1 below is a 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 2-2), and the Slope Distribution Map (Plate 2-3).

Table 2-1: General Slope Instability Potential in the City of Torrance

Area	Geologic Conditions	Types of Potential Slope Instability
Palos Verdes Hills	• Moderate to steep natural slopes, many in excess of 26 degrees along stream channels • Highly fractured, sheared, faulted, and crushed bedrock due to movement on the Palos Verdes fault • Bedrock formations composed of clays and silts having weak shear resistance • Soils and loose debris at the toes of slopes and in drainage courses	***Most Common***: Soil slips on steep slopes, soil slumps and small slides on the edges of active stream channels; small debris or mud flows in canyons. ***Least Common***: Large deep-seated landslides.
Coastal Bluffs	• Moderate to locally steep slopes, many in the range of 26 degrees or more • Highly fractured and jointed siltstone, mudstone, and shale in the lower part, sand and silty sand (older dune sand) in the upper part • Soils and loose debris in tributary drainages and swales	***Most Common***: Soil slips and small to large slumps on moderate to steep slopes and in drainage swales, especially during periods of heavy rainfall. Spalling of coastal bluffs from wave erosion. ***Least Common:*** Large, deep-seated landslides.

2.4.1.3 Mitigation of Slope Instability in Future Development

All proposed projects in hillside areas should require a site-specific geotechnical evaluation of any slopes that may impact the future use of the property or adjacent properties. 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.

Temporary slope stability is also a concern, especially where earthwork construction is taking place next to existing improvements. Temporary slopes are those made for slope stabilization backcuts, fill keys, alluvial removals, retaining walls, and utility lines. The risk of slope failure is higher in temporary slopes because they are generally cut at a much steeper gradient. In general, temporary slopes should not be cut steeper than 1:1 (horizontal:vertical), and depending on field conditions flatter gradients may be necessary. The potential for slope failure can also be reduced by cutting and filling large excavations in segments, and not leaving temporary excavations open for long periods of time. The stability of large temporary slopes should be analyzed prior to construction, and mitigation measures provided as needed.

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, earth-flows, 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. 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 (Wyllie and Norrish, 1996).

2.4.1.4 Mitigation of Slope Instability in Existing Development

There are a number of options for management of potential slope instability in developed hillsides. Implementation of these options should reduce the hazard to an acceptable level, including reducing or eliminating the potential for loss of life or injury, and reducing economic loss to tolerable levels. Mitigation measures may include:

- Protecting existing development and population where appropriate by physical controls such as drainage, slope-geometry modification, protective barriers, and retaining structures;
- Posting warning signs in areas of potential slope instability;
- Encouraging homeowners to install landscaping consisting primarily of drought-resistant, preferably native vegetation that helps stabilize the hillsides;
- Incorporating recommendations for potential slope instability into geologic and soil engineering reports for building additions and new grading; and
- Providing public education on slope stability, including the importance of avoiding heavy irrigation and maintaining drainage devices. Publications by both the U.S. Geological Survey (such as Fact Sheet FS-071-00, dated May 2000) and the California Geological Survey (such as Note 33, most recently updated in November, 2001) provide public information on landslide and mudslide hazards.

2.4.2 Compressible Soils

Compressible soils are typically geologically young (Holocene in age) unconsolidated sediments of low density that may compress under the weight of proposed fill embankments and structures. The settlement potential and the rate of settlement in these sediments can vary greatly, depending on the soil characteristics (texture and grain size), natural moisture and density, thickness of the compressible layer(s), the weight of the proposed load, the rate at which the load is applied, and drainage. Areas of the city where compressible soils are most likely to occur are the active and recently active stream channels, beach deposits, and young alluvial fan deposits. Deep fill embankments, generally those in excess of about 60 feet deep, will also compress under their own weight. Areas covered with un-engineered artificial fill may also be susceptible to this hazard. In the Palos Verdes Hills, compressible soils are commonly found in canyon bottoms, swales, and at the base of natural slopes.

2.4.2.1 *Mitigation of Compressible Soils*

When development is planned within areas that contain compressible soils, a geotechnical soil analysis is required to identify the presence of this hazard. The analysis should consider the characteristics of the soil column in that specific area, and also the load of any proposed fills and structures that are planned, the type of structure (i.e., a road, pipeline, or building), and the local groundwater conditions. At a minimum, removal and recompaction of the near-surface soils is generally required. Deeper removals may be needed for heavier loads, or for structures that are sensitive to minor settlement. Based on the location-specific data and analyses, partial removal and recompaction of the compressible soils is often performed, followed by settlement monitoring for a number of months after additional fill has been placed, but before buildings or infrastructure are constructed. Similar methods are used for deep fills. In cases where it is not feasible to remove the compressible soils, buildings can be supported on specially engineered foundations that may include deep caissons or piles anchored in non-compressible materials underlying the weak soils.

2.4.3 Collapsible Soils

Hydroconsolidation or soil collapse typically occurs in recently deposited, Holocene, soils that accumulated in an arid or semi-arid environment. Soils prone to collapse are also commonly associated with wind-deposited sands and silts, and alluvial fan and debris flow sediments deposited during flash floods. These soils are typically dry and contain minute pores and voids. The soil particles may be partially supported by clay, silt or carbonate bonds. When saturated, collapsible soils undergo a rearrangement of their grains and a loss of cementation, resulting in substantial and rapid settlement under relatively light 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. Typically, differential settlement of structures occurs when landscaping is heavily irrigated in close proximity to the structure's foundation.

Most of the sediments that underlie the Torrance area are generally not susceptible to this hazard due to their age and density. However, localized areas, such as recently active drainage channels and deposits of younger alluvium in the southern part of the city could meet the conditions needed for collapse to occur.

2.4.3.1 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 the in-place pre-saturation and pre-loading of the susceptible soils 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.

2.4.4 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.

The northeastern and southern parts of the city are underlain by fine-grained flood-plain sediments that are composed primarily of silty sand with variable amounts of clay. Sediments of this type are typically in the moderate range for expansion potential, and may be locally in the high range, depending on the clay content. Expansive soils are specifically known to occur in the area around Ocean Avenue and Lomita Boulevard, where continuous fixing of the roadways is required due to damage caused by shrinking and swelling of the underlying materials (Torrance Public Work Department, personal communication, 2005). Soils developed on the older surficial deposits, such as older alluvium, are commonly clay-rich and will probably fall in the moderately expansive range. Bedrock of the Monterey Formation, as well as silty intervals in the San Pedro Sand, may also be in the moderate to high range. Topsoils developed on fine-grained bedrock units will also be moderately to highly expansive. Areas underlain by beach and dune sands have very little expansion potential. 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.

2.4.4.1 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 "pre-saturated" 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 stronger 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.

2.4.5 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 in valleys filled with recent alluvium.

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 or noted in the Torrance area (Torrance Public Works Department, personal communication, 2005). The West Coast Groundwater Basin, which underlies the city, is managed by the Water Replenishment District of Southern California. This agency monitors groundwater levels and quality, storing an extensive database of information. Numerous projects and programs through local, State, and Federal agencies are currently in progress in the Torrance area to maintain groundwater levels in the West Coast Basin and reduce the dependency on imported water, while still meeting the present and future water needs of a growing population. These projects and programs include water treatment facilities, expansion of water recycling infrastructure, injecting water into the ground, capturing storm water before it reaches the ocean, spreading captured water for infiltration, preventing seawater intrusion into fresh water aquifers, and a pilot desalinization program.

Subsidence due to oil and gas extraction has been reported in several areas of southern California, including in the Torrance oil field region. Most subsidence associated with this oil field has occurred in the Redondo Beach area, where a bowl-shaped depression is indicated by land surveys conducted between 1978 and 1994. The surveys indicate a subsidence rate of as much as 3 centimeters per year (cm/yr) between 1978 and 1989, and about 2 millimeters per year (mm/yr) during the 23 years between 1989 and 1994 (Hodgkinson et al., 1996). Damage to structures and infrastructure associated with this period of subsidence has not been reported in the Torrance area (Torrance Public Works Department, personal communication, 2005). More recent surveys appear to indicate that subsidence is no longer occurring in the area, at least at the previous rates. Subsidence due to oil extraction was also reported in the Wilmington oil field, to the east and south of Torrance, where as much as 30 feet of subsidence was reported during the 1940s. To counteract the subsidence, a pilot waterflooding program was begun in 1953; the results of this program showed that subsidence could be effectively stopped and prevented using this technique. Waterflooding also increased oil recoverability, thus, in the early 1960s the City of Long Beach permitted an increase in oil extraction from its offshore areas (Tennyson, 2005).

2.4.5.1 Mitigation of Ground Subsidence

Although subsidence due to groundwater extraction has not been reported in the Torrance area, increased pumping of water in the future, to meet increased residential and industrial needs, could lead to subsidence in the area. Prevention of subsidence due to groundwater withdrawal requires a regional approach to groundwater conservation and recharge. Some measures that are successfully being implemented to manage subsidence in areas where subsidence has occurred due to water extraction include:

- Increased use of reclaimed water, storm water, or imported water.
- Implementation of artificial recharge programs.
- Determination of the safe yields of the groundwater basins, so that available supplies can be balanced with extraction.
- Monitoring of the groundwater and basin conditions.
- Establishment of a monitoring program to detect changes in ground elevations above producing aquifers.
- Protecting groundwater quality.
- Reducing long-term water demand with specific programs of water conservation.
- Acquiring additional imported water supplies, and encouraging water conservation through public education.

In areas where subsidence due to petroleum and gas extraction has been reported in the past, oil field operators and local and State officials have relied on waterflooding and other similar techniques to counteract subsidence. In areas such as the Wilmington oil field, these techniques have been successful in stopping subsidence. In some areas, operators have even seen rebound of the land surface. Since waterflooding is also helpful in increasing petroleum and gas production, while helping with the problem of disposing of the highly saline waters that are typically a by-product of oil and gas development, the practice of pumping of water back into the oil-bearing formations is now used in many oil fields.

2.4.6 Erosion

Erosion is a significant concern locally in Torrance, especially along the shoreline, where beach sediments and coastal bluffs are highly susceptible to erosion by wave action. Other parts of the city, including slopes (both natural and man-made) within the Palos Verdes Hills are also susceptible to the impacts from precipitation, stream erosion, and man’s activities.

2.4.6.1 Mitigation of Erosion

Erosion will have an impact on those portions of the city located above and below natural and man-made slopes. Hillside homes above natural slopes should not be permitted at the head of steep drainage channels or gullies without protective measures against headward erosion of the gully. Structures placed near the base of slopes or near the mouths of small canyons, swales, washes, and gullies will need protection from sedimentation.

Mitigation of erosion and sedimentation typically includes structures that slow down stream velocity, such as check dams and drop structures, devices to collect and channel the flow, and catchment basins. Elevating structures above the toes of the slopes can also be helpful. Diversion dikes, interceptor ditches, swales, and slope down-drains are commonly lined with asphalt or concrete, whereas ditches can also be lined with gravel, rock, decorative stone, or grass.

There are many options for protecting manufactured slopes from erosion, such as terracing slopes to minimize the velocity attained by runoff, adding berms and v-ditches, and installing adequate storm drain systems. Other options include establishing protective vegetation, and placing mulches, rock facings (either cemented on non-cemented), gabions (rock-filled galvanized wire cages), or building blocks with open spaces for plantings on the slope face. All slopes within developed areas should be protected from concentrated water flowing over the tops of the slopes. This is usually attained with the use of berms or walls. All hillside building pads should be engineered to direct drainage away from slopes.

Temporary erosion control measures should be provided during the construction phase of a development, as required by current grading codes. In addition, a permanent erosion control program should be implemented for new developments. This program should include proper care of drainage control devices, proper irrigation, and rodent control. Erosion control devices should be field-checked following periods of heavy rainfall to assure they are performing as designed and have not become blocked by debris.

2.4.7 Wind-Blown Sand

Wind erosion is a serious environmental problem attracting the attention of many across the globe. It is a common phenomenon occurring mostly in relatively flat, bare areas; dry, sandy soils; or anywhere the soil is loose, dry, and finely granulated. Wind erosion damages land and natural vegetation by removing soil from one place and depositing it in another. It causes soil loss, dryness and deterioration of soil structure, nutrient and productivity losses, air pollution, and sediment transport and deposition.

Soil movement is initiated as a result of wind forces exerted against the surface of the ground. For each specific soil type and surface condition, there is a minimum velocity required to move soil particles. This is called the threshold velocity. Once this velocity is reached, the quantity of soil moved is dependent upon the particle size, the cloddiness of particles, and wind velocity itself. Suspension, saltation, and surface creep are the three types of soil movement that occur during wind erosion. While soil can be blown away at virtually any height, the majority (over 93%) of soil movement takes place at or within one meter (3 feet) of the ground surface.

Wind-blown sand was a major concern in the Torrance area when the city was first established. The westerly winds, which in the summer reportedly keep the temperature in

Torrance up to ten degrees cooler than neighboring Los Angeles, used to pick up large amounts of sand from undeveloped properties, and this wind-borne sand would impact the equipment of many of Torrance's founding industries. At Union Tool, this sand required an unusual amount of maintenance of the machine tools to keep them running (Fridrich et al., 1984). Now that the area is mostly developed, covered in hardscape and landscaping vegetation, wind-blown sand no longer poses a hazard.

2.5 Summary of Issues

The city of Torrance is in an area of diverse terrain at the western margin of the Los Angeles basin. The western and central portions of the city are developed on an area once known as the El Segundo Sand Hills, a series of sand dunes that extended from the sea to about four miles inland. The sand dunes give this area its characteristic topography of shallow hills and closed depressions. The northeastern part of the city and the flat area between Lomita Boulevard and Pacific Coast Highway are located on an area known as the Torrance Plain. This is a prehistoric flood plain that was intermittently flooded by the sea, but is today slightly elevated above the modern flood plain. The southern portion of the city is located at the base of the north flank of the Palos Verdes Hills, a block of bedrock that has been uplifted by movement on the Palos Verdes fault. A small portion of the city on its west side is located on coastal bluffs fronting the Pacific Ocean. Each of these regions is underlain by geologic deposits with unique characteristics and susceptible to a variety of geologic hazards.

Of these hazards, slope instability poses one of the greatest concerns, especially along the coastal bluffs and the base of the Palos Verdes Hills. Although relatively stable in historic times, bluffs along beaches are typically susceptible to erosion, heavy precipitation, and more recently, the adverse effects of increased runoff and irrigation from development. Although only one landslide is shown on the geologic maps of the area, we saw evidence for surficial slope instability that could be attributed in part to the recent storms of the 2004-2005 winter. Surficial slope damage has been reported locally in some areas of the Palos Verdes Hills, along the southern portion of the city. Similar small slides, slumps, and mudflows may be expected to occur throughout the hilly portions of the city during future winters of heavy and prolonged rainfall. Although slope failures tend to impact a relatively small area, the dollar loss can be high if structures are damaged. Since insurance policies typically do not cover landslide damage, slope failures can cause both an economic and emotional burden to property owners in the failure area. Even if a slope failure does not impact adjacent properties, the visual impact of a ruined slope can cause alarm among adjacent homeowners. For these reasons, mitigation measures designed to prevent or reduce the impact of potential slope failures should be considered on an on-going basis. There are numerous methods for mitigating slope instability; therefore, selecting the most appropriate method for a given area should be considered taking into account the local geological conditions, safety needs, type and cost of construction repair, and aesthetics.

Compressible soils underlie some portions of the city, specifically those areas underlain by active and recently active stream channels, beach deposits, and young alluvial fan deposits. Compressible soils can also occur in canyon bottoms, swales, and at the base of natural slopes, such as along the Palos Verdes Hills. These are generally young sediments of low density with variable amounts of organic materials. Under the added weight of fill embankments or buildings, these sediments will settle, causing distress to improvements. Areas of un-engineered artificial fill are also susceptible to this hazard. Low-density soils, if sandy in composition and saturated with water, will also be susceptible of the effects of liquefaction during a moderate to strong earthquake (see Chapter 1). Recently active drainage channels and deposits of younger alluvium in the southern part of the city may also be susceptible to collapse. In these areas, geotechnical analyses should be conducted prior to development or re-development to determine whether or not these hazards are present. If the soils are found to be compressible, liquefiable or susceptible to collapse, there are a variety of engineering solutions that can be implemented to make these soils suitable as foundation materials.

Similarly, some of the geologic units in the Torrance area, including both surficial soils and bedrock, have fine-grained components that are moderate to highly expansive. These materials may be present at the surface or exposed by grading activities. Man-made fills can also be expansive, depending on the soils used to construct them. Expansive soils, if left untreated, can cause substantial structural distress; but there are relatively easy and inexpensive solutions that can effectively deal with this geotechnical hazard. Soil erosion typically occurs in areas where unconsolidated sediments are exposed at the surface, allowing water, wind and gravity to transport the soil particles from one place to another. In Torrance, erosion occurs locally along the shoreline where beach sediments and coastal bluffs are exposed to wave action, and in areas both above and below natural and man-made slopes. There are several short-term and long-term erosion control measures available. The methods used to mitigate soil erosion do require constant monitoring to assure that they are performing as designed. Similarly, property owners in expansive soil areas need to maintain constant moisture levels in their lots, especially adjacent to the foundations, to prevent excessive watering or alternating wetting and drying that could lead to damage to their structures.

Ground subsidence due to water or oil extraction is reportedly not occurring in the Torrance area at this time, although subsidence due to oil extraction has been reported in the area in the past. Studies conducted in the 1950s and 1960s showed that pumping water into the oil-bearing formations (waterflooding) can effectively stop and even reverse subsidence due to oil extraction. Therefore, waterflooding or other similar mitigation measure should be required of the local oil field operators as a condition for continued or increased production of oil from the sediments underlying the Torrance area. Furthermore, land surveys to monitor changes in the elevation of the land should be conducted on a regular basis to monitor subsidence rates in the area. If subsidence starts to occur at an accelerated pace, the land surveys can help identify whether this is related to oil and/or groundwater extraction, or some other cause, like tectonics. To prevent the potential for future subsidence due to water extraction, local water agencies need to manage the local water supplies to prevent the sudden or long-term drop in the groundwater level. This can be accomplished by reducing pumping of local wells, importing water, and using artificial recharge (Johnson, 1998; Stewart et al., 1998).

Losses resulting from geologic hazards can be greatly reduced by:

- Strict adherence to grading ordinances – many of these ordinances have been developed as a result of past disasters;
- Sound project design that avoids severely hazardous areas;
- Detailed, site-specific geotechnical investigations followed by geotechnical oversight during grading and during construction of foundations and underground infrastructures;
- Effective agency review of projects; and

- Public education that focuses on reducing losses from geologic hazards, including the importance of proper irrigation practices, and the care and maintenance of slopes and drainage devices.

CHAPTER 3: FLOODING HAZARDS

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, and access to water supplies and transportation routes. Notwithstanding, these benefits come with a price – flooding is one of the most destructive natural hazards in the world, 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 Torrance and surrounding areas are, like most of southern California, subject to unpredictable seasonal rainfall. Most years, the scant winter rains are barely sufficient 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 1862, 1884, 1916, 1938, 1969, 1978, 1980, 1983, 1988, 1992, 1995, 1998 and 2005 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 the area increases, there is an increased pressure to build on flood-prone areas, and in areas upstream of already developed areas. With increased development also comes 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 Torrance lies at the western edge of the greater floodplain of the Los Angeles and San Gabriel Rivers. Prior to man's intervention in historic times, these rivers collected runoff from the surrounding mountains, spreading storm water and sediment loads across the basin. The natural rivers were rarely confined to a distinct channel and often radically changed their courses, building up in this manner the present basin floor and creating the underlying aquifers. When Spanish explorers first encountered the basin in the 1700s, the Los Angeles region was heavily vegetated and dotted with vast marshes, shallow lakes, and small ponds (Gumprecht, 1999). In the northeastern part of Torrance, the flood plain was slightly elevated and had been gently incised by Dominguez Creek and its associated tributaries, ponds, and wetlands. In the central and western parts of the city, rainwater collected in shallow depressions within the dunes of the El Segundo Sand Hills. The southeastern part of the City was drained by shallow streams that meandered towards the Bixby Slough, a remnant of which is now called Machado Lake (see Plate 2-1). Runoff from streams in the Palos Verdes Hills collected in depressions at the base of the hills or joined the Bixby Slough drainage system, eventually reaching San Pedro Bay. Along the western coastal margin, small channels conveyed runoff to the ocean.

In the late 1800s and early 1900s, the rapidly developing Los Angeles basin was subject to several episodes of severe flooding. In response, natural channels were dredged, marshes were filled, and major rivers in the basin were confined to artificial channels in order to control flooding and sedimentation. This included the portion of Dominguez Creek that flows through Torrance, which by 1925, was channelized. Because the Torrance area, like most of the Los Angeles basin, is now highly urbanized, runoff is largely controlled by streets, retention basins, storm drains, and flood control channels. The main channels in the Torrance area are the Dominguez Channel and the Torrance Lateral, which still collect water from the elevated Torrance Plain, carrying it to San Pedro Bay. The Dominguez Channel, which is maintained by the County of Los Angeles Flood Control District, collects storm runoff from sections of the cities of Hawthorne, Gardena, Lawndale, and Redondo Beach. The channel flows southerly, emptying into the Los Angeles Harbor area.

In the southeastern part of the city, the Wilmington Drain discharges runoff to Machado Lake. In the south-central part of the city, runoff is directed via storm drains to the Walteria Retention Basin (Plates 2-1 and 3-2), where it is dissipated by infiltration and evaporation. Within the El Segundo Sand Hills, local runoff is directed to detention or retention basins scattered throughout the area. Many of these basins occupy what were natural depressions between the dunes.

Figure 3.1: **Bishop Montgomery Basin Occupies What Was Once Part of a Natural Closed Depression in Dunes of the El Segundo Sand Hills**

3.1.2 Meteorological Setting

Average yearly precipitation in the Torrance area is about 13 inches (see Tables 3-1 and 3-2), whereas nearly 15 inches of precipitation fall annually in Los Angeles (Table 3-3) and more than 17 inches in San Gabriel (Table 3-4). These tables show that areas closer to the coast receive a little less precipitation, on average, than inland areas.

Table 3-1: Average Annual Rainfall by Month
Recorded at the Torrance Municipal Airport Weather Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	3.1	2.9	2.2	0.9	0.1	0.0	0.0	0.1	0.2	0.3	1.3	2.2	**13.5**

Data based on 58 complete years between 1933 and 1995.
Source: http://www.worldclimate.com/

Table 3-2: Average Annual Rainfall by Month
Recorded at the Palos Verdes FC43D Weather Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	2.7	2.8	2.1	0.9	0.1	0.1	0.0	0.1	0.3	0.3	1.3	2.0	**12.7**

Data based on 55 complete years between 1931 and 1995.
Source: http://www.worldclimate.com/

Table 3-3: Average Annual Rainfall by Month
Recorded at the Los Angeles Civic Center Weather Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	3.6	3.0	2.6	1.1	0.2	0.1	0.0	0.1	0.3	0.2	1.7	1.9	**14.9**

Data based on 43 complete years between 1950 and 1995.
Source: http://www.worldclimate.com/

Table 3-4: Average Annual Rainfall by Month
Recorded at the San Gabriel Fire Department Weather Station

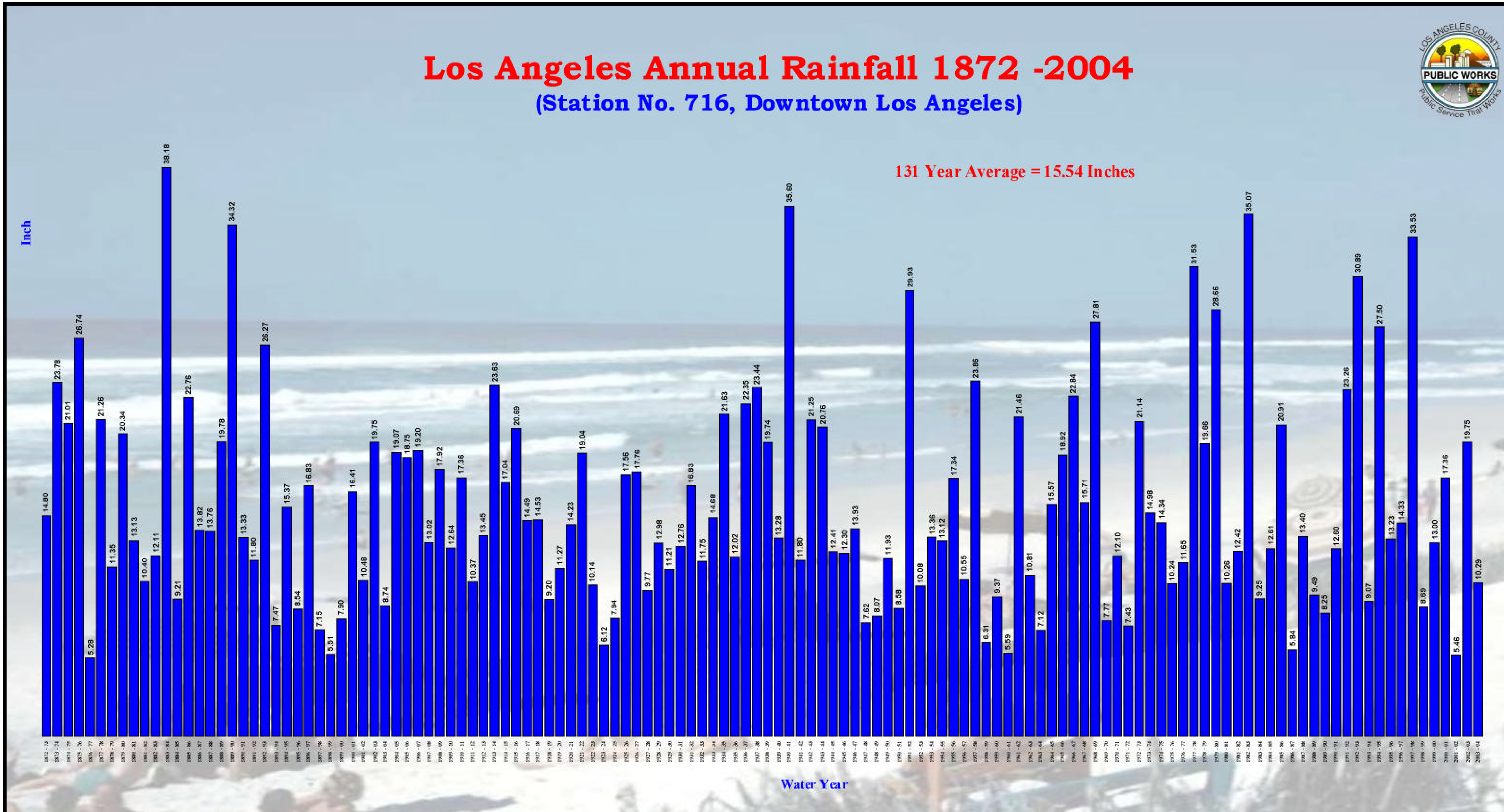
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	4.2	3.5	3.1	1.3	0.2	0.1	0.0	0.1	0.3	0.5	1.9	2.4	**17.6**

Data based on 53 complete years between 1939 and 1995.
Source: http://www.worldclimate.com/

Not only does rainfall vary from one location to the next, often within short distances, it is also extremely variable from year to year, ranging from one-third the normal amount to more than double the normal amount. This is illustrated in Plate 3-1, which shows the variation in annual rainfall at downtown Los Angeles over the last 132 years.

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

<u>Winter storms</u> 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 through 3-4. The storms originate over the Pacific Ocean and move



Earth Consultants International

Project Number: 2431
Date: July 2005

Annual Rainfall in the City of Los Angeles, California for the Period Between 1872 and 2004

(from the Los Angeles County Public Works Department)

Plate 3-1

eastward (and inland). The mountains, such as the Santa Ana, 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 San Gabriel and San Bernardino 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.

The recent severe storms of December 2004 and January 2005 have been blamed on a different climatic condition, one where the sub-tropical jet stream carries moisture-laden air directly from the tropics to the west coast of the U.S. Because it passes over the Hawaiian Islands, it is commonly called the "Pineapple Express." At the same time this condition was developing, the northern jet stream shifted towards the California Coast, allowing storms from the north to tap into the deep tropical moisture, dramatically increasing the rainfall in southern California (NOAA, 2005a). Powerful winter storms during February 2005, however, have been attributed to a weak, but persistent El Niño condition, combined with an atmospheric condition that blocked or slowed the normal eastward movement of the storms (NOAA, 2005b). These events combined to give the Los Angeles area record-breaking rainfall in 2005, in addition to spawning numerous waterspouts and small tornadoes. Total rainfall for Torrance in the current water year (2005) has been more than 27 inches (Rainfall data for Torrance Municipal Airport weather station, Los Angeles Department of Public Works).

Local <u>thunderstorms</u> can occur at any location, and usually affect relatively small areas. These storms are usually more prevalent in the higher mountains during the summer. <u>Tropical rains</u> 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 Stream Flow: Daily Mean and Past Floods

3.1.3.1 Daily Mean Flow

In coastal Los Angeles County, including the Torrance area, flooding is difficult to predict, and thus plan for, because rainfall varies from year to year. The channels in the Torrance area are typical of southern California. Except for man-induced runoff (irrigation and industrial discharges, for instance) streamflow is negligible other than during and immediately after rains because climate and basin characteristics are not conducive to continuous flow.

The record of daily stream flow data for Dominguez Channel is poor. The channel has a stream gage located at Vermont Avenue (#F378D), however it has been monitored only intermittently, and according to the Los Angeles County Public Works Department, it is not currently being monitored. The U.S. Geological Survey also has no stream gaging stations near Torrance that we can refer for daily or historical stream flow data (http://waterdata.usgs.gov/ca/nwis).

3.1.3.2 Past Floods: Implications for Existing Flood Hazard

Historically, flooding after heavy rains in the city of Torrance has consisted of flooded streets, flooding of sumps and depressions, and general flooding along Dominguez Channel. The City's past flooding problems have been related to the inability of local drainage facilities to handle runoff during storms (FEMA, 1979). Rainfall would collect in the southern part of the city, around the intersection of Pacific Coast Highway and Crenshaw, and form a lake that covered whole blocks of land. Lake Walteria, as it was known, would persist for a few weeks, often requiring the use of row boats to move people and goods back and forth, and then disappear until the next rainy season. Since drainage in this area was improved, Lake Walteria is no longer part of the seasonal landscape (Fridrich et al., 1984). Similarly, rainwater would collect in and near Madrona Marsh, although this wetland typically remained wet year-round, providing a habitat for ducks, geese and many other waterfowl (see Figure 3.2). Madrona Marsh has been preserved and is an important migratory stop for a variety of birds (Fridrich et al., 1984).

Flash floods are short in duration, but have 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 Palos Verdes Hills in the southern part of the city consist of sedimentary rock types that are fairly 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 hills into man-made and natural channels in the built environment.

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.

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.

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 Torrance has participated as a regular member in the NFIP since December 18, 1979 (City ID No. – 060165). The city's most current effective FIRM map was revised in 1997. Since the City is a participating member of the NFIP, flood insurance is available to any property owner in the city. In fact, to get secured financing to buy, build, or improve structures in SFHAs, property owners are required to purchase flood insurance. Lending institutions that are federally regulated or federally insured must determine if the structure is located in a SFHA and must provide written notice requiring flood insurance. FEMA recommends that all property owners purchase and keep flood insurance. Keep in mind that approximately 25 percent of all flood claims occur in low to moderate risk areas. Flooding can be caused by heavy winter rains, inadequate drainage systems, clogged inlet structures, failed protective devices such as levees, as well as by tropical storms.

3.1.5 Flood Zone Mapping

As mentioned above, the City of Torrance has participated in the National Flood Insurance Program since 1979. The extent of flooding within Torrance has been analyzed through Flood Insurance Studies. The potential flood zones in the City mapped by FEMA are presented in Flood Insurance Rate Maps (FIRMs). Plate 3-2 shows the FIRM inundation limits for both the 100-year (in red) and 500-year (in blue) flood events, in addition to the 100-year coastal flood event (in green).

Only a few, small, isolated areas within the City have been mapped as Special Flood Hazard Areas, and these result primarily from ponding of water in shallow depressions or sumps, and not from channel flooding. Several of the SFHAs occupy low points that were once natural closed depressions in the El Segundo Sand Hills. For example, the Madrona Marsh Nature Preserve, the largest SFHA in the city, occupies what was once a large, natural depression. Other SFHAs appear to be man-made depressions or sumps.

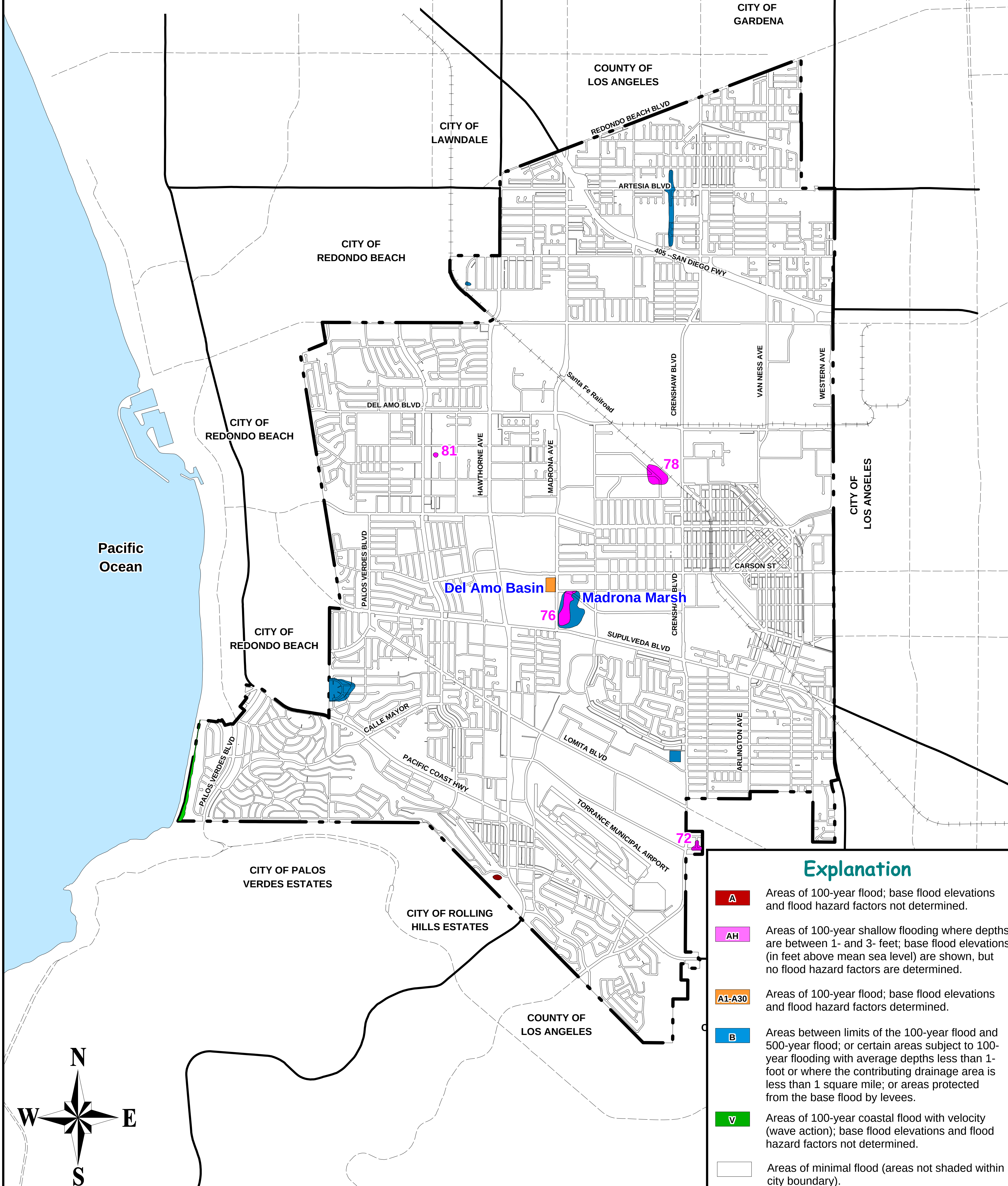
Figure 3.2: **Madrona Marsh Nature Preserve, One of the Last Remaining Natural Wetlands in the Highly Urbanized Los Angeles Basin**, is included in the Flood Insurance Rate Maps for Torrance as a Special Flood Hazard Zone.

FEMA (1979) also considered flooding of the Torrance coastline by storm surge and wave run-up by adding 3 feet to the highest tide observed in the period between 1941 to 1959, resulting in a flood elevation of 7.9 feet. This concern was realized during the 1978-1979 storms, when storm surge caused considerable damage to the local beach. Except for beach structures, such as restrooms and lifeguard stations, the area that would be affected by storm surge is not developed.

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

A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
AH	Areas of 100-year shallow flooding where depths are between 1- and 3- feet; base flood elevations (in feet above mean sea level) are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than 1-foot or where the contributing drainage area is less than 1 square mile; or areas protected from the base flood by levees.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
	Areas of minimal flood (areas not shaded within city boundary).

Scale: 1:48,000

1 0 1 2 3
Kilometers

4000 0 4000 8000 12000
Feet

Torrance City Boundary

Base Map: City of Torrance (2005)

Source: Federal Emergency Management Agency, 1979, Flood Insurance Rate Map (Panel Numbers: 060165 0001B, 060165 0003B, 060165 0004B, and 060165 0005B)

Earth Consultants International

Project Number: 2431
Date: July, 2005

FEMA Flood Map

Torrance, California

Plate 3-2

3.1.6 Urban Street Flooding

The FEMA mapping shows that overbank flooding from the major open channels generally does not occur. Persistent flood-prone areas in the Torrance area are generally small and localized, often being associated with low areas having poor drainage and inadequate storm drains (LACDPW, 2004). Localized flooding still occurs along Hawthorne and Sepulveda boulevards, near the Del Amo Fashion Center, but the Los Angeles County Flood Control District is reportedly fixing this problem. In general, street flooding due to storm runoff is no longer perceived as a problem in Torrance (Torrance Public Works Department, personal communication, 2005).

3.1.7 Existing Flood Protection Measures

During the past 70 years, private corporations, the Los Angeles County Flood Control District (LACFCD), and the U.S. Army Corps of Engineers have constructed several reservoirs in the Palos Verdes Hills to minimize flood damage to downstream areas, such as Torrance. The LACFCD has also made channel alterations consisting primarily of concrete side-slopes and linings for Dominguez Creek. These flood control structures are presently owned and operated by the LACFCD, which has jurisdiction over the majority of watercourses in the Torrance area, as well as the regional flood control system in Los Angeles County. All of these structures help regulate flow in the smaller streams and hold back some of the flow during intense rainfall periods that could otherwise overwhelm the storm drain system in Torrance.

There are 13 retention and detention basins scattered throughout the city that are used to store runoff. As the County upgrades the capacity of their storm drain system, these basins are likely to be abandoned (Torrance Public Works Department, personal communication, 2005). The currently active basins are cleaned periodically to maintain their storage capacity.

3.1.8 Future Flood Protection

As new development is considered, it is important that hydrologic studies be conducted to assess the impact that increased development may have on the existing development downgradient. 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 the California Environmental Quality Act (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.

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 Orange 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.

3.1.9 Flood Protection Measures for Property Owners

Although the flood hazard in the city of Torrance has been estimated by FEMA to be minor, property owners in potential flood areas 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 web page 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

Seismically induced inundation refers to flooding that results when water retention structures, such as dams and water tanks, fail due to an earthquake. There are no dam-impounded open reservoirs within or above the city of Torrance, however seismically induced inundation can also occur if strong ground shaking causes structural damage to water tanks and enclosed water reservoirs. If an above-ground 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 (elephant's 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.

There is currently one active above-ground water storage tank in Torrance, at the north end of town. The Yukon tank is of steel construction, has a storage capacity of 900,000 gallons, and is associated with the groundwater well currently servicing the city. According to spoke-persons from the City's Public Works Department (personal communication, 2005), there are two other above-ground water storage tanks in the city, but these are not being used.

In addition to the Yukon tank, there are two enclosed water reservoirs in Torrance. These reservoirs, referred to as the Walteria and Ben Haggot reservoirs (the Ben Haggott reservoir is also referred to in the State database as the 18M Walteria, or Walteria Dam 2), are located in the southern part of the city, on the north flank of the Palos Verdes Hills, and south of the Palos Verdes fault zone. Because of their size, these reservoirs are considered dams and are therefore under the purview of the California Division of Dam Safety. 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. The Walteria Reservoir (California State Dam Number 1049-000) was constructed in 1952, has a storage capacity of 10 million gallons (approximately 31 acre-feet), and is a buried steel-reinforced concrete facility with a depth capacity of 29 feet. The roof of the structure houses 8 tennis courts and associated facilities. The Ben Haggott (Walteria 2, California State Dam Number 1049-002) Reservoir was constructed in 1987, has a storage capacity of 18.7 million gallons (approximately 58 acre-feet), and is also a buried steel-reinforced concrete facility. Both reservoirs are joined by pipes, and can be operated either together, or separately. There is a 24-inch inlet-outlet pipe that is part of this municipal water storage, pressure regulation and distribution system.

It is unclear whether the Yukon tank or the two reservoirs are fitted with flexible joints and pipe connections that could withstand shaking associated with an earthquake on a nearby seismic source. The two buried reservoirs in the southern portion of Torrance are located south of the Palos Verdes Hills, therefore, rupture of this fault could shear the main water lines leading to the rest of the city, essentially leaving most of the area without water for some time after the earthquake. Rupture of the water mains in this area could also result in the flooding of the area immediately surrounding and downgradient of the failed pipes, since the reservoirs drain by gravity. According to the City's Natural Hazards Mitigation Plan (2004), if these reservoirs fail catastrophically as a result of earthquake-induced damage, they could empty in as little as 18 minutes. This would allow little time to evacuate the areas immediately down-gradient from the reservoirs, with the potential for significant loss of life and damage to property. The inundation pathway for these reservoirs has been mapped (JMM, 1984), as required by the California Division of Dam Safety, and is shown on Plate 3-3. Inundation from these reservoirs, with an estimated maximum discharge of 7,300 cubic feet per second (cfs), would impact both residential and commercial areas near Crenshaw Boulevard and Pacific Coast Highway, and would spill onto the southeastern edge of the Torrance Airport.

3.3 Summary of Issues, Planning Opportunities and Mitigation Measures

The city of Torrance is unique in its landforms and drainage. The portion of the city developed on the El Segundo Sand Hills is characterized by undulating topography consisting of alternating hills and low-lying closed depressions. As a result, when it rains, water collects in the depressions, with the potential for flooding of relatively small, localized areas. The Federal Emergency Management Agency has identified the areas most susceptible to flooding in the city, and has classified them either 100- or 500-year flood zones. These are shown in this report on Plate 3-2. Flooding as a result of coastal processes also poses a hazard to a small portion of the city, in Malaga Cove.

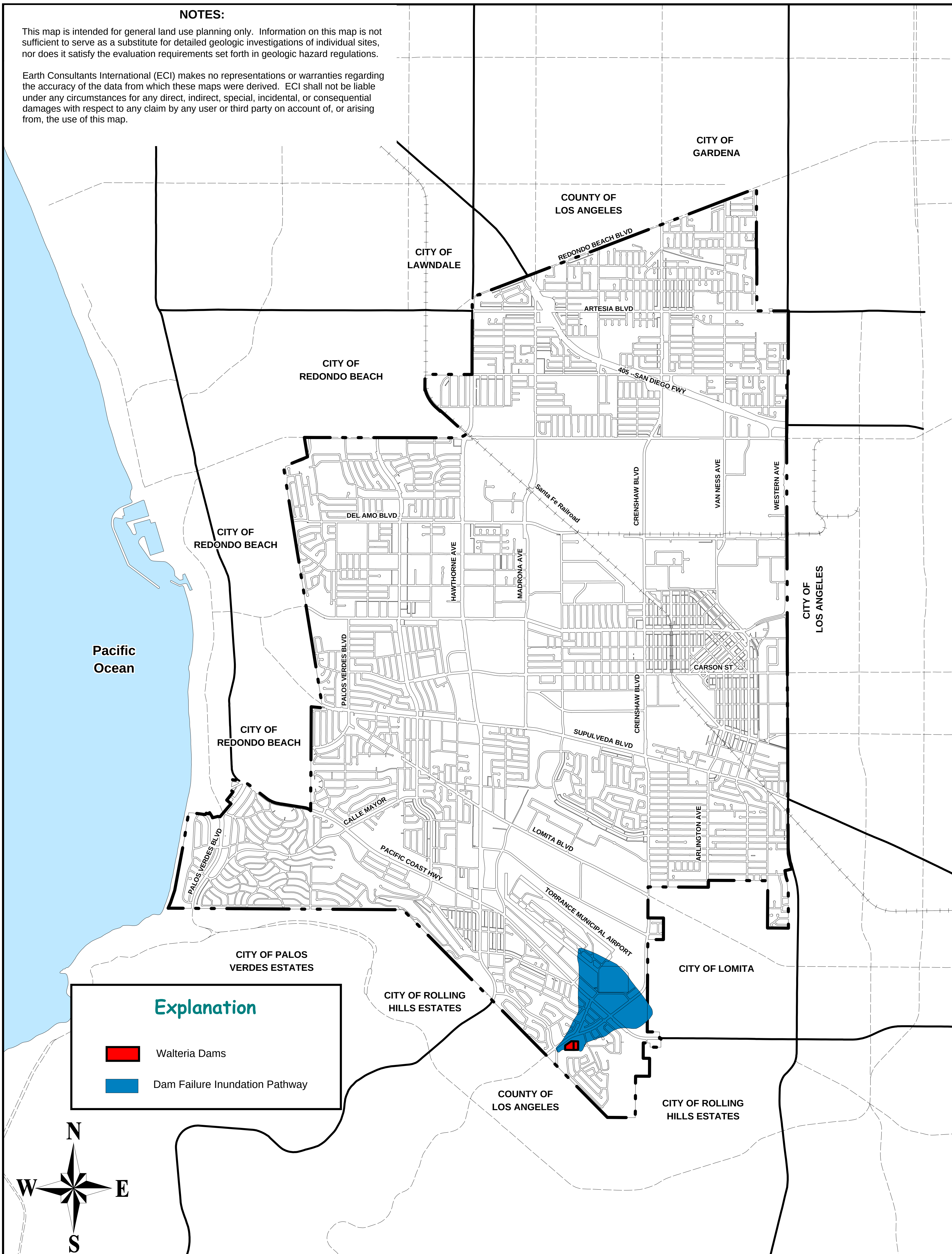
The National Flood Insurance Program makes federally subsidized flood insurance available in communities that agree to adopt and enforce floodplain management ordinances to reduce future flood damage. Owners of all structures within the FEMA-mapped Special Flood Hazard Areas (100-year flood) are required to purchase and maintain flood insurance as a condition of receiving a federally related mortgage or home equity loan on that structure. Estimates indicate that 75 percent of households located in the 100-year floodplain do not have insurance. In addition, between 20 and 25 percent of the National Flood Insurance Program claims come from structures located outside the designated 100-year flood zone, where insurance is not required. As a comparison, structures located in the 100-year flood plain have a 26 percent chance of being flooded over the course of a 30-year mortgage that experience a fire (4 percent chance in 30 years). National Flood Insurance is available in the city of Torrance; homeowners within the 100- and 500-year flood zones, and those at the base of hills (outside the flood zones), where they can be impacted by mudflows and storm-induced landslides, should be encouraged to buy flood insurance.

To ensure public participation in the National Flood Insurance Program and support of City-funded mitigation measures, property owners need to be informed about the potential for flooding in their area, including flooding of access routes to and from their neighborhoods. Community outreach and public information programs that not only identify the hazards but provide potential solutions need to be prepared and made available. The Federal Emergency Management Agency (FEMA) has excellent materials that describe specific mitigation measures that can be implemented to reduce flood damage to residential structures. A community's success in responding to a natural disaster is also dependent on how well its government officials, residents, businesses, and institutions (schools, churches, social organizations) cooperate and coordinate together to make effective decisions. To accomplish this, the City can rely on the vendor list, updated annually, that the City has of businesses, organizations and individuals that can be called in for help during emergencies.

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: 1:48,000

1 0 1 2 3

Kilometers

4000 0 4000 8000 12000

Feet

Torrance City Boundary

Base Map: City of Torrance (2005)

Source: Governor's Office of Emergency Services

Project Number: 2431

Date: July, 2005

Dam Inundation

Torrance, California

Plate 3-3

There are several flood retention and water storage structures that, should they fail catastrophically, have the potential to flood portions of the city. The flood retention and detention basins do not pose a significant concern, as these structures hold water only during relatively small periods of time, typically following a severe winter-storm, and they are surrounded by slopes that would prevent a significant release of water. The water storage facilities, on the other hand, have the potential to cause flooding if they fail catastrophically. The two tanks in the southern part of the city are located south of the Palos Verdes fault zone, and their failure, or damage to the main water lines conveying water from the tanks to the rest of the city, could be sheared during an earthquake. This could lead to flooding of those areas near to and downgradient from the ruptured water mains, while leaving a large sector of the city without water for probably days following the earthquake. A sudden reduction in water availability following an earthquake also has implications regarding the fire department's success in fighting fires that may occur in the city immediately following an earthquake. Flood inundation zones for these water storage tanks should be developed to determine whether or not there are critical facilities, such as schools and day-care centers located within the path of the potential floodwaters. Similarly, facilities using, storing, or otherwise involved with substantial quantities of onsite hazardous materials should not be permitted in the inundation zones, unless all standards of elevation, anchoring, and flood proofing have been satisfied, and hazardous materials are stored in watertight containers that are not capable of floating.

The structure that poses the highest risk to a sector of the community is the Ben Haggott reservoir. Since this reservoir is located within Torrance, its failure would immediately impact those areas down gradient, within its inundation pathway. The reservoir is located in the Palos Verdes Hills area of the city, and although not located astride the Palos Verdes fault zone, it is located south of the fault zone, in an area that is thought to be rising as a result of movement on the Palos Verdes Hills fault. The design of the Ben Haggott and Walteria reservoirs should be reviewed to confirm that these structures can withstand the near-source ground accelerations that the Palos Verdes, Newport-Inglewood and Puente Hills faults are believed capable of generating (see Chapter 1).

CHAPTER 4: FIRE HAZARDS

4.1 Vegetation Fires

Wildfires are a significant hazard throughout the United States, and especially in the West, where wildfires occur often and have been part of the natural environment for millennia. Large areas of southern California are particularly susceptible to wildfire due to the region's weather, topography and native vegetation. The typically mild, wet winters characteristic of our Mediterranean climate result in an annual growth of grasses and plants that dry out during the hot summer months. This dry vegetation provides fuel for wildfires in the autumn, when the area is intermittently impacted by Santa Ana (or Santana) winds, the hot, dry winds that blow across the region in the late fall. These winds often fan and help spread the fires. Furthermore, many of our native plants have a high oil content that makes them highly flammable.

Notwithstanding what was said above, wildland fire is a natural process. Wildfires are a necessary part of the natural ecosystem of southern California. Many of the native plants require periodic burning to germinate and recycle nutrients that enrich the soils. For example, some of the chaparral plants, such as ceanothus, have heat-resistant seeds that sprout only after being exposed to fire. Similarly, closed-cone coniferous trees have seed cones that only open after being exposed to the heat of a fire. The seeds themselves are protected by a thick coat of resin that insulates them. When the cones open, the seeds are released onto the ground, where they are more likely to sprout on the rich, ash-covered soil that has been cleared of underbrush. Other plants have fire-resistant roots that allow them to re-sprout quickly in recently burned areas.

Figure 4-1: View of the Cedar Fire of October 2003 moving down Oak Canyon, toward the 52 Freeway, in San Diego County. This fire burned more than 270,000 acres, destroyed 2,820 structures, damaged 63 others, and caused 14 fatalities. A signal flare set off by a lost hunter caused the fire.

Wildfires become an issue, however, when they extend out of control into developed areas, with a resultant loss of property, and sometimes unfortunately, loss of life. 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 increasing number of people living and playing in wildland areas. Today, approximately 10 percent of all wildland fires in the United States are started by lightning strikes, and the rest are caused by humans (http://www.nps.gov/fire/educational). Between 1988 and 2000, human-induced fires burned nearly eight times more brush than fires caused by lightning (http://www.nifc.gov/stats/index.html). The most common causes of wildfires are arson, sparks from brush-clearing equipment and vehicles, improperly maintained campfires, improperly disposed cigarettes, and children playing with matches.

As the 2003 fires in southern California showed, wildfires that consume hundreds of thousands of acres of vegetated property overwhelm local emergency response resources (Figures 4-1 and 4-2). 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 area or UWI area) 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. It has become increasingly clear that continuous planning, preparedness, and education are required to reduce the fire hazard potential, and to limit the destruction caused by fires. This is discussed in detail in this document.

Figure 4-2: View of one of the many fires that ravaged the southern California area in the fall of 2003, forcing the evacuation of entire neighborhoods, and the closing of roads.

4.1.1 Wildfire Susceptibility and Historical Wildland Fires in the Torrance Area

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

- fuel loading (that is, the density and type of vegetation),
- topography (slope),
- weather,
- dwelling density,
- 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, fuel modification zones, etc.).

In Los Angeles County, these conditions generally lead to wildland fires in the undeveloped or slightly developed portions of the hills and mountains that surround the extensively developed basin. Areas in the County specifically known for their high to very high wildland fire susceptiblility include Malibu, Glendale, Burbank, and the mountainous regions of Altadena, La Canada Flintridge and Pasadena, to mention a few. Wildland fires have also occurred historically in the Palos Verdes Hills, in the southern portion of Torrance, and to the south of the city, in what is now Rolling Hills, Rolling Hills Estates and Palos Verdes Estates. Plate 4-1 shows those areas in the northern Palos Verdes Hills that have reportedly burned at least once between 1930 and 2003, the year for which the most recent data are available from the California Department of Forestry (http://frap.cdf.ca.gov/data/frapgisdata/select.asp). The graphic shows areas that reportedly burned at least once during a 20-year period. Overlap of some of these burnt areas indicates that wildland fire has impacted the same area more than once during the time period covered by the graphic. Most of the burnt areas in Plate 4-1 are south of Torrance, with three exceptions: wildland fires ignited two areas in the southernmost portion of the city sometime between 1930 and 1949, and a more recent but significantly smaller fire was reported in the undeveloped slope north of Via Valmonte and west of Hawthorne Boulevard sometime between 1970 and 1989. In fact, according to personnel from the City's Fire Department, small vegetation fires occasionally still occur on this slope, but these are not considered to pose a concern to the adjacent structures (Fire Department, personal communication, 2005).

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.

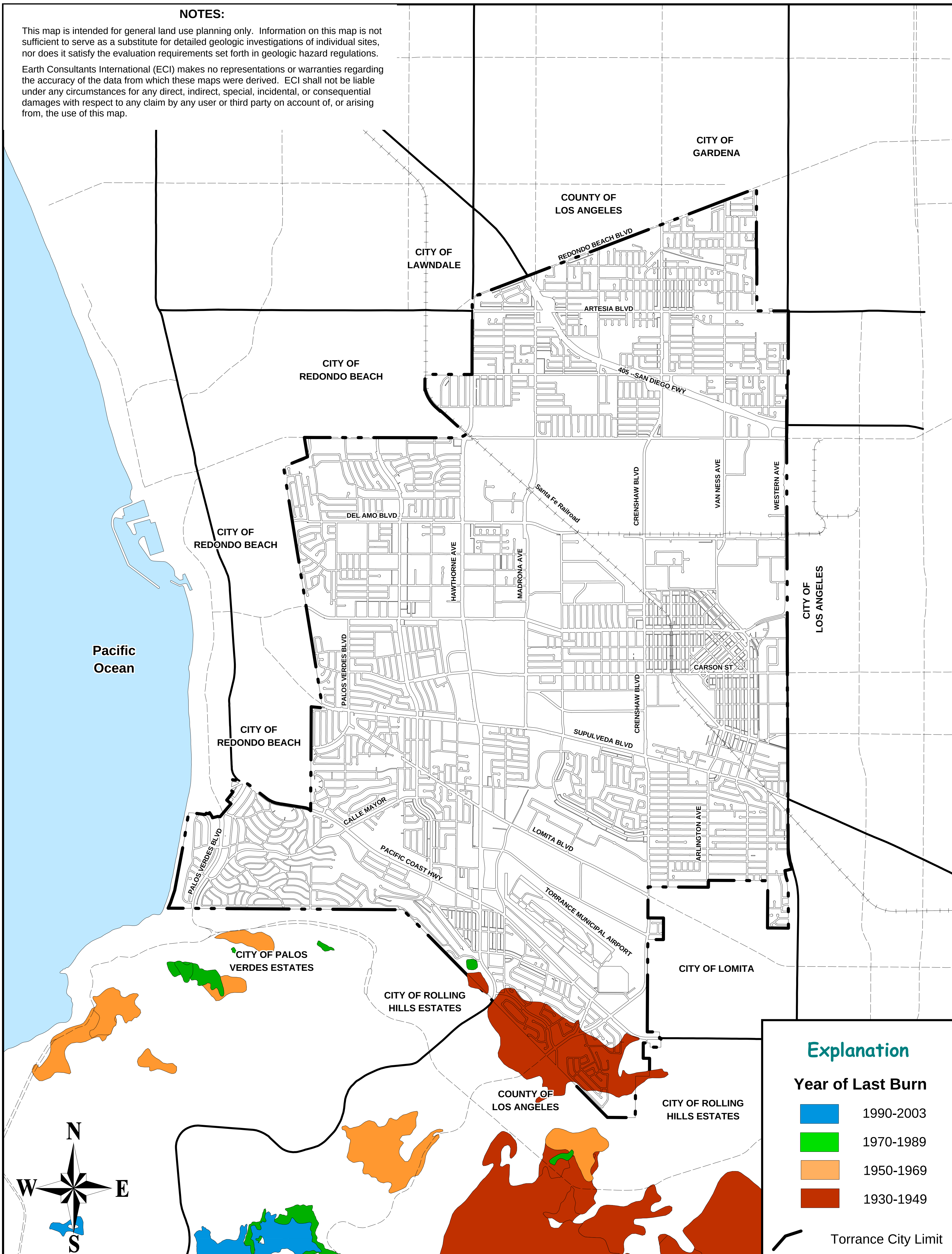
HUD Study System: In April 1973, the CDF published a study funded by the Department of Housing and Urban Development (HUD) under an agreement with the Governor's Office of Planning and Research (Helm et al., 1973). As is often the case, the study was conducted in response to a disaster: during September and October 1970, 773 wildfires burned more than 580,000 acres of California land. The HUD mapping process relied on information obtained from U.S. 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 (available at http://www.fs.fed.us/r5/fire/south/fwx/index.shtml) 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 California Department of Forestry and Fire Protection (CDF) to develop and implement a system to rank 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 USGS 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.

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: 1:48,000

Kilometers: 1 0 1 2 3

Feet: 4000 0 4000 8000 12000

Base Map: City of Torrance (2005).
Source: California Fire and Resource Assessment Program (FRAP) @ http://frap.cdf.ca.gov/data/frapgisdata/select.asp

This map shows areas in Torrance and the northern Palos Verdes Hills that have burned between 1930 and 2003.

Earth Consultants International

Project Number: 2431
Date: July, 2005

Historical Wildland Fires in and Near Torrance, California

Plate 4-1

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 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 50022). The VHFHSZ mapped in and near Torrance by the CDF (2001) are shown in yellow on Plate 4-2. The map shows that some areas along the southernmost edge of Torrance are considered by the State to have a very high fire hazard. The City of Torrance, however, considers their wildland fire risk to be insignificant, and since the City ultimately has financial responsibility for these areas, future versions of this map will likely not include these neighborhoods of Torrance. If and when the State issues a new VHFHSZ Map for this area, Plate 4-2 should be updated.

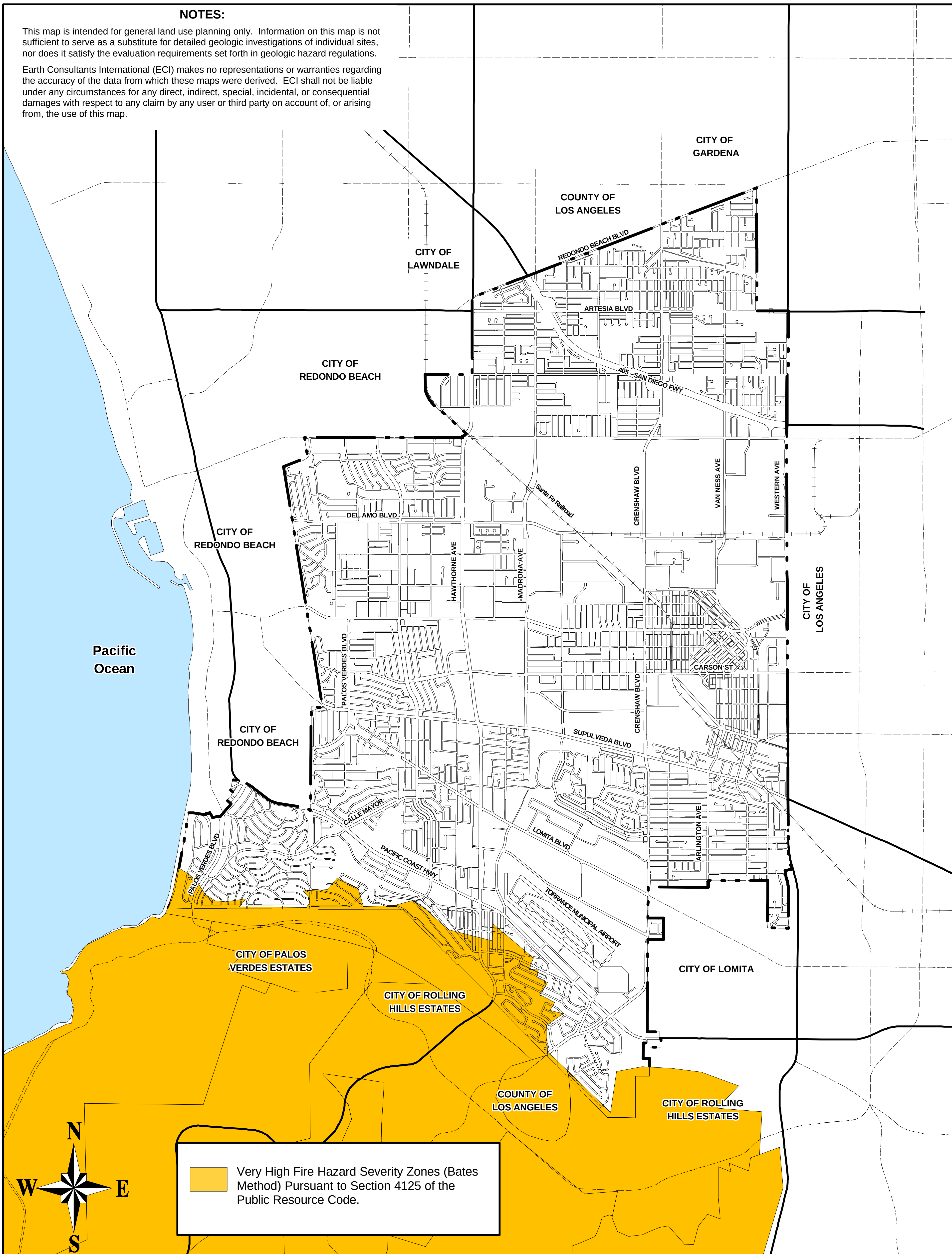
California Fire Plan: The 1996 California Fire Plan is a cooperative effort between the State Board of Forestry and Fire Protection and the CDF (California Board of Forestry, 1996). This system ranks the fire hazard of the wildland areas of the State using four main criteria: fuels, weather, assets at risk, and level of service (which is a measure of the Fire Department's success in initial-attack fire suppression). The California Fire Plan uses GIS-based 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. For additional information visit the webpage at http://www.fire.ca.gov/FireEmergencyResponse/FirePlan/FirePlan.asp.

The **moderate** fire threat area includes those areas where there are only moderate amounts of vegetative fuel, typically grasses, but there are no structures (assets) that can burn. The **high** and **very high** fire hazard zones are based on the availability of fuel (fuel load) and terrain. In some cities in southern California, the high and very high fire threat areas include high-density residential subdivisions that are located at the urban-wildland interface. These are the areas where even though hardscape (concrete, asphalt and structures) and landscaping vegetation predominate, the high concentration of structures can allow fires to jump from one building to the next, and the loss due to fire would be greatest. These are therefore the areas where enhanced onsite protection for structures and people is necessary. Some of the mitigation measures that homeowners and the City can implement to reduce the risk of wildland fire are provided in Section 4.1.2.

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.

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: 1:48,000

1 0 1 2 3 Kilometers

4000 0 4000 8000 12000 Feet

Torrance City Limit

Base Map: City of Torrance
Sources: Fire and Resource Assessment Program, California Department of Forestry and Fire Protection (2001)

Earth Consultants International

Project Number: 2431
Date: July, 2005

Fire Severity Map

Torrance, California

Plate 4-2

In the developed, relatively flat areas of the city, vegetation fires are not considered a hazard, as the topography, lack of fuel loading (due to carefully maintained and regularly watered landscaping), and effective fire suppression services combine to mitigate the potential for wildland fires. This is reflected in the Very High Fire Hazard Severity Zones Map for Torrance and vicinity that shows no fire hazard in most of the city. The southern portion of the city, adjacent to the Palos Verdes Hills, however, is, given its topography and past fire history, still classified by the State of California as a Very High Fire Hazard Severity Zone (see yellow zones on Plate 4-2).

California Fire Alliance: During the 2000 fire season wildfires burned millions of acres throughout the United States. These fires dramatically illustrated the threat to human lives and development. Under Presidential Executive Order, the National Fire Plan was created as a cooperative, long-term effort of the USDA Forest Service, Department of the Interior, and the National Association of State Foresters, to protect communities and restore ecological health on Federal lands. The Plan outlined five key points: 1) firefighting, 2) rehabilitation and restoration, 3) hazardous fuel reduction, 4) community assistance, and accountability. The Plan outlined a comprehensive strategy with a commitment to funding for a continued level of "Hazardous Fuel Reduction" and new funding for a "Community Assistance/Community Protection Initiative." The intent of the Community Assistance initiative is to provide communities interfacing with federal lands an opportunity to get technical assistance and funding to reduce the threat of wildfires.

A major component of the National Fire Plan was funding for projects designed to reduce fire risks to people and their property. A fundamental step in realizing this goal was the identification of areas that are at high risk of damage from wildfire. Federal fire managers authorized State Foresters to determine which communities were under significant risk for wildland fire on Federal lands. The CDF undertook the task of generating the state's list of communities at risk. With California's extensive Wildland-Urban Interface situation, the list of communities extends beyond just those on Federal lands. The CFA identified 1,283 fire-threatened communities in California. The list does not include the city of Torrance. For additional information refer to http://www.cafirealliance.org/communities_at_risk.php.

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.

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, 1990) 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.

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 Protection Strategies

4.1.2.1 Vegetation Management

Although increased development in and around the southern portion of the city has reduced that area's susceptibility to fire hazards to the extent that the Fire Department no longer considers this area at risk, homeowners can choose to implement some of the fire protection strategies discussed below. These are strategies used by other communities to reduce their vulnerability to wildland fires, and while some of the strategies need to be implemented at a regional or city-wide scale to be effective, many others can be undertaken by homeowners on an individual basis. Experience and research have shown that vegetation management is an effective means of reducing the wildland fire hazard. Therefore, in those areas identified as susceptible to wildland fire, land development is governed by special State, county and local codes, and property owners are required to follow maintenance guidelines aimed at reducing the amount and continuity of the fuel (vegetation) available.

Requirements for vegetation management at the urban-wildland interface (UWI) in California were revisited following the 1993 wildland fires that impacted large areas of Orange, Los Angeles and Ventura counties. The International Fire Code Institute formed a committee to develop an Urban-Wildland Interface Code under the direction of the California State Fire Marshal. The first draft of this code was published in October 1995.

Hazard reduction and ***fuel modification*** are the two methods that communities most often employ to reduce the risk of fire at the UWI. Both methodologies use the principle of reducing the amount of combustible fuel available, which reduces the amount of heat, associated flame lengths, and the intensity of the fire that would threaten adjacent structures. The purpose of these methods is to reduce the hazard of wildfire by establishing a defensible space around buildings or structures in the area. Defensible space is defined as an area, either natural or man-made, where plant materials and natural fuels have been treated, cleared, or modified to slow the rate and intensity of an advancing wildfire, and to create an area for firefighters to suppress the fire and save the structure. These standards require property owners in the UWI 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.

Fuel or vegetation treatments often used include mechanical, chemical, biological and other forms of biomass removal (Greenlee and Sapsis, 1996) within a given distance from habitable structures. The intent of this hazard reduction technique 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. Hazard reduction includes requirements for the maintenance of existing trees, shrubs, and ground cover within a 100-foot wide setback zone, to reduce the amount of fuel on those sides of any structure that face the UWI. These requirements include: clearing all dead or drying foliage; planting fire-resistive vegetation; keeping clearances between tree stands, bushes and shrubs, and between trees and structures; irrigating ground covers, storing firewood and combustible materials away from habitable structures; using fire-resistant roofing and construction materials; cleaning vegetation debris from roofs and rain gutters; and using spark arresters on chimneys.

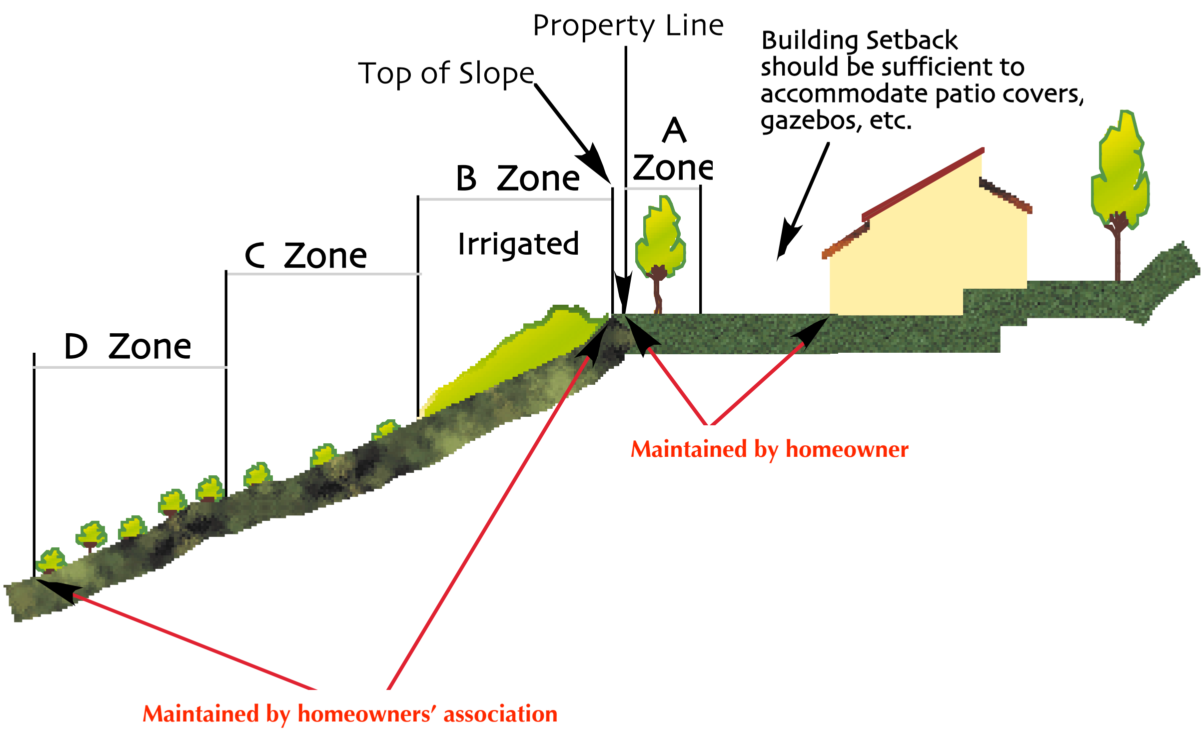
In some new communities or developments proposed adjacent to a wildland area, residents are required to comply with **fuel modification** requirements. A **fuel modification zone** is a ribbon of land surrounding a development within a fire hazardous area that is designed to diminish the intensity of a wildfire as it approaches the structures. Fuel modification includes both the thinning (reducing the amount) of native combustible vegetation, and the removal and replacement of native vegetation with fire-resistive plant species. These modification zones may be owned by individual property owners or by homeowners' associations. Emphasis is placed 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 zones are typically divided into four areas referred to as the A, B, C and D zones. The A Zone is the closest to the homes, and is the last 20-feet of the backyard of the private residences. The B, C and D zones lie outside the fence line and are within the common area typically owned by an association. Any dead or dying vegetation in these zones should be removed, and certain fire-prone species of vegetation are required to be removed when found in any of the four fuel modification zones. Each of these zones is described further below and shown graphically on Figure 4-3.

- The **A Zone** is the defensible space where firefighters will set up hose lines to extinguish the approaching fire. The A zone includes ornamental plants and single specimen trees. All plants in this area are required to be irrigated and must be fire-resistive.

- The **B Zone** is generally the next 50 feet just outside the back fence line. This zone is an area where natural vegetation has been replaced with fire-resistive, drought-tolerant plants. The B zone is fitted with automatic water sprinklers on a permanent basis. Non-approved vegetation must be removed from this zone.
- The **C and D zones** are the next 100 feet away from the homes. Each of these zones is a minimum of 50 feet in width. These zones are called the thinning zones. Natural vegetation is reduced by 50 percent in the C zone, and by 30 percent in the D zone. A way to imagine this thinning principle is as follows: in the 50-percent thinning zone (C zone) two people can walk side by side around clumps of vegetation. In a 30 percent thinning zone (D Zone), two people would have to walk single file between clumps of natural vegetation. These areas are not irrigated.

Figure 4-3: Fuel Modification Zones that can be Used in Very High Fire Hazard Severity Areas



The City of Torrance does not have fuel modification or defensible space requirements for the hillside areas. However, on a site-specific basis, the Fire Chief may require the removal of brush, flammable vegetation and combustible growth in the area 30 to 100 feet from buildings or structures. In some cases, especially on hillside properties, the Fire Chief may in fact require the fire break to be up to 200 feet from a structure to mitigate the convective and radiant heat transfer resulting from the slope of the property (Torrance Fire Code: City Ordinance No. 3524). Grass or other vegetation less than 18 inches in height above the ground and located more than 30 feet from such buildings or structures may be maintained where necessary to stabilize the soil and prevent erosion.

4.1.2.2 Notification and Abatement

Typically, City codes specify that property owners are required to mitigate the fire hazard in their properties by implementing vegetation management practices. Therefore, if uncontrolled or high weeds, brush, plant material, or other prohibited items are present in a property, the Fire Marshal has the authority to give the property owner of record a notice to abate the hazard. If the owner does not abate the hazard during the time period specified in the notice, the City may take further action to reduce the fire hazard. Enforcement options that the Code Compliance Officers may use include notice of violations, correction notices, inspection notices, notice and order, summary abatement, citations, inspection and abatement warrants, and warnings. The City of Torrance has a weed abatement program for vacant lots. Property owners are given 30 days from when the notice is issued to clear the overgrown vegetation.

4.1.2.3 Building to Reduce the Fire Hazard

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 1994-1996, new roofing materials standards were approved by California for Very High Fire Hazard Severity Zones.

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.

The City of Torrance enforces a Class B roofing material requirement. According to the Fire Department (personal communication, 2005), most roofs in the city are made of composite materials, and many may in fact exceed the Class B criteria.

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 opening 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 is 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.

The City of Torrance does not have specific requirements regarding attic ventilation openings, exterior wall construction, and windows, but every proposed construction project in the city is reviewed by the City's Fire Department for compliance with the Uniform Fire Code (2001) and City amendments to the Uniform Fire Code (referred to as the Torrance Fire Code).

4.1.2.4 Restricted Public Access

In addition to the fire-susceptibility conditions described before, 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. Therefore, since the early 1990s, the EROS Data Center (EDC) in Sioux Falls, South Dakota, has produced weekly and biweekly maps for the 48 contiguous states and Alaska (available at http://edc.usgs.gov/). These maps, prepared under the Greenness Mapping Project, display plant growth and vigor, vegetation cover, and biomass production, using multi-spectral data from satellites of the National Oceanic and Atmospheric Administration (NOAA). The EDC also produces maps that relate vegetation conditions for the current two weeks to the average (normal) two-week conditions during the past seven years. EDC maps provide comprehensive growing season profiles for woodlands, rangelands, grasslands, and agricultural areas. With these maps, fire departments and land managers can assess the condition of all vegetation throughout the growing season, which improves planning for fire suppression, scheduling of prescribed burns, and study of long-term vegetation changes resulting from human or natural factors.

Another valuable fire management tool developed jointly by the U.S. Geological Survey and the U.S. Forest Service is the Fire Potential Index (FPI). The FPI characterizes relative fire potential for woodlands, rangelands, and grasslands, both at the regional and local scale. The index combines multi-spectral satellite data from NOAA with geographic information system (GIS) technology to generate 1-km resolution fire potential maps. Input data include the total amount of burnable plant material (fuel load) derived from vegetation maps, the water content of the dead vegetation, and the fraction of the total fuel load that is live vegetation. The proportion of living plants is derived from the greenness maps described above. Water content of dead vegetation is calculated from temperature, relative humidity, cloud cover, and precipitation. The FPI is updated daily to reflect changing weather conditions.

Local fire authorities can obtain data from either of the two sources above to better prepare for the fire season. When the fire danger in a Very High Fire Hazard Severity 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, hazardous fire areas can be closed to public access during at least part of the year. Typically, the fire season in southern California begins in May and lasts until the first rains in November, but different counties or jurisdictions can opt to start the fire season earlier and end it later. With more site-specific data obtained from the FPI or Greenness Mapping Project, however, the fire hazard of an area can be assessed on a weekly or bi-weekly basis. These data can also be used to establish regional prevention priorities that can 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.

Use of signage during high and extreme fire conditions along the major north-south roads that cut through the city and adjacent areas to the south, in the Palos Verdes Hills, can help reduce the fire hazard by alerting and educating motorists, residents and visitors alike, about the potential fire hazard in the area.

4.1.2.5 Real-Estate Disclosure Requirements

California state law [Assembly Bill 6; Civil Code Section 1103(c)(6)] 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, such as a Very High Fire Hazard Severity Zone (see Plate 4-2), or in a State Responsibility Area.

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. Un-informed homeowners may attempt landscaping or structural modifications that could be a detriment to the fire-resistant qualities of the structure, with potentially negative consequences.

4.1.2.6 Fire Safety Education

Individuals can make an enormous contribution to fire hazard reduction and need to be educated about their important role. In addition to the specific code requirements and guidelines mentioned in the sections above regarding defensible space, appropriate landscaping and construction materials, there are other tasks that homeowners can take to reduce the risk of fire in their property. Some of these tasks 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, but do not mow during the hottest time of the day.
- 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 maintain it regularly.
- Store and use flammable liquids properly.
- Dispose of smoking materials carefully.
- Do not light fireworks.
- Become familiar with local regulations regarding vegetation clearings, disposal of debris, and fire safety requirements for equipment.
- Follow manufacturers' instructions when using fertilizers and pesticides.
- When building, selecting or maintaining a home, consider the slope of the terrain. Be

sure to build on the most level portion of the lot, since fire spreads rapidly on slopes, even minor ones.

- Watch out for construction on ridges and cliffs. Keep a single-story structure at least 30 feet away from edges; increase distance if structure exceeds one story.
- Use construction materials that are fire-resistant or non-combustible whenever possible.
- For roof construction, the City of Torrance requires a minimum Class B rating; however, Class-A asphalt shingles, slate or clay tile, metal, cement and concrete products, or terra-cotta tiles are preferred.
- Constructing a fire-resistant sub-roof can add protection.
- On exterior wall cladding, fire-resistive materials such as stucco or masonry are much better than vinyl, which can soften and melt.
- Install an approved automatic fire sprinkler system. The City of Torrance has specific sprinkler requirements, as discussed further later in this chapter.
- A driveway should provide easy access for fire engines. The driveway and access roads should be well maintained, clearly marked, and include ample turnaround space near the house. The city of Torrance has specific requirements regarding roadway widths for fire engine access that are discussed further later in this chapter.
- So that everyone has a way out, provide at least two ground level doors for safety exits and at least two means of escape (doors or windows) – in each room.
- Keep 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.
- If an all-wood fence is attached to your home, a masonry or metal protective barrier between the fence and house is recommended.
- Use non-flammable metal when constructing a trellis and cover it with high-moisture, non-flammable vegetation.
- Prevent combustible materials and debris from accumulating beneath patio decks or elevated porches. Screen, or box in, areas that lie below ground level with wire mesh.
- Make sure an elevated wooden deck is not located at the top of a hill where it will be in the direct line of a fire moving up slope.
- 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.

4.1.2.7 Other Fire Hazard Reduction Techniques

Before European settlers arrived, many areas of the United States experienced small but frequent wildfires that impacted primarily the grasses and low-lying bushes, without severely damaging the tree stands. Native Americans in California reportedly 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 various tribes (Coleman, 1994). However, in the early 20th Century, as development started to encroach onto the foothills, wildfires came to be unacceptable, and in the early 1920s, the Fire Service began campaigns to prevent wildfires from occurring. Unfortunately, over time, this has led to an increase in fuel loads. This is significant because wildfires that impact areas with fuel buildup are more intense and significantly more damaging to the ecosystem than periodic, low-intensity fires.

Over time, fire suppression and increasing populations have produced these results:

- Increased losses to life, property, and resources;
- Increased difficulty in suppressing fires, increased safety problems for firefighters, and reduced productivity by fire crews on perimeter lines;
- Longer periods between recurring fires;
- Increased volume of fuel per acre; and
- 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. Nevertheless, many still find the notion of “prescribed fire” difficult to accept given that it goes against nearly 100 years of common practice and beliefs. Prescribed fire does carry 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. This fire triggered 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.

4.1.3 Post-Fire Effects

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.

Figure 4-4: Photograph Showing Denudation of Slopes Following the 1993 Laguna Beach Fire. Sandbags, plastic covers, hay bales, and other measures were implemented as soon as possible to reduce the potential for slope instability during the winter following the fire.

(Photograph courtesy of Mr. Robert Lemmer, Earth Consultants International)

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. Chaparral plant communities will take three to five years. Oak woodland, if it 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.

4.2 Structure Fires

Torrance's permanent residential population is currently about 138,000, and there are nearly 56,000 housing units (2000 Census). A large percentage of the housing stock in the city of Torrance consists of single-family, detached structures, but there are some areas of the city where apartments and condominiums are also present. Single-family units predominate in the hillside areas. Multiple-family units have special fire protection needs, including the requirement to have fire and life safety systems in place, such as automatic fire sprinklers and smoke detectors, in conformance with the City's Building and Fire Codes. Nearly 70 percent of Torrance's residential stock dates from before 1970, prior to the City's adoption of fire sprinkler ordinances. Therefore, 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. As discussed in detail below, in some areas of Torrance older structures abut each other, increasing the probability of a structural fire not being confined only to its building of origin.

The previous section described in detail the wildfire risk in the city. Review of the maps provided would suggest that most of the extensively developed portion of Torrance does not have a fire hazard, but this is not so — it is just not a wildfire hazard. Building fires, although only a small percentage of the incidents that the Fire Department responds to on an annual basis, account for a high percentage of the yearly losses in the city (60 percent in 2003, and 85 percent in 2005, based on data provided by the Torrance Fire Department). Structural fires are especially an issue in high-density areas, where there is a higher potential for fire to spread from one structure to the next. Furthermore, the narrow spaces between the structures and the property lines in medium- to high-density areas also provide limited room for emergency access (see Figure 4-5). For example, in high-density residential areas, emergency access and exits can be hindered if projections, such as bay windows and roof awnings, are made into the setback between structures, or if non-structural items, such as garbage cans or sheds are stored in those areas. In the older section of downtown Torrance, north of Torrance Boulevard and west of Madrona Avenue, narrow streets and alleys make it difficult to maneuver and position response vehicles so as to be most effective in fighting a fire, and have the potential to severely constrain efforts to evacuate the area if necessary during a fire or other disaster. Structure fires in this older section of the city — where some of the buildings date from the 1910s to 1930s, were built to older building standards and fire codes, and are made from non-fire resistive construction materials with no internal sprinklers and other fire safety systems in place — could also severely tax the Fire Department. Loss of life could be great if a structure fire occurs in one of the low-income, old hotels in the older section of the city. The following sections discuss the potential fire targets in the city (Section 4.2.1), and the City's fire suppression capabilities (Section 4.3).

The large industrial and commercial base in Torrance also means that there is a potential for chemical fires to occur in some areas of the city, with the potential to impact nearby residential areas. Issues associated with the storage, use and disposal of hazardous materials are discussed in more detail in Chapter 5, including a discussion of chemical fires, an issue highly relevant to Torrance given its wide industrial base. Finally, fires after earthquakes are a real concern in southern California, given the region's seismic potential. This is discussed further in Section 4.4.

Figure 4-5: Photograph illustrating the difficulty of maneuvering emergency equipment and victims through a narrow building setback, especially if non-structural additions project into this area. Dumpsters and other things stored in this area can also make access to the back of a residence difficult, if not impossible. Residents should maintain this area free of obstructions. (Courtesy of the Newport Beach Fire Department).

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. The structures at risk 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.

These occupancies are called "Target Hazards." 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 of the structure, location, size, and occupancy load, among other factors. Four classifications of risk are considered, as follows:

- High Probability/High consequences (Example: multi-family dwellings and residential buildings (condominiums and apartments), single-family residential homes in the older sections of the city, hazardous materials occupancies (see Chapter 6), and large shopping centers (such as Del Amo Fashion Center).
- Low Probability/High consequences (Example: Torrance Memorial Medical Center, Little Company of Mary Hospital and other medical facilities, mid-size shopping malls, industrial occupancies, large office complexes and upscale homes in the hilly southern portion of the city).
- High Probability/Low consequences (Example: older detached single-family dwellings in the relatively level portions of the city).
- Low Probability/Low Consequences (Example: newer detached single-family dwellings in the level portions of the city and small office buildings).

In order to address the Fire Department's capability to respond effectively to the structural fire risk in Torrance, "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. For example, residential areas adjoining, and intermixed with commercial areas occur both east and west of Hawthorne Boulevard, between Del Amo Boulevard to the north, and Torrance Boulevard to the south. Similarly, medium to high-density residential areas are present to the south of Sepulveda Boulevard, east and west of Hawthorne Boulevard, and also along Pacific Coast Highway, west of Hawthorne Boulevard. Given these combined risks within the same geographic area, it is appropriate for the Torrance Fire Department to have two fire stations (Fire Stations #5 and #6) near the older, intensely developed portion of the city where commercial and residential uses co-exist. For the location and distribution of fire stations in the City of Torrance, refer to Plates 1-4 and 4-2.

Some of the high probability/high consequence risks that fire departments worry the most are high-rise buildings due to the specialized fire-fighting equipment needed, the limited routes of access into and out of a building, and the potential for great loss of life. Fire departments typically define a high-rise as a building with floors for human occupancy located 55 feet or more above the lowest level of fire department access, as provided by their truck-mounted ladders. The City of Torrance is more stringent, however, and considers as high-rises all buildings with usable floor areas that are located more than forty (40) feet or four (4) stories above the lowest level of fire department vehicle access. High-rise buildings are now required to have several redundant fire and life safety systems in place, including automatic fire sprinklers and fire alarm detectors. Personnel from the Torrance Fire Department (personal communication, 2005) indicated that there is only one residential high-rise structure in the city built in the 1970s that is considered a high fire risk. This building, however, is (as of 2005, when this report was written) being fitted with automatic fire sprinklers, which is expected to reduce its risk. As discussed before, the Torrance Fire Department also considers the older structures in downtown Torrance as having a high fire risk. Many of these buildings may be awarded historical building status in the near future, which would limit the type of upgrades that could be implemented to reduce their vulnerability to fire.

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. The City of Torrance has adopted the 2001 California Fire Code with City amendments and exceptions (City Ordinance 3524, referred to as the Torrance Fire Code). The City's Fire Chief is authorized and directed to enforce the provisions of the Torrance Fire Code throughout the city.

These provisions include constructions standards and sprinkler and fire hydrant requirements 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, purpose, type, material, location, proximity to other structures, and the type of fire suppression systems installed. Given the detailed fire prevention requirements that the City of Torrance has for building construction standards, it is best to refer to the City's most current Fire and Building Codes, available from the City's Fire Prevention Administration Office and the Building and Safety Department, both located at City Hall. Torrance's private road standards for fire equipment access are summarized in Table 4-1. For more specific information regarding road widths for fire apparatus access, refer to Section 85.2.5 of the City's Fire Code.

Some of the more significant Fire Code items that help reduce the hazard of structural fire in the city include requirements regarding fire-extinguishing systems such as automatic fire sprinklers (Municipal Code Section 85.2.7). Fire sprinklers can help contain a fire that starts inside a structure from spreading to other nearby structures, and also help prevent total destruction of a building. The City of Torrance has very specific requirements regarding the installation of automatic fire-sprinklers depending on the type of occupancy and floor area. For more information regarding your specific needs, visit the City's Fire Prevention Administration Office at City Hall.

Fire Flow is the flow rate of water supply (measured in gallons per minute – gpm) available for fire fighting measured at 20 pounds per square inch (psi) residual pressure. Available fire flow is the total water flow available at the fire hydrants, also measured in gallons per minute. As of the writing of this report, Torrance had adopted the section of the 2001 California Fire Code that lists the minimum required fire-flow and flow duration for buildings of different floor areas and construction types (Appendix III-A; see Table 4-2 below), except that a reduction in required fire flow of up to 50 percent is allowed when the building is provided with an approved automatic sprinkler system. The resulting fire flow cannot be less than 1,500 gallons per minute. The Fire Department conducts semi-annual inspections of all fire hydrants in the city to make sure that they are working properly at the appropriate flows for the area. For additional information regarding the required fire-flow for your building, contact the City's Fire Department. Local water districts are required to test their fire protection capability for various land uses per the flow requirements of the California Fire Code.

Table 4-1: Minimum Private Road Widths for Fire Apparatus Access

Location of Parking	Minimum Road Width
Parking not permitted on road	25 feet
Parking permitted on one side of road only	28 feet
Parking permitted on both sides of road	34 feet
Signage	When required by the Fire Chief, approved signs or other approved notices shall be provided and maintained for fire apparatus roads to identify such and prohibit their obstruction, or both. The Fire Chief has the authority to designate fire apparatus access roads on private property. (Torrance Fire Code Section 85.2.4).
Other Requirements for Fire Access Roadways	The maximum grade allowed for fire department access roadways or streets is 10 percent, unless approved otherwise by the Fire Chief. The angles of approach and departure for any means of access shall not exceed the design limitations of the fire apparatus of the fire department, or 8 percent, whichever is greater. Fire apparatus access roads shall be designed and maintained to ensure that all-weather driving capabilities are maintained in accordance with the Uniform Fire Code. When the height of a structure at the roof eaves exceeds 27 feet or exceeds the fire department's capability to access the roof safely utilizing ground ladders, the location and width of the access roadways shall be such that truck-mounted ladders may be utilized. The minimum road width shall not be less than 30 feet, or as approved by the Fire Chief.

Emergency water storage is critical, especially when battling large structural fires or fires after earthquakes. During the 1993 Laguna Beach fire, "water streams sprayed on burning houses sometimes fell to a trickle" (Orange County Fire Department, 1994), primarily because most water reservoirs in Laguna Beach were located at lower elevations, and the water district could not supply water to the higher elevations as fast as the fire engines were using it. The two largest water reservoirs in Torrance are located in the Palos Verdes hills, allowing for water to be gravity-fed to most of the city. However, breaks in the water mains, especially if the result of surface ground rupture associated with movement on the Palos Verdes fault, could leave the city without water after an earthquake. Even if the Palos Verdes fault does not break, ground failure due to liquefaction and landsliding could lead to leaks and breaks in the water distribution system. Leaking irrigation lines and open valves in destroyed homes can also reduce the amount of water available to fire fighters. Although a seven-day emergency storage supply is recommended, especially in areas likely to be impacted by fires after earthquakes, the water storage reservoirs in the city of Torrance provide only 1-1/2 days of emergency storage supply. As of this writing, the City's Public Works Department is reviewing options to develop more ground water and increase their water storage (Torrance Public Works Department, personal communication, 2005).

Table 4-2: Minimum Fire Protection Flow Rates (from the Uniform Fire Code)

Land Use	Flow (gallons per minute)	Duration (hours)	Fire Suppression Storage (million gallons)	Residual Pressure (psi)
Residential Single-Family	2,000	4	0.48	20
Residential-Estate, Single Family Adjacent to Wildland	2,500	4	0.60	30
Residential Multi-Family	3,000	4	0.72	20
Commercial/Industrial	4,000	4	0.96	20
Schools	3,500	4	0.84	20

4.3 Fire Suppression Responsibilities

The Torrance Fire Department is responsible for fire suppression within the city of Torrance. The Torrance Fire Department, which was formed immediately after the City was incorporated in 1921, constantly monitors the fire hazard in the city, and has ongoing programs for public education, and investigation and alleviation of hazardous situations. Fire-fighting resources in Torrance include Fire Station Nos. 1 through 6, as shown on Table 4-3 below. Combined, these fire stations are manned by approximately 160 emergency response personnel. [According to spoke-persons from the Fire Department (personal communication, 2005), there are plans to build another fire station in the city. Current plans call for fitting this proposed new fire station mostly with equipment currently residing at other stations, with the exception of rescue equipment, which would be purchased for the new station.] The general telephone number for the Torrance Fire Department is **310-781-7042. For emergencies, dial 911.**

The Fire Department responds to a variety of emergency response calls, vegetation and structure fires, vehicle accidents, medical and rescue calls, public assistance, and false alarms. Statistics from the Torrance Fire Department regarding incidents that they responded to during 2003 and 2004 are summarized in Table 4-4, below.

Table 4-3: Fire Stations in the City of Torrance

Fire Station No.	Street Address	Units Available			Area of First Response or Other Distinctive Characteristics
		Engine Companies	*Ladder Truck*	*Paramedic Squad*	
1	1701 Crenshaw Blvd.	2	1	1	One Air and Lighting Unit; houses Battalion Chief and Administrative Offices
2	225135 Robinson Way	1	0	0	First responder to any Airport incidents
3	3535 182nd St.	1	0	1	First responder to any 405 Freeway accidents
4	5205 Calle Mayor	1	0	1	First responder to any Torrance Beach incidents
5	3940 Del Amo Blvd.	1	0	0	Houses Hazardous Materials Response Unit; Engine company personnel cross-trained
6	21401 Del Amo Circle Dr.	1	1	1	Engine company personnel cross-trained as part of Hazardous Materials Response Team
City Hall	3031 Torrance Blvd.				Houses the Fire Prevention and Hazardous Materials Administration Offices

Table 4-4: 2003 and 2004 Statistics, City of Torrance Fire Department

Type of Incident	Sub-Type	Responses in 2003		Responses in 2004	
		Number	Percent	Number	Percent
Fires	Structural	57	0.49	50	0.42
	Vehicles	74	0.63	72	0.60
	Brush / vegetation	26	0.22	27	0.22
	Rubbish, trash	77	0.66	100	0.83
	Other	64	0.55	68	0.57
Total Fires		**298**	**2.54**	**317**	**2.64**
Medical and Rescue Emergencies	Motor vehicle	763	6.52	736	6.13
	All others	7,392	63.12	7,411	61.77
Hazardous Condition (No Fire)		1,029	8.79	1,113	9.28
Public Assistance / Service Calls		916	7.82	938	7.82
False Alarms/Calls And Good Intent Calls		1,313	11.21	1,483	12.36
Total Number of Incidents		**11,711**	**100**	**11,998**	**100**

Table 4-4 above shows that the six fire stations in the city of Torrance respond to nearly 12,000 incidents a year, which resolves to an average of about 2,000 incidents per station. Note that about 70 percent of the responses are medical and rescue emergency calls. This is typical of most communities. In Torrance, these medical emergencies are handled by the closest available engine company and the closest paramedic squad from one of the four fire stations with paramedic squads (Fire Stations 1, 3, 4 and 6). Therefore, on average, each paramedic squad responds to approximately 2,000 calls a year. These numbers are well within the number of calls recommended by the Insurance Services Office (ISO) when rating a community for fire insurance rates. Specifically, the ISO recommends that a second company be put in service in a fire station if that station receives more than 2,500 calls per year. The reason for this recommendation is to assure reliability of response to a structure fire. If an engine company provides support to the paramedic squad by responding to medical aid calls, and this impacts the station's response to structure fire calls, it may be prudent to add another paramedic squad or support squad vehicle and increase staffing at that fire station with the most medical aid traffic. A high volume of calls also creates a high potential for multiple calls occurring at once (multiple queuing), which can result in a company being unavailable to respond to a structure fire. Thus, if this forces a response from other stations farther away, it can result in a larger fire before assistance arrives.

Table 4-4 also shows that fires in Torrance represent less than 3 percent of all calls, and structure fires represent less than 0.5 percent of all calls. This is due to the use of modern fire and building codes, effective fire prevention inspection work by the Fire Department, and effective public education. Fires, when they do occur in newer occupancies, are kept small by fire sprinkler systems and the efforts of the Fire Department. This improvement in fire safety of our communities has in fact raised a concern that in some areas, when a major structure fire does occur, fire department personnel will have to apply "seldom used skills." In these instances, this could result in an increase in firefighter injuries, and perhaps larger fires than would have occurred in past years when fire departments were accustomed to responding to more structure fires due to the absence of sprinkler systems, poor construction, and lack of ongoing Code enforcement. The Torrance Fire Department, however, requires its personnel to train extensively and continuously: every fire response individual is required 30 hours of training per month.

The National Fire Protection Association (NFPA Standard 1710, 2001) recommends that in 90 percent of the time, fire departments respond to fire calls within six 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 scene prior to the fire spreading beyond the room of origin, which can result in total destruction, and this typically occurs within 8 to 10 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 4 minutes (or less) driving or travel time. The NFPA Standard 1710 (2004) also states that in 90 percent of the time, fire departments should take 8 minutes or less for the deployment of a full first alarm assignment at a fire suppression incident, and 8 minutes or less for the arrival of an advanced life support unit at an emergency medical incident if this service is provided by the fire department. 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:

- Access obstructions
- Traffic calming devices and median strips on major roadways
- Traffic congestion
- Weather
- Multiple alarms
- Delayed response

- Winding access roads in hillside developments
- 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.

Actual response statistics for the Torrance Fire Department were not available. However, personnel from the Fire Department (personal communication, 2005) indicated that they are on scene within 7 minutes of the dispatch center receiving the emergency call 95 percent of the time. In Torrance, response times vary as a result of traffic density, the time of day or night, and emergency unit availability. The Fire Department relies on traffic-signal actuation devices (Opticom) at critical intersections to deal with traffic congestion and improve their driving time response. To date, approximately 60 intersections in the city have been fitted with pre-empting Opticom devices.

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 a fire at Del Amo Fashion Center, a local hospital, or a large condominium or apartment complex. Structure 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 routinely rely on automatic and mutual aid agreements to address the fires 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. Beyond this response, additional fire units are requested via the automatic or mutual aid agreements.

4.3.1 Automatic and Mutual Aid Agreements

Although the Torrance Fire Department is tasked with the responsibility of fire prevention and fire suppression in the city, in reality, fire-fighting agencies team up and work together during emergencies. These teaming arrangements are handled through automatic and mutual aid agreements, which obligate fire 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 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 include 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.

Torrance is part of the Los Angeles County Operational area, and more specifically, part of the South Bay area (also referred to as Area G). The Operational Area is part of the Standardized Emergency Management System (SEMS), further described below in Section 4.3.2, that promotes effective disaster management, response and cooperation across jurisdictional boundaries. Other jurisdictions, in addition to Torrance, that are part of Operational Area G include Redondo Beach, El Segundo, Gardena, Hawthorne, Hermosa Beach, Inglewood, Manhattan Beach, and Palos Verdes Estates. As a result of being part of the same Operational Area group, all of these jurisdictions have mutual aid agreements that allow them to obtain additional emergency resources, as needed, from non-affected members in the group. Given its geographic location, Redondo Beach is the first responder to mutual aid requests from the city of Torrance. Furthermore, each of these cities is signatory to a Joint Powers Agreement that provides for the joint use and operation of machinery, equipment, vehicles and personnel in the event of a fire, disturbance or other local emergency that cannot be met solely by the requesting city.

Numerous other agencies are available to assist the City if needed. These include the City's Police Department and California Highway patrol, who, depending on the location of the incident, would provide support during evacuations and to discourage people from traveling to the incident area to watch their operations, as this can hinder fire suppression and emergency response efforts. Several State and Federal agencies have roles in fire hazard mitigation, response and recovery, depending on the type of incident and its location. These agencies include the Office of Emergency Services, Office of Aviation Services, National Weather Service, the Department of the Interior, and, in extreme cases, the Department of Defense. In forest areas (and therefore not applicable to Torrance), other agencies that may be involved include the Fish and Wildlife Service, National Park Service, US Forest Service, National Association of State Foresters, and the Department of Agriculture. Private companies and individuals may also be asked to provide assistance in some cases.

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 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 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 Torrance

The Insurance Services Office (ISO) provides rating and statistical information for the insurance industry in the United States. 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. Torrance has maintained a Class 1 ISO rating for nearly a decade.

4.4 Earthquake-Induced Fires

Although wildland fires can be devastating, earthquake-induced fires have the potential to be the worst-case fire-suppression scenarios for a community because an earthquake typically causes multiple ignitions distributed over a broad geographic area. In addition, if fire fighters are involved with search and rescue operations, they are less available to fight fires, and the water distribution system could be impaired, limiting even further the fire suppression efforts. If earthquake-induced fires occur during Santa Ana wind conditions, the results can be far worse.

The major urban conflagrations of yesteryear in major 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 also 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. 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. The moderately sized, M 6.7 Northridge earthquake of 1994 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 ruptured transmission line was ignited by a downed power line. In many of the destroyed mobile homes, fires erupted when inadequate bracing allowed the houses 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). Although the threat that existed in San Francisco in 1906 was far greater than that in Torrance today, there are some sections in Torrance where due to ground failure, breaks in the gas mains and the water distribution system could lead to a significant fire-after-earthquake situation. This is especially true of the areas identified in Chapter 1 as susceptible to surface fault rupture, liquefaction, and earthquake-induced slope instability and subsidence.

As discussed in the Seismic Hazards section of this report (Chapter 1), there are several major earthquake-generating faults that could affect the Torrance area. The three most significant faults to the Torrance area include the Palos Verdes and Newport-Inglewood strike-slip faults, and the Puente Hills thrust fault. A moderate to strong earthquake on any of these faults could trigger multiple fires, disrupt lifelines services (such as the water supply), and trigger other geologic hazards, such as landslides, which could block roads and hinder disaster response. 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. The majority 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 Torrance following a major earthquake will most likely be curtailed due to damage to the water distribution system — damage to the water reservoirs on the south side of the Palos Verdes fault, and especially broken water mains that extend across the fault traces, and in areas of ground deformation, including liquefaction, subsidence, and slope instability (see Chapter 1 – Seismic Hazards, and Chapter 3 – Flooding Hazards).

4.5 Summary and Recommended Programs

Torrance's Fire Department manages the fire hazard in the city very effectively by providing extensive fire prevention and public education programs. The City has also invested and continues to invest on infrastructure and equipment — such as fire hydrants, centralized dispatch center, emergency response vehicles fitted with GPS receivers for navigation and Opticom pre-empting devices – that help the Fire Department be as responsive as possible. This commitment has earned the City an ISO rating of 1, the highest grade possible, a grade that they have held onto for nearly a decade.

The Fire Department considers the City's vulnerability to wildland fires low to none. The State of

California currently still maps very high fire hazard severity zones (VHFHSZs) in the city's hilly southern portion, but, given that the City has financial responsibility for these areas, and therefore has ultimate say on how these areas are mapped, future versions of the State's VHFHSZ maps are likely to exclude Torrance. When available, a newer version of the State map should replace Plate 4-2. Nevertheless, residents in hillside areas should be encouraged to continue safe fire practices, including maintaining a fire-safe landscape, and keeping combustibles (such as fire wood) a safe distance away from all structures. Similarly, the City should continue to fund the weed abatement and notification program, to reduce the potential for vegetation fires to occur in vacant or poorly maintained lots.

As indicated above, structure fires in the city of Torrance represent a very small percentage of the annual emergency calls that the Fire Department receives and responds to. However, the fires that do occur in the city represent a high (60 to 85 percent) of the total annual losses. Therefore, programs that can be continued or implemented to further reduce these losses should be encouraged. Specifically the City:

- Should continue to regularly reevaluate specific fire hazard areas and adopt reasonable safety standards, covering such elements as adequacy of nearby water supplies, routes or throughways for fire equipment, clarity of addresses and street signs, and maintenance.
- Encourage owners of non-sprinklered properties, especially high- and mid-rise structures and high-occupancy structures, to retrofit their buildings and include internal fire sprinklers. The City may consider some form of financial assistance (such as low-interest or no-interest loans) to encourage property owners to do this as soon as possible.
- Continue to conduct emergency response exercises, including mock earthquake-induced fire-scenario exercises to prepare for the multiple ignitions that an earthquake is expected to generate. Civilians should be encouraged to participate in these exercises as much as possible, to empower neighborhoods to be self-reliant in the face of a natural or man-made disaster. These training sessions should use the adopted emergency management system (SEMS).
- Most importantly, the City should improve the adequacy of its water storage capacity and distribution network in the event of an earthquake. Redundant systems should be considered and implemented in those areas of the city where fault rupture, liquefaction and other modes of ground failure could result in breaks to both the water and gas mains, with the potential for significant conflagrations. This includes considering alternate sources of water, such as the ocean, open reservoirs, and swimming pools, and providing fire engines with engine-driven pumps that can be used to obtain water from these alternate sources.
- Should encourage the local gas and water purveyors to review and retrofit their main distribution pipes, with priority given first to those lines that cross or are located near the mapped trace or projections of the Palos Verdes fault (see Chapter 1).

CHAPTER 5: HAZARDOUS MATERIALS MANAGEMENT

5.1 Introduction

A high standard of living has driven society's increased dependence on chemicals. Hydrocarbon fuels that power our vehicles, chlorine used to treat our drinking water and pools, and pesticides used in the agricultural sector are a few examples of 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, sometimes with negative consequences because exposure to many of these chemicals is often hazardous to human health and to the environment. Recognizing these potential health hazards, Federal, State, and local regulations have been implemented since the late 1960s to dictate the safe use, storage, transportation, and handling 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 (Federal Code of Regulations – FCR - Title 40: Protection of the Environment, Part 261). 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 wastes that are in the forms of solids, semi-solids, liquids, and gases. Producers of such wastes include private businesses, and 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 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, is carcinogenic (causes cancer), has bioaccumulative properties (accumulates in the body's tissues), is persistent in the environment, or is water reactive (California Code of Regulations, Title 22; California Health and Safety Code, Division 20, Chapter 6.5).

This report will deal with hazards associated with the use of hazardous wastes and materials in the city of Torrance, 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 in the city. Some of these programs are discussed in this report. 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 City of Torrance Fire Department, the Los Angeles County Department of Health Services Bureau of Environmental Protection, and/or the U.S. Environmental Protection Agency. All of these agencies have dedicated web pages where extensive information about hazardous wastes is provided. This report 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 greater 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 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 (NO_2)
- Ground-level ozone (O_3)
- Sulfur dioxide (SO_2)

For each of these pollutants, the EPA tracks two kinds of air pollution trends: 1) air concentrations based on actual measurements of pollutant concentrations in the ambient (outside) air at selected monitoring sites throughout the country, and 2) 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. California has established State standards for some of these pollutants that are more restrictive than the National standards, which are also shown on Table 5-1. The health effects of two of these pollutants, ozone and particulate matter, are discussed further 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. The releases of man-made chemicals, such as chlorofluorocarbons (CFCs), and natural emissions from volcanic eruptions destroy this beneficial ozone, resulting in seasonal thinning of the ozone layer over Antarctica and Earth’s southern hemisphere. 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
(where California standards are different than National standards,
California standards are also provided)

Pollutant	**Unallowable Concentration*** ppm or μg/m³ (where noted)	Type
Carbon Monoxide		
8-hour average (US) 8-hour average (CA)	9.5 >9.0	Primary
1-hour average (US) 1-hour average (CA)	>35 >20	Primary
Nitrogen Dioxide		
AAM (US) 1-hour average (CA)	>0.0534 >0.25	Primary and Secondary
Ozone		
1-hour average (US) 1-hour average (CA)	>0.12 >0.09	Primary and Secondary
8-hour average	>0.08	Primary and Secondary
Lead		
Quarterly average (US) Monthly average (CA)	>1.5 μg/m³ 1.5 μg/m³	Primary and Secondary
Particulate (PM_{10})		
AAM (U.S.) AAM (CA)	>50 μg/m³ >20 μg/m³	Primary and Secondary
24-hour average (US) 24-hour average (CA)	>150 μg/m³ >50 μg/m³	Primary and Secondary
Particulate ($PM_{2.5}$)		
AAM (US) AAM CA)	>15 μg/m³ >12 μg/m³	Primary and Secondary
Sulfur Dioxide		
AAM (US)	>0.03	Primary
24-hour average (US) 24-hour average (CA)	>0.14 >0.04	Primary
3-hour average (US) 1-hour average (CA)	>0.50 >0.25	Secondary

*Concentration in units of air, by volume.
AAM = Annual Arithmetic 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.
ppm= parts per million; μg/m³= micrograms per cubic meter.
US = 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 (PM_{10}) 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 ($PM_{2.5}$) 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 and unpaved roads, and agricultural or vacant fields (think Santa Ana wind conditions). 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).

Peak air quality statistics for the six principal pollutants measured in the year 2002 in the Southwest Coastal Los Angeles County area, which includes Torrance, are listed in Table 5-2. The data show that none of the peak values in the Southwest Coastal Los Angeles County area exceeded the National or State ambient air quality standards, with one exception: The maximum allowable concentration of PM_{10} based on its Annual Arithmetic Mean (AAM) as defined by the State (of more than 20 $\mu g/m^3$) was exceeded 12 times in 2002 (also see Table 5-4). As of the writing of this report, the 2003-2004 air quality data were not yet available. The reader is encouraged to go to http://www.aqmd.gov to look for more recent air quality information, if available, that may have been posted by the South Coast Air Quality Management District as since the writing of this report.

Table 5-2: Year 2002 Peak Air Quality Statistics for Criteria Pollutants in the Southwest Coastal Los Angeles County Area

Pollutant	State Unallowable Standard	Maximum Concentration in Southwest Coastal Los Angeles County Area
Carbon Monoxide		
8-hour average	>9 ppm	6.1 ppm
Nitrogen Dioxide		
1-hour average	>0.25 ppm	0.10* ppm
Ozone		
1-hour average	>0.09 ppm	0.088 ppm
8-hour average (US)	>0.08 ppm	0.073 ppm
Lead		
Monthly maximum	1.5 $\mu g/m^3$	0.02 $\mu g/m^3$
Particulate (PM_{10})		
Annual Arithmetic Mean (CA)	>20 $\mu g/m^3$	37.4 $\mu g/m^3$
24-hour average (US)	150 $\mu g/m^3$	121.0 $\mu g/m^3$
Sulfur Dioxide		
1-hour average	>0.25 ppm	0.07 ppm
24-hour average	>0.045 ppm	0.007 ppm

ppm = parts per million; $\mu g/m^3$ = micrograms per cubic meter
*Less than 12 months of data, 2001 concentration was 0.11 $\mu g/m^3$
Source: http://www.aqmd.gov/smog/

5.2.2 Air Quality Index

The EPA uses the Air Quality Index (AQI) to assess and report daily air quality in a given area (see Table 5-3). The AQI expresses how clean or polluted the air is in a given area, and what associated health concerns the residents should be aware of. The AQI focuses on health effects that can happen within a few hours or days after breathing polluted air. EPA uses the AQI for five of the six major air pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The EPA determines the index value on a daily basis for each of the measured pollutants, and then 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 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 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, and newspapers) serving metropolitan areas with populations exceeding 200,000. Additional information is available at www.epa.gov/airnow/ or www.aqmd.gov/smog/. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level the EPA has set to protect public health. So, AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy — at first for certain sensitive groups of people, then for everyone as AQI values increase.

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

Index Value	PSI Descriptor; General Health Effects	Cautionary Statements
0 to 50	Good; None for the general population.	None Required.
51 to 100	Moderate; Few or none for the general population.	None Required.
101 to 150	Unhealthful for sensitive groups; Mild aggravation of symptoms among susceptible people, with slight irritation of symptoms in the healthy population.	General population should reduce vigorous outdoor activity. Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151 to 200	Unhealthful; Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.	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 to 300	Very Unhealthful; Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease; widespread symptoms in the healthy population.	General population should reduce vigorous outdoor activity; 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. Elderly and persons with heart or lung disease should stay indoors.
301 to 500	Hazardous; Adverse symptoms in healthy people; early onset of certain significant aggravation of symptoms and decreased exercise tolerance in healthy persons. Premature death of ill and elderly persons.	Everybody should avoid outdoor exertion. Keep windows and doors closed.

Source: http://cfpub.epa.gov/airnow

The South Coast Air Quality Management District (SCAQMD) monitors and provides 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 2002. The last column in Table 5-4 provides the number of days that Criteria Air Pollutant concentrations for the area around Torrance were in excess of Federal or State standards for the year 2002.

Table 5-4: Air Quality in the Torrance Area in 2002

Pollutant	Measurement Location	# Days in excess
Ozone	Southwest Coastal Los Angeles County, Station No. 094	0*
Carbon Monoxide	Southwest Coastal Los Angeles County, Station No. 094	0**
Nitrogen Dioxide	Southwest Coastal Los Angeles County, Station No. 094	0***
Sulfur Dioxide	Southwest Coastal Los Angeles County, Station No. 094	0#
PM_{10}	Southwest Coastal Los Angeles County, Station No. 094	12##

*1-hour average CA standard (1-hour and 8-hour average US standards were not exceeded)
**8-hour average CA standard
***1-hour average CA standard
#1-hour and 8-hour average CA standard
##CA Standard AAM
Source: www.aqmd.gov

Significant improvements in the air quality of the larger Los Angeles basin region are attributed to emission reduction and reduced reactivity of emitted organic compounds in the region (SCAQMD, 2001). As everybody who owns a vehicle in California knows, vehicular emissions are monitored through the State's Smog Check Program. Emissions from stationary sources are also monitored. 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 restaurants, hotels, dry cleaners, tire shops, welding shops, car repair shops, hospitals, and industrial and manufacturing facilities. Those facilities that release emissions into the air are required to obtain a permit to do so from the EPA. According to a spoke person from the SCAQMD (personal communication, April 2005), there are 471 facilities permitted to release emissions into the air in the Torrance area.

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 stay up to date with any new rules. If necessary, SCAQMD takes enforcement action to bring businesses into compliance. The SCAQMD does not provide a list of all permitted facilities but it does provide information on facilities that were found to be non-compliant or for which there are violation reports. Ten of the facilities in the Torrance area were cited in the past year (as of December 31, 2004) for emission violations. For updated information, refer to http://www.aqmd.gov/nov/.

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 forth by the U.S. Environmental Protection Agency (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 that 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 reason 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 test positive for Total Coliform.

Two water agencies provide drinking water to the citizens of Torrance. The two agencies are:

- Torrance Municipal Water Department (TMWD), and
- California Water Service Company (Rancho Dominguez and Hermosa-Redondo Districts).

The sources of the drinking water distributed in Torrance by these two agencies include ground water and imported water. Ground water provides 12 percent of Torrance's water supply and is pumped from two deep wells in the city. The remaining 88 percent of Torrance's potable water supply is purchased from the Metropolitan Water District of Southern California (MWD), a regional wholesaler of imported surface water. The water Torrance receives from the WMD comes from their northern Orange County Diemer Treatment Plant, were it has undergone an advanced multi-stage treatment and quality testing. The water from the City's wells and the WMD is blended together, and is then tested by the Torrance Municipal Water Department (TMWD) before it is distributed to the residents of Torrance. The TMWD performs more than 2,000 water quality tests a year to determine the presence of any radioactive, biological, inorganic, volatile organic or synthetic organic contaminants. Neither the TMWD, nor the California Water Service Company, is listed in the EPA Safe Drinking Water Violation Report for Los Angeles County (see www.epa.gov/safewater/dwinfo/ca.htm).

This means that the water provided by these agencies meets standards for Coliform levels and does not exceed the maximum levels for the contaminants routinely tested.

According to the EPA, (www.epa.gov/enviro/html/pcs/), five (5) facilities in the Torrance area have EPA permits to discharge to local water sources. These facilities have obtained permits which allow them to discharge specified pollutants (e.g., chemicals, water temperature, oxygen content, etc.) up to a defined limit. The discharge from these facilities is monitored by the EPA and State agencies to ensure that the facility does not exceed its permit discharge allowance.

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 (see the website at 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 coughing, 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 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. At larger facilities, such as water reservoirs and municipal or neighborhood pools, proper operations and maintenance are critical 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 need to 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 Environmental Profile of the City of Torrance

Various Federal and State programs regulate the use, storage, and transportation of hazardous materials. These will be discussed in this report as they pertain to the city of Torrance 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 Torrance 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 legislated extensively, and the laws governing hazardous waste 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)

Storm Water and Dry-Weather Runoff. "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 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 a "point source." A point source is defined by the EPA as a discrete conveyance, 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 "non-point 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 non-point sources that discharge pollutants into waters of the United States. Though individual households do not need NPDES permits, cities like Torrance hold NPDES permits to operate their municipal separate storm sewer systems (MS4s). Torrance's MS4 Permit (effective December 13, 2001) directs it to keep pollutants out of its MS4 to the maximum extent practicable and to ensure that dry-weather flows entering recreational waters from the MS4 do not cause or contribute to exceedances of water quality standards. The Permit requires the City to do the following:

- Control contaminants into storm drain systems;
- Educate the public about storm water impacts;
- Detect and eliminate illicit discharges;
- Control runoff from construction sites;
- Implement "best management practices (BMPs)" and site-specific runoff controls for new development and redevelopment; and
- Prevent pollution from municipal operations, including fixed facilities (like City Hall and fire stations) and field activities (like trash collection).

Specific programs that local governments typically implement in support of the NPDES program include:

- Regular maintenance of public right-of-ways, including street sweeping, litter collection, and storm drain facility maintenance;
- Implementation of spill response procedures;
- Periodic screening of water samples collected from the storm sewer system and local streams, to test for specific contaminants;

- Adoption and enforcement of ordinances prohibiting the discharge of pollutants into the storm drain system;
- Plan review procedures to ensure that unauthorized connections to the storm sewer system are not made; and
- Public education efforts to inform residents about storm water quality. These efforts typically include utility bill inserts describing the NPDES program, storm drain stenciling, booths at public events, and school programs. Measures that can be taken by businesses and residents to reduce the potential for contamination of the local waters and ocean are available at www.ci.torrance.ca.us/city/dept/ENG/enghome.html.

In Torrance, NPDES permits are issued by the California Regional Water Quality Control Board, Los Angeles Region (RWQCB) as part of their Storm Water Program (see www.waterboards.ca.gov/losangeles/). This program coordinates all the incorporated cities (except Long Beach) and the county government in Los Angeles County to regulate and control storm water and urban runoff into all Los Angeles County waterways, and ultimately, into the Pacific Ocean. The RWQCB Storm Water Program administers the current NPDES MS4 Permit and is implemented by the Watershed Regulatory Section of the RWQCB, Los Angeles. The Los Angeles Region has jurisdiction over all coastal drainages flowing to the Pacific Ocean between Rincon Point (on the coast in western Ventura County) and the eastern Los Angeles County line, as well as the drainages of five coastal islands (Anacapa, San Nicolas, Santa Barbara, Santa Catalina, and San Clemente). The Regional Board's jurisdiction also includes all coastal waters within three miles of the continental and island coastlines. The Los Angeles Region is the State's most densely populated and industrialized region with over 700 discharges of wastewater from point sources into surface waters.

In support of its MS4 Permit (NPDES No. CAS004001) and obligation to keep waterways clean by reducing or eliminating contaminants from storm water and dry-weather runoff, the City complies with the California Regional Water Quality Control Board’s Monitoring and Reporting Program (CI 6948). The City has a storm water education program, an aggressive inspection team that issues citations for water quality violations, and requires the use of “best management practices” in many residential, commercial, and development-related activities to reduce runoff.

Wastewater. Torrance maintains a wastewater collection system, which directs wastewater to the Joint Water Pollution Control Plant (JWPCP), a facility operated by the Los Angeles County Sanitation District. Torrance’s wastewater collection system is maintained to eliminate sanitary sewer overflows (SSOs). SSOs threaten public health and resources by discharging pollutants – including untreated sewage, cleaning chemicals, endocrine disruptors and related medicines, discarded food from sink disposals, and laundry and bath waters – into rivers or the ocean.

5.4.2 Comprehensive Environmental Response, Compensation and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), is a regulatory or statute 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 most recent EPA data available, there is one CERCLIS site in the city of Torrance and three sites within 1,000 feet of the city's western border (see Table 5-5). Of these facilities, only the Montrose Chemical Corporation, which is not located within Torrance, is on the National Priorities List (NPL). The Montrose Chemical Corporation was proposed for listing on the NPL in 1984, with final listing occurring in 1989. Clean-up activities for the pesticide DDT and the raw material chlorobenzene are currently ongoing for affected soil and ground water. No clean-up completion date is known at this time. More information on the Montrose Chemical site is available at www.epa.gov/superfund/sites/nplfs/fs0900993.pdf.

Of the other three CERCLIS sites, only the Martin Marietta Aluminum Inc. site is considered a No-Further-Remedial-Action-Planned (NFRAP) site, and will most likely not be included in next year's Superfund list. The NFRAP status means that to the best of EPA's knowledge, no immediate or long-term risks to human health or the environment are associated with the site, and no further steps will be taken to list that site on the NPL list. The remaining sites on the list, Classic Cleaners and Garrett Corporation Air Research, are in various stages of assessment to determine their inclusion or non-inclusion in the NPL list.

Table 5-5: CERCLIS Sites in the Torrance Area

Facility Name	Facility Address	EPA ID	Status
Classic Cleaners	2831-2833 Pacific Coast Highway	CAL000032438	Not on NPL, PA Ongoing
Garrett Corporation, Air Research	3201 Lomita Boulevard	CAD020146189	Not on NPL, Reassessment Ongoing
Martin Marietta Aluminum Inc.	19200 Western Avenue	CAD983643669	Not on NPL, NFRAP
Montrose Chemical Corp.	20201 Normandie Avenue	CAD008242711	On NPL

NPL – National Priorities List
PA – Preliminary Assessment
HRS – Hazard Ranking System
NFRAP – No Further Remedial Action Planned
Sources: http://www.epa.gov/superfund/sites/cursites/index.htm

5.4.3 Emergency Planning and Community Right-To-Know (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/triexplorer/facility.htm. 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.

The following types of facilities are required to report their activities to the EPA and the regulatory State agencies:

Facilities with ten or more full-time employees 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 19 facilities in the city of Torrance listed in the Toxic Release Inventory for year 2002 (the most recent TRI data available) are summarized in Table 5-6.

Table 5-6: Toxic Release Inventory of Facilities in the Torrance Area

Facility Name, Address	EPA ID	Chemicals
Alcoa Fastening Systems 3000 W. Lomita Boulevard	CAD001946383	Chromium compounds, hydrochloric acid
Bachem Inc. 3132 Kashiwa Street	CAD077243640	Acetonitrile, dichloromethane, methanol, N,N-dimethylformamide
Hi-Shear Corporation 2600 Skypark Drive	CAD990843377	Methyl ethyl ketone, nickel, nitrate compounds, nitric acid
Honeywell Turbo Technologies 3201 W. Lomita Boulevard	CAD020146189	Copper
Commonwealth Aluminum - Torrance Coil Coating 2303 Jefferson Street	CAT080013477	Glycol ethers, lead compounds

Facility Name, Address	EPA ID	Chemicals
Martin Brass Foundry 2341 Jefferson Street	CAD008352072	Copper, lead
Moog Aircraft Group - Torrance Operations 20263 Western Ave	CAD982437089	Lead compounds, nickel
United States Gypsum Co. 401 Van Ness Avenue	CAD981374069	Barium, lead, methanol, vinyl acetate, zinc compounds
Ball Metal Beverage Container Co. 500 Crenshaw Boulevard	CAD009537200	Glycol ethers, hydrogen fluoride, lead, n-butyl alcohol, sulfuric acid & acid aerosols
BOC Gases 2535 Del Amo Boulevard	CAD095135687	Ammonia
Dow Chemical Co. 305 Crenshaw Boulevard	CAD009547050	1-Chloro-1,1-difluoroethane, antimony compounds, chlorodifluoromethane, cumene, decabromodiphenyl oxide, ethylbenzene, styrene, zinc compounds
Hitachi Automotive Products Inc. 475 Alaska Avenue	CAD070656871	Lead
Honeywell Cpg 19500 Mariner Avenue	CAD981428717	Ethylene glycol, methanol, nitrate compounds
Naturalife ECO Vite Laboratories 20433 Earl Street	N/A	Methanol
Praxair Distribution Inc. 19200 Hawthorne Boulevard	CAD000625863	Propylene
Torrance Latex Plant Union Carbide Corporation 19206 Hawthorne Boulevard	CAD081735755	Acrylic acid, acrylonitrile, butyl acrylate, ethyl acrylate, methyl methacrylate, styrene, vinyl acetate
Union Carbide-Torrance Terminal 19500 Mariner Avenue	CAD008388894	Butyl acrylate, glycol ethers, diethanolamine, ethylene glycol, methanol, methyl isobutyl ketone, n-butyl alcohol, vinyl acetate
Honeywell 2525 W. 190th Street	CAD071896336	Nickel, nitric acid, toluene
Spectrum Plating Co. 527 Van Ness Ave	CAR000054056	Lead compounds

Source: U.S. EPA, 2002, TRI On-site and Off-site Reported Releases in Torrance, California; List of EPA-regulated Facilities in Envirofacts (http://www.epa.gov/triexplorer/facility.htm).

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.

The EPA lists the following 12 transporters of hazardous waste based in the Torrance area:

- Adams Trucking - 5321 Edgemere Drive
- Allwaste Service of Los Angeles, Inc. - 23033 Mariposa
- Bauer Oil Company - 4525 Cadison Street
- Cameron Environmental Inc. - 20741 Manhattan Place
- Cosworth Engineering Inc. - 3031 Fujita Avenue
- Ecotech - 1920 Del Amo Boulevard, Suite A
- M.E.D. Trucking Company Inc. - 23228 Hawthorne Boulevard
- Miura Trucking - 18209 Illinois Court
- Opto Sensors Inc. - 20775 South Western Avenue
- R.E. Williams and Sons Inc. - 1745 Border Avenue
- Ray's Trucking - 17103 South Haas
- Rons Trucking - 2814 West 179th Street

Transportation of hazardous materials on the portions of the freeways and major roads that extend through the city is most likely also conducted by other companies that are not based out of Torrance. Additional licensed hazardous waste haulers may be found listed on the City's website, at www.torrnet.com/streetsvcs/Sanitation/hhwbusiness1.htm.

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 kilograms (Kg) of hazardous waste per month (approximately equivalent to between 220 and 2,200 pounds, or between 27 and 275 gallons). 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 Torrance area are not listed in this report. As of April 2005, there were approximately 379 small-quantity generators of hazardous materials in the Torrance area (see http://www.epa.gov/enviro/html/rcris/ and search for small quantity generators under the RCRA Info database).

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 (2,200 pounds or about 275 gallons) of hazardous waste per month. Large-quantity generators are fully regulated under RCRA. The large-quantity generators, as of April 2005, in the city and within ¼ mile of its borders are listed in Table 5-7 below, and their locations are shown on Plate 5-1. A substantial release from the large-quantity generators immediately outside of the City's border could adversely affect the city similar to that from a generator within the city. Those large-quantity generators located within ¼-mile of the city are indicated by a plus sign (+) next to its name. Additional information on each of the permitted sites below is available at http://www.epa.gov/enviro/html/rcris/.

Table 5-7: EPA-Registered Large-Quantity Generator (LQG) Facilities in the Torrance Area

Facility Name, Address	EPA ID	RCRA Tons Generated
23930 40 Madison Street Warehouse 23930 Madison Street	CAR000156935	Not Available at this time
Alcoa Fastening Systems 3000 West Lomita Boulevard	CAD001946383	7,850*
Allied-Signal, Garrett Processing Division 19800 Van Ness Avenue	CAD097871982	Not Available at this time
American Honda Motor Co 1919 Torrance Boulevard	CAD981404676	12*
American Polystyrene Corporation+ 1225 West 196th Street	CAD048489306	Not Available at this time
Amp Inc. 435,455 & 365 Maple Avenue	CAD008495327	Not Available at this time
Avnet 2040 West Artesia Boulevard	CAD008474348	Not Available at this time
Bachem Inc. 3132 Kashiwa Street	CAD077243640	421*
Ball Metal Beverage Container 500 Crenshaw Boulevard	CAD009537200	97#
Boeing Electron Dynamic Devices Inc. 3100 West Lomita Boulevard	CAD041666819	189*
Boeing Satellite Systems Inc. 3100 West Lomita Boulevard	CAR000160770	Not Available at this time
Chevron 93512 5550 West 190th Street	CAD983583238	6*
Classic Cleaners 2833 Pacific Coast Highway	CAD981614951	Not Available at this time
Commonwealth Aluminum Torrance Coil Coating 2303 Jefferson Street	CAT010013477	8*
ConocoPhillips Torrance Tank Farm 2650 Lomita Boulevard	CAT000625301	3*
Cushion Cut Inc. 2565 West 237th Street	CAD009657776	0.4#
Douglas Aircraft Company+ 19503 S. Normandie Avenue	CAD086510005	254*
Dow Chemical Company Torrance Facility 305 Crenshaw Boulevard	CAD009547050	568*
El Camino Community College District+ 16007 Crenshaw Boulevard	CAD981691637	12*
Electrolux Construction Products 2012 Abalone Avenue	CAR000149088	Not Available at this time
Elm Street Water Yard 1001 Elm Street	CAR000151738	Not Available at this time
ExxonMobil Oil Corporation+	CAL000056160	4*

Facility Name, Address	EPA ID	RCRA Tons Generated
21700 South Vermont Avenue		
ExxonMobil Oil Corporation 18200 Crenshaw Boulevard	CAL000056167	3*
ExxonMobil Oil Corporation Torrance Refinery 3700 West 190th Street	CAD008354052	881*
General Motors Advanced Techincal Vehicle 3050 Lomita Boulevard	CAR000052894	7*
Geron Furniture Inc.+ 19808 South Normandie Avenue	CAD054869557	2*
Global Communication Semiconductors Inc. 23155 Kashiwa Court	CAL000188396	784*
Harbor UCLA Diagnostic Imaging+ 21828 South Normandie Avenue	CAD982401648	Not Available at this time
Harbor UCLA Medical Center+ 1000 West Carson Street	CAD079605366	Not Available at this time
Hi Shear Corporation 2600 Skypark Drive	CAD990843377	113*
Honeywell Inc. 2525 West 190th Street	CAD071896336	113*
Honeywell International Inc. 20225 Western Avenue	CAT080010663	6*
JCI Jones Chemicals Inc.+ 1401 West Del Amo Boulevard	CAD008352205	17*
Magnavox Electronic Systems Company 2829 Maricopa Street	CAD099457061	Not Available at this time
Major Paint Company 4300 West 190th Street	CAD006914469	Not Available at this time
Martin Marietta Technologies Inc.+ 19200 South Western Avenue	CAD030398622	0#
Mercedes-Benz Of South Bay 3233 Pacific Coast Highway	CAD981682545	Not Available at this time
Mobil Oil Corp Product Pipeline Facility Undefined Address	CAT080010564	Not Available at this time
Montrose Chemical Corporation+ 20201 South Normandie Avenue	CAD008242711	Not Available at this time
Moog Inc. Torrance Operations 20263 Western Avenue	CAD982437089	41*
Motorcar Parts and Accessories Inc 2929 California Street	CAD982052326	Not Available at this time
Pall Rochem 3904 Del Amo Boulevard, Suite 801	CAD983641697	Not Available at this time
Panasonic Disc Manufacturing Corporation 20608 Madrona Avenue	CAR000031393	85*
Pasminco Inc. 22219 South Western Avenue	CAD982029225	Not Available at this time
Phenomenex Building 1 2320 West 205th Street	CAR000055020	Not Available at this time
Photo Sciences Inc. 2542 West 237th Street	CAD982462839	171*
Polypeptide Laboratories 365 Maple Avenue	CAR000030080	334*
PPG Industries Inc. Torrance	CAD008323438	335#

Facility Name, Address	EPA ID	RCRA Tons Generated
465 Crenshaw Boulevard		
RR Donnelley & Sons Company+ 19681 Pacific Gateway Drive	CAD098627516	8#
Raytheon Systems Company Sensors and Electronics 24120 Garnier Street	CAD982462012	33#
Redman Equipment & Manufacturing Company+ 19800 Normandie Avenue	CAD008247900	16*
Robinson Helicopter Company 2901 Airport Drive	CA0000372243	30*
Shell Service Station 3101 Artesia Boulevard	CAR000126425	Not Available at this time
Shell Service Station 18910 Crenshaw Boulevard	CAR000080622	Not Available at this time
Shell Service Station 136178+ 22930 South Western Avenue	CAD981405558	6*
Shell Service Station 136182+ 25904 Rolling Hills	CAR000107318	6*
Site A 2545 West 190th Street	CAR000103259	29*
Spectrum Plating Company LLC 527 Van Ness Avenue	CAR000054056	35*
Star Biochemicals Inc. 20910 Higgins Court	CAD982522427	25*
Stewart Filmscreen Corporation+ 161 West Sepulveda Boulevard	CAR000001958	17*
Threebond International Inc. 20815 Higgins Court	CAD062095500	24#
Union Carbide Corporation 19206 Hawthorne Boulevard	CAD081735755	Not Available at this time
Union Carbide Corporation 19500 Mariner Avenue	CAD008388894	4*
Vertex Microwave Products Inc. 3111 Fujita Street	CAD982023087	2*
Vought Aircraft Industries Inc. 640 Alaska Avenue	CAD000627224	16*
Vought Company 2135 Dominguez Avenue	CAD000627281	Not Available at this time
Vought Company 2203 Dominguez Avenue	CAD000627349	Not Available at this time
Younger Optics 2925 California Street	CAL000168014	0*

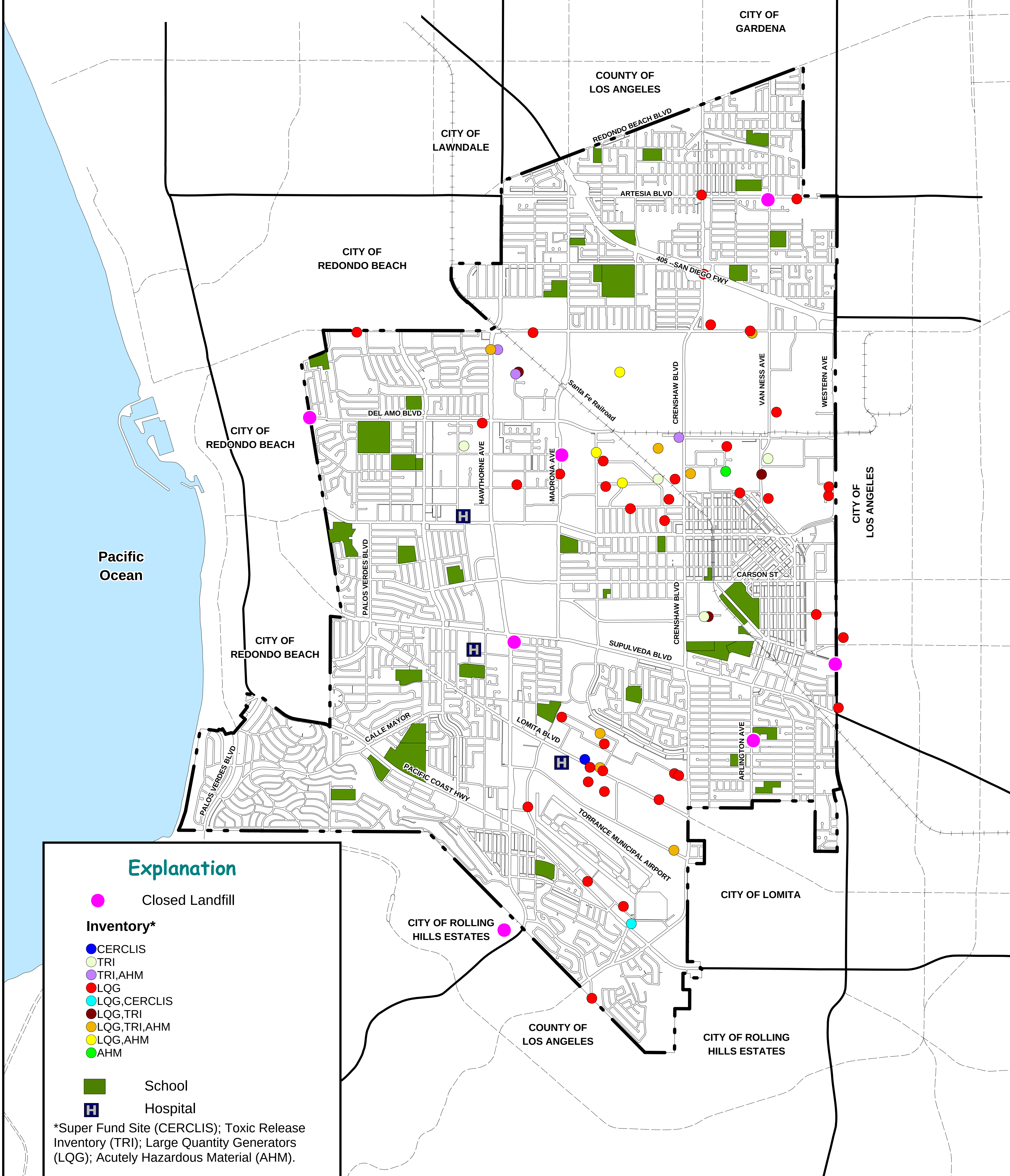
Sources:

*List of Large Quantity Generators in the United States: The National Biennial RCRA Hazardous Waste Report (Based on 2001 Data); and

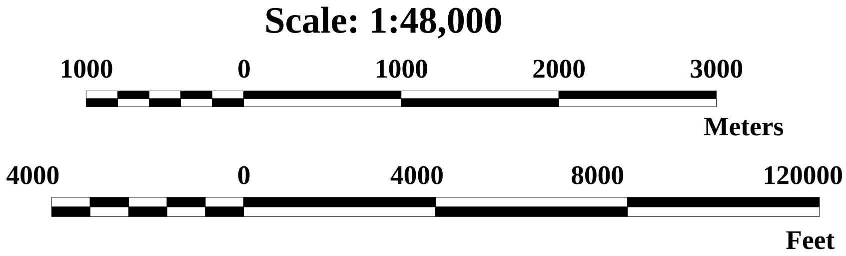
#List of Large Quantity Generators in the United States: The National Biennial RCRA Hazardous Waste Report (Based on 1999 Data).

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.



Scale: 1:48,000



Torrance City Limit

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Sources: United States Environmental Protection Agency 2005; California Integrated Waste Management Board (http://www.ciwmb.ca.gov/), 2005; City of Torrance, 2005. List of Large Quantity Generators in the United States: The National Biennial RCRA Hazardous Waste Report (Based on 2001 and 1999 Data).

Earth Consultants International

Project Number: 2431
Date: July, 2005

Hazardous Materials Site Map

Torrance, California

Plate 5-1

In addition to the facilities listed in Table 5-7 above, the following businesses and facilities in Torrance have been reported as large-quantity generators in years prior to 2001:

- Motorcar Parts and Accessories Inc. - 2727 Maricopa;
- Motorcar Parts and Accessories Inc. - 2929 California Street;
- Costco Wholesale No. 476 - 2751 Skypark Drive;
- Garrett GE Engine Services Corp Aviation Inc. - 20251 South Western Avenue; and
- Garrett Engine Boosting Systems - 3201 West Lomita Boulevard.

As reported elsewhere in this document, some of these businesses may have since ceased their operations in Torrance.

5.4.5 Hazardous Materials Disclosure Program

Both the Federal Government (Code of Federal Regulations, EPA, SARA and Title III) and the State of California (California State Health and Safety Code, Division 20, Chapter 6.95, Sections 25500–25520; California Code of Regulations, Title 19, Chapter 2, Sub-Chapter 3, Article 4, Sections 2729-2734) require all businesses that handle more than a specified amount of hazardous materials or extremely hazardous materials, termed a reporting quantity, to submit a hazardous materials Emergency Response Business Plan (ERBP) to its local Certified Unified Program Agency (CUPA). The CUPA with responsibility for the City of Torrance is the Los Angeles County Fire Department, with the Torrance Fire Department listed as the local participating agency for the CUPA program.

ERBPs are designed to be used by responding agencies, such as the Torrance Fire Department, during a release to allow for a quick and accurate evaluation of each situation for an appropriate response. ERBPs 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 such decisions as evacuating the surrounding areas. A Hazardous Materials Analyst with the Torrance Fire Department's Hazardous Materials Division reviews annually submitted ERBPs.

ERBPs need to be submitted by any business that uses, generates, processes, produces, treats, stores, emits, or discharges a hazardous material in the following reportable quantities:

- 55 gallons of more of a liquid,
- 500 pounds or more of a solid, and/or
- 200 cubic feet or more of (compressed) gas.

Any new business that meets the criteria above must submit a full hazardous materials disclosure report that includes an inventory of the hazardous materials generated, used, stored, handled, or emitted; and emergency response plans and procedures to be used in the event of a significant or threatened significant release of a hazardous material. The ERBP needs to identify the procedures to follow for immediate notification to all appropriate agencies and personnel in the event of a release, identification of local emergency medical assistance appropriate for potential accident scenarios, contact information for all emergency coordinators of the business, a listing and location of emergency equipment at the business, an evacuation plan, and a training program for business personnel. On subsequent years, once the full contingency plan is on file at the Fire Department, and if nothing has changed, businesses are allowed to submit an ERBP Certification Checklist, which is part of a hazardous materials reporting packet available at the Department or its website at www.ci.torrance.ca.us/ city/dept/fire/hazpack.html. The Fire Department conducts yearly inspections of all these businesses to confirm that their business plan is in order and up-to-date.

As discussed above, one of the main reasons that businesses are required to submit information regarding the specific compounds used in their facilities is that Fire Departments need this information to respond appropriately in the event of a fire. 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 above 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 CO_2 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. CO_2 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 CO_2 reacts with these materials. CO_2 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 #5 is the designated Hazardous Materials (HAZMAT) Response Unit headquarters for the city of Torrance, with personnel from Station #6 cross-trained in hazardous materials response to provide backup (see Chapter 4, Section 4.3). Fire Station #5 is responsible for the deployment of the necessary equipment to contain runoff from a chemical fire.

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 emergency response 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 Torrance Fire Department 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 document 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, and then call the Governor's Office of Emergency Services (OES) Warning Center at 1-800/852-7550. The City of Torrance has developed a Hazardous Materials Response Plan (known as Standard Operating Guideline – SOG) that establishes the responsibility of different responding agencies to any hazardous materials release incident. The Local Authority for scene management in the event of a hazardous materials spill is the Torrance Fire Department. The Fire Department's Hazardous Material Division's personnel that first respond to the incident make the decision to call in other agencies, depending on the situation. The Torrance Police Department also responds to the first call to assess whether there were any law violations or negligent acts that caused the incident, documenting the resources spent by the City for civil recovery, and documenting any exposures or injuries. The Police Department would also direct the evacuation of the surrounding area, if deemed necessary by the Fire Department.

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 (CERCLA - Superfund), 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); and
- 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; and
- Name and phone number of contacts to obtain additional information.

In the event of a release/spill, at a minimum, the following government agencies must be notified:

- Local Emergency Response agency (911 or Local Fire Department);
- The Certified Unified Program Agency (CUPA) (Los Angeles County Fire Department at 323/890-4045) and Participating CUPA Agency (Torrance Fire Department at 310/781-7000);
- Governor's Office of Emergency Services Warning Center (1-800/852-7550 or (916/845-8911); and
- California Highway Patrol (CHP) (911), only if the spill/release occurred on a highway.

In addition to the aforementioned notification 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 (310/732-2043) if the spill occurred in a waterway;

- California Occupational Safety and Health Administration (Cal/OSHA) (Torrance Enforcement District Office (310/516-3734) if serious injuries or harmful exposures to workers occurred during the spill;
- Department of Toxic Substances Control (DTSC) Cypress Regional Office (714/484-5300) 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; and
- 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, and
- Title 42, U.S. Code §9603, 11004.

The 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 aims to be proactive: 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 Torrance Fire Department is designated as the local administering agency for this program.

It should be noted that Torrance has developed a **Community Warning System** (TCWS) used to alert the community of a chemical release that has the potential to impact the area. In the event of a chemical emergency, the Fire Department has the responsibility of deciding whether or not areas of the community should be notified, and selecting the tools to be used for the notification procedure.

The TCWS includes:

1. community alert sirens on the ExxonMobil property that are used to alert residents within a 1.2 mile radius of the Torrance Refinery,

2. Crenshaw Boulevard barriers,
3. a Radio Alert Network (RAN) of tone-activated radios installed in large-occupancy facilities,
4. the Community Alert Network (CAN), which is a computerized telephone calling system, and.
5. emergency services provided by the Torrance Police and Fire Departments to isolate and secure affected areas.

The alert sirens at the ExxonMobil property are used when a chemical release poses a significant threat to the health or safety of a large segment of the community. The emergency release need not have occurred at the ExxonMobil property; the sirens can be used in response to an emergency at the refinery or any other local facility. When used, the sirens will wail continuously for several minutes, followed by a break, followed by additional continuous wailing. These sirens are tested on the first Wednesday of every month at approximately 11:30 A.M. When the sirens are being used (other than during testing), residents are to Shelter in Place, that is, stay indoors with windows and doors closed and air conditioning units turned off, until the area is given the "all clear" by the Fire Department. Chimes (such as the Westminster Abbey chimes) are used to signal the "all clear," once the emergency has passed.

Street closure barriers (similar to railroad barriers) on Crenshaw Boulevard are activated by the Police Department to prohibit vehicular access to the area between 190th Street and Del Amo Boulevard in the event of a chemical release that has the potential to impact that street. Literature provided by the Fire Department indicates that "if the barrier goes down behind your vehicle, keep driving, unless emergency personnel direct otherwise." If the barriers prohibit your vehicle from entering the affected area, stop and Shelter in Place until emergency service personnel direct you appropriately. In all cases, close windows and vents, and turn off the air conditioner or heater in your vehicle. If your engine stalls, do not start the engine, unless directed otherwise by emergency service personnel. Tune your radio to 1620 AM CitiSounds to listen for further instructions.

The Radio Alert Network (RAN) consists of tone-activated, one-way communication devices (radio receivers) that can be placed on a table or desktop. The system is designed to provide emergency response information to facilities with large populations, such as schools, day care facilities, convalescent homes and senior centers, enabling them to mobilize their charges to a safe location, as appropriate, as expeditiously as possible. When a chemical release or other emergency situation occurs, the Torrance Fire Department will activate the radio receivers and transmit emergency information and instructions. The Fire Department provides information on where to go, and what to do, and when the danger is over, delivers a message of "all clear, emergency over." Tone-activated radio receivers are available for purchase from the Torrance Fire Department.

The Community Alert Network (CAN) is a computerized telephone calling system that can automatically dial the phones of residences and businesses within the area identified by the Fire Department as being at risk from the chemical release (or other emergency that could affect a large segment of the population, like criminal activity).

The Fire Department uses this tool if the affected area can be clearly identified, and the calls can be made with sufficient time to warn the potentially affected population. A recorded message identifies the emergency and tells people what to do. Follow the instructions in the pre-recorded message. When the danger is over, the Fire Department will deliver a message of "all clear, emergency over." The Fire Department notes that some voice mail systems, answering machines, and residents with unlisted numbers are not able to receive the recorded message, and suggests that those with automated switchboards and unlisted numbers contact and submit a direct-line number to the Fire Department's CAN Administrator (1701 Crenshaw Boulevard, Torrance, California 90501). Unlisted numbers are held in confidence.

In addition to the Crenshaw Boulevard barriers, the Police and Fire Departments may close other roads to isolate and secure affected areas, and evacuate people and businesses. In these cases, the police or fire officials will issue case-specific instructions; people should follow these instructions closely.

5.5 Leaking Underground Storage Tanks (LUSTs)

Leaking underground storage tanks (LUSTs) or LUFTs (leaking underground fuel tanks) 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 are available 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 tanks with flexible connections and monitoring systems. Many older tanks were single-walled steel tanks that have 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 most recent State Water Resources Control Board's (SWRCB) Leaking Underground Fuel Tank (LUFT) GeoTracker database, dated April 2005 (available at http://geotracker.swrcb.ca.gov/), 115 LUFT cases have been reported in the Torrance area between 1978 and 2005. Of these, according to the LUFT database, 56 sites have been remediated and closed, leaving 51 cases still open. The open cases are listed in Table 5-8, below. Please note however, that this list is reportedly not updated as often as necessary, so several of the cases in Table 5-8 may be further along in the assessment and remediation process than the list indicates, and some of the cases may already be closed.

Table 5-8: Leaking Underground Storage Tanks Reported in the Torrance Area

SITE NAME	ADDRESS	CASE No.	CASE TYPE	STATUS, CONTAMINANT	REPORT DATE
A Able Muffler (Abandoned)	1889 Torrance Blvd	121594-79	S	7, G	10-Nov-92
Alexair/Mission Air (Former Texaco)	2955 Airport Dr	905050107	S	5R, G	01-Jul-91
American Honda Motors Co. Building 320	1919 Torrance Blvd	905010198	O	3B, MTBE	01-Jan-04
Anza Torrance Shell	4437 Sepulveda	905030107	S	7, G	23-Jan-97
Arco #0154	3015 182nd St	905040089	O	7, G	14-Mar-89
Arco #0210	4000 Redondo Beach Blvd	905040061	O	7, G	14-Mar-89
Arco #1008	1210 Crenshaw Blvd	905010098	S	5C, G	09-Feb-98
Arco #1235	1800 Artesia Blvd	905040034A	O	5R, G	21-Aug-01
Arco #6171	23510 Crenshaw Blvd	905050034	O	5C, G	17-Jun-86
Caltrans Torrance Maintenance	18101 Bailey Dr	905040261	O	7, G	15-May-89
Chevron #9-1078	17405 Crenshaw Blvd	905040270	O	5R, H	03-Nov-99
Chevron #9-2770	4135 Pacific Coast Hwy	905050161A	S	5C, G	05-May-86
Chevron #9-5589	3604 Redondo Beach Blvd	905040198	O	7, G	26-Feb-93
Los Angeles County Municipal Court	825 Maple St	R-12717	S	1, D	22-Jun-94
D. Holman Revocable Trust	2186 Redondo Beach Blvd	905040070	O	5C, G	16-Mar-89
Exxon #7-6256	22501 Crenshaw Blvd	905050070	S	1, G	01-May-92
Exxon #7-8712	18201 Crenshaw Blvd	905040107	O	7, G	17-Apr-92
Fairchild Fasteners	3000 Lomita Blvd	905050216	S	3B, P	01-Jun-89
Fast Fuel #15 (Challenge Marketing)	2472 Pacific Coast Hwy	905010089	S	7, H	19-Apr-93
Great American Aircraft (Chevron Refueling Site)	2825 Earhart Apron	905050225	S	3B, G	10-Sep-98
Hi-Shear Corp	2600 Skypark Dr	905090025	O	3B, P	15-Mar-91
Hughes Aircraft	3100 Lomita Blvd	905050016	O	5C, S	08-Feb-85
Ken's Welding	807 Van Ness Ave	905010152	S	5C, WW	11-Oct-90
Madrona Car Wash	3405 Sepulveda Blvd	905030089	O	5C, G	18-Apr-92
Major Paint	4300 190th St	905040016	O	7, S	18-Nov-83
Mobil #11-L9N	1640 Crenshaw Blvd	121594-78	S	3B, G	04-Feb-94
Mobil #17-L9C	3006 Sepulveda Blvd	004029	S	1, G	24-Mar-86
Mobil #18-ECP (Former #11-ECP)	19009 Crenshaw Blvd	905040161	O	5C, G	08-Apr-87
Mobil #18-EDP (Former #11-EDP)	18203 Western Ave	905040225	O	7, H	26-Sep-96

SITE NAME	ADDRESS	CASE No.	CASE TYPE	STATUS, CONTAMINANT	REPORT DATE
Mobil 11-MRK	24510 Hawthorne Blvd	905050243	S	3B, G	30-Jul-02
Mobil 18-D9E	18200 Crenshaw Blvd	905040207	O	7, G	14-Sep-90
Mobil 18-L81	20306 Anza Ave	905030116	S	3B, G	20-Mar-86
MOOG Inc./Allied Signal (Former)	20263 Western Ave	SLIC338	S	7, ED	01-Feb-89
Peyton Cramer Mazda (Former)	4343 190th St	905040289	S	3A, WO	23-Mar-00
PPG Industries, Inc.	465 Crenshaw Blvd	905030170	O	7, G	26-May-99
S & M Moving Systems	1915 Abalone Ave	905010170	S	1, G	25-May-99
Shell Service Station	3101 Artesia Blvd	905040043A	S	7, H	11-Nov-02
Texaco	3900 Sepulveda Blvd	905030034	S	1, G	07-Sep-93
Texaco	18910 Crenshaw Blvd	905040216	O	5C, D	01-May-90
Texaco #1228 (Inactive)	3960 Artesia Blvd	905040052	O	5C, G	20-Oct-88
Texaco Service Station	23140 Hawthorne Blvd	905050234	S	3A, G	20-Mar-00
Theim Industries	1918 Artesia Blvd	081189-03	O	1, G	15-Jul-89
Torrance Car Wash	2476 Sepulveda Blvd	905010116	S	3B, D	02-Sep-94
Tosco - 76 Station #4599 (Former)	3971 Artesia Blvd	905040152	O	7, G	25-Aug-92
Tosco - 76 Station #5096	25905 Rolling Hills Rd	905050061	O	5R, G	25-Feb-86
Toyota Motor Sales	19001 Western Ave	905090043	S	1, D	13-May-86
UCC/Linde Division	19200 Hawthorne Blvd	905030134	S	3A, A	08-Dec-86
Unocal #5273 (Former)	2976 Sepulveda Blvd	905030043A	O	3B, G	31-Oct-02
Unocal #6075	1875 190th St	905040170A	O	5C, G	12-Mar-97
West Torrance Shell	20305 Anza Ave	905030189	S	1, G	14-Dec-00
Yniguez Family Trust	18145 Crenshaw Blvd	905040143	O	3B, G	02-Jan-93

Source: GeoTracker (http://geotracker.swrcb.ca.gov/)
Abbreviations Used for Case Type: S = Soil contaminated; **O** = ground water not used for drinking contaminated.
Abbreviations Used for Contaminant: G = Gasoline; D = Diesel, H = Hydrocarbons; S = Solvents; A = Acetone; P = Perchlorethylene; WO = Waste Oil; WW = Waste Water; MTBE = Methyl-tert-butyl-ether; ED = Ethylene dichloride.
Abbreviations Used for Status: 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.

It is also important to note that none of the leaks that have been reported in Torrance have impacted a drinking source of ground water. Of the cases listed in Table 5-8, 26 impacted ground water that is not used for drinking purposes, and the rest impacted the surrounding soil only.

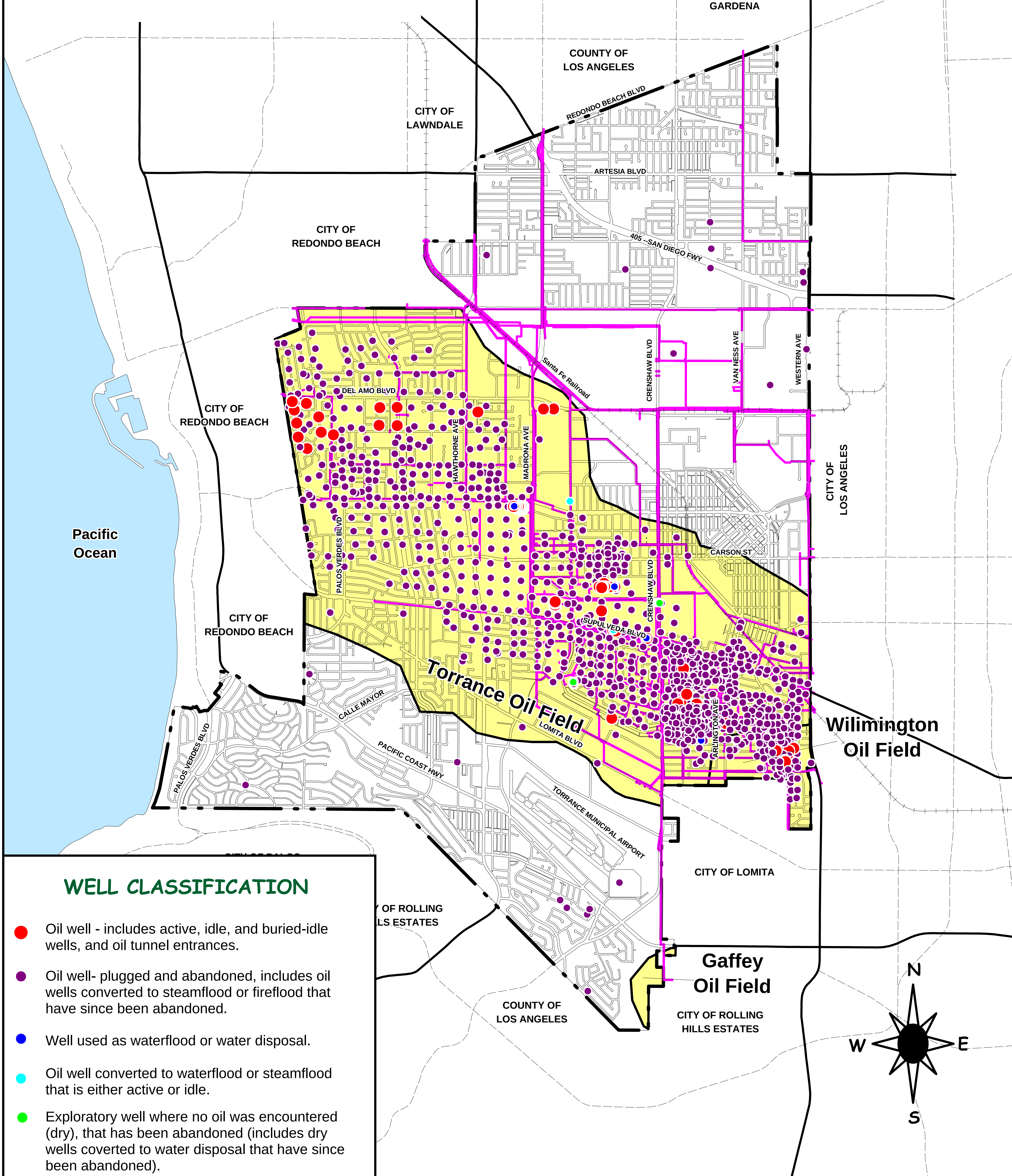
5.6 Household Hazardous Waste and Recycling

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).

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.



WELL CLASSIFICATION

- Oil well - includes active, idle, and buried-idle wells, and oil tunnel entrances.
- Oil well- plugged and abandoned, includes oil wells converted to steamflood or fireflood that have since been abandoned.
- Well used as waterflood or water disposal.
- Oil well converted to waterflood or steamflood that is either active or idle.
- Exploratory well where no oil was encountered (dry), that has been abandoned (includes dry wells coverted to water disposal that have since been abandoned).

Scale: 1:48,000

1000 0 1000 2000 3000 Meters

4000 0 4000 8000 120000 Feet

Torrance City Limit

Oil / Gas Pipeline

Base Map: City of Torrance (2005).
Sources: California Division of Oil, Gas, and Geothermal Resources (2005).

A BALANCED CITY TORRANCE INDUSTRIAL-RESIDENTIAL-COMMERCIAL

Earth Consultants International

Project Number: 2431
Date: July, 2005

Oil Fields and Oil Wells

Torrance, California

Plate 5-2

Insert Plate 5-2: Oil Fields, Oil Wells

The Torrance Oil Field underlies a large portion of Torrance, extending between the city's east and west borders, and from about Lomita Boulevard on the south to approximately the BNSF railroad right-of-way on the north. The Chanslor-Canifield Midway Oil Company completed the discovery well, Del Amo No. 1, on June 6, 1922, at a depth of 3,500 feet. Initial production from this well was 300 barrels (bbl) of oil per day. Although slow to develop at first, the region boomed after several large wells were completed in Lomita. By May 1924, a peak production of 72,000 bbl daily from 345 wells had been reached. Then, on July 22, 1936, the Chanslor-Canifield Midway Oil Company opened a deeper pay zone when the Del Amo No. 23 well was completed at a depth of 4,887 feet. Wells from the deeper zone reached a daily production of up to 700 bbl. By January 1941 the Torrance Oil Field was the largest in the Los Angeles Basin, covering an area seven miles long and one mile wide, with approximately 1,200 wells drilled into it and having produced an estimated total of 100 million bbl of oil. By September 1941, there were 656 flowing wells producing 9,277 bbl of oil daily. However, by then the Torrance Field had become a flush field with many of its early wells too unprofitable to operate. As of December 2003, there were still 122 wells producing 379,681 bbl of oil and 77,703 million cubic feet (cf) of natural gas. Also, at the end of 2003, the field was estimated to have 7,653 million bbl and 2,018 million cf of oil and gas reserves, respectively (California Division of Oil, Gas and Geothermal Resources, 2003 Annual Report).

5.7.1 Environmental Hazards Associated with Oil Fields

Petroleum contains several components that are considered hazardous by the State of California, such as benzene, a known carcinogen. Oil field activities often include the use of hazardous materials like fuels and solvents. Day-to-day practices in some of the earlier oil fields were not environmentally sensitive, and oil-stained soils and other contaminants can often be found in and around oil fields. This typically becomes an issue when the oil field is no longer economically productive, and the property becomes a valuable real estate asset if developed, usually for residential purposes. Assessing the feasibility of developing an oil field property requires comprehensive site investigations in order to accurately identify and characterize any soil and groundwater contamination that may have resulted from the oil field operations. These site investigations are required by local and/or regional environmental laws and regulations, and vary in scope according to applicable government regulations, generally accepted standards of practice, and site-specific conditions (Fakhoury and Patton, 1992).

The major areas of potential environmental concern associated with oil and gas production include:

Oil spilled adjacent to oil wells: Oil-stained soil (often discolored) that occurs around oil wells and the pumping units. Although none of the wells in Torrance have been reported to have spilled oil leading to adverse environmental conditions, it could happen if not monitored closely. For example, an oil well spill in Newport Beach (South Basin Oil Co. Well #1) led to its listing as a Superfund site.

Heavy metals and oil contained in sumps, pits and spill containment areas: In many oil fields, sumps were often used in the construction and maintenance of wells. Sumps are usually earthen berms constructed to contain the waste products from drilling and well completion operations. Alternatively, drilling waste materials are piped to or disposed of in metal or concrete containers. Typical waste materials consist of petroliferous cuttings, drilling fluid, additives, formation water, sludge, and crude oil. Drilling fluid typically consists of a water-based clay suspension with various chemical additives. Additives may have included any variety of heavy metals, such as arsenic, which was used as a corrosion inhibitor, or chromium and barite, which were used as weighting compounds.

Wells and Cellars: Wells and cellars are often built around wells to collect oil spilled during well maintenance or equipment malfunction, but occasionally oil may spill outside the well cellar.

Oil releases from above ground and underground storage tanks: Oil-stained soils are often encountered adjacent to storage tanks. Releases may occur if a pipeline connected to the tank ruptures, if the tank itself is punctured or damaged, or during the transfer of crude between the storage tanks and transport vehicles. Released oil could impact the surrounding soils.

Oil releases from broken pipelines: Buried and aboveground pipelines often exist in oil fields. These pipelines carry crude oil, water, and natural gas from the oil wells to storage tanks. A pipeline rupture would result in the release of crude oil that could impact the surrounding soils. There are also pipelines transporting petroleum products offshore. A pipeline rupture of an offshore transmission line could threaten the Torrance Beach and shoreline, with a potentially significant negative impact on the local marine wildlife.

Spilled refined fuels used in the operation and maintenance of oil-field vehicles and generators, and boneyards (disposal sites): Oil fields often have an equipment maintenance area where equipment and supplies are stored and where generators and other pumping equipment are serviced. Refined fuel (gasoline, diesel) storage tanks are often present in these areas to supply fuel for the vehicles used in servicing and maintaining the oil field. Spills of refined product can impact the soil and ground water. Refined fuels pose a greater hazard to the environment than crude oil because the lighter hydrocarbon fractions present in refined fuels are more soluble and volatile, thereby posing a greater environmental and health hazard than crude oil. Some of the constituents in gasoline and diesel fuel, including benzene, toluene, ethylbenzene and isomers of xylene, are known to be harmful to human health.

Tank bottom material used to oil roads: Road oiling was historically a common practice in some oil fields to control dust. The oiling material was typically a residue consisting of water, oil, sediment and sludge from storage tanks. This material was sprayed on road surfaces.

Formation water spilled onto the ground surface: Formation water, often containing high concentrations of total dissolved solids (approximating saline water), is often produced as part of the development of an oil field (oil wells typically produce oil, gas and water in varying quantities). If large quantities of this saline water are disposed of onto the ground surface and the water infiltrates the soil, the water quality of any near-surface aquifers, as well as the underground drinking water source, could be impacted.

Natural Hydrocarbon Seeps: In some oil fields, the occurrence of near-surface or at-the-surface deposits of natural tar and tar-saturated sediments, or concentrations of methane at explosive or near-explosive limits also pose a constraint to development. No oil and gas seeps have been reported in the Torrance area to date, (California Division of Oil and Gas, 1987). The potential hazards of gas (methane) are discussed further below.

If these oil fields are ultimately developed into other uses, such as residential areas, those portions of the field with potential environmental concerns should be identified, and characterized by type and extent of contamination. Once established, a complete presentation of the findings, conclusions and recommendations should be done to determine risk assessments, feasibility studies and remedial action plans. The types of concern may include: crude oil, volatile organic compounds (VOCs), semi-VOCs, metals, and polychlorinated biphenyls (PCBs). The extent of contamination is investigated by conducting site inspections, and addressing the impacts of chemical discharge to both the soil and ground water.

5.7.2 Methane Gas

Methane is a naturally occurring gas that typically forms as a by-product of bacterial digestion of organic matter, and therefore, occurs ubiquitously, although generally at very low concentrations, in the air we breathe. If free of impurities, methane is colorless and odorless, and under normal atmospheric conditions, does not pose a health hazard, as it is not poisonous. However, at high concentrations, this gas is flammable, and at concentration of between 55,000 and 140,000 parts per million (ppm), it is explosively combustible. At very high concentrations it can cause asphyxiation due to oxygen displacement. Methane is not toxic below levels that would lead to asphyxiation. The fact that it is colorless and odorless makes it especially hazardous, as it cannot be readily detected without special sensors.

In the subsurface, methane forms in areas where organic-rich sediments, such as in a swamp, are undergoing bacterial decomposition. Because of its origin, this type of methane is referred to as "biogenic". A man-made example of such an area would be a landfill or dairy pasture. Methane and other natural gases can also form at great depth, where they are most often associated with petroleum deposits. Since this type of methane forms as a result of thermal (heat) alteration of petroleum and/or organic matter in the rocks, it is termed "thermogenic" or "petrogenic". Methane produced near the surface is generally at low to very low pressures, whereas that derived from oil-producing zones is generally at high pressures (Cobarrubias, 1992). There are numerous chemical characteristics of the gas that may reveal clues about its origin. However, the processes by which the gas forms and moves through the rocks or sediments are often very complex, altering and adding to the chemical characteristics of the gas. Consequently, it frequently becomes very difficult to determine the source. Some gases may be a combination of both thermogenic and biogenic processes.

Regardless of the environment in which it forms, methane is lighter than air, and therefore tends to migrate upwards through permeable sediments, rock fractures, and even man-made structures (such as well casings). If the geologic unit is permeable enough, the gases eventually reach the surface and mix with the atmosphere. Under certain conditions, the gas can become trapped under an impermeable layer. In nature, these impermeable layers are typically comprised of clay, claystone or similar fine-grained materials. As the gas accumulates under the impermeable layer, it can build up to high concentrations and pressures. Man-made structures, such as pavement or building foundations can also prevent gas from venting to the atmosphere. Methane can accumulate in the upper reaches of poorly ventilated building components, such as basements, crawlspaces, and attics, sometimes with catastrophic results. For example, in 1985, there was a methane gas explosion and fire in the Fairfax area of Los Angeles (in the former Salt Lake oil field) that resulted from gas trapped beneath the pavement.

Following the Fairfax incident and in response to the Methane Gas Hazards Reduction Act, the Division of Oil and Gas (now known as the Division of Oil, Gas and Geothermal Resources - DOGGR) conducted a survey and found that gas seeps are present in several southern California communities overlying oil fields (California Division of Oil and Gas, 1987). The survey concentrated on areas believed to have the greatest potential for leakage, and as a result, the Torrance Field was not tested because the field is under lower pressure than other fields. Also, the DOGGR does not conduct annual field inspections so current data on gas leakage are not available. Since the Torrance area has not been tested, it is possible that small gas seeps may be present in the area. This gas, if present, would consist primarily of methane, although small amounts of other natural gases may be part of the mix.

Mitigation of Methane Gas**:** Given the potential for combustible gases to accumulate in or under buildings or structures, the City of Torrance adheres to the established requirements of the DOGGR regarding the construction of buildings over abandoned oil wells. That is, no structure should be built over any oil wells, unless absolutely necessary, and then, proper venting above the roofline will be provide. Also, any structure to be built immediately adjacent to the surface location of a wellhead is required to adhere to the following regulations, designed for future re-abandonment of the oil wells, if necessary:

a) No structure or property line shall be closer than ten (10) feet to any two (2) adjacent sides of the said well; and
b) No structure or property line shall be closer than fifty (50) feet from the third (3rd) side of the said well; and
c) The fourth (4th) side shall have open access so that an oil well abandonment rig can be driven onto the site.

Another option for mitigating methane hazards is for the City is to establish a Hazard Area. Torrance's Municipal Code (Section 81.5.1 - Creation of Hazard Areas) allows the City Council to declare any area or parcels of land in the City a hazard area if a hazard exists which is materially detrimental to life or property and to the public welfare, and the provisions of the Building Code and grading laws of the City are insufficient to protect persons or property from such hazards. According to the provisions of Section 81.5.1, it is unlawful for any person to construct, erect or locate any building or structure or to excavate or fill earth or any other substance on land in a hazard area without approval from the appropriate agencies.

As mentioned above, the California DOGGR does not approve of placing buildings directly on top of an abandoned well. Specific tasks that can be undertaken to reduce the hazard of methane gas in an abandoned oil field include:

- Baseline Study – Prior to grading, a baseline study can be performed to gain a better understanding of the current distribution and concentrations of methane in the area proposed for development. This study can include soil gas sampling and analysis performed by a methane consultant. Since the distribution of methane can change with depth, the consultant's report should include a work plan for further investigation during grading, including sampling intervals, procedures, and potential mitigation measures that might be implemented during grading.

- Excavation Sampling – During grading, soil gas sampling and analysis should be performed on the bottom of all excavations in the development area. This would include cuts to design grade, overexcavation of building pads, the bottoms of areas where unsuitable foundation soils have been removed, buttress cuts, etc. "Bottoms" sampling should also be conducted at each well location. The sampling and analysis should include a determination of gas pressure, hydrocarbon concentration, and chemical composition. If anomalous, and potentially hazardous gas seeps are identified, the methane consultant shall recommend specific remedial measures.

- Evaluation of Subsurface Structures - During grading, any subsurface structures that may act as a conduit for methane gas (such as sewer lines, storm drains, subdrains, etc.) should be evaluated by the methane consultant with respect to the local conditions. The methane consultant should provide specific remedial recommendations, such as venting, as needed.

- Documentation of Oil-Impacted Fill Placement – Full-time monitoring of the grading activities should be provided by the environmental consultant in order to document the depth, lateral extent, and concentrations of any crude oil-impacted fills. This information should be provided to the methane consultant for evaluation and consideration in the final methane remedial recommendations.

- Abandoned Oil Wells – All non-operational oil wells should be properly abandoned or re-abandoned to conform with the current DOGGR standards and subjected to DOGGR inspections. During grading, venting systems for abandoned oil wells should be constructed in accordance with recommendations and guidelines from the DOGGR and to the satisfaction of Torrance's Director of Building and Safety. Building placement should not be allowed directly over an abandoned well.

- Final Grade Soil Gas Survey – At the completion of grading, and prior to the issuance of building permits, sampling and analysis should be performed by the methane consultant at future building locations. Based on the data collected prior to, during, and at the completion of grading, the methane consultant should make final recommendations for methane mitigation during construction. The analysis and recommendations should consider the guidelines recommended by the DOGGR as minimum requirements. Any deviations from the guidelines should be supported by scientific evidence, and approved by the City's Director of Building and Safety.

- Maintenance/Monitoring Manual – Prior to the issuance of occupancy permits, the methane consultant should prepare a manual describing the responsible parties, upkeep, monitoring program, record-keeping required, and reporting required with respect to the methane mitigation installed within the project. The report should include a map showing the locations of all monitoring wells, vents, or other pertinent structures.

- All methane investigations and analyses should be performed by a California registered engineer and/or geologist with demonstrated proficiency in the subject of soil gas investigation and mitigation. All methane reports, work plans, mitigation plans, and monitoring plans are subject to the review and approval of the City of Torrance. An independent third party review could be required at the discretion of the City.

In addition to methane gas associated with oil fields, methane gas is also produced by active and old abandoned landfills. There are no active landfills within the Torrance city limits, however, there are nine closed landfills listed on the California Integrated Waste Management Board website at http://www.ciwmb.ca.gov/ (see Plate 5-1) that are near the city. Those closed sites are listed below:

- Royal Boulevard Land Reclamation Site, 20950 South Royal Boulevard
- Gardena Valley Dump #4 - Alpine Village, 833 West Torrance Boulevard
- Higgins Brick & Tile Co. West, 2200-2214 West Artesia Boulevard
- Standard Oil Company DS, southeast corner of Sepulveda and Hawthorne Boulevards
- Sunnyglen Construction Company, north of Del Amo Boulevard and east of Prospect Avenue
- Plaza Del Amo Landfill, 1700 Plaza Del Amo
- Torrance Sump, 233rd Street, northeast corner of 233rd Street and Arlington Avenue
- Disposal Gardens (AKA Torrance Sand & Gravel), north flank of Palos Verdes Hills
- Torrance Municipal Dump, 20466-20500 Madrona Avenue

The closure dates of the Royal Boulevard Land Reclamation Site and the Plaza Del Amo Landfill are 12/31/1987 and 12/31/1953, respectively. The Gardena Valley Dump #4 closed in 1994 and is currently undergoing an environmental assessment for possible listing in the NPL (superfund site – see Section 5.4.2). The closure dates of the other landfills were not available when this report was written. Information regarding the type of waste, liner type, etc. for each of these landfills was also not available, most likely because these sites pre-date the permitting and environmental regulations now applicable to landfills. Moreover, that these landfills appear to pre-date the current regulations suggests that they are not equipped with any type of methane gas collection and/or monitoring systems. Since methane is a common by-product of landfills, there is a high potential for shallow methane to be present in these areas. Mitigation measures for gas seepage from these landfills are similar to those employed in natural (oil) gas seepage areas, except that geotechnical issues associated with differential settlement of the refuse also need to be considered. In landfills where hazardous materials were accepted, such as the Gardena Valley Dump #4, far more stringent requirements apply to ensure that leachate from the landfill that may contain hazardous waste does not impact the ground water.

5.8 Hazardous Materials Incidence Response along Transportation Routes and Due to Pipeline Failures

Torrance is intersected by several major transportation routes, including the San Diego Freeway (Interstate 405), and the Santa Fe Railroad, and Pacific Coast Highway (State Highway 1). The Interstate 405 and the railroad track are used to transport hazardous materials, posing a potential for spills or leaks from non-stationary sources to occur within the area. Trucks and trains carrying hazardous materials are required to have placards that indicate at a glance the chemicals being carried, and whether or not they are corrosive, flammable or explosive. The conductors are required to carry detailed "material data sheets" for each of the substances on board. These documents are designed to help emergency response personnel assess the situation immediately upon arrival at the scene of an accident, and take the appropriate precautionary and mitigation measures. The California Highway Patrol is in charge of spills that occur in or along freeways, with Caltrans, and local sheriffs and fire departments responsible for providing additional enforcement and routing assistance.

While train derailment can occur at anytime, it is during an earthquake that a derailment and hazardous materials release would result in the greatest impact. 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. A derailment in the Northridge earthquake included a train with 29 cars and one locomotive. One of 13 tank cars spilled an estimated 2,000 gallons of sulfuric acid, and 1,000 gallons of diesel fuel spilled from the locomotive.

Additionally, several oil and gas lines extend through the city (see Plate 1-5). Rupture of any portion of these pipelines would adversely impact the area. Pipeline operators are responsible for the continuous maintenance and monitoring of their pipelines to evaluate and repair, when necessary, corroded sections of pipe that no longer meet the pipeline strength criteria. All excavations or drilling operations near pipelines, or anywhere else, for that matter, should be conducted only after proper clearance by the appropriate utility agencies or companies. California law requires that all excavations be cleared in advance. This is done locally by the **Underground Service Alert of Southern California,** or **DigAlert.** The telephone number is **1-800-227-2600**. Calls need to be made at least two (2) working days before digging, and the proposed excavation area needs to be delineated or marked.

Pipeline failures during an earthquake are more often the result of permanent ground deformations, including fault rupture, liquefaction, landslides, and consolidation of loose granular soils. Therefore, those pipelines that extend across areas susceptible to liquefaction (see Plate 1-3), slope instability (Plate 1-3 and Plate 2-2), or are underlain by sediments susceptible to earthquake-induced settlement (youthful sediments in Plate 2-2), are most vulnerable to damage during an earthquake. Tectonic uplift or subsidence can also impact a pipeline. Seismic shaking typically has less of an impact on buried utilities than it does on above-ground structures, but still almost forty percent of the pipe ruptures reported in previous earthquakes can be attributed to seismic wave propagation effects (O'Rourke and Liu, 1999). This hazard is most prevalent in youthful sediments like those that underlie most of Torrance. Therefore, since these pipelines are located within 15 miles of three significant seismic sources in the southern California area, seismic shaking has the potential to significantly impact them. The type of material, age and health of these pipelines, also influence the amount of damage that the pipes may experience. Studies conducted by Eguchi (1991) [as referenced in O'Rourke and Liu (1999)] indicate that damage to X-grade welded steel pipes as a result of wave propagation is typically an order of magnitude less than that for ductile iron pipes, and nearly two orders of magnitude less than that for welded steel gas-welded joint, concrete or asbestos cement pipes.

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 Torrance Fire Department observes the 2001 version of the Uniform Fire Code (UFC), which identifies 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.

A list of the "Significant Hazardous Materials Sites" in the city of Torrance was compiled from the data reported in the sections above. With the exceptions noted below, the list includes facilities that are identified in the following City, State and/or Federal databases:

- Superfund-Active or Archived Sites (CERCLIS)
- RCRA/RCRIS-EPA Registered Large Quantity Generators
- Toxic Release Inventories (TRIs)
- Acutely Hazardous Materials (AHM) Facilities

There are 93 reported Significant Hazardous Materials Sites in the city of Torrance (see Tables 5-5, 5-6, and 5-7 above). Of these 93 sites, one is currently on the NPL (Superfund) with three other sites pending further review before possible listing (see Table 5-5), 20 are from the TRI database (see Table 5-6), and 68 are currently listed as Large Quantity Generators of hazardous waste (see Table 5-7). The City of Torrance has designated 18 sites as Acutely Hazardous Materials (AHM) facilities in the City's latest Emergency Operations Plan (City of Torrance, 2002). Their list of AHM facilities includes sites already included on the TRI and Large Quantity Generators tables (see Tables 5-6 and 5-7) provided earlier in this report. The AHM sites are shown on Plate 5-1. Furthermore, and more importantly, these lists are snapshots in time, and are often based on EPA data that date back to the late 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 as the data become available. In fact, several facilities that used to generate, use or store hazardous materials in Torrance have since closed their plants, and those sites have now been redeveloped into other, cleaner uses.

Located throughout the city of Torrance are 379 reported Small-Quantity Generators of hazardous materials. A comparison of the distribution of hazardous materials sites with the location of critical facilities (with emphasis on schools and hospitals) in the study area indicates that in most cases, critical facilities are located within one (1) mile of a significant hazardous site.

Most of the hazardous materials generators are located within five miles of the Palos Verdes fault. The active traces of the Palos Verdes fault through the southern portion of Torrance are not well documented, but a review of the Fault Map (Plate 1-2) suggests that there are no hazardous materials sites located on the fault. However, at least three sites (all large-quantity generators) on or near Pacific Coast Highway, near the city's southeastern corner (see Plate 5-1), are located within 200 to 600 feet of what is interpreted as the most active trace of the fault. These sites are anticipated to experience very strong ground motions, and possible surface deformation, if the Palos Verdes fault causes an earthquake. The remaining hazardous materials sites north of the Palos Verdes fault are not located astride any know active faults, therefore impact due to surface fault rupture at these sites is considered low to nil, although they would still experience strong ground motions, as discussed extensively in Chapter 1.

The city is also within 15 miles of the Newport-Inglewood and Puente Hills faults (near-source seismic sources). These faults, and the Palos Verdes fault, have a relatively high probability of generating an earthquake in the next 30 years. As a result, all of the hazardous materials sites in Torrance could be subject to moderate to severe seismic shaking. Their business plans should address and provide for and implement mitigation measures designed to reduce the potential for releases of hazardous materials during an earthquake.

It has been shown in previous urban earthquakes that hazardous materials spills can occur even when the buildings housing these materials do not suffer significant damage. Hazardous material containers not properly secured and fastened can easily be punctured and/or tipped over, pipelines may rupture, and storage tanks may fail. Containers may also explode if subject to high temperatures, such as those generated by a fire. Improperly segregated chemicals could react forming a toxic gas cloud. In a worst-case scenario, several hazardous materials releases could occur simultaneously.

> **Northridge Earthquake**. As a result of the 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).
>
> **Whittier-Narrows Earthquake.** The 1987 Whittier Narrows earthquake, a significantly smaller event than the Northridge earthquake, caused 22 hazardous materials situations, including the collapse of a chlorine tank that forced the evacuation of an area 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 do so than under non-earthquake conditions. Hazardous materials response teams responding to a release as a result of an earthquake 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.

In addition to fault rupture and strong ground shaking, another earthquake-related hazard is liquefaction. Liquefaction can occur when ground shaking from a moderate to large earthquake causes the pore pressure of saturated, loose, fine- to medium-grained soils (sand and silt) to suddenly increase, causing the soil to lose strength and behave as a liquid. When soils liquefy, the structures built on them can sink, tilt, and suffer significant structural damage. Potential liquefaction zones have been identified along the Dominguez Channel as it traverses the northern part of the city (see Plate 1-3). Fortunately, no Significant Hazardous Materials sites are reportedly located within the Dominguez Channel liquefaction susceptible area.

Schools and Hospitals Near Significant Hazardous Materials Sites. Torrance's Unified School District has 31 public schools located throughout the city. Twenty-two of these schools in the eastern and northern portion of the city are located within one (1) mile of a Significant Hazardous Materials Site (see Plate 5-1). Torrance Memorial Medical Center is located within about 2,000 feet of a Toxic Release Inventory (TRI) facility and a site being evaluated for inclusion on the NPL.

The TRI facilities 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 potentially hazardous chemicals used at a TRI facility are released into the atmosphere, evacuation of the surrounding area may be required. The TRI for the Torrance Latex Paint, Union Carbide Corporation facility reports the use of acrylonitrile at that site. This is a colorless, manufactured chemical that is currently used in the making of plastics, synthetic rubber, and acrylic fibers (in the past, this chemical was mixed with carbon tetrachloride to make a pesticide, but this type of pesticide is no longer manufactured). In a poorly ventilated area, release of acrylonitrile into the air can pose a health hazard, but when released into a ventilated area, such as the surrounding neighborhood, the chemical is quickly broken down by sunlight and other chemicals (its concentration is reduced in half within 5 to 50 hours of its release), or is incorporated back into the soil and water by rain, greatly reducing its health hazard (see www.atsdr.cdc.gov/tfacts125.html). Nevertheless, short-term evacuation of special need populations, such as children and the elderly, located near the source may be appropriate if this chemical is released into the air. The Torrance Latex Paint, Union Carbide Corporation facility is located within one mile of Edison Elementary School, Lynn and Magruder Middle Schools, Torrance North High School, and the Children's Center.

Since schools and hospitals have special evacuation needs, Significant Hazardous Material facilities 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. Similar mitigation measures should be considered for other facilities where the populations have special evacuation needs, such as nursing homes and child care centers. As discussed previously, the City's Fire Department manages a Community Warning System that includes a Radio Alert Network whereby facilities such as schools, childcare centers, and nursing homes are notified, via one-way radio receivers, of chemical emergencies.

5.10 Summary of Findings and Natural Hazards Overlays

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, storage, 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 agencies, are summarized below, as they pertain to the city of Torrance.

5.10.1 Summary of Findings

Air Quality: Data from the South Coast Air Quality District for the year 2002 show that the maximum allowable concentration of PM_{10}, based on the Annual Arithmetic Mean as defined by the State, was exceeded 12 times in 2002 (see Table 5-4) in the Southwest Coastal Los Angeles County area, which includes the city of Torrance. All other pollutants were below both Federal and State air quality standards. Air quality criteria are expected to become more stringent, however, as the results of recent studies indicate that air quality in many parts of the southern California area is still poor.

Drinking Water Quality: Two water agencies provide drinking water to the Torrance area. The two agencies are the Torrance Municipal Water Department and the California Water Service Company (a combination of the Rancho Dominguez and Hermosa-Redondo Districts). Neither of these agencies is listed on the EPA Safe Drinking Water Violation Report.

National Pollutant Discharge Elimination System (NPDES): In the city of Torrance, NPDES permits are issued by the California Regional Water Quality Control Board, Los Angeles region as part of their Storm Water Program. The City of Torrance holds a NPDES permit (No. CAS004001) to operate its municipal separate storm sewer system (MS4). The permit obligates the City to keep waterways clean by reducing or eliminating contaminants from storm water and dry-weather runoff. The City has a storm water education program, and an aggressive inspection team that issues citations for water quality violations, and requires the use of "best management practices" in many residential, commercial, and development-related activities to reduce runoff. The City also requires the use of "best management practices" in many residential, commercial, and development-related activities to reduce runoff.

Superfund Sites: According to the EPA, there are four Superfund sites in, or near, the city of Torrance (see Table 5-5), but only one of them is listed in the National Priority List (NPL). Furthermore, one of the sites is considered by the EPA as a "No Further Remedial Action Planned (NFRAP) site, while the remaining three sites are being evaluated by the EPA for inclusion or not on the NPL.

Toxic Release Inventory: According to the EPA records, there are twenty facilities in the Torrance area that are listed in the most recently available Toxics Release Inventory (TRI) list (see Table 5-6). TRI sites 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 South Coast Air Quality Management District also issues permits to facilities that emit chemicals, both toxic and non-toxic, into the atmosphere. These facilities include manufacturing plants, restaurants, hotels, dry-cleaners, and other small businesses.

Hazardous Waste Sites: According to the most recent EPA and City data available, there are 68 large quantity generators (see Table 5-7) and approximately 379 small quantity generators in the Torrance area. In addition, there are 12 transporters of hazardous waste with offices in the city. The number of small quantity generators is expected to increase if development increases in Torrance, since this list includes businesses like gasoline stations, dry cleaners, and photo-processing shops.

Leaking Underground Storage Tanks: According to data from the State Water Resources Control Board, 107 underground storage tank leaks have been reported in the Torrance area between 1978 and April 2005. Of these, according to the State's list, 56 sites have been either cleaned up or deemed to be of no environmental consequence, leaving 51 cases that are still open and in various stages of the remediation process. However, the leaking underground fuel tank list is not updated as often as necessary and some of the cases listed active may be already closed. None of the leaks that have been reported in Torrance have impacted a drinking source of ground water. The California Regional Water Quality Control Board provides oversight and conducts inspections of all underground tank removals and installation of new tanks.

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. Business plans are currently reviewed by the Torrance Fire Department, who also conducts annual on-site reviews of permitted businesses to confirm that the information in their business plans is current and correct.

Household Hazardous Waste: The County of Los Angeles and the Sanitation Districts of Los Angeles County operate five household hazardous waste collection centers throughout the County in accordance with the California Integrated Solid Waste Management Act of 1989 (AB 939). These centers are located in the cities of San Pedro, Playa del Rey, Boyle Heights, Sun Valley, and West Los Angeles. The San Pedro Center is closest to the City at 1400 North Gaffey Street. The County also sponsors numerous one-day local collection events throughout the County, with one generally located in Torrance. Also, residents of Torrance may turn in their used motor oil to a certified center and receive 16 cents per gallon or an equivalent coupon. Currently there are 13 certified centers in Torrance. For additional information go to www.torrnet.com/PublicWorks/Sanitation/oilrcyc.htm.

Oil Fields: The Torrance Oil Field underlies the central part of the city, extending from its east to west borders (see Plate 5-2). Hazardous materials are often associated with oil fields and related facilities. This is generally the result of poor practices in the early days of exploration, when oil cuttings, brine water, and other by-products were dumped onto the ground. The development of oil fields for residential or commercial purposes typically involves a detailed study to identify any areas impacted by oil or other hazardous materials, and the remediation of the property prior to development.

5.10.2 Hazards Overlays

The city of Torrance is a vital economic and residential region, where, especially in the older sections of the city, 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 only a few areas 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 zoning plan - 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 68 large-quantity and 379 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 471 active, permitted sites that are known to release toxic chemicals into the air – the EPA monitors these facilities closely to reduce the potential of future emissions at concentrations above the acceptable limits.

Strong ground shaking caused by an earthquake on one of the many faults in the region could cause the release of hazardous materials at any of the hazardous materials facilities in the city. 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. None of the significant hazardous materials sites are known to be located over the Palos Verdes fault, or within a liquefaction-susceptible area. There is only one hazardous materials site (a Toxic Release Inventory facility) in the city that is located on a flood-susceptible area, at the intersection of California Street and Alaska Avenue (compare Plates 3-1 and 5-1). Seasonal and intermittent shallow flooding in this area is not anticipated to pose a threat to this facility, but all hazardous materials should be stored in water-proof containers that are not likely to float and topple over in the event of flooding (whether as a result of a storm, or a break in a water main).

CHAPTER 6: AVIATION HAZARDS ASSESSMENT STUDY

6.1 Introduction and Scope of the Evaluation

The City of Torrance seeks to assess and identify the potential for small aircraft crashes in the city, and the impact of such an event on the health and safety of persons in the affected area, property, facilities, and infrastructure. This report will encompass each of these and discuss potential mitigation measures that can be taken by the city and its emergency response agencies to reduce the potential losses from this type of scenario.

6.1.1 City of Torrance

The City of Torrance was incorporated in 1921 and has a population of more than 138,000 (*US Census 2000)*. The city is located at 33°50'5" North, 118°20'29" West (33.834815, -118.341330) in the South Bay area of Los Angeles County. Torrance is the 4th largest city of the 88 cities in Los Angeles County, and the 12th largest city in California. Torrance covers an area of approximately 21 square miles (12,312 acres). The population density is 2,600/km (6,700/mi).

The city receives an average rainfall of 12.55 inches per year.

The median income for a household in the city is $56,500 and the median income for a family is $67,000.

Torrance is home to the U.S. headquarters of two of the three largest Japanese auto makers, Toyota Motor Sales, U.S.A. and American Honda Motor Company. Robinson Helicopters are designed and built in Torrance as are Garrett Systems turbochargers, used on automobile engines worldwide. California's aerospace industry began in Torrance and surrounding communities. Torrance was a major oil-producing region, once dotted with thousands of oil wells and oil derricks. The large ExxonMobil refinery in the north end of the city is responsible for much of Southern California's gasoline supply.

6.2 Torrance Municipal Airport - Zamperini Field

The Torrance Department of General Services handles the entire administration at the airport, whereas airport operations, including field maintenance, is handled by the Torrance Department of Public Works. The airport is located at 3301 Airport Drive, within the southeastern area of the city. Torrance Municipal Airport, also known as Zamperini Field, encompasses 500 acres of which 140 acres are leased at commercial rates for non-aeronautical purposes.

The airport has two runways and is used exclusively for general aviation. The first runway (29R-11L) is 5,000 feet long by 150 feet wide of asphalt paving, and the second runway (29L-11R) is 3,000 feet long by 75 feet wide of asphalt paving. The airport is 101 feet above sea level. The maximum weight per wheel is 20,000 lbs.

The airport generated approximately
- 428,000 flight operations in 1974,
- 356,000 flight operations in 1980,
- 243,000 flight operations in 1990, and
- 197,000 flight operations in 2004.

Each takeoff and landing is considered an operation.

The FAA tower at the airport operates from 7am to 8pm. From 10pm to 7am there is a curfew and there are no departures, except by exemption.

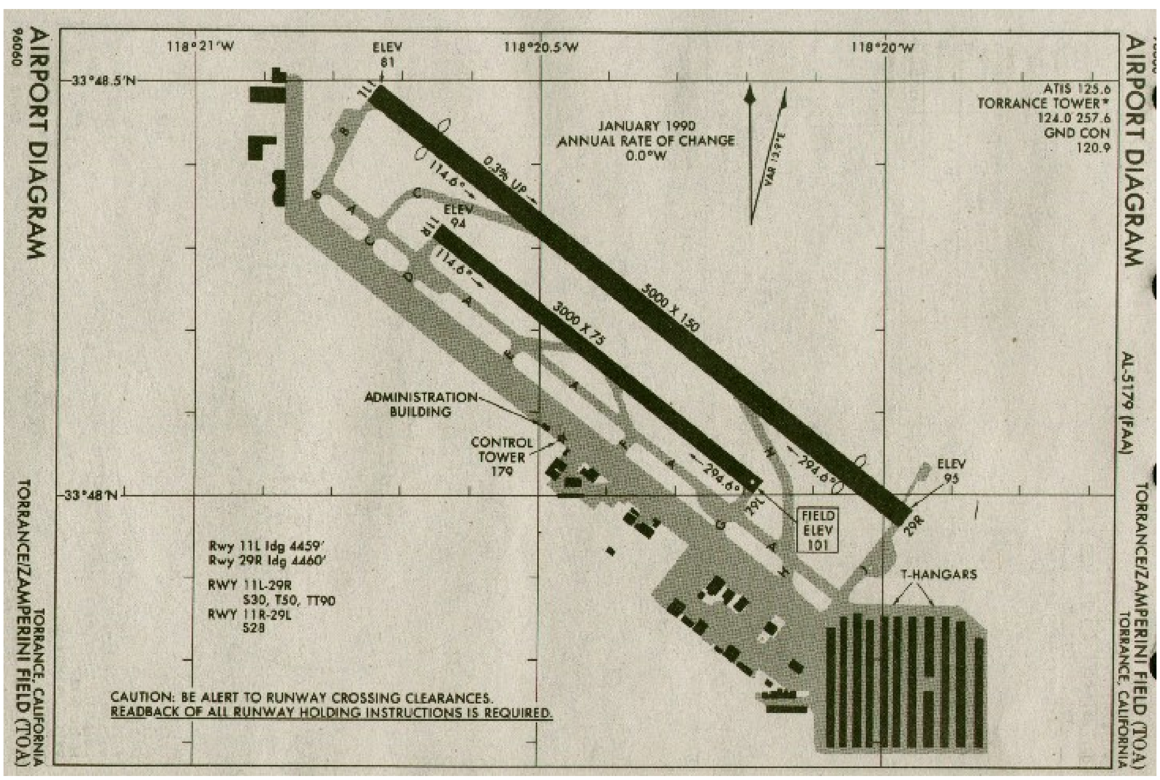
The airport administration is part of the General Services Department, while the airport field maintenance is handled by the Public Works Department. Airport operations consist of 7 members headed by a Supervisor.

The airport is surrounded by mainly 2-story commercial and industrial buildings, including warehouses. Robinson Helicopter Company is located on the airport but independent from airport operations and is therefore not part of this assessment.

6.2.1 Air Operations

The 197,000 flight operations in 2004 consisted mainly of single-engine planes, some twin-engine aircraft and a significant number of helicopters. The heavy helicopter traffic is due to the Robinson Helicopter Factory located on the airport premises. According to the Airport's Supervisor, corporate aircraft and business jets are rather rare.

General activity consists of planes landing on the runway and then taxing to a hangar, or taxing from a hangar to the runway and taking off. The largest plane accommodated is a Class III Type Aircraft, such as a Dissault Falcon. The field has previously accommodated a C130 for air shows, but not in the last few years.



6.2.2 Airport Personnel

Operations are handled by the seven members of the airport operations division within the Public Works Department. The airport personnel have limited training for emergency response and are required to attend a safety training course on a regular basis: a six-hour class provided by the City's Fire Department. Attendees reportedly receive a manual that covers procedures in spill containment, hazardous material, and the use of fire extinguishers. According to the Airport Supervisor, the FAA provides videos on airport safety procedures that are available for viewing by the airport's personnel. However, airport operations personnel have not been trained in Incident Command System.

Airport operations personnel have been issued protective equipment (safety gear with Nomex jackets, helmet, and gloves). The airport operations vehicle is equipped with fire extinguishers, tool-boxes, and other materials needed to respond to small fuel spills and minor accidents. The truck carries absorbent for about 7 to 10 gallons of fuel, hydraulic oil, or other fluids. The Torrance Fire Department (TFD) is called for every incident. Airport Operations maintains direct radio communication with the Air Traffic Control Tower and the Torrance Fire Department (TFD).

6.2.3 Airport Fire Rescue Services

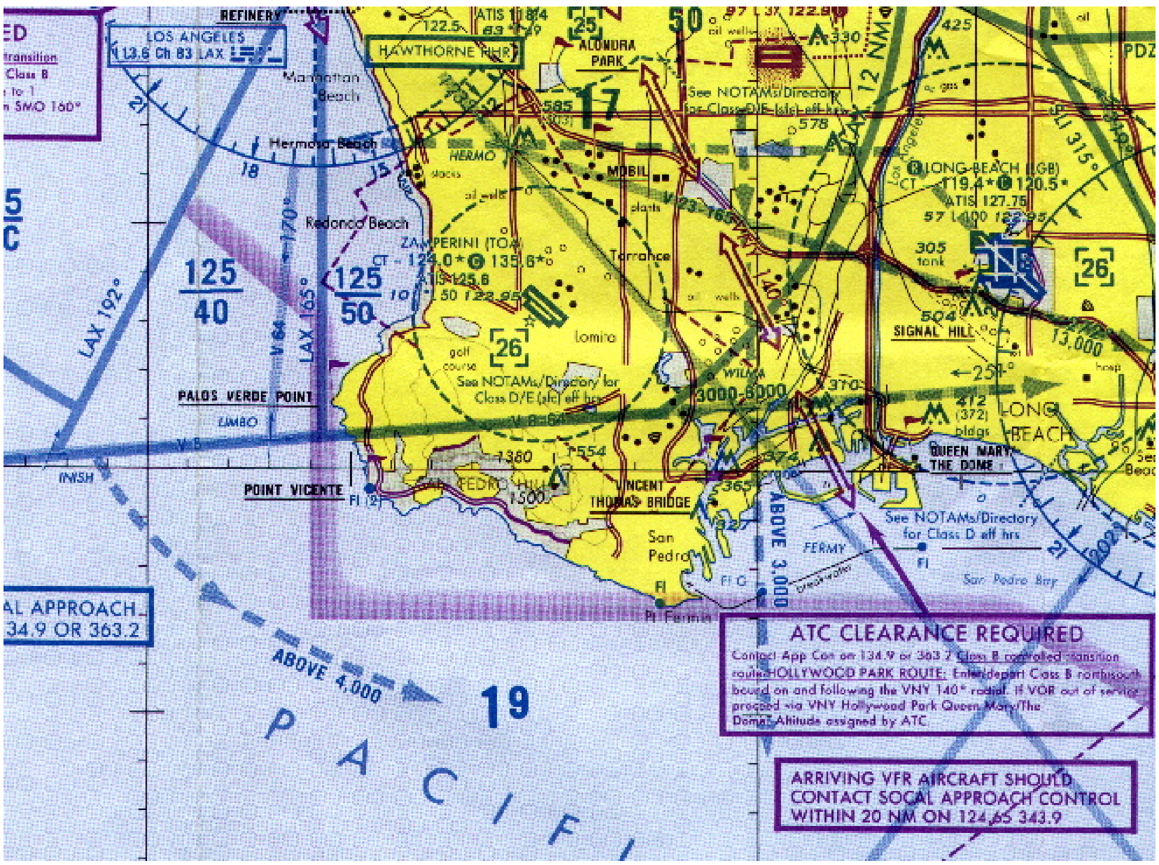
According to the Airport Supervisor, the TFD Station No. 2 is the closest station to the Airport and would be the first to respond. If unavailable, then units from station No. 4 will respond. Station No. 2 maintains a foam truck for use in aircraft fire rescue. The fire department vehicles are reportedly equipped with automatic gate openers that allow them direct access to the airfield.

6.2.4 Fuel Storage

All fuel is stored in underground tanks. Airplane fuel is kept on the west end of the airfield, whereas gasoline and diesel are available near the tower.

6.2.5 Departure Route

Standard Departure (North Turn): Best rate of climb is 45 degrees, right turn prior to Hawthorne Boulevard, cruise climb power to an elevation of 1,500 feet above Mean Sea Level (MSL).



6.2.6 Airplanes Operating at Torrance Municipal Airport

Torrance Airport can handle planes with a maximum per wheel weight of 20,000 lbs. However the majority of airplanes are light, single-, sometimes twin-engine models, used mainly for recreational purposes, limited in size and seating capacity (usually 2 to 8), with a small amount of fuel carried (less than 200 gallons on average), and with a typical gross weight not exceeding 12,500 lbs.

Airplanes parked at the southwestern apron, view towards the Northwestern take-off direction

According to the Airport Supervisor, the majority of airfield traffic is generated by helicopters from the Robinson Helicopter Manufacturing Plant located at the southern end of the airport.

6.3 Airplane Crashes

General Aviation (GA) accidents are common and happen regularly in the greater Los Angeles area. The vast majority of these accidents occur during landing approach (19%) or take-off (24%) on or in the near vicinity of the airport. With 9% of all GA accidents in the United States occurring in the State of California, statistically the probability of a general aviation plane crash at or near the Torrance airport is rather high. A conservative estimate would expect an accident to occur every three to five years. However, the potential impact is limited since the speed, weight, and fuel load of small airplanes and helicopters are restricted. In that regard, a small airplane crash can be compared to a high-speed car accident, which is a daily occurrence in the County of Los Angeles.

The city of Torrance has experienced a rather significant number of general aviation accidents in the last few years. Between 1988 and 2004, at least 26 general aviation accidents have occurred at the airport or within the city of Torrance. Of these, two were fatal accidents: one in 1997 with four fatalities, and another in 2003 that claimed the lives of two people. All accidents involved smaller aircraft such as Cessna 120, 150, 152, 172 and 180, Piper PA 28 and 38, Robinson Helicopters R 22 and a Beech C 23. Some of those accidents are described below:

- On Thursday, November 4, 2004, at 17:34 Pacific Standard Time (PST), a Cessna T210M aircraft, registration: N732RW, collided with a series of obstacles while on the final approach segment for landing on runway 29R. The airplane came to rest inverted in the backyard of a residence in the city of Lomita, located directly below the final approach path for runway 29R. The airplane was destroyed on impact and a subsequent fire ensued. The pilot, the sole occupant, sustained serious injuries.

- On August 6, 2004 a Cessna TR182 aircraft, registration: N4657S, landed with the airplane's landing gear partially extended following failure of a hydraulic supply line. While in cruise flight, the gear up light on the instrument panel went out. The pilot decided to return to the airport, and after discussing the situation with the tower, he landed with the nose gear down and the main gear about halfway down. Both occupants were not injured in the emergency landing.

- On November 6, 2003, at 15:28 PST, a Pacific Coast Helicopters Robinson R22 Beta II, registration N206TV, and a Robinson Helicopter Company Robinson R44, N442RH, collided in midair while in the traffic pattern at Zamperini Field. Both helicopters were destroyed. The R22 came to rest between runways 29R and 29L; the R44 came to rest on the departure end of runway 29L and was partially consumed by a post-crash fire. The solo student pilot in the R22 sustained serious injuries. The certified flight instructor (CFI) and the private pilot undergoing instruction (PUI) in the R44 sustained fatal injuries.

- In July of 2003, a Piper Warrior aircraft lost power while climbing out of Torrance airport and crashed into a front yard. The airplane was destroyed but the pilot walked away.

- On April 19, 2001 a Cessna 172P aircraft, registration: N97984, veered off the runway during a touch-and-go landing, encountered soft terrain, and nosed over. The single pilot with 78 hours total flight-time experience escaped without injuries.

- On Sunday, September 21, 1997, a Beech C23 aircraft, registration: N543JL, crashed into a three-story commercial office building about 2,000 feet from the departure end of the runway. The aircraft never climbed beyond 150 to 200 feet above ground level after take-off and was partially consumed by a post-impact fire. All four people aboard died.

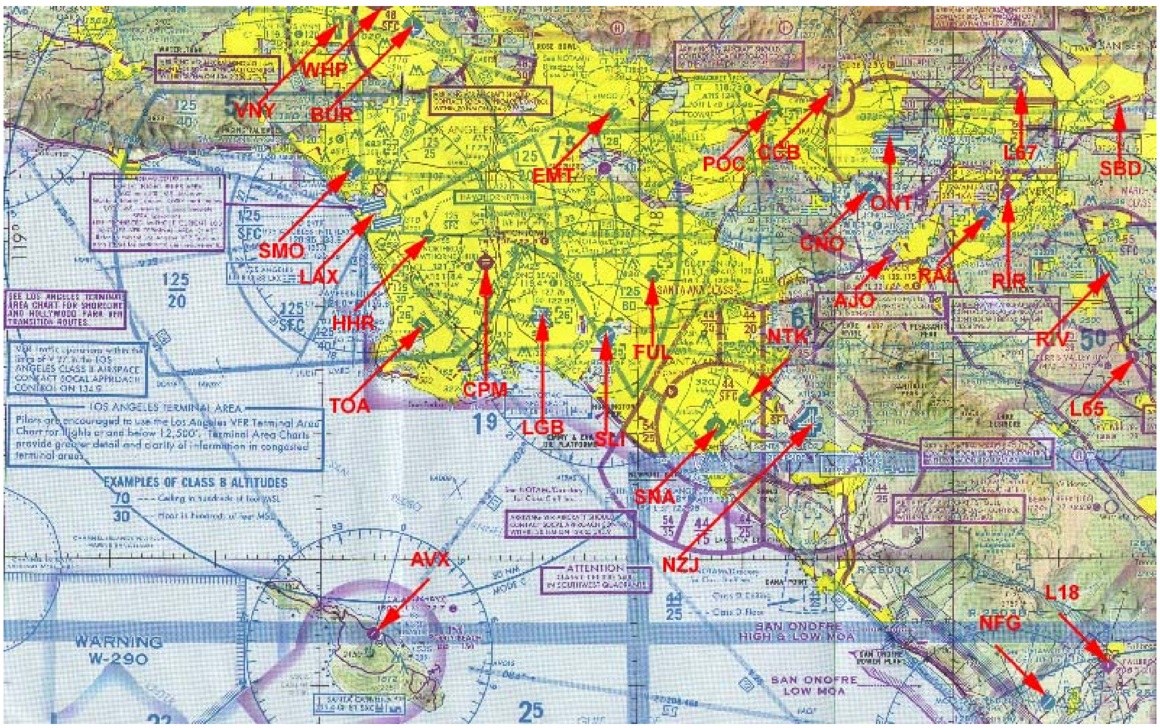
6.3.1 Probability and Location, Impact and Vulnerability

6.3.1.1 Commercial Aviation

The probability of a major commercial aircraft crashing into the city of Torrance is very low, but in general higher in the Greater Los Angeles area compared to other regions throughout the globe.

The Greater Los Angeles Area creates, with the fourth busiest airport on the planet (LAX), other domestic and international airports serving large passenger and cargo aircraft (i.e., Burbank, Ontario, Orange County), and numerous GA airports including the busiest GA airport in the world (Van Nuys), one of the most dense air traffic spots in the world. These many aircraft in the region increase the probability for a major technical failure, an in-flight break-up or a mid-air collision. The likelihood of such an occurrence was twice proven in southern California. On September 25, 1978 a Cessna GA plane collided with a Pacific Southwest Boeing 727 passenger jet on landing approach to San Diego. In the subsequent crash, all 137 people aboard both planes and 13 people on the ground died. A few years later, on August 31, 1986, a Piper Archer GA airplane made an unauthorized penetration into controlled airspace and collided with an AeroMexico DC-9 passenger aircraft above the city of Cerritos, in Los Angeles County. All 67 occupants of both aircraft and 18 people on the ground died.

While the probability for a major aircraft crashing into a community in an industrialized country may be a one-in-400-years event, the likelihood increases in large metropolitan areas with significant air traffic. Considering other factors, such as weather, flight patterns, and the size of the community, such a scenario is still rare with a probability of once in 150 to 170 years. At this point in time, this hazard can neither be prevented nor mitigated, except for shutting down commercial aviation.



Air Traffic and Airports in the Greater Los Angeles Area

6.3.1.2 General Aviation

The high number of small general aviation aircraft accidents usually does not generate large number of casualties. Aside from the planes' occupants (rarely more than four persons in the majority of the aircraft used at Torrance airport), victims on the ground are rare. The accident site and impact forces are comparable to a high-speed car accident, and even if a small airplane crashes into a building, the number of fatalities seldom exceeds four and rarely are more than five injured reported.

For example, on Friday, June 6, 2003 at 15:55 PST, a Beech 36 aircraft coming from nearby Santa Monica airport crashed into a three-story apartment building in the densely populated Fairfax district of Los Angeles, setting the structure ablaze. The pilot and three people on the ground died, seven others were injured with four people needing hospital treatment.

Such a low number of casualties may increase dramatically in circumstances in which a small airplane hits a group of people or a crowd on the ground, which every conscious pilot will try to avoid. While rare, even a small single engine GA aircraft that crashes into a crowded place, such as a restaurant, schoolyard, fair, or market place could generate a multiple victim event. Such a scenario may be comparable to the car accident that happened in the city of Santa Monica on July 17, 2003. A 4-door passenger car steered by an 88-year-old man crashed through a pedestrian mall, claiming the lives of 10 people and injuring 63 others. Such a devastating potential lies in every moving vessel or piece of machinery, including small aircraft.

6.3.2 Mitigation

To reduce the risk of airplanes hitting people and property on the ground, each airport is required to maintain a Runway Protection Zone (RPZ) for each end of each active runway. The size of the RPZ is determined by the type of landing approach used for that runway.

The Federal Aviation Administration (FAA) mandates the airport operator to restrict uses of RPZ land under its control to those compatible with airport operations. The importance of this responsibility is clearly illustrated by the fact that nearly 50 percent of all aircraft accidents occur during landing approach or departure.

FAA Advisory Circular 150-5300 defines the requirements for public-use airports and identifies land uses prohibited on the RPZ, such as residences and places of public assembly (i.e., churches, schools, hospitals, office buildings, shopping centers, and other uses with similar concentrations of persons). The airport operator is responsible for control over the RPZ and is responsible for clearing RPZ areas (and maintaining them clear) of incompatible objects and activities.

According to the Torrance Airport Association, the City of Torrance has control over 57 percent of the RPZ for runway 29R. The remaining 43 percent is controlled by the City of Lomita. During an on-site visit it was seen that the RPZ's at the Zamperini Airfield are rather spacious and free of prohibited and incompatible land uses.

The RPZ, intended to protect people and property on the ground, may not be confused with the need for Obstacle Free Areas (OFA), Obstacle Free Zones (OFZ), Object Clearing Criteria, and other FAA requirements.

View southeast, towards the City of Lomita, from the apron at the southwestern midpoint of the airfield

6.4 Response Agencies and Procedures

6.4.1 Torrance City Fire Department (TFD)

The Torrance Fire Department operates 7 engine companies, 2 truck companies, 4 paramedic squads, 1 air and light unit, and 1 command vehicle from 6 fire stations throughout the city (see Chapter 4 – Fire Hazards). Each fire station is staffed around the clock, 24 hours per day. Engine and truck personnel cross-train to staff the hazardous materials and technical rescue units when needed.

The first responders to any Torrance Airport incident will usually be the four-person crew of the single engine company at Fire Station No. 2. This fire station is located at 25135 Robinson Way, adjacent to Pacific Coast Highway. Depending on the location of the aviation accident, the Fire Department would receive assistance, primarily for crowd control, by the Torrance City Police Department.

6.4.2. Safety of Crews Responding to Torrance Municipal Airport

See particulars under Airport Operations Personnel and Torrance Fire Department.

6.4.3 Communication

See particulars under Airport Operations Personnel and Torrance Fire Department.

6.4.4 Training and Coordination

See particulars under Airport Operations Personnel and Torrance Fire Department.

6.5 Aftermath of an Airplane Crash

6.5.1 Financial Impacts

A general aviation aircraft accident is not expected to have an impact on the financial situation of the city of Torrance, assuming that the City as operator of the airport carries appropriate insurance to cover claims of negligence and/or safety violations following an aircraft accident.

6.6 Summary and Recommendations

This assessment is based on the current utilization of Torrance Airport by mainly small and recreational aircraft. However, General Aviation (GA) also includes much heavier, larger and complex aircraft such as Business and Executive Jets. Those can frequently be seen at other GA airports in the region such as Santa Monica and Van Nuys. Those aircraft, usually flown by experienced pilots with a commercial license, have a lower accident probability compared to recreational planes, but the impact forces and the potential for damage are much higher.

The aircraft accident rate with 26 events in less than twenty years in the city of Torrance seems rather high. According to the Airport Operations Supervisor, the Municipal Airport has never had an external or internal safety audit. Such a safety audit is outside the scope of this evaluation but is highly recommended to identify the root causes of the accidents.

The airport operations staff seemed well motivated, trained and equipped to act as "first responders" in a proficient and safe manner. Training for airport operations personnel should continue, and records substantiating this training effort should be maintained. It is recommended that their training program include the topic of Incident Command System (ICS) to allow for coordination with other emergency service departments. The Torrance Fire Department should also train their personnel to respond to mass casualty events. Training and proficiency in Managing Mass Casualty Events is a must in an urban area such as southern California, and for a fire department the size of Torrance's.

Finally, since the Torrance Fire Department (TFD) is the primary and exclusive fire responder to the Municipal Airport, knowledge of and training in "General Aviation Firefighting for Structural Firefighters" should be required. This course is designed to train fire-fighting personnel to respond to an aircraft-related accident in a timely and efficient manner.

6.7 Sources

A 2-hour interview was conducted with Airport Supervisor Michael Blyleven, and a visit was made to the airfield at the same time. The information presented here was also compiled from various sources within the emergency services and aviation community, including the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB), with whom the author maintains mutually beneficial relationships.

Major Aviation Disasters – Publication by Gunnar J Kuepper
www.edmus.info

This report was compiled for Earth Consultants International, Inc by:

Gunnar J. Kuepper
Chief of Operations
Emergency & Disaster Management, Inc.
Airport Center
5959 West Century Boulevard, Suite 700
Los Angeles, CA 90045
(310) 649-0700
fax (310) 649-1126
e-mail: gjk@edmus.info
web: www.edmus.info

Appendix I: Typical GA Aircraft Including Those Used at Torrance Airport

Small Aircraft

Cessna 150

- 2 seats
- 123 mph (196 Km/h) cruising speed
- 100 hp engine
- 1,600 lb max gross weight

Cessna 180

- 4 seats
- 167 mph (267km/h) top speed
- 230 hp engine
- 2,550 lb max gross weight

Cessna 310

- 6 seats
- 238 mph (383 km/h) top speed
- Combined 570 hp in 2 engines
- 5,500 lbs max gross weight

Piper Cherokee PA 28

- 4 seats
- 141 mph (235 km/h) cruise speed
- 160 hp engine
- 2,440 lb max gross weight

Helicopters

Robinson R22

- 2 seats
- 113 mph (180 km/h) top speed
- 124 hp engine
- 1,300 lb max gross weight

Robinson R44

- 4 seats
- 149 mph (209 km/g) top speed
- 225 hp engine
- 2,400 lb max gross weight

Executive Jets

Lear Jet 25

- 2 pilot crew, 8 passenger capacity
- 545 mph (877 km/h) top speed
- 2 jet engines
- 15,000 lbs max gross weight

Dissault Falcon

- 2 pilot crew, 14 passengers
- 690 mph (1,100 km/h) top speed
- 3 turbofan engines
- 63,000 lbs max gross weight

Appendix II: Partial List of General Aviation Aircraft Accidents in Torrance and the Greater Los Angeles Area

A) General Aviation Accidents in Torrance

Accident occurred Friday, August 06, 2004 in Torrance, CA
Aircraft: Cessna TR182, registration: N4657S
Injuries: 2 Uninjured.

The pilot landed with the airplane's landing gear partially extended following a failure of a hydraulic supply line. While in cruise flight the pilot heard a bang from under the airplane, and at the same time the gear up light on the instrument panel went out. He cycled the landing gear switch with no effect. He then pumped the manual landing gear handle with no effect. The gear down light did not illuminate. The pilot decided to return to the airport, and after discussing the situation with the tower he landed with the nose gear down and the main gear about halfway down. Examination of the airplane revealed that a braided hydraulic line leading to the nose gear hydraulic actuator had separated and pulled out of its connector fitting. Red fluid was on the airplane's skin behind the nose gear. A review of the maintenance logbook revealed that the airplane had its annual inspection signed off on April 13, 2004. During that inspection one of the two nose gear hydraulic actuator lines had been replaced. The newly installed hydraulic line was not the one that failed. According to the manufacturer, the hydraulic hose for the nose gear is inspected "on condition" and replacement is at the discretion of the inspecting mechanic or the airplane owner.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: A wheels up landing due to the failure of the hydraulic hose leading to the nose gear actuator, which depleted the hydraulic system of pressurized fluid.

Accident occurred Thursday, April 19, 2001 in Torrance, CA
Aircraft: Cessna 172P, registration: N97984
Injuries: 1 Uninjured.

During a touch-and-go landing, the aircraft veered off the runway, encountered soft terrain, and nosed over. No skid marks were found leading to the accident site. The tires were examined and no flat spots were observed. The airplane was uprighted and rolled to see if there was any resistance from the brakes. None was noted. The brakes were inspected and operated with no defects observed. The wind was calm at the time of the accident. The pilot received his private certificate on April 4, 2001, and had approximately 78 hours total time when the accident occurred. All of the pilot's primary flight training experience was accrued in the Katana DA-20 airplane. After obtaining his private pilot certificate, the pilot received 3.7 hours of flight instruction in the Cessna 172, and had logged an additional 2.4 hours of flight time prior to the accident. A flight instructor from the same flight school flew with the pilot in another Cessna 172 the day after the accident. He stated that the pilot had a tendency to land very flat, with no flare. The instructor was experienced in both the Katana DA-20 and the Cessna 172. He stated that the landing characteristics of the Katana require little or no flare by the pilot. In contrast, the Cessna 172 requires a considerable amount of flare to achieve a proper touchdown attitude. Since the pilot had received all of his primary training in a Katana, his tendency in any airplane would be to land it like a Katana. In the event of a nose first landing, the airplane will "wheel barrow" and can become nearly impossible to control. This landing condition can easily result in a rapid and uncontrollable change in direction on the runway.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The failure of the pilot-in-command to execute a proper landing flare, which resulted in an improper touchdown attitude and a subsequent loss of directional control. A factor in the accident was the difference between landing characteristics of the Katana and the Cessna 172, and the resulting habit interference for the pilot.

B) General Aviation Accidents in the vicinity of Torrance and within the County of Los Angeles

Accident occurred Wednesday, June 01, 2005 in Van Nuys, CA
Aircraft: Mooney M20C, registration: N6574U
Injuries: 1 Fatal.

On June 1, 2005, at 2306 Pacific daylight time, a Mooney M20C, N6574U, collided with mountainous terrain while executing a localizer instrument approach at Van Nuys Airport, Van Nuys, California. The private pilot operated the airplane under the provisions of 14 CFR Part 91. The pilot was the sole occupant and was fatally injured; the airplane was destroyed. Instrument meteorological conditions prevailed, and no flight plan had been filed. The flight originated at Orange County Airport, Santa Ana, California.

Los Angeles Approach controllers reported that the pilot requested an instrument flight rules (IFR) clearance while over Six Flags Magic Mountain, Valencia, California. He was told to maintain VFR (visual flight rules) and was given a vector to the Van Nuys ILS (Instrument Landing System) approach to runway 16R. Once established on the ILS the pilot was cleared for the approach in to Van Nuys. While on the localizer the airplane made a sudden diversion to the right, veering off the localizer course. He was then directed to climb to 5,000 feet on a southerly heading. The pilot acknowledged the instructions, stated that he had a problem, and was climbing. The pilot made no further transmissions before radar contact was lost. The wreckage was located in a ravine between two residential subdivisions in Van Nuys at latitude 34 degrees 17.097 minutes north and 118 degrees 31.814 minutes west, at an elevation of 1,253 feet mean sea level (msl).

The owner of the airplane told the National Transportation Safety Board investigator that he had spoken to the pilot just before he left San Jose, California. The pilot planned to leave San Jose Airport and fly to Orange County Airport, meet a friend for dinner, then fly to Whiteman Airport, where he normally operates. They discussed the weather, and the owner advised the pilot to monitor the weather closely. Whiteman Airport is about 4 miles northeast of Van Nuys Airport.
The Van Nuys weather observation for 2151 was: few clouds at 1,200 feet, broken at 2,400 feet; visibility of 6 statute miles in haze; and winds from130 degrees at 8 knots. A special observation was issued at 2322 stating that the clouds were broken at 1,200 feet, overcast at 2,400 feet; visibility of 6 statute miles in haze; and winds from 140 degrees at 6 knots. The 2251 observation was overcast at 1,400 feet; visibility of 6 statute miles in haze; and the winds were 150 degrees at 6 knots.

Accident occurred Sunday, March 27, 2005 in Long Beach, CA
Aircraft: Piper PA-32-301T, registration: N8243L
Injuries: 1 Uninjured.

On March 27, 2005, about 1440 Pacific standard time, a Piper PA-32-301T, N8243L, veered off the runway during landing rollout at Daugherty Field, Long Beach, California. The airplane overran three airport signs and was substantially damaged. The private pilot, who co-owned the airplane, was not injured during the personal flight. Visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed. The flight was performed under the provisions of 14 CFR Part 91, and it originated from Santa Barbara, California, about 1415.

The pilot indicated to the National Transportation Safety Board investigator that no evidence of any mechanical malfunction was noted with his airplane during the takeoff or en route flight. Upon arriving at Long Beach, his home base airport, nothing unusual was noted. The pilot landed on runway 30. Within seconds after touchdown, the airplane veered left. The pilot reported that he immediately tried to straighten out the airplane's course, but he was not successful. The pilot said it "felt like I hit something." However, he had not observed anything on the runway. No vibration or shimmy was noted at any time during the landing rollout. The pilot additionally reported that he lost directional control, and the airplane exited the left side of the runway and impacted the signs.
After coming to a stop on a taxiway adjacent to the runway, the pilot exited the airplane. The pilot reported that the bottom portion of the airplane's left wing was lacerated in two locations. One of the lacerations started beneath the wing's leading edge, and it terminated near the wing's trailing edge. Also, the fuel tank was punctured.

Accident occurred Saturday, December 04, 2004 in Santa Monica, CA
Aircraft: Piper PA-28-181, registration: N253FD
Injuries: 2 Uninjured.

The airplane overran the runway and collided with a ditch during landing. The certified flight instructor (CFI) and student were on their last power-off approach. Approximately 2,500 feet down the 4,987-foot runway, the airplane continued to float. By the time it touched down, the CFI felt that it was too late to initiate a go-around procedure. The CFI applied the brakes, retracted the flaps, and turned the airplane to the right to avoid a ditch. An unedited surface weather observation (METAR) was issued for the airport about 20 minutes prior to the accident. The winds were reported from 070 degrees at 6 knots. The following METAR issued about 40 minutes following the accident reported winds from 100 degrees at 7 knots, with directional variations between 070 and 190 degrees. The CFI reported that she encountered no mechanical malfunctions with the airplane.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The certified flight instructor's inadequate supervision, inadequate compensation for the tailwind condition, and delayed remedial action, which resulted in a runway overrun and collision with a ditch.

Accident occurred Thursday, May 20, 2004 in Hawthorne, CA
Aircraft: Cessna R172K, registration: N758ND
Injuries: 1 Uninjured.
The airplane landed hard during night conditions. The pilot said that he flared the airplane higher than normal. The airplane stalled about 10 feet above ground level, and the nose of the airplane to rapidly dropped, resulting in the nose wheel impacting the runway surface hard. The pilot had accumulated a total of 3.5 hours in the same make and model as the accident airplane. The pilot reported no preimpact mechanical malfunctions or failures with the airplane.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's misjudged flare and failure to maintain adequate airspeed, resulting in a stall and hard landing. Factors in the accident were the night conditions and the pilot's lack of familiarity in the make and model of airplane.

Accident occurred Monday, April 12, 2004 in Long Beach, CA
Aircraft: Cessna 172S, registration: N669SP
Injuries: 1 Uninjured.

The airplane experienced a hard landing. The student pilot was attempting to land, but did not flare before touchdown. One propeller blade collided with the runway during touchdown, and the nose wheel impacted the runway surface hard, pushing it into the firewall. This resulted in the firewall bending and the elevator controls jamming, becoming inoperative. The airplane porpoised down the runway, and the student applied brake pressure. The student taxied to the ramp area uneventfully. The student pilot reported no pre-impact mechanical malfunctions or failures with the airplane.

The NTSB determines the probable cause(s) of this accident as follows: the student pilot's inadequate flare, which resulted in a hard landing and porpoise.

Accident occurred Tuesday, March 16, 2004 in Los Angeles, CA
Aircraft: Mooney M20K, registration: N1148V
Injuries: 2 Fatal.

On March 16, 2004, about 1703 Pacific standard time, a Mooney M20K, N1148V, descended into a residence about 0.53 nautical miles south-southeast of the Santa Monica Municipal Airport, Los Angeles, California. Impact forces and fire destroyed the airplane and a portion of the private residence. The two private pilots in the airplane were fatally injured. The male pilot in the left front seat held an instrument rating. The female pilot in the right front seat was not instrument rated. Neither the sole occupant in the residence nor anyone else on the ground was injured. The airplane was registered to a private individual, but was being operated with permission by the accident pilot. Instrument meteorological conditions prevailed, and an instrument flight plan was in effect at the time of the accident. The personal flight was performed under the provisions of 14 CFR Part 91, and it originated from the Mammoth Yosemite (uncontrolled) Airport, near Mammoth Lakes, California, at an undetermined time before 1538.
According to ground and airborne witnesses, a layer of low elevation clouds covered the ground inland from the Pacific coast shoreline to at least 2 miles east of the Santa Monica Municipal Airport. Ground based witnesses, located in the vicinity of the accident site, reported that no blue sky was visible in the area.

At 1651, approximately 12 minutes prior to the accident, the Santa Monica Municipal Airport, reported, in part, the following weather conditions: wind from 230 degrees at 6 knots; visibility 1/2-mile, mist, overcast ceiling at 200 feet above ground level; temperature/dew point 14/13 degrees Celsius; and altimeter 29.92 inches of mercury. The airport's elevation is 175 feet mean sea level.

Preliminary information from the Federal Aviation Administration (FAA) indicates that about 1657, a radar controller issued the pilot an instrument approach clearance to perform the VOR approach into Santa Monica. During the approach, about 1659, the airplane passed the Bevey Intersection (final approach fix) at an approximate elevation of 2,600 feet mean sea level (msl), as indicated by the airplane's Mode C altitude reporting transponder. Thereafter, the airplane continued descending while proceeding toward the airport.

About 1702:07, when the airplane was approximately 0.4 miles east of the approach end of runway 21 and approximately 700 feet msl, the pilot advised the controller that he was "going around." This location was also about 1,000 feet northwest of the crash site. Thereafter, the airplane never departed the area. At 1702:26, the airplane was about 900 feet southeast of the crash site at 500 feet msl. About the time of the last radar return, at 1703:08, the airplane was approximately 400 feet north-northwest of the crash site at 700 feet msl.

Several witnesses reported hearing the airplane flying over the area, and three witnesses reported observing the airplane seconds prior to its descent into the residence. In summary, the auditory witnesses indicated that the airplane's noise sounded like it was circling over the area. The engine revved up as it was descending, and then the engine sound completely stopped just before the impact. The eyewitnesses reported that the airplane was turning with a steep angle of bank as it descended. No witnesses reported observing fire or smoke trailing from the airplane.
The on-scene examination of the accident site and airplane wreckage revealed the south wall and roof area of the single-family residence were destroyed. Homes circumferentially located around the main impact site did not sustain impact damage. The airplane's propeller, engine assembly, and the forward cockpit area were found on a northerly heading in the kitchen area of the residence, at ground level. The wings and aft empennage were found a few yards south and east of the kitchen. The accident site elevation is estimated at 200 feet msl.

All of the airplane's flight control surfaces were located at the impact site, with the exception of the right horizontal stabilizer, right elevator, and the upper portion of the rudder assembly, which were consumed by the post impact ground fire. The fire destroyed the cockpit, fuselage, and most of the instruments including the installed global positioning satellite receiver with its moving map indicator.

Accident occurred Friday, January 23, 2004 in Compton, CA
Aircraft: Cox Thorpe T-18, registration: N64EC
Injuries: 1 Fatal.

After encountering downwash induced wake vortices from a helicopter, the airplane rolled over and impacted terrain while on short final approach. The pilot of the airplane was performing practice touch-and-go takeoffs and landings at the airport and made a radio transmission stating his intentions. A police helicopter pilot was on a 2-mile straight in approach for the same runway, and made a radio transmission stating his intentions. While on final approach for the runway, with the airplane pilot beginning a flare about 8 feet above ground level, the police helicopter's pilot was attempting a practice autorotation and descended in front of the airplane. At the last moment, the airplane's pilot saw the helicopter and made an abrupt turn to the right in an attempt to execute a go-around. The airplane rolled over inverted and impacted terrain. The helicopter pilot stated he never saw the airplane or heard the pilot's radio transmissions. Federal Aviation Regulations state that "when two or more aircraft are approaching an airport for the purpose of landing, the aircraft at the lower altitude has the right of way, but it shall not take advantage of this rule to cut in front of another which is on final approach to land, or to overtake that aircraft." (14 CFR 91.113)

The NTSB determines the probable cause(s) of this accident as follows: both pilots' failure to see and avoid one another that resulted in the airplane's encounter with downwash induced wake vortices from the helicopter, and the airplane pilot's subsequent loss of control.

Accident occurred Friday, November 14, 2003 in Van Nuys, CA
Aircraft: OMF OMF-100-160, registration: N290MF
Injuries: 1 Serious, 1 Uninjured.

A passenger sustained serious injuries after walking into a moving propeller at night. The passenger said that after she got out of the airplane, she walked to the front and into the moving propeller. The passenger was not briefed on exiting procedures for the airplane. This was the passenger's first flight in a small airplane.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's failure to either brief the passenger about disembarking from an airplane with the propeller running or to shutdown the engine during the passenger's disembarkation. The night lighting condition and the passenger's lack of familiarity with airplanes were factors.

Accident occurred Tuesday, October 28, 2003 in Los Angeles, CA
Aircraft: Cessna 310C, registration: N6674B
Injuries: 1 Uninjured.

The aircraft landed long, overran the departure end of the runway, and collided with an airport perimeter fence. On final approach the pilot executed a go-around because he was not properly aligned with the active runway. The pilot said that on the second approach he "landed long and too fast," overran the departure end of the runway and collided with the airport perimeter fence. The pilot said there were no mechanical malfunctions with the airplane.
The NTSB determines the probable cause(s) of this accident as follows: the pilot's misjudgment of distance and speed on the approach resulting in an overrun.

Accident occurred Friday, June 06, 2003 in Los Angeles, CA
Aircraft: Beech A36TC, registration: N1856P
Injuries: 5 Fatal, 7 Serious.

During the en route climb-out, the airplane entered the base of an overcast cloud layer, and then descended out of the clouds in a spinning, steep nose down attitude that continued to impact with a 3-story apartment building. A post-impact fire destroyed the airplane. Earlier that day, the pilot received three weather briefings from the FSS. Each briefer indicated that AIRMETS were in effect for IFR conditions and mountain obscuration, and advised the pilot to call back after 1300 for updated weather. During the second briefing, the briefer stated that VFR flight was not recommended. On the last briefing, the briefer indicated that the weather conditions were marginal towards the east with at least 3 miles visibility. The pilot inquired if he could legally fly, to which the briefer replied that yes, he was legal to fly, but that the weather conditions were marginal. After takeoff, the pilot asked the controller if he knew if the weather was clearing towards the east. The controller stated that it was not clear towards the east. The pilot then said that he was going to fly towards the east, and find a break or hole in the clouds to "pop up through." Controllers received no further transmissions from the pilot on any frequency. Cloud bases in the area for a 12-hour period ranged from 2,200 feet to 3,100 feet overcast, with tops ranging from 3,800 feet to 4,000 feet agl.

The pilot did not hold an instrument rating. The pilot and passengers had been at the airport for at least 8 hours waiting for weather conditions to clear. One passenger was going to be dropped off at Las Vegas, and the pilot and remaining two remaining passengers were going to continue to Sun Valley, Idaho. Post accident examination of the airframe and engine revealed no mechanical anomalies. The NTSB determines the probable cause(s) of this accident as follows: the pilot's in-flight loss of control due to spatial disorientation, and failure to maintain airspeed, which resulted in a stall/spin. Also causal was the pilot's disregard of the weather information provided and his attempt to continue VFR flight into IMC. A factor in the accident was the pilot's self-induced pressure to complete the flight.

Accident occurred Sunday, March 23, 2003 in Van Nuys, CA
Aircraft: Cessna 172P, registration: N63788
Injuries: 1 Serious.

The airplane collided with a building during an aborted landing. While in the landing flare, the pilot noted that the airplane was in a slightly high flare attitude that resulted in a bounced landing. He initiated an aborted landing and lost directional control during the takeoff roll. The airplane veered to the left of the runway and became airborne. He attempted to regain directional control with right rudder and aileron control inputs. The airplane started a turn to the right, but not enough to avoid impacting a building. The pilot reported no pre-impact mechanical malfunctions or failures with the airplane.

The NTSB determines the probable cause(s) of this accident as follows: the pilot's failure to maintain directional control during an aborted landing. A contributing factor is the pilot's improper recovery from a bounced landing.

Accident occurred Saturday, February 01, 2003 in Long Beach, CA
Aircraft: Pitts S-2B, registration: N300PS
Injuries: 1 Serious.

The airplane experienced a loss of control, which resulted in a stall/mush while practicing touch-and-go takeoffs and landings. The pilot stated he "lost control" of the airplane during a landing and added power to execute a go-around and pulled up. An airline pilot, who reported having approximately 11,500 hours total time with about 250 hours in the Pitts S-2B, witnessed the accident. He said that when he first saw the airplane it was on a divergent course to the left side of runway 25R at an altitude of 5 feet. As the airplane came to the left edge of the runway it made a pull up, resulting in the nose coming up about 60 degrees. It continued on its upward path while rotating right. At approximately 25 feet, the nose passed vertical; at the 180-degree point of rotation, the right wing struck the ground followed by the nose. The witness pilot further reported that the airplane landed with a left, quartering tailwind of an estimated 8 knots. A Federal Aviation Administration airworthiness inspector examined the airplane. The brakes and tailwheel steering were found in working order. Flight control continuity could not be established because of the post impact fire.
The NTSB determines the probable cause(s) of this accident as follows: the pilot's excessive pull up, which resulted in a failure to obtain/maintain flying speed and a subsequent stall/mush.

Accident occurred Saturday, November 02, 2002 in Long Beach, CA
Aircraft: Cessna T182T, registration: N184TA
Injuries: 2 Uninjured.

During the takeoff roll portion of a touch-and-go, the airplane veered off the runway and collided with a taxiway sign. The CFI said the first two circuits around the traffic pattern were uneventful, and the student performed satisfactorily. During the third touch-and-go landing the student indicated that the airplane turned right without his application of right rudder pressure. The CFI responded by instructing her student in the proper usage of the rudder pedal. The flight continued around the traffic pattern. The student then performed a normal power on approach with 30 degrees of wing flaps extended for another touch-and-go landing. The touchdown was not hard, and no vibrations or unusual noises were noted. As the student increased the engine power to takeoff and was raising the wing flaps, the airplane again started an uncommanded right turn. The student told the CFI to take control of the airplane and she immediately took the controls and applied left rudder to redirect the airplane back onto the runway. The CFI said that when she pushed on the left pedal the airplane veered even more toward the right, and it collided with a taxiway sign. Thereafter, the CFI elected to continue the takeoff, full engine power was developed, and the airplane took off. During the climb out both pilots had difficulty maintaining control of the airplane. The CFI made an emergency landing at the airport on runway 30. The touchdown, rollout, and taxi to parking were accomplished by the CFI without difficulty. No unusual sounds, vibrations, or braking problems were noted. All of the tires remained inflated and an exhaustive examination of the control system, nose wheel steering mechanism and brakes/tires found no evidence of an anomaly. A series of low and high-speed taxi tests up to 55 knots were performed with the accident airplane under the supervision of FAA Inspectors and the airplane operated normally with no difficulty maintaining directional control. Cessna Aircraft Company personnel subsequently performed a ground steering test on an exemplar airplane to determine the nose gear operating characteristics as the nose gear (tire) is lifted off the ground. When the nose strut extends to the point where the tire is no longer resting on the ground, the strut/wheel is designed to center and lock out rudder pedal steering. The test results noted three specific pitch attitudes: 1) with the center of the leading edge of the elevator approximately 34 inches above the ground, the nose wheel is on the ground, and the strut and wheel turn when the rudder pedals were operated; 2) When the center of the leading edge of the elevator is 29.5 inches above the ground, the nose tire is just touching the ground, and the nose wheel does not turn with application of rudder pedals; 3) when the center of the leading edge of the elevator was about 16 inches above the ground (tailcone tiedown also contacting the ground), the nose wheel was also off the ground and would not move using the ruder pedals. The FAA reported that the top of the "J2" sign was about 34 inches above ground level. In a normal 3-point resting attitude the airplane's elevator is about 41 inches above ground level . To contact the top of the taxiway sign, a Cessna T182T needs to pitch upward such that its elevator lowers 7 inches.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The student's failure to maintain directional control and the instructor's inadequate supervision of the flight by his delayed remedial action.

Accident occurred Saturday, October 19, 2002 in Van Nuys, CA
Aircraft: Piper PA-28-235, registration: N9483W
Injuries: 2 Uninjured.

The airplane collided with obstacles and the ground during a forced landing following a loss of engine power. The pilot stated that shortly after takeoff, and during initial climb out, the airplane's engine failed. The pilot attempted to verify the proper operation of the fuel and engine systems, but was unable to determine the source of the problem, and, due to his low altitude, he was focused on finding a suitable emergency landing location. During the landing rollout, the airplane collided with obstacles and terrain. The Federal Aviation Administration inspector who responded to the accident recalled the pilot stating that one of the two tip tanks was selected at the time of the accident. The inspector examined the airplane on scene and found only residual fuel in the outboard tanks, while fuel remained in the inboard tanks. The inspector opined that insufficient fuel remained in either of the two outboard tanks to supply power to the engine. The inspector drained 1 1/2 ounces of fluid consistent with the appearance and odor of aviation fuel through the carburetor drain plug. The post-accident examination of the engine and fuel system revealed no evidence of mechanical malfunction.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: Fuel starvation due to the pilot's mismanagement of the fuel system and failure to select a tank containing fuel.

Accident occurred Friday, February 22, 2002 in Long Beach, CA
Aircraft: Beech 77, registration: N38026
Injuries: 1 Uninjured.

During rollout from a touch-and-go landing on runway 25L, the airplane veered left, exited the runway, and collided with a fence. According to the student pilot, his landing had been normal, but when he retracted the wing flaps he observed the airplane veering left of course. Despite his efforts, he was unable to regain directional control. The student pilot indicated that during the mishap he had not experienced any mechanical malfunction or failure with the airplane. The accident occurred during the student pilot's second solo flight in the airplane. Two minutes after the accident the local wind was reported at 200 degrees. Its speed was 6 knots.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: A loss of directional control due to the pilot's inadequate compensation for the existing crosswind condition.

Accident occurred Saturday, February 02, 2002 in Hawthorne, CA
Aircraft: Aviat Pitts S-2B, registration: N300PS
Injuries: 2 Uninjured.

On the landing rollout the airplane veered to the right of runway centerline and struck a taxi light with the left wing. The purpose of the flight was to practice full stall touch-and-go takeoffs and landings. The student had conducted five touch-and-go takeoffs and landings to a full stall with no discrepancies noted. The sixth touch-and-go landing was the accident landing. The CFI observed that the student had the control stick full aft and was applying left rudder to correct for the drift to the right. As the airplane continued to drift to the right the CFI applied full left rudder; however, the left wing struck the taxi light. During the airplane inspection it was observed that the tension of the right main landing gear bungee cord was slack. No further mechanical anomalies were noted.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: Failure of the student to maintain directional control of the airplane on the landing rollout and failure of the CFI to adequately supervise the flight. A contributing factor was the decreased tension of the right main landing gear shock cord/bungee.

Accident occurred Saturday, January 05, 2002 in Buena Park, CA
Aircraft: Cessna T337H, registration: N1348L
Injuries: 1 Fatal.

The airplane collided with terrain while turning from base to final for landing. The pilot contacted the air traffic control tower approximately 20 miles from the airport. The controller cleared the pilot into the traffic pattern, and shortly thereafter, cleared the airplane to land. The turn to base was early, and the airplane remained high during the base leg and the turn to final. The controller informed the pilot that the landing gear did not appear to be down, and then the airplane rolled to the right. A pilot witness observed the right wing drop 70-80 degrees and the airplane enter a sharp right turn through 180 degrees of rotation. The nose started dropping and after 360 degrees of turn, the nose was down about 70 degrees. to a vertical nose down attitude. After 360 degrees of turn, the nose was down about 70 degrees. In a post accident examination, investigators discovered no preimpact engine or control malfunctions with the airplane. Review of the pilot's personal medical records indicated that he had routinely used a prescription sleep aid (triazolam) and two prescription medications (codeine and butalbital) for the treatment of severe headaches. The pilot noted none of these medications on his applications for a medical certificate. A postmortem toxicological examination of the pilot detected the presence of these medicationscodeine and butalbital, consistent with recent use. Barbiturates (the class of medications which include butalbital) have been shown in many studies to impair judgment and performance; impairment that does not always correlate with subjective effects. They have an effect on the inner ear, and may increase susceptibility to spatial disorientation. Studies have shown residual adverse effects of triazolam on piloting related skills in the morning following its use. Codeine, a narcotic painkiller, has been shown to have mild impairing effects on performance at typical doses.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows:
the pilot's failure to maintain control of the airplane during the landing approach. Factors included the pilot's distraction when informed that his landing gear was not down, and his impairment from the effects of prescription drugs.

Accident occurred Saturday, December 29, 2001 in Long Beach, CA
Aircraft: Piper PA-28-161, registration: N4390S
Injuries: 1 Uninjured.

The pilot reported he approached the 150-foot-wide runway with "crosswind correction," on center, and aligned with the runway. The runway was wet following a rain shower. As the airplane got close to the runway a left drift developed. The pilot attempted to lower the right wing to arrest the drift; however, the airplane touched down on both main landing gear about the same time. The airplane began a "severe slip" toward the left edge of the runway and, although the airplane was aligned with the runway, it traveled sideways. The pilot maintained crosswind correction and stopped the airplane. He was notified later that the left wing had been damaged by a taxiway sign. He reported there was no mechanical malfunction. In a weather observation taken 7 minutes after the accident, the surface wind was variable at 5 knots.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The student pilot's inadequate compensation for wind, and his failure to maintain directional control of the aircraft during the landing roll.

Accident occurred Sunday, December 02, 2001 in Long Beach, CA
Aircraft: Bellanca 8KCAB, registration: N50554
Injuries: 1 Serious, 1 Uninjured.

The airplane impacted the ocean in an uncontrolled descent after experiencing a loss of control while maneuvering. The certified flight instructor (CFI) demonstrated a 4-point roll and transferred control of the airplane to the pilot under instruction (PUI) so that he could demonstrate the maneuver. Shortly after transferring control, the airplane's nose pitched down 20-30 degrees. The PUI asked the CFI if he was causing the nose to pitch down, to which the CFI responded in the negative. The CFI attempted to correct the nose down pitch but the control stick had no effect and the trim would not budge. Both the CFI and the PUI bailed out of the airplane before it impacted the ocean. The airplane was not recovered, and the reason for the loss of control was not determined.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The loss of aircraft control while maneuvering for undetermined reasons.

Accident occurred Friday, October 12, 2001 in Van Nuys, CA
Aircraft: Piper PA-28-140, registration: N15831
Injuries: 2 Uninjured.

A Piper Malibu, piloted by a private pilot, and a Piper Cherokee airplane, piloted by a student pilot on his third solo flight, collided on runway 16R at Van Nuys Airport, which is served by an air traffic control tower. The Cherokee was preparing for takeoff, and had been cleared to taxi into position and hold on the runway. The Malibu was on a visual approach and had been cleared to land on runway 16R. According to the Malibu pilot, during the landing roll he encountered the Cherokee on the runway despite his clearance to land. The accident occured shortly after sunset. During an interview with the air traffic controller (LC1) who was handling the aircraft, he indicated that he had instructed the Malibu to make a left base for runway 16R after the pilot made initial contact with the control tower. He then cleared a Hawker jet on final to land. The Cherokee pilot radioed that he was ready for departure when the Hawker jet on short final, and he instructed the pilot to hold short. According to LC!, as the Hawker jet rolled past intersection 13, the Cherokee was cleared into position and he advised the pilot of the position of the Malibu. He then observed the Cherokee. He did not clear the Cherokee for takeoff, but instructed the Cessna to follow the Malibu. LC1 was checking for extended landing gear o the Cessna on final, when someone shouted "You got a guy at 13. He said no one had mentioned the Cherokee prior to the accident. According to LC1, he believes this accident is the result of the human error, a lapse of memory and scanning. He acknowledged that he did not remember the Cherokee (holding) in position and hold on the runway. The investigation revealed an obstructed view of from the LC1 workstation. FAA Order 7110.65, para. 2-9-4(f) states: Do not authorize an aircraft to taxi into position and hold at an intersection between and sunrise or anytime when the intersection is not visible.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The failure of the air traffic controller to provide effective separation on the runway surface as specified in FAA Order 7110.65, Paragraph 3-9-6.

Accident occurred Friday, July 27, 2001 in Hawthorne, CA
Aircraft: Williams RV-6A, registration: N131LH
Injuries: 2 Uninjured.

Upon arriving at the destination airport, the pilot elected to land long on runway 25 in order to be closer to the airplane's hangar. According to the pilot, during landing flare a windshear or gust was encountered. Although he attempted to take corrective action, he lost control of his airplane, it impacted the runway hard, and a wing broke. No gusts were reported by the airport facility that indicated the local wind was from 250 degrees at 7 knots. The pilot had arrived at the destination airport after flying over 643 nautical miles on a nonstop flight.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's failure to maintain control of his airplane during the landing flare.

Accident occurred Friday, July 27, 2001 in Hawthorne, CA
Aircraft: Williams RV-6A, registration: N131LH
Injuries: 2 Uninjured.

Upon arriving at the destination airport, the pilot elected to land long on runway 25 in order to be closer to the airplane's hangar. According to the pilot, during landing flare a windshear or gust was encountered. Although he attempted to take corrective action, he lost control of his airplane, it impacted the runway hard, and a wing broke. No gusts were reported by the airport facility that indicated the local wind was from 250 degrees at 7 knots. The pilot had arrived at the destination airport after flying over 643 nautical miles on a nonstop flight.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's failure to maintain control of his airplane during the landing flare.

Accident occurred Monday, April 02, 2001 in Long Beach, CA
Aircraft: Cessna 172S, registration: N669SP
Injuries: 1 Uninjured.

The student pilot landed hard, veered to the right of the runway, and stuck a taxiway sign with the lower portion of the left wing strut. The pilot, on his fifth solo flight, had been approved by his flight instructor to practice landing-pattern work. Winds at the time of the accident were from 160 degrees at 9 knots.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The student pilot's inadequate compensation for the exisiting crosswind and his improper landing flare that resulted in a hard landing, and loss of directional control during the landing roll.

Accident occurred Wednesday, March 28, 2001 in Santa Monica, CA
Aircraft: Cessna 172N, registration: N2838E
Injuries: 3 Fatal.

The airplane impacted the water descending at a high rate of speed. On a dark moonless night, the noninstrument rated private pilot rented an airplane and flew below a marine layer of clouds along the coastal shoreline. The pilot initiated a course reversal turn, during which the airplane turned away from the city lights. During the turn, seconds after the airplane was headed nearly perpendicular to the shoreline, the pilot commenced a descending right turn with a vertical descent rate of over 2,100 feet per minute. A witness about 1 mile away reported that the airplane looked as though it was falling straight down into the water. The pilot had taken his primary flight lessons from a Texas-based school, and he was, by his own admission, not familiar with flying around marine cloud layers. No evidence of mechanical malfunction or failures was noted during the wreckage examination.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's loss of airplane control while maneuvering due to spatial disorientation. Contributing factors were the dark night, the marine cloud layer that restricted the pilot's cruising altitude, and the pilot's lack of familiarity with nighttime flight over the ocean.

Accident occurred Thursday, February 15, 2001 in Long Beach, CA
Aircraft: Cessna 152, registration: N68763
Injuries: 4 Fatal.

A midair collision occurred between the Cessna 152 and a Cessna 172, which were flying between 800 and 1,000 feet above the ocean in an established student training practice area. The flight instructors and their respective students lost control of their airplanes, which descended into the ocean and sank. An eyewitness in a ship observed the airplanes seconds prior to the collision. The witness stated that "one plane appeared to bank and turn directly into the other plane." Another witness, who was airborne in a helicopter, reported that before the impact he had observed one of the airplanes performing counterclockwise orbits, like a turn about a point ground reference maneuver. This airplane had completed several circles when it collided with another airplane that was flying in a westerly direction. Neither the Cessna 152's empennage nor the Cessna 172's engine was recovered. Radar tracks for the airplanes could not be determined. The collision occurred in a near head-on trajectory, based upon the severity of the impact damage to the leading edge of the Cessna 152's right wing, the lack of impact damage in the Cessna 172's aft fuselage and empennage, the witness statements, and the locations where the airplanes were found (the Cessna 152 was west of the Cessna 172).

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The failure of the flight crews of both airplanes to maintain adequate visual lookout for traffic.

Accident occurred Thursday, October 26, 2000 in Gardena, CA
Aircraft: Grumman American AA-5A, registration: N26470
Injuries: 1 Serious, 2 Minor.

The airplane collided with an electrical line during an off airport forced landing following a loss of engine power. The pilot was doing a test flight after completion of some cylinder and carburetor work. He took off once and put it back on the ground, because he wanted to make sure everything was working fine. He did a run-up, checked the instruments, and took off again. At 400 feet the engine lost power and he could not return to the airport. The airplane sustained substantial damage and caught fire when it came to rest after contacting the wires. The throttle and mixture handles were full forward. The primer was in the locked position. The carburetor heat handle was forward in the off (cold) position. The magneto switch was in the both position. The fuel pump switch was in the on position. The fuel selector valve was in the right position. The wing fuel tanks were breached and the fuel sump contained water. Investigators disconnected the fuel inlet line to the carburetor, blew into the line, and did not hear or see any leaks in the lines or at the fuel selector valve. The electric fuel pump and its attached fuel lines sustained thermal damage and were partially consumed by the post crash fire. The carburetor sustained thermal damage and could not be tested due to melted material, which clogged the fuel inlet and obstructed the float needle. Both magnetos sustained thermal damage and one sustained mechanical damage. The internal components of both magnetos were in good condition and appeared to have accrued a low number of hours. A serviceable housing cover, which included a distributor lock and capacitor, was attached to the unit that only sustained thermal damage. The magneto produced and sustained a normal running spark from 350 rpm through 2,800 rpm.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The engine lost power for undetermined reasons.

Accident occurred Tuesday, October 17, 2000 in Van Nuys, CA
Aircraft: Gulfstream G-1159A, registration: N162JC
Injuries: 6 Uninjured.

The Gulfstream descended from above and behind the Beech C90 and collided with it while both aircraft were on 2.5-mile final approach to the same runway. Visual meteorological conditions prevailed. The Gulfstream was on an ILS instrument approach and the Beech was on a VFR approach. Both airplanes subsequently landed without additional damage or injury to the occupants. Upon initial contact with the air traffic control tower, the Beech C90 was instructed to make a straight-in approach to the runway and was given a transponder code. The pilot miss-set the assigned code, which, due to an air traffic control computer software anomaly, caused the Beech's identifying data block to be suppressed and not available to the radar approach controller. The approach controller attempted to provide traffic advisories to the overtaking Gulfstream pilot but could not determine the Beech's type, destination, or altitude. (Altitude data became available to the controller 1 minute 14 seconds before the collision via a conflict alert message.) The controller did not issue a traffic alert to the Gulfstream crew when the Beech's altitude became known. Additionally, for unrelated reasons, the approach controller experienced frequent failures of his communication radio transmitter and was required to repeat transmissions to the Gulfstream and other aircraft. Despite the traffic point-out, in front of them 1 mile, altitude unknown, and later at short distance at a known altitude near theirs, the Gulfstream flight crew did not visually identify and avoid the Beech nor did they request radar separation services. On initial contact with the tower, the Gulfstream crew was cleared to land on the same runway the tower had previously cleared the Beech to make a straight-in approach to. When asked by the Gulfstream if there was any traffic in their vicinity, the tower replied, "nothing reported." The tower controller realized his mistake approximately 16 seconds later, however, the collision had already occurred. The Gulfstream pilot reported there were no TCAS 2 traffic advisories within 3 miles and there were no resolution advisories. The Gulfstream first officer recalled a TCAS "traffic" advisory close by at near their altitude, but no annunciation in the minute or two before the collision. With the model TCAS aboard the Gulfstream, when the aircraft's landing gear is extended, the lower TCAS antenna goes into an omni-directional mode wherein targets detected on the lower antenna only are displayed to the flight crew on the cockpit TCAS display with a text message of range and delta altitude but no bearing information. The Beech's transponder antenna was on the lower fuselage and airframe structure shielded it from interrogation by the Gulfstream's TCAS.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The failure of the pilot of the other airplane to correctly set a new transponder code and an anomaly in ATC software that precluded the controller from manually overriding the resulting inhibition of displayed data. Factors in the accident were impaired function of the collision avoidance system in the airplane due to structural masking of the other airplane's transponder antenna, an intermittent failure of the approach controller's communication radio transmitter which interfered with his ability to communicate traffic information to the pilots, the failure of both the approach controller and the tower controller to issue safety alerts when the traffic conflict became apparent, and the failure of the flight crew to maintain an adequate visual lookout to see and avoid the other airplane.

Accident occurred Wednesday, May 31, 2000 in Long Beach, CA
Aircraft: Piper PA-28-140, registration: N6349W
Injuries: 2 Minor.

The airplane veered off the runway during the takeoff phase of a touch-and-go. The flight instructor noticed the plane veering and told the student to correct it with left rudder. When the student did not correct for the drift, the flight instructor tried to take over, but the student would not relinquish the controls. The airplane veered off the runway, and the nose gear subsequently collapsed and the airplane came to rest inverted.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The student pilot's failure to maintain directional control during takeoff and his subsequent failure to relinquish control of the airplane.

Accident occurred Sunday, May 28, 2000 in Hawthorne, CA
Aircraft: Piper PA-46-310P, registration: N567YV
Injuries: 3 Fatal.

The aircraft collided with the ground in a steep nose down descent angle while maneuvering to return to the runway during the takeoff initial climb from the airport. Pilot and mechanic witnesses on the airport described the engine sounds during the takeoff as abnormal. The takeoff ground roll was over 3,000 feet in length, and the airplane's climb out angle was much shallower than usual. Two other witnesses said the engine sounded "like a radial engine," and both believed that the power output was lower than normal. One mechanic witness said the engine was surging and not developing full power; he believed the symptoms could be associated with a fuel feed problem, a turbocharger surge, or an excessively lean running condition. The ground witnesses located near the impact site said the airplane began a steep left turn between 1/4- and 1/2-mile from the runway's end at a lower than normal altitude. The bank angle was estimated by the witnesses as 45 degrees or greater. The turn continued until the nose suddenly dropped and the airplane entered a spiraling descent to ground impact. The majority of these witnesses stated that they heard "sputtering" or "popping" noises coming from the airplane. Engineering personnel from the manufacturer developed a performance profile for a normal takeoff and climb under the ambient conditions of the accident and at gross weight. The profile was compared to the actual aircraft performance derived from recorded radar data and the witness observations. The ground roll was 1,300 feet longer than it should have been, and the speed/acceleration and climb performance were consistently well below the profile's predictions. Based on the radar data and factoring in the winds, the airplane's estimated indicated airspeed during the final turn was 82 knots; the stall speed at 45 degrees of bank is 82 knots and it increases linearly to 96 knots at 60 degrees of bank. No evidence was found that the pilot flew the airplane from December until the date of the accident. The airplane sat outside during the rainy season with only 10 gallons of fuel in each tank. Comparison of the time the fueling began and the communications transcripts disclosed that the pilot had 17 minutes 41 seconds to refuel the airplane with 120 gallons, reboard the airplane, and start the engine for taxi; the maximum nozzle discharge flow rate of the pump he used is 24 gallons per minute. Review of the communications transcripts found that a time interval of 3 minutes 35 seconds elapsed from the time the pilot asked for a taxi clearance from the fuel facility until he reported ready for takeoff following a taxi distance of at least 2,000 feet. During the 8 seconds following the pilot's acknowledgment of his takeoff clearance, he and the local controller carried on a nonpertinent personal exchange. The aircraft was almost completely consumed in the postcrash fire; however, extensive investigation of the remains failed to identify a preimpact mechanical malfunction or failure in the engine or airframe systems. The pistons, cylinder interiors, and spark plugs from all six cylinders were clean without combustion deposits. The cockpit fuel selector lever, the intermediate linkages, and the valve itself were found in the OFF position; however, an engineering analysis established that insufficient fuel was available in the lines forward of the selector to start, taxi, and perform a takeoff with the selector in the OFF position.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: A partial loss of power due to water contamination in the fuel system and the pilot's inadequate preflight inspection, which failed to detect the water. The pilot's failure to perform an engine run-up before takeoff is also causal. Additional causes are the pilot's failure to maintain an adequate airspeed margin for the bank angle he initiated during the attempted return to runway maneuver and the resultant encounter with a stall/spin. Factors in the accident include the pilot's failure to detect the power deficiency early in the takeoff roll due to his diverted attention by a nonpertinent personal conversation with the local controller, and, the lack of suitable forced landing sites in the takeoff flight path.

Accident occurred Sunday, May 21, 2000 in Los Angeles, CA
Aircraft: Stinson 108-1, registration: N8398K
Injuries: 1 Uninjured.

During landing rollout the pilot's right foot slipped off the rudder pedal. The pilot's tennis shoe became lodged beneath the pedal and he was unable to dislodge it. Directional control was lost, and the airplane ground looped.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's loss of directional control during landing rollout due to the pilot's foot becoming wedged under a rudder pedal, which restricted its movement.

Accident occurred Sunday, May 07, 2000 in Burbank, CA
Aircraft: McCoy GLASAIR III, registration: N1ML
Injuries: 1 Uninjured.

The purpose of the flight was to practice takeoff's and landings at a nearby airport. According to the pilot, while on final approach, the airplane experienced a downdraft and lost about 75 feet in altitude. The pilot initiated a go-around, but was unable to arrest the descent. The airplane's right main landing gear struck a telephone pole and was sheared off. The pilot requested to make an emergency landing at the accident airport due to the availability of ARFF equipment. After landing, the remaining landing gear collapsed, and the airplane veered off the runway and struck a taxiway sign with the right wing. Review of the aviation surface observations for the hour before and after the accident revealed winds out of the west at 7 knots. No unusual meteorological conditions were reported.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The failure of the pilot to maintain a proper glidepath, which resulted in a collision with a power pole and damage to the landing gear.

Accident occurred Saturday, April 22, 2000 in Brentwood, CA
Aircraft: Emigh Aircraft TROJAN A2, registration: N8324H
Injuries: 2 Fatal.

The owner/pilot of a vintage unregistered airplane, along with two other airplanes, had flown from one private airstrip to another for lunch. The airplane/owner pilot did not possess a medical certificate. They departed after lunch and the accident plane owner/pilot radioed one of the other pilots and stated he was 'going to check the stock.' The airplanes went their separate ways. Witnesses reported that the accident airplane was flying low, about 100 feet above ground level. Two of the witnesses stated that the plane suddenly spiraled downward counterclockwise; one stated that the plane was turning when the nose started to move up and then it just fell out of the sky. The private rated passenger pilot possessed a medical certificate and was rated for single engine land airplanes and reported about 85 flight hours. The toxicological report for the passenger rated pilot was positive for over-the-counter medications with impairment potential.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: The pilot's failure to maintain control of the airplane.

Accident occurred Friday, January 21, 2000 in Compton, CA
Aircraft: Myers Q-2, registration: N813S
Injuries: 1 Minor.

The purpose of the flight was to relocate the airplane to another airport. During the run-up, no discrepancies were noted with the airframe or engine. The pilot indicated that rotation speed was 80-85 mph, with a stall speed of 68 mph. On the takeoff roll, the airplane became airborne at 70 mph with no manual inputs from the pilot. He attempted to land the airplane to avoid a stall. The left wing contacted the runway and the airplane veered to the left. He reduced power and applied the brakes increasing the direction of travel to the left. The pilot observed a vehicle coming in his direction on the taxiway, as well as a parked vehicle on the taxiway. As he maneuvered to avoid the moving and parked vehicles, the left canard struck and was sheared off by the parked vehicle. The pilot was not able to control the airplane and it slid into a parked car and came to rest near a hangar. A witness stated that there were no discrepancies noted with the sound of the engine during the takeoff roll. He observed the airplane either liftoff, or hop up into the air, and then the left wing struck the runway. The airplane was inspected on scene with no discrepancies noted with airframe or braking system.

The NTSB determines the probable cause(s) of this accident as follows: Failure of the pilot to maintain directional control of the airplane during the takeoff roll.

Appendix A:
REFERENCES, AERIAL PHOTOGRAPHS and WEBSITES

American Society for Testing Materials (ASTM) E-108, Standard Test Methods for Fire Tests of Roof Coverings.

Andrews, P. L., 1986, BEHAVE: Fire behavior prediction and fuel modeling system BURN subsystem, part 1: US Department of Agriculture, Forest Service, General Technical Report INT-194, Intermountain Research Station, Ogden, Utah, 130p.

Andrews, P.L., and Bevins, C.D., 1999, Update and expansion of the BEHAVE Fire Modeling System: Fire Management Notes.

Andrews, P.L., and Bradshaw, L.S., 1990, RXWINDOW: Defining windows of acceptable burning conditions based on desired fire behavior: US Department of Agriculture, Forest Service, General Technical Report INT-273, Intermountain Research Station, Ogden, Utah, 54p.

Andrews, P.L., and Chase, C.H., 1989, BEHAVE: Fire behavior prediction modeling system-BURN subsystem Part 2: U.S. Department of Agriculture, Forest Service, General Technical Report INT-260, Intermountain Research Station, Ogden, Utah, 93p.

Barrette, Brian, 1999, System for Rating Structural Vulnerability in SRA: Sacramento, California, dated September 1999.

Barrows, A.G., 1974, A Review of the Geology and Earthquake History of the Newport-Inglewood Structural Zone: Southern California: California Division of Mines and Geology Special Report 114, 115p.

Barrows, A.G., Tan, S.S., and Irvine, P.J., 1994, Investigation of Surface Geologic Effects and Related Land Movement in the City of Simi Valley Resulting from the Northridge Earthquake of January 14, 1994: California Division of Mines and Geology Open File Report 94-09, 41p., 1 plate.

Barrows, A.G., Irvine, P.J., and Tan, S.S, 1995, Geologic surface effects triggered by the Northridge earthquake *in* Woods, M.C., and Seiple, W.R. (editors), The Northridge, California, Earthquake of 17 January 1994: California Division of Mines and Geology Special Publication 116, pp 65-88.

Bates, R.L., and Jackson, J.A., 1987, (editors), Glossary of Geology: American Geological Institute, Alexandria, Virginia, 788p.

Blake, T. F., 2000a, EQFAULT, A Computer Program for the Estimation of Peak Horizontal Ground Acceleration from 3D Fault Sources.

Blake, T.F., 2000b FRISKSP, A Computer Program for the Estimation of Median Peak Horizontal Ground Acceleration from 3D Fault Sources.

Blake, T.F., Holligsworth, R.A., and Stewart, J.P., (editors), 2002, Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California: Southern California Earthquake Center, 110p. + Appendix A.

Bolt, Bruce A., 1993, Earthquakes: W.H. Freeman and Company, New York, 331p.

Boore, D.M, Joyner, W. and Fumal, T. E., 1997, Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes: A summary of recent work: Seismological Research Letters, Vol. 68, No. 1, pp 128-153.

Borchardt, G., and Kennedy, M.P., 1979, Liquefaction Potential in Urban San Diego – A Pilot Study: California Geology, Vol. 32, pp. 217-221.

Borrero, J., Dolan J., Synolakis, C.E., 2001, Tsunami sources within the Eastern Santa Barbara Channel: Geophysical Research Letters, Vol. 28, pp. 643-647.

Brandsma, M., Divoky, d., and Hwang, L.S., 1978, Circumpacific variation of computed tsunami features in Tsunami Symposium: Ottawa, Canada, Marine Sciences Directorate, Department of Fisheries and Environment Manuscript Report Series 48, pp. 132-151.

Bray, J.D., 2001, Developing Mitigation Measures for the Hazards Associated with Earthquake Surface Fault Rupture; in A Workshop on Seismic Fault-Induced Failures – Possible Remedies for Damage to Urban Facilities: Research Project 2000 Grant -in-Aid for Scientific Research (No. 12355020), Japan Society for the Promotion of Science, Workshop Leader, Kazuo Konagai, University of Tokyo, Japan, pp. 55-79, January 11-12, 2001.

Brewer, L., 1992, Preliminary damage and intensity survey: Earthquakes and Volcanoes, Vol. 23, No. 5, pp. 219-226.

Bryant, W.A., 1985, Southern Newport-Inglewood Fault Zone, Southern Los Angeles and Northern Orange Counties: California Division of Mines and Geology Fault Evaluation Report FER-172 (unpublished).

Bryant, W.A., 1988, Recently Active Traces of the Newport-Inglewood Fault Zone, Los Angeles and Orange Counties, California: California Division of Mines and Geology Open-File Report 88-14.

Building Technology, Inc., 1990a, Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action. Volume 1: Findings, Conclusions and Recommendations: Federal Emergency Management Agency Publication No. 198, 104p.

Building Technology, Inc., 1990b, Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action. Volume 2: State and Local Case Studies and Recommendations: Federal Emergency Management Agency Publication No. 199, 130p.

Building Technology, Inc., 1990c, Financial Incentives for Seismic Rehabilitation of Hazardous Buildings – An Agenda for Action. Volume 3: Applications Workshops Report: Federal Emergency Management Agency Publication No. 216, 200p.

Bullard, T.F., and Lettis, W.R., 1993, Quaternary fold deformation associated with blind thrust faulting, Los Angeles basin, California: Journal of Geophysical Research, Vol. 98, pp. 8,348-8,369.

Burgan, R.E. and Rothermel, R.C., 1984, BEHAVE: Fire prediction and fuel modeling system-FUELsubsystem: U.S. Department of Agriculture, Forest Service, General Technical Report INT-167, Intermountain Forest and Range Experiment Station, Ogden, Utah, 126p.

Burgan, R.E., 1987, Concepts and interpreted examples in advanced modeling: U.S. Department of Agriculture, Forest Service, General Technical Report INT-238, Intermountain Research Station, Ogden, Utah, 40p.

Byerly, P. 1930, The California earthquakes of November 4, 1927: Bulletin of the Seismological Society of America, Vol. 20, pp. 53-66.

California Building Standards Commission, 2001, California Building Code.

California Board of Forestry, 1996, California Fire Plan: A Framework for Minimizing Costs and Losses from Wildland Fires: a report dated March 1996.

California Code of Regulations, Title 14, Article 10, Seismic Hazards Mapping Act.

California Code of Regulations, Title 24, California Building Standards Code.

California Department of Forestry, 1993, Rater Instruction Guide: Very High Fire Hazard Severity Zone.

California Department of Water Resources, 1986, Statutes and Regulations Pertaining to Supervision of Dams and Reservoirs: Division of Safety of Dams, 46p.

California Department of Water Resources (DWR), 1961, Planned utilization of the ground water basins of the coastal plain of Los Angeles County, Appendix A – Ground water geology.

California Division of Mines and Geology (CDMG), 1976, Environmental Geology of Orange County, California: Division of Mines and Geology Open-file Report 79-8 LA, 474p.

California Division of Mines and Geology (CDMG), 1996, Probabilistic Seismic Hazard Assessment for the State of California: DMG Open File Report 96-08.

California Division of Mines and Geology (CDMG), 1997, Guidelines for Evaluating and Mitigating Seismic Hazards in California: Special Publication 117, 74p.

California Division of Mines and Geology (CDMG), 1998, Maps of Known Active Near-Source Zones in California and Adjacent Potions of

Nevada, to be used with the 1997 Uniform Building Code published by the International Conference of Building Officials.

California Division of Mines and Geology, 1998, Seismic Hazard Evaluation of the Long Beach 7.5-Minute Quadrangle, Los Angeles County, California: Open File Report 98-19, 39p. + plates.

California Division of Mines and Geology, 1998, Seismic Hazard Evaluation of the San Pedro 7.5-Minute Quadrangle, Los Angeles County, California: Open File Report 98-24, 39p. + plates.

California Division of Mines and Geology, 1998, Seismic Hazard Evaluation of the Torrance 7.5-Minute Quadrangle, Los Angeles County, California: Open File Report 98-26, 39p. + plates.

California Division of Mines and Geology (CDMG), 1999, Recommended Criteria for Delineating Seismic Hazard Zones in California: Special Publication 118, May 1992, Revised July 1999.

California Division of Oil and Gas, 1980, Onshore Oil and Gas Seeps in California: Publication No. TR26; text by Hodgson, S.F., 97p. (Re-issued in 1987).

California Division of Oil and Gas, 1991, California Oil and Gas Fields Volume 2: Southern, Central Coastal, and Offshore California.

California Division of Oil, Gas, and Geothermal Resources, 1997, Map No. 126.

California Division of Oil, Gas and Geothermal Resources, 2003, Annual Report, 257p.

California Geological Survey (CGS), 2001, Hazards from "mudslides," debris avalanches and debris flows in hillside and wildfire areas: CGS Note 33, available at http://www.consrv.ca.gov/dmg/pubs/notes/33/index.htm.

California Geological Survey (CGS), 2003, California Fault Parameters, http://www.consrv.ca.gov/cgs/rghm/psha/fault_parameters/htm/index.htm.

California Geological Survey, 2004, Guidelines for Evaluating the Hazard of Surface Fault Rupture, CGS Note 49, available at http://consrv.gov.cgs/information/publications/cgs_notes/index.htm.

California Office of Planning and Research (OPR), 1987, General Plan Guidelines.

California Seismic Safety Commission, 2003, Status of the Unreinforced Masonry Building Law, 2003 Report to the Legislature, Adopted June 12, 2003.

Campbell, R.H., 1975, Soil slips, debris flows, and rainstorms in the Santa Monica Mountains and vicinity, southern California: United States Geological Survey Professional Paper 851, 51p.

Cannon, S.H., 2001, Debris-Flow Generation from Recently Burned Watersheds: Environmental & Engineering Geosciences, Vol. VII, No. 4, November 2001, pp. 321-341.

Cao, T., Bryant, W.A., Rowshandel, B., Branum, D., and Wills, C.J., 2003, The revised 2002 California probabilistic seismic hazard maps, dated June 2003, 11p. Available at http://www.consrv.ca.gov/cgs/rghm/psha/index.htm

Chang, S.E., 2003, Evaluating disaster mitigations: methodology for urban infrastructure systems: American Society of Civil Engineers, Natural Hazards Review, Vol. 4, No. 4, November 1, 2003, pp. 186-196.

Clarke, S.H., Jr., Greene, H.G., and Kennedy, M.P., 1985, Earthquake-related phenomena offshore; *in* Ziony, I., (editor), Evaluating Earthquake Hazards in the Los Angeles Region: United States Geological Survey Professional Paper 1360, pp. 347-374.

Claypole, E.W., 1900, The Earthquake at San Jacinto, December 25, 1899: The American Geologist, Vol. XXV, Feb. 1900, pp. 106-108, plate III.

Cobarrubias, J.W., 1992, Methane Gas Hazard within the Fairfax District, Los Angeles; *in* Pipkin, B.W., and Proctor, R.J., (editors), Engineering Geology Practice in southern California: Association of Engineering Geologists Special Publication No. 4, pp. 131-143.

Coffman, J. L., and Stover, C.W., 1993, Seismicity of the United States, 1568-1989: U.S. Geological Survey Professional Paper 1527.

Coleman, Ronny J., 1994, Policy Context on Urban-Widland Fire Problem: California State and Consumer Services Agency, A Special Report for the Governor Pete Wilson, dated January 19, 1994, 13p.

Davis, D. J., 1980, Rare and Unusual Postfire Flood Events Experienced Flood Events in Los Angeles County During 1978 and 1980; *in* Storms, Floods and Debris Flows in Southern California and Arizona 1978 and 1980: Proceedings of a Symposium, September 17-18, 1980, published by the National Academy Press.

Davis, T.L., Namson, J., and Yerkes, R.F., 1989, A cross section of the Los Angeles area: Seismically active fold and thrust belt, the 1987 Whittier Narrows Earthquake, and Earthquake Hazard: Journal of Geophysical Research, Vol. 94, pp. 9644-9664.

Dibblee, T.W, Jr., 1999, Geologic Map of the Palos Verdes Peninsula: Dibblee Foundation Map DF70; Map Scale: 1:24,000.

Dolan, J.F., and Sieh, K., 1992, Tectonic geomorphology of the northern Los Angeles basin—Seismic hazards and kinematics of young fault movement; *in* Ehlig, P.L., and Steiner, E.A., (editors), Engineering Geology Field Trips, Orange County, Santa Monica Mountains, Malibu: Association of Engineering Geologists, Southern California Section, 35th Annual Meeting, Long Beach, California, October 2-9, 1992, pp. B20-B26.

Dolan, J. and Sieh, K., 1993, Sources of Destructive Earthquakes in the Los Angeles metropolitan region; *in* The Characteristics of Earthquake Ground Motions for Seismic Design: Volume I, Southern California Earthquake Center, Year 1 Annual Technical Report.

Dolan, J.F, and Sieh, K.E., 1992, Tectonic geomorphology of the Northern Los Angeles Basin: Seismic hazards of young fault movement; *in* Ehlig, P.K. and Steiner, E.A. (editors), Engineering Geology Field Trips, Orange County, Santa Monica Mountains and Malibu, guidebook, Volume: Association of Engineering Geologists, pp. B20-B26.

Dolan, J.F., Sieh, K., Rockwell, T.K., Yeats, R.S., Shaw, J., Suppe, J., Huftile, G.J., and Gath, E.M., 1995, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region: Science, v. 267, p. 199-205.

Dolan, J.F., and Pratt, T.L., 1997, High-resolution seismic reflection profiling of the Santa Monica fault zone, west Los Angeles, California: Geophysical Research Letters, Vol. 24, No. 16, pp. 2051-2054.

Dolan, J.F., Sieh, K., and Rockwell, T.K., 2000, Late Quaternary activity and seismic potential of the Santa Monica fault system, Los Angeles, California: Geological Society of America Bulletin, Vol. 112, pp. 1559-1581.

Dolan, J.F., Gath, E.M., Grant, L.B., Legg, M., Lindvall, S., Mueller, K., Oskin, M., Ponti, D.F., Rubin, C.M., Rockwell, T.K., Shaw, J.H., Treiman, J.A., Walls, C., and Yeats, R.S. (compiler), 2001, Active faults in the Los Angeles Metropolitan Region: Southern California Earthquake Center (SCEC) Special Publication Series No. 001, dated September, 2001.

Dolan, J.F., Christofferson, S.A., and Shaw, J.H., 2003, Recognition of paleoearthquakes on the Puente Hills blind thrust fault, California: Science, Vol. 300, pp. 115-118.

Drumm, P.L., 1992, Holocene displacement of the central splay of the Malibu Coast fault zone, Latigo Canyon, Malibu; *in* Pipkin, B.W., and Proctor, R.J., (editors), Engineering Geology Practice in Southern California: Association of Engineering Geologists Special Publication 4, pp. 247-254.

Earthquake Engineering Research Institute (EERI), 1986, Reducing Earthquake Hazards: Lessons Learned from Earthquakes: Earthquake Engineering Research Institute, Publication No. 86-02, 208p.

EERI (Earthquake Engineering Research Institute), 1992, Landers and Big Bear earthquakes of June 28 & 29, 1992, Special Report, Newsletter, August 1992, pp. 1-12.

EERI (Earthquake Engineering Research Institute), 1995, Northridge, California, 1994 Earthquake, Vol. 11, Issues S1 and S2.

Ellen, S.D., and Fleming, R.W., 1987, Mobilization of debris flows from soil slips, San Francisco Bay region, California; *in* Costa, J.E. and Wieczorek, G.F., (editors), Debris flows/avalanches: Process, recognition, and mitigation: Geological Society of America Reviews in Engineering Geology, Vol. VII, pp. 31-40.

Ellsworth, W.L., 1990, Earthquake History, 1769-1989; *in* Wallace, R.E., (editor), The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515.

Ewing, L. and Wallendorf, L., (editors), 2002, Solutions to Coastal Disasters '02: Conference Proceedings of the meeting held in San Diego, California on February 24-27, 2002: American Society of Civil Engineers, Reston, Virginia, 1,019p.

Federal Code of Regulations, Title 40: Protection of Environment; available at http://www.epa.gov/epahome/cfr40.htm

Federal Emergency Management Agency (FEMA), 1979, Flood Insurance Rate Maps (FIRMs) for the City of Torrance, California; Community Panels No. 060165 0001B, 060165 0003B, 060165 0004B, and 060165 0005B.

Federal Emergency Management Agency, FEMA-73, 1985, Comprehensive Earthquake Preparedness Planning Guidelines: City: Earthquake Hazard Reduction Series 2, 80p.

Federal Emergency Management Agency (FEMA), 1987, FEMA-135, Abatement of Seismic Hazard to Lifelines: Water and Sewer Lifelines and Special Workshop Presentations: Earthquake Hazard Reduction Series No. 2, 181p.

Federal Emergency Management Agency (FEMA), 1987, FEMA-139, Abatement of Seismic Hazard to Lifelines: Proceedings of a Workshop on Development of an Action Plan – Volume 5: Papers on Gas and Liquid Fuel Lifelines: Building Seismic Safety Council; Earthquake Hazard Reduction Series No. 30, 134p.

Federal Emergency Management Agency (FEMA), 1988, FEMA-154, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook: Applied Technology Council (ATC21), Earthquake Hazards Reduction Series No. 41, 185p.

Federal Emergency Management Agency (FEMA), 1988, FEMA-155, Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation: Applied Technology Council (ATC-21-1), Earthquake Hazards Reduction Series No. 42, 137p.

Federal Emergency Management Agency (FEMA), 1988, FEMA-156, Typical Costs for Seismic Rehabilitation of Existing Buildings, Volume 1 – Summary: by Englekirk and Hart Consulting Engineers, Inc., Los Angeles, California; Earthquake Hazard Reduction Series No. 39.

Federal Emergency Management Agency (FEMA), 1989, FEMA-173, Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings – Supporting Report: Building Systems Development, Inc., Integrated Design Services and Rubin, Claire B.; Earthquake Hazard Reduction Series No 46, 190p.

Federal Emergency Management Agency (FEMA), 1989, FEMA-174, Establishing Programs and Priorities for the Seismic Rehabilitation of Buildings – A Handbook Building Systems Development, Inc., Integrated Design Services and Rubin, Claire B.; Earthquake Hazard Reduction Series No 45, 122p.

Federal Emergency Management Agency (FEMA), 1989, FEMA-175, Seismic Evaluation of Existing Buildings: Supporting Documentation: Applied Technology Council (ATC-22-1); Earthquake Hazard Reduction Series No. 48, 160p.

Federal Emergency Management Agency (FEMA), 1989, FEMA-178, A Handbook for Seismic Evaluation of Existing Buildings (Preliminary): Applied Technology Council (ATC-22); Earthquake Hazard Reduction Series No. 47, 169p.

Federal Emergency Management Agency, FEMA-232, 1998, Home Builder's Guide to Seismic Resistant Construction: Earthquake Hazard Reduction Series, 75p.

Federal Emergency Management Agency, FEMA-315, 1998, Seismic Rehabilitation of Buildings: Strategic Plan 2005: Earthquake Hazard Reduction Series, 40p.

Federal Emergency Management Agency (FEMA), 2001, http://www.fema.gov/library/landsli.htm.

Field, M.E., and Edwards, B.D., 1980, Slopes of the southern California continental borderland: A regime of mass transport *in* Field, M.E., Bouma, A.H., Colburn, I.P., Douglas, R.G., and Ingle, J.C., (editors), Proceedings of the Quaternary depositional environments of the Pacific Coast: Pacific Coast Paleogeography Symposium No. 4: Los Angeles California Society of Economic Paleontologists and Mineralogists, Pacific Section, pp. 169-184.

Finney, M.A., 1995, FARSITE- A Fire Area Simulator for Managers; *in* The Biswell Symposium: Fire Issues and Solutions in Urban Interface and Wildland Ecosystems: US Department of Agriculture, Forest Service, General Technical Report PSW-158, Berkeley, California.

Finney, M.A. 1998, FARSITE: Fire Area Simulator-model development and evaluation: US Department of Agriculture, Forest Service, Research Paper RMRS-RP-4, Rocky Mountain Research Station, Ft. Collins, Colorado, 47p.

Fischer, P.J., and Mills, G.I., 1991, The offshore Newport-Inglewood – Rose Canyon fault zone, California: Structure, segmentation and tectonics; *in* Abbott, P.L., and Elliot, W.J., (editors.), Environmental Perils, San Diego Region: Geological Society of America Field Trip guidebook prepared by the San Diego Association of Geologists, pp. 17-36.

Fisher, F. L., 1995, Building Fire Safety in the Wildland Urban Intermix: The Role of Building Codes and Fire Test Standards: Report prepared for the California/China Bilateral Conference on

Fire Safety Engineering held August 14-15, 1995 in Sacramento, California, 13p.

Fisher, M.A., Normark, W.R., Langenheim, V.E, Calvert, A.J., and Sliter, R., 2004, The offshore Palos Verdes Fault Zone near San Pedro, southern California: Seismological Society of America Bulletin, Vol. 94, No. 2, pp. 506-530.

Fugro-McClelland (West), Inc., 1993, Revised Draft Palos Verdes Fault Studies, 2020 Plan Geotechnical Investigation, Port of Los Angeles (Volume 1); Consultants Report dated September 28, 1993, Project No. 0902-2029.

Fugro West, Inc., 1994, Palos Verdes Fault Studies, 2020 Plan Geotechnical Investigation, Port of Los Angeles: Consultants Report to the Cit of Los Angeles Harbor Department.

Fuis, G.S., Mooney, W.D., Healey, J.H., McMechan, G.A., and Lutter, W.J., 1982, Crustal structure of the Imperial Valley Regio: *in* The Imperial Valley, California, Earthquake of October 15, 1979, U.S. Geological Survey Professional Paper 1254, pp. 25-49.

Fuis, G.S., and Kohler, W.M., 1984, Crustal structure and tectonics of the Imperial Valley region, California: *in* Rigsby, C.A., (editor), The Imperial Basin – Tectonics, Sedimentation, and Thermal Aspects, Society of Economic Paleontologists and Mineralogists, Pacific Section Annual Convention, San Diego, California, Vo. 40, pp. 1-13.

Fuis, G.S., and Mooney, W.D., 1990, Lithospheric structure and tectonics from seismic-refraction and other data: *in* Wallace, R.E., (editor), The San Andreas Fault System, California, U.S. Geological Survey Professional Paper 1515, pp. 207-238.

Fumal, T.E., Davis, A.B., Frost, W.T., O'Donnell, J., Sega, G., and Schwartz, D.P., 1995, Recurrence Studies of the Tujunga Segment of the 1971 San Fernando earthquake, California: EOS (Supplement), Vol. 76, No. 46, 364p.

Garcia, A.W., and Houston, J.R., 1975, Type 16 flood insurance study – Tsunami predictions for Monterey and San Francisco Bays and Puget Sound: U.S. Army Corps of Engineers Waterways Experiment Station Technical Report H-75-17, 21p.

Gath, E.M., Gonzalez, T., and Rockwell, T.K., 1992, Evaluation of the late Quaternary rate of slip, Whittier Fault, southern California: U.S. Geological Survey Final Technical Report, 24p.

Gosnold, William D., Jr., LeFever, Julie A., Todhunter, Paul E., and Osborne, Leon F., Jr., 2000, Rethinking Flood Prediction: Why the Traditional Approach Needs to Change: Geotimes, Vol. 45, No. 5, pp. 20-23.

Grant, L. and Sieh, K., 1995, Paleoseismic evidence of clustered earthquakes on the San Andreas fault in the Carrizo Plain, California: Journal of Geophysical Research, Vol. 99, No. 4, pp. 6,819-6,841.

Grant, L.B., Waggoner, J.T., Rockwell, T.K., and von Stein, C., 1997, Paleoseismicity of the north branch of the Newport-Inglewood fault zone in Huntington Beach, California, from Cone Penetrometer Test Data: Bulletin of the Seismological Society of America, Vol. 87, No. 2, pp. 277-293.

Grant, L.B., Mueller, K. J., Gath, E.M., Cheng, H., Edwards, R.L., Munro, R., Kennedy, G.L., 1999, Late quaternary uplift and earthquake potential of the San Joaquin Hills, southern Los Angeles Basin, California: Geology, November 1999, Vol. 27, No. 11, pp. 1031-1034,

Grant, L.B., Ballenger, L.J., and Runnerstom, E.E., 2002, Coastal uplift of the San Joaquin Hills, southern Los Angeles Basin, California, by a large earthquake since A.D. 1635: Bulletin of the Seismological Society of America, Vol. 92, No. 2, pp. 590-599.

Grauzinis, V. J., Joy, J.W., and R. R. Putz, The Reported Tsunami of December 1812, unpublished manuscript.

Greenlee, J., and Sapsis, D., 1996, Prefire Effectiveness in Fire Management: A Summary of State-of-Knowledge: dated August 1996. Can be obtained from www.ucfpl.ucop.edu/UWI%20Documents/103.PDF.

Griggs, G.B., Marshall, J.S., Rosenbloom, N.A., and Anderson, R.S., 1991, Ground Cracking in the Santa Cruz Mountains in Baldwin, J.E. and Sitar, N. (editors), Loma Prieta Earthquake: Association of Engineering Geologists, Engineering Geologic Perspectives, Special Publication No. 1, pp. 25-41.

Guptil, P.D., and Heath, E.G., 1981, Surface faulting along the Newport-Inglewood zone of deformation: California Geology, pp. 142-148.

Guptil, P., Armstrong, C., and Egli, M., 1992, Structural features of West Newport Mesa *in* Heath, E., and Lewis, L., (editors), The Regressive Pleistocene Shoreline, Coastal Southern California, South Coast Geological Society Annual Field Trip Guide Book No. 20, pp. 123-136.

Harp, E.L., and Jibson, R.W., 1996, Landslides triggered by the 1994 Northridge, California, Earthquake: Bulletin of the Seismological Society of America, Vol. 86, No. 1B, pp. S319-S332.

Harris, V.E., LeBlanc, J.J., and Wiebe, K.H., 1992, Pleistocene aquifers of the West Coast Basin; *in* Heath, E.G., and Lewis, W.L., (editors), The regressive Pleistocene shoreline, coastal southern California: South Coast Geological Society, Inc. Annual Field Trip Guide Book No. 20, pp. 315-336.

Hart, E.W., and Bryant, W.A., 1999, Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Fault Zones Maps: California Division of Mines and Geology Special Publication 42.

Hauksson, E, and Jones, L.M., 1989, The 1987 Whittier Narrows earthquake sequence in Los Angeles, southern California:

Seismological and tectonic analysis: Journal of Geophysical Research Vol. 94 pp. 9569-9589.

Hauksson, E., 1990, Earthquakes, faulting and stressing the Los Angeles Basin: Journal of Geophysical Research, Vol. 95, pp. 15,365-15,394.

Hauksson, E., and Gross, S., 1991, Source parameters of the 1933 Long Beach earthquake: Seismological Society of America Bulletin, Vol. 81, pp. 81-98.

Hauksson, E., Gee, L., Given, D., Oppenheimer, D., and Shakal, T., 2004, The California Integrated Seismic Network: Abstract, Seismological Society of America Annual Meeting, April 14-16, Palm Springs, California.

Hayes, E., 1988, A Review of Information on Seismic Hazards Needed for the Earthquake-Resistant Design of Lifeline Systems in the United States: U.S. Geological Survey Open File Report ICSSCTR-10, 71p.

Heck, N.H., 1947, List of Seismic Sea Waves: Bulletin of the Seismological Society of America, Vol. 37, No. 4.

Helm, R., Neal, B., and Taylor, L., 1973, A Fire Hazard Severity Classification System for California's Wildlands: A report by the Department of Housing and Urban Development and the California Department of Conservation, Division of Forestry to the Governor's Office of Planning and Research, dated April 1, 1973.

Hodgkinson, K.M., Stein, R.S., Hudnut, K.W., Satalich, J., and Richards, J.H., 1996, Damage and Restoration of Geodetic Infrastructure Caused by the 1994 Northridge, California, Earthquake: U.S. Geological Survey Open-File Report #96-517; available on the web at http://pasadena.wr.usgs.gov/fema/

Holzer, T.L., 1984, Ground failure induced by ground-water withdrawal from unconsolidated sediment: man-induced land subsidence: Review in Engineering Geology, Vol. 6, pp. 67-105.

Houston, J.R., 1980, Type 19 flood insurance study: Tsunami predictions for southern California: U.S. Army Corps of Engineers Waterways Experimental Station Technical Report HL-80-18, 172p.

Houston, J.R., and Butler, H.L., 1979, A numerical model for tsunami inundation: US. Army Corps of Engineers Waterways Experimental Station Technical Report HL-79-2, 54p.

Houston, J.R, and Garcia, A.W., 1974, Type 16 flood insurance study: Tsunami predictions for Pacific coastal communities: U.S. Army Corps of Engineers Waterways Experiment Station Research Report H-74-3, 10p.

Houston, J.R., and Garcia, A.W., 1978, Type 16 flood insurance study: Tsunami predictions for the west coast of the United States: U.S. Army Corps of Engineers Waterways Experiment Station Research Report H-78-26, 38p.

Houston, J.R., Whalin, R.W., Garcia, A.W., and Butler, H.L., 1975, Effect of source orientation and location in the Aleutian Trench on tsunami amplitude along the Pacific coast of the continental United States: U.S. Army Corps of Engineers Waterways Experiment Station Research Report H-75-4, 22p.

Iida, K., 1963, Magnitude, energy, and generation mechanisms of tsunamis and a catalog of earthquakes associated with tsunamis; in Proceedings of the 10th Pacific Science Congress Symposium: International Union of Geodesy and Geophysics Monograph NO. 24, pp. 7-18.

Iida K., Cox, D. C, and G. Pararas-Carayannis, 1967, Preliminary Catalog of Tsunamis Occurring in the Pacific Ocean: University of Hawaii, Honolulu.

Imamura, A., 1949, List of Tsunamis in Japan: Journal of the Seismological Society of Japan, Vol. 2, pp. 22-28 (in Japanese, as referenced in McCulloch, 1985).

International Conference of Building Officials (ICBO), 1997, Uniform Building Code.

International Conference of Building Officials (ICBO), 1998, California Building Code.

International Conference of Building Officials (ICBO), 2001, California Building Code, Division IV, Earthquake Design.

Insurance Services Office, Inc. (ISO), 1997, The Wildland/Urban Fire Hazard: ISO, New York, December 1997.

Insurance Services Office, Inc. (ISO), 2001, Guide for Determination of Needed Fire Flow: Edition 10-2001, 26p.

Jacoby, G., Sheppard, P. and Sieh, K., 1988, Irregular recurrence of large earthquakes along the San Andreas Fault in southern California -- Evidence from trees near Wrightwood: Science, Vol. 241, pp. 196-199.

Jennings, Charles W., 1994, Fault Activity Map of California and Adjacent Areas with Location and Ages of Recent Volcanic Eruptions: California Division of Mines and Geology, California Geologic Data Map Series, Map No. 6, Map Scale: 1:250,000.

James M. Montgomery Consulting Engineers (JMM), 1984, Combined Inundation Study for Walteria Dam and the Proposed Walteria Dam 2, Torrance, California.

Johnson, I.A., 1998, Land Subsidence Due to Fluid Withdrawal in the United States - An Overview; *in* Borchers, J.W. (editor), Land Subsidence, Case Studies and Current Research: Association of Engineering Geologists, Proceedings of the Dr. Joseph F. Poland Symposium on Land Subsidence, Special Publication 8, pp. 51-57.

Jones, L.M., 1995, Putting Down Roots in Earthquake Country: Southern California Earthquake Center (SCEC) Special Publication, Los Angeles, California.

Jones, L., Mori, J., and Hauksson, E., 1995, The Landers Earthquake: Preliminary Instrumental Results: Earthquakes and Volcanoes, Vol. 23, No. 5, pp. 200-208.

Joy, J.W., 1968, Tsunamis and their Occurrence along the San Diego County Coast: Westinghouse Ocean Research Laboratory Report, No. 68-567-OCEAN-RL, San Diego, California.

Joyner, W. B., and Fumal, T. E., 1985, Predictive mapping of earthquake ground motion; *in* Ziony, J. I., (editor), Evaluating Earthquake Hazards in the Los Angeles Region, An Earth-Science Perspective: U.S. Geological Survey Professional Paper 1360, pp. 203-217.

Keefer, D.K., and Johnson, A.M., 1983, Earth flows: Morphology, mobilization, and movement: United States Geological Survey Professional Paper 1264, 55p.

Kuhn, G.G. and Shepard, F.P., 1985, Beach Processes and Sea Cliff Erosion in San Diego County, California; *in* Komar, P.D., (editor), Handbook of Coastal Processes and Erosion: CRC Press.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Richardson, J.R., Chang, F., 1991, Stream stability at highway structures: U.S. Department of Transportation No. FHWA-IP-90-014 Hydraulic Engineering Circular 20, 195p.

Lander, J.F., 1968, Seismological Notes: March and April 1968: Bulletin of the Seismological Society of America, Vol. 58, No. 5, pp. 1709-1714.

Lander, J.F., and P.A. Lockridge, 1989, United States Tsunamis 1690-1988: U.S. Department of Commerce, Publication 41-2.

Law/Crandall, Inc., 1994, Report of fault rupture hazard investigation, Wastewater Treatment Plant No. 2, Huntington Beach, California for the County Sanitation Districts of Orange County, Project No. 2661.30140.0001, dated June 13, 1994.

Lazarte, C.A., Bray, J.D., Johnson, A.M., and Lemmer, R.E., 1994, Surface Breakage of the 1992 Landers Earthquake and its Effects on Structures: Bulletin of the Seismological Society of America, Vol. 84, No. 3, pp 547-561.

Legg, M.R., 1985, Geologic structure and tectonics of the inner continental borderland offshore northern Baja California, Mexico: unpublished PH.D thesis, University of California Santa Barbara, 410p.

Legg, M.R., and Kennedy, M.P., 1991, Oblique divergence and convergence in the California Continental Borderland; in Abbott, P.L., and Elliott, W.J., (editors), Environmental Perils of the San Diego Region: San Diego Association of Geologists Guidebook, pp. 1-16.

Legg, M.R. and Goldfinger, C., 2001, Earthquake Potential of Major Faults Offshore Southern California: Collaborative Research with

Oregon State University and Legg Geophysical: U.S. Geological Survey Grant No. 01HQGR0017; available at http://erp-web.er.usgs.gov/reports/abstract/2001/sc/g0017.htm.

Lindvall, S.C., and Rockwell, T.K., 1995, Holocene activity of the Rose Canyon fault zone in San Diego, California: Journal of Geophysical Research, Vol. 100, pp. 24,121-24,132.

Louderback, G.D., 1954, Seismological Notes, 1954 San Jacinto Earthquake: Bulletin of the Seismological Society of America, Vol. 44, No. 3, pp. 529-542.

Louie, J.N., Allen, C.R., Johnson, D.C., Haase, P.C., and Cohn, S.N., 1985, Fault Slip in Southern California: Bulletin of the Seismological Society of America, Vol. 75, pp. 811-833.

Lund, Le Val, 1994, Lifelines Performance in the Landers and Big Bear (California) Earthquakes of 28 June 1992: Bulletin of the Seismological Society of America, Vol. 84, No. 3, pp. 562-572.

Lund, Le Val, 1996, Lifeline Utilities Performance in the 17 January 1994 Northridge, California Earthquake: Bulletin of the Seismological Society of America, Vol. 86, No. 1B, pp. S350-S361.

Marine Advisors, Inc., (compilers), 1965, Examination of Tsunami Potential at the San Onofre Nuclear Generating Station, Report A-163, Los Angeles, California.

Marlow, M.S., Gardner, J.V., and Normark, W.R., 2000, Using high-resolution multibeam bathymetry to identify seafloor surface rupture along the Palos Verdes fault complex in offshore southern California: Geology, Vol. 28, No. 7, pp. 587-590.

Martin, G.R., and Lew, M., 1999, (editors), Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Evaluating and Mitigating Seismic Hazards in California – Liquefaction Hazards: Southern California Earthquake Center Publication, 63p.

McCulloch, D. S., 1985, Evaluating Tsunami Potential _in_ Ziony, I., (editor), Evaluating Earthquake Hazards in the Los Angeles Region: United States Geological Survey Professional Paper 1360, pp. 375-413.

McGarr, A., Vorhis, R. C., 1968, Seismic Seiches from the March 1964 Alaska earthquake: U.S. Geological Survey Professional Paper 544-E, 43p.

McNeilan, T., Rockwell, T.K., and Resnick, G., 1996, Sense and rate of Holocene slip, Palos Verdes fault, southern California: Journal of Geophysical Research, Vol. 101, B4, pp. 8317-8334.

Mendenhall, W.C., 1905, Development of underground waters in the eastern coastal plain region of Southern California: U.S. Geological Survey Water-Supply and Irrigation Paper No. 137.

Merck Company, 1983, The Merck Index of Chemicals, Drugs and Biologicals, 10th Edition, Rahway, New Jersey, pp. 852-853.

Montandon, F., 1928, Tremblements de Terre: Moterdaux pour l'Etude des Calamites, Geneva, Switzerland, No. 16, 345p.

Morton, D.M., Campbell, R.H., Jibson, R.W., Wesson, R.L., and Nicholson, C., 1989, Ground fracturing and landsliding produced by the July 8, 1986 North Palm Springs Earthquake *in* Sadler, P.M., and Morton, D.M., (editors), Landslides in a Semi-Arid Environment with Emphasis on the Inland Valleys of Southern California: Inland Geological Society, Volume 2, pp. 183-196.

Mueller, K.J., 1997, Recency of folding along the Compton-Los Alamitos Trend: Implications for seismic risk in the Los Angeles Basin: EOS Transactions of the American Geophysical Union, Vol. 78, p. F702.

National Fire Protection Association (NFPA), 2001, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations and Special Operations to the Public by Career Fire Departments: NFPA Standard 1710, 2001 Edition.

Oakeshott, Gordon B., (editor), 1975, San Fernando, California, Earthquake of 9 February 1971: California Division of Mines and Geology, Bulletin 196, 462p.

O'Rourke, T.D., Grigoriu, M.D., and Khater, M.M., 1985, A state of the art review: Seismic response of buried pipelines, *in* Sundararajan, C. (editor), Decade of Progress in Pressure Vessel Technology: American Society of Civil Engineers.

O'Rourke, M.J., and Liu, X., 1999, Response of buried pipelines subject to earthquake effects: ASCE, Multidisciplinary Center for Earthquake Engineering Research Monograph #3, Buffalo, New York, 249p.

Oskin M., Sieh, K., Rockwell, T., Miller G., Guptill, P., Curtis, M., McArdle, S. and Elliot, P., 2000, Active parasitic folds on the Elysian Park anticline: Implications for seismic hazard in central Los Angeles, California: Geological Society of America Bulletin, Vol. 112, No. 5, pp. 693-707.

Palm, R., 1981, Real Estate Agents and Special Studies Zone Disclosure: The Response of California Home Buyers to Earthquake Hazard Information: University of Colorado at Boulder, Natural Hazards Research and Applications Information Center, Monograph Series No. 032.

Patterson, A.C., and Rockwell, T.K., 1993, Paleoseismology of the Whittier fault based on 3-dimenstional trenching at the Olinda Oil Field, Orange County, southern California: Geological Society of America, Abstracts with Programs, Vol. 25, No. 5, pp. 131.

Person, Waverly J., 1986, Earthquakes: July - August 1986: Earthquakes and Volcanoes, Vol. 19, No. 1, pp. 32-35.

Person, Waverly J., 1992, Earthquakes: March - April 1992: Earthquakes and Volcanoes, Vol. 23, No. 5, pp. 227-233.

Petersen, M. D., Bryant, W.A., Cramer, C. H., Cao, T, Reichle, M.S, Frankel, A.D., Lienkaemper, J.J., McCrory, P.A, and Schwartz, D. P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: California Department of Conservation Open File Report 96-08.

Peterson M. D. and Wesnousky, S.G., 1994, Fault slip rates and earthquake histories for active faults in southern California: Bulletin of the Seismological Society of America, Vol. 84, No. 5, pp. 1608-1649.

Peterson, M. D., Toppozada, T. R., Cao, T., Cramer, C. H., Reichle, M. S. and Bryant, W. A., 2000, Active Fault Near-Source Zones Within and Bordering the State of California for the 1997 Uniform Building Code: Earthquake Spectra, Vol. 16, No. 1, pp. 69-83.

Phillips, Clinton B., 1983, Instructions for Zoning Fire Hazard Severity in State Responsibility Areas in California: California Department of Forestry, dated December 1983.

Poland, J.F., and Garret, A.A., 1959, Geology, hydrology, and chemical character of ground waters in the Torrance-Santa Monica area, California: U.S. Geological Survey Water-Supply Paper 1461.

Reneau, S.L., and Dietrich, W.E., 1987, The importance of hollows in debris flow studies; examples from Marin County, California; *in* Costa, J.E. and Wieczorek, G.F. (editors), Debris flows/avalanches: Process, recognition, and mitigation: Geological Society of America Reviews in Engineering Geology, Vol. VII, pp. 165-179.

Richardson, E.V., Harrison, L.J., Richardson, J.R., and Davis, S.R., 1993, Evaluating scour at bridges (2d ed.): U.S. Department of Transportation Hydraulic Engineering Circular 18, 132p.

Rico, H., Hauksson, E., Given, D., Friberg, P., and Frechette, K., 2004, The CISN Display - Reliable delivery of real-time earthquake information and Shakemap to Critical End-users: Abstract, Seismological Society of America Meeting, April 14-16, Palm Springs, California.

Rogers, A. M., Tinsely, J. C., and Borcherdt, R. D., 1985, Predicting relative ground response; *in* Ziony (editor), Evaluating Earthquake Hazards in the Los Angeles Region, An Earth Science Perspective: U.S. Geological Survey, Professional Paper 1360, pp. 221-248.

Roth R., Holtom, R., and Sai-on S., 1986, California Earthquake Zoning and Probable Maximum Loss Evaluation Program, California Administrative Code Title 10, Chapter 5, Subchapter 3, Section 2307: California Department of Insurance, Los Angeles, California, 44p.

Rzonca, G.F., Spellman, H.A., Fall, E.W., and Shlemon, R.J., 1991, Holocene displacement of the Malibu Coast fault zone, Winter Mesa, Malibu, California — Engineering geologic implications: Bulletin of the Association of Engineering Geologists, Vol. 28, pp. 147-158.

Salsman, G. S., 1959, The Tsunami of March 9, 1957 as Recorded at Tide Stations: United States Coast and Geodetic Survey, Technical Bulletin No. 6.

Savage, W.U., 1995, Utility lifelines performance in the Northridge earthquake; *in* Woods, M.C., and Seiple, W.R., (editors), The Northridge Earthquake of 17 January 1994: California Division of Mines and Geology Special Publication 116, pp. 153-162.

Schneider, C.L., Hummon, C., Yeats, R.S., and Huftile, G.J., 1996, Structural Evolution of the Northern Los Angeles Basin based on growth strata: Tectonics, Vol. 15, pp. 341-355.

Sharpe, R., 1982, An Investigation of the Correlation between Earthquake Ground Motion and Building Performance: Applied Technology Council, U.S. Contract Survey, No. 14-08-0001-19892, 113p.

Shaw, J.H. and Suppe, J., 1994, Active faulting and growth folding in the eastern Santa Barbara Channel, California: Geological Society of America Bulletin, Vol. 106, pp. 607-626.

Shaw, J. H., and Suppe, J., 1996, Earthquake hazards of active blind-thrust faults under the central Los Angeles basin, California: Journal of Geophysical Research, Vol. 101, pp. 8623-8642.

Shaw, J.H., and Shearer, P., 1999, An elusive blind-thrust fault beneath metropolitan Los Angeles: Science, Vol. 283, pp. 1516-1518.

Shaw, J.H., Plesch, A., Dolan, J.F., Pratt, T.L., and Fiore, P., 2002, Puente Hills blind thrust system, Los Angeles, California: Bulletin of the Seismological Society of America, Vol. 92, No. 8, pp. 2,946-2,960.

Shlemon, R.J., and Hakakian, M., 1992, Fissures produced both by groundwater rise and by groundwater fall: a geological paradox in the Temecula-Murrieta area, southwestern Riverside County, California *in* Stout, M.L., (editor), Proceedings, Association of Engineering Geologists, 35th annual Meeting, pp. 165-169.

Shlemon, R.J., Elliot, P., and Franzen, S., 1995, Holocene displacement history of the Newport-Inglewood, North Branch fault splays, Santa Ana River floodplain, Huntington Beach, California: The Geological Society of America 1995 Annual Meeting, Abstracts with Programs, New Orleans, Louisiana.

Sieh, K., Jones, L., Hauksson, E., Hudnut, K., Eberhart-Phillips, D., Heaton, T., Hough, S., Hutton, K., Kanamori, H., Lilje, A., Lindvall, S., McGill, S., Mori, J., Rubin, C., Spotila, J. A., Stock, J., Thio, H., Treiman, J., Wernicke, B., and Zachariasen, J., 1993, Near-field investigations of the Landers Earthquake sequence, April to July, 1992: Science, Vol. 260, pp. 171-176.

Soloviev, S.L., and Go, C.N., 1975, A catalogue of Tsunamis of the Eastern Shore of the Pacific Ocean: Academy of Sciences of the USSR, "Nauka" Publishing House, Moscow, 204p.

South Coast Air Quality Management District, 2002, Current Air Quality and Trends in the South Coast Air Quality Management District, 2000 Air Quality Standards Compliance Report, Vol. 15, No. 12, 10p. (available at www.aqmd.gov).

Southern California Earthquake Center (SCEC), 1999, Recommended procedures for implementation of DMG SP117 Guidelines for Evaluating and Mitigating Seismic Hazards in California – Liquefaction Hazards in California: Martin, G.R., and Lew, M., (editors), 63p.

Southern California Earthquake Center (SCEC), 2002, Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California; by Blake, T.F., Hollingsworth, R.A., and Stewart, J.P. (editors), 110p. + Appendix.

Southern California Earthquake Center (SCEC), 2005, Southern California fault index, http://www.data.sece.org/fault_index/palos.html

Spaeth M.G. and S.C. Berkman, 1972, Tsunami of March 28, 1968 as Recorded at Tide Stations at the Seismic Sea Wave Warning System, *in* The Great Alaska Earthquake of 1964: Oceanography and Coastal Engineering, National Academy of Sciences, pp. 38-110.

Spangle, W. E., 1988, Putting Seismic Safety Policies to Work: Prepared for the Bay Area Regional Earthquake Preparedness Project, 39p.

Spittler, T.E., Harp, E.L., Keefer, D.K., Wilson, R.C., and Sydnor, R.H., 1990, Landslide features and other coseismic fissures triggered by the Loma Prieta earthquake, Santa Cruz Mountains, California *in* McNutt, S.R., and Sydnor, R.H., (editors.), The Loma Prieta (Santa Cruz Mountains), California, Earthquake of 17 October 1989: California Division of Mines and Geology Special Publication 104, pp. 59-66.

State of California, Office of Planning and Research (OPR), 1987, General Plan Guidelines.

State of California, SSC-01, Seismic Safety Commission, 1988, Steps to Earthquake Safety for Local Governments, Report No. SSC 88-01.

State of California, SSC-03, Seismic Safety Commission, 1987-03, Guidebook to Identify and Mitigate Seismic Hazards in Building, Report No. SSC 87-03.

Stein, R.S., King, G.C.P., Lin, J., 1992, Change in Failure Stress on the Southern San Andreas Fault System Caused by the 1992 M=7.4 Landers Earthquake: Science, Vol. 258, pp. 1328-1332.

Stephenson, W.J., Rockwell, T.K., Odum, J.K., Shedlock, K.M., and Okaya, D.A., 1995, Seismic reflection and geomorphic characterization of the onshore Palos Verdes fault zone, Los Angeles, California: Seismological Society of America Bulletin, Vol. 85, No. 3, pp. 943-950.

Stermitz, F., 1964, Effects of the Hebgen Lake Earthquake on Surface Water: U.S. Geological Survey Professional Paper 435, pp. 139-150.

Stewart, C.A., Colby, N.D, Kent, R.T., Egan, J.A., and Hall, N.T., 1998, Earth Fissuring, Ground-Water Flow, and Ground-Water Quality in the Chino Basin, California: *in* Borchers, J.W., (editor), Land Subsidence, Case Studies and Current Research: Association of Engineering Geologists Special Publication No. 8, Proceedings of the Dr. Joseph F. Poland Symposium on Land Subsidence.

Stewart, J.P., Bray, J.D., McMahon, D.J., and Kropp, A.L., 1995, Seismic performance of hillside fills: Reprint from Landslides Under Static and Dynamic Conditions-Analysis, Monitoring, and Mitigation: Geotechnical Engineering Division/ASCE, held October 23-27, 1995, San Diego.

Sudduth, C., 1985, Evaluating earthquake ground failure potential for development decisions, summary of Working Group V and audience discussion; *in* Future Directions in Evaluating Earthquake Hazards in Los Angeles Region, An Earth-Science Perspective: U.S. Geological Survey, Professional Paper 1360, pp. 320.

Sydnor, Robert, 2003, Engineering Geology and Seismology for Public Schools and Hospitals in California: unpublished California Geological Survey Special Publication ### to accompany California Geological Survey Note 48 Checklist; February 3, 2003 version.

Synolakis C.E., 1987, The runup of solitary waves: Journal of Fluid Mechanics, Vol. 185, pp. 523-545.

Synolakis, C.E., Liu, P.L., Yeh, H., and Carrier, G., 1997, Tsunamigenic seafloor deformations: Science, Vol. 278, pp. 598-600.

Synolakis, C.E., Borrero, J., and Eisner, R., 2002, Developing Inundation Maps for Southern California; in Ewing, L. and Wallendorf, L., (editors), Solutions to Coastal Disasters '02: Conference Proceedings of the meeting held in San Diego, California on February 24-27, 2002: American Society of Civil Engineers, Reston, Virginia, pp. 848-862.

Synolakis, Costas Emmanuel, 2002, Professor of Civil Engineering, University of Southern California, Los Angeles, California, and Director of the University of Southern California Tsunami Research Group, personal communication via telephone and e-mail regarding tsunami inundation maps for Orange County and Newport Beach.

Talley, C.H., Jr. and Cloud, W. K., (editors), 1962, United States Earthquakes, 1960: United States Coast and Geodetic Survey.

Tan, S.S., 1998, Slope failure and erosion assessment of the fire areas at Fillmore (April 1996) and Piru (August 1997), Ventura County, California: California Division of Mines and Geology Open-File Report 98-32.

Teggart, F. J., 1911, The Portola expedition of 1769-1770, Diary of Miguel Costanso, Publication of the Academy of Pacific Coast History, Vol. 2, No. 4.

Tennyson, M.E., 2005, Chapter H: Growth History of Oil Reserves in Major California Oil Fields During the Twentieth Century; *in* Dyman, T.S., Schmoker, J.W., and Verma, M., (editors), Geologic, Engineering, and Assessment Studies of Reserve Growth: U.S. Geological Survey Bulletin 2172-H.

Tinsley, J.C., Youd, T.L., Perkins, D.M., and Chen, A.T.F., 1985, Evaluating liquefaction potential *in* Ziony, J.I., (editor), Evaluating Earthquake Hazards in the Los Angeles Region – An Earth Science Perspective: U.S. Geological Survey Professional Paper 1360, pp. 263-316.

Tinsley, J.C., and Fumal, T.E., 1985, Mapping quaternary sedimentary deposits for aerial variations in shaking response; *in* Ziony, J.I., (editor), Evaluating Earthquake Hazards in the Los Angeles Region – An Earth Science Perspective: U.S. Geological Survey Professional Paper 1360, pp. 101-125.

Titov, V.V. and Synolakis, C.E., 1998, Numerical modeling of tidal wave runup: Journal of Waterways, Port, Coastal and Ocean Engineering, ASCE, Vol. 124, No. 4, pp. 157-171.

Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of Isoseismal Maps and Summaries of Reported Effects for Pre-1900 California Earthquakes: California Division of Mines and Geology Open File Report 81-11 SAC.

Toppozada, T.R. and Parke, D.L., 1982, Areas damaged by earthquakes, 1900-1949: California Division of Mines and Geology, Open-File Report, pp. 82-17.

Toppozada, T.R., and others, 1988, Planning Scenario for a Major Earthquake on the Newport-Inglewood Fault (Los Angeles and Orange Counties): California Division of Mines and Geology Special Publication No. 99.

Townley, S.D., 1939, Earthquakes in California, 1769 to 1928: Bulletin of the Seismological Society of America, Vol. 29, No. 1, pp. 21-252.

Trask, J.B., 1856, Untitled paper on earthquakes in California from 1812 to 1855: Proceedings of the California Academy of Natural Science, San Francisco, Vol. I, No. 2.

Treiman, J.A., 1994, Malibu Coast fault, Los Angeles County, California: California Department of Conservation, Division of Mines and Geology, unpublished Fault Evaluation Report FER-229, October 3, 1994, 42p.

Treiman, J.A., 1995, Surface faulting near Santa Clarita; *in* Woods, M.C., and Seiple, W.R., (editors), The Northridge, California, Earthquake of 17 January 1994: California Division of Mines and Geology Special Publication 116, pp. 103-110.

Treiman, J., compiler, 2000a, Fault number 99, Malibu Coast fault, in Quaternary fault and fold database of the United States, Ver 1.0: U.S. Geological Survey Open-File Report 03-417, available at http://qfaults.cr.usgs.gov.

Treiman, J.A., compiler, 2000b, Fault number 101, Santa Monica fault, in Quaternary fault and fold database of the United States, Ver 1.0: U.S. Geological Survey Open-File Report 03-417, available at http://qfaults.cr.usgs.gov.

Tsutsumi, H., and Yeats, R.S., 1999, Tectonic Setting of the 1971 Sylmar and 1994 Northridge earthquakes in the San Fernando Valley, California: Bulletin of the Seismological Society of America, Vol. 89, pp. 1232-1249.

Tsutsumi, H., Yeats, R.S., and Huftile, G. H., 2001, Late Cenozoic tectonics of the northern Los Angeles fault system, California: Geological Society of America, Vol. 113, No. 4, pp. 454-468.

U.S. Army Corps of Engineers, Los Angeles District, February 1986, Coast of California Storm and Tidal Waves Study: Southern California Coastal Processes Data Summary, Ref. No. CCSTWS 86-1, 572p.

United States Environmental Protection Agency, 2001, List of Reported RCRA Sites in the United States, *in* The National Biennial RCRA Hazardous Waste Report (Based on 1999 Data), dated June 2001: USEPA Solid Waste and Emergency Response (#5306W), EPA530-R-01-013, 427p.

United States Environmental Protection Agency, 2003, List of Reported RCRA Sites in the United States, *in* The National Biennial RCRA Hazardous Waste Report (Based on 2001 Data), dated July 2003: USEPA Solid Waste and Emergency Response (#5306W), EPA530-R-03-009, 365p.

U.S. Geological Survey, 1951, Long Beach and Vicinity (Topographic), includes Redondo, Torrance, Long Beach, Los Alamitos, Seal Beach and San Pedro Quadrangles; Map Scale 1:24,000

U.S. Geological Survey, 1964, (Photorevised 1981), Torrance quadrangle, 7.5 Minute Series (Topographic), Scale 1:24,000.

U.S. Geological Survey, 1964 (Photorevised 1981), Inglewood quadrangle, 7.5 Minute Series (Topographic), Scale 1:24,000.

U. S. Geological Survey, 1963 (Photorevised 1981), Redondo Beach quadrangle, 7.5 Minute Series (Topographic), Scale 1:24,000.

U.S. Geological Survey, 1986, Earthquake Hazards in Southern California: Proceedings of XXXII Conference: U.S. Geological Survey Open File Report 86-401, pp. 158-172.

U.S. Geological Survey, 1996, USGS Response to an Urban Earthquake, Northridge '94: U.S. Geological Survey Open-File Report 96-263, 78p.

U.S. Geological Survey, 2000, Landslide hazards, USGS Fact Sheet FS-071-00, available at http://greenwood.cr.usgs.gov/pub/fact-sheets.fs-071-00.

Wald, D.J., Quitoriano, V., Heaton, T.H., and Kanamori, H., 1999, Relationships between peak ground acceleration, peak ground velocity, and Modified Mercalli Intensity in California: Earthquake Spectra, the Professional Journal of the Earthquake Engineering Research Institute (EERI), Vol. 15, No. 3, pp. 557-564.

Walls, C., Rockwell, T., Mueller, K., Bock, Y., Williams, S., Pfanner, J., and Fang, P., 1998, Escape tectonics in the Los Angeles metropolitan region and implications for seismic risk: Nature, Vol. 394, pp. 356-360.

Ward, S.N., and Valensise, G., 1994, The Palos Verdes terraces, California: Bathtub rings from a buried reverse fault: Journal of Geophysical Research Vol. 99, pp. 4485-4494.

Weldon, R.J., Fumal, T.E., and Biase, G.P., 2004, Implications from a long window of observation: the San Andreas fault at Wrightwood, California: Seismological Society of America, Abstracts, Annual Meeting, April 14-16, Palm Springs, California.

Wells, W.G., 1987, The effects of fire on the generation of debris flows in southern California; _in_ Costa, J.E. and Wieczorek, G.F., (editors), Debris flows/avalanches: Process, recognition, and mitigation: Reviews in Engineering Geology, Vol. VII, Geological Society of America, pp. 105-114.

Wells, D.L. and Coppersmith, K., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, Vol. 84, pp. 974-1002.

Wesnousky, S.G., 1986, Earthquakes, Quaternary faults, and seismic hazard in California: Journal of Geophysical Research, Vol. 91, No. B12, pp. 12,587-12,631.

Wolfe, M. R., Bolton, P. A., Heikkala, Greene M. M., May, P. J., 1986, Land-Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners: Natural Hazards Research and Applications Information Center, Special Publication 14, 122p.

Wood, H.O., 1916, California Earthquakes—Generatrices and History: Bulletin of the Seismological Society of America, Vol. 6, No. 2, pp. 55-180.

Wood, H.O., 1933, Preliminary Report on the Long Beach earthquake of March 10, 1933: Bulletin of the Seismological Society of America, Vol. 23, No. 2, pp. 43-56.

Woodward-Clyde Consultants, 1979, Report of the evaluation of maximum earthquake and site ground motion parameters associated with the offshore zone of deformation, San Onofre Nuclear Generation Station: Santa Ana, California, unpublished consulting report prepared for Southern California Edison, WCC Project No. 41101.

Working Group on California Earthquake Probabilities (WGCEP), 1988, Probabilities of Large Earthquakes Occurring in California on the San Andreas Fault: U.S. Geological Survey Open-File Report 88-398, 62 pp.

Working Group on California Earthquake Probabilities (WGCEP), 1992, Future Seismic Hazards in Southern California, Phase I, Implications of the Landers Earthquake Sequence: National Earthquake Prediction Council, California Earthquake Prediction Evaluation Council, and Southern California Earthquake Center, 42p.

Working Group on California Earthquake Probabilities (WGCEP), 1995, Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, Vol. 85, No. 2, pp. 379-439.

Wright, T.L., 1991, Structural geology and tectonic evolution of the Los Angeles basin, California; *in* Biddle, K. (editor), Active Margin Basins, American Association of Petroleum Geologists Memoir 52, pp. 35-134.

Wyllie, D.C., and Norrish, N.I., 1996, Stabilization of rock slopes; *in* Turner, A.K., and Schuster, R.L. (editors), Landslides – investigation and mitigation: Transportation Research Board Special Publication 247, pp. 474-504.

Yeats, R.S, Huftile, G.J., and Stitt, L.T., 1999, Late Cenozoic tectonics of the east Ventura Basin, Transverse Ranges, CA: American Association of Petroleum Geologists Bulletin, Vol. 78, pp.1040-1074.

Yeats, R.S. (compiler), Dolan, J.F., Gath, E.M, Grant, L.B., Legg, M., Lindvall, S., Mueller, K., Oskin, M., Ponti, D.F., Rubin, C.M., Rockwell, T.K., Shaw, J.H., Treiman, J.A., Walls, C., 2001, Active faults in the Los Angels Metropolitan Region: Southern California Earthquake Center, Group C.

Youd, T. L., 1978, Major cause of earthquake damage is ground failure: Civil Engineering, Vol. 48, No. 4, pp. 47-51.

Youd, T.L., and Perkins, D.M., 1978, Mapping liquefaction-induced ground failure potential: Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, Vol. 104, No. GT4, pp. 433-446.

Youd, L. T., 1986, Geologic effects-liquefaction and associated ground failure: Proceedings of the 1986 Annual Conference Western Seismic Policy Council, pp. 8-30.

Youd, T. L., and Keefer, D. K., 1981, Earthquake-induced ground failures; in Hays, W. W., (editor), Facing Geologic and

Hydrologic Hazards: U. S. Geologic Survey Professional Paper 1240-B, pp. 23-31.

Youd, T.L., Idriss, I.M. Andrus, R.D. Arango, I., Castro, G., Christian, J.T., Dobry, R., Liam Finn, W.D.L., Harder, L.F., Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., Stokoe, K.H., II, 2001, Liquefaction resistance of soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils: ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 127, No. 10, pp. 817-833

Zappe, D.P., 1997, Statement of the Riverside County Flood Control and Water Conservation District Regarding Impacts of the Endangered Species Act on Flood Control Activities; Witness Testimony made at the Resources Committee of the House of Representatives on April 10, 1997. The text of his statement is available on the web at http://resourcescommittee.house.gov/105cong/fullcomm/apr10.97/zappe.htm

Ziony, J.I., and Yerkes, R.F., 1985, Evaluating earthquake and surface-faulting potential; *in* Ziony, J.I. (editor), Evaluating Earthquake Hazards in the Los Angeles Region – An Earth-Science Perspective: U.S Geological Survey Professional Paper 1360, pp. 33-91.

Acknowledgments

Chapter 3 was prepared with the assistance from many individuals from the City of Torrance Public Works Department.

Chapter 4 was prepared with assistance from individuals from the City of Torrance Fire Department. ECI would like to acknowledge the help received from Fire Chief Rick Bongard, Operations Chief Don Thompson, and Battalion Chief Ken C. Carter.

Useful Websites

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).

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.

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 acceleratio maps available for downloading.

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.

Tsunami Hazards and Weather

http://www.prh.noaa.gov/pr/ptwc/bulletins.htm
Pacific Tsunami Warning Center
National Weather Service

http://www.usc.edu/dept/tsunamis/
USC Tsunami Research Group

http://www.oes.ca.gov/
California Office of Emergency Services

http://www.pmel.noaa.gov/tsunami-hazard/
The National Tsunami Hazard Mitigation Program

http://hurricanes.noaa.gov
Homepage for the National Oceanic and Atmospheric Administration web page on hurricanes and other coastal processes

http://www.usatoday.com/weather/whhcalif.htm

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 has been removed due to safety concerns; but may be posted again in the future in limited form).

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://www.fema.gov/fema/nfip.htm
FEMA website about the National Flood Insurance Program.

http://www.worldclimate.com/
Precipitation rates at different rain stations in the world measured over time.

http://waterdata.usgs.gov
Stream gage measurements for rivers throughout the US.

Fire Hazards, Wildfires and Related Topics

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://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.

Appendix B
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*.)

Beach nourishment – Replacement of beach sand removed by ocean waters.

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.

Berm – Horizontal portion of the backshore beach formed by sediments deposited by waves.

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.

Bulkhead –Wall or other structure, often of wood, steel, stone, or concrete, designed to retain or prevent sliding or *erosion* of the land. Occasionally, bulkheads are use to protect against wave action.

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.

Coastal A zone – The portion of the *Special Flood Hazard Area* landward of a *V zone* or landward of an open coast without mapped *V zones* (e.g., shorelines of the Great Lakes), in which the principal sources of flooding are astronomical tides, *storm surge*, seiches, or *tsunamis*, not riverine sources. The *flood* forces in coastal A zones are highly correlated with coastal winds or coastal seismic activity. Coastal A zones may therefore be subject to wave effects, velocity flows, *erosion*, *scour*, or combinations of these forces. See *A zone* and *Non-coastal A zone*. (Note: the *National Flood Insurance Program* regulations do not differentiate between coastal A zones and *non-coastal A zones*.)

Coastal barrier – Depositional geologic feature such as a bay barrier, tombolo, barrier spit, or barrier island that consists of unconsolidated sedimentary materials; is subject to wave, tidal, and wind energies; and protects landward aquatic habitats from direct wave attack.

Coastal Barrier Resources Act of 1982 (CBRA) – Act (Pub. L. 97-348) that established the Coastal Barrier Resources System (CBRS). The act prohibits the provision of new flood insurance coverage on or after October 1, 1983, for any *new construction* or *substantial improvements* of structures located on any designated undeveloped coastal barrier within the CBRS. The CBRS was expanded by the Coastal Barrier Improvement Act of 1991. The date on which an area is added to the CBRS is the date of CBRS designation for that area.

Coastal flood hazard area – Area, usually along an open coast, bay, or inlet, that is subject to inundation by storm surge and, in some instances, wave action caused by storms or seismic forces.

Coastal High Hazard Area – Under the *National Flood Insurance Program*, an area of special flood hazard extending from offshore to the inland limit of a *primary frontal dune* along an open coast and any other area subject to high-velocity wave action from storms or seismic sources. On a *Flood Insurance Rate Map*, the Coastal High Hazard Area is designated Zone V, VE, or V1-V30. These zones designate areas subject to inundation by the *base flood* where *wave heights* or *wave runup depths* are greater than or equal to 3.0 feet.

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.

Design flood protection depth – Vertical distance between the eroded ground elevation and the *Design Flood Elevation*.

Design stillwater flood depth – Vertical distance between the eroded ground elevation and the *design stillwater flood elevation*.

Design stillwater flood elevation – Stillwater elevation associated with the *design flood*, excluding 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.

Dune – See *Frontal dune* and *Primary frontal dune*.

Dune toe – Junction of the gentle slope seaward of the dune and the dune face, which is marked by a slope of 1 on 10 or steeper.

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.

Episodic erosion – Erosion induced by a single storm event. Episodic erosion considers the vertical component of two factors: general beach profile lowering and localized conical scour around foundation supports. Episodic erosion is relevant to foundation embedment depth and potential undermining. See *Erosion*.

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.

Fetch – Distance over which wind acts on the water surface to generate waves.

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.

Frontal dune – Ridge or mound of unconsolidated sandy soil, extending continuously alongshore landward of the sand beach and defined by relatively steep slopes abutting markedly flatter and lower regions on each side.

Gabion – Rock-filled cage made of wire or metal that is placed on slopes or embankments to protect them from *erosion* caused by flowing or fast-moving water.

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.

High-velocity wave action – Condition in which *wave heights* or *wave runup depths* are greater than or equal to 3.0 feet.

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.

Hurricane – Tropical cyclone, formed in the atmosphere over warm ocean areas, in which wind speeds reach 74 miles per hour or more and blow in a large spiral around a relatively calm center or "eye." Hurricane circulation is counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Hurricane clip or strap – Structural connector, usually metal, used to tie roof, wall, floor, and foundation members together so that they can resist wind forces.

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*.

Jetty – Wall built out into the water to restrain currents or protect a structure.

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)

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.

Littoral – Of or pertaining to the shore, especially of the sea; coastal.

Littoral drift – Movement of sand by littoral (longshore) currents in a direction parallel to the beach along the shore.

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.

Mangrove stand – Under the *National Flood Insurance Program*, an assemblage of mangrove trees, which are mostly low trees noted for a copious development of interlacing adventitious roots above the ground and which contain one or more of the following species: black mangrove (Avicennia Nitida), red mangrove (Rhizophora Mangle), white mangrove (Languncularia Racemosea), and buttonwood (Conocarpus Erecta).

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."

Marsh – Wetland dominated by herbaceous or non-woody plants often developing in shallow ponds or depressions, river margins, tidal areas, and estuaries.

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 – For the purposes of this manual, 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.

Primary frontal dune – Under the *National Flood Insurance Program*, a continuous or nearly continuous mound or ridge of sand with relatively steep seaward and landward slopes immediately landward and adjacent to the beach and subject to erosion and overtopping from high tides and waves during major coastal storms. The inland limit of the primary frontal dune occurs at the point where there is a distinct change from a relatively steep slope to a relatively mild slope.

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.

Sand dunes – Under the *National Flood Insurance Program*, natural or artificial ridges or mounds of sand landward of the beach.

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*.

Seawall – Solid barricade built at the water's edge to protect the shore and to prevent inland *flooding*.

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 composite effect of all storms considered over decades and centuries (expressed as an annual average *erosion* rate). Shoreline retreat considers the horizontal component of *erosion* and is relevant to long-term land use decisions and the siting of buildings.

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.

Sixty (60)-year setback – A state or local requirement that prohibits new construction and certain improvements and repairs to existing coastal buildings located in an area expected to be lost to *shoreline retreat* over a 60-year period. The inland extent of the area is equal to 60 times the average annual long-term recession rate at a site, measured from a reference feature.

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.

Start of construction (for other than new construction or substantial improvements under the Coastal Barrier Resources Act) – Under the *National Flood Insurance Program*, date the building permit was issued, provided the actual start of construction, repair, reconstruction, rehabilitation, addition placement, or other improvement was within 180 days of the permit date. The actual start means either the first placement of permanent construction of a structure on a site, such as the pouring of slab or footings, the installation of piles, the construction of columns, or any work beyond the stage of excavation; or the placement of a manufactured home on a foundation. Permanent construction does not include land preparation, such as clearing, grading, and filling; nor does it include the installation of streets and/or walkways; nor does it include excavation for a basement, footings, piers, or foundations or the erection of temporary forms; nor does it include the installation on the property of accessory buildings, such as garages or sheds not occupied as dwelling units or not part of the main structure. For a *substantial improvement*, the actual start of construction means the first alteration of any wall, ceiling, floor, or other structural part of a building, whether or not that alteration affects the external dimensions of the building.

State Coordinating Agency – Under the *National Flood Insurance Program*, the agency of the state government, or other office designated by the Governor of the state or by state statute to assist in the implementation of the *National Flood Insurance Program* in that state.

Stillwater elevation – Projected elevation that flood waters would assume, referenced to the *National Geodetic Vertical Datum*, *North American Vertical Datum*, or other datum, in the absence of waves resulting from wind or seismic effects.

Storage capacity - Dam storage measured in acre-feet or decameters, including dead storage.

Storm surge – Rise in the water surface above normal water level on the open coast due to the action of wind stress and atmospheric pressure on the water surface.

Storm tide – Combined effect of *storm surge*, existing astronomical tide conditions, and breaking *wave setup*.

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.

Substantial damage – Under the *National Flood Insurance Program*, damage of any origin sustained by a *structure* whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement – Under the *National Flood Insurance Program*, any reconstruction, rehabilitation, addition, or other improvement of a *structure*, the cost of which equals or exceeds 50 percent of the market value of the structure before the *start of construction* of the improvement. This term includes structures, which have incurred *substantial damage*, regardless of the actual repair work performed. The term does not, however, include either (1) any project for improvement of a structure to correct existing violations of state or local health, sanitary, or safety code specifications which have been identified by the local code enforcement official and which are the minimum necessary to assure safe living conditions, or (2) any alteration of a "historic structure," provided that the alteration will not preclude the structure's continued designation as a "historic structure."

Surge – See *Storm surge*.

Swale - In hillside terrace, a shallow drainage channel, typically with a rounded depression or "hollow" at the head.

Thirty (30)-year erosion setback – A state or local requirement that prohibits new construction and certain improvements and repairs to existing coastal buildings located in an area expected to be lost to *shoreline retreat* over a 30-year period. The inland extent of the area is equal to 30 times the average annual long-term recession rate at a site, measured from a reference feature.

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.

Tropical depression – Tropical cyclone with some rotary circulation at the water surface. With maximum sustained wind speeds of up to 39 miles per hour, it is the second phase in the development of a *hurricane*.

Tropical disturbance – Tropical cyclone that maintains its identity for at least 24 hours and is marked by moving thunderstorms and with slight or no rotary circulation at the water surface. Winds are not strong. It is a common phenomenon in the tropics and is the first discernable stage in the development of a *hurricane*.

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.

V zone – See *Coastal High Hazard Area*.

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.

Wave – Ridge, deformation, or undulation of the water surface.

Wave crest elevation – Elevation of the crest of a wave.

Wave height – Vertical distance between the wave crest and wave trough.

Wave runup – Rush of wave water up a slope or structure.

Wave runup depth – Vertical distance between the maximum wave runup elevation and the eroded ground elevation.

Wave runup elevation – Elevation, referenced to the *National Geodetic Vertical Datum* or other datum, reached by *wave runup*.

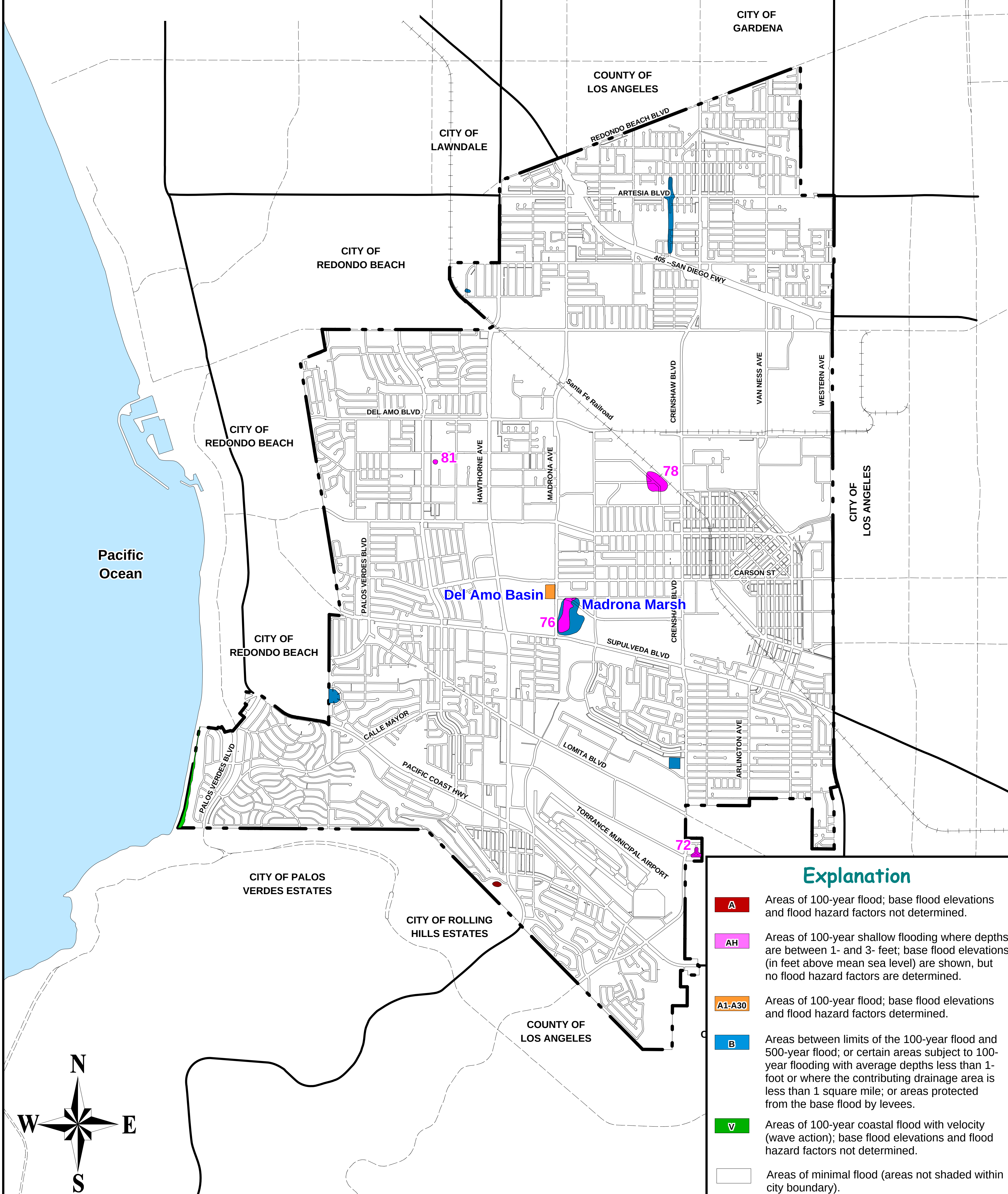
Wave setup – Increase in the stillwater surface near the shoreline, due to the presence of breaking waves.

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.

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

A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
AH	Areas of 100-year shallow flooding where depths are between 1- and 3- feet; base flood elevations (in feet above mean sea level) are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than 1-foot or where the contributing drainage area is less than 1 square mile; or areas protected from the base flood by levees.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
	Areas of minimal flood (areas not shaded within city boundary).

Scale: 1:48,000

1 0 1 2 3

Kilometers

4000 0 4000 8000 12000

Feet

Torrance City Boundary

Base Map: City of Torrance (2005)

Source: Federal Emergency Management Agency, 1979, Flood Insurance Rate Map (Panel Numbers: 060165 0001B, 060165 0003B, 060165 0004B, and 060165 0005B).

Earth Consultants International

Project Number: 2431
Date: July, 2005

FEMA Flood Map

Torrance, California

Plate 3-2