TECHNICAL BACKGROUND REPORT
to the SAFETY ELEMENT
of the

YUCCA VALLEY
GENERAL PLAN

SEISMIC HAZARDS
GEOLOGIC HAZARDS
FLOOD HAZARDS
FIRE HAZARDS
HAZARDOUS MATERIALS MANAGEMENT
SEVERE WEATHER HAZARDS

Prepared by:

Earth Consultants International

1642 E. Fourth Street, Santa Ana, California 92701
(714) 544-5321 & (714) 412-2654

September 2012

TABLE OF CONTENTS

Section **Page No.**

CHAPTER 1: SEISMIC HAZARDS 1-1
1.1 SEISMIC CONTEXT – EARTHQUAKE BASICS 1-1
1.2 REGULATORY CONTEXT 1-8
1.2.1 Alquist-Priolo Earthquake Fault Zoning Act 1-8
1.2.2 Seismic Hazards Mapping Act 1-9
1.2.3 California Building Code 1-9
1.2.4 Unreinforced Masonry Law 1-10
1.2.5 Real Estate Disclosure Requirements 1-11
1.2.6 California Environmental Quality Act 1-12
1.3 NOTABLE PAST EARTHQUAKES 1-12
1.3.1 Wrightwood Earthquake of December 8, 1812 1-12
1.3.2 San Jacinto Earthquake of 1899 1-14
1.3.3 San Jacinto Earthquake of 1918 1-14
1.3.4 North San Jacinto Fault Earthquake of 1923 1-14
1.3.5 Long Beach Earthquake of 1933 1-15
1.3.6 Desert Hot Springs Earthquake of 1948 1-15
1.3.7 Borrego Mountain Earthquake of 1968 1-15
1.3.8 San Fernando (Sylmar) Earthquake of 1971 1-16
1.3.9 Homestead Valley Earthquake Sequence of 1979 1-16
1.3.10 North Palm Springs Earthquake of 1986 1-17
1.3.11 Joshua Tree Earthquake of 1992 1-17
1.3.12 Landers Earthquake of 1992 1-17
1.3.13 Big Bear Earthquake of 1992 1-18
1.3.14 Northridge Earthquake of 1994 1-18
1.3.15 Hector Mine Earthquake of 1999 1-18
1.3.16 Baja California Earthquake of 2010 1-19
1.4 SEISMIC GROUND SHAKING 1-20
1.4.1 Pinto Mountain Fault Zone 1-26
1.4.2 Burnt Mountain Fault 1-27
1.4.3 Eureka Peak Fault 1-27
1.4.4 Landers (or Kickapoo) Fault 1-28
1.4.5 Emerson South – Copper Mountain Fault Zone 1-28
1.4.6 North Frontal Fault 1-29
1.4.7 Johnson Valley Fault 1-29
1.4.8 San Andreas Fault Zone 1-29
1.4.9 Calico – Hidalgo Fault Zone 1-33
1.4.10 Pisgah – Bullion Mountain – Mesquite Lake Fault Zone 1-34
1.4.11 Lenwood – Lockhart – Old Woman Springs Faults 1-34
1.4.12 Helendale – South Lockhart Fault 1-35
1.5 SURFACE FAULT RUPTURE 1-36
1.5.1 Definitions 1-36
1.5.2 Faults in the Town of Yucca Valley Area 1-37
1.5.2.1 Pinto Mountain Fault Zone 1-39
1.5.2.2 Burnt Mountain Fault 1-40
1.5.2.3 Eureka Peak Fault 1-41
1.5.2.4 Lower Covington Flat Fault 1-41
1.5.2.5 Southern Johnson Valley Fault 1-42
1.5.3 Mitigation of Primary Fault Rupture 1-42

TABLE OF CONTENTS (Continued)

Section Page No.

1.6 GROUND FAILURE DUE TO EARTHQUAKE SHAKING 1-44
1.6.1 Liquefaction 1-44
1.6.2 Earthquake-Induced Slope Failure 1-46
1.6.3 Seismically Induced Settlement 1-52
1.6.4 Deformation of Sidehill Fills 1-52
1.6.5 Ridgetop Fissuring and Shattering 1-53
1.7 OTHER POTENTIAL SEISMIC HAZARDS 1-53
1.7.1 Seiches 1-53
1.7.2 Tsunami 1-54
1.8 VULNERABILITY OF STRUCTURES TO EARTHQUAKE DAMAGE 1-55
1.8.1 Unreinforced Masonry Structures 1-60
1.8.2 Soft-Story Buildings 1-60
1.8.3 Wood-Frame Structures 1-60
1.8.4 Pre-Cast Concrete Structures 1-61
1.8.5 Tilt-up Buildings 1-61
1.8.6 Reinforced Concrete Frame Buildings 1-62
1.8.7 Multi-Story Steel Frame Buildings 1-62
1.8.8 Mobile Homes 1-62
1.8.9 Combination Types 1-62
1.9 SUMMARY AND RECOMMENDATIONS 1-63

CHAPTER 2: GEOLOGIC HAZARDS 2-1
2.1 PHYSIOGRAPHIC SETTING 2-1
2.2 GEOLOGIC SETTING 2-1
2.3 GEOLOGIC UNITS AND THEIR ENGINEERING PROPERTIES 2-2
2.3.1 Sedimentary Deposits 2-3
2.3.1.1 Surficial Sediments 2-3
2.3.1.2 Sedimentary Rock (Map Symbol: Ts) 2-7
2.3.2 Crystalline Rocks 2-7
2.3.2.1 Volcanic Rocks 2-7
2.3.2.2 Metamorphic Rocks 2-10
2.4 GEOLOGIC HAZARDS IN THE YUCCA VALLEY AREA 2-11
2.4.1 Slope Instability 2-11
2.4.1.1 Types of Slope Failures 2-11
2.4.1.2 Susceptibility to Slope Failure 2-15
2.4.1.3 Mitigation of Slope Instability in Future Development 2-15
2.4.1.4 Mitigation of Slope Instability in Existing Development 2-17
2.4.2 Compressible Soils 2-18
2.4.3 Collapsible Soils 2-18
2.4.4 Expansive Soils 2-19
2.4.5 Corrosive Soils 2-19
2.4.6 Land Subsidence due to Groundwater Withdrawal 2-20
2.4.6.1 Subsidence in Yucca Valley 2-21
2.4.6.2 Prevention of Subsidence 2-22
2.4.7 Erosion and Sedimentation 2-23
2.5 SUMMARY OF ISSUES 2-24

CHAPTER 3: FLOOD HAZARDS 3-1
3.1 STORM FLOODING 3-1
3.1.1 Hydrologic and Geomorphic Setting 3-1

TABLE OF CONTENTS (Continued)

Section Page No.

3.1.2 Weather and Climate 3-2
3.1.3 Past Flooding 3-5
3.1.4 National Flood Insurance Program (NFIP) 3-7
3.1.5 FEMA Flood Zone Mapping 3-9
3.1.6 Flood Zone Mapping in the Town of Yucca Valley 3-12
3.1.7 Flood Management Policies 3-15
3.1.8 Existing Flood Control 3-16
3.1.9 Future Flood Control 3-16
3.1.10 Flood Protection Measures for Property Owners 3-18
3.1.11 Bridge Scour and Flood Channel Crossings 3-19
3.2 SEISMICALLY INDUCED INUNDATION 3-20
3.2.1 Dam Failure 3-20
3.2.2 Inundation From Above-Ground Storage Tanks 3-20
3.3 SUMMARY 3-21

CHAPTER 4: FIRE HAZARDS 4-1
4.1 WILDFIRES 4-1
4.1.1 Local Characteristics and History on Local Fires 4-3
4.1.1.1 Fuel Loads and Topography 4-4
4.1.1.2 Weather 4-5
4.1.1.3 Wildfire History 4-6
4.1.2 Regulatory Context and Fire Risk Areas 4-8
4.1.2.1 HUD Study System 4-9
4.1.2.2 California Department of Forestry and Fire Protection – State Responsibility Areas System 4-9
4.1.2.3 Bates Bill Process 4-10
4.1.2.4 California Fire Plan 4-10
4.1.2.5 National Fire Plan 4-12
4.1.2.6 California Fire Alliance (CFA) 4-13
4.1.2.7 Real-Estate Disclosure Requirements 4-13
4.1.3 Fire Prevention and Suppression Programs and Regulations 4-15
4.1.3.1 Vegetation Management 4-15
4.1.3.2 Notification and Abatement 4-17
4.1.3.3 Building to Reduce the Fire Hazard 4-17
4.1.3.4 Restricted Public Access 4-20
4.1.3.5 Fire Safety Education 4-21
4.2 STRUCTURE FIRES 4-22
4.2.1 Target Fire Hazards and Standards of Coverage 4-24
4.2.2 Regulatory Context 4-25
4.3 FIRE SUPPRESSION SERVICES 4-27
4.3.1 Response Objectives and Statistics 4-28
4.3.2 Automatic and Mutual Aid Agreements 4-30
4.3.3 Standardized Emergency Management System (SEMS) and National Incident Management System (NIMS) 4-32
4.4 CHEMICAL FIRES 4-35
4.5 FIRES FOLLOWING EARTHQUAKES 4-36
4.6 SUMMARY AND RECOMMENDED PROGRAMS 4-38

CHAPTER 5: HAZARDOUS MATERIALS MANAGEMENT 5-1
5.1 SETTING AND DEFINITIONS 5-1

TABLE OF CONTENTS (Continued)

Section Page No.

5.2 REGULATORY CONTEXT AND LISTS OF SITES 5-1
5.2.1 Federal Clean Water Act (33 U.S.C §1251 et seq., 1972) and California Water Code. 5-1
5.2.2 Comprehensive Environmental Response, Compensation and Liability Act 5-4
5.2.3 Emergency Planning and Community Right-To-Know Act (EPCRA) 5-6
5.2.4 Resources Conservation and Recovery Act 5-7
5.2.5 Cortese List 5-9
5.2.6 Hazardous Materials Disclosure Program 5-10
5.2.7 Hazardous Materials Incident Response 5-13
5.2.8 Hazardous Material Spill/Release Notification Guidance 5-15
5.3 LEAKING UNDERGROUND STORAGE TANKS (LUSTS) 5-19
5.4 DRINKING WATER QUALITY 5-19
5.4.1 Contaminants of Concern in Groundwater 5-19
5.4.1.1 Coliform 5-19
5.4.1.2 Perchlorate 5-20
5.4.1.3 Arsenic 4-21
5.4.1.4 Nitrate and Nitrite 4-22
5.4.1.5 Hexavalent Chromium 4-22
5.5 HOUSEHOLD HAZARDOUS WASTE AND RECYCLING 5-23
5.6 RELEASES DUE TO TRANSPORTATION ACCIDENTS AND PIPELINE FAILURES 5-25
5.7 EARTHQUAKE-INDUCED RELEASES OF HAZARDOUS MATERIALS 5-27
5.8 OTHER POTENTIAL HAZARDOUS MATERIALS RELEASE INCIDENTS 5-29
5.9 HAZARD ANALYSIS 5-29
5.10 SUMMARY OF FINDINGS 5-30

CHAPTER 6: SEVERE WEATHER HAZARDS 6-1
6.1 HIGH WINDS 6-1
6.1.1 Definitions and Setting. 6-2
6.1.2 Types of High Winds in Southern California 6-2
6.1.2.1 Santa Ana WInds 6-2
6.1.2.2 Thunderstorm-Related Tornadoes 6-3
6.1.2.3 Macrobursts and Microbursts 6-6
6.1.2.4 Dust Storms 6-7
6.1.3 Historic Southern California Windstorms 6-7
6.2 OTHER EXTREME WEATHER EVENTS 6-23
6.2.1 Hail 6-23
6.2.2 Heavy Snow and Ice 6-24
6.2.3 Temperature Extremes. 6-29
6.3 COMMUNITY VULNERABILITY TO SEVERE WEATHER DAMAGE 6-34
6.3.1 Hazards Assessment Summary. 6-34
6.3.1.1 Windstorms 6-34
6.3.1.2 Hail 6-35
6.3.1.3 Heavy Snow and Ice 6-36
6.3.1.4 Temperature Extremes 6-36
6.3.2 Damage Assessment 6-37
6.3.2.1 Structural Damage 6-38
6.3.2.2 Lifelines and Critical Facilities 6-38
6.3.2.3 Infrastructure 6-39

TABLE OF CONTENTS (Continued)

Section **Page No.**

APPENDICES

APPENDIX A: REFERENCES **A-1**
APPENDIX B: GLOSSARY **B-1**

FIGURES, TABLES AND PLATES

Figure 1-1: Regional Fault Map 1-3
Figure 1-2: Local Active and Potentially Active Faults 1-5
Figure 1-3: Notable Regional Earthquakes 1-13
Figure 1-4: ShakeMap for a Magnitude 7.8 Earthquake Scenario on the Southern San Andreas Fault 1-25
Figure 1-5: Modified Mercalli Intensity ShakeMap for the June 28, 1992 Landers Earthquake 1-26
Figure 1-6: View of Steep Slope of the Sawtooth Mountains Showing Abundant Rounded Boulders, Many of Them Perched Atop Other Boulders 1-49

Figure 3-1: Yucca Valley's Dry, Arid Landscape is Deceiving 3-7

Figure 4-1: View of the Cedar Fire of October 2003 Moving Down Oak Canyon, Toward the 52 Freeway, in San Diego County 4-2
Figure 4-2: View of a Backfire to the Station Fire Behind Homes in La Crescenta 4-3
Figure 4-3: Typical Fuel Loads in the Yucca Valley Region 4-4

Figure 6-1: View from Space of Smoke from the October 2003 Fires in Southern California Carried Offshore by Strong Santa Ana Winds 6-4
Figure 6-2: View of a Tornado 6-4

Table 1-1: Abridged Modified Mercalli Intensity Scale 1-6
Table 1-2: Estimated Horizontal Peak Ground Accelerations and Seismic Intensities in the Town of Yucca Valley Area 1-23
Table 1-3: Earthquake-Induced Slope Failures in Arid Environments 1-51
Table 1-4: Seismic Source Type 1-59

Table 2-1: General Slope Instability Potential Within Yucca Valley 2-15

Table 3-1: Average Annual Rainfall by Month for the Twentynine Palms Weather Station 3-3
Table 3-2: Average Annual Rainfall by Month for the Morongo Valley Weather Station 3-3
Table 3-3: Above-ground Water Tanks in the Yucca Valley General Plan Area 3-21

Table 4-1: Response Statistics for the Yucca Valley Fire Stations for Fiscal Years 2009 to 2012 4-23
Table 4-2: Fire Stations In and Near the Town of Yucca Valley 4-28

Table 5-1: EPA-Registered Small- and Large-Quantity Generators of Hazardous Materials in the Town of Yucca Valley 5-8
Table 5-2: Leaking Underground Fuel Tanks Reported in the Town of Yucca Valley 5-18
Table 5-3: Regional Household Hazardous Waste Collection Centers 5-24

TABLE OF CONTENTS (Continued)

Section **Page No.**

Table 5-4: Active Landfills, Transfer Stations, and Land Disposal Sites Near the Town of Yucca Valley 5-24
Table 5-5: Routes Through Yucca Valley and Surrounding Areas Used to Transport Hazardous Materials and Explosives 5-25

Table 6-1: The Beaufort Scale 6-2
Table 6-2: The Fujita-Pearson Tornado Damage Scale 6-5
Table 6-3: Enhanced Fujita Scale 6-6
Table 6-4: Major Southern California Windstorms (1858-2011) and Strong Winds Reported in the Yucca Valley Area (1973-October 2011) 6-8
Table 6-5: Tornadoes and Funnel Clouds Reported In and Near San Bernardino County Between 1914 and 2011 6-18
Table 6-6: Dust Storms Reported in San Bernardino County Between 1989 and 2011 6-21
Table 6-7: Hail Events In the Yucca Valley Area Between 1956 and 2011 6-23
Table 6-8: Significant Heavy Snow and Ice Events in Southern California That Likely Impacted the Yucca Valley Area Between 1948 and 2010 6-25
Table 6-9: Historical High Heat, Excessive Heat and Extreme Cold Events Reported in Southern California that Impacted or Are Inferred to Have Impacted the Yucca Valley Area 6-31

Plate 1-1: Faults and Historical (1800-2011) Seismicity Map 1-21
Plate 1-2: Fault Map 1-38
Plate 1-3: Seismic Hazard Zones 1-47
Plate 1-4a: Engineering Site Classes 1-57
Plate 1-4b: Site Class Definitions (Based on Soil Profile Types) (from CBC, 2010) 1-58

Plate 2-1a: Geologic Map 2-4
Plate 2-1b: Explanation for Geologic Map 2-5
Plate 2-2a: Engineering Materials Map 2-8
Plate 2-2b: Explanation for Engineering Materials Map 2-9
Plate 2-3: Slope Distribution Map 2-14

Plate 3-1a: Flood Hazard Map 3-13
Plate 3-1b: Flood Hazard Map, Yucca Wash Area 3-14

Plate 4-1: Historical Wildland Fires (1910-2008) in and Near Yucca Valley 4-8
Plate 4-2: High Fire Hazard Areas in and Near Yucca Valley 4-11

Plate 5-1: Hazardous Materials Site Map 5-5

CHAPTER 1: SEISMIC HAZARDS

Earthquake-triggered geologic effects include ground shaking, surface fault rupture, landslides, liquefaction, subsidence, tsunamis and seiches. Some of these hazards can occur in the Town of Yucca Valley, as discussed in detail below. Earthquakes can also lead to reservoir failures, urban fires, and toxic chemical releases. Where appropriate, and if applicable to Yucca Valley, these hazards are discussed in Chapters 3, 4 and 5, respectively.

In seismically active southern California, an earthquake has the potential to cause far-reaching loss of life or property, and economic damage. This is so because damaging earthquakes are relatively frequent, affect widespread areas, trigger many secondary effects, and can overwhelm the ability of local jurisdictions to respond. 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. The record shows that local government, emergency relief organizations, and residents can and must take action to develop and implement policies and programs to reduce the effects of earthquakes. Thus, this document not only discusses the potential hazards that can impact the Town of Yucca Valley, but also provides action items and programs that can help the Town become more self-sufficient in the event of an earthquake.

1.1 Seismic Context – Earthquake Basics

The outer 10 to 70 kilometers of the Earth consist of enormous blocks of moving rock referred to as ***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 that radiate 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. Most earthquakes occur on or near plate boundaries. Southern California has many earthquakes because it straddles the boundary between the North American and Pacific plates, and fault rupture accommodates their motion.

By definition, the break or fracture between moving blocks of rock is called a ***fault***, and such differential movement produces a fault rupture. 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. 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.

Total ***displacement*** is the length, measured in kilometers (km), of the total movement that has occurred along a 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

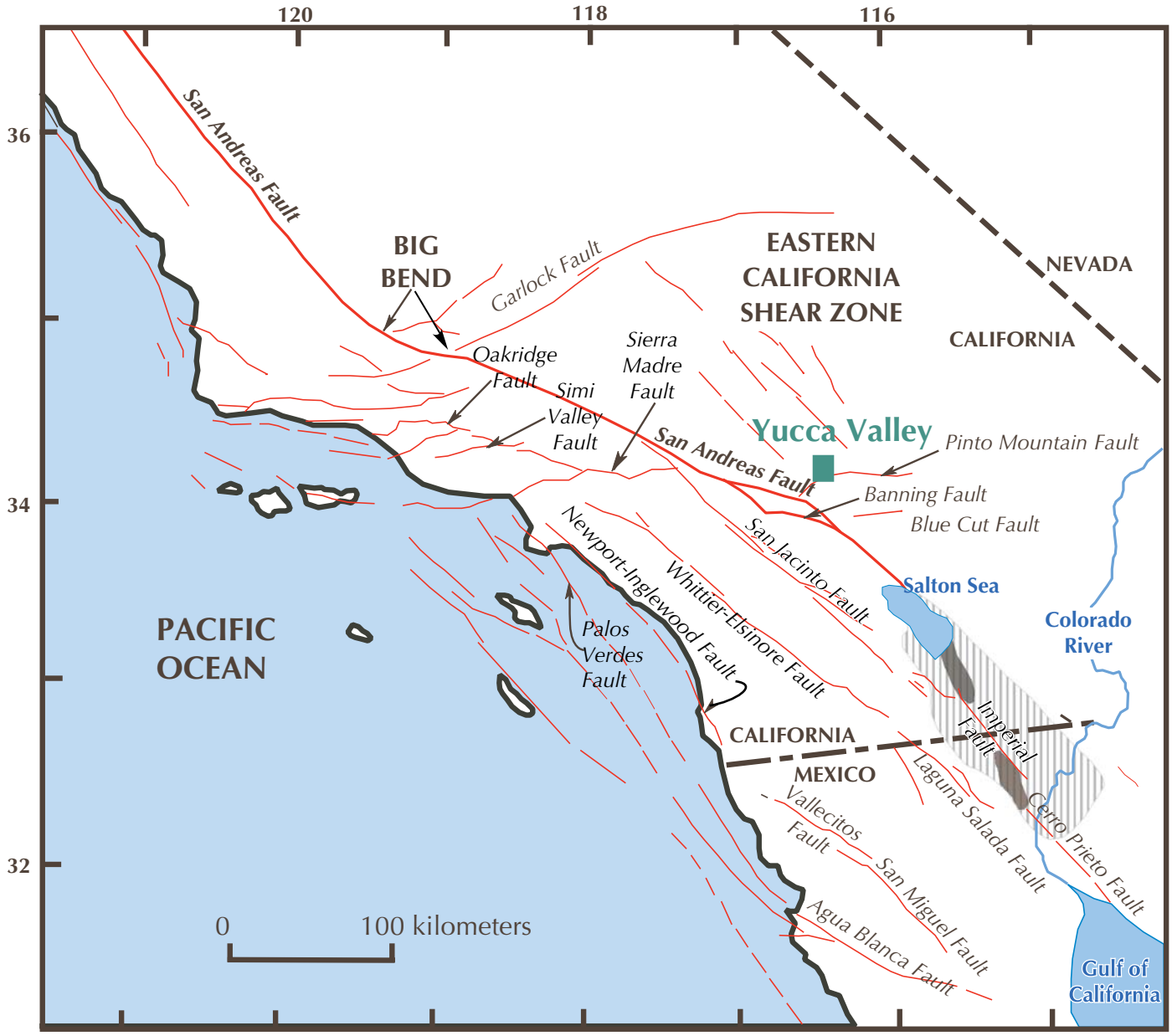
the cumulative movement of the fault over many earthquakes. ***Slip rate*** is a speed, expressed in millimeters per year (mm/yr). Slip rate is estimated by measuring an amount of offset accrued during a known amount of time, obtained by dating the ages of geologic features. Slip rate data also are used 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 trenches across the fault to obtain ***paleoseismic*** evidence of earthquakes that have occurred during prehistoric time. Paleoseismic studies show that faults with high slip rates generally have shorter recurrence intervals between major earthquakes. This is so because a high slip rate indicates rocks that, at depth, are moving relatively quickly, and the stored energy trapped within the locked, surficial rocks needs to be released in frequent (geologically speaking), large earthquakes.

The Town of Yucca Valley and most of the eastern part of southern California, is riding on the North American Plate, which is moving southeasterly (relative to the Pacific Plate), at about 50 millimeters per year (mm/yr), or about 165 feet in 1,000 years. 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, Los Angeles (which is on the Pacific Plate) will be almost next to San Francisco (which, like Yucca Valley is on the North American Plate).

Although the San Andreas fault is the principal separation between the Pacific and North American plates, only about 70% 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 faults offshore, in the Pacific Ocean. To the east of the San Andreas fault, slip is distributed among faults of the Eastern California 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 further 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," located about 170 miles (275 km) northwest of Yucca Valley (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. ***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 a unique east-west trend to its landforms and underlying geologic structures that is a direct consequence of the plates colliding at the Big Bend. Many of southern



Source: Modified from Fuis and Mooney, 1990.

MAP EXPLANATION

Fault

Onshore Spreading Center

New Crust (late Cenozoic)

Earth Consultants International

Project Number: 3114
Date: 2011

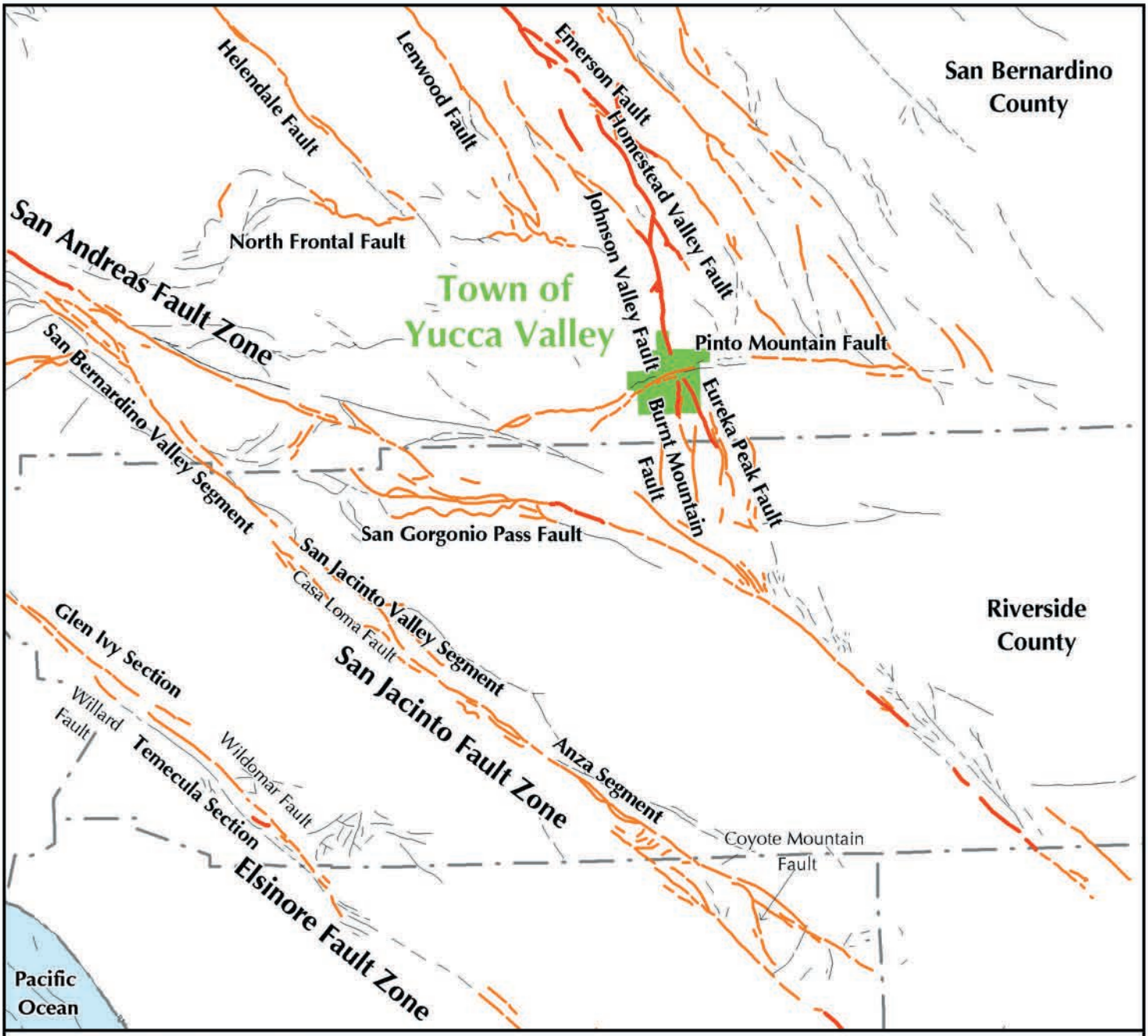
Regional Fault Map

Figure 1-1

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. Thrust faults in southern California have been particularly hazardous because many are "***blind***;" that is, they do not extend to the surface of the Earth, and have therefore been difficult to detect and study before they rupture. Some of the latest earthquakes in southern California, including the 1987 Whittier Narrows earthquake and the 1994 Northridge earthquake, occurred on previously unknown blind thrust faults. A great amount of research in the last 15 years has gone into learning to recognize subtle features in the landscape that suggest the presence of a buried thrust fault at depth, and developing techniques to confirm and study these structures. Some geologists have started to develop paleoseismic data for these buried thrust faults, including recurrence interval, estimates of the maximum magnitude earthquake these faults are capable of generating, and displacement per event. A smaller kink in the San Andreas fault occurs in the vicinity of San Gorgonio Pass, to the northwest of Palm Springs. This kink (or "knot" as it is often called) is a result of a slight bend and a step in the main fault's surface trace. As with the Big Bend, complex fault patterns, including thrust faulting, have developed in this area to accommodate these changes.

The portion of the Town of Yucca Valley south of the Pinto Mountain fault is located in the Transverse Ranges Province described above. The part of Town north of the Pinto Mountain fault is located in the southwestern portion of the Mojave Desert Province, an arid region of alluvial fans, desert plains, dry lakebeds, and scattered mountain ranges described in more detail in Chapter 2. The east-trending Garlock fault defines the northern boundary of this province, whereas the San Andreas fault defines its western boundary. These faults, and other seismically active faults that are part of the Eastern California Shear Zone (also referred to as the Eastern Mojave Shear Zone), including the Burnt Mountain, Eureka Peak, Landers, Johnson Valley, Mesquite Lake-Pisgah-Bullion Mountains, South Emerson–Copper Mountain, Calico-Hidalgo, and Lenwood-Lockhart-Old Woman faults, have the potential to impact the Yucca Valley region (see Figure 1-2). With the exception of the Pinto Mountain fault, which is a left-lateral strike-slip fault, all other faults mentioned above are right-lateral strike slip. Each of these faults is discussed in more detail in Section 1.4 below, and those that extend across the Town of Yucca Valley are described further in Section 1.5.

Strong ground shaking causes the vast majority of earthquake damage. As mentioned previously, when a fault breaks in the subsurface, the seismic energy released by the earthquake radiates away from the hypocenter in waves that are felt at the surface as shaking. In general, the bigger and closer the earthquake, the more damage it may cause. However, other effects discussed below are also important. Earthquakes are typically classified by the amount of damage reported, or by how strong and how far the shaking was felt. 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. The most commonly used measure of seismic intensity is called the ***Modified Mercalli Intensity*** (MMI) scale, which has 12 damage levels (see Table 1-1). Although it has limited scientific application, intensity is intuitively clear and quick to determine. Limitations of this scale are related to the fact that earthquake damage depends on the characteristics of human-made structures, and the complex interaction between the ground motions and the built environment, rather than the size of the earthquake alone. Governing factors include a building'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 structures.



Modified from: Jennings, 1995

Explanation

N
W E
S

0 15
Miles

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: 3114
Date: 2011

Local Active and Potentially Active Faults

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 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 did not recognize it as an earthquake. Standing automobiles may have rocked 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 made 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; plaster cracked in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may have stopped. (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 ran 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 ran 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 riverbanks 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 and others (1999)

Scientists used to measure the amplitude of ground motion, as recorded by an instrument a given distance from the epicenter, to report the size of an earthquake (such as the Richter magnitude, a traditional measure of earthquake size that is no longer preferred). Seismologists now find that the most meaningful factor in determining the size of an earthquake is the amount of energy released when a fault ruptures. This measure is called the ***seismic moment*** (abbreviated M_w), and most moderate to large earthquakes today are reported using moment magnitude. Both traditional magnitude scales and seismic moment scales are logarithmic. Thus, 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, in the Richter-magnitude scale, a magnitude 7 earthquake produces 100 times (10 x 10) the ground motion amplitude of a magnitude 5 earthquake. Similarly, a moment magnitude 7 earthquake releases approximately 1,000 times more energy (32 x 32) than a moment magnitude 5 earthquake.

An important point to remember is that any 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.

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), the age of its most recent activity, its total displacement, and its slip rate. These values allow an estimation of how often a fault produces damaging earthquakes, and how big an earthquake can be expected the next time the fault ruptures. 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, however, 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.

In general, the degree of shaking can depend upon:

- **Source effects.** These include earthquake size, location, and distance. 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. This is in part because during the Kobe earthquake, the fault's orientation and movement directed seismic waves into the city, whereas during the Northridge earthquake, the fault's motion directed waves away from populous areas. Similarly, the seismic energy released during the Landers earthquake was directed away from the most densely areas of Yucca Valley and the Coachella Valley to the south.

- **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 the seismic waves during the 1989 M_W 7.1 Loma Prieta earthquake 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 resonant periods coincide, tremendous damage can occur.

  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-rise buildings 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.

1.2 Regulatory Context

1.2.1 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; 2007). 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.

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, 2007).

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 these 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. There are several Alquist-Priolo Earthquake Fault Zones mapped through the Town of Yucca Valley. The faults included in these zones are, from west to east, the Morongo Valley, Pinto Mountain, Johnson Valley, Burnt Mountain fault, and Eureka Peak faults. These faults and boundaries of the State-delineated fault zones are discussed further in Section 1.5.

1.2.2 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, 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, with emphasis on the large metropolitan areas of Los Angeles, Orange and Ventura counties (funding for this program limits the geographic scope of this studies to these three counties in southern California). As a result, at this time, there are no State-issued (and therefore official) seismic hazard zone maps for the Town of Yucca Valley. Nevertheless, the methodology that the CGS uses to prepare these maps is well documented, and can be duplicated in areas that the CGS has yet to map. To that end, and for the purposes of this study, we have followed a simplified version of the CGS methodology to identify areas in Yucca Valley that are susceptible to liquefaction or earthquake-induced slope instability. These hazards are discussed in more detail in Section 1.6.

1.2.3 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. In 1980, recognizing that many building code provisions are not affected by local conditions, and 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, at a minimum, the latest edition of the Uniform Building Code (UBC). The law states that every local agency, such as individual cities and counties, 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 on the publication cycle of the UBC, the CBC used to be updated and republished every three years.

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. However, the California Building Standards Commission, after careful review of the 2000 IBC, chose not to use it, but instead continued to adopt the older 1997 UBC as the basis for the CBC. The 2001 CBC (based on the 1997 UBC) was used throughout the State from 2001 to 2007, often with local, more restrictive amendments based upon local geographic, topographic or climatic conditions.

Since then, the California Building Standards Commission (BSC) issued the 2007 edition of the CBC based on the 2006 IBC, and more recently, the 2010 edition of the CBC based on the 2009 IBC. The 2010 CBC became effective on January 1, 2011. Based on the last two cycles, updates to the building code can again be expected every three years. [For updates and additional information regarding the CBC, refer to the California Building Standards Commission website at www.bsc.ca.gov/.]

The CBC provides requirements for structural design that apply to the construction, alteration, replacement, and demolition of every building or structure and any appurtenances connected or attached to such buildings or structures throughout the state of California. The code is meant to safeguard the public's health, safety and general welfare through structural strength, general stability and means of egress by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of all buildings and structures within its jurisdiction. It is important to recognize, however, that building codes provide minimum standards. With respect to seismic shaking, for example, the provisions of the building code are designed to prevent the catastrophic collapse of structures during a strong earthquake; however, structural damage to buildings, and potential loss of functionality, are expected. Specific provisions contained in the California Building Code that pertain to seismic and geologic hazards are discussed further in other sections of this document.

1.2.4 Unreinforced Masonry Law

Enacted in 1986, the Unreinforced Masonry Law (Senate Bill 547, codified in Section 8875 *et seq.* of the California Government Code) required all cities and counties in what the Building Code at the time referred to as 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. Some jurisdictions implemented 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. Prior to 1997, local governments could adopt other building standards that preceded the UCBC, and in fact, in

many jurisdictions, retrofits were conducted in accordance with local ordinances that only partially complied with the latest UCBC. Then, starting in 1997, California required all jurisdictions to enforce the 1997 Uniform Code for Building Conservation (UCBC) Appendix Chapter 1 as the model building code, although local governments could adopt amendments to that code under certain circumstances (ICBO, 2001; CSSC, 2006). The UCBC standards were meant to significantly reduce but not necessarily eliminate the risk to life from collapse of the structure. The 2010 California Building Code (CBC) includes newly approved building standards for historical buildings (2010 California Historical Building Code, Part 8 of Title 24), and building standards for existing buildings (2010 California Existing Building Code, Part 10 of Title 24) based on the 2009 International Existing Building Code.

Although the Town of Yucca Valley is located in the Seismic Zone 4 area identified in the building code in effect when the Unreinforced Masonry Law was enacted, there is no record that the Town has reported to the Seismic Safety Commission whether or not it has unreinforced masonry buildings in its jurisdiction. Essentially, the Town of Yucca Valley is not included in either the 2003 or 2006 reports by the Seismic Safety Commission.

1.2.5 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 is located within one or more State-mapped hazard areas. For example, if a property lies 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: (1) Using the Natural Hazards Disclosure Statement as provided in Section 1102.6c of the California Civil Code, or (2) using 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 (Option 2) can be substituted for the Natural Hazards Disclosure Statement (Option 1) only if the Local Option Statement contains substantially the same information and substantially the same warnings as the Natural Hazards Disclosure Statement.

California State law also states 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 includes a sample of a residential earthquake hazards report that buyers are required to fill in, and describes structural weaknesses common in homes that if they fail in an earthquake can result in significant damage to the structure. The booklet then provides detailed information on actions that homeowners can take 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. This mandate, therefore, applies to all properties within the official Alquist-Priolo maps for Yucca Valley, and within any other fault hazard management zones if defined in

the Safety Element. In addition, those regions in the study area that have the potential of being impacted by other natural hazards, such as seismically induced liquefaction or slope instability, as identified in this report, should be disclosed to prospective buyers, following the provisions of the Natural Hazards Disclosure Act.

1.2.6 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. The law requires that these documents be issued in draft form and made available at local libraries and government offices for individuals and organizations to review and comment on. The comments are addressed in the final report submitted for approval or refusal by the Planning Commission and/or Town Council.

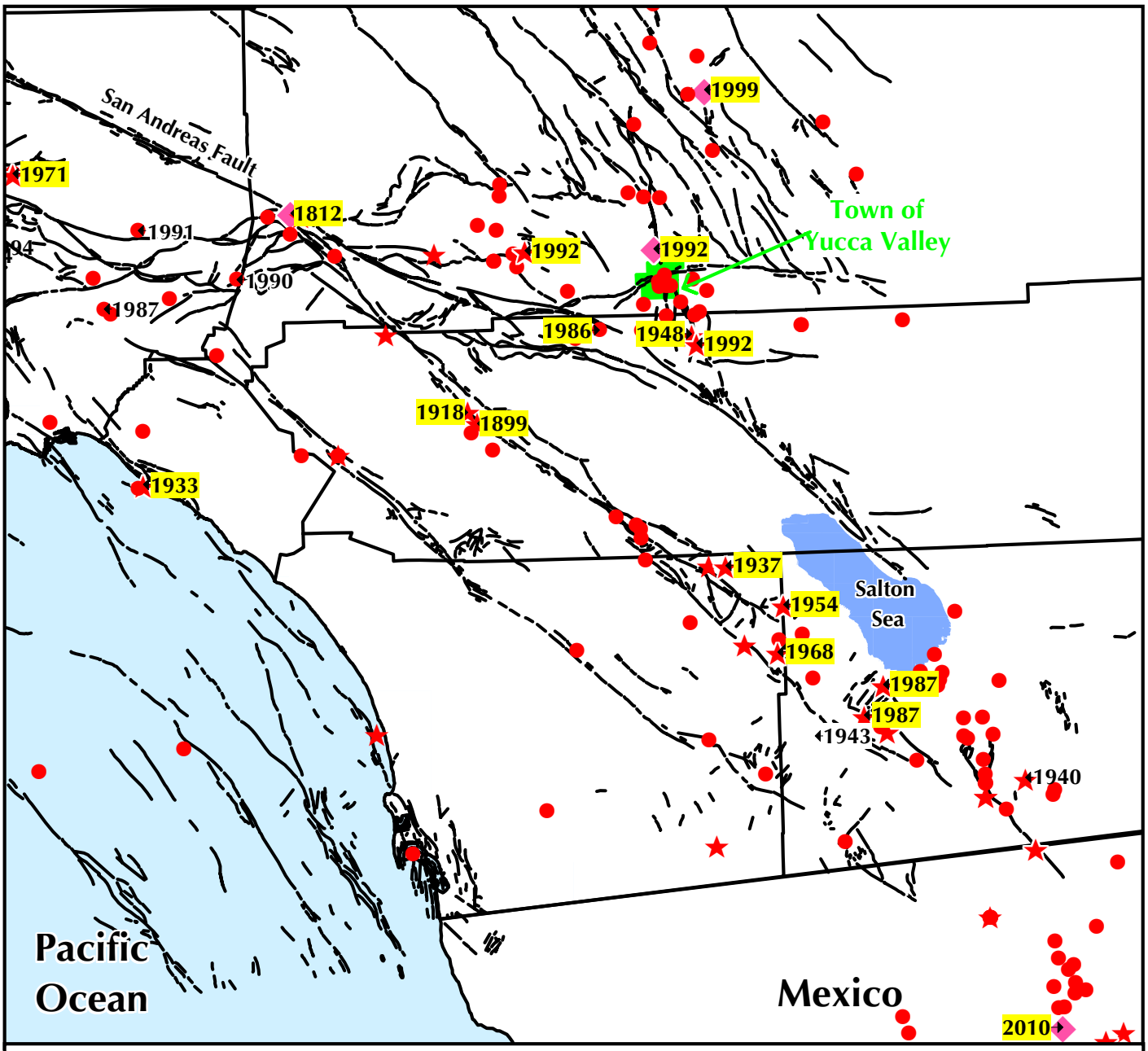
1.3 Notable Past Earthquakes

Figure 1-3 shows the approximate epicenters of some of the historical earthquakes that have resulted in significant ground shaking in the southern California area, including Yucca Valley. The most significant of these events, either because they were felt strongly in the area, or because they led to the passage of important legislation, are described below.

1.3.1 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 and others, 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).

The worst reported 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. The earthquake also damaged walls and destroyed statues at San Gabriel Mission, and is thought to have triggered an earthquake thirteen days later that damaged several missions in the Santa Barbara area (Deng and Sykes, 1996). Strong aftershocks that occurred for several days after the main earthquake collapsed many buildings that had been damaged by the main shock. The Wrightwood earthquake would have been felt in the Yucca Valley area, with Modified Mercalli (MM) intensities in the IV to V range (see Table 1-1).



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

N
W E
S

0 20
Miles

Explanation

- Magnitude 7+
- Magnitude 6 - 7
- Magnitude 5 - 6
- Quaternary faults
- 1899 Earthquakes discussed further in the text

Earth Consultants International

Project Number: 3114
Date: 2011

Notable Regional Earthquakes

Figure 1-3

1.3.2 San Jacinto Earthquake of 1899

This earthquake occurred at 4:25 A.M. on December 25, 1899. The main shock is estimated to have had a magnitude of 6.5. Several smaller aftershocks followed the main shock, and in the city of San Jacinto as many as thirty smaller tremors were felt throughout the day. The epicenter of this earthquake is not well located, but damage patterns suggest the location shown on Figure 1-3, near the city of San Jacinto, with the causative fault most likely being the San Jacinto fault. The cities of San Jacinto and Hemet both reported extensive damage, with nearly all brick buildings either badly damaged or destroyed. Six people were killed in the Soboba Indian Reservation as a result of falling adobe walls. In Riverside, chimneys toppled and walls cracked (Claypole, 1900). The main earthquake was felt over a broad area that includes San Diego to the southwest, Needles to the northeast, and Arizona to the east. No surface rupture was reported, but several large "sinks" or subsidence areas were reported about 10 miles to the southeast of San Jacinto. It is estimated that the Yucca Valley area would have been impacted with effects consistent with MM intensities in the IV range.

1.3.3 San Jacinto Earthquake of 1918

This magnitude 6.8 earthquake occurred on April 21, 1918 at 2:32 P.M. Pacific Standard Time (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 irrigation canals, but none of the cracks are thought to have been caused directly by surface fault rupture. 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).

1.3.4 North San Jacinto Fault Earthquake of 1923

This earthquake occurred about 7 miles south of San Bernardino on July 22, 1923, at 11:28 P.M. PST. The M_L 6.3 earthquake on the San Jacinto fault caused minor damage primarily in the cities of San Bernardino and Redlands, where chimneys collapsed and windows broke. Two public buildings in San Bernardino, the San Bernardino County Hospital and the Hall of Records, were badly damaged, and extensive damage was sustained by the State Hospital building in Patton. However, most of the buildings that sustained damage were deemed of poor construction. Slight damage was reported in Los Angeles. Two people were critically injured, but no deaths were reported. The shaking was felt as far away as

Needles and Santa Barbara. Seismic shaking in the Yucca Valley area as a result of this earthquake is estimated at MM intensity V.

1.3.5 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 killed 115 people and caused $40 to 50 million in property damage (www.scecdc.scec.org/quakedex.html). The earthquake ruptured the Newport-Inglewood fault, and shaking was felt from the San Joaquin Valley to Northern Baja California (Mexico). The epicenter was located at 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. This earthquake would have been felt only slightly in the Yucca Valley area, and is therefore discussed herein only because it led to code changes that apply to all of California. Specifically, the regional significance of this earthquake is that damage to school buildings was especially severe, which 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.

1.3.6 Desert Hot Springs Earthquake of 1948

This magnitude 6.5 earthquake struck on December 4, 1948 at 3:43 P.M. PST. The fault involved is believed to be the South Branch of the San Andreas (or Banning fault, depending on nomenclature used), with the epicenter located about 13 miles to the south-southwest of Yucca Valley. The shaking from this earthquake was felt over a large area (as far away as central Arizona, parts of Mexico, Santa Catalina Island, and Bakersfield), and caused damage in regions far from the epicenter. In the Los Angeles area, a 5,800-gallon water tank split open, water pipes broke at UCLA and in Pasadena, and plaster cracked and fell from many buildings. In San Diego, a water main broke. In Escondido and Corona, walls cracked. The administration building of Elsinore High School was permanently closed, due to the damage it sustained, as was a building at the Emory School in Palm City. Numerous other instances of minor structural damage were reported. Closer to the epicenter, landslides and ground cracks were reported, and a road leading to the Morongo Indian Reservation was badly damaged (Louderback, 1949). In Palm Springs, the city hit hardest by the quake, merchandise was thrown from shelves with losses in the thousands of dollars. Part of a furniture store collapsed. Two people were injured when a crowd fled a movie theater in panic. Fortunately, despite the damage brought on by this earthquake, no lives were lost. Shaking in Yucca Valley was strong to severe, estimated at about 0.2g, with MM intensities in the VIII to IX range.

1.3.7 Borrego Mountain Earthquake of 1968

This magnitude 6.5 earthquake struck on April 8, 1968 at 6:29 P.M. PST. It resulted in about 18 miles of surface rupture along the Coyote Creek fault (a branch of the San Jacinto Fault Zone), and triggered slip was observed on fault systems up to 40 miles away. When the Borrego Mountain earthquake struck, it was the largest and most damaging quake to hit southern California since the Kern County earthquake of 1952. It was felt as far away as Las Vegas, Fresno, and even Yosemite Valley. The quake caused damage across most of southern California – power lines were severed in San Diego County, plaster cracked in Los Angeles, and the Queen Mary, in dry-dock at Long Beach, rocked back and forth on its keel blocks for 5 minutes. A few ceilings collapsed at various places in the Imperial

Valley. Close to the epicenter, the quake caused landslides, hurling large boulders downslope, damaging campers' vehicles at Anza-Borrego Desert State Park, and caused minor surface rupture, cracking Highway 78 at Ocotillo Wells (Lander, 1968).

The event apparently caused small displacements along the Superstition Hills fault (2.2 cm, <1 inch), Imperial fault (1.2 cm, < 0.5 inch), and the Banning-Mission Creek fault (0.9 cm; 0.35 inch), 45, 70, and 50 km (28, 43.5, and 31 miles), respectively, from the epicenter. These fresh breaks and displacements were not noticed immediately after the mainshock, but no other significant events occurred at that time that could have caused them. These are probably among the first noted instances of triggered slip, and they proved to be some of the most intriguing features of the Borrego Mountain earthquake.

1.3.8 San Fernando (Sylmar) Earthquake of 1971

This magnitude 6.6 earthquake occurred on the San Fernando fault, the westernmost segment of the Sierra Madre fault zone, on February 9, 1971, at 6:00 A.M. PST. The surface rupture caused by this earthquake was nearly 20 km (12 miles) long , and occurred in the Sylmar-San Fernando area of Los Angeles. Maximum slip measured at the surface was nearly 2 meters (6 feet). The earthquake caused over $500 million in property damage and 65 deaths. Most of the deaths occurred when the Veteran's Administration Hospital collapsed. Several other hospitals, including the Olive View Community Hospital in Sylmar suffered severe damage. Newly constructed freeway overpasses also collapsed, in damage scenes similar to those 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 called the Earthquake Fault Zone) Act was passed in 1972.

1.3.9 Homestead Valley Earthquake Sequence of 1979

Several moderate-magnitude earthquakes occurred in the Homestead Valley area near Landers starting on March 15 1979, and continuing until at least October of that year. In September 1979 approximately two seismic events per day were being recorded in the region (McJunkin, 1980). Five of the largest events occurred between 12:17 P.M. PST and 3:17 P.M. PST on March 15th. These events ranged in magnitude between 4.1 and 5.2. Surface cracks, surface displacements suggesting fault rupture, ground lurching, rock slides, and the lateral movement of a water tank, a house, a stove, and a water bed were reported in the epicentral area following the main shock of magnitude 5.2. The house, a detached garage, and the water tank were damaged. These structures were all located near to and south of the section of the Johnson Valley fault that experienced minor surface fault rupture (Stierman and others, 1980; McJunkin, 1980; Williams and McWhirter, 1980). Based on these observations, McJunkin (1980) estimated that ground accelerations exceeding 0.4g were experienced in the immediate vicinity of the epicenter, with accelerations attenuating rapidly away from the epicentral location. The largest offsets measured on these cracks showed up to 10 cm (4 inches) of cumulative, horizontal, right-lateral movement, and up to 5 cm (2 inches) of vertical displacement (Hawkins and McNey, 1979; Hill and others, 1980).

Felt effects associated with the M 5.2 main shock, which occurred approximately 23 km (14 miles) north of Yucca Valley, is estimated to have been in the MM intensity VI range in Yucca Valley.

1.3.10 North Palm Springs Earthquake of 1986

This magnitude 5.6 earthquake occurred on July 8, 1986 at 2:21 A.M. PDT, along either the Banning fault or the Garnet Hill fault. The epicenter was about 10 km (6 miles) northwest of Palm Springs, and about 21 km (13 miles) to the west-southwest of Yucca Valley. The North Palm Springs earthquake was responsible for at least 29 injuries and the destruction or damage of 51 homes in the Palm Springs-Morongo Valley area. It also triggered landslides in the region. Damage caused by this quake was estimated at over $4 million. Ground cracking was observed along the Banning, Mission Creek, and Garnet Hill faults, but these cracks were due to shaking, not surface rupture (Person, 1986). Most of the ground fractures occurred on the northern side of the fault, between Whitewater Canyon on the west, and Highway 62 on the east. Fractures varied from single, discontinuous breaks less than 1 mm (0.04 inch) wide, to extensively fractured zones 30 to 40 meters (100 to 120 feet) wide (Morton and others, 1989).

1.3.11 Joshua Tree Earthquake of 1992

This magnitude 6.1 earthquake struck on April 22, 1992 at 9:50 P.M. PDT, approximately 19 km (12 miles) to the south of downtown Yucca Valley. This event resulted from right-lateral strike-slip faulting and was preceded by a magnitude 4.6 foreshock. The Joshua Tree earthquake raised some concern due to its proximity to the San Andreas fault. A San Andreas Hazard Level B was declared following this quake, meaning that the San Andreas fault was given a 5 to 25% chance of generating an even larger earthquake within three days. Although this did not happen, the concern caused by the Joshua Tree earthquake was at least partially warranted: about two months and 6,000 aftershocks later, the Landers earthquake broke the surface of the Mojave Desert in the largest quake to hit southern California in 40 years. The aftershocks of the Joshua Tree quake indicated that the fault that slipped is a north- to northwest-trending, right-lateral strike-slip fault at least 14 km (9 miles) long (Jones and others, 1995). Based on these data, and the location of the shocks, researchers suggested that the Eureka Peak fault may have been the fault responsible for this earthquake.

Damage caused by the Joshua Tree earthquake was slight to moderate in the communities of Joshua Tree, Yucca Valley, Twentynine Palms, Desert Hot Springs, and Palm Springs. Thirty-two people had to be treated for minor injuries. Though somewhat forgotten in the wake of the Landers earthquake, the Joshua Tree event was significant on its own, and was felt as far away as San Diego, Santa Barbara, Las Vegas, Nevada, and even Phoenix, Arizona (Person, 1992). In Yucca Valley, MM intensities in the VII range are estimated.

1.3.12 Landers Earthquake of 1992

On June 28, 1992, most people in southern California were awakened at 4:57 A.M. PDT by the largest earthquake to strike California in 40 years. Centered near Landers, the earthquake had a magnitude of 7.3, and was associated with more than 80 km (50 miles) of surface rupture on five separate but related faults: the Johnson Valley, Landers (or Kickapoo), Homestead Valley, Emerson, and Camp Rock faults (Sieh and others, 1993). The average right-lateral strike-slip displacement on these faults was about 3 to 4.5 meters

(10 to 15 feet); the maximum was up to 5.5 meters (18 feet). Other nearby faults, including faults that extend through Yucca Valley, also experienced triggered slip and minor surface rupture. The Landers earthquake released about four times as much energy as the very destructive Loma Prieta (northern California) earthquake of 1989, but because it occurred in a relatively unpopulated area about 190 km (120 miles) from Los Angeles and the energy released was directed away from the more densely populated areas to the south, the earthquake caused relatively little damage for its size (Brewer, 1992), and did not claim many lives (one child unfortunately died when a chimney collapsed). Seismic intensities of MM level VIII were reported in the Town of Yucca Valley (http://pasadena.wr.usgs.gov/shake/ca/STORE/XLanders/ciim_display.html).

1.3.13 Big Bear Earthquake of 1992

This magnitude 6.4 earthquake struck approximately 3 hours after the Landers earthquake on June 28, 1992 at 8:05 A.M. PDT, and is technically considered an aftershock of the Landers earthquake (indeed, the largest aftershock), although it occurred more than 32 km (20 miles) west of the Landers rupture, on a fault with a different orientation and sense of slip than those involved in the main shock. From its aftershocks, the causative fault was determined to be a northeast-trending left-lateral fault. This orientation and slip are considered "conjugate" to the faults that slipped in the Landers rupture. The Big Bear earthquake did not break the ground surface, and, in fact, no surface trace of a fault with the proper orientation has been found in the area. The Big Bear earthquake caused a substantial amount of damage in the Big Bear area, but fortunately, it claimed no lives. However, landslides triggered by the quake blocked roads in the mountainous areas, making the clean-up and rebuilding process from the Landers earthquake even more difficult (http://www.data.scec.org/chrono_index/bigbear.html). Its effects in Yucca Valley are consistent with MM intensity V (http://earthquake.usgs.gov/earthquakes/dyfi/events/ci/bigbear/us/index.html).

1.3.14 Northridge Earthquake of 1994

On January 17th, 1994, at 4:31 A.M. PST, a M_w 6.7 earthquake struck the San Fernando Valley in the Los Angeles region. This moderate-sized tremor is to date the most expensive earthquake in United States history, due primarily to its proximity to the heavily populated northern Los Angeles area. The rupture occurred on the previously unidentified eastern continuation of the Oak Ridge fault, a blind thrust fault. The earthquake (whose epicenter is just outside and west of the area covered in Figure 1-3) produced widespread ground accelerations of about 1g, 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 out of commission several major freeways for days to months. Most damage was focused in the northern Los Angeles area; MM intensities of between about level II and IV (see Table 1-1) were recorded in the Landers – Twentynine Palms area. No responses specific to Yucca Valley are available in the U.S. Geological Survey's database of seismic shaking (http://pasadena.wr.usgs.gov/shake/ca/STORE/XNorthridge/ciim_stats_8).

1.3.15 Hector Mine Earthquake of 1999

Southern California's most recent large earthquake was a widely felt magnitude M_w 7.1. It occurred on October 16, 1999, at 2:46 A.M. PDT, in the Mojave Desert, about 53 km (33 miles) to the north-northeast of Yucca Valley, in a remote area. Although this earthquake occurred on northwest-trending strike-slip faults within the Eastern California Shear Zone

similar to those that ruptured during the Landers earthquake, the Hector Mine event is not considered an aftershock of the Landers earthquake (Haukson and others, 2002). With no towns or communities nearby, the earthquake was named after an open pit quarry, the Hector Mine, located about 22 km (14 miles) northwest of the epicenter. Geologists documented nearly 48 km (26 miles) of surface rupture on the Lavic Lake fault, the central section of the Bullion fault, and small sections of the Mesquite Lake and West Calico faults (Teiman and others, 2002). Average displacements of 2.5 meters (8.2 feet) and a maximum of 5.5 meters (18 feet) of right-lateral offset were measured on the Lavic Lake fault. MM intensities of V (http://earthquake.usgs.gov/eqcenter/dyfi/events/ci/hectormi/us/index.html; see Table 1-1) were reported in the Yucca Valley area, based on more than 100 responses to the U.S. Geological Survey's "Did You Feel It" survey (http://pasadena.wr.usgs.gov/shake/ca/).

1.3.16 Baja California Earthquake of 2010

A magnitude 7.2 earthquake that occurred just south of the U.S. / Mexico border on Easter Sunday, April 4, 2010, at 3:40 P.M. PDT, was felt throughout Mexico, southern California, Arizona, and Nevada. Researchers believe that there were two sub-events: first a magnitude 6 earthquake that ruptured an 18-km (11.2-mile) long section of the Pescadores fault, followed, about 15 seconds later, by a larger event on the Borrego fault. Both of these faults are part of the Laguna Salada fault system, which is the southern extension of the Elsinore fault. The total length of the zone of surface rupture is approximately 120 km (75 miles), extending across several faults, some unknown prior to the earthquake. Maximum surface fault rupture of about 4.3 meters (14 feet) of predominantly right-lateral displacement was measured on the Pescadores fault; both right-lateral strike-slip and down-to-the-east vertical displacements were observed along the zone of fault rupture.

Surface rupture continued northward to just past the border into California. The main earthquake caused triggered slip of up to a few centimeters on several faults in the Salton Sea area, and as far north as the Mecca Hills, about 13 km (8 miles) to the southeast of the city of Coachella (Weldon, 2010; Wei and others, 2011). Secondary effects, including liquefaction, rockfalls and shattering were reported along a wide area in the El Centro and Brawley region, and westward toward San Diego. A peak instrumental ground acceleration of 1.1g was recorded at the Salton Sea. Similar or stronger shaking may have occurred closer to the epicenter, but given the lack of instrumentation in that area, went unrecorded. Based on observations reported by at least 140 residents, shaking in the Town of Yucca Valley as a result of this earthquake was weak to light, in the MM intensity III range (http://earthquake.usgs.gov/earthquakes/dyfi/events/ci/14607652/us/index.html).

By November 2010, more than 10,000 aftershocks had been recorded (Haukson and others, 2010). Many of the aftershocks occurred along the Elsinore, San Jacinto, and the southern extension of the San Andreas fault through the Brawley area. The largest aftershock was a magnitude 5.7 event on June 14, 2010 that occurred just north of the International Border, about 8 km (5 miles) from Ocotillo. A M_s 5.4 aftershock occurred on the San Jacinto fault on July 7, 2010, with its epicenter about 24 km (15 miles) northwest of Borrego Springs.

In addition to the earthquakes described above, thousands of small earthquakes have occurred and will continue to occur in the immediate vicinity of Yucca Valley. This is

discussed further in Section 1.4 below.

1.4 Seismic Ground Shaking

Seismic shaking and fault rupture are the geologic hazards that have the greatest potential to severely impact the Yucca Valley area, given that the town is intersected by and located near several significant seismic sources (faults) that have the potential to cause moderate to large earthquakes. Plate 1-1 shows the approximate epicentral locations of earthquakes instrumentally detected between 1932 and December 2011 in and around the Town of Yucca Valley, and the approximate location of earlier earthquakes extending back to 1800. The epicentral locations of earlier earthquakes are approximate because prior to 1932 there were no instruments available to measure the location and magnitude of an earthquake. The map shows most seismic activity in Yucca Valley is coincident with the location of the north-south trending faults that extend through the General Plan area that ruptured in 1992. In fact, a large percentage of the seismic events shown on Plate 1-1 are aftershocks of the 1992 Landers earthquake, with most of these occurring in the 1990s. Some aftershocks of the Landers sequence have continued into the new millennium. The east-trending Pinto Mountain fault has a relatively low number of earthquakes associated with it, possibly suggesting that the section of the fault that extends through the Yucca Valley area is locked. A ***locked fault*** is one that is not slipping because the frictional forces on the fault exceed the shear forces across the fault. A locked fault stores strain that is eventually released, typically during an earthquake.

In order to provide a better understanding of the shaking hazard posed by these local faults and other, more distant seismic sources, we conducted a deterministic seismic hazard analysis for a central point in the town and several other randomly selected points within town limits using the software program EQFAULT by Blake (2000). 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 a given distance; 100 km (62 miles) was used for the analyses reported herein. The fault database (including fault locations and earthquake magnitudes of the maximum magnitude earthquakes for each fault) used to conduct these calculations is that used by the California Geological Survey (CGS) and the U.S. Geological Survey (USGS) for the National Seismic Hazard Maps (Petersen and others, 1996; Cao and others, 2003). However, as described further in the text, paleoseismic studies suggest that some of these faults may actually generate even larger earthquakes than those used in the analyses. Where appropriate, this is discussed further below.

PHGA depends on the size of the earthquake (which is dependent on the rupturing fault's dimensions), the proximity of the rupturing fault to the study area, and local soil and rock conditions. The effects of the underlying soil (or rock) on the ground motions are estimated by use of attenuation relationships that have been derived empirically by several researchers from analyses of recordings of earthquake shaking in similar soils during earthquakes of various sizes and at various distances. The underlying geologic conditions, as described in Chapter 2, were considered in the Yucca Valley study, with sites underlain by alluvial deposits analyzed using alluvium as the underlying material, and sites underlain by rock analyzed using rock. Different attenuation equations, including those by Campbell and Bozorgnia (1997), Bozorgnia, Campbell and Niazi (1999), Boore and others (1997), Sadigh and others (1997), and Abrahamson and Silva (1997) were used to obtain a range of potential ground motions that could be felt in different areas

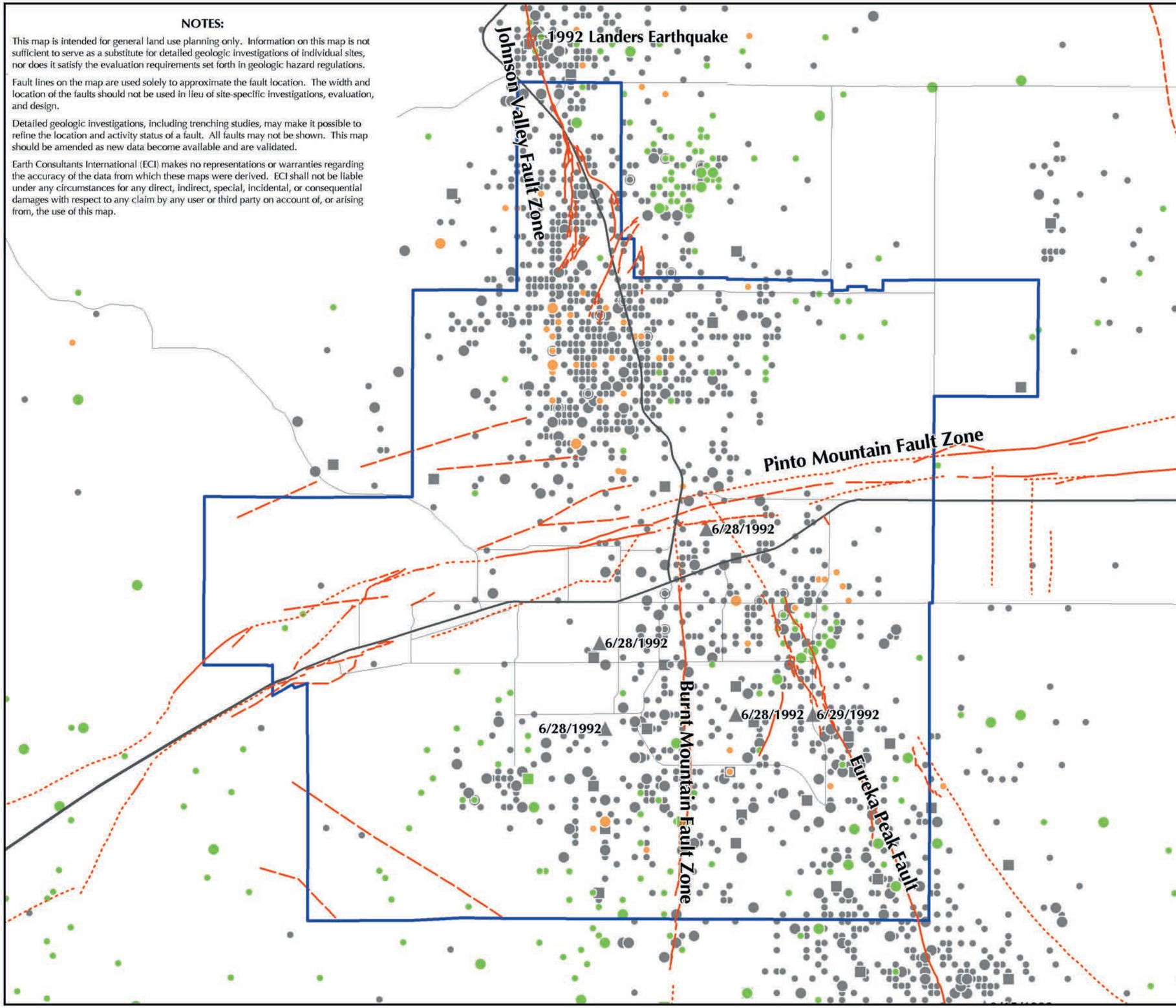
NOTES:

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.



Faults and Historical (1800-2011) Seismicity Map

Yucca Valley, California

Explanation

Earthquake Magnitude

- 7+
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3

Pre-1992 earthquakes in green
1992 - 1999 earthquakes in gray
2000 - 2011 earthquakes in orange

Quaternary Fault; solid where well located, dashed where approximately located, dotted where concealed or inferred.

Yucca Valley Town Boundary

N
W E
S

5000 0 5000
Feet

1500 0 1500
Meters

Scale: 1:60,000

Base Map: From Town of Yucca Valley.
Sources: Southern California Earthquake Center (January 1932 to December 2011); National Earthquake Information Center (1800 to 1931); US Geological Survey (2011).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 1-1

around Yucca Valley. The ground motions presented in Table 1-2 are the ranges of the acceleration values calculated using these various attenuation equations.

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 Yucca Valley area are listed in Table 1-2. For maps showing most of these faults, refer to Figures 1-1 and 1-2, and Plate 1-2. Those faults included in Table 1-2 that could have the greatest impact on the Yucca Valley area, or that are thought to have a higher probability of causing an earthquake, are described in more detail in the following pages. The deterministic analyses indicate that the Pinto Mountain, Burnt Mountain, and Eureka Peak faults have the potential to generate very strong ground shaking in Yucca Valley, with median PHGA values as high as 0.7g to 0.8g. Shaking at these levels can cause significant damage to older structures, and moderate damage to even newer buildings constructed in accordance with the latest building code provisions.

Table 1-2 shows:

- The approximate distance, in miles and kilometers, between the fault and various points in the Yucca Valley area, given as a range. Since these measurements are based on specific, but randomly selected points in the study area; other points in the town could be closer or farther away from the faults than the distances provided herein;
- The maximum magnitude earthquake (M_{max}) each fault is estimated capable of generating;
- The range in peak horizontal ground accelerations (PHGA), provided both for the median (50th percentile) and median plus 1 sigma standard deviation (84th percentile), or intensity of ground motion, expressed as a fraction of the acceleration of gravity (g), that could be experienced in different areas of Yucca Valley if the M_{max} occurs on the faults listed; and
- The range in Modified Mercalli seismic Intensity (MMI) values estimated for the Yucca Valley area.

The peak horizontal ground accelerations and intensities summarized in Table 1-2 are shown from largest to lowest for each fault; these should be considered as approximate values, since different areas of Yucca Valley are expected to feel and respond to each earthquake differently in response to site-specific conditions. As mentioned before, peak ground accelerations and seismic intensity values generally decrease with increasing distance away from the causative fault. However, local site conditions, such as deep basins or reflection off the hard rock forming the mountains in the region, 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 Yucca Valley General Plan area. 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. The most significant faults in Table 1-2 are discussed in greater detail in the subsections below.

Table 1-2: Estimated Horizontal Peak Ground Accelerations and Seismic Intensities in the Town of Yucca Valley Area

Fault or Fault Segment	Approx. Distance to Yucca Valley (miles)	Approx. Distance to Yucca Valley (km)	Magnitude of M_{max}	PGHA (g) from M_{max} (median, median + 1 sigma)	MMI from M_{max}
Pinto Mountain	0 – 4.8	0 – 7.8	7.2	0.8 – 0.35, 1.2 – 0.58	XII – IX
Burnt Mountain	0 – 5.4	0 – 8.7	6.5	0.75 – 0.21, 1.2 – 0.34	XII - VIII
Eureka Peak	0 – 6.0	0 – 9.6	6.5	0.74 – 0.16, 1.2 – 0.27	XII - VII
Landers (faults involved in the Landers 1992 earthquake)	0 – 6.8	0 - 10.9	7.3	0.65 – 0.23, 1.0 – 0.39	XI - IX
Emerson – South Copper Mountain	6.8 – 16.5	11 – 26.5	7.0	0.37 – 0.10, 0.58 – 0.18	X - VII
North Frontal (East segment)	7.7 – 15.5	12.4 – 24.9	6.7	0.36 – 0.15, 0.57 – 0.25	X – VIII
Johnson Valley (Northern)	8.5 – 17.2	13.6 – 27.7	6.7	0.25 – 0.09, 0.39 – 0.15	X - VII
San Andreas (entire southern)	11.3 – 31.1	18.2 – 50.1	8.0	0.38 – 0.19, 0.57 – 0.29	X – VIII
San Andreas (San Bernardino + SG-GH + Coachella)	11.3 – 31.1	18.2 – 50.1	7.7	0.33 – 0.17, 0.49 – 0.26	X – VIII
San Andreas (San Bernardino S + N)	21.5 – 30.8	34.6 – 49.6	7.5	0.30 – 0.15, 0.44 – 0.25	X - VIII
San Andreas (SG-GH + Coachella)	22 – 31.1	35.4 – 50.1	7.2	0.26 – 0.12, 0.45 – 0.21	IX – VIII
Calico – Hidalgo	14.2 – 23.1	22.9 – 37.2	7.3	0.26 – 0.10, 0.38 – 0.16	IX - VII
Pisgah – Bullion Mountain. – Mesquite Lake	15.6 – 25.1	25.1 – 40.4	7.3	0.24 – 0.09, 0.31 – 0.15	IX – VII
Lenwood – Lockhart - Old Woman Springs	15.8 – 24.5	25.4 – 39.4	7.5	0.23 – 0.11, 0.37 – 0.19	IX - VII
North Frontal (West Segment)	22.9 – 30.6	36.9 – 49.2	7.2	0.18 – 0.08, 0.29 – 0.12	IX – VII
Helendale – South Lockhart	27 – 35.1	43.5 – 56.6	7.3	0.13 – 0.07, 0.22 – 0.11	IX – VI

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

The ground motions presented in Table 1-2 are based on the largest earthquake that each fault, or fault segment, is believed capable of generating, referred to as the ***maximum magnitude earthquake*** (M_{max}). This deterministic approach is useful to study the effects of a particular earthquake on a building or community. However, since many potential earthquake sources pose a hazard to the region, it is also important to consider the overall likelihood of damage from a plausible suite of earthquakes, including earthquakes of different sizes on the same fault. 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 given radius of the project site, or in this case, the Town of Yucca Valley. Most seismic hazard analyses consider a distance of 100 km (62 miles), but this is arbitrary. PSHA has been utilized by the U.S. Geological Survey to produce national seismic hazard maps such as those used by the Uniform Building Code (ICBO, 1997), the International Building Code (ICC, 2009) and the California Building Code (CBSC, 2010).

We ran the interactive ground motion module from the California Geological Survey (http://www.consrv.ca.gov/CGS/rghm/pshamap/pshamap.asp) and that by the U.S. Geological Survey (http://earthquake.usgs.gov/research/hazmaps/design/; https://geohazards.usgs.gov/deaggint/2008/) to estimate the ground motions that have a 10 and 2% probability, respectively, of being exceeded in 50 years in the vicinity of Town Hall. [Seismic design parameters in the 2010 California Building Code are based on the maximum considered earthquake, with a ground motion that has a 2% probability of being exceeded in 50 years and a recurrence interval of about 2,500 years.] For Yucca Valley, the estimated level of ground motion that has a 10% probability of being exceeded in 50 years is approximately 0.5g. The level of ground motion with a 2% probability of being exceeded in 50 years is nearly 1.0g. The principal sources responsible for these levels of shaking are the Pinto Mountain and Burnt Mountain faults, with the Pinto Mountain fault contributing most to the seismic hazard. These levels of shaking are in the moderate to very high range for southern California, and can be expected to cause significant damage, particularly to older and poorly constructed buildings.

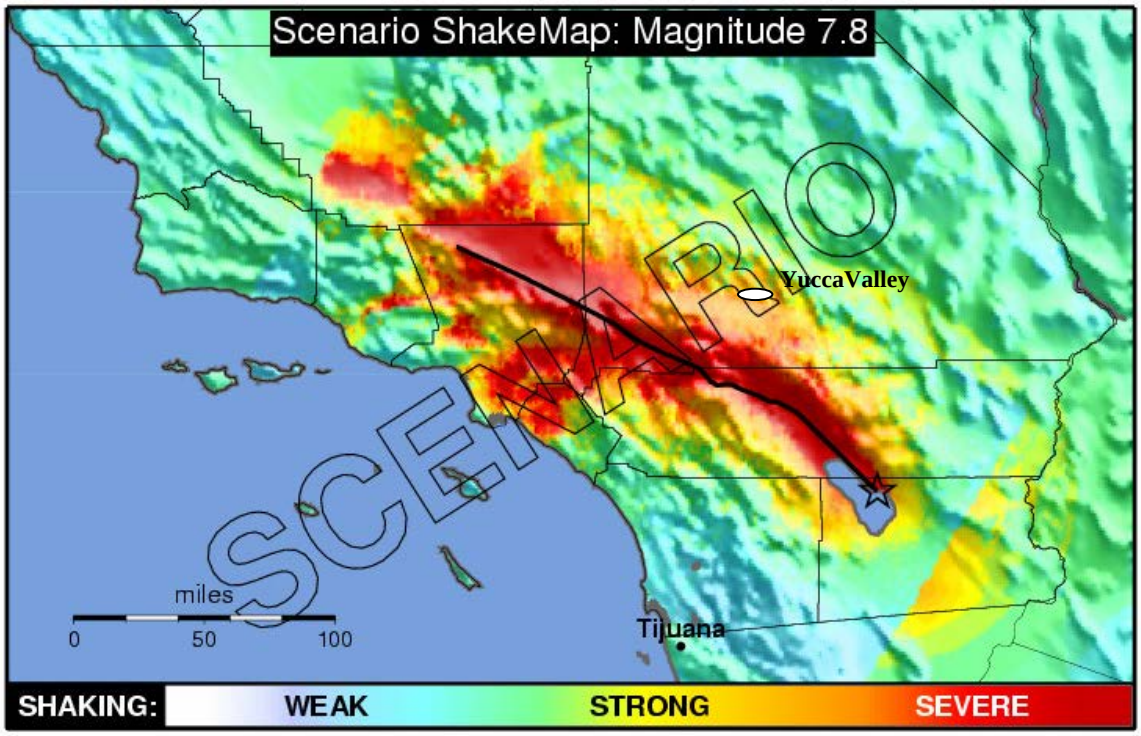
Regardless of which fault causes a damaging earthquake, there will always be ***aftershocks***. By definition, these are smaller earthquakes that happen close to the ***mainshock*** (the biggest earthquake of the sequence) in time and space. These smaller earthquakes occur as the Earth adjusts to the 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.

Another way to communicate the seismic shaking hazard is with the use of ShakeMaps. A ShakeMap is a representation of the various levels of ground shaking throughout the region where an earthquake occurs. ShakeMaps are compiled from the California Integrated Seismic Network (CISN) – a network of seismic recording instruments located throughout the state – and are automatically generated following moderate to large earthquakes. Preliminary real-time maps are posted within minutes on the Internet (http://earthquake.usgs.gov/eqcenter/shakemap/) giving disaster response personnel an immediate picture of where the most damage likely occurred. Although several shaking parameters can be illustrated on ShakeMaps, such as peak acceleration and peak velocity, most people can relate more easily to maps illustrating the intensity of ground shaking. Using actual instrumental ground motion recordings and comparing them to observed

Modified Mercalli Intensities from recent California earthquakes, scientists can now estimate shaking intensities within a few minutes after an earthquake.

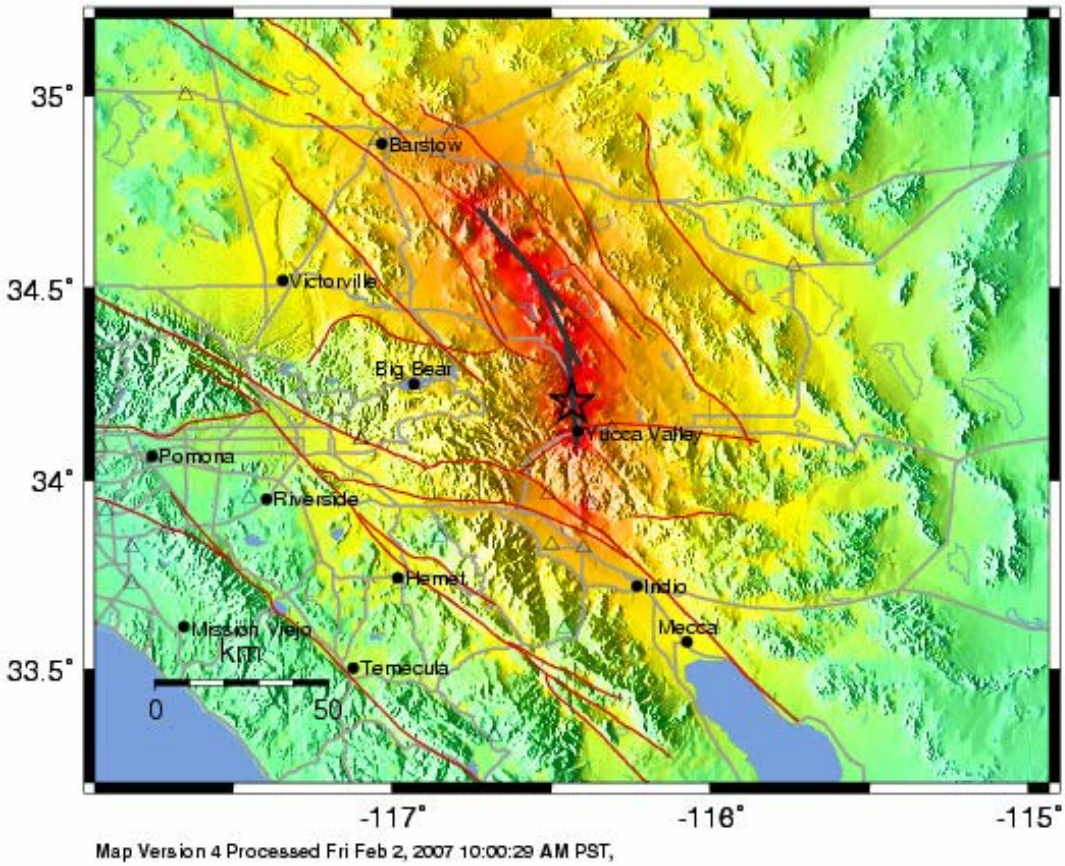
Figure 1-4:
ShakeMap for a Magnitude 7.8 Earthquake Scenario on the Southern San Andreas Fault



Source: http://earthquake.usgs.gov/eqcenter/shakemap/sc/shake/ShakeOut2_full_se/#Decorated

ShakeMaps can also be used for planning and emergency preparedness by creating hypothetical earthquake scenarios. These scenarios are not predictions – knowing when or how large an earthquake will be in advance is still not possible. However, using realistic assumptions about the size and location of a future earthquake, we can make predictions of its effects, and use this information for loss estimations and emergency response planning. Figure 1-4 is an intensity ShakeMap for the hypothetical magnitude 7.8 "Shakeout" earthquake scenario that involves rupture of the entire southern San Andreas fault south and west of the Town of Yucca Valley. The ShakeMap shows that the area in and around Yucca Valley would experience strong shaking. As a comparison, Figure 1-5 shows the intensity ShakeMap for the 1992 Landers earthquake, which is based on actual reports of damage observed and shaking felt by residents throughout the region. Seismic ground shaking in the Town of Yucca Valley was perceived as severe to violent. As strong as this earthquake was felt in Yucca Valley, had the faults that caused the Landers earthquake ruptured from north to south, instead of from south to north, the shaking in Yucca Valley would have most likely been perceived as violent to extreme.

Figure 1-5: Modified Mercalli Intensity ShakeMap for the June 28, 1992 Landers Earthquake



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: http://earthquake.usgs.gov/eqcenter/shakemap/sc/shake/9108645/

1.4.1 Pinto Mountain Fault Zone

The ***Pinto Mountain fault*** is a prominent left-lateral strike-slip fault zone that bounds the north side of the Little San Bernardino Mountains and extends in a westerly direction through the heart of Yucca Valley (see Section 1.5) and on to the Morongo Valley, where it is known as the ***Morongo Valley fault***. The fault zone is at least 73 km (45 miles) long, and possibly as much as 90 km (56 miles) long, ending at its west end against the San Andreas fault. Relative recent studies show that this fault has ruptured repeatedly in the last 14,000 years, with at least four surface-rupturing earthquakes within the past about 9,400 years (Cadena and others, 2004). Current estimates on its rate of slip (rate of movement averaged over time) suggest a rate of between 1.1 and 2.3 mm/yr (40 to 90 inches/1000 yr). Additional studies may refine those estimates further. A magnitude 7.2 earthquake on this fault could generate median peak horizontal ground accelerations in

the Yucca Valley area of about 0.8g to 0.35g (at the 84th percentile, the peak ground motions range between 1.2g and 0.58g). Such an earthquake would cause extensive damage typical of MM intensities of between XII and IX. A potentially larger magnitude 7.5 earthquake on the Pinto Mountain fault could generate stronger ground shaking and more damage in the Yucca Valley area. Rupture of the Pinto Mountain fault is considered the worst-case scenario for Yucca Valley.

1.4.2 Burnt Mountain Fault

Like several other Mojave (or Eastern California) Shear Zone faults, the Burnt Mountain fault was unknown prior to late June 1992, when a 6-km (3.7-mile) length of this fault ruptured at the ground surface, probably during a large aftershock of the Landers earthquake, experiencing about 6 cm (2.4 inches) of right-lateral offset. Geologists later mapped the area and determined that the Burnt Mountain fault has a total length of about 21 km (13 miles). Based on their location, the Burnt Mountain and Eureka Peak faults are thought to be important structures that are accommodating the transfer of strain from the San Andreas fault system to the Eastern California Shear Zone (http://www.data.scec.org/fault_index/burntmtn.html).

The Burnt Mountain fault is thought to have a long-term slip rate of about 0.5 mm/yr (20 inches/1000 yr), but fault-specific studies are needed to better define the fault's earthquake history and rate of slip. Based on its length (using the relations by Wesnousky, 1986), this fault is thought capable of producing a magnitude 6.0 to 6.5 earthquake. However, larger magnitude earthquakes are possible if this fault ruptures together with other faults in the area. Using the California Geological Survey preferred magnitude of 6.5, the Burnt Mountain fault is capable of generating peak ground horizontal accelerations in the Yucca Valley study area of between about 0.75g and 0.21g (and at the 84th percentile, of between 1.2g and 0.34g), with MM intensities in the XII to VIII range.

1.4.3 Eureka Peak Fault

This 20-km (12 miles) long, right-lateral strike-slip fault was "discovered" when it broke the ground surface during the 1992 Landers earthquake sequence, in part as a result of a large aftershock (Hough and others, 1993). Although the maximum surface offset measured on the 11-km (6.8-mile) long section of the fault that ruptured was only 21 cm (8 inches), and therefore considerably less than the 2- to 3-meter (6- to 9-foot) offsets measured elsewhere, this small amount of offset allowed geologists to map the fault and discover the nearby Burnt Mountain fault (http://www.data.scec.org/fault_index/eureka.html). Creepmeters installed along the fault following the Landers earthquake suggest that the fault slipped about 12 cm (4.7 inches) immediately following the main earthquake sequence, and that it has since continued to slip (Behr and others, 1994). In fact, geologists think that most of the slip on this fault occurred in two separate but closely spaced events, plus some afterslip. The first rupture is thought to have occurred about 30 seconds after the Landers mainshock, whereas the second rupture episode was probably as a result of a magnitude 5.7 aftershock that occurred less than three minutes after the mainshock. Seismologists have also suggested that the Eureka Peak fault caused the Joshua Tree earthquake in April 1992, and transferred strain onto the faults that ruptured during the Landers earthquake, three months later (Jones and others, 1995).

Slip rate on this fault is estimated at 0.6 mm/yr (24 inches/1000 yr), but its earthquake history prior to 1992 is poorly resolved. Based on its length, the Eureka Peak fault alone is though capable of generating M_w 5.5 to 6.8 earthquakes, and, as the Landers earthquake showed, if combined with other faults, it has the potential to generate even larger earthquakes. Using a magnitude 6.5 earthquake (slightly larger than the magnitude 6.4 event that the California Geological Survey (Cao and others, 2003) prefers as the maximum magnitude event on this fault), the Eureka Peak fault is estimated capable of generating median peak ground accelerations in the Yucca Valley area of between about 0.74g and 0.16g (and ground motions in the 1.2g to 0.27g at the 84th percentile), with MM intensities in the XII to VII range.

1.4.4 Landers (or Kickapoo) Fault

The Landers fault was the name given to the group of faults that ruptured during the 1992 Landers earthquake, including the Homestead Valley, Kickapoo, and Johnson Valley faults, and segments of the Burnt Mountain and Eureka Peak faults. [The name Landers fault is also used to refer to the Kickapoo fault, but in this report we use the term Landers to refer to the group of faults that ruptured in 1992.] The interval between major ruptures on these faults is uncertain, but is probably in the thousands of years, which is why these faults were unknown or poorly known prior to 1992. As a result of the 1992 earthquake some of these faults experienced significant lateral displacements – the Kickapoo fault moved laterally nearly 3 meters (9.5 feet) (Sieh and others, 1993). Individually, these faults could rupture in smaller earthquakes (similar to the 1979 Homestead Valley earthquake swarm that ruptured a portion of the southern Johnson Valley and Homestead Valley faults), but their combined lengths allowed for the magnitude 7.3 earthquake that shook southern California on the morning of June 28, 1992. Ground shaking in the Yucca Valley area due to a Landers-type earthquake on these faults with an epicenter closer to the Town is estimated at median horizontal ground accelerations of between 0.65g and 0.23g (1.0g to 0.39g at the 84th percentile), with MM intensities in the XI to IX range.

1.4.5 Emerson South – Copper Mountain Fault Zone

The right-lateral strike-slip Emerson South fault last ruptured on June 28, 1992, during the M_w 7.3 Landers earthquake. This earthquake illustrated the transfer of strain from one fault segment to the next: rupture on the South Johnson Valley fault was transferred to the Emerson fault by the right-stepping Kickapoo (Landers) and Homestead Valley faults, and rupture on the Emerson fault was in turn transferred northward to the Camp Rock fault.

The ***Emerson South fault*** is about 55 km (34 miles) long, and is estimated to slip at a rate of about 0.5 mm/yr (20 inches/1000 yr). The penultimate (prior to 1992) surface-rupturing earthquake on this fault is thought to have occurred about 9,000 years ago, so this fault seems to have long periods of dormancy between ruptures (Rubin and Sieh, 1997). Alone, the fault is thought capable of rupturing in a magnitude 6.5 earthquake, but the fault is essentially continuous with the Copper Mountain fault to the south. The ***Copper Mountain fault*** is about 17 km (11 miles) long, and is also thought to slip at about 0.5 mm/yr (20 inches/1000 yr). Its past earthquake history is uncertain, but its most recent rupture is thought to have occurred in the Holocene. An earthquake on the combined Emerson South – Copper Mountain faults of estimated magnitude 7.0 would generate median peak ground accelerations in Yucca Valley of about 0.37g to 0.1g (with values in the 0.58g to 0.18g range at the 84th percentile). The Southern California Earthquake Center suggests

that these faults could generate an even larger magnitude 7.3 earthquake, consistent with the size of the Hector Mine earthquake of 1999 that ruptured the northern section of the Emerson fault (http://www.data.scec.org/fault_index/emerson.html). That event would generate slightly stronger seismic shaking in the Town of Yucca Valley.

1.4.6 North Frontal Fault Zone

This south-dipping, partially blind reverse fault zone along the east flank of the San Bernardino Mountains consists of several fault splays that have a combined total length of approximately 65 km (40 miles). Several of the fault splays interact with other nearby faults; the most significant of these is the Helendale fault, which seems to right-laterally offset the North Frontal fault zone, dividing it into two main segments (referred to as the East and West segments; Meisling, 1984; Bryant, 1986b).

The North Frontal fault is thought to have moved in the past 10,000 years, making it an active fault. However, the fault has not been studied in detail, and its recurrence interval, slip rate and other fault parameters are not well understood, although a slip rate of about 0.5 mm/yr (20 inches/1000 yr) is attributed to it. Furthermore, movement on this fault is thought to be responsible for uplift of the San Bernardino Mountains at an average rate of about 1 mm/yr (40 inches/1000 yr). Based on its length, the East segment of the North Frontal fault zone is thought capable of generating a maximum magnitude 6.7 earthquake. An earthquake of that size on this fault would be felt in Yucca Valley with median peak ground accelerations of between about 0.36g and 0.15g, and felt effects consistent with MM intensities in the X to VIII range. If the more distant West segment of the North Frontal fault zone ruptured in a 7.2 earthquake, the Yucca Valley area is expected to experience ground shaking of between about 0.18g and 0.08g, with MM intensities in the IX to VII range.

1.4.7 Johnson Valley Fault

The ***Southern Johnson Valley fault*** is one of the five faults that ruptured during the 1992 Landers earthquake, whereas its northern extension, the ***Northern Johnson Valley fault***, did not. Trenching studies have shown that the Northern Johnson Valley fault last ruptured about 5,800 and 7,500 years ago in large earthquakes. A smaller earthquake may have ruptured the fault about 11,500 years ago (Rockwell and others, 2000). These data suggest that the Northern segment of the Johnson Valley fault is at or near the end of its cycle, and is a likely candidate for an earthquake on the not-too-distant future. The California Geological Survey (Cao and others, 2003) assign a magnitude 6.7 to this fault segment. An earthquake of that size would generate median peak ground shaking in the Town of Yucca Valley of about 0.25g to 0.09g (between 0.39g and 0.15g at the 84th percentile), with felt effects consistent with MM intensities in the IX to VII range. Rockwell and others (2000), however, estimate that the Northern fault segment is capable of generating a slightly larger magnitude 6.8 earthquake. Furthermore, the trenching studies suggest that the Northern and Southern segments of the fault, in addition to the Kickapoo fault, all ruptured together in the penultimate event about 5,800 years ago, suggesting that all three faults could be involved in a future, larger-than-magnitude-7.0 earthquake.

1.4.8 San Andreas Fault Zone

The San Andreas fault is the principal boundary between the Pacific and North American plates. The fault extends nearly 1,300 km (800 miles), from near Cape Mendocino in

northern California to the Salton Sea region in southern California. This fault is considered the "Master Fault" in southern California because it has frequent, large earthquakes and controls the seismic hazards of the area. Many refer to an earthquake on the San Andreas fault as "The Big One," and for many parts of southern California, this is indeed true. However, as shown above, several other faults closer to Yucca Valley have the potential to cause stronger ground shaking, and therefore more local damage, than the San Andreas fault. Nevertheless, the San Andreas fault should be considered in all seismic hazard assessment studies in southern California given its high probability of causing an earthquake in the near future. In 2007-2008, a group of scientists referred as the 2007 Working Group on California Earthquake Probabilities (WGCEP, 2008) calculated that the southern San Andreas fault had a 59% probability of causing an earthquake of at least magnitude 6.7 in the next 30 years. That probability increases with each passing year without an earthquake.

Large faults, such as the San Andreas fault, are often divided into segments or sections in order to evaluate their future earthquake potential. The sections are typically based on physical characteristics along the fault, particularly changes in dip and/or strike, and style of faulting. Each fault section is assumed to have a characteristic slip rate, recurrence interval (time between moderate to large earthquakes), and displacement (amount of offset during an earthquake). Historical records and studies of prehistoric earthquakes show it is possible for more than one section to rupture during a large quake or for ruptures to overlap into adjacent sections. For example, the last major earthquake on a portion of the southern San Andreas fault (and the largest earthquake reported in California) was the 1857 Fort Tejon (magnitude 8) event. The 1857 earthquake ruptured the Cholame, Carrizo, Big Bend, and Mojave North and Mojave South sections of the fault, resulting in displacements of as much as 9 meters (27 feet) along the rupture zone. There are data that suggest that these sections and portions of sections, which are combined into a fault segment, tend to rupture together time and time again in what is referred to as a "characteristic earthquake."

The definition and naming of the various sections, segments, fault strands and fault splays have varied over time, the result of many investigators working on different aspects and parts of the fault zone, and the recent efforts to compile these data into a unified model. In this report, the fault nomenclature used follows that defined by the 2007 Working Group on California Earthquake Probabilities (2008). The southern San Andreas fault is now divided into ten sections named, from north to south, Parkfield, Cholame, Carrizo, Big Bend, Mojave North, Mojave South, San Bernardino North, San Bernardino South, San Gorgonio-Garnet Hill, and Coachella (WGCEP, 2008). The southernmost sections are discussed further below as these are the sections closest to the Yucca Valley area. Specifically, the Yucca Valley area is, at a minimum, about 34.6 km 2 (1.5 miles) from the San Bernardino South section,18 km (11 miles) from the San Gorgonio–Garnet Hill segment, and 35.4 km (22 miles) from the Coachella segment. Each of these sections is discussed further in the following paragraphs.

The ***San Bernardino (South and North) segments*** combined are about 70 km (43 miles) long and extend from the Burro Flats area northward to approximately Cajon Pass. These faults, like the Coachella section, appear to be nearly vertical, and are predominantly strike-slip in motion. Slip rate on the San Andreas fault in this area decreases southward.

At the north end of the San Bernardino North segment, in the area of Cajon Pass and Pittman Canyon, the fault has a slip rate of 22±6 mm/yr (72.2±2 feet/1000 yr). To the south, some of the slip is being transferred to the San Jacinto fault through the Crafton Hills fault and related structures, so that slip on the San Bernardino South segment is estimated at 16±6 mm/yr (5.25± 2 feet/1000 yr) (WGCEP, 2008). Both segments appear to have last ruptured in 1812. If both sections rupture together in the future, the resultant magnitude 7.5 earthquake could cause peak ground accelerations in the Town of Yucca Valley of between about 0.44g and 0.15g. If these fault sections rupture in conjunction with the Mojave and/or Coachella Valley segments, higher ground motions could be expected in the region.

The ***San Gorgonio-Garnet Hill section*** is about 66 km (41 miles) long, and extends northwesterly and westerly from just north of the city of Indio, through the San Gorgonio Pass, to just south of Burro Flats. From south to north, this section is comprised of two main branches (the Banning fault on the south, and the Mission Creek fault on the north) in addition to several other faults, including the Garnet Hill fault. At its western end, the Garnet Hill fault merges with the San Gorgonio Pass fault. Unlike the San Bernardino and Coachella sections to the north and south, respectively, this section is very complex, being mostly oblique strike-slip, with a major thrust component of movement (Yule and Sieh, 2003). Each of these faults that are part of the San Gorgonio-Garnet Hill section is discussed further in the paragraphs below.

The *Banning fault* is an older, right-lateral strike-slip structure dating back to latest Miocene time (about 4 or 5 to 7.5 million years ago), when it is thought to have served as an ancestral strand of the San Andreas fault (Matti and Morton, 1993). Based on geologic and geomorphic characteristics, as well as the fault's tectonic history during the last two million years, Matti and others (1992) divided the Banning fault into three segments. The western segment, extending from the San Jacinto fault southeastward to the Calimesa area, is considered not active because it does not break Quaternary alluvium and has no surface expression (the location of the fault has been inferred from gravity data and other indirect geologic evidence). The central segment, which extends from Calimesa to Cottonwood Canyon, for the most part also does not affect Quaternary deposits, and has been overprinted by reverse and thrust faults that are probably related to development of the San Gorgonio Pass fault zone. There is, however, a 3-km (2-mile) long section of the central Banning fault with thrust-type motion that offsets young alluvium in Millard Canyon. Therefore, the fault is active in that area (Yule and Sieh, 2003). The easternmost portion of the ancestral Banning fault, from Cottonwood Canyon to its junction with the Coachella section of the fault near the Indio Hills, has been reactivated during Quaternary time, and has many geomorphic characteristics of youthful strike-slip activity.

The *Mission Creek fault* has right-lateral strike-slip motion along most of its trace, but gradually evolves into thrust-type motion at its western end. Some researchers have suggested this fault is either an older strand of the San Andreas that is less active than other strands, or that is no longer active (Matti and others, 1992; Yule and Sieh, 2003). This is most likely true for the northern end of the fault, but trenching near its southern end, at Thousand Palms Oasis, has shown that at this site, the fault has experienced four, and probably as many as five, surface-rupturing earthquakes in the past about 1,200 years

(Fumal and others, 2002). The most recent earthquake on this strand is most likely the same A.D. 1680 event reported by Sieh (1986) and Sieh and Williams (1990) at a site in Indio. Comparison of data obtained at the Thousand Palms Oasis site with data from the Indio site to the south, and the Wrightwood site about 120 km (75 miles) to the northwest, suggests that the southernmost 200 km (125 miles) of the San Andreas fault have ruptured together, and thus has the potential to rupture again together in large earthquakes (Fumal and others, 2002; Fumal, Rymer and Seitz, 2002).

The *Garnet Hill fault* parallels the trend of the Banning fault, extending from a few miles west of Whitewater south to Thousand Palms, where the fault trace dies out. The fault is primarily a right-lateral strike-slip fault along most of its trace, but splays into a series of oblique reverse faults at its western end. Based on seismological data, Yule and Sieh (2003) concluded that the Garnet Hill fault and the Banning fault merge at a depth of about 5 km (3.1 miles), and that the single fault plane below this depth was the source of the 1986 North Palm Springs earthquake. They further suggested that the Garnet Hill fault merges with the San Gorgonio Pass fault zone to carry slip between the disconnected segments of the San Andreas fault, thus making the Banning-Garnet Hill-San Gorgonio Pass system a significant seismic source in the region.

The *San Gorgonio Pass fault zone* consists of a series of north-dipping reverse and thrust faults linked by strike-slip tear faults, giving its surface trace an irregular, saw-tooth appearance (Yule and Sieh, 2003). This zone begins near Cottonwood Canyon and extends westward to the Calimesa area. Faults within this east-west trending zone have thrust ancient crystalline rock southward over younger sedimentary rock and alluvial sediments. These faults formed during the Pleistocene in response to compression created by the bend and the step-over in the trace of the San Andreas fault; activity of some of these faults has continued into the Holocene, as indicated by many youthful scarps that are present in young alluvium (Matti and others, 1992; Yule and Sieh, 2003).

The San Gorgonio-Garnet Hill section is thought to have last ruptured in 1812, although additional studies need to be conducted to confirm this (Yule and others, 2006; Dawson and others, 2008). Paleoseismic data also suggest that the Coachella, San Gorgonio-Garnet Hill, and San Bernardino sections ruptured simultaneously in earthquakes that occurred around A.D. 1500, and possibly A.D. 1680 (Dawson and others, 2008, summarizing data by Fumal and others, 2002, Yule and others, 2006, and McGill and others, 2002). Investigators suggest that some of the strain is also being transferred northward onto the faults in the Indio Hills and probably the Eastern California Shear Zone. The 2007 WGCEP (2008) assigned a slip rate of 10±6 mm/yr (32.8±0.5 feet/1000 year) to the San Gorgonio-Garnet Hill section.

The ***Coachella segment*** comprises the relatively straight, predominantly right-lateral strike-slip fault that extends from Bombay Beach in the Salton Sea northward to the Biskra Palms area north of Indio, a distance of about 67.6 km (42 miles). This section is the only section of the southern San Andreas fault that has not produced a major earthquake in historic times (Sieh and Williams, 1990; Fumal and others, 2002; Philibosian and others, 2011). Paleoseismic studies suggest that the last surface-rupturing earthquake on this section occurred more than 320 years ago, around A.D 1680 (Sieh and Williams, 1990) or A.D. 1690 (Philibosian and others, 2011). The data also suggest that in the A.D. 1680

earthquake, the Coachella section ruptured together with the San Gorgonio-Garnet Hill and San Bernardino segments, and that this also happened in an earthquake around A.D. 1450. The 2007 WGCEP assigned a slip rate of 20±3 mm/yr (65.6±10 feet/1000 year) to this segment. Rupture of the Coachella fault segment in a magnitude 6.8 earthquake is estimated capable of generating peak ground accelerations in Yucca Valley of about 0.18g to 0.08g.

Based on the paleoseismic record, however, larger earthquakes that involve rupture of several segments of the southern San Andreas fault should be considered. Rupture of the Coachella and San Gorgonio-Garnet Hill fault segments in a magnitude 7.2 earthquake is estimated capable of generating peak ground accelerations in Yucca Valley of about 0.26g to 0.12g (0.45g to 0.21g at one standard deviation above the mean). If the San Bernardino (South and North), San Gorgonio-Garnet Hill and Coachella sections rupture together in a magnitude 7.7 earthquake, Yucca Valley would experience peak ground accelerations of between 0.33g and 0.17g (0.49g to 0.26g at the 84th percentile). These are strong to very strong ground motions. If these sections ruptured together with the Mojave sections to the north in a magnitude 8.0 earthquake, peak horizontal ground accelerations of between about 0.57g and 0.19g could be anticipated in the Yucca Valley area.

1.4.9 Calico – Hidalgo Fault Zone

The ***Calico fault*** is a 55-km (34-mile) long, right-lateral strike-slip structure that exhibited triggered slip during the 1992 Landers earthquake and was the source of a M_L 5.3 earthquake that shook the eastern California area on March 18, 1997. The 1997 earthquake is considered the last large aftershock of the 1992 Landers earthquake, and its epicenter was on the northern section of the fault, about 19 km (12 miles) east-northeast of Barstow, near the Calico Mountains.

The Calico fault is the longest and possibly the fastest-slipping of the faults in the Eastern California Shear Zone, with a slip rate estimated at about 1.8±0.3 mm/yr (5.9±1 feet/1000 yr). The recurrence interval between earthquakes on this fault is estimated at about 1,500 years (http://www.scecdc.scec.org/fault_index/), although researchers have suggested that in this portion of the southern California fault system, earthquakes recur in clusters, with long periods of inactivity between clusters (Rockwell and others, 2000). Geologists have been conducting paleoseismic studies of the Calico fault in an effort to better understand its past earthquake history and test the strength of the earthquake clustering hypothesis (Oskin and others, 2007). Ganev and others (2010) excavated trenches across the Calico fault and have found evidence for four surface-rupturing earthquakes on this fault in the past about 9,000 years. The most recent of these events occurred between about 600 and 2,000 years ago, whereas the two prior events occurred clustered in time, between about 5,000 and 6,000 years ago.

Based on its length, the Calico fault is thought capable of generating a M_w 6.5 to 7.1 earthquake; however, the Calico fault is essentially continuous with the ***West Calico*** and ***Hidalgo faults*** to the south, and all three of these faults could rupture at the same time, potentially producing a larger magnitude earthquake. The 40-km- (25-mile-) long Hidalgo fault is thought to have a slower slip rate of only about 0.5 mm/yr (20 inches/1000 yr), and its earthquake history is unknown. Alone, the Hidalgo fault is thought capable of

generating a M_w 6.4 to 7.1 earthquake. For the purposes of this study, and in conformance with the California Geological Survey's fault parameters database (Cao and others, 2003), these faults are assumed to break together in a M_w 7.3 earthquake. Such an event would produce median peak horizontal ground accelerations in the Town of Yucca Valley of between about 0.26g and 0.10g (and between 0.38g and 0.16g at the 84th percentile), with MM intensities in the IX to VII range.

1.4.10 Pisgah – Bullion Mountain – Mesquite Lake Fault Zone

The ***Pisgah fault*** is a 34-km- (21-mile-) long, right-lateral strike-slip fault that experienced triggered slip in 1992, as a result of shaking from the Landers earthquake. The fault is thought to have last moved in the Holocene, but the interval between surface-rupturing earthquakes is unknown. The fault is thought to have a slip of about 0.8 mm/yr (2.6 feet/1000 yr), but geologic studies need to be conducted to confirm these estimates. If only the Pisgah fault ruptured in an earthquake, the resulting event would have a magnitude M_w between 6.0 and 7.0. However, the Pisgah fault may also rupture together with the 55-km- (34-mile-) long ***Bullion fault*** to the south, and the 40-km- (22-mile-) long ***Mesquite Lake fault*** farther south. The Bullion fault last ruptured on October 16, 1991 during the M_w 7.1 Hector Mine earthquake. Prior to that, both the Bullion and Mesquite Lake faults appear to have ruptured during a large earthquake in the mid to late Holocene (Madden and others, 2006).

Relatively recent studies of the Mesquite Lake fault have shown that this fault has had three large surface-rupturing earthquakes in the past about 10,200 years, each creating an apparent vertical offset of between 1.0 and 1.2 meters (3.3 to 3.9 feet), suggesting similar-sized earthquakes. The trenching data indicate this fault has a horizontal slip rate of between 0.7 and 0.9 mm/yr (2.3 and 3 feet/1000 yr), consistent with the slip rates estimated for several other faults in the Eastern California Shear Zone. The paleoseismic data also seem to suggest that earthquakes on this fault occur in clusters, separated by seismically quiet periods that last several thousands of years in between, and that seismic activity in the shear zone flip flops between the eastern and western faults in the region (Madden and others, 2006).

A magnitude 7.3 earthquake is estimated if all three fault segments – the Pisgah, Bullion Mountain and Mesquite Lake – ruptured together. An earthquake of that size on these faults would generate median peak horizontal ground accelerations in the Yucca Valley area of about 0.24g to 0.1g (0.31g to 0.15g at the 84th percentile), with MM intensities of IX to VII.

1.4.11 Lenwood – Lockhart – Old Woman Springs Faults

Another of the Eastern California Shear Zone faults, the ***Lenwood fault*** is a right-lateral strike slip fault approximately 75 km (47 miles) long with a slip rate of about 0.8 mm/year (2.6 feet/1000 yr). Trenching studies have shown that the fault has ruptured at least three times in the Holocene, roughly 200-400, 5,000-6,000, and 8,300 years ago, for a recurrence between major surface ruptures of 4,000 to 5,000 years. Prior to the 1992 Landers earthquake, when the fault experienced triggered slip near its southeast end, aseismic creep on this fault had been recorded but not verified (http://www.scecdc.scec.org/fault_index/).

The ***Lockhart fault*** is a right-lateral strike-slip fault approximately 70 km (44 miles) long north of the Lenwood fault. The ***North Lockhart fault*** – a segment that shows no evidence of Holocene activity – adds 10 km (6 miles) to the length above. The interval between major surface-rupturing earthquakes on the Lockhart fault is estimated at between 3,000 and 5,000 years (Jennings, 1994), with the central portion of the fault having ruptured during the Holocene, and segments both to the north and south believed to have last ruptured in the Quaternary (http://www.data.scec.org/fault_index/lockhart.html).

The ***Old Woman Springs fault*** segment is the main trace of a complex system of faulting at the junction between the Eastern segment of the North Frontal Fault Zone and the Lenwood fault. The Old Woman Springs trace is about 10 km (6 miles) long and exhibits right-lateral strike-slip movement with some vertical slip. The fault is thought to have last moved in the Holocene (http://www.scecdc.scec.org/fault_index/), and is therefore considered active.

Although the Lenwood and Lockhart faults form essentially a continuous, 150-km- (90-mile-) long system, there is no evidence that both of these faults have ruptured together in the past. Nevertheless, such an event might be possible, as evidenced by the rupture of five separate fault segments during the Landers earthquake. For the purposes of this study, these faults, together with the Old Woman Springs fault, are assumed to rupture together in a magnitude 7.5 maximum magnitude earthquake. Such an event would generate median peak ground accelerations in the Town of Yucca Valley of between about 0.23g and 0.11g, and MM intensities in the IX to VII range. If only one of these faults ruptures in an earthquake, the smaller magnitude event would cause lesser ground motions in Yucca Valley than those reported above.

1.4.12 Helendale – South Lockhart Fault

The ***Helendale fault*** is the westernmost of the right-lateral strike-slip faults that combined are referred to as the Eastern California Shear Zone. The Helendale fault is 90 km (56 miles) long, but it also seems to form a continuous fault with the South Lockhart fault to the north. Towards its southern end, the Helendale fault seems to offset the North Frontal fault, separating it into East and West segments, as discussed above, in Section 1.4.6.

The ***South Lockhart fault*** is a right-lateral strike-slip fault with a minor dip-slip component (Bryant, 1987). The central and southern segments of the South Lockhart fault display evidence of Holocene rupture, including deformed Holocene sediments and well-defined scarps (Bryant, 1987). The northern segment of the South Lockhart fault is poorly defined and does not show evidence of Holocene rupture, indicating that the whole fault may not rupture at the same time. Rupture of multiple segments of both the Helendale and the South Lockhart faults may result in a large-magnitude earthquake that would be greater than if the South Lockhart, or the Helendale fault ruptured alone.

Petersen and Wesnousky (1994) calculated a slip rate for the Helendale fault of 0.8 mm/yr (2.6 feet/1000 yr) and a recurrence interval for large surface-rupturing events of 3,000 to 5,000 years. Paleoseismic studies of the Helendale fault indicate, however, a recurrence interval of 6,000 to 11,000 years (Bryan and Rockwell, 1995), with evidence of as many as three earthquakes in the past 16,500 years. Paleoseismic studies on the South Lockhart fault are required to better understand the earthquake history of this fault. Based on the

data available at this time, the California Geological Survey uses a maximum earthquake of magnitude 7.3 to estimate the ground motion hazard resulting from the combined Helendale-South Lockhart faults. An earthquake of that size is anticipated to generate horizontal peak ground accelerations in Yucca Valley of between about 0.13g and 0.07g (0.22g to 0.11g at the 84th percentile), with MM intensities of between IX and VI.

1.5 Surface Fault Rupture

1.5.1 Definitions

Primary fault rupture refers to fissuring and displacement of the ground surface along a fault that breaks in an earthquake. 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 was locally hundreds of feet wide (Lazarte and others, 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.

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 and generally costly to safely reduce the effects of this hazard through building and foundation design. Therefore, the preferred and traditional mitigation measure for this hazard is to avoid active faults by setting structures back from the fault zone. In California, 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 (CGS Note 42 by Hart and Bryant, 2007). The final approval of a fault setback lies with the local reviewing agency.

Secondary fault rupture refers to ground surface displacements along faults other than the main traces of active regional faults. Secondary ground deformation includes fracturing, shattering, warping, tilting, uplift and/or subsidence. Unlike the regional faults, most of 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 (1.2 miles) from the main trace (Ziony and Yerkes, 1985). Triggered slip as a result of a regionally large earthquake can also occur in faults many kilometers away from the causative fault. For example, as a result of the 1992 Landers earthquake, triggered surface slips were documented in the Coachella Valley area (Rymer, 2000). Similarly, following the 1999 Hector Mine earthquake, triggered surface slips were recorded in the Salton Trough (Rymer and others, 2002; Meltzner and others, 2006). More recently, as a result of the April 4, 2010 Sierra El Mayor earthquake in Baja California, triggered slip was reported on the San Andreas, Superstition Hills, Imperial and Brawley fault zones.

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, and previously not active faults may be reactivated. Consequently, the State of California, under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act of 1972 (Hart and Bryant, 1999, 2007; http://www.conservation.ca.gov/cgs/rghm/ap/Pages/main.aspx), classifies faults according to the following criteria:

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

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

- ***Not active***: faults that have conclusively NOT moved in the past 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 are generally required for dams or nuclear power plants. An important subset of active faults is those with historical earthquakes. In California, that means faults that have ruptured since 1769, when the Spanish first arrived and settled in the area. However, since many parts of the State were not settled until well into the middle of the 1800s, some historical earthquakes most likely went un-noticed and therefore unreported.

The underlying assumption in this classification system is that if a fault has not ruptured in the past 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. For example, and especially significant for the Yucca Valley area and adjacent communities, some of the faults that ruptured in the 1992 Landers and 1999 Hector Mine earthquakes were previously thought to be not active, as they appeared to have not moved in at least 11,000 years. Also, although simple in theory, the evidence necessary to determine whether a fault has or has not moved during the past 11,000 years can be difficult to obtain.

1.5.2 Faults in the Town of Yucca Valley Area

There are several main faults and several secondary faults zoned by the State of California under the criteria of the Alquist-Priolo Act within the limits of the Yucca Valley General Plan Update area (see Plate 1-2). The main fault zones include the Pinto Mountain, Burnt Mountain, Eureka Peak, and Johnson Valley (southern segment). The Alquist-Priolo Earthquake Fault Zone maps for these fault zones in the Yucca Valley area include the following quadrangles: Yucca Valley North, Yucca Valley South, Joshua Tree South (all three became official maps on July 1, 1993), and Joshua Tree North (became official March 1, 1988). Secondary faults that have been zoned include several short fault traces associated with the Pinto Mountain fault zone, a cross fault associated with the Eureka

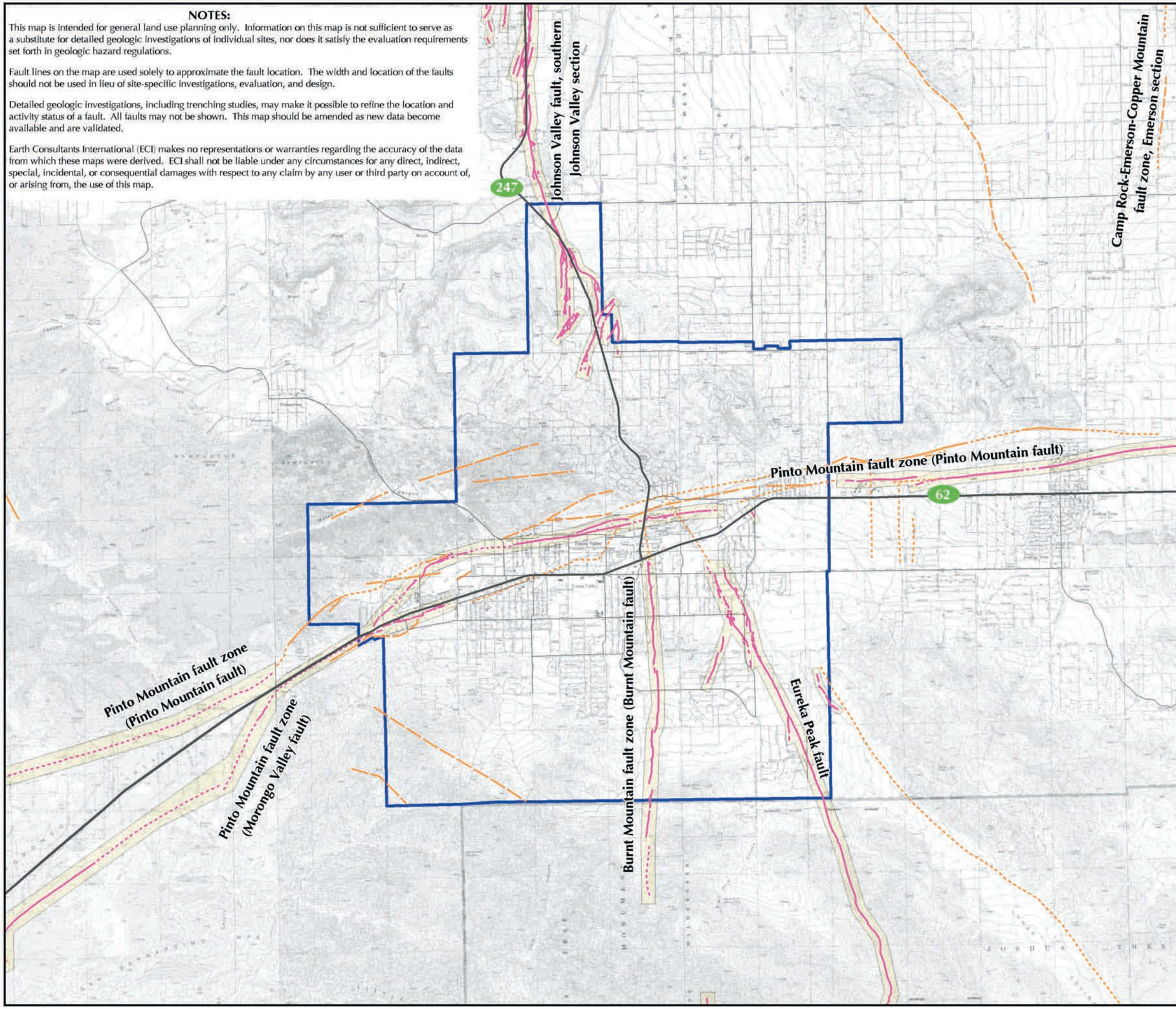
NOTES:

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.



Fault Map

Yucca Valley, California

Explanation

Faults; solid where location is known, dashed where approximate, dotted where inferred or concealed under young deposits.

- Alquist-Priolo Earthquake Fault; active in the Holocene. From CGS (2002).
- Alquist-Priolo Earthquake Fault Zone. From CGS (2002).
- Fault; active in the Holocene or Late Quaternary but not zoned under the Alquist-Priolo Act. From USGS (2003), USGS and CGS (2006), and Dibblee (1967).
- Yucca Valley Town Boundary

N W E S

7000 0 7000
Feet

1500 0 1500 3000
Meters

Scale: 1:84,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley.
Source: Alquist-Priolo Earthquake Fault Zones [Reproduced with permission CGS CD-ROM 2001-05 (2002)], USGS and CGS (2006) Quaternary fault and fold database for the United States, accessed April 2010, from USGS web site: http://earthquakes.usgs.gov/regional/qfaults, Dibblee (1967), and USGS (2003).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 1-2

Peak fault that also ruptured in 1992, and a zone of *en-echelon* fractures that were mapped east of the Eureka Peak fault following the Landers earthquake. Secondary faults in the area that are not zoned by the State of California include several fault splays associated with the Pinto Mountain fault, two faults subparallel to and north of the Pinto Mountain fault, two northwest-trending faults in bedrock in the southeastern portion of the Town, the northern extensions of the Burnt Mountains and Eureka Peak faults, and the northwestern terminus of the Lower Covington Flat fault inferred by Dibblee (1967b). The most significant of these faults are discussed further below.

1.5.2.1 Pinto Mountain Fault Zone

According to Bryant (2000), the Pinto Mountain fault was first recognized by Vaughan in 1922, but it was Hill (1928) who first named and mapped it. Subsequent mapping of the Pinto Mountain fault, or sections of it, was conducted by Bader and Boyle (1960), Dibblee (1967b, 1968a), Bacheller (1978), Grimes (1981), Bryant (1986a), Howard and others (1995), and Hopson (1996). The western extension of the fault zone, consisting of two branches that bound the Morongo Valley, were mapped by Allen (1957) and Dibblee (1967c). The Pinto Mountain was evaluated for zoning purposes by the California Division of Mines and Geology (now the California Geological Survey) in 1986 (Fault Evaluation Report 181 by Bryant, 1986a). A supplement to this study for the western segment of the Pinto Mountain fault (and for the Mesquite Lake and East Airfield faults in and near Twentynine Palms) was issued in 1988 (Bryant, 1988).

In the Yucca Valley area, the Pinto Mountain fault is complex, with several subparallel fault traces mapped or inferred along a zone approximately 1 km (3,000 feet) wide. Some of the fault traces clearly offset late Quaternary to early Holocene sediments, whereas other traces appear to not offset late Quaternary sediments. Based on an analysis of aerial photographs, in addition to a limited field reconnaissance, Bryant (1986a) defined those traces considered to be most well-defined and sufficiently active. The fault traces that met these criteria were then zoned by the State Geologist in accordance with the Alquist-Priolo Earthquake Fault Zone Act (red fault traces shown on Plate 1-2). However, given the relatively rapid rate of deposition in the Yucca Valley area, faults with little to no geomorphic expression in alluvium (orange faults in Plate 1-2 that are shown as dotted through the alluvium in the valley) should be considered active until proven otherwise by direct geologic methods such as trenching.

Case in point, a section of the fault shown as buried by alluvium (Dibblee, 1967b) was trenched by Bush and Rasmussen (1979, as referenced by Bryant, 1986a). The trenches exposed several fractures in alluvium in a 70-meter (230-foot) wide zone. Because the fractures were oriented similarly to the regional trend of the Pinto Mountain fault, Bryant (1986a) opined that these could very well be faults, even though the consultants proposed that they were associated with ground shaking rather than fault rupture. Bryant (1986a) ultimately chose to zone this fault. Farther to the east, in the Twentynine Palms area, Bryant (1986a), refers to trenching studies by James (1986) just north of Twentynine Palms Highway, between Panorama Drive on the east, and Sunrise Road on the west. The trenches exposed a broad zone of Holocene-age, down-to-the-south normal faults in between fault traces that, given their stronger geomorphic expression, had been mapped by Bader and Boyle, Dibblee, and Bacheller.

Bryant (1986a) postulated that the Pinto Mountain fault in the Yucca Valley area is a left-lateral oblique fault, with a larger component of vertical displacement than other sections of the fault farther east. Furthermore, he suggested that the fault in this area is stepping left (south) and transferring strain onto the Morongo Valley fault, now considered the western extension of the Pinto Mountain fault zone (Bryant, 2000). These suggestions, in addition to the recency of activity of the various fault strands mapped in the area, have not been evaluated further, as no paleoseismic trenching studies of the Pinto Mountain fault have been conducted in the Yucca Valley area.

The only paleoseismic study to date of the Pinto Mountain fault evaluated the central branch of the Pinto Mountain fault in the Twentynine Palms area. This study conducted by Cadena and others (2004), included the excavation of a trench about 100 m (300 ft) west of the Oasis of Mara, where the fault was observed to extend upwards to within 0.5 m (1.6 ft) of the ground surface. Several fault strands within the zone were interpreted as having ruptured repeatedly in the past about 14,000 years; the faulted sediments suggest five to six ruptures in that time frame, with four events occurring in the past about 9,400 years, for an approximate recurrence interval of about 2,500 to 3,000 years. Although the fault has not ruptured historically, sections of it did experience minor slip associated with the 1992 Landers earthquake (Bryant, 1992; Hart and others, 1993).

1.5.2.2 Burnt Mountain Fault

This is one of two "new" faults first identified following the 1992 Landers earthquake (the second fault, the Eureka Peak fault, is discussed below). The Burnt Mountain fault is north- to northwest-trending and at least 21 km (13 miles) long. At its southern end, it appears to step left and transfer strain onto the East Wide Canyon fault. Only a 6-km (3.7-mile) long section of the Burnt Mountain fault ruptured the ground surface in 1992, displaying no more than about 5.5 cm (2.2 inches) of right-lateral offset. The width of the zone was generally less than about 1 meter (3 feet), with only a few sections being as wide as 5 meters (16 feet). Geologists mapping the surface rupture following the Landers earthquake also found a short – about 0.5-km (0.3-mile) – zone of right-stepping fractures trending in a northeasterly direction (Treiman, 1992). The right-stepping nature of the cracks indicate that the feature has an overall left-lateral sense of movement. This cross fault was also zoned in accordance with the Alquist-Priolo Earthquake Fault Zone Act.

A review of historical aerial photographs and topographic maps (Bryant, 1992) shows that the Burnt Mountain fault was expressed in the landscape before the Landers earthquake but had not been recognized as a fault by geologists that had worked in the area prior to 1992. Geomorphic characteristics that were there for someone to recognize as fault-controlled include a west-facing scarp north of Burnt Mountain, vegetation lineaments along the southwest side of Burnt Mountain, a subtle north-trending linear ridge in older alluvium, aligned ridges, and a straight canyon margin farther south (Bryant, 1992). All of these features indicate that the Burnt Mountain fault has ruptured the ground surface in the Holocene or late Pleistocene, prior to 1992. However, to date, there are no published paleoseismic studies of the fault, so data on past earthquakes, earthquake recurrence, and slip rate are not currently available for the Burnt Mountain fault.

1.5.2.3 Eureka Peak Fault

This north- to northwest-trending fault experienced as much as 21 cm (8.3 inches) of right-lateral offset as a result of the 1992 Landers earthquake sequence, with additional slip occurring in the weeks and months after the main shock. Witness accounts suggest that at least part of the rupture on this fault occurred in response to a M_w 5.7 aftershock that occurred about 3 minutes after the main Landers shock (Sieh and others, 1993; Hough and others, 1993) that propagated southward for about 11 km (6.8 miles) (Heaton and others, 1992 as reported by Treiman, 1992). Geologists mapping the surface rupture extended the length of the fault southward for a total length of about 20 km (12 miles), based on geomorphic evidence that had not been recognized previously.

Pre-1992 evidence for the Eureka Peak fault is less well defined than that for the Burnt Mountain fault, but there were some landscape features identified from older aerial photographs that hinted at the fault's presence. These features include the "linear margin of a ridgeline, several straight stream channels and some vegetation lineaments" (Treiman, 1992). Field mapping of the 1992 rupture after the Landers earthquake showed that the fault follows the top of the margin or bank of a wash that drains Lower Covington Flat. Land immediately to the west of the fault, on the side opposite the wash, dropped down in this area, suggesting that the wash is not controlled by faulting.

Near its northern end, just south of Joshua Drive, the fault split into two branches, with the area between the two branches dropping down slightly. The eastern branch was found to be better defined, with discrete minor faults that could be mapped northward to just south of Yucca Trail. The western branch consisted of several minor faults and fractures spread across a zone nearly 100 meters (330 feet) wide (Treiman, 1992). Two zones of fracturing were also identified to the west of the main zone of rupture. The southernmost of these zones was mapped just east and north of the eastern end of Andreas Road, where the fractures coalesced into two main traces, a north-trending trace that terminated against the main trace of the Eureka Peak fault, and a northwesterly trace parallel to but about 150 meters (500 feet) west of the main fault trace. The second, more northerly, zone consisted of several diffuse right-stepping cracks that extended in a northeasterly direction for more than 900 meters (3,000 feet) approximately in between Emerson Avenue on the east and Balsa Avenue on the west. Both of these zones were included in the official Alquist-Priolo Earthquake Fault Zone map issued by the California Geological Survey for the Yucca South Quadrangle after the Landers earthquake.

Gary Rasmussen and Associates (1992) trenched the southern end of the westerly branch of the Eureka Peak fault in the vicinity of Palomar Avenue. The trenches exposed a complex zone of faulting 9 to 13.7 meters (30 to 45 feet) wide consisting of two main fault splays and numerous fractures. The main splays showed evidence of past (pre-1992) surface rupturing events in the Holocene and late Pleistocene that indicate that this fault has been active in the past and has the potential to rupture again in the future.

1.5.2.4 Lower Covington Flat Fault

This feature had been mapped as an inferred fault before the Landers earthquake (Dibblee, 1967b), although it was not named. Treiman (1992) gave it this name because the fault extends across the Lower Covington Flat, a geomorphic surface to the southeast of Yucca

Valley. The fault did not rupture during Landers except for a zone of left-stepping cracks less than about 1 km (0.6 mile) long near its northern end (Treiman, 1992). The left-stepping nature of the cracks indicates that the overall slip on this structure, as minor as it appears to be, is right lateral. To date, we are not aware of any trenching studies of this feature that would provide additional information on whether or not this is a deep-seated fault that has had recurrent movement in the Holocene. The feature should be investigated if development is proposed across it.

1.5.2.5 Southern Johnson Valley Fault

The Johnson Valley fault zone consists of a series of sub-parallel, northwest-trending, predominantly right-lateral strike-slip faults. The main trace is approximately 60km (37 miles) long, but it can be extended northward to include the Upper Johnson Valley fault, for a total length of about 85 km (53 miles). The southern part of the fault zone, within Yucca Valley and to the north, last ruptured during the 1992 Landers earthquake.

In 1988, prior to the Landers earthquake, sections of the fault zone in the Yucca Valley North and Landers 7.5-minute quadrangle maps had been included in an Alquist-Priolo Earthquake Fault Zone because of fault-related features in the landscape that suggested Holocene activity (Bryant, 1986a). Sections of the fault had also experienced minor surface rupture during the March 1979 Homestead Valley earthquake swarm (Manson, 1986; Bryant, 1986a; Hill and others, 1980). The 1992 surface rupture of the Johnson Valley fault was complex, the result of the fault rupturing through unconsolidated granular alluvium. The fault zone varied in width from a few meters to more than 100 meters (330 feet), and consisted of multiple strands, left-stepping *en echelon* fractures and fissures, scarps, moletracks, grabens, minor pressure ridges and thrust faults (Bryant, 1992). Maximum right-lateral strike slip displacement of nearly 3.10 meters (10.2 feet) was measured just west of Acoma Road, approximately 0.8 km (½ mile) north of the community of Flamingo Heights. Closer to this community, just south of Hondo Road, Herzberg (1996; as summarized in Rockwell and others, 2000) excavated a trench across the main trace of the fault. Two other trenches farther north were excavated across the 1992 rupture on the Johnson Valley fault as well. The data obtained from these trenches indicate that the Johnson Valley fault has ruptured 5 times in the last about 25,000 years, for an average recurrence interval of 5,000 years.

1.5.3 Mitigation of Primary Fault Rupture

In most cases, it is impractical to reduce the damage potential of surface fault rupture by engineering design, and most regulatory agencies, following the position of the California Geological Survey, currently do not allow engineering design for habitable structures (although this is being reconsidered for "minor" faults at this time). Therefore, the most often-used mitigation measure is to simply avoid placing structures on or near active fault traces.

In accordance with the requirements of the Alquist-Priolo Earthquake Fault Zone Act, geologic investigations, which generally include fault trenching, need to be performed if conventional structures designed for human occupancy are proposed within an Alquist-Priolo zone. These studies must evaluate whether or not an active segment of the fault extends across the area of proposed development, generally following the guidelines for evaluating the hazard of fault rupture presented in Note 49, published by the CGS, which

is available on the worldwide web at http://www.consrv.ca.gov/CGS/rghm/ap/index.htm. Geologic investigations to locate and better characterize the recency of activity should be conducted for other east-trending and north- to northwest-trending faults in the Yucca Valley area not currently included in an Alquist-Priolo Earthquake Fault Zone, especially if a critical or high-occupancy facility is proposed across one of these traces. The results of these studies should be submitted to the California Geological Survey for appropriate action regarding the future zoning of these faults if the studies indicate that they have had activity in the Holocene.

Based on the results of these geologic studies, appropriate structural setbacks may be recommended to prevent the placement 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, as part of a geologic investigation, the project geologist is 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 such as folding or fracturing, a setback distance less than 50 feet could 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.

As it occurred in 1992 on the Burnt Mountain and Eureka Peak faults, several of the faults across or near the Yucca Valley study area could move sympathetically (triggered slip) with movement on a regional fault such as the Pinto Mountain. Although offsets due to secondary faulting are typically measured in inches or fractions of inches, if structures placed across these features are not designed properly, structural damage could occur. 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 above).

Lazarte and others (1994) outlined three approaches to mitigation of fault rupture hazard, which could be applied to secondary deformation as well. The first is avoidance using 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. Rationale behind this second method 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," and involves strengthening foundation elements to withstand a limited amount of ground deformation. Studies of foundation performance in the Landers earthquake showed 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 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). However, extensive research in this area has been and is being conducted by Bray (2001) and others. This will hopefully lead to an increase in the use of these techniques to mitigate the hazard of secondary ground deformation, provided that the CGS

and local regulatory agencies are willing to consider and approve the use of alternatives to structural setbacks.

1.6 Ground Failure due to Earthquake Shaking

Various types of ground failure that are the result of earthquake shaking can cause substantial damage to the built environment. The most destructive of these failures include liquefaction and slope failure, but other tectonically induced forms of ground failure are also possible. These are described further below.

1.6.1 Liquefaction

Liquefaction is a geologic process that causes various types of ground failure. It typically occurs within the upper15 meters (50 feet) of the surface, in saturated, loose, fine- to medium-grained sandy to silty soils in the presence of ground accelerations over 0.2g (Borchardt and Kennedy, 1979; Tinsley and Fumal, 1985). Earthquake shaking suddenly increases pressure in the water that fills the pores between soil grains, causing the soil to have a total or substantial loss of shear strength, and behave like a liquid or semi-viscous substance. 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.

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. That is, when soils liquefy, the structures built on them can sink, tilt, and suffer significant structural damage. In addition to loss of bearing strength, liquefaction-related effects include 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; water or water-soil slurries may bubble onto the ground surface, resulting in features called "sand boils," "sand blows," "sand volcanoes," or "mud spouts." Seepage of water through cracks may also be observed.

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 down-slope 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 degrees and 3 degrees, and can displace the ground surface by several feet to tens of feet. 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 in the area. Thus, liquefaction compromised San Francisco's ability to fight the fires that caused about 85% of the damage (Tinsley and others, 1985). Lateral spreading was also reported in and around the Port of Los Angeles

during both the 1933 and 1994 earthquakes (Barrows, 1974; Stewart and others, 1994; Greenwood, 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 degrees. Flows are principally liquefied soil or blocks of intact material riding on a liquefied subsurface. Displacements are often in the tens to hundreds of feet, but under 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 and others, 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 and others, 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 1 meter (3 feet), and structures in the Kwangishicho apartment complex tilted as much as 60 degrees (Tinsley and others, 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 and others, 1994).

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 Yucca Valley area as a result of an earthquake on any of the several active faults in the region. The second condition – geologically young, loose, unconsolidated sediments – occurs locally in some areas, typically along the active drainages, and on the young alluvial fans. Note the distribution of Holocene-aged Quaternary-aged deposits on Plate 2-1. The third condition – water-saturated sediments within about 15 meters (50 feet) of the surface, has not been reported historically in the Yucca Valley area, and as a result, the hazard of liquefaction occurring in the alluvial sediments underlying the valley portion of the study area is currently considered low to very low (see Plate 1-3).

The Pinto Mountain fault is known to form a barrier to groundwater contained in the sediments at the base of the Pinto Mountains. As the water in the basin rises, it is forced up to the ground surface, forming springs, such as the one that feeds the Oasis of Mara in

the Twentynine Palms area. In the Yucca Valley area, several of the faults that combined form the Pinto Mountain fault zone form groundwater barriers, but at depths greater than 50 feet. Extensive pumping in the area beginning in the 1960s has caused significant declines in the groundwater levels. With the replenishment of water back into the aquifers, first with State Project water, and then with reclaimed water, the groundwater levels have recovered, and could theoretically rise to within 50 feet or less of the ground surface (the groundwater basins are floored by impermeable bedrock and are bounded by faults that act as barriers to water, so the basins act as bathtubs, with water levels increasing or decreasing substantially if surface water is recharged into or pumped out of the basins, respectively. As a result, if unchecked recharge occurs in the area, liquefaction susceptibility could increase in the future. However, personnel from both the U.S. Geological Survey and the Hi-Desert Water District are aware of this issue and, as reclaimed water is recharged into some of the sub-basins in the area, they will reportedly monitor and maintain groundwater levels below the critical 50-foot depth to avoid developing a liquefaction susceptibility condition (M. Ban, Hi-Desert Water District, personal communication, July 2012).

At this time, site-specific geotechnical studies to evaluate the liquefaction potential of properties in Yucca Valley are not deemed necessary, given the depth to groundwater (see Plate 1-3).

1.6.2 Earthquake-Induced Slope Failure

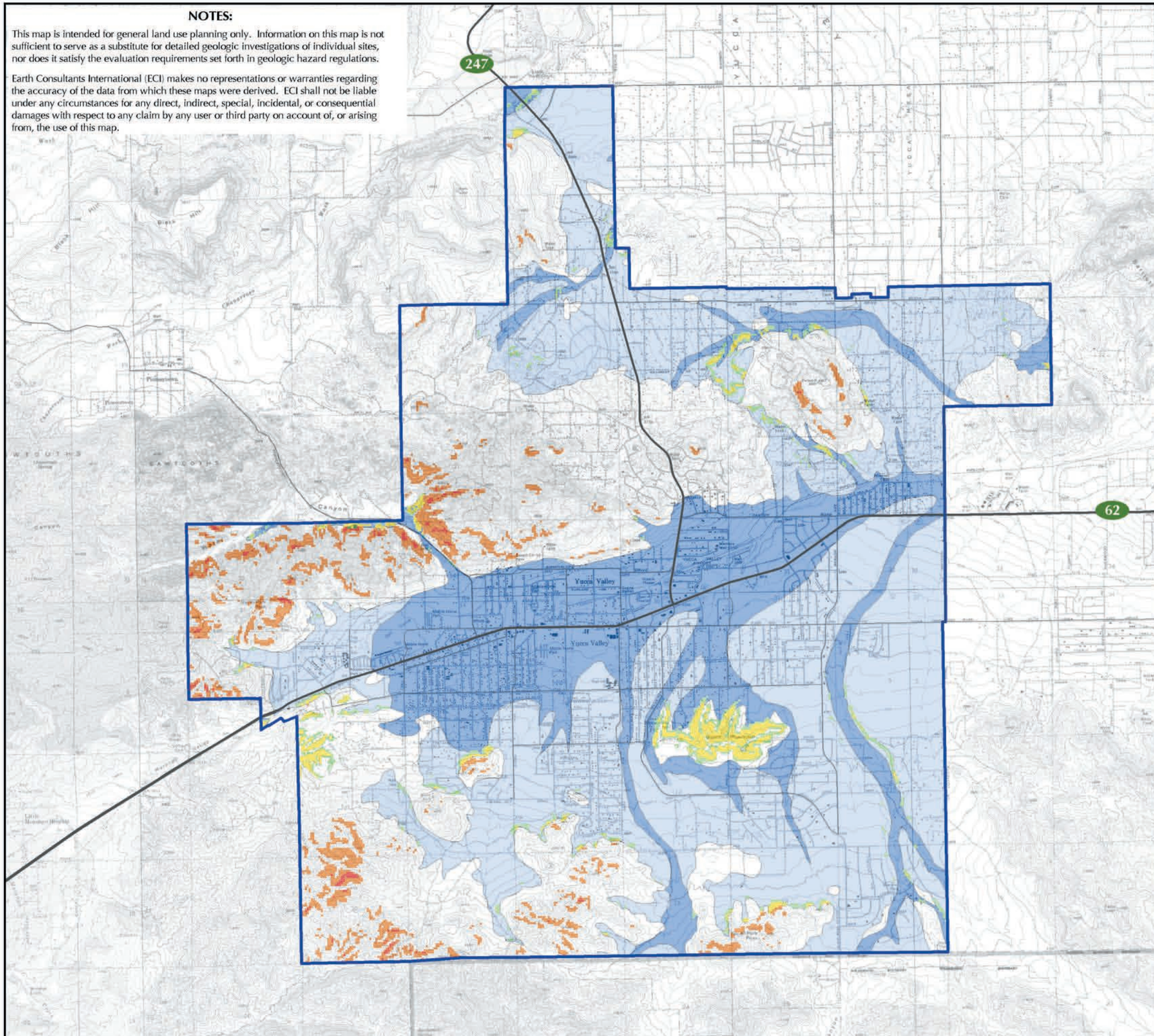
Strong ground motions can worsen existing unstable slope conditions. Seismically induced landslides can overrun structures, harm people or damage property, sever utility lines, and block roads, thereby hindering rescue operations after an earthquake. Over 11,000 landslides were mapped shortly after the 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). Rockfalls 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 can also occur (Spittler and others, 1990; Barrows and others, 1995).

A combination of geologic conditions leads to landslide vulnerability. These include high seismic potential; rapid uplift and erosion resulting in steep slopes and deeply incised canyons; highly fractured and folded rock; and rock with inherently weak components, such as silt or clay layers. The orientation of the slope with respect to the direction of the seismic waves (which can affect the shaking intensity) can also control the occurrence of landslides. Ground water conditions at the time of the earthquake also 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 rockfalls and reactivation of older landslides that was manifested as ground cracking in the scarp areas but with very little movement (Griggs and others, 1991).

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.



Seismic Hazard Zones

Yucca Valley, California

Explanation

Liquefaction Susceptibility

Low — Areas underlain by coarse-grained Holocene age sediments, groundwater depth greater than 100 feet or unknown.

Very Low to None — Areas underlain by coarse-grained Pleistocene sediments, groundwater depth greater than 100 feet or unknown.

Earthquake-Induced Slope Instability

Rock Falls, **Rock Slides** — Areas underlain by bedrock where the local topographic, geological, and geotechnical conditions indicate a potential for permanent ground displacements, such that mitigation may be required. Refer to text for additional information.

Soil Falls, **Soil Slides**, **Soil Slumps** — Areas underlain by Holocene and Pleistocene sediments where the local topographic, geological, and geotechnical conditions indicate a potential for earthquake-induced soil block falls, slides, or soil slumps. Mitigation measures may be required if these areas are developed. Refer to text for additional information.

Yucca Valley Town Boundary

N W E S

5000 0 5000
Feet

1500 0 1500 3000
Meters

Scale: 1:60,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley.
Sources: Slope gradients used in the slope instability analysis derived from the USGS 30m Digital Elevation Model. Geological descriptions used in the analyses derived from Dibblee (2008).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 1-3

Keefer and Wilson (1989) conducted a survey of the slope failures caused by over 40 earthquakes around the world and found that seismic shaking is one of the most important triggers of landslides in arid and semi-arid regions such as the Yucca Valley area. Even in regions that receive very little precipitation, earthquakes larger than about magnitude 6 have caused hundreds to thousands of slope failures.

One of the most comprehensive and still widely used landslide classification schemes is that by Varnes (1978). His classification emphasizes the type of movement (falls, topples, rotational slides, translational slides, lateral spreads, flows, and combinations of the above), followed by the type of material involved (bedrock and engineering soils, with soils further divided into predominantly coarse-grained and predominantly fine-grained). Keefer (1984) and Keefer and Wilson (1989) used a modification of Varnes' (1978) scheme to classify earthquake-induced landslides. Their primary criteria include material, mechanism of movement and amount of internal disruption; secondary criteria include water content, velocity, depth, and geologic environment. Keefer and Wilson (1989) consider only two types of material – bedrock and soil, with soil comprising all uncemented or slightly cemented aggregate of mineral grains, including young sedimentary deposits, the regolith or weathered deposits that mantle bedrock, and man-made fill slopes. A review of their classification shows that earthquake-induced landslides that occur in rock and sedimentary deposits under dry conditions fall, with one exception, into their Category I landslides. The landslides in this category are all highly or very highly disrupted, having occurred rapidly or extremely rapidly. With the exception of rock avalanches, the materials involved are mostly shallow, generally less than 3 meters (10 feet) deep. The specific types of landslides in this category include rock falls, rock slides, rock avalanches, soil falls, and soil slides. These types of slope failures are described further in Table 1-3 and below. The geologic and slope conditions commonly necessary for these failures to occur were used to evaluate the earthquake-induced slope instability potential in the Yucca Valley area and develop the potential earthquake-induced landslide zones shown on Plate 1-3.

Rockfalls may happen suddenly and without warning, but are more likely to occur in response to earthquake-induced ground shaking, during periods of intense rainfall, or as a result of man's activities, such as grading and blasting. Wilson and Keefer (1985) reported that ground acceleration of at least 0.10g in steep terrain is necessary to induce earthquake-related rockfalls. Although exceeding this level of shaking does not guarantee that rockfalls will occur, this is certainly a concern in the Sawtooth Mountains given the high ground accelerations anticipated in the area when the Pinto Mountain fault ruptures next. The hazard is compounded by several bouldery outcrops in the area that, although picturesque, can be precariously perched, ready to roll downhill if dislodged by shaking. This has happened in the past. The Joshua Tree earthquake in April 1992, plus several of its aftershocks, caused hundreds of landslides, mostly in the form of rock falls, in the Little San Bernardino Mountains near Yucca Valley (Rymer, 2000). The 1992 Landers earthquake also caused several blocky soil failures along Old Woman Springs Road, near its intersection with Aberdeen Road, just north of the Town of Yucca Valley.

The last type of slope failure included in Table 1-3, soil slumps, falls into Keefer and Wilson's (1989) Category II. This landslide category is characterized by relatively coherent slides that move slower than Category I slides, and are generally deep-seated. Soil slumps may occur in both dry and wet soil conditions.

Topographically, Yucca Valley includes a wide range of landscapes. The broad central valley is bounded both to the north and south by gently sloping alluvial fans that rise to mountains. The alluvial fans generally consist of massive to poorly bedded sand and gravel that have been uplifted above the active drainages. To the northwest, the Sawtooth Mountains have rounded forms with granitic boulder outcrops; some of these boulders can be shaken loose by strong ground shaking (see Figure 1-6). To the south, the alluvial fans and foothills rise to the Little San Bernardino Mountains. These mountains, unlike the Sawtooths, are steep, jagged, and with far fewer rock outcrops, a reflection of the underlying gneissic rock. The steeper parts of the hills in the Yucca Valley area are for the most part currently undeveloped, although some development is encroaching onto the Sawtooths, westerly from Old Woman Springs Road. Some of these access roads, in addition to the structures built at the base of these steeper slopes could be susceptible to earthquake-induced slope failures. To the west-southwest, Pioneertown Road extends through some very steep terrain that is susceptible to rock slides, rock falls and soil slides.

Figure 1-6: View of Steep Slope of the Sawtooth Mountains Showing Abundant Rounded Boulders, Many of Them Perched Atop Other Boulders.
Notice the Boulders Upslope from the Residences to the Left.

In addition to the slopes identified within or adjacent to the Town, there are many areas in the Little San Bernardino Mountains and Pinto Mountains to the south and west of Yucca Valley that could fail during an earthquake. Slope failures onto Highway 62 as it approaches Yucca Valley from the west have the potential to significantly impede traffic into and out of the area immediately and for several days after an earthquake. This could impact Yucca Valley' residents and visitors, in addition to restricting access to and from the area by emergency response teams.

The hills and mountains in the Yucca Valley area have not been mapped within a State-delineated Seismic Hazard Zone for seismically induced landsliding because this mapping program has not yet been funded for San Bernardino County. Nevertheless, mapping procedures similar to those used by the California Geological Survey (CGS) were used to identify the potentially unstable slopes identified in Plate 1-3. Until an official map of seismic hazards is issued for this area by the CGS, Plate 1-3 should be used as the official map for the area. Following the intent of the SHMA, all development projects proposed within or near the potentially unstable slopes identified in Plate 1-3 should be evaluated to determine their potential for seismically induced landsliding. These studies should be conducted and reviewed by State-licensed engineering geologists and/or civil engineers (for landslide investigation and analysis, this typically requires both) following the guidelines published by the State for evaluating and mitigating seismically induced landslides (CDMG, 1997; CGS, 2008). Another helpful source is the Southern California Earthquake Center-sponsored publication entitled "Recommended Procedures for Implementation of DMG Special Publication 117" (Blake and others, 2002)

For suspect slopes, appropriate geotechnical investigation and slope stability analyses should be performed for both static and dynamic (earthquake) conditions. 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.

Table 1-3: Earthquake-Induced Slope Failures in Arid Environments

Landslide Type	Geologic Material. Environment	Minimum Slope (in degrees)	Velocity; Depth; Type of Movement	Potential Location in Yucca Valley
Consolidated Bedrock (Igneous, Metamorphic and Sedimentary)				
Rock Falls	Weakly cemented, intensely fractured or weathered; with conspicuous planes of weakness dipping out of slope; precariously perched boulders. Common near ridge crests and on ledges; artificially cut slopes, and slopes undercut by active erosion.	34	Extremely rapid (>10 ft/sec); shallow (<10 ft deep); bouncing, falling and free-falling.	Throughout the Sawtooth Mountains, where rounded granitic boulders crop out, forming picturesque rock formations, some precariously perched. Locally in the Little San Bernardino Mountains.
Rock Slides	Weakly cemented, intensely fractured or weathered; conspicuous planes of weakness dipping out of slope, or boulders surrounded by weak matrix. Common in hillside flutes and channels, artificially cut slopes, and slopes undercut by active erosion.	25	Rapid to extremely rapid (>1 ft/sec); shallow (<10 ft deep); translational (planar or gently undulatory) sliding on basal shear surface, typically a pre-existing discontinuity such as bedding, joint, or fault.	Throughout the Sawtooth and Little San Bernardino Mountains, where the bedrock types include planes of weakness along which surficial landslides could occur.
Unconsolidated and Weakly Consolidated Deposits (Older Alluvium, Alluvium, Colluvium, Soil, Artificial Fill)				
Soil Falls	Granular soils that are slightly cemented or contain clay binder. Generally common on bluffs and steep slopes such as stream banks, terrace faces, and artificially cut slopes.	34 – 40 (possible); >40 (more likely)	Extremely rapid to very slow (>1 ft/5 yr to >10 ft/sec); bouncing, falling, free falling.	The steep slopes necessary for this type of slope failure occur locally in the Planning Area, along Pioneertown Road.
Soil Slides	Holocene and Pleistocene loose, unsaturated sands, coarse-grained sediments, sensitive clays.	15	Moderate to rapid (>1 ft/sec); shallow (<10 ft deep); translational sliding on basal shear surface or zone of weakened sensitive clay.	Throughout the Town, in areas underlain by Older Alluvium and Very Old Alluvium Fanglomerate where exposed in steep slopes, canyon walls and over-steepened stream banks.
Soil Slumps	Loose, dry to wet sand or silt; uncompacted or poorly compacted man-made fill consisting of sand, silt or clay; pre-existing soil slump deposits. Common on embankments built on soft, saturated materials; in hillside cut-and-fill areas; and on river floodplains.	10	Slow to rapid (> 5ft/year to < 1 ft/sec; deep (> 10 ft); sliding on basal shear surface with a component of headward rotation.	May occur along gentler slopes in the Sawtooth and Little San Bernardino Mountains, on the slopes of Burnt Mountain, and along canyon walls and stream banks.

Sources: Modified from Varnes (1978), Keefer (1984), Keefer and Wilson (1989) and CGS (2008).

1.6.3 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. As shown in Plate 2-1, certain areas of the Town of Yucca Valley are underlain by young, unconsolidated alluvial deposits, and artificial fill. These sediments are susceptible to 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.

1.6.4 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 and others, 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 and others, 1995).

This hazard could occur locally in Yucca Valley along some of the roads and building pads cut onto the sides of the Sawtooth Mountains, where grading involving the placement of fill was required to make a level pad for the building foundation or road crossing. Settlement of sidehill fill could also occur along the approaches to several of the bridges that extend across Yucca Wash, where minor settlement of the bridge embankments could result in a step up of a few inches to the actual bridges.

Hillside grading designs are typically conducted 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.

1.6.5 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 1989 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 35 km (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 and others, 1995).

Ridgetop shattering may occur locally in the mountains bordering the Yucca Valley area, including the Sawtooths and Little San Bernardinos. Particularly susceptible to this hazard would be the long, narrow ridgetop dominating the view to the north when entering the Town of Yucca Valley from the west, both to the west-southwest and northeast of Pioneertown Road. To the south, ridgetop shattering could also occur locally along the top of Burnt Mountain, and at the top of the mountain flanking South Park.

Projects located or proposed 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. Alternatively, 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 Other Potential Seismic Hazards

1.7.1 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. 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, Montana, 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 were reported in fourteen other bodies of water in the state of Washington (McGarr and Vorhis, 1968).

Given the lack of large bodies of water in Yucca Valley, seiches as a result of ground shaking are not likely to occur in the study area. Water in swimming pools is known to slosh during earthquakes, but in most cases, the sloshing does not lead to significant damage. However, property owners down-gradient from pools that could seiche during an earthquake should be aware of the potential hazard to their property should the pool lose substantial amounts of water during an earthquake. Small seiches could occur in the existing and proposed reservoirs used for groundwater recharge. The amplitude of the seiche waves that could occur in these water bodies cannot be predicted given that several parameters combine to form these waves, although, given the relatively shallow depth of these bodies of water, the seiches are anticipated to be relatively minor.

Damage as a result of sloshing of water inside water reservoirs is discussed further in the chapter on Flooding Hazards (Chapter 3). 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 of those earthquakes, the American Water Works Association (AWWA) developed new Standards for Design of Steel Water Tanks (D-100) that provide new criteria for seismic design (Lund, 1994).

1.7.2 Tsunami

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. 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 can travel across an entire ocean basin, or they can be local. 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 and others, 2002). Inundation refers to the horizontal distance that a tsunami wave penetrates inland (Synolakis and others, 2002).

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 tsunami has increased substantially.

Given Yucca Valley's inland location, the tsunami hazard in the Town is nil. However, everyone, including Yucca Valley residents visiting or vacationing in coastal areas, should be aware of the hazards posed by tsunami, and should be able to recognize when to evacuate to higher ground. Essentially, if a moderate to strong earthquake is felt, or if the ocean recedes suddenly, coastal residents and visitors should immediately move to higher ground, at least 50 to 100 feet above mean sea level. Because tsunami surges can continue for several hours, it is best to stay at high ground for at least 12 hours; 24 hours is better.

1.8 Vulnerability of Structures to Earthquake Damage

Although it is not possible to prevent earthquakes from occurring, their destructive effects can be minimized, especially since 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."]

Therefore, the vulnerability of a community to earthquake damage can be reduced with a comprehensive hazard mitigation program that includes the identification and mapping of hazards, prudent planning and enforcement of building codes, and expedient retrofitting and rehabilitation of weak structures.

As discussed previously, building codes have generally been made more stringent following damaging earthquakes. To mitigate for seismic shaking in new construction, recent building codes use amplification factors to account for the impacts that soft sediments and proximity to earthquake sources have on ground motion. Three main

effects are considered: (1) soft soils, (2) proximity to earthquake sources (referred to as near-source factors), and (3) the seismic characteristics of the nearby earthquake sources (seismic source type). Each of these effects is discussed further below.

- **Soft-Soil Effects**: The soft soil amplification factors were developed from observations made after the 1985 Mexico City, 1989 Loma Prieta and other earthquakes that showed the amplifying impact that underlying soil materials have on ground shaking. The ground-shaking basis for code design includes six soil types based on the average soil properties for the top 30 feet (100 feet) of the soil profile (see Plate 1-4).

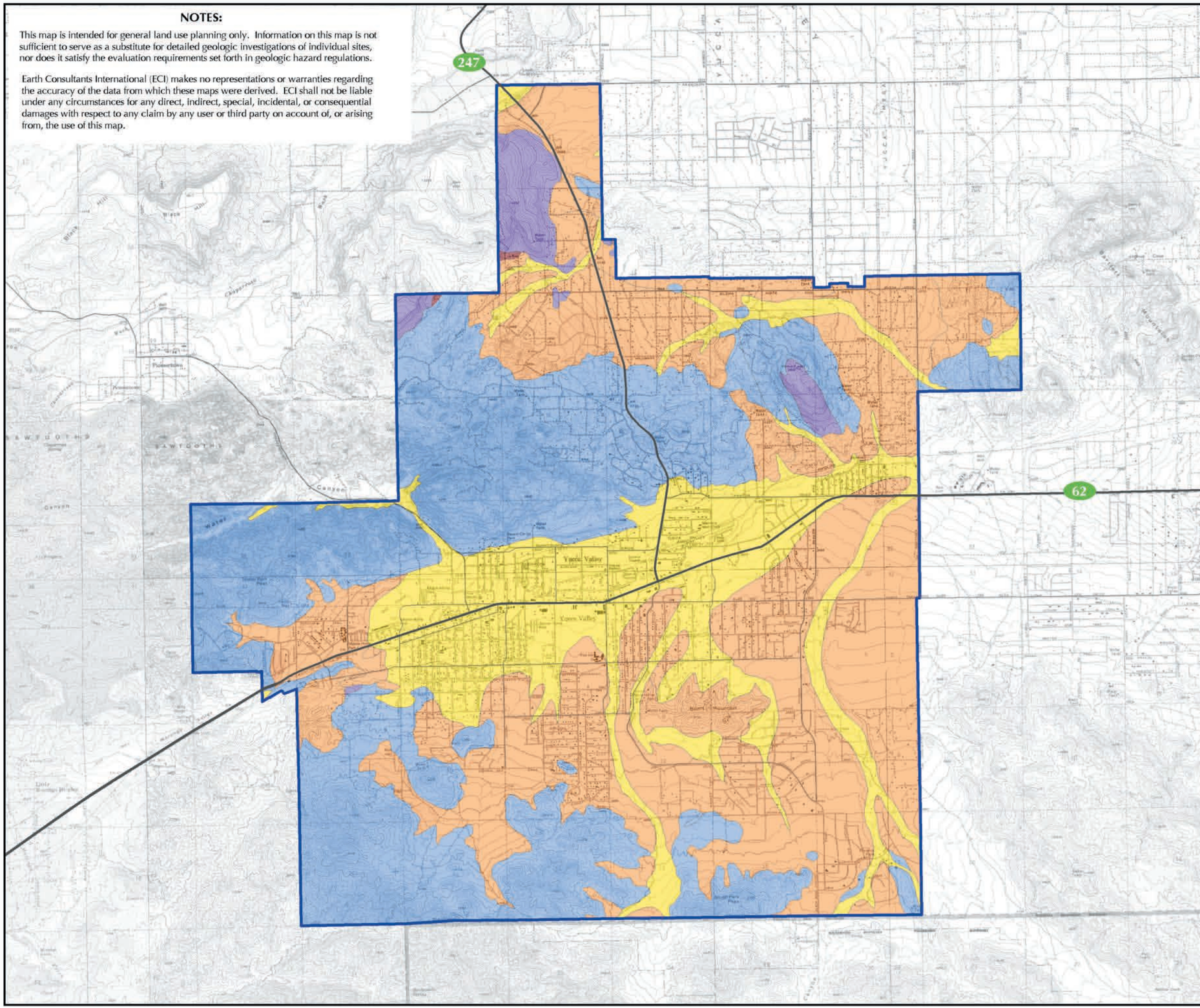
- **Near-Source Factors***:* The Yucca Valley area is subject to near-source design factors given that there are several faults that extend across portions of the town, or within 15 km (9.3 miles) (see Table 1-2). These parameters, which first appeared in the 1997 Uniform Building Code (UBC), address 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 the result of observations of intense ground shaking at levels higher than expected near the fault ruptures at Northridge in 1994, and again one year later, in Kobe, Japan. The 1997 UBC also included a near-source factor that accounted 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 in Kobe, Japan. 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. Directivity also played a factor in the 1992 Landers earthquake, with the rupture unzipping toward the north, away from the more densely populated center of Yucca Valley, and the cities to the south, in the Coachella Valley. However, the rupture direction of a given source cannot be predicted, and as a result, the UBC required a general increase in estimating ground shaking of about 20% to account for directivity.

- **Seismic Source Type***:* Near-source factors also include a classification of seismic sources based on slip rate and maximum magnitude potential. These parameters are used in the classification of three seismic source types (A, B and C) summarized on Table 1-4.

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.



Engineering Site Classes

Yucca Valley, California

(Based on Soil Profile Types per CBC, 2010)

Symbols

Yucca Valley Town Boundary

For Site Class Descriptions and Properties See Plate 1-4b

N
W E
S

5000 0 5000
Feet

1500 0 1500
Meters

Scale: 1:60,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley.
Sources: Based on data from Dibblee, 2008 and CBC, 2010.

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2011

Plate 1-4a

Symbols

Town of Yucca Valley Boundary

Site Class Definitions (Based on Soil Profile Types) (from CBC, 2010)

Site Class	Soil Profile Name/Generic Description	Average Soil Properties for the Upper 100 feet		
		Shear Wave Velocity (feet/second)	Standard Penetration Resistance (blows/foot)	Undrained Shear Strength (psf)
A	Hard Rock	>5,000	N/A	N/A
B	Rock	2,500 to 5,000	N/A	N/A
C	Very dense soil and soft rock	1,200 to 2,500	>50	>2,000
D	Stiff soil profile	600 to 1,200	15 to 50	1,000 to 2,000
E	Soft soil profile	<600	<15	<1,000
	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index PI > 20 2. Moisture Content w>= 40%, and 3. Undrained shear strength < 500 psf			
F	Any profile containing soil having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays, where the thickness of this section is more than 10 feet. 3. Very high plasticity clays (more than 25 feet of clay with plasticity index PI > 75). 4. Very thick soft/medium stiff clays (thickness of the soil > 120 feet).			

From Table 1613.5.2 of the 2010 California Building Code
psf = pounds per square foot

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2011

Explanation for Engineering Site Classes

Plate 1-4b

Table 1-4: 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 and San Jacinto faults, for example, are classified as Type A. The Type A slip rate (>5 mm/yr; >16.4 feet/1000 yr) is common only to tectonic plate boundary faults. Type C seismic sources are considered not capable of producing large magnitude events such that their 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 Type A fault closest to Yucca Valley is the San Andreas fault. Type B faults in the region include the Pinto Mountain, Johnson Valley, Mesquite Lake, Emerson South–Copper Mountain, Calico–Hidalgo, Landers, Lenwood–Lockhart–Old Woman Springs, and others listed in Table 1-2 (Cao and others, 2003). The Burnt Mountain and Eureka Peak faults are right at the boundary between Type B and Type C faults given the size of the maximum magnitude earthquake that they are anticipated to generate (M 6.5) and their relatively low slip rate, currently estimated at 0.5 mm/yr (~20 inches/1000 yr). Detailed paleoseismic studies of these faults are necessary to further characterize their seismic potential.

Current building codes based on the United States-focused International Building Code, including the 2010 California Building Code, incorporate the seismic-source and near-source factors by using the maps prepared by the U.S. Geological Survey National Hazards Mapping Project. These maps are based on seismic hazard computations for all regions of the United States and incorporate the most recent fault and seismic source data to develop the "maximum considered earthquake" ground motions for a given site. The user provides the site location using either an address or coordinates, and provides the soil-site effects in accordance with the classifications presented in Plates 1-4a and 1-4b. Future building codes, starting with the 2012 International Building Code, will be using what they have termed a "risk-targeted maximum considered earthquake." The ground motions that the new buildings codes will use are based on computational models that consider the likelihood of a building collapsing as a result of seismic shaking (FEMA, 2009).

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. This section assesses the general earthquake vulnerability of structures and facilities common in the southern California area, including in Yucca Valley. This analysis is based on past earthquake performance of similar types of buildings in the United States. The effects of design earthquakes on particular structures within the Town are beyond the scope of this study.

1.8.1 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. As a result, the State Legislature passed Senate Bill 547, addressing the identification and seismic upgrade of URMs.

It is unknown whether there are any unreinforced masonry structures in the Town of Yucca Valley. Inventory requests from the Seismic Safety Commission in 2003 and 2006 to the Town of Yucca Valley appear to have gone unanswered.

1.8.2 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, 1995). There are many other cases of soft-story collapses in past earthquakes. In response, the State encourages the identification and mitigation of seismic hazards associated with these types of potentially hazardous buildings, and others such as pre-1971 concrete tilt-ups, mobile homes, and pre-1940 homes. The Town of Yucca Valley should consider conducting an inventory of their soft-stories, and encouraging the structural retrofit of these structures to withstand collapse during an earthquake.

1.8.3 Wood-Frame Structures

Most wood-frame structures in Yucca Valley can be anticipated to experience slight to extensive damage as a result of ground shaking expected in the region, the level

of damage generally associated with the age of the structure, its condition, and its location relative to the causative fault, among other conditions. 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 during 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).

1.8.4 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), Turkey (1999) and China (2008) 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, 1995).

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.

1.8.5 Tilt-up Buildings

Tilt-up buildings have concrete wall panels, often cast on the ground, or fabricated off-site and trucked in, which are then 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.

1.8.6 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, 1995), where infilling between columns confined the length of the columns that could move laterally in the earthquake.

1.8.7 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.

1.8.8 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 of 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. Loss estimation analyses typically show that a large percentage of the mobile homes in the southern California area are likely to experience more than moderate damage as a result of an earthquake on a local fault. As discussed in the Fire Hazards Chapter (Chapter 4), when manufactured homes fall off their supports, gas line connections are often severed. The resultant gas leaks can ignite, which can lead to the complete loss of the structure due to fire.

1.8.9 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 Summary and Recommendations

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. This is particularly important in the Yucca Valley area and other areas immediately adjacent to or bisected by active faults.

Earthquake Sources, Design Earthquake Scenarios and Fault Rupture:

- 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.

- The Pinto Mountain fault is the most significant seismic source in the Town of Yucca Valley General Plan area. The fault extends across the Town in an east to east-northeast direction, locally underlying Highway 62, and extending across all north-south access roads that connect Highway 62 with the northern part of Town. A high pressure gas transmission line that extends across the Town both extends along and locally crosses the Pinto Mountain fault zone, a condition that can result in dozens of breaks of the pipeline in Yucca Valley when the Pinto Mountain fault ruptures next. This fault has not caused an earthquake in historic times, but paleoseismic studies indicate that it has a recurrence interval of between about 2,500 and 3,000 years.

- Several faults within 100 km (62 miles) of Yucca Valley can generate earthquakes as large or larger than the M_w 6.7 Northridge earthquake, the single most-expensive earthquake yet to impact the United States. Unfortunately, we cannot predict when a fault will break causing an earthquake, but we can anticipate the size of the resulting earthquake and estimate the level of damage that the earthquake would generate in the region. Strong to moderate ground shaking due to future earthquakes on regional sources, including the Pinto Mountain and San Andreas faults, should be expected and designed for.

- The Landers earthquake occurred at Yucca Valley's back door, so to speak. However, surface fault rupture through Yucca Valley was minor, measured for the most part in inches, and the strongest shaking was directed away from the center of Town. Rupture of the Pinto Mountain fault through the heart of the Town would be the worst-case earthquake for Yucca Valley, with surface rupture potentially measuring tens of feet, and strong ground shaking made worse by seismic waves bouncing off the mountains to the north and south. A M7.2 earthquake on this fault would result in significant damage in the Town.

Secondary Earthquake Effects:

- The California Geological Survey (CGS) has not conducted mapping in the Yucca Valley area under the Seismic Hazards Mapping Act. This report presents a liquefaction susceptibility map that was prepared using a similar method used by the California Geological Survey (CGS). Shallow ground water levels (less than about 50 feet from the ground surface) have not been reported historically in Yucca Valley. Therefore, although young alluvial sediments underlie the valley, and strong ground shaking can occur in the region, the liquefaction susceptibility of the Yucca Valley area is currently considered low to none. Recharging of the groundwater sub-basins could result in the rise of water to levels of concern. The Hi-Desert Water District and the U.S. Geological Survey reportedly will monitor the rise in groundwater to prevent the potential for liquefaction from becoming a reality.

- Soil falls, slides and slumps may occur in the hillside areas of the Sawtooth Mountains, on Burnt Mountain, at the northern edges of the Little San Bernardino Mountains, and along the edges of several of the drainages in the area. All of these

types of slope failure can occur as a result of strong ground shaking.

- Precariously perched rocks are common in some areas of the Sawtooth Mountains. Earthquake-induced ground shaking could dislodge some of these rocks, posing a rockfall hazard to areas adjacent to and below these slopes.

- Those areas of Yucca Valley underlain by youthful unconsolidated alluvial sediments may be susceptible to seismically induced settlement. Geotechnical studies to evaluate this potential hazard should be conducted in areas underlain by Holocene sediments where developments are proposed. If the sediments are found to be susceptible to this hazard, mitigation measures designed to reduce settlement should be incorporated into the design.

Earthquake Hazard Reduction:

- 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, including contents, in those buildings. Especially hard-hit structures include manufactured homes, and residential structures other than single-family homes (that is, multi-family residential buildings, including duplexes, condominiums and apartments).

- The High Desert Medical Center in Joshua Tree, located less than 1 mile from the Pinto Mountain fault, would experience severe shaking during an earthquake on that fault, and is not expected to be more than 50% functional immediately following the earthquake (Earth Consultants International, 2009). As a result, the hospital may not be able to meet the demand for medical care in the aftermath of a large earthquake in the area, given that it services several of the communities that would be hard-hit by such an event. Emergency management personnel and planners need to develop a contingency plan that provides for medical care at facilities other than the local hospital, such as the Robert E. Bush Naval Hospital within the Twentynine Palms Marine Base, in addition to agreements with hospitals outside of the region that can provide assistance. Given the extensive damage anticipated to the local transportation system, critical victims that need to be transported elsewhere for treatment may have to be airlifted out of the area.

- The inventory and retrofit of potentially hazardous structures, such as pre-1952 wood-frame buildings, concrete tilt-ups, pre 1971- reinforced masonry, soft-story buildings and especially mobile homes, are recommended.

- 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. 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% of the original cost of the structure. Current building codes incorporate two significant changes that impact the Town of Yucca Valley. First, there is recognition that soil types can have a significant impact on the

amplification of seismic waves, and second, the proximity of earthquake sources will result in high ground motions and directivity effects. However, for those areas of Yucca Valley already developed, and given that 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.

- While the earthquake hazard mitigation improvements associated with the latest building code address new construction, the retrofit and strengthening of existing structures requires the adoption of ordinances. The Town of Yucca Valley could consider the implementation of ordinances aimed at retrofitting older wood-frame residential buildings that are not tied-down to their foundations, pre-cast concrete buildings, steel-frame buildings, soft-story structures, and manufactured housing. Although retrofitted buildings may still incur severe damage during an earthquake, their mitigation results in a substantial reduction of casualties by preventing collapse.

- Effective management of seismic hazards in Yucca Valley includes technical review of consulting reports submitted to the Town by licensed engineering geologists and/or civil engineers 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; CGS, 2008).

- Rupture of the Pinto Mountain fault through the Town of Yucca Valley has the potential to result in hundreds to thousands of leaks and breaks in the potable water system. Hardest hit areas may be without water at the tap for weeks to months. The Town and its lifeline service providers should consider retrofitting the older pipelines in these systems, to reduce the number of potential breaks as a result of corrosion and age, in addition to developing plans to truck in water that is delivered directly to the Town residents. Residents should be encouraged to store at least a 7-day supply of water for all family members, including pets, so that they can be self-sufficient immediately following the earthquake, until service is restored or, if necessary, the Town can arrange for water to be trucked in.

CHAPTER 2: GEOLOGIC HAZARDS

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 geology, soils, topography, climate, and land use. The geologic setting and types of geologic hazards affecting the Town of Yucca Valley are discussed in the following sections.

2.1 Physiographic Setting

The high-desert Town of Yucca Valley encompasses highly variable terrain that includes a broad central valley, gently sloping alluvial fans, and rugged mountains. Within the Town limits, the gradient of the central east-west trending valley falls very gently to the east, from an elevation of about 3,400 feet above sea level (asl) at its western edge, to about 3,100 feet asl at its eastern edge. North of the valley, the Sawtooth Mountains form rounded hills with picturesque bouldery outcrops. In addition to the Sawtooths, the valley is framed by the San Bernardino Mountains to the west, the Bartlett Mountains to the east, and the Little San Bernardino Mountains to the south. Peaks within the Town have elevations of between 3,800 and 4,500 feet asl, with the highest peak within the Town's southern boundary reaching up to an elevation of about 4,600 feet asl. South of Yucca Valley, the Little San Bernardino Mountains rise to more than 5,000 feet asl. Compared to the Sawtooths, the Town's sparsely vegetated hillsides to the south are moderately steep, jagged, and have considerably fewer outcrops – a reflection of the variation in the underlying rock types within Yucca Valley.

The most extensively developed area of Yucca Valley lies along State Highway 62, which generally coincides with the axis of the central valley. Development near the highway is predominantly commercial with a few multi-family residential units. Single family homes comprise most of the remaining development away from Highway 62, with the highest concentration of homes spreading across the valley floor and up the gently sloping alluvial fans. Scattered rural and semi-rural residential development has spread out into hilly areas to the north and south. More than half of the Town's area is still undeveloped however, including many of the steeper hills and ridgelines. The mountains that border the Town on the south are dedicated to open space and recreation, as part of Joshua Tree National Park and Big Morongo Canyon Preserve.

2.2 Geologic Setting

Southern California is divided into distinct geomorphic provinces, that is, regions having their own unique physical characteristics formed by geologic, topographic, and climatic processes. Yucca Valley is located at the boundary of two very distinct provinces. The northern part of the Town, generally north of State Highway 62, lies within the Mojave Desert Province, an arid region of alluvial fans, desert plains, dry lakebeds, and scattered mountain ranges. This province covers a large portion of eastern California, stretching from the southern end of the Sierra Nevada Mountains to the Colorado River. Faults in the Mojave Desert Province have a predominant northwesterly trend; however, some faults with a trend more aligned with the Transverse Ranges described below are also present.

In contrast, the southern part of the Town reaches up the north flank of the Little San Bernardino Mountains, a moderately high range that is the southernmost extension of the Transverse Ranges Province. This province is a region whose characteristic features are a series of generally east-west trending ranges that include the San Gabriel and San Bernardino Mountains. These ranges are called "transverse" because they lie at an oblique angle to the prominent northwesterly structural grain of the southern California landscape, a trend that is generally aligned with the San Andreas fault. The Transverse Ranges are being intensely compressed by active tectonic forces, therefore they are some of the fastest rising (and fastest eroding) mountains in the world. In Yucca Valley, the boundary of these two provinces is defined by the Pinto Mountain fault, a wide zone of multiple fault strands.

The physical features of the area's landscape are a result of geologic and climatic processes that have affected this region in the last few million years. The most striking feature is the dramatic contrast between the desert plains and the adjacent mountains – a direct result of movement along geologically young faults that have both elevated and down-dropped great blocks of the Earth's crust. As a result, the mountains are composed of rocks that have been sheared and intensely fractured under the strain of tectonic movement. The down-dropped blocks form deep basins that are filled with multiple generations of overlapping alluvial fans having a range of ages coincident with the rise of the local mountains. Yucca Valley overlies two such basins: The Warren Valley Groundwater Basin underlies the main valley and gently sloping terrain to the south; the southwestern edge of the Copper Mountain Groundwater Basin underlies the northern part of the Town, with the Sawtooth Mountains, the Pinto Mountain fault zone, and the Bartlett Mountains forming a barrier between the two basins (California Department of Water Resources, 2004). The Warren Valley Basin is estimated to be deepest along the Pinto Mountain fault zone, however its actual depth is unknown since very few of the local groundwater wells, the source of most geologic data for the basin, have been drilled deep enough to reach the bottom. Geophysical data however, suggest the basin is more than 3,000 feet deep at its deepest part (Nishikawa and others, 2003). The maximum depth of the section of the Copper Mountain Basin that underlies the Yucca Valley area is unknown. Like other valleys in the region, sediments beneath Yucca Valley are estimated to range in age from Holocene near the surface, to more than 1 million years old at great depth. Deposition is still ongoing, with the youngest sediments filling active drainage channels and blanketing the Yucca Wash floodplain.

The physiographic and geologic histories of the Yucca Valley area are important in that they control to a great extent the geologic hazards, as well as the natural resources, within the area. For example, erosion and flooding pose significant hazards in Yucca Valley due to the fractured condition of the rock in the local mountains, the sandy nature of the valley sediments, and the intense thunderstorms that occur in the high desert. On the other hand, deep, alluvium-filled basins which are bounded at depth by relatively impermeable rock and faults function as natural underground reservoirs (aquifers) for groundwater, the area's primary source of drinking water.

2.3 Geologic Units and Their Engineering Properties

To a large degree, past study and characterization of the geology in the Yucca Valley region has been undertaken in order to understand the source, quality, and availability of groundwater or other natural resources (Bader and Moyle, 1960; Lewis, 1972; Huff and others, 2002; Nishikawa and others, 2003; and many others). The general distribution of geologic units that are exposed at

the surface is shown on the Geologic Map (Plates 2-1a and 2-1b). This map is a modified, composite version of geologic maps published for this area (Bortugno and Spittler, 1986; Dibblee, 2008a,b; and Nishikawa and others, 2003). In the sections that follow, the general physical and engineering characteristics of each geologic unit in Yucca Valley, from youngest to oldest, are summarized using the descriptions derived from the published maps and reports (Dibblee, 1967a,b,c and 2008a,b; in addition to those mentioned above). General engineering characteristics are shown on the Engineering Materials Map (Plates 2-2a and 2-2b).

There are isolated deposits of man-made fill throughout Yucca Valley, including fills associated with roadway embankments, levees, and graded developments. These deposits vary widely in size, age, and composition, and although some may cover a significant area, due to the scale of Plate 2-1a, they are not shown on the Geologic Map.

2.3.1 Sedimentary Deposits

2.3.1.1 Surficial Sediments

Surficial geologic units comprise those sedimentary deposits that overlie bedrock in the area. In Yucca Valley these units consist predominantly of unconsolidated or semi-consolidated sand, silt, and gravel. The youngest sediments are water-laid alluvium deposited in active or recently active gullies, washes and floodplains. Gently sloping areas in the southern and northern parts of the Town consist of older, slightly elevated alluvial fan sediments that have been dissected by the active washes and gullies. Erosional remnants of very old fans are present in isolated areas, where they form deeply incised hills, such as Burnt Mountain. These sedimentary units and their estimated ages have been categorized by researchers primarily by noting the degree of soil development on the surface, stratigraphic position, degree of stream incision, relative uplift, and other physical characteristics. Most of the units do not have formal names, but they have been labeled with symbols that emphasize their age and mode of deposition. At depth, this sequence of alluvial sediments is underlain by crystalline bedrock similar to that exposed in the surrounding mountains.

Young Alluvium (Map Symbol: Qya)

Young alluvium includes sediments deposited by water in washes, on small fans emanating from canyons within the local hills and mountains, and as floodplain deposits on the valley floor. These deposits predominantly consist of unconsolidated, coarse-grained sediments filling the major active drainage courses, including the Yucca Wash, Water Canyon, Covington Wash, West Burnt Mountain Creek, East Burnt Mountain Creek, and Pipes Wash, as well as silt, sand and gravel in numerous unnamed washes and gullies that cross the older alluvial fans. The upper reaches of these drainages, especially near the mountains, may contain very large boulders deposited during flash floods. Finer-grained alluvium, including fine sand, silt, and clay, is generally present where past floodwaters have spread out on the valley floor. Young alluvium has no pedogenic soil development on the surface, and is typically reworked by floodwaters or buried by new sediment during storms. Young alluvium is Holocene in age, and may be up to about 100 feet thick (Nishikawa and others, 2003).

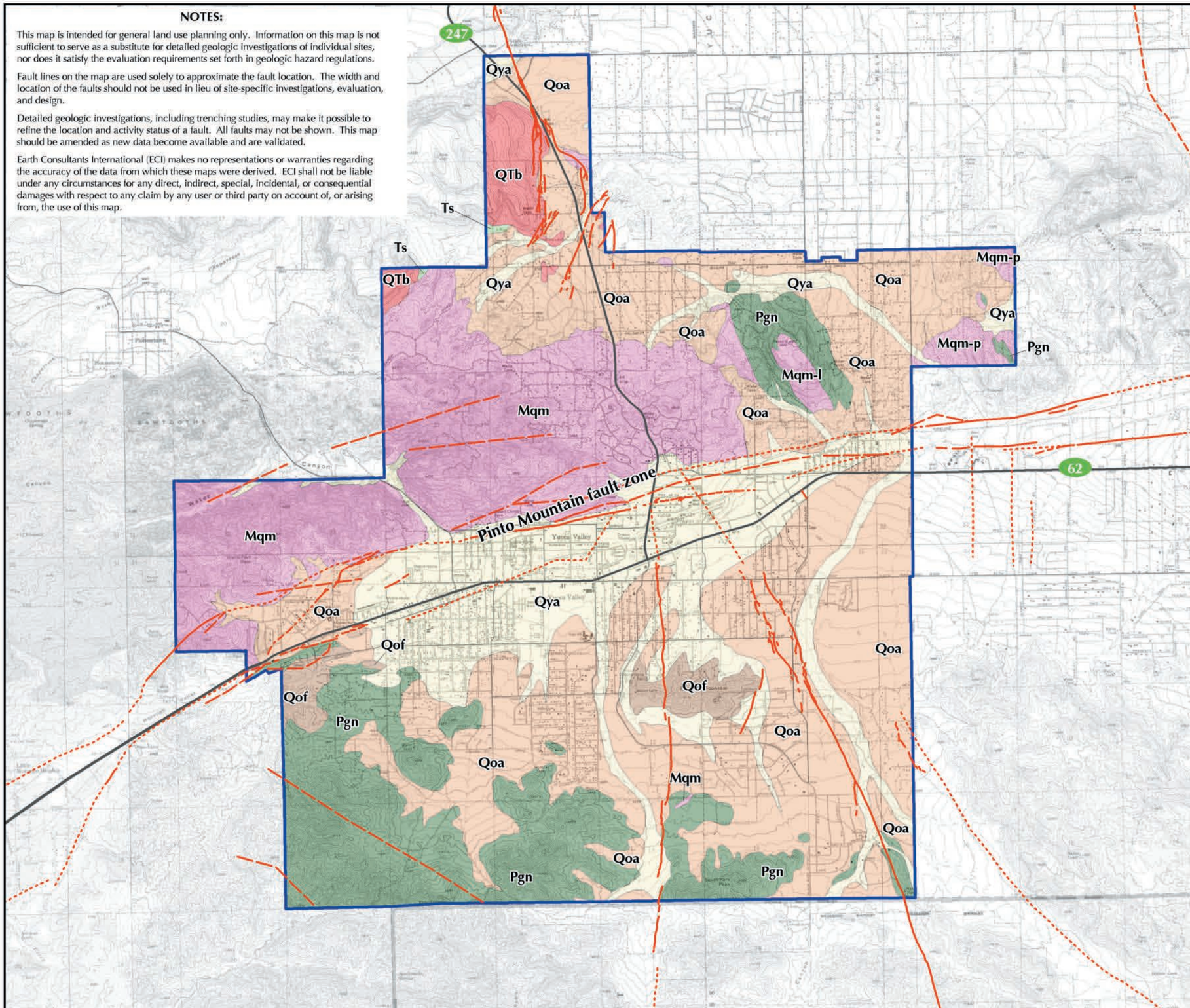
NOTES:

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.



Geologic Map

Yucca Valley, California

For Geologic Unit Descriptions
See Plate 2-1b

N
W E
S

5000 0 5000
Feet

1500 0 1500
Meters

Scale: 1:60,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER (1997) and Town of Yucca Valley.
Sources: Modified from Dibblee (2008).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 2-1a

Geologic Unit Descriptions

SEDIMENTARY DEPOSITS

Surficial Sediments

Qya Young Alluvium - Unconsolidated, undissected sand and gravel filling valleys, stream channels, and washes; contains some fine sand, silt, and clay in valley areas. Late Pleistocene to Holocene age.

Qoa Older Alluvium - Massive to poorly-bedded sand and gravel valley fill, now slightly elevated; dissected by active drainages. Predominantly sand, pebbles, and cobbles; or coarse sand and cobbles. Pleistocene age.

Qof Very Old Alluvium (Fanglomerate) - Massive, weakly consolidated sand, gravel, and boulders of ancient alluvial fan deposits. Only erosional remnants remain. Probable early Quaternary or possible Tertiary age.

Sedimentary Rock

Ts Sandstone - Massive to faintly bedded, light-colored, fine- to medium-grained sandstone; locally contains lenses of pebble-cobble conglomerate. Probable late Tertiary age.

CRYSTALLINE ROCK UNITS

Igneous Rocks

QTb Basalt - Dark-colored lava flows exposed on flat-topped hills and ridges in the northern part of the town. Probable late Tertiary or Quaternary age.

Mqm Quartz Monzonite - Massive, light-colored, medium- to coarse-grained granitic rock. Exposed primarily in rocky hills north of the Pinto Mountain fault zone. Probable Cretaceous or possible Jurassic age (Mesozoic).

- **Mqm-l** Leuocratic quartz monzonite; faintly gneissoid locally.
- **Mqm-p** Monzonite porphyry; contains abundant, large, rectangular phenocrysts of orthoclase feldspar. Early Cretaceous to late Jurassic age.

Metamorphic Rocks

Pgn Gneissic Rocks. Composition is variable, ranging from quartz monzonite to quartz diorite. Exposed primarily in the hills south of the Pinto Mountain fault zone. Within Yucca Valley, rock foliation dips steeply to the northwest. Age unknown, but possibly as old as Precambrian.

Symbols

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

Geologic Contact

Yucca Valley Town Boundary

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Explanation for Geologic Map

Plate 2-1b

Engineering Properties of Young Alluvium: How and where these young sediments were deposited have a significant bearing on the properties of these materials. At the base of the mountains and hills, where it is generally deposited rapidly, alluvium is coarse-grained, poorly sorted, and often has organic debris. As a result, the major engineering issues affecting these geologically young deposits are: 1) compressibility, which occurs when additional loads are applied, and 2) collapse (hydroconsolidation) upon introduction of irrigation water if the deposit is dry. Being unconsolidated, sandy alluvium is highly susceptible to erosion. Alluvium filling mountain drainages with gradients steeper than about 27 degrees (50 percent slope) may form mudflows if it becomes saturated. Boulders in the alluvium near the base of slopes and in active channels may be a hindrance to earthwork and foundation construction. Alluvium is suitable for use as fill, once organic materials and oversized rocks are removed, however alluvium typically requires the addition of water to achieve the level of compaction needed to support a building or structure. Alluvial deposits also have moderate to high permeability, except where silt or clay layers may retard the downward percolation of water. The potential for expansive soils is generally low, except where deposits of silt and clay are exposed. Most young alluvium in the Yucca Valley area is not water-bearing.

Older Alluvium (Map Symbol: Qoa)

Older alluvial fan deposits are Pleistocene in age (ranging from about 11,000 to 1 million years old), and generally consist of massive to crudely stratified sand and pebble-cobble gravel eroded from bedrock exposed in the adjacent hills and mountains. Deposits closer to the mountains are typically coarse grained, transitioning to finer-grained sediments (silty sand) downslope, near the valley axis. Well drillers logs indicate layers of clay, sandy clay and gravelly clay are present throughout the sedimentary sequence. The oldest deposits are commonly tilted, folded, and/or faulted near the major active fault zones.

Engineering Properties of Older Alluvium*:* Older alluvium is generally denser than young alluvium, and therefore will provide better support for foundations and structures. Clayey pedogenic soils that develop on the fan surface, or clayey beds within the unit would be in the expansive range. Slope stability can be a problem where slopes have become oversteepened, typically by stream erosion or man's activities. These deposits are less permeable than the young alluvium, nevertheless the deeper part of the sequence is the main water-bearing unit in Yucca Valley, yielding most of the Town's well water.

Very Old Alluvium (Map Symbol: Qof)

This unit is classified as a fanglomerate, meaning it was deposited in an alluvial fan environment and is comprised mostly of boulders and cobbles in a sand matrix. Where exposed at the surface, the fanglomerate is light gray in color, massive, and contains sub-rounded rock fragments transported from mountains to the south and northwest. At depth, this unit underlies the sequence of young and old alluvium filling the mid to upper part of the basin, and is estimated to be at least 2,000 feet thick. The fanglomerate is estimated to be early Quaternary to possible late Tertiary age (1 million to about 5 million years old).

Engineering Properties of Very Old Alluvium: Except for the uppermost weathered surface, the fanglomerate should provide good foundation support. If clayey pedogenic soils have developed on the surface, these may be expansive; otherwise the unweathered

portion generally has low expansion potential. Boulders are likely to be a hindrance to earthwork and foundation construction. This unit is not water-bearing near the surface, but despite its increased consolidation with depth, it does contribute a small percentage of the area's water supply to deep wells.

2.3.1.2 Sedimentary Rock (Map Symbol: Ts)

Sedimentary rock consisting of buff-colored, fine- to medium-grained sandstone, locally with lenses of rounded pebble-cobble conglomerate and minor thin lenses of siltstone, is present in the northern part of the Town. Sediments in this unit were deposited on the quartz monzonite rock described below, and were then buried by the basaltic lava flows that cap the hills in this area. Consequently, exposure of this unit at the surface by erosion is very limited. The sandstone is described as friable (grains are not well cemented together), and massive to very faintly bedded. Based on its position between the monzonite and the basalt, it is estimated to be Tertiary in age (between about 1.6 and 65 million years old).

Engineering Properties of Sedimentary Rock: Friable, massive sandstone generally provides good foundation stability, being relatively dense, low in expansion potential, and resistant to slope failure. Nevertheless, it is susceptible to erosion, and would generally not perform well in slopes steeper than 50 percent (2:1 horizontal:vertical). This unit is not water-bearing.

2.3.2 Crystalline Rocks

The oldest geologic units in the Yucca Valley area consist of hard, crystalline rock that is exposed in the mountains and buried beneath the alluvium. Crystalline rock classifications are based primarily on genesis, texture, and mineral composition. Because the rocks are highly variable in texture and mineralogy, often grading from one type to another, the units are usually named for the dominant rock type. Numerous studies have discussed the mineralogy and character of the rocks in the region, along with their genesis (Bacheller, 1978; Dibblee, 1967a,b,c, 2008a,b; Miller, 1938; Rogers, 1954, 1958, 1961). Based on genesis alone, the rocks in this area can be classified into three main groups: 1) igneous rocks that crystallized from molten lava that flowed out on the surface (volcanic rocks); 2) igneous rocks that crystallized from the molten state deep within the Earth's crust (plutonic rocks); and 3) rocks of sedimentary origin that have recrystallized under extreme conditions of heat and pressure deep below the Earth's surface (metamorphic rocks).

2.3.2.1 Igneous Rocks

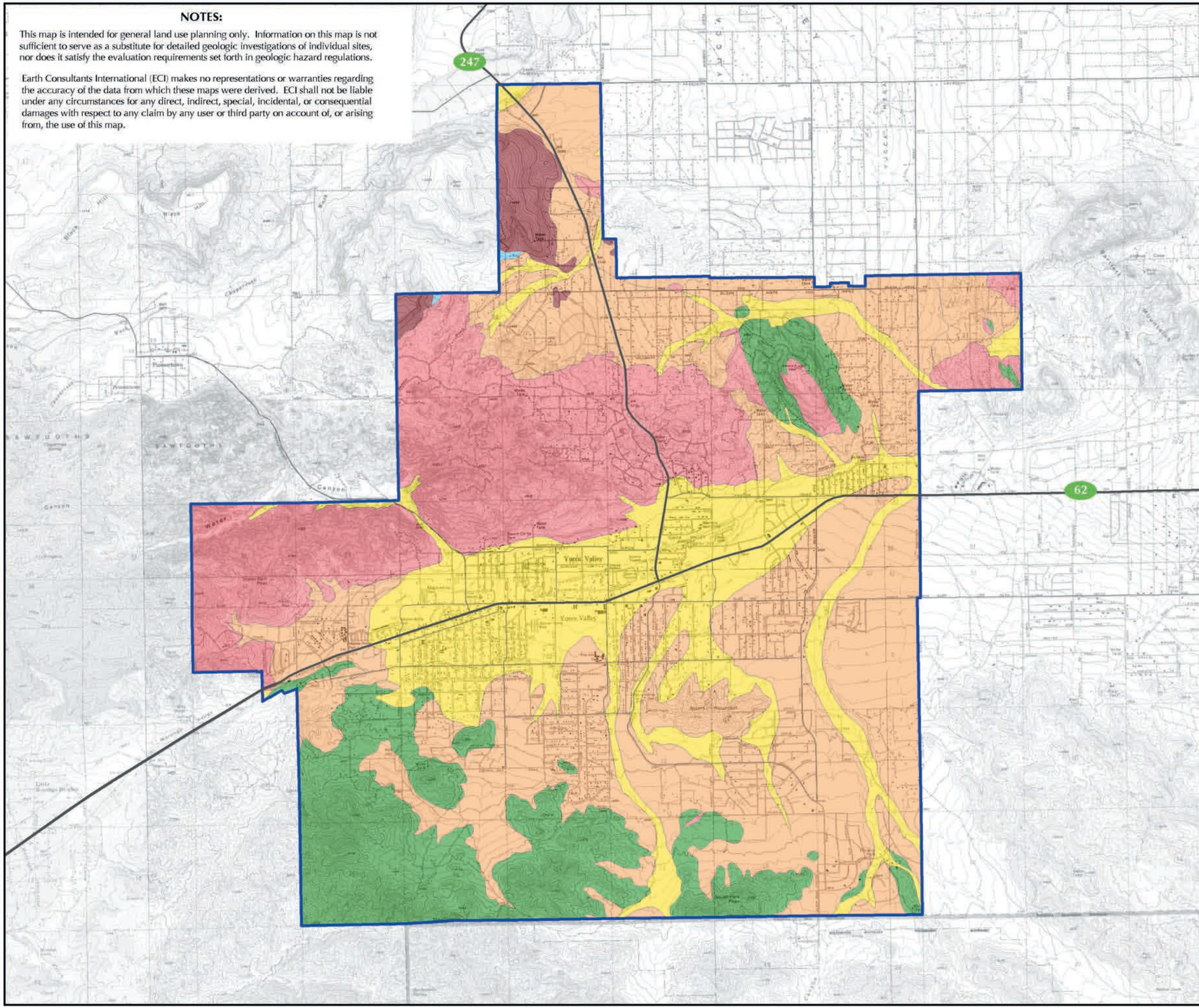
Volcanic Rock: Basalt (Map Symbol: QTb)

Volcanic rocks are those that solidified on the ground surface. Because these rocks cooled very quickly, they are very fine grained (microcrystalline). Classified as basalt, these rocks are black, hard, massive, and vesicular (meaning they have small voids caused by gas bubbles trapped in the flowing lava). This unit is resistant to erosion and tends to form relatively flat-topped hills and ridges.

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.



Engineering Materials Map

Yucca Valley, California

Symbols

Yucca Valley Town Boundary

For Engineering Materials Descriptions See Plate 2-2b

N
W E
S

0 7000 14000 Feet

0 2000 4000 Meters

Scale: 1:84,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER (1997) and Town of Yucca Valley.
Sources: Based on data from Dibblee (2008).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 2-2a

GENERAL ENGINEERING CHARACTERISTICS OF GEOLOGIC UNITS IN THE YUCCCA VALLEY GENERAL PLAN AREA

SEDIMENTARY MATERIALS

Young Alluvium (Qya)
COMPOSITION: Variable, but commonly contains locally derived silt, sand, and gravel; may also contain vegetation and debris, or boulders near the mountains. DENSITY: Low; compressible. EXPANSION POTENTIAL: Generally low; locally moderate, depending on fine-grained fraction. SLOPE STABILITY: Generally poor. EROSION/SEDIMENTATION POTENTIAL: Highly susceptible to erosion, especially where water flow is concentrated; locally subject to sedimentation carried by floodwaters and debris flows. PERMEABILITY: Moderate to High. EASE OF EXCAVATION: Easy. SUITABILITY AS FILL: Generally good after organics, debris, and oversize rocks are removed. Clay or organic-rich deposits should not be placed near finish grades.

Old Alluvium (Qoa, Qof)
COMPOSITION: Variable mix of silt, sand, gravel and boulders; weathered surface may be enriched with clay due to pedogenic soil development. DENSITY: Generally dense below the upper few feet. EXPANSION POTENTIAL: Generally low; locally moderate to high, depending on original composition and degree of pedogenic soil development. SLOPE STABILITY: Good except where oversteepened by stream erosion or man's activities. EROSION/SEDIMENTATION POTENTIAL: Moderate. PERMEABILITY: Highly variable, but overall less permeable than young alluvium. Although generally not water-bearing near the surface, both Qoa and Qof have water-bearing layers (aquifers) at depth. EASE OF EXCAVATION: Easy. SUITABILITY AS FILL: Generally good; oversize rocks may require special handling.

Sandstone (Ts)
COMPOSITION: Fine- to medium-grained sand with lenses of rounded pebbles and cobbles. DENSITY: Generally dense below the upper weathered surface. EXPANSION POTENTIAL: Low. SLOPE STABILITY: Good except where oversteepened by stream erosion or man's activities. EROSION/SEDIMENTATION POTENTIAL: Moderate. PERMEABILITY: Generally moderate, due to lack of cementation. Generally not water-bearing. EASE OF EXCAVATION: Easy. SUITABILITY AS FILL: Generally good.

CRYSTALLINE ROCKS

Basalt (Qtb)
COMPOSITION: Massive, microcrystalline. DENSITY: Very dense. EXPANSION POTENTIAL: Low. SLOPE STABILITY: Generally good in cut and natural slopes that are not oversteepened. EROSION POTENTIAL: Very low. PERMEABILITY: Low. EASE OF EXCAVATION: Difficult to very difficult where unweathered. May require blasting. SUITABILITY AS FILL: Relatively poor for unweathered rock, as excavation may produce significant oversize rock fragments. Blasting may produce smaller rock sizes that can be used for rock fills, however these require greater amounts of applied water, and compaction is difficult to verify.

Quartz Monzonite (Mqm, Mqm-l, Mqm-p)
COMPOSITION: Fractured, homogeneous, fine- to coarse-grained granitic rocks. DENSITY: Very dense. EXPANSION POTENTIAL: Low. SLOPE STABILITY: Generally good in cut slopes that are not oversteepened. Localized shear zones may provide planes of weakness. Natural slopes are typically covered with large boulders that pose a rockfall hazard. EROSION POTENTIAL: Very low. PERMEABILITY: Low. EASE OF EXCAVATION: Difficult to very difficult where unweathered. May require blasting. SUITABILITY AS FILL: Good for weathered, decomposed granitics. Relatively poor for unweathered rock, as excavation may produce significant oversize rock fragments. Blasting may produce smaller rock sizes that can be used for rock fills, however these require greater amounts of applied water, and compaction is difficult to verify.

Gneissic Rocks (Pgn)
COMPOSITION: Fractured heterogeneous mix of metamorphosed sedimentary rocks; faintly laminated; laminae are steeply dipping to near vertical and locally undulating. DENSITY: Very dense. EXPANSION POTENTIAL: Very low. SLOPE STABILITY: Good in natural slopes. Generally good in cut slopes. Localized shear zones may provide planes of weakness. Due to steeply dipping foliation, cut slopes that are oversteepended (such as road cuts) may be unstable. EROSION POTENTIAL: Very low. PERMEABILITY: Low. EASE OF EXCAVATION: Difficult to very difficult where unweathered. May require blasting. SUITABILITY AS FILL: Moderate to poor, as excavation may produce significant oversize rock fragments. Blasting may produce smaller rock sizes that can be used for rock fills, however these require greater amounts of applied water, and compaction is difficult to verify.

Plutonic Rocks: Quartz Monzonite (Map Symbol: Mqm, Mqm-l, Mqm-p)
Commonly referred to as "granitic," these rocks generally have large grains that can easily be seen without magnification. They often have a spotted appearance and have somewhat variable mineral assemblages. Most of these rocks crystallized from magmas that were emplaced over a period of time ranging between about 65 million and 225 million years ago, during the latter part of the Mesozoic Era, probably during the Cretaceous, or possibly as old as late Jurassic.

In the Yucca Valley area, the predominant mineral assemblage is a light-colored, massive, medium- to coarse-grained rock composed mainly of quartz and feldspars, with various accessory minerals such as biotite, sphene, zircon, apatite, and iron oxides. The quartz monzonite in Yucca Valley includes a subgroup labeled "porphyry" (Mqm-p). A porphyritic rock contains very large crystals (called "phenocrysts") embedded within a finer grained matrix. In this area, the monzonite porphyry is light gray, medium-grained, and has large phenocrysts of potassium feldspar. Leucocratic quartz monzonite ((Mqm-l) is very light colored (white to light gray), fine- to medium-grained, massive, and faintly gneissoid. These rocks form hills in the easternmost end of the Sawtooth Mountains, and the western part of the Bartlett Mountains.

2.3.2.2 Metamorphic Rocks

Gneissic Rocks (Map Symbol: Pgn)
The most ancient rocks in the Yucca Valley area are metamorphic rocks that are possibly as old as Precambrian in age (more than about 500 million years old). These rocks occur predominantly in the mountains south of the central valley, but are also present in isolated areas north of the Pinto Mountain fault zone. This group consists of gneissic rocks ranging in mineral composition from quartz monzonite to quartz diorite. The minerals in gneissic rocks are separated into layers, commonly giving the rock a banded appearance. The bands may be relatively straight, undulating, or contorted.

Engineering Properties of Crystalline Rock: The various crystalline rock types have similar engineering properties. They are very hard where not highly weathered, and tend to form steep, rugged slopes and deep canyons. They are typically non-water bearing, except where extensively jointed and fractured. Accordingly, these materials have low to moderately low permeabilities, except where joints, shears and foliation surfaces provide avenues for water to move in and around the rock mass. Metamorphic rocks tend to break along fracture surfaces, yielding pebble to cobble size fragments. Fractured granitic rocks tend weather into boulder-covered slopes, as well as decomposing along grain boundaries, resulting in abundant sand-size detritus. Unweathered rock cannot be excavated easily; blasting is typically required.

Because these rocks are brittle and have been subjected to millions of years of tectonic activity, they are typically very fractured and may be sheared near fault zones. These types of deformation, along with the inherent jointing or foliation (banding of minerals) present in the rocks, locally serve as planes of weakness along which slope instability can occur. Large prehistoric landslides have been mapped in similar rock types in the San Bernardino Mountains. However, no landslides have been mapped in or adjacent to Yucca Valley.

2.4 Geologic Hazards in the Yucca Valley Area

2.4.1 Slope Instability

A significant part of Yucca Valley encompasses hillside terrain. At present, many of the steepest hills and mountains remain largely undeveloped. However, scattered rural and semi-rural homesites are built out in the rocky slopes of the Sawtooths north of the main valley and into the lower reaches of the Little San Bernardino Mountains on the south. In addition, many homes are present in gently sloping areas along the base of mountain slopes. As the Town's population increases, the pressure to develop hillside homes will most likely intensify. Consequently, slope instability remains a hazard in Yucca Valley. Although a slope failure tends to affect a relatively small area (as compared to an earthquake or major flood), and is generally a problem for only a short period of time, the dollar loss can be high. Homeowner's insurance policies typically do not cover land slippage, and this can add to the anguish of the affected property owners.

The bedrock underlying the mountains and hills of Yucca Valley is generally not prone to landsliding. Nevertheless, areas of high topographic relief, such as steep canyon walls, are likely to be impacted by rockfalls and rockslides, typically in response to strong seismic shaking. Soil slips and mudflows during or after periods of intense rainfall not only impact canyon areas, but also valley areas downstream.

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 mud or debris flows. 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. Furthermore, slope failures often occur as elements of interrelated natural hazards in which one event triggers a secondary event, such earthquake-induced rockfall, fire-flood sequences, or storm-induced mudflows.

Gross or Global Failures

Landslides are movements of relatively large landmasses, either as nearly intact bedrock blocks, or as jumbled mixes of bedrock blocks, fragments, debris, and soils. Landslide materials are commonly porous and very weathered in the upper part and along the margins of the slide. They may also have open fractures and joints. The head of the slide may have a graben (pull-apart area) that has been filled with soil, bedrock blocks and fragments.

From an engineering perspective, landslides are generally unstable (may be subject to reactivation), and may be compressible, especially around their margins, which are typically highly disturbed and broken. The headscarp area above the landslide mass is also unstable, since it may be over-steepened, cracked, and subject to additional failures. The type of movement is generally described as follows:

- 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 gross 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 increased pore pressures, increased plasticity of weak clays, and increased 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.

Surficial Failures

Surficial failures typically occur in drainage swales and in the thick colluvial sediments and deeply weathered bedrock near the base of steep slopes. Surficial failures happen most often during particularly heavy and/or prolonged rainfall. The most common types of surficial instability are described below.

Slope creep in general involves deformation and movement of the outer soil or rock materials that cover a slope, due to the forces of gravity overcoming the shear strength of the material. Movement is imperceptibly slow and relatively continuous on moderate to steep slopes. Creep occurs most often in soils that develop on fine-grained bedrock units. Rock creep is a similar process, and involves permanent deformation of the outer few feet of the rock face resulting in folding and fracturing. Rock creep is most common in highly fractured, fine-grained rock units, such as siltstone, claystone and shale, but can also occur in igneous rocks, such as those that form the local mountains.

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 soil creep is not catastrophic, it can cause damage to structures and improvements located at the tops of slopes. Soil creep and creep of graded fill slopes is not a widespread hazard in Yucca Valley, since most soils in this area are coarse-grained and non-expansive.

Soil slip is generated by strong storms, and is widespread in steeper slope areas, particularly after winters with prolonged and/or heavy rainfall. Failure occurs on canyon

sideslopes, and in soils that have accumulated in swales, gullies and ravines. Slope steepness has a strong influence on the development of soil slips, with most slips occurring on slopes having gradients between about 27 and 56 degrees (50 to 150 percent slope) (Campbell, 1975). Slopes within this range of gradients are present in the foothills and mountains within and surrounding Yucca Valley (see Plate 2-3).

Debris flows are 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 typically occurs during an intense rainfall event, following saturation of the soil by previous rains.

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. 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 as a result of crashing into a structure (Ellen and Fleming, 1987; Reneau and Dietrich, 1987). Recognition of this hazard led FEMA to modify its National Flood Insurance Program to include inundation by "mudslides."

Watersheds that have been recently burned typically yield greater amounts of soil and debris than those that have not burned. Erosion rates during the first year after a fire are estimated to be 15 to 35 times greater than normal, and peak discharge rates range from 2 to 35 times higher. These rates drop abruptly in the second year, and return to normal after about 5 years (Tan, 1998). In addition, debris flows in burned areas can develop 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).

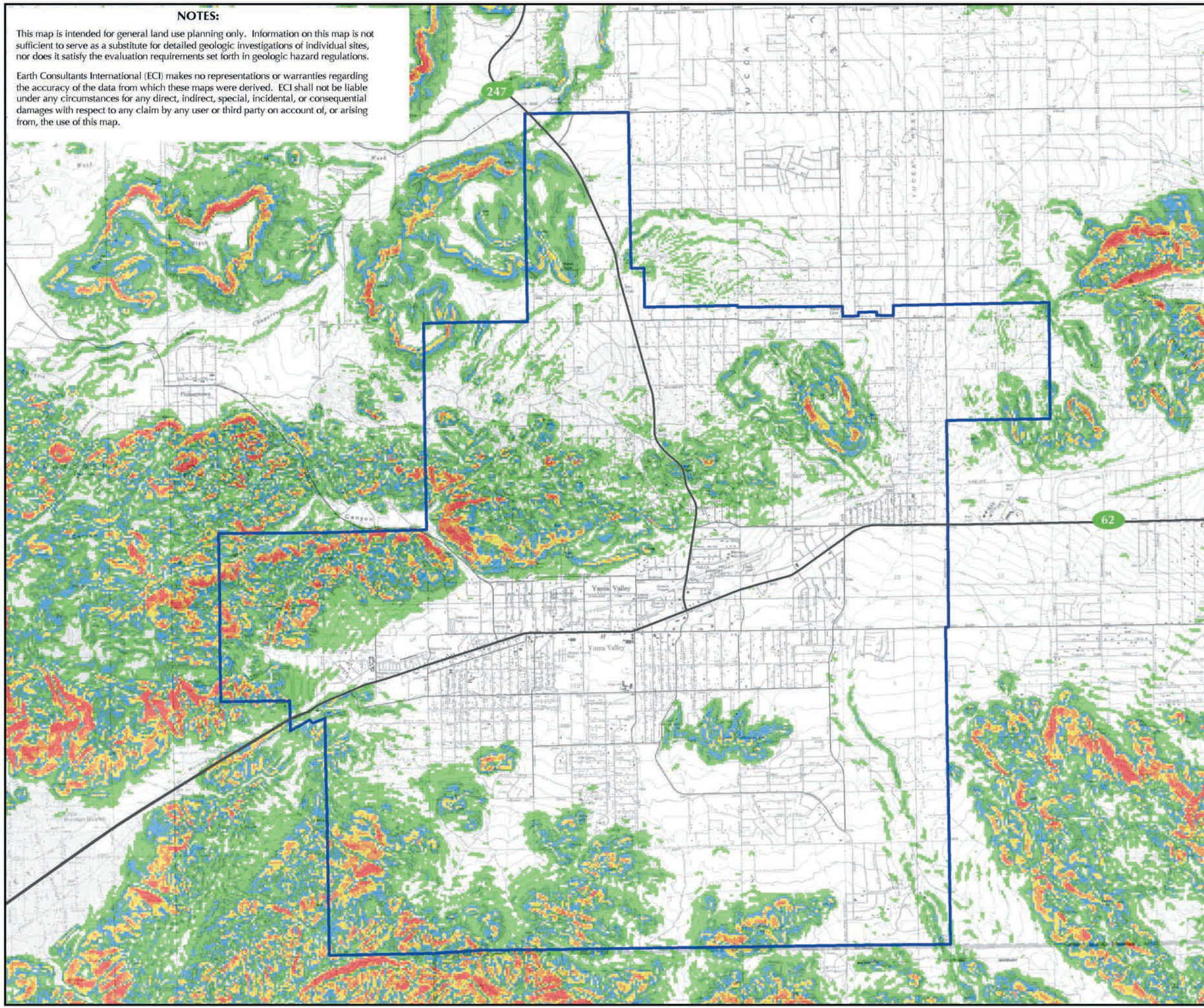
Rockfalls are free-falling to tumbling masses of bedrock that have broken off steep canyon walls or cliffs. The debris from repeated rockfalls typically collects at the base of extremely steep slopes in cone-shaped accumulations of angular rock fragments called talus. Rockfalls can happen wherever fractured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

The granitic bedrock that forms the Sawtooth and Bartlett Mountains commonly weathers into large boulders that perch precariously on slopes, posing a rockfall hazard to areas adjacent to and below these slopes. Rockfalls can occur suddenly and without warning, but are more likely to occur in response to earthquake-induced ground shaking, during periods of intense rainfall, or as a result of man's activities, such as grading and blasting.

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.



Slope Distribution Map

Yucca Valley, California

Explanation

Slope (in % grade)

- 0 to 10
- 10 to 20
- 2 0 to 30
- 30 to 40
- 40 to 50
- 50 to 60
- 60 and greater

Town of Yucca Valley Boundary

N
W E
S

0 7000 14000 Feet

0 2000 4000 Meters

Scale: 1:84,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER (1997) and Town of Yucca Valley.
Source: Derived from USGS 30m Digital Elevation Model.

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 2-3

2.4.1.2 Susceptibility to Slope Failure

Developments that encroach upon the edges of natural slopes may be impacted by slope failures. Even if a slope failure does not reach the adjacent property, the visual impact will generally cause alarm to homeowners. The natural hillsides in Yucca Valley are vulnerable to the types of slope instability mentioned above, mostly in the form of surficial failures and rockfalls. Table 2-1 below summarizes the geologic conditions in the parts of Yucca Valley 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), and internal structures within the rock (such as joints and foliation). Catalysts that ultimately allow slope failures to occur in vulnerable terrain are most often water (intense and/or prolonged rainfall), erosion and undercutting by streams, man-made alterations to the slope, and seismic shaking. For additional information on rockfall and seismic shaking see Chapter 1 – Seismic Hazards.

Table 2-1: General Slope Instability Potential within Yucca Valley

Location	Existing Geologic Conditions	Types of Potential Slope Instability
Sawtooth and Bartlett Mountains	Moderate to steep natural slopes, many in excess of 26 degrees (50% slope gradient). Fractured and faulted bedrock; soils and loose debris at the toes of slopes and in drainage courses. Locally, small to large boulders perched on slopes.	***Most Probable:*** Rockfalls and rockslides, falling boulders, soil slips, slumping of over-steepened stream banks; small to large debris flows in canyons; sedimentation at the mouths of canyons and downstream. ***Least Probable:*** Large, deep-seated landslides.
Little San Bernardino Mountains	Moderate to steep natural slopes, many in excess of 26 degrees (50% slope gradient). Fractured and faulted bedrock; soils and loose debris at the toes of slopes and in drainage courses. Foliation dipping steeply to the northwest.	***Most Probable:*** Rockfalls and rockslides, soil slips, slumping of over-steepened stream banks; small to large debris flows in canyons; sedimentation at the mouths of canyons, and downstream. ***Least Probable:*** Large, deep-seated landslides.
Burnt Mountain	Moderate to steep slopes. Although the sediments forming these hills are generally granular with massive to crude bedding, there is a localized potential for slope failure if natural slopes are over-steepened by erosion or grading operations.	***Most Probable:*** Slumps on over-steepened slopes; soil slips, small debris flows, sedimentation at the mouth of canyons. ***Least Probable***: Large, deep-seated landslides.

2.4.1.3 Mitigation of Slope Instability in Future Development

Careful land management in hillside areas can reduce the risk of economic and social losses from slope failures. This generally includes land use zoning and ordinances to restrict development in unstable areas and to preserve ridgelines, scenic vistas and unique outcrops; and grading codes for earthwork construction that include requirements for

geologic and soil engineering investigation and review, evaluation of the local drainage patterns, and where warranted, placement of engineered drainage structures. Other important factors in the mitigation of slope instability include risk assessments (which may include landslide susceptibility maps), a concerned local government, and an educated public.

Geotechnical studies should analyze any slopes that may impact the future use of a property, as well as any impact to adjacent properties. This includes existing slopes that are to remain natural, and any proposed graded slopes. The investigation may include 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 prevent excessive ground water (typically landscape water) from building up within the slope area. If it is not feasible to mitigate the slope stability hazard, building setbacks are typically imposed.

Yucca Valley has adopted the 2010 California Building Code, along with certain amendments for erosion control and the requirements for geotechnical reports. As the Town develops its own hillside ordinances, policies, and development codes, some suggested items for inclusion are:

- Develop standards and guidelines for design and construction in hillside areas based on slope steepness.
- Utilize steeper hillside areas for open space or rural, low-density development.
- Allow higher density development on the lower hillside slopes.
- Protect and preserve as much as possible existing landforms, drainage patterns, natural ridgelines and rock outcroppings, scenic vistas, and native vegetation.
- Discourage mass grading, terracing and unnatural contours.
- Encourage variety in design.
- Provide safe traffic circulation in hillside areas.
- Mitigate slope instability, erosion, and sedimentation by requiring soils reports, and where necessary, engineered drainage facilities.
- Set forth parameters for design that will retain the natural beauty of the area while protecting residents and property from slope failures and wildfires.

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 underground 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 actual field conditions, flatter gradients or shoring 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 geotechnically 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 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 buildings to areas outside of the potential debris flow path.

There are numerous methods for mitigating rockfalls. 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 re-grade the slope, however this may go against the Town's desire to protect natural outcroppings. Possible alternatives could include locally trimming hazardous overhangs. 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 the management of potential slope instability where development has already taken place. 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 improved 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 maintaining drainage devices and avoiding heavy irrigation. U.S. Geological Survey Fact Sheet FS-071-00 (May, 2000) and California Geological Survey Note

33 (March, 2004) provide public information on landslide and mudslide hazards. Both of these are available on the World Wide Web.

2.4.2 Compressible Soils

Compressible soils are typically geologically young, 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.

In Yucca Valley, compressible soils are most likely to occur where young Holocene-age deposits are present. This would generally include the modern and prehistoric floodplains of Yucca Wash and other major drainages. Compressible soils are also commonly found in hillside areas, typically in canyon bottoms, swales, and at the base of natural slopes. Although the older alluvium in the Yucca Valley area is relatively dense, the upper few feet, which are commonly weathered and/or disturbed, are typically compressible. Deep fill embankments, generally those more than about 60 feet deep, will also compress under their own weight.

When development is planned within areas that contain potentially 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. Removal and recompaction of the near-surface soils is generally the minimum that is 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 sometimes performed, followed by settlement monitoring for a number of months after additional fill has been placed, but before buildings or infrastructure are constructed. In cases where it is not feasible to remove the compressible soils, buildings can be supported on specially engineered foundations that may include caissons or piles.

2.4.3 Collapsible Soils

Hydroconsolidation or soil collapse typically occurs in Holocene-age soils that were deposited in an arid or semi-arid environment. Soils prone to collapse are commonly associated with wind-deposited sands and silts, and alluvial fan or 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.

The young alluvial sediments in the Yucca Valley area may be locally susceptible to this hazard due to their low density, granular nature, rapid deposition in the alluvial fan environment, and the generally dry condition of the near-surface soils.

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

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 valley is underlain by alluvial sediments that are composed predominantly of granular materials (silty sand, sand, and gravel). Such units typically have a low expansion potential, although pockets of fine-grained expansive soils are present within these units. Silt and clay beds within the older alluvium, although not prevalent, are potentially expansive. Argillic (secondary clay from weathering) soil profiles that have developed on the older fan deposits probably fall in the moderately expansive range. The rock units in Yucca Valley are generally not expansive, except where they have been chemically altered (by natural processes), are very weathered, or contain clayey sheared zones. 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.

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 geotechnical 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 Corrosive Soils

Corrosive soils can, over time, cause extensive damage to buried metallic objects, commonly impacting such things as buried pipelines (such as water mains), and even affecting steel elements within foundations. The electrochemical and bacteriological processes that take place between the soil and the buried structure are complex and depend on a number of factors involving the structure type and certain soil characteristics. For instance, the type, grade, length, and size of the piping, as well as the materials used in

pipe connections, can determine which electrochemical reactions will take place in differing soils. For soils, the most common factor used in identifying the potential for corrosion is electrical resistivity. Soils with low resistivity are especially susceptible to corrosion reactions. Other soil characteristics that increase the risk of corrosion to metals are low pH (acidic soils), wet soils, high chloride levels, low oxygen levels, and the presence of certain bacteria.

Soils with high concentrations of soluble sulfates are not directly corrosive to metals, however the presence of sulfate-reducing bacteria in the soil may cause sulfates to convert to sulfides, which are compounds that do increase the risk for corrosion. If the concentration of soluble sulfates is high enough, the soil will be corrosive to concrete.

Corrosion testing is an important part of geotechnical investigations. Onsite soils, as well as any imported soils, are typically tested in the laboratory for resistivity, pH, chloride, and sulfates. For treatment of high sulfate content, special cement mixes and specified water contents are typically used for concrete that will be in contact with the soil. For corrosion of metals, there are a number of procedures used to protect the structure, including cathodic protection, coatings such as paint or tar, or wrapping with protective materials. As mentioned above, the corrosion processes are complex; consequently, the site-specific recommendations must be provided by an engineer who is a corrosion specialist.

2.4.6 Land Subsidence due to Groundwater Withdrawal

Land 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 subsidence has been reported (such as the Coachella Valley and the Mojave Desert), this phenomenon is usually associated with the extraction of groundwater from below the surface in sediment-filled valleys and floodplains. Land subsidence can also occur during a moderate to major earthquake in the region (see Chapter 1 – Seismic Hazards).

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 due to the overdraft of groundwater supplies can also result in the permanent loss of aquifer storage capacity (Sneed and others, 2003).

In the Mojave region, groundwater occurs in sediment-filled basins that are floored by crystalline rock, and bounded by faults or various types of impervious rock – all of which act as barriers to groundwater movement. For the most part, natural groundwater replenishment (recharge) in the aquifers occurs by infiltration of stormwater runoff that percolates through the alluvial sediments. During the early years of population growth in the high desert, the rate of groundwater extraction exceeded the natural replenishment, resulting in declining water levels and overdraft of the groundwater supply in more densely populated areas, including Yucca Valley. Since then, overdraft has been greatly reduced in many of the affected areas by careful management of local water supplies, including

reducing pumping of local wells, importing water, and the use of artificial recharge (Johnson, 1998; Stewart and others, 1998, California Regional Water Quality Control Board, 2010).

Because surface water is scarce, Yucca Valley, like many other high desert communities, relied entirely on groundwater from the underlying aquifers for their domestic supply since the early 1900s to the mid 1990s. The main sources of Yucca Valley's water supply are wells in the northern part of the Warren Valley Groundwater Basin. This basin underlies the Town's alluvial area south of the Pinto Mountain fault zone. The Warren Valley Basin was in a state of overdraft for many years, with water levels in some areas dropping as much as 300 feet between 1940 and 1994. This condition led a to court ruling in 1977 to establish groundwater extraction rights. Since 1995, recharge sites (percolation ponds) located in the Yucca Valley region receive water from the California Aqueduct via the Morongo Basin Pipeline, and water levels in the Warren Valley Basin have recovered significantly. Further, excess imported water can be "banked" in the local aquifer during wet years, thereby increasing the reserves for dry years when local and State Water Project supplies may be limited. A significant amount of recharge to the Warren Valley Basin is also supplied by irrigation and septic system return flows that percolate back into the ground (Kennedy/Jenks, 2011).

Groundwater is distributed to the community by the Hi-Desert Water District (HDWD). The HDWD service area includes Yucca Valley and the unincorporated area to the north called Yucca Mesa. The District currently has thirteen active production wells, 16 storage tanks, about 12.66 million gallons of tank storage capacity, and nearly 300 miles of distribution pipelines, serving a population of about 24,000. All but one of their wells are located in the Warren Valley Basin. In addition to the District wells, there are currently two commercial businesses extracting water from the Basin and 16 individual minimal producers (HDWD, 2012). The HDWD also owns and operates the area's three recharge ponds.

2.4.6.1 Subsidence in Yucca Valley

Recognizing the potential for declining water levels to induce or renew land subsidence, the United States Geological Survey (USGS), in cooperation with the Mojave Water Agency (MWA), has been conducting geologic and hydrologic studies in portions of the high desert region, including the detection and measurement of subsidence (Sneed and others, 2003; Stamos and others, 2009). Four locations within their study area showed minor subsidence during the study period of 1992–1999, although the subsidence could not be tied definitively to groundwater levels, due to insufficient groundwater data. However, during the time that measurements were recorded, groundwater levels in these areas were at or below historically low levels. In 2009 the USGS reported that ground deformation, mostly subsidence, occurred in the same four areas for time intervals between 1999 and 2000, and between 2003 and 2004. The USGS continues to monitor these areas, but has not yet published their latest results. The closest of the known subsidence areas to Yucca Valley is Lucerne Valley, approximately 35 miles to the northwest.

To date, subsidence has not been reported in Yucca Valley. However, the thick alluvial deposits comprising these aquifers may be susceptible to compaction (with resulting

subsidence at the surface) should rapid groundwater withdrawal occur beneath the area in response to the water needs of the Town's growing population.

2.4.6.2 Prevention of Subsidence

Prevention of ground subsidence, while insuring a low-cost, sustainable supply of quality water for the future, requires a comprehensive approach to groundwater conservation and recharge. To that end, the following elements will promote, either directly or indirectly, the prevention of ground subsidence:

- Continue to increase the understanding of the geology, hydrology, and hydraulic control within and between the local groundwater basins. To help achieve that end, the Mojave Water Agency has developed a searchable digital database of maps, publications, reports, and updated information about their current research regarding the geology and hydrology of the high desert area (http://ca.water.usgs.gov/mojave/).
- Determine the safe yields of groundwater basins so that available supplies can be balanced with extraction.
- Increase natural recharge by developing spreading basins to capture and percolate stormwater runoff. In rural areas, individual property owners should be encouraged to collect stormwater in rain barrels or cisterns.
- Water recycling. At the current time, the HDWD does not recycle water. At a minimum, the Town should consider requiring developers of new or redeveloped commercial and multi-unit projects to install dual water systems in order to accommodate future recycling should it become available.
- Continue to monitor the groundwater levels in both HDWD wells and available private wells.
- Monitor ground elevations in areas where groundwater levels are decreasing.
- Minimize adverse land use effects on the supply and quality of the local groundwater. For example, there is currently no community-wide sewage treatment and disposal system in Yucca Valley. Wastewater is discharged to individual septic tanks and leaching systems. This is thought to contribute to high concentrations of nitrate locally in groundwater wells of the Warren Valley Basin (Nishikawa and others, 2003). As a consequence, the California Regional Water Quality Control Board - Colorado River Basin Region, has recommended a septic prohibition for parts of Yucca Valley (2010) and adopted the prohibition in the form of an amendment to the Basin Plan for the Colorado River Basin Region (2011). The HDWD has developed a plan for a centralized sewer collection and wastewater treatment facility. Treated water would be returned to Warren Valley Basin aquifer. See Chapter 5 – Hazardous Materials Management for further information on this plan.
- Continue to encourage water conservation and protection of water quality through public education and water conservation programs.
- Many of these basin management objectives, as well as others, are outlined in the HDWD 2010 Urban Water Management Plan (Kennedy/Jenks, 2011).

The HDWD has already implemented several water saving programs, including discouraging the wasteful use of water, and providing public information on water conservation, desert landscaping, and resource management. Information on these programs is available on the HDWD website at http://www.hdwd.com/Education.

According to the HDWD's 2010 Urban Water Management Plan (Kennedy/Jenks, 2011), the District currently has water supply capabilities to meet daily demands as well as future demands into the year 2035, even for multi-dry years. This supply includes local groundwater, future imported water allotments, and imported groundwater currently banked in the Warren Valley Basin aquifer. In addition, the HDWD has contingency plans for long-term and short-term shortages, and catastrophic interruption in services due to regional power outages or earthquakes, for example.

Consequently, for the entire Yucca Valley region, meeting future demands will require aggressive water management, the development of wastewater treatment where groundwater is impaired, the continued development of new water sources, continuing public education, the widespread use of native desert plants in landscaping, and the implementation and enforcement of stringent water conservation measures.

2.4.7 Erosion and Sedimentation

Erosion and sedimentation are influenced by several factors, including topography, rock and soil types, climate, and vegetation. The topographic relief between the desert and the adjacent mountains makes erosion and sedimentation an important issue for communities built on alluvial fans and within hillside areas. The fractured and weathered condition of the bedrock forming the mountains, combined with rapid geologic uplift leads to high erosion rates. Further, erosion can increase significantly when mountain slopes are denuded by wildfires.

Sediments forming the alluvial fans in Yucca Valley are typically dry, loose, and sandy, resulting in a high susceptibility to erosion, particularly of the youngest, unconsolidated materials. Flooding due to infrequent but violent thunderstorms can result in severe erosion, especially if flows are concentrated. Thunderstorms that follow a season of mountain wildfires can transport great volumes of sediment onto the low-lying areas below.

The natural erosion processes mentioned above are often accelerated through man's activities – whether they are for agricultural or land development uses. Development often increases the potential for erosion and sedimentation by removing protective vegetation, altering natural drainage patterns, and constructing cut and fill slopes that may be more susceptible to erosion than the original, natural slope conditions. Developments also reduce the surface area available for infiltration, leading to increased runoff and erosion downstream of the project.

Because man-made flood control structures are scarce, and most runoff travels throughout the Town in natural washes and gullies or by sheet flow, erosion is a significant hazard in Yucca Valley. New developments should not be placed where they obstruct natural flows, or direct flows to neighboring properties. Homes on natural slopes should not be

permitted at the head of steep drainage channels or gullies without protective measures against headward erosion of the gully. Buildings placed near the base of slopes and/or near the mouths of small canyons, swales, washes, and gullies will need protection from sedimentation. Developments in the valley that are adjacent to natural drainage channels should be adequately set back from eroding channel banks. Alternatively, modification of the channel to reduce erosion should be included in the project design.

Mitigation of erosion and sedimentation typically includes structures to slow down stream velocity, such as check dams and drop structures, energy dissipaters at the point of discharge, devices to collect and channel the flow, catchment basins, and berms. Interceptor ditches, swales, and slope down-drains are commonly lined with asphalt or concrete, however ditches can also be lined with gravel, rock, or decorative stone. Elevating structures above the surrounding area is another mitigation measure used often. Homes can be constructed on short piles or columns, such that the home is elevated a foot or two above the ground. Along with the minimal alteration of the land's natural contours, this not only protects the home from flooding and sedimentation, but also allows natural drainage patterns to continue largely uninterrupted.

There are many options for protecting manufactured slopes from erosion, such as terracing slopes to minimize the velocity attained by runoff, the addition of berms and v-ditches, and installing adequate storm drainage structures. Other measures 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 by the use of berms or walls. All hillside building pads should be engineered to prevent water from flowing over the tops of slopes.

Temporary erosion control measures must be provided during the construction phase of a development, as required by local building codes and ordinances, as well as State and Federal stormwater pollution regulations (see Chapter 5). In addition, permanent erosion control and clean water runoff measures are required for new developments. These measures might include desilting basins, percolation areas to cleanse runoff from the development, proper care of drainage control devices, appropriate irrigation practices, rodent control, temporary and permanent plantings, and mulching. 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.

2.5 Summary of Issues

The Yucca Valley area is highly diverse geologically. This diversity is strongly related to the youthful (in geologic terms) seismic setting of the surrounding region, which includes the ongoing uplift of the surrounding mountains – a result of tectonic movement along the Pinto Mountain fault and other major fault zones. This, along with the local climate, geology, and hydrology, has resulted in a landscape that is complex in geologic processes. These elements combine in various ways to create geologic hazards, as well as benefits to the community. Hazards that have the greatest impact on the Yucca Valley are summarized below.

Most of Yucca Valley's existing development is situated on the broad valley floor, with scattered residential development in the surrounding hillsides. As Yucca Valley's population grows in the next decades, new development will be needed to meet the demand for homes. When meeting this demand, it is imperative to manage land uses in a responsible way, as development disrupts natural processes, often leading to negative impacts on the environment as well as on the development and adjacent properties. The impacts of land development can be minimized, however, if both site-specific and regional planning elements are recognized and considered, the project incorporates knowledge gained from scientific research in developing and implementing a design appropriate to the area, and protective measures are constructed and maintained for the lifetime of the project.

Slope instability is a potential hazard where development has encroached onto the hills and mountains. The rock types forming the local mountains are generally resistant to deep-seated landsliding, so future slope failures are more likely to consist of surficial soil failures and the erosion of sandy geologic materials. Such failures typically occur during exceptional and/or prolonged rainfall, and may manifest as mud or debris flows. Large debris flows may impact properties in the valley downslope, sometimes at considerable distance from the source. Rockfall is a hazard in and near the base of the Sawtooth and Bartlett Mountains, in areas where the bedrock forms bouldery outcrops. Rockfall is more likely to occur as a result of earthquake-induced ground shaking, posing a threat to structures and passing motorists.

Potentially compressible and/or collapsible soils underlie a significant part of Yucca Valley, typically where geologically sediments have been deposited, such as active or recently active alluvial fans, floodplains, washes, and canyon bottoms. These sediments generally have low density and variable amounts of organic materials. Under the added weight of fill embankments or buildings, these sediments can settle, causing distress to improvements.

Although not prevalent, some of the geologic units in Yucca Valley may have fine-grained components that are likely to be expansive. These materials may be present at the surface or may be exposed by grading activities. Man-made fills can also be expansive, depending on the soils used to construct them.

Sediments in the valley areas may be corrosive to metallic objects, such as pipelines, that are in contact with the soil. All foundation soils and soils used to bury metal pipelines should be tested for corrosion potential; if and where necessary, mitigation measures developed by a corrosion engineer should be implemented during the construction of these works.

Regional ground subsidence from groundwater withdrawal is a potential hazard that can proactively be prevented by aggressive water management, the reuse of treated wastewater, the continued development of new water sources, continuing public education, the widespread use of drought-tolerant plants in landscaping, and the implementation and enforcement of stringent water conservation measures, especially during droughts. The Town should also consider requiring new subdivisions or commercial developments to install the infrastructure for water recycling, so that these sites can be connected to recycled water mains as they become available. With the expected increase in population, water shortage is one of the most serious challenges ahead.

Overdraft of the aquifers underlying Yucca Valley could result in ground subsidence, with resultant negative impact on the area's environmental quality.

Because of the topographic relief in and around Yucca Valley, erosion and sedimentation are inherently significant elements of the natural setting. Land development can have adverse impacts on these elements by altering the natural processes, topography, and protective vegetation, in addition to reducing the area of natural infiltration. This in turn can lead to damage from increased flooding, erosion, and sedimentation in other areas, typically downstream. Erosion and sedimentation are also important considerations on a site-specific basis, with respect to developments adjacent to slopes and drainage channels. These issues are not only critical during the design of a project, but also during construction and during the long-term maintenance of the developed site.

Losses resulting from geologic hazards are generally not covered by insurance policies, causing additional hardship on property owners. The potential for damage can be greatly reduced by:

- Strict adherence to grading ordinances – many of which have been developed as a result of past disasters;
- Sound land planning and 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 infrastructure;
- Effective geotechnical and design review of projects performed by qualified, California-registered engineering geologists, soil engineers, and design engineers; and
- Public education that focuses on reducing losses from geologic hazards, including the importance of proper irrigation and landscaping practices, in addition to the care and maintenance of slopes and drainage devices.

CHAPTER 3: FLOOD HAZARDS

Floods are natural and recurring events that only become hazardous when man encroaches onto alluvial fans and floodplains, modifying the landscape and building structures in the areas meant to convey excess water during floods. Unfortunately, these areas have been alluring to populations for millennia, since they provide level to gently sloping terrain, have fertile soils suitable for agriculture, and have 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 natural hazard. Furthermore, average annual flood losses (in dollars) have increased steadily over the last decades as development in flood-prone areas has expanded.

Yucca Valley and the 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 results in flooding. Historic flood events in southern California have resulted in an increased awareness of the potential for public and private losses as a result of this hazard, particularly in urbanized parts of floodplains and alluvial fans. As the population in the area increases, there is increased pressure to build on flood-prone areas, and in areas upstream of previously developed land. With increased development also comes an increase in impervious surfaces, such as concrete and asphalt. Water that used to be absorbed into the ground becomes runoff to downstream areas. New construction can also block or divert natural flow patterns, causing flooding and erosion to areas that have not flooded in the past. This is especially true for developments near the base of the mountains and downstream from canyons that have the potential to convey mudflows.

3.1 Storm Flooding

3.1.1 Hydrologic and Geomorphic Setting

The Town of Yucca Valley is located at the western edge of the Mojave Desert, an arid region with hot summers, cool winters, and infrequent, but potentially violent rainstorms. The southern part of the Town consists largely of a gently sloping alluvial plain shaped by a combination of sediments deposited by floodwaters emerging from canyons in the nearby mountains, and by past flooding of the valley's main drainage course, the Yucca Wash. North of Yucca Wash, the rugged, rocky, Sawtooth Mountains divide the southern valley from volcanic hills and sparsely populated alluvial fans in the northernmost part of the Town. The Little San Bernardino Mountains frame the Town on the south, where they exert tremendous influence on the local climate, and ultimately, on the flood hazard in Yucca Valley.

Yucca Valley has no perennial rivers or streams. When a storm arrives, the normally dry rocky canyons of the adjacent hills and mountains disperse runoff into broad desert washes or onto alluvial fans and plains – all of which are laced with a complex and dynamic drainage network that ultimately terminates in desert playas several miles to the east and northeast of the Town. Drainage channels in the local mountains are well incised; however, they lose their strong definition upon reaching the alluvial plain, where sediment-laden water is carried in shallow washes and by sheet flow. Drainage channels

that are dry most of the year can quickly become dangerous torrents of water, sand, mud and rocks, capable of transporting boulders, trees, and even cars.

The valley in the southern part of the Town receives runoff from small to very large canyons in the Little San Bernardino Mountains. These canyons disperse floodwaters into numerous washes crossing the valley, including Covington Wash, East and West Burnt Mountain Creeks, Long Canyon, and Hospital Canyon, as well as smaller unnamed drainages – all having the potential to carry flash floods into the most densely populated parts of the Town. Several large drainages emerge from the southern flank of the Sawtooths as well, including Pinon Creek and Water Canyon. Runoff from mountains to the north and south of the valley is collected in the east-flowing Yucca Wash, the main drainage channel. North of the Sawtooths, stream channels also flow eastward, either passing through the gap between the Sawtooth and Bartlett Mountains to Yucca Wash, or continuing eastward north of the Bartlett Mountains.

Floods on alluvial fans have characteristics that are significantly different from those caused by river flooding. Although typically shallow in depth, flows can strike with little warning, travel at very high speeds, and carry tremendous amounts of sediment and debris. The Federal Emergency Management Agency (FEMA) defines an active alluvial fan flood hazard based on three related criteria: 1) unpredictable flow paths; 2) abrupt deposition and erosion; and 3) an environment where the combination of sediment availability, slope, and topography creates an ultra-hazardous condition. The active portions of the fan generally have shallow, braided stream channels, and sparse vegetation. FEMA also defines an inactive alluvial fan surface as one that has relatively stable flow paths and a low level of sedimentation/erosion such that it does not cause instability in the established flow paths. Inactive surfaces usually have some soil development as well as incised, typically single-strand channels that behave more like rivers during floods. At their downstream margins, fans merge with the flatter topography of the valley floor.

Alluvial fans, including those in Yucca Valley, are highly diverse because of variations in geology, vegetation, topography of the source area, climate, tectonism (fault movements), and land uses. A particular fan may show characteristics of both active and inactive processes, especially if it has been modified by man-made structures. Therefore, it is generally not reasonable to assume that the flood risk on a fan surface is uniform. Furthermore, these characteristics make realistic assessments of flood risk and development of reliable mitigation measures particularly challenging.

3.1.2 Weather and Climate

The mountains that frame the Mojave Desert have a powerful effect on the climatic conditions in the high desert region. Capturing precipitation from strong Pacific storms that pass through, the mountains separate the semi-arid environment to the west from the dry, desert regions to the east. Most precipitation in southern California occurs in the winter months, between November and April. However, high-intensity, short-duration tropical thunderstorms arriving from the south can occur during the summer and fall, typically during July through September. Flash flooding associated with these powerful storms frequently results in damage to roadways, power poles, trees, and structures. These storms are highly localized, drenching one area with several inches of rain in a short period of time, while leaving nearby areas completely dry. Mountain thunderstorms can inundate

the adjacent desert areas with floodwaters, mud, rock and debris, even if no rain actually falls on the desert.

Not only does rainfall vary from one location to the next, often within short distances, it is also extremely variable from year to year. The average yearly precipitation (often informally referred to as the "normal" amount) in the Yucca Valley area is less than 10 inches, as measured over several decades (see Tables 3-1 and 3-2). The concept of "normal" is deceiving however, as the annual rainfall in a single year can range from almost none to nearly four times the average amount. In fact, in the high desert areas, it is not unusual to receive half the yearly average amount in a single storm, and sometimes within a few hours.

Table 3-1: Average Annual Rainfall* by Month for the Twentynine Palms Weather Station (elevation: 1,975 feet above mean sea level)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	0.5	0.3	0.4	0.1	0.1	0.0	0.6	0.7	0.4	0.3	0.3	0.5	4.3

Data based on 55 complete years between 1935 and 1995.
Source: http://www.worldclimate.com/
*Average rainfall = Mean monthly precipitation, including rain, snow, hail, etc.

Table 3-2: Average Annual Rainfall* by Month for the Morongo Valley Weather Station (elevation: 2,562 feet above mean sea level)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	2.1	1.1	1.1	0.5	0.1	0.0	0.4	0.3	0.3	0.2	1.1	1.7	9.0

Data based on 26 complete years between 1942 and 1972.
Source: http://www.worldclimate.com/
*Average rainfall = Mean monthly precipitation, including rain, snow, hail, etc.

Most flood damage is from winter storms, but it is often a consequence of flash flooding from intense summer thunderstorms as well, as described below. The hazards associated with these storms, other than flooding, which is covered in this section, are discussed in more detail in Chapter 6.

Winter storms are characterized by heavy and sometimes prolonged precipitation over a large area. These storms usually occur between November and April, and are responsible for most of the precipitation recorded in southern California. The storms originate over the Pacific Ocean and move eastward (and inland). Mountain ranges, such as the San Bernardino Mountains, form a rain shadow, slowing down or stopping the eastward movement of this moisture. A significant portion of the moisture is dropped on the mountains as snow. If large storms are coupled with snowmelt from these mountains, large peak discharges can be expected in the main watersheds at the base of the mountains.

Some of the severe winter storm seasons that have historically impacted southern California have been related to El Niño events. El Niño is the name given to a

phenomenon that originates every few years, typically in December or early January, in the southern Pacific Ocean, off the western coast of South America, but whose impacts are felt worldwide. Warmer than usual water in the southern Pacific is statistically linked with increased rainfall in both the southeastern and southwestern United States (including the desert areas), droughts in Australia, western Africa and Indonesia, a reduced number of hurricanes in the Atlantic Ocean, and an 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 following year. Often a water year is identified only by the calendar year in which it ends, rather than by giving both years, as above.] In recent history, these are two of the worst storm seasons in southern California.

More recently, the 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 California. Because it passes over the Hawaiian Islands, it is commonly referred to as the "Pineapple Express." In December 2004, as 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 southern California, including the high desert, record-breaking rainfall in the 2005 water year.

Monsoon storms typically develop in late summer to fall, and are usually most prevalent in the higher mountains and the deserts, but can also move into nearby valleys. They develop when moist, unstable air moves into our area from Mexico through Arizona (Mexican monsoons), from the Sea of Cortez (Gulf Surge), or at times from tropical storms or hurricanes originating off the coast of Baja California. Once the monsoonal moisture enters California and flows up steep mountain slopes, explosive thunderstorms can develop. Although these high-intensity, short-duration storms typically impact relatively small areas, they often release torrential rainfall that causes flash flooding and mudslides. Frequently packing lightning, hail, very strong wind gusts, and even small tornadoes, thunderstorms cause power outages and damage to people and property. Such storms have impacted Yucca Valley and the surrounding area in the past.

During the late 1800s and 1900s (the approximate length of historical records), the overall climate in the Mojave Desert has fluctuated as well. For instance, from about the turn of the 20th century until 1946, the region experienced wetter than usual winters. From 1947 to 1976, there was a drought, and from 1977 to 1998, there was higher-than average rainfall. Between 1999 and 2004, the region saw below-average rainfall, suggesting that another drought period has begun (Brooks and Minnich, 2006). Scientists believe these climatic changes in the desert are ultimately related to changes in ocean-surface water temperatures and atmospheric pressure in the eastern Pacific. Even small changes in climate are important in the desert ecosystem because they ultimately affect sediment yield, frequency of runoff (floods), recharge of shallow aquifers, vegetation density, fire

frequency and intensity, and the landscape's ability to recovery from man-made disturbances (Hereford and Longpre, 2009).

Much research in the last decade has focused on the study of a meteorological phenomenon called the ***Atmospheric River*** (AR). ARs are narrow streams of water vapor transported in the lower atmosphere that are probably responsible for most of the very large storms on the west coast of the United States. Typically packing high wind speeds, ARs are no more than 400 to 500 kilometers wide, but are thousands of kilometers long, sometimes extending across whole ocean basins. When ARs traveling across the Pacific Ocean collide with the mountain ranges in the west coast, the vapor is forced upwards, where it condenses and rains out, leading to significant flooding (Ralph and Dettinger, 2011).

The U.S. Geological Survey's Multi Hazards Demonstration Project (MHDP) has been combining various science disciplines to test and improve the resiliency of communities to natural disasters. By developing a disaster scenario (such as the 2008 ShakeOut Earthquake Scenario discussed in Chapter 1) scientists, engineers, and other experts are engaging emergency planners, first responders, businesses, universities, insurance companies, government agencies and the public in preparing for a major natural disaster. The second major project of the MHDP is a catastrophic winter storm scenario consisting of a hypothetical (but not unrealistic) Pacific storm striking the west coast of California, similar in intensity to the 1861-1862 series of storms that resulted in state-wide flooding that left the central coast impassible, the capital underwater for three months, and the State bankrupt. Named the ***ARkStorm*** (for Atmospheric River 1,000), the impacts of such a storm today are expected to overwhelm the State's flood protection system, which is normally designed to control the 100- to 200-year storm runoff. Property damages and business disruptions from the ARkStorm are estimated to be on the order of $725 billion, nearly three times the loss expected for the hypothetical southern California ShakeOut earthquake (Porter and others, 2011). The USGS report indicates an ARkStorm is not only plausible, but probable, and may not be a worst case. The geological record suggests that six megastorms have occurred in California in the last 1,800 years – all more severe than the 1862 event. The products of the ARkStorm Scenario are intended to be used by emergency planners, policymakers and other to review disaster preparedness, conduct risk assessments and disaster drills, explore ways to adequately fund response and recovery, plan future hazards mapping, and educate the public.

Although ARkStorm flooding in the high desert is predicted to be less severe than in southern California coastal areas, Yucca Valley would be impacted by shallow landsliding in the local hills and mountains. Much of the damage in Yucca Valley would likely be from alluvial fan flooding and debris flows. Additional information on this megastorm scenario can be obtained from http://pubs.usgs.gov/of/2010/1312/.

3.1.3 Past Flooding

Because of the arid climate and dry washes, the casual visitor might be surprised to learn that desert environments such as those in Yucca Valley are the sites of infrequent but catastrophic flooding. Even residents often quickly forget about the flood risk once the streets are cleared of debris and dry weather returns. The flood hazards in Yucca Valley can be classified into two general categories: 1) flash flooding down natural and man-

made channels, and 2) sheet flooding across the alluvial fans, plains, and valleys upon which most of the development in the Town currently lies.

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 (man-made structures). The local mountains are steep, sparsely vegetated, and consist of rock types that are fairly impervious to water. Consequently, little precipitation infiltrates the ground. When a major storm moves in, water collects rapidly and runs off quickly, making a steep, rapid descent from the mountains onto the valley floor. Because of the steep terrain, and the constant shedding of debris from mountain slopes (primarily as dry ravel and rock falls), flood flows often carry large amounts of mud, sand, and rock fragments. Sheet flow occurs when the capacities of the existing channels (either natural or man-made) are exceeded or when channels become blocked, causing water to flow into the adjacent areas.

Historical descriptions suggest the flood of 1862 was probably the largest recorded event in southern California, although very little data on discharge or rainfall rates are available for that year. During the last century, one of the most disastrous southern California storm periods on record occurred during February 27 to March 4, 1938, when a series of strong storms centered over the San Gabriel and San Bernardino Mountains unleashed record-breaking rainfall in areas already saturated by previous storms. Many high desert communities were isolated as roads and bridges were destroyed, and hundreds of people were left homeless (San Bernardino County Flood Control District, 2006). Stream gages on rivers emanating from the mountains, including the Mojave River, logged record discharges, and losses were estimated at more than $78 million (1938 dollars) due to the extensive development that had taken place on the floodplains of major rivers (Troxell, 1942). Prior to 1938, citizens had already developed an awareness of the need for flood control and water conservation, however the 1938 floods made it clear that growing cities in the region did not have adequate flood protection. This led to the formation of new flood control districts in San Bernardino and Riverside counties, as well as other areas of southern California.

In January and February of 1969, a series of closely spaced, intense storms in the mountains again released heavy rainfall on saturated ground. Total precipitation in the San Bernardino Mountains (Lake Arrowhead rain gage) reached more than 80 inches for the two-month period. As a result, storm flows in the Mojave River reached all the way to Soda Lake, causing heavy damage to highways, bridges, and properties. Erosion of stream banks, channels, and flood plains, as well as the deposition of sediment was severe (Waananen, 1969). Many desert areas had flooding up to 2 feet in depth, with resultant damage to homes, streets, and utilities (FEMA, 2008).

Intense rainfall and damaging floods also occurred in January 2005. The western part of the Morongo Basin (Yucca Valley) was the hardest hit, as roadways were washed out or buried by sand and mud, and extensive damage to structures occurred. Communities to the east of Yucca Valley escaped serious damage from the storm, but were temporarily isolated due to access to the west being cut off.

Figure 3-1: Yucca Valley's Dry, Arid Landscape is Deceiving.
Flash floods can rapidly inundate major roadways with water and debris, cutting off access temporarily to residents and emergency personnel.

Southern California's winter storms generally impact a wide area, including parts of the Mojave Desert, and the events described above are some of the most severe winter storms on record. However, significant flood damage in Yucca Valley area occurs during summer thunderstorms that tend to be localized, but of high intensity. Just in the last decade, flood damage from summer storms has resulted in major road closures due to washouts or inundation by rocks, mud, sand, and debris, power outages, uprooted trees, and structure damage from wind and water. The toll on residents includes injuries from traffic accidents, vehicles stranded by or trapped within mud or swift-moving water, and temporary isolation due to road closures. One of the worst incidents occurred during August 2003, when a car was swept into a flooded channel, just east of Yucca Valley, killing two of the occupants and a rescuer. The consequences of flooding are therefore emotional and social, as well as financial and environmental.

3.1.4 National Flood Insurance Program (NFIP)

Because floods are the leading cause of natural disaster losses in the United States, the nation invests significant resources to reduce the risk of flooding. Because floods can be widespread and cause catastrophic losses, insurance companies generally consider flood hazards too costly to insure (National Research Council, 2009). In order to manage the increasing flood losses, the Federal Emergency Management Agency (FEMA) was mandated by the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 to evaluate flood hazards and provide affordable flood insurance to residents in communities that regulate future floodplain development. To that end, FEMA created

Flood Insurance Rate Maps **(FIRMS)** for the purpose of setting flood insurance premiums and for regulating the elevations and flood proofing of structures in mapped flood zones.

The National Flood Insurance Program (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. Floodplain management may include such measures as requirements for zoning, subdivisions, and building construction, as well as special-purpose floodplain ordinances. 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, and managing their erosion hazard.

The Town of Yucca Valley has participated as a regular member in the NFIP since 1997 (Community ID No. 060750#), and the required floodplain regulations are set forth in Chapter 8.04 of the Yucca Valley Town Code. The Town's most current effective FIRM maps are dated August 2008 (six community panels), however maps and flood elevations are amended periodically to reflect changes in estimated flood zones.

Because Yucca Valley is a participating member of the NFIP, flood insurance is available to any property owner in the General Plan area. In fact, to secure financing to buy, build, or improve structures in a Special Flood Hazard Zone (SFHZ – see definition below), 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 SFHZ and must provide written notice requiring flood insurance.

FEMA recommends that most property owners, whether residential or commercial, purchase and keep flood insurance, even if they are not located in a mapped flood hazard zone. Keep in mind that approximately 20 to 25% of all flood claims occur outside of mapped high flood risk areas, and typical homeowner or business insurance policies do not cover flooding. Residents or business owners that rent property can also purchase coverage for the contents of their homes or business inventories. In low to moderate risk areas, property owners should ask their agents if they are eligible for the FEMA Preferred Risk Policy, which provides inexpensive flood insurance protection. Insured property owners can be reimbursed for all covered losses, even if the flood is not officially declared a Federal disaster area. Residents should also be aware that localized flooding could be caused by a temporary situation, such as a storm drain inlet or culvert that becomes blocked by debris during a storm. Hillside areas are generally outside of mapped flood zones, however these areas can be vulnerable to mudslides, which are also covered under flood insurance.

FEMA also recommends that residents do not forgo purchasing insurance, assuming instead Federal disaster assistance will pay for flood damage. In order to receive assistance, a community must first be declared a Federal disaster area, and these declarations are issued in less than 50% of flood events. Remember also that Federal assistance is usually in the form of a loan, which must be repaid with interest. Furthermore, if uninsured property

owners do receive Federal assistance, they must purchase flood insurance to remain eligible for future disaster relief.

3.1.5 FEMA Flood Zone Mapping

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. For riverine flooding, the extent of potential flooding is predicted from statistical analyses and hydrologic models that rely heavily on data from U.S. Geological Survey stream gages and land surface topography.

Some FEMA flood map features that are relevant to the residents of the Yucca Valley area include:

Flood Insurance Study (FIS). 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. The Yucca Valley General Plan area is included in the FIS for San Bernardino County, currently updated in August 2008. This document includes community descriptions, flooding sources (including Yucca Wash), information on historical flooding, existing flood protection measures, hydrologic and hydraulic analyses, and definition of potential flood areas.

Special Flood Hazard Area (SFHA). Using information gathered in FIS studies, FEMA engineers and cartographers delineate Special Flood Hazard Areas on FIRMs. SFHAs are those areas subject to a high risk of inundation by a "base flood" which FEMA sets as a 100-year flood. As mentioned above, SFHAs are regulated zones, requiring the mandatory purchase of flood insurance. They are also subject to special standards and regulations that apply to new construction, and in some cases, existing buildings. Floodplain regulations required by the NFIP apply only to properties located in a SHFA. However, these are minimum requirements, and local jurisdictions may regulate areas outside of the SHFAs, based on knowledge specific to their area.

Base Flood. The base flood, also called the 100-year flood, is defined by looking at the long-term average period between floods of a certain size, and identifying the size of the flood that has a one (1) percent chance of occurring during any given year. This base flood has a 26% 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 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 preserving and restoring the natural and beneficial value of the floodplain.

Base Flood Elevation (BFE). This is the calculated elevation of the water surface during a base flood event. The BFE is important because it is the regulatory standard used for the elevation or flood proofing of structures. Further, the height of the first floor elevation above the BFE determines the amount of the flood insurance premium. BFEs are shown on FIRMs for those flooding sources that have been analyzed using detailed methods. BFEs on the maps have been rounded to whole-foot elevations and are intended for use in flood insurance rating purposes only. For construction or floodplain management, data in the FIS should be utilized as well.

Floodway. 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.

Mapped flood areas outside of the 100-year flood zone. FIRMs in the Yucca Valley area also show the estimated limits of areas with moderate to low risk of flooding. The flood having a 0.2% annual chance of occurring (also called the 500-year flood) is usually the basis for these categories, with moderate risk defined as the zone between the limits of the 100-year and 500-year floods, and low risk defined as the area outside of the 500-year flood limits. These zones may also include areas where the base flood is less than one foot deep, where the drainage basin is small (less than one square mile), or areas that are protected from the base flood by levees. Flood insurance is available for properties in these zones, but is not mandated by the NFIP.

Letter of Map Revision (LOMR). A Letter of Map Revision is a modification to the FIRM or floodway boundaries, generally based on physical changes that affect the hydraulic or hydrologic characteristics of the flood source (usually as a result of development or new flood control facilities). The letter is typically accompanied by an annotated copy of the portion of the map that has been revised. Modifications to the FIRM maps are usually made in response to an agency supplying new hydraulic data that show that the flooding hazard in a specific area has changed or been abated.

In addition to their original purpose of setting insurance rates and regulating flood hazards, FIRMs are now widely used by local and regional planners for other purposes, including land-use planning, emergency preparedness and response, natural resource management, and risk assessment. Therefore, it should be noted that there are many uncertainties inherent in the establishment of FEMA flood zones (Larson, 2009). Given the importance

of these maps, some of the limitations that communities should be aware of are discussed below:

- 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 changes in the area. Conditions that affect the maps and decisions made on their basis may include changes in corporate boundaries, changes in population, man-made and natural changes to the landscape, removal of vegetation, changes to hydrologic systems, construction of flood control facilities, and potential climate changes. These changes in the environment may increase or reduce the area susceptible to flooding.

- The level of detail studied and presented on the maps, as well as the boundaries of the area studied, depend on the type of flood hazard, the funding available, and the risk of flood damage at the time. For instance, areas studied by approximate methods do not provide BFEs on the map, and some study areas are limited in extent.

- The maps do not necessarily identify all areas susceptible to flooding, such as drainages of small size, areas of localized ponding during storms, or areas where drainages are restricted by temporary or permanent structures.

- The analytical process used to construct these maps relies on many assumptions and limited data. The data used may be too old, incomplete, interpolated, and/or inaccurate. For example, in relatively flat floodplains, small elevation errors in the topography can result in large errors in flood zone boundaries.

- One major drawback is the very short time period for which we have meteorological records. Research on some parts of southern California has shown that slight climate fluctuations between wet and dry cycles have occurred since the late 1800s (Hereford and Longpre, 2009). Global climate change is still intensely debated, but many scientists now believe even slight global warming could bring an increase in precipitation overall, although the specific effects on the Yucca Valley region are not known.

- Long-term changes in the watershed or floodplain, primarily the result of man's activities, are even harder to predict. Flood control structures, such as berms and levees, can actually increase the flood risk to other areas. The design of high-density developments often requires taking drainages that used to be spread over a wide area and constricting them into narrow channels, thereby increasing the velocity and erosive power of the flow, and perhaps leading to overtopping. Consequently, there are clearly limitations in using hydrologic calculations based on past, imperfect records to predict the future.

- Larson (2009) also argues that the process of placing a line on a map (flood zone boundaries) conveys a sense of certainty about the risk to the public and policy makers that does not exist.

Flood Map Modernization Program. Because many flood maps and related products were outdated, FEMA started its Map Modernization (Map Mod) Program in 2003 to reduce reliance on paper maps and transition to digital processes for distributing and reading flood maps. The program also includes collecting new flood data for unmapped areas. In response to funding limitations and feedback from stakeholders, FEMA changed its goals mid-way through the program, in 2006. Rather than try to create digitized flood maps for the entire nation, it was decided to improve the accuracy of the newly updated maps by establishing two criteria: 1) a floodway boundary standard that would insure flood maps match the topographic data used (although use of the standard itself does not validate the accuracy of the topographic data); and 2) guidelines for determining whether an existing flood study is adequate for current use or if an updated study is needed. The adjusted goal is to have 65% of the continental United States land area and 92% of the population covered by digital maps (National Research Council, 2009). The FIRMs covering Yucca Valley were updated in 2008.

Risk MAP Program. With the Risk Mapping, Assessment and Planning (MAP) Program approved in March 2009, FEMA is moving from simply portraying flood hazard zones on maps to more accurately communicating and assessing the flood risk of local communities. Building on the digitized maps that are already available, FEMA has developed a 5-year plan to fill in data gaps, increase public awareness, increase their outreach on flood risks, support state and local agencies in risk-based mitigation planning, and provide an enhanced digital platform that improves communication and sharing of risk data.

3.1.6 Flood Zone Mapping in the Town of Yucca Valley

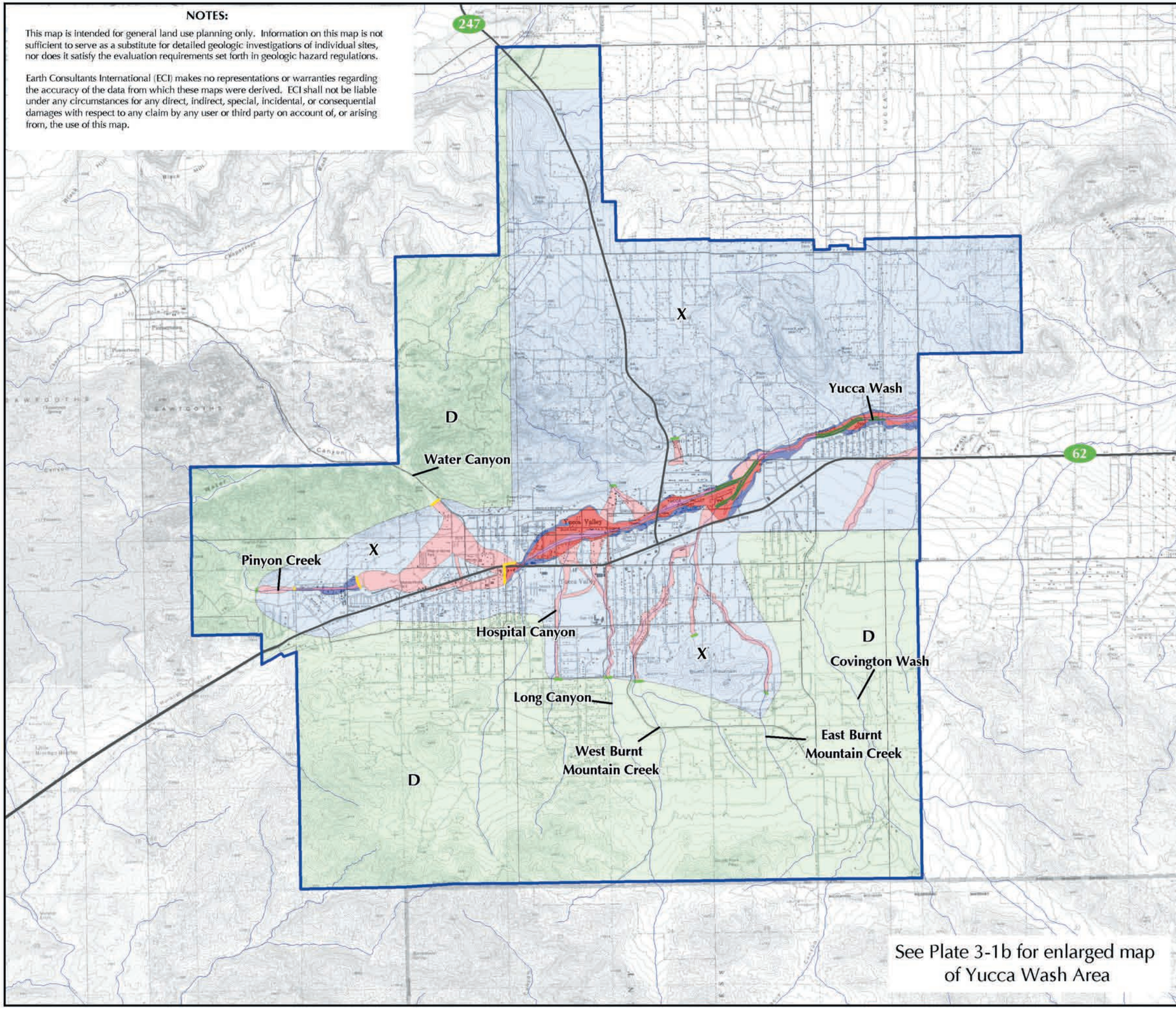
As part of the National Flood Insurance Program, the extent of flooding on portions of Yucca Valley has been analyzed through the Flood Insurance Study (FIS) for San Bernardino County (FEMA, 2008). The potential flood zones mapped by FEMA are published in Flood Insurance Rate Maps. The Flood Hazard Maps for Yucca Valley (Plates 3a and 3b) show the FIRM inundation limits for the 100-year and 500-year flood, however it should be noted that the study areas are limited and the flood zoning for the entire Town is incomplete. Consequently, there are areas outside of the mapped flood zones that are likely to be subject to flood hazards. San Bernardino County has also published flood hazard zones, most of which coincide with the FEMA zones.

The flood areas identified on Plates 3a and 3b generally cover the low-lying parts of the Town along Yucca Wash, the alluvial fan at the mouth of Water Canyon, and washes that carry runoff from the mountains through populated areas, including the lower reaches of Pinon Creek, Hospital Canyon, Long Canyon, West and East Burnt Mountain Creeks, and Covington Wash. It should be noted that the mid to upper reaches of these drainages are not identified as SFHZs because they have not been studied by FEMA. These areas, as well as other unmapped portions of Yucca Valley, are still vulnerable to flood inundation. Numerous residences, businesses, and mobile homes are within mapped 100-year SFHZs. The Yucca Valley Airport and several schools are within a 100-year flood SFHZ, including Our Lady of the Desert High School, Calvary Baptist Church School, and Yucca Valley Community Day School.

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.



Flood Hazard Map
Yucca Valley, California

Explanation

FEMA Flood Insurance Rate Zones
High Risk Areas (Special Flood Hazard Areas)

- **A** — Zone that corresponds to the 100-year flood areas, as determined by approximate methods. Because detailed hydraulic analyses were not performed, no base flood elevations or depths have been determined. Mandatory flood insurance is required.
- **AE** — Zone that corresponds to the 100-year flood areas, as determined by detailed hydraulic analyses. In most cases, base flood elevations are shown at selected intervals.* Mandatory flood insurance is required.
- **AE** — Floodway zone*. Watercourse channel that generally must be kept free of encroachment. Development is subject to special regulations.

Moderate and Low Risk Areas

- **X** — Zone that corresponds to areas between the limits of the 100-year and 500-year floods. No base flood elevations or depths have been determined. Flood insurance is available but not required.
- **X** — Zone that corresponds to areas outside of the 500-year flood or areas protected from the 100-year flood by levees. Flood insurance is available but not required.
- **D** — Zone outside of FEMA Study - flood hazard is undetermined.
- Limit of detailed study.
- Limit of FEMA Study.
- Levee
- Yucca Valley Town Boundary

* See FEMA Flood Insurance Rate Maps and FEMA FLood Insurance Study for San Bernardino County for Base Flood Elevations.

N
W E
S

Scale: 1:60,000

5000 0 5000
Feet

1000 0 1000
Meters

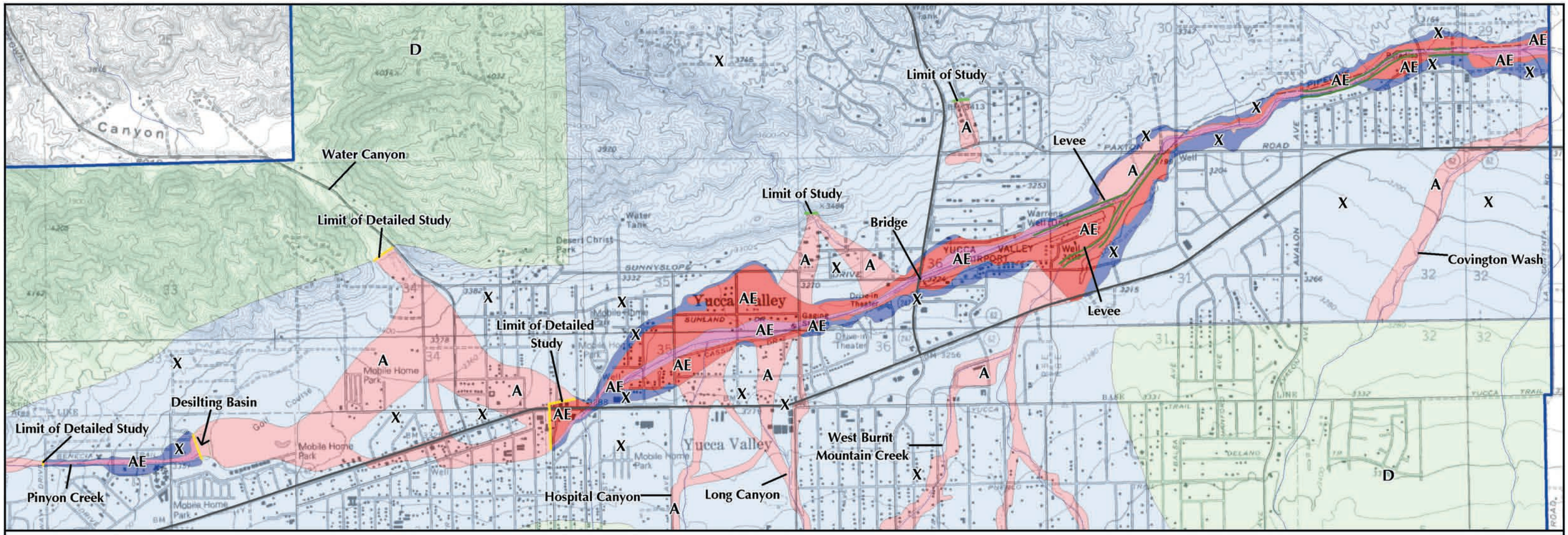
Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley.
Source: Federal Emergency Management Agency, San Bernardino County, Flood Insurance Rate Maps (Panel Numbers: 06071C8115H, 06071C8120H, 06071C8140H, 06071C8855H, 06071C8860H, 06071C8880H).

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 3-1a



N
W E
S

Scale: 1:24,000

2000 0 2000
Feet

500 0 500
Meters

Explanation

FEMA Flood Insurance Rate Zones

Moderate and Low Risk Areas

- X — Zone that corresponds to areas between the limits of the 100-year and 500-year floods. No base flood elevations or depths have been determined. Flood insurance is available but not required.
- X — Zone that corresponds to areas outside of the 500-year flood or areas protected from the 100-year flood by levees. Flood insurance is available but not required.
- D — Zone outside of FEMA Study - flood hazard is undetermined.
- Limit of FEMA Study.
- Limit of detailed study.
- Levee
- Yucca Valley Town Boundary

High Risk Areas (Special Flood Hazard Areas)

- A — Zone that corresponds to the 100-year flood areas, as determined by approximate methods. Because detailed hydraulic analyses were not performed, no base flood elevations or depths have been determined. Mandatory flood insurance is required.
- AE — Zone that corresponds to the 100-year flood areas, as determined by detailed hydraulic analyses. In most cases, base flood elevations are shown at selected intervals.* Mandatory flood insurance is required.
- AE — Floodway zone*. Watercourse channel that generally must be kept free of encroachment. Development is subject to special regulations.

See Plate 3-1a for enlarged map of the entire town.

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

* See FEMA Flood Insurance Rate Maps and FEMA FLood Insurance Study for San Bernardino County for Base Flood Elevations.

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley. Source: Federal Emergency Management Agency, San Bernardino County, Flood Insurance Rate Maps (Panel Numbers: 06071C8115H, 06071C8120H, 06071C8140H, 06071C8855H, 06071C8860H, 06071C8880H).

Flood Hazard Map
Yucca Wash Area
Yucca Valley, California

Plate 3-1b

Storms smaller than the estimated 100-year event have caused localized flooding and sedimentation problems in Yucca Valley, including areas outside of the mapped FEMA zones. Many of the drainage courses in the Town are unimproved and have insufficient capacity, leading to flooding, erosion, and sedimentation on nearby properties. Damage to structures occurs mostly in older buildings that are not adequately elevated above the ground surface, and/or have inadequate floodproofing. The Yucca Valley area still has many unpaved roads in residential areas, and these, along with the natural drainage channels, are vulnerable to erosion and sedimentation. Sediment loads are deposited when the stream velocity slows down, resulting in property damage, or in some cases, parts of the community being temporarily isolated due to eroded or flooded access roads.

As the population of Yucca Valley grows, the consequences of flooding are likely to increase. In light of the uncertainties with respect to estimating floods, land use planning in the Town could benefit from additional mapping, a conservative approach to permitting, and a strong adherence to an area-wide, long-term vision for flood safety as individual projects are considered.

3.1.7 Flood Management Policies

The NFIP provides Federal funds, emergency aid, and/or assistance in the event of a major flood. However, the key to reducing the flood risk lies at the local and County level, primarily in the form of proactive land use planning, zoning, and the enforcement of building codes. Responsibility also lies with individual property owners, especially in rural areas, since they are the stewards of many of the natural drainage channels.

As mentioned above, to qualify for the NFIP, cities and counties are required to adopt and enforce minimum flood hazard management standards. In Yucca Valley, general provisions for flood hazard reduction are provided in the Town Code and these apply to all lands in Areas of Special Flood Hazard. These areas are based on the FEMA maps, however the areas shown to be at risk in these maps are a minimum. Based on local conditions, additional areas may be included in the application of these provisions. The goal is to reduce flood losses by protecting floodways (major drainages that periodically convey dangerous, turbulent floodwater and debris) from encroachment, regulate land uses in areas vulnerable to flooding, minimize the disturbance of natural drainage patterns, prevent the obstruction of flow paths that would divert floodwater to other areas, and provide and implement standards designed to increase a building's resistance to damage from water or debris.

Much of Yucca Valley is rural or semi-rural, and drainage issues are typically addressed on a parcel-by-parcel basis. In order to obtain permits for new construction, applicants are required to evaluate the proposed project's impact on the existing drainage, including the cumulative effect of the project when combined with all other existing and anticipated development. The permit applications are reviewed to determine if the project will be reasonably safe from flooding, erosion, sedimentation, and mudslides, and will not cause or increase the potential for such hazards downstream. The code also provides minimum standards of construction, such as anchoring, placement and type of utility equipment, building materials, building elevation, and floodproofing (i.e., water-tight walls and resistance to hydrostatic pressures and buoyancy).

3.1.8 Existing Flood Control

As mentioned previously, a significant portion of Yucca Valley encompasses alluvial fans or plains that slope down gradually from the base of the mountains. Most of these areas have at least scattered development, however, higher density development is present on the alluvial fans in the main valley, between the Sawtooth and Little San Bernardino Mountains. Most of the existing development in Yucca Valley has been completed without significant alteration to the natural terrain. As a result, natural drainage courses pass through developed or semi-developed areas. Small channels pass through private yards, and some structures are built within the flow paths of shallow drainages. Most streets, many of which are unpaved, follow the natural contours of the land, crossing arroyos and gullies without the benefit of culverts or bridges. These crossings can quickly become filled with high velocity floodwaters, trapping vehicles or washing them downstream. Where flows are concentrated or obstructed, the sandy soils that are prevalent can easily erode, forming new gullies and undermining structures.

Development in Yucca Valley has occurred in a piecemeal fashion over the years, much of it before the Town incorporated, and without the benefit of a planned drainage network. Many existing drainage courses are unimproved, and brief but intense storms can quickly overwhelm them, pushing water and sediment over low-lying areas and making unpaved roads impassible. The number of flood control facilities in the Town is limited, and these are located primarily in the lowest part of the main valley, along Yucca Wash. Some of these improvements have been made under the direction of the San Bernardino County Flood Control District (SBCFCD), and others have been constructed by developers as a condition of approval for their projects.

Regional Facilities. The SBCFCD operates and maintains regional flood control facilities along Yucca Wash and small portions of several tributaries, including Old Woman Springs Creek, Covington Wash, Burnt Mountain Creek, Long Canyon, High School Canyon, Hospital Canyon, and Church Street. These improvements consist mostly of open, graded earth channels, locally with rock reinforcements. Levees are present along the eastern portion of the Yucca Wash and Burnt Creek channels. Desilting basins are present in Long Canyon and Old Woman Springs Creek.

Local Facilities. The Town of Yucca Valley has the responsibility of maintaining local flood control improvements. These mostly consist of small unlined earth channels, although some sections are locally lined with concrete or have some form of slope protection. Some streets are constructed with high curbs, so that they function as flood control channels during storms.

3.1.9 Future Flood Control

The existing flood control structures have provided some protection to the central, most densely populated part of the Town; nevertheless, additional protection is needed. Because of the natural drainage patterns in Yucca Valley and the widespread rural and semi-rural character over much of the General Plan area, a comprehensive Town-wide stormdrain network, typical of more urban areas, is not practical. The Town of Yucca Valley Master Plan of Drainage (MPD), prepared for the San Bernardino County Flood Control District in 1999, presents detailed plans for improving and extending the existing facilities throughout the densely populated valley and into the sparsely developed areas to

the south and north. The MPD is meant to be a guideline for planning and building future regional and local drainage facilities, and intends to largely make use of existing drainage courses by improving them as open concrete-lined or rock-lined channels, supplemented with storm drain pipes and detention/debris basins. Other planned improvements include new or improved culverts at road crossings, more streets improved to carry storm flows, and all-weather road crossings. For the rural parts of the Town, the study recommends maintaining the natural washes as managed floodplains.

The MPD also recommends utilizing rock for channel stabilization as much as possible for aesthetic reasons, utilizing detention basins for groundwater recharge, utilizing drainage facilities for wildlife corridors and recreational use, and developing Town ordinances to regulate development in areas where floodplain management is necessary.

As new developments are considered, it is important that hydrologic studies be conducted to assess the impact that increased development may have on the existing development down gradient. These studies should quantify the effects of increased runoff and alterations to natural stream courses. Such constraints should be identified and analyzed in the earliest stages of planning. If any deficiencies are identified, the project proponent needs to prove that these can be mitigated to a satisfactory level prior to proceeding forward with the project, in accordance with California Environmental Quality Act (CEQA) guidelines.

The methodology for analysis and design of regional flood-control structures is set forth by the San Bernardino County Flood Control District (SBCFCD). Future responsibilities for operation of regional flood control facilities will be with the SBCFCD, whereas the local storm drains and other structures outside of the regional system, if constructed in the future, would be the responsibility of the Town. Therefore, both agencies must be involved in the planning and approval of mitigation measures, to assure compatibility.

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

- Some researchers have questioned whether or not the current methodology for evaluating average flood recurrence intervals is still valid, since we are presently experiencing a different, warmer and wetter climate. Even small changes in climate can cause large changes in flood magnitude (Gosnold and others, 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 underlying groundwater table. 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 San Bernardino 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 cleared of vegetation and other obstructing debris in a timely manner, future flooding of adjacent areas could develop.

3.1.10 Flood Protection Measures for Property Owners

As discussed above, flooding remains a significant risk to structures and residents Yucca Valley. The Town and property owners can take measures, however, to promote safety during future floods and reduce damages.

At the Community level:

- Develop a system whereby storm warnings are issued in real time, and, if necessary, evacuations can be conducted in short notice.
- Continue public education regarding dangers of fast-moving floodwaters, especially considering the influx of new residents from non-desert areas.
- Continue to educate the public on the risks of flooding, including the uncertainties inherent in flood hazard zoning.
- Establish easements for entrenched flow paths.
- Create local flood zone designations, based on scientific mapping and local knowledge of the problems areas.
- Create flood overlays for zoning and land use maps.
- Provide information regarding the potential flood hazards outside the 100-year flood zone; residents in these areas may consider purchasing flood insurance once they understand the risks.
- In existing developments, continue efforts to channel floodwaters down streets with the use of berms.
- Create an atmosphere of working with nature and the natural processes inherent in the desert environment, rather than trying to control them (which often comes with unintended consequences).

For Property Owners:

- Elevate homes on fill pads or piers.
- Orient homes and pads to provide minimum obstruction to the direction of flow, and do not force flows onto adjacent properties.
- Try to accommodate natural flows rather than restrict them.

- Any grading to direct flow around the home should include directing it back to its natural path downstream.
- Minimize the disturbance to the surrounding soil and native vegetation.
- Protect foundations or piers from erosion and scour.
- Numerous methods are available for flood protection – which methods are most appropriate for an individual lot should be based on local conditions surrounding and upstream from the lot.
- Some lots may require special engineering studies to determine the hazard and design appropriate mitigation.

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; 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 Town's Building and Safety Division of the Community Development Department. Refer to them for advice regarding whether or not flood protection measures would be appropriate for your property.

3.1.11 Bridge Scour and Flood Channel Crossings

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

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

In the Yucca Valley area, scour could occur at any of the several bridges crossing existing flood control channels. Because the channels only carry floodwaters occasionally, any scouring that occurs during the very sporadic but high-intensity storms may go undetected. Therefore, bridges should be inspected during and after a flood event to determine whether or not there is scour damage that could impact their foundations. Any damage observed near the bridge supports should be repaired as soon as possible, before the next storm

event or storm season, as appropriate. These bridges are particularly important because to serve as "all-weather" crossings, especially for emergency personnel during a flood.

3.2 Seismically Induced Inundation

3.2.1 Dam Failure

Seismically induced inundation refers to flooding that occurs when water retention structures, such as dams, fail due to an earthquake. Statutes governing dam safety are defined in Division 3 of the California State Water Code (California Department of Water Resources, 1986). These statutes empower the California Division of Dam Safety to monitor the structural safety of dams that are greater than 25 feet in dam height or have more than 50 acre-feet in storage capacity. Currently there are no water storage reservoirs with dams that impact the Yucca Valley General Plan area. There are however, five planned detention/debris basins and one existing basin (Long Canyon) that fall under the jurisdiction of the State (due to embankment height and/or storage capacity), even though they will contain stormwater only on a temporary basis. Old Woman Springs Basin does not come under State jurisdiction (John M. Tettemer & Associates, 1999).

3.2.2 Inundation From Above-Ground Water Storage Tanks

Seismically induced inundation can also occur if strong ground shaking causes structural damage to aboveground water tanks. If a tank is not adequately braced and baffled, sloshing water can lift a water tank off its foundation, splitting the shell, damaging the roof, and bulging the bottom of the tank (causing what is referred to as "elephant's foot") (EERI, 1992). Movement can also shear off the pipes leading to the tank, releasing water through the broken connections. 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.

The Hi-Desert Water District maintains sixteen aboveground water tanks, with a total capacity of 12.9 million gallons. All the tanks are located within the Town limits except Reservoir 33, which is located to the northeast, in the Yucca Mesa area. The two newest tanks were constructed in recent years (2000 and 2003), however many of the older tanks were constructed 20 years ago or more, before the adoption of newer earthquake design standards. Older tanks may not meet the new construction requirements for safety, lacking the flexible joints and other seismic upgrades that can help limit the damage that a failed water tank could cause to areas downstream. According to the District, some of the tanks have been retrofitted with seismic valves.

If there is the potential for a water tank or its associated pipe connections to fail catastrophically during an earthquake, its inundation path should be identified to evaluate whether or not habitable structures are located within the floodway. The evaluation should also address whether a water reservoir is self-contained. Specifically, in the event of a catastrophic breakage, will the water be contained within the site, or will it pose a hazard to properties downstream? This hazard should be considered during the review of

any future tank projects. All existing tanks within Yucca Valley should be evaluated for inundation impacts, and the hazard mitigated if there is a threat to downstream structures.

Table 3-3: Above-ground Water Tanks in the Yucca Valley General Plan Area

Tank No.	Capacity (millions of gallons)	Year Built	Seismic Valves
Tank 14	2.0	1983	Yes
Tank 18	1.0	1986	Yes
Section 19	0.15	1966	No
Section 23	0.15	2003	No
Section 30	0.50	1969	No
Palomar	0.98	1978	No
FWH	0.98	1978	No
Alta Loma	1.00	1977	No
Golden Bee	0.42	1988	No
Hospital	0.21	ND	No
Homestead	0.50	2000	No
Lower Fox	2.22	1992	No
Upper Fox	1.50	1992	Yes
Lower Ridge	0.01	1992	Yes
Upper Ridge	0.50	ND	Yes

Source: Hi-Desert Water District.
Abbreviations: ND = No Data

In addition to the potential inundation of downslope properties, tank failures can significantly reduce the water resources available to suppress earthquake-induced fires. Damaged tanks and water mains can also limit the amount of water available to residents. Similar damage can be expected to the groundwater wells in the region, also limiting the water available to the community after an earthquake. Therefore, it is of paramount importance that the water storage tanks in the area retain their structural integrity during an earthquake, so water demands after an earthquake can be met. In addition to evaluating and retrofitting water reservoirs to meet current standards, this also requires that the tanks be kept at or near full capacity at all times.

3.3 Summary

Yucca Valley encompasses broad, gently sloping alluvial plains surrounded by rocky hills and steep mountains. The most concentrated development occupies the main valley floor, along Yucca Wash. Although the existing flood control structures have helped to alleviate flooding problems, numerous structures identified in the County's Master Plan of Drainage remain to be funded and built. Yucca Valley's areas of rural to semi-rural development have been built out with only minor alterations to the natural topography. As a result, facilities that can help reduce the flood hazard, such as underground pipelines, culverts and bridges are rare. This leads to localized flooding, road closures, erosion damage, and even temporary isolation during and following strong storms, particularly when the area is hit by high-intensity summer thunderstorms or winter storms that occur when the ground is already saturated.

Drainages within Yucca Valley that will be flooded by the 100-year flood, as identified by FEMA, include the Yucca Wash, Water Canyon, Old Woman Springs Creek, Covington Wash, East and West Burnt Mountain Creeks, Long Canyon, Hospital Canyon, and Pinon Creek. Many homes and businesses are impacted by these drainages. In addition, it is important to note that the FEMA flood zones are based on limited studies, and large portions of Yucca Valley have never been evaluated. Further, storms smaller than the 100-year-event frequently result in property damage or flooded roadways in localized areas. For these reasons FEMA encourages property owners outside of the Special Flood Hazard Areas to purchase flood insurance.

FEMA's 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 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. Residents and business owners outside of the regulated zones should be encouraged to buy flood insurance as well, because between 20 and 25% of the National Flood Insurance Program claims are for structures located outside the designated 100-year flood zones, where insurance is not required. Yucca Valley is a member of the National Flood Insurance Program; consequently, flood Insurance is available to residents and property owners.

For those portions of the Yucca Valley where flooding is a persistent problem, the Town should have evacuation plans in place. Critical facilities such as schools should also have evacuation plans that cover the possibility of flooding. Facilities using, storing, or otherwise involved with substantial quantities of onsite hazardous materials should not be permitted in the flood 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 Town should continue to require that future planning for new developments consider the impact on flooding potential, as well as the impact of flood control structures on the environment, both locally and regionally. Flood control should not be introduced in the undeveloped areas at the expense of environmental degradation. Land development planning should continue to consider leaving watercourses natural wherever possible, or continuing to develop them as parks, nature trails, golf courses or other types of recreation areas that can withstand inundation.

Because many of the natural drainages cross private yards in rural areas, the citizens of Yucca Valley should make an effort to be educated about their drainage and flooding issues, and not rely entirely on the local agencies. Drainage channels need to be kept free of debris and should not be altered in such a way that runoff is obstructed or significantly changed.

Water tanks in the area are placed on hilltops or sideslopes, above the properties that they supply with domestic water. Emergency planning should consider the potential for water tanks to fail, impacting developed properties below. Given the anticipated extensive damage to the regional potable water system (including tanks, water mains, and distribution lines) resulting from a large-magnitude earthquake on nearby active faults, it is very important that the water storage tanks in the area remain structurally sound, and that they be maintained as full of water as possible. Thus, even if the water distribution pipelines are damaged, the Town would have access to stored water that can be distributed to the community using water trucks or other similar methods, at least until water can be imported while the pipelines are repaired.

CHAPTER 4: FIRE HAZARDS

4.1 Wildfires

Wildfires are a significant hazard throughout the United States, and especially in the West, where they occur often. 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. Although wildfires are often considered highly disruptive and even dangerous, the fact is that wildland fires are a necessary part of the natural ecosystem of southern California, and have been part of the natural environment for millennia. Many of the native plants require periodic burning to germinate and recycle nutrients that enrich the soils. Native Americans took advantage of this, and used fire extensively to control their environment by enhancing feed for wildlife, decreasing insects and diseases that impact wild foods, increasing the abundance and density of edible tubers, greens and other useful plants, and clearing underbrush to ease travel and provide increased visibility (Anderson, 2006).

Wildfires become a hazard 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 in general increased in the last few decades with the encroachment of residences and other structures into the wildland environment, and the increasing number of people living and playing in wildland areas. According to the National Interagency Fire Center, between 2001 and 2008, humans caused approximately 84% of the wildland fires in the U.S. (519,193 human-caused fires vs. 95,294 lightning fires); however, fires caused by lightning strikes burned nearly 1.7 times more land (approximately 35.3 million acres burned by lightning vs. 20.5 million acres burned by man) (http://www.nifc.gov/). The most common human 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, 2006, 2007 and 2009 fires in southern California have shown, the containment of wildfires that consume hundreds of thousands of acres of vegetated property require the participation of a multi-jurisdictional emergency response effort, with thousands of people at or near the fire lines combating the flames, clearing brush ahead of the fire to establish defensible zones, and assisting evacuees (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 potentially 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 limit the destruction caused by fires. These mitigation measures are discussed in this document.

Wildfires 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. 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 or sediment type, the shape of the drainage basin, and the presence or absence of water-repellent 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.) If this debris overwhelms the flood control structures, widespread damage can ensue in areas down gradient from the failed structures. As an example, in San Bernardino County 16 people died as a result of debris flows during the 2004 storms that followed the 2003 fire season. During the storms of 2010, the Los Angeles County Public Works Department and several cities had crews cleaning out the debris basins between the mountains and the communities at the foot of the 250-square-mile area that burned during the Station Fire. These efforts helped significantly in reducing the hazard of mudflows, although unfortunately nearly 50 homes and dozens of cars were still seriously damaged by mudflows in the communities of La Crescenta, La Canada Flintridge, and Acton.

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 killed 14 people. The fire was cased by a signal flare set off by a lost hunter.

Other effects of wildfires are economic 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.

With some exceptions, the impact of wildland fire on plant communities in southern California 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 usually re-sprout in 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 take hold. On the other hand, some of the dominant plant species in the deserts bioregion, such as shadscale, blackbrush, creosote bush, brittlebrush, and cacti are killed by fire and will not re-sprout. Others, such as Mojave yucca, banana yucca, and Joshua trees, are top-killed, with sprouting generally stimulated by fire. Joshua trees will re-sprout, but if most or all of their foliage is scorched or destroyed by the fire, they will generally die within 5 years. Because many fires in the desert are patchy and of low intensity, plants will often survive in unburned islands (Brooks and Minnich, 2006). With the introduction of non-native species that burn at higher intensities, however, the damage will generally be more widespread. Furthermore, the non-native, invasive species re-sprout more quickly and spread faster, crowding out the native desert plants in the process.

Figure 4-2: View of a Backfire to the Station Fire Behind Homes in La Crescenta.
The 2009 Station fire burned 160,557 acres, 209 structures and caused 2 deaths. It is considered the 10th largest California fire by acreage burned
(http://cdfdata.fire.ca.gov/incidents/incidents_statsevents).
(Photograph by Jae C. Hong/AP Photo, taken on September 1, 2009).

4.1.1 Local Characteristics and History on Local Fires

The fire hazard of an area is typically based on the combined input of several parameters. These conditions include: 1) fuel loads – that is, the type of fuel or vegetation, and its density and continuity, 2) topography – elevation and slope, 3) weather, 4) wildfire history, 5) dwelling density, and 6) existing local mitigation measures that help reduce the area's fire rating – such as fuel modification zones, fire-rated construction, fire hydrants, etc. These conditions as they pertain to the Town of Yucca Valley and immediate surrounding areas are discussed further below.

4.1.1.1 Fuel Loads and Topography

Yucca Valley is located in the lower Mojave section of the Southeastern Deserts Bioregion, an area characterized by isolated, steep-sided mountain ranges separated by broad alluvial basins. The predominant natural vegetation assemblage in the lower elevation areas of the Mojave section is desert shrub, which may include alkali sink vegetation, creosote bush scrub, and succulent scrub (Brooks and Minnich, 2006). Significantly, more than one-third of the desert floor in the Mojave section is typically barren of vegetation (Figure 4-3). The limited amount of vegetation and low surface fuel loads typically hinder the spread of fire.

Figure 4-3: **Typical Fuel Loads in the Yucca Valley Region.**
View to the west of the southern portion of Yucca Valley showing scattered stands of scrubland and Joshua Trees separated by areas barren of vegetation.
The Little San Bernardino Mountains can be in the distance, at left.

At higher elevations both inside and outside the Town, including areas such as Joshua Tree National Park, the major vegetation types include Joshua Tree woodland, shad-scale scrub, creosote bush scrub, blackbrush scrub, and desert scrub-steppe. Given the increased diversity of surface fuel, and relatively higher loads and continuity of vegetation, the spread of fire in these regions is higher than in the desert floor. This is reflected in the higher number of fires reported historically in Joshua Tree National Park and in the mountains to the northwest, compared with the Yucca Valley area proper.

As discussed previously, unlike the primary vegetation types common in other bioregions of southern California, desert plants do not need fire to reproduce, and many of the native

plants common to this area are highly susceptible to and killed off by fire. Furthermore, native desert plant communities may take decades to re-establish after a fire, whereas non-native grasses are quick to invade burned areas, generally at the expense of the native plants. Researchers have argued that the introduction by livestock ranchers, in the early 20th century, of non-native annual grasses to the desert has resulted in a marked increase in the number and size of the fires reported in the region. This trend has been particularly noticeable since the mid 1970s: before about 1977, fires in the eastern deserts generally burned less than 300 acres; fires since then have typically burned thousands of acres. Brooks and Minnich (2006) report that although some of the most significant recent fires in Joshua Tree National Park were fueled by large "stands of native trees, shrubs and perennial grasses," fire spread was "facilitated by stands of the non-native annual grasses red brome and cheat grass." This was especially the case in areas that had previously burned and as a result, the cover of these non-native grasses was particularly high.

Joshua Tree National Park representatives are particularly concerned about the potential future arrival of buffelgrass (*Pennisetum ciliare*), a very invasive grass native to the African savannah that was introduced in the Sonoran desert in Arizona, and has been found to quickly crowd out native species. When stands of buffelgrass burn, they can generate fires that burn almost three times hotter than those generated by flammable native vegetation. Fires this hot are highly detrimental to cacti and native trees, with the potential to eliminate them from the environment (http://www.buffelgrass.org/introduction.php). The potential future arrival of buffelgrass to the area may increase the fire frequency and fire danger in the lower elevation areas of Joshua Tree National Park and the surrounding areas, including Yucca Valley (K. Messaros, Joshua Tree National Park Service, personal communication, October 2009).

4.1.1.2 Weather

As discussed in the Flood Hazards section (Chapter 3), the Yucca Valley area is predominantly arid due to the rain shadow effect caused by the Peninsular Ranges. Average annual precipitation in Yucca Valley is about 6.8 inches, based on precipitation recorded at the Yucca Valley California Department of Forestry station for the water years between 1956-57 and 1992-93 (Kennedy/Jenks/Chilton, 2001). Precipitation is somewhat evenly distributed throughout the year, with higher levels generally reported in the fall and winter months, between November and March. In some years, precipitation associated with thunderstorms emanating from the Gulf of Mexico makes a substantial contribution to the rainfall levels for July and August.

The rainfall measurements made between 1956 and 1993 also show that variations in annual precipitation for this region are relatively high: some years the region received less than 3 inches of rainfall (water years 1984-85, 1988-89, 1989-90, 1995-96), whereas other years total rainfall exceeded 10 inches (1957-58, 1968-69, 1975-76, 1977-78, 1978-79, 1979-1980, 1982-83). As a result, there is a significant variation in the frequency and extent of wildland fires in the area. In years when rainfall is above average, an increased amount of fine fuels in the desert floor can result in an increase in fire spread. Long-term variations in rainfall rates have also been noted in the desert bioregion, with high rainfall and drought periods that last about 20 to 30 years. For example, a mid-century drought was reported between 1946 and 1977, followed by a high-rainfall period between 1977

and 1998. More recently, below-average rainfall was recorded between 1999 and 2004, suggesting that the region has entered a new drought cycle. If this is the case, it may be that the region may see a reduction in frequency and size of wildland fires in the next several years (Brooks and Minnich, 2006).

The summer thunderstorms that sometimes sweep through the Yucca Valley area often include lightning. In fact, lightning frequency is higher in the desert than in any other bioregion in California; the Mojave section averages 30 lightning strikes per 100 square kilometers per year (based on Bureau of Land Management detection data by van Wagtendonk and Cayan, 2008, as reported in Brooks and Minnich, 2006). As discussed in the opening paragraphs, lightning is responsible for a significant percentage of the acreage burned by wildfires in the United States, although human-caused fires are far more common. Many of the large fires recently reported in the region have been the result of lightning. In fact, records kept by Joshua Tree National Park staff indicate that 74% of the fires in the park since 1945 have been caused by lightning. Outside of the park, however, in the Mojave section, human-caused fires were 3.6 times more common than lightning-caused fires for the period between 1980 and 2001 (Brooks and Minnich, 2006).

4.1.1.3 Wildfire History

According to data by the California Department of Forestry and Fire Protection (Cal Fire; http://frap.cdf.ca.gov/data/frapgismaps/download.asp), there have been a few but significant large fires (defined as 300 acres or greater by Cal Fire, and ten acres or greater by the U.S. Forest Service) in the Yucca Valley area between 1910 and 2008 (see Plate 4-1). Some of these fires are discussed further below, in chronological order from most recent to oldest.

The 2008 Acoma fire (blue area in the southern part of Yucca Valley in Plate 4-1) began on June 7, 2008, was 100% contained within 24 hours, and was completely controlled a few days later. The fire burned 356 acres and threatened about 200 homes, prompting voluntary evacuations. The only mandatory evacuation order, as a precaution, was issued for the Desert Manor Board and Care Facility. One outbuilding was destroyed and one resident was treated for smoke inhalation. The fire was human-caused, but whether it was ignited on purpose or as a result of an accident is yet undetermined (http://firefighterparamedicstories.blogspot.com/2008/06/acoma-fire-news-coverage.html).

The Covington and Whispering Pines fires of July 2006 impacted Joshua Tree National Park. Both of these fires were ignited by lightning. The Covington fire burned about 300 acres, whereas the Whispering Pines fire burned nearly 1,000 acres. The Covington fire started at approximately 1:30 PM local time on Thursday, July 21, and by the end of the day had burned about 225 acres and was threatening 550 homes in the southeastern portion of Yucca Valley. Voluntary evacuations were called along Santa Barbara Drive and Joshua Lane. The Whispering Pines blaze began in the early evening of Saturday, July 23rd, and about 450 fire personnel from several different fire departments responded and built containment lines to prevent the blaze from moving into Yucca Valley. The fire destroyed two uninhabited structures and damaged a third in the community of Whispering Pines. Two fire-fighters suffered heat-related injuries, and another person was injured in a traffic accident while moving fire-fighting equipment (based on articles in the

Los Angeles Times dated July 21 and July 25, 2006, respectively, http://articles.latimes.com/2006/jul/21/local/me-fires21 and http://articles.latimes.com/2006/jul/25/local/me-fires25). Also in July 2006, the Pushwalla Complex fire burned more than 2,000 acres in Joshua Tree National Park.

The largest historical fire to have impacted the area is the July 2006 Sawtooth-Millard-Heart Complex fire that combined burned approximately 85,700 acres in the Yucca Valley – San Gorgonio areas (blue zone to the west-northwest of Yucca Valley in Plate 4-1). The Sawtooth Complex fire was started by lightning on July 9 at 8:30 AM local time in the mountains near Big Bear Lake, and in the afternoon of July 14th, it merged with the Millard Complex Fire. The fire was contained on July 19th. Several communities to the northwest of Yucca Valley were placed on mandatory evacuation. Ultimately, the Sawtooth Complex fire alone burned approximately 61,700 acres (250 square kilometers), and destroyed 50 homes, 8 mobile homes, 13 garages, 171 outbuildings, 194 vehicles (including 3 recreational vehicles), 27 trailers, 2 railcars, and 9 tractors. Twelve additional residences were damaged. Seventeen individuals were injured, and one civilian died. The fire cost nearly $17 million to battle, and 861 fire personnel from various agencies, including the California Department of Forestry, San Bernardino County Fire Department, U.S. Forest Service, Los Angeles County Fire Department, the California Department of Corrections and Rehabilitation, the California Highway Patrol, the Red Cross and the California Office of Emergency Services, were involved in the response (http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=94).

The Pioneer fire of June 2005 burned 1,900 acres. The fire started on June 18th, at about 4:30 in the afternoon near Pioneertown, about 4 miles west of Yucca Valley, and by 11:00 that evening had threatened 1,000 acres. Voluntary evacuations occurred in Pioneertown while 380 fire personnel completed a 3-mile long fire break with dozers and hand-crews to keep the fire from advancing and impacting the Pipes Canyon Preserve and approximately 250 homes (http://wildfirenews.com/archive/070805.shtml).

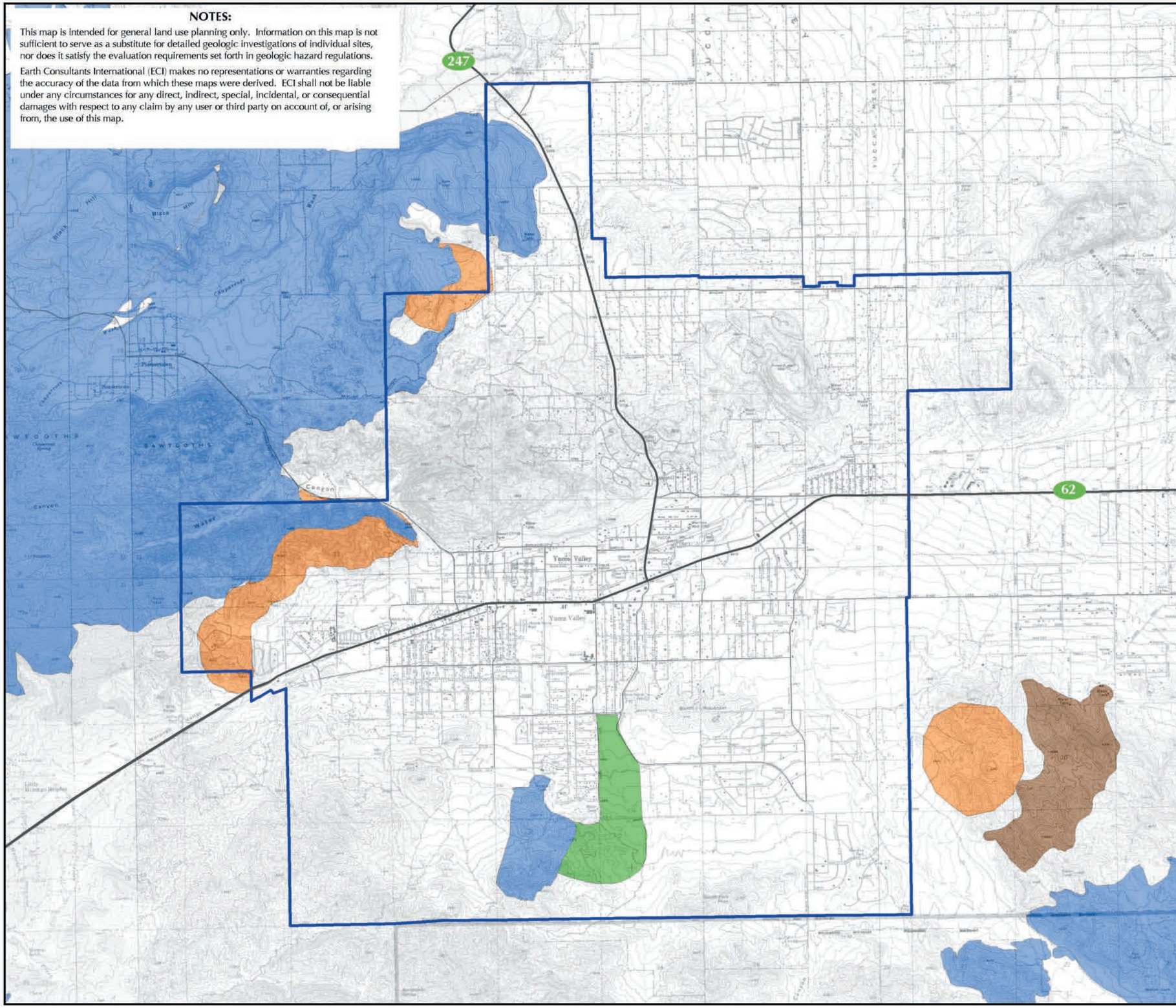
The Paradise fire started on June 22, 2005 at 12:53 PM local time and was 100% contained by June 24, 2005 at 7:00 in the morning. This fire, in the Morongo Valley off Highway 62, destroyed six residences and damaged one more. One minor injury was reported. In total, 3,022 acres were burned and 1,030 fire personnel responded.

Another significant fire near Yucca Valley was the 1999 Juniper Complex fire which burned 13,894 acres in Joshua Tree National Park (JTNP) and extended at its closest approach about 1.5 miles south of Yucca Valley, within the park boundaries (just outside the area covered in Plate 4-1, to the south of the Town).

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.



Historical Wildland Fires (1910-2008)

in and Near Yucca Valley, California

Explanation

Year of Last Burn

- 2000-2008
- 1980-1990
- 1990-2000
- 1970-1980

Yucca Valley Town Boundary

N
W E
S

5000 0 5000
Feet

1500 0 1500
Meters

Scale: 1:60,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997 and Town of Yucca Valley.
Source: California Fire and Resource Assessment Program (FRAP) @ http://frap.fire.ca.gov/data/frapgisdata/select.asp

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 4-1

As Plate 4-1 shows, most wildland fires in and around Yucca Valley have occurred and are more likely to occur in the future in the hillside and foothill areas, and not in the valley proper. In the developed, relatively flat areas of the Town, vegetation fires are not considered a significant hazard, as the topography, lack of fuel loading (either as a result of little to no vegetation, or due to carefully maintained, drought-tolerant landscaping), combine to mitigate the potential for wildland fires. This is not to say that vegetation fires do not occur in developed areas, but these tend to be smaller and less intense in heat. This is discussed further in the sections below that address regulatory mapping of fire hazard areas.

4.1.2 Regulatory Context and Fire Risk Areas

Since the early 1970s, several fire hazard assessment and classification systems have been developed for the purpose of quantifying the severity of the fire hazard in a given area. Many of these are regulatory in that they were implemented as a result of legislation enacted either at the State or Federal level. 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.

4.1.2.1 HUD Study System

In April 1973, the California Department of Forestry (CDF – now the California Department of Forestry and Fire Protection) 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 and others, 1973). As is the case with several other more recent programs, 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 (now available in real-time at http://gacc.nifc.gov/oscc/predictive/fuels_fire-danger/index.htm) to determine the ***Fire Hazard Severity*** of an area. This system was the basis for several subsequent studies and programs that have been conducted as a result of more recent legislation, as described further below.

4.1.2.2 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.

The Town of Yucca Valley is surrounded by State Responsibility Areas to its east and west (purple areas in Plate 4-2). The area within the Sawtooth Mountains to the west is classified as a very high fire hazard severity zone, whereas other areas of lower relief are classified as either high or moderate fire hazard severity zones. ***Federal Responsibility Areas* (FRAs)** (CDF, 2007) have been mapped to the south of the Town, within Joshua Tree National Park boundaries, and both inside and outside the Town limits, as shown by the orange shading in Plate 4-2. Most of the Town and the area to the north-northeast are located within Local Responsibility Areas (LRAs), as described further below.

4.1.2.3 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 subjective criteria for fuels, fire history, terrain influences, housing density, and occurrence of severe fire weather. To qualify as a VHFHSZ, an area had to score ten or more points in the grading scale. The original VHFHSZ maps that were prepared as a result of the Bates Bill are now more than ten years old and outdated. In the last few years, the CDF has been re-mapping both SRAs and LRAs using GIS technology and new data and science to better describe the potential fire behavior and fire probability for a give area. Areas are being mapped in the Moderate, High and Very High categories. The CDF (2008) has included most of the Town of Yucca Valley as a Local Responsibility Area, with the higher relief areas classified as having a Very High to High fire hazard, and the lower relief areas having a Moderate fire hazard (red zones in Plate 4-2).

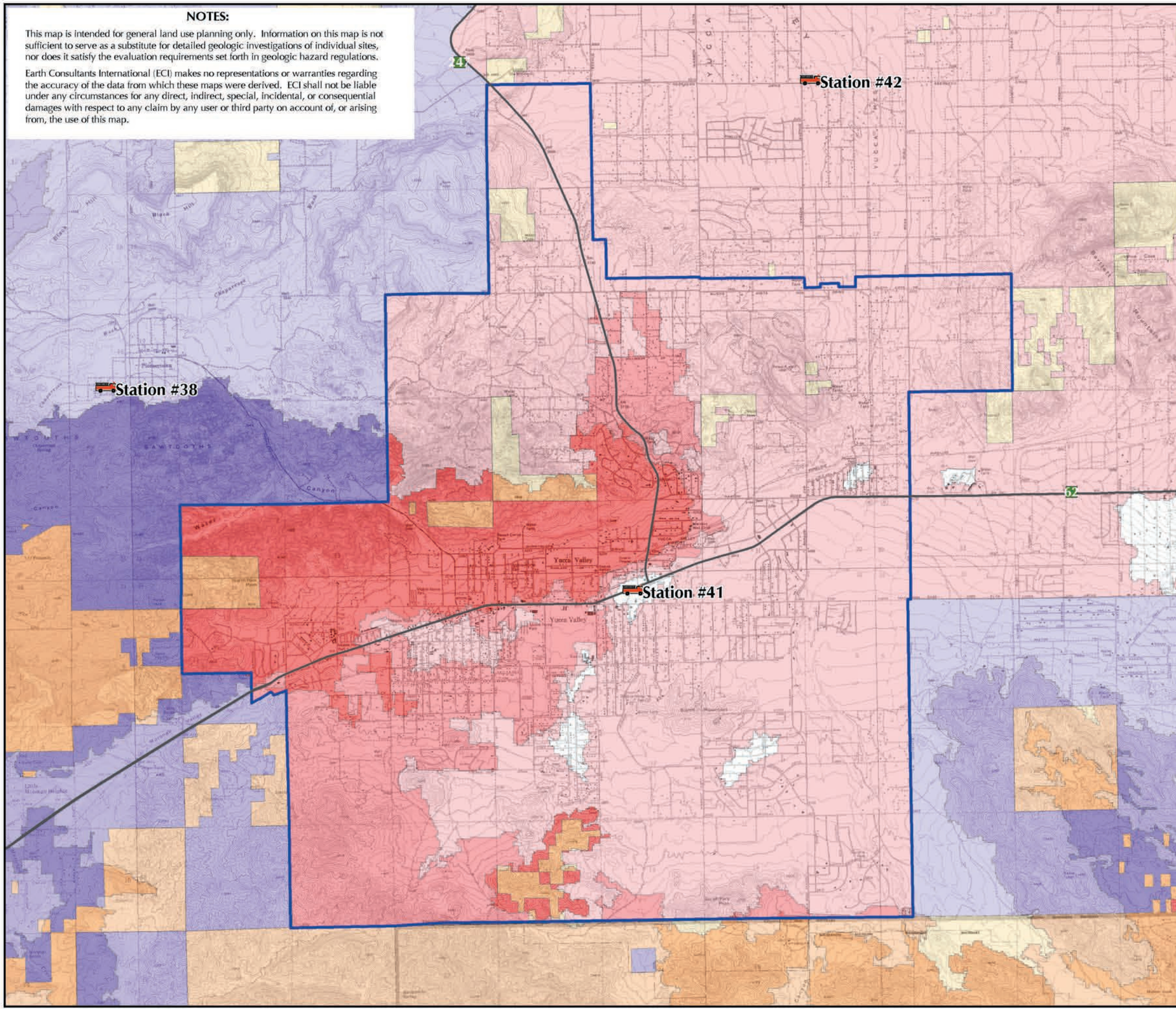
4.1.2.4 California Fire Plan

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). The main objective of the California Fire Plan is to reduce total costs and losses from wildland fire in the State by protecting assets at risk before a fire occurs. To do so, the plan identifies pre-fire management prescriptions that can be implemented to reduce the risk, and analyzes policy issues and develops recommendations for changes in public policy (http://cdfdata.fire.ca.gov/fire_er/fpp_planning_cafireplan).This system ranks the fire hazard of all 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 very high, high or moderate. The high and very high fire hazard zones are based on the availability of fuel (fuel load), terrain and assets at risk. 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

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.



High Fire Hazard Areas

in and Near Yucca Valley, California

Explanation

Local Responsibility Area

- Very High Fire Hazard Severity Zone
- High Fire Hazard Severity Zone
- Moderate Fire Hazard Severity Zone
- Urban Unzoned

Federal Responsibility Area

- Very High Fire Hazard Severity Zone
- High Fire Hazard Severity Zone
- Moderate Fire Hazard Severity Zone

State Responsibility Area

- Very High Fire Hazard Severity Zone
- High Fire Hazard Severity Zone
- Moderate Fire Hazard Severity Zone

- Fire Station
- Yucca Valley Town Boundary

N W E S

5000 0 5000
Feet

1000 0 1000
Meters

Scale: 1:60,000

Base Map: USGS Topographic Map from Sure!MAPS RASTER (1997) and Town of Yucca Valley.
Sources: Fire and Resource Assesment Program, California Department of Forestry and Fire Protection (2007), http://www.yucca-valley.org/departments/fireprotection.html

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2012

Plate 4-2

greatest. These are therefore the areas where enhanced onsite protection for structures and people is necessary.

Under the California Plan, and given the area's vegetation types and slope characteristics, the Town of Yucca Valley is mapped as having a **moderate** to **high** fuel rank and potential fire behavior, with the high fuel rank areas located in the hillsides to the south and west-northwest of the Town (http://frap.cdf.ca.gov/data/frapgismaps/download.asp).

4.1.2.5 National Fire Plan

During the year 2000 fire season, wildfires burned millions of acres of land throughout the United States, prompting politicians, fire managers and government agencies to re-think their approach to fire management. Under Presidential Executive Order, the Secretaries of Agriculture and the Interior were tasked with preparing a report that outlined recommendations to minimize both the short- and long-term impacts of wildfires with a broader effort and closer cooperation between agencies and fire programs. The resulting report, entitled the "National Fire Plan," has as its main purposes to protect communities and restore ecological health on Federal lands (http://www.forestsandrangelands.gov/NFP/index.shtml). The Plan outlines five key points: 1) firefighting, 2) rehabilitation and restoration, 3) hazardous fuel reduction, 4) community assistance, and 5) accountability. The Plan, which was first funded in 2001, commits 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 that interface with federal lands an opportunity to get technical assistance and funding to reduce their threat of wildfires.

As part of the Community Assistance/Community Protection Initiative, the National Fire Plan funded a study to identify areas that are at high risk of damage from wildfire. Under this program, Federal fire managers authorized State foresters to determine which communities are at significant risk from wildland fire on Federal lands. In California, this task was undertaken by the ***California Fire Alliance*** (CFA), a cooperative group of State, Federal and local agencies that in 2001 generated a list of communities at risk. Given California's extensive Urban-Wildland Interface (UWI), the list of communities extends beyond just those on Federal lands. To date, the CFA has identified 1,289 fire-threatened communities in California, and in 2001 the Town of Yucca Valley was identified as a ***Community at Risk***, given that it has and is adjacent to federally regulated lands with a high wildland fire hazard (http://www.cafirealliance.org/communities_at_risk/).

Under the auspices of the National Fire Plan, the CDF also produced a Wildland Fire Threat Map, released on October 20, 2005, that takes into account the combined effects of potential fire behavior (fuel rank) and expected fire frequency (fire rotation) from the past 50 years to create four threat classes for risk assessment. These threat classes are extreme, very high, high and moderate. Areas that do not support wildland fuels (such as open water, and agricultural lands) were not considered in the analysis. Most large urbanized areas receive a moderate fire threat classification to account for fires carried by ornamental vegetation and flammable structures. The Fire Threat Map (available at http://www.frap.fire.ca.gov/data/frapgismaps/download.asp) shows that the hillside areas of the Town of Yucca Valley are mapped as having either a **high** or **very high** fire threat,

whereas the valley portion is mapped as having a **moderate** fire threat. Immediately south of the Town, Joshua Tree National Park has been mapped as having mostly a **very high** fire threat. Wildland fires that begin in the undeveloped, upland areas of the park could spread north into the southern portion of Yucca Valley.

4.1.2.6 California Fire Alliance (CFA)

In addition to generating and updating the Communities at Risk list described above, the CFA funds a variety of projects designed to reduce the threat of wildfire before it happens. As part of this effort, the CFA encourages the development of Community Wildfire Protection Plans (CWPP), as defined by the Healthy Forest Restoration Act (HFRA) of 2003. CWPPs enable a community to plan how it will reduce its risk of wildfire by identifying strategic sites and methods for fuel reduction projects across the landscape and jurisdictional boundaries. Benefits of having a CWPP include National Fire Plan funding priority for projects identified in a CWPP. The USDA Forest Service and Bureau of Land Management can expedite the implementation of fuel treatments identified in a CWPP through alternative environmental compliance options offered under the HFRA. The CWPP must be agreed to by three entities: the local government, the local Fire Department, and the CDF. Communities developing CWPPs are encouraged to integrate their CWPP planning process into other planning processes, including the Safety Element of the General Plan (i.e., this document), Local Hazard Mitigation Plans, Flood Mitigation Plans, and other local hazard, evacuation and emergency plans. The Town of Yucca Valley does not have a Community Wildfire Protection Plan on file with the California Department of Forestry and Fire Protection.

4.1.2.7 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 Local, State or Federal 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.

Although Federal, State and to some degree, local agencies have inventoried and classified the fire hazard of a given area, some users are in need of additional detail, or need to evaluate the fire conditions of an area at a specific time of the year, or under specific fuel loading and weather conditions. The tools below are not regulatory, but in that they are used by specific industry groups, or have applications that can be useful to an agency such as the County Fire Department or the National Forest Service, they are described further.

- **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 and Verisk Analytics. Updated versions of this system are being developed that include the factors of elevation, aspect, and relative slope position.

- **BEHAVE, FARSITE, FlamMap and Other Models**: These are computer programs, typically PC-based, that can be used by 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, used since 1984, 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). A newer version of it is referred to as the BehavePlus Fire Modeling System (Andrews and Bevins, 1999). This software has been updated on a regular basis to make it more user-friendly and provide additional fire modeling capabilities. **FARSITE** (Fire Area Simulator; Finney, 1995, 1998) is a GIS-based software that "simulates the growth and behavior of a fire as it spreads through variable fuel and terrain under changing weather conditions" (http://fire.org/). This software can be used to project the growth of ongoing wildfires and prescribed fires in two dimensions (unlike BEHAVE, which is a one-dimensional model), and can be used as a planning tool for fire prevention, fire suppression, and fuel assessment. **FlamMap**, whose continued development is funded by the Bureau of Land Management, combines elements of the two older models, BEHAVE and FARSITE, but is not a replacement for either. The software computes potential fire behavior characteristics such as fire spread, flame length, fireline intensity, etc., over an entire FARSITE landscape using constant weather and fuel moisture conditions. Some other models also used by fire managers include EMBYR, DYNAFIRE, LANDFIRE, NEXUS, FireFamily Plus, and FOFEM (http://www.forestencyclopedia.net/p/p452).

- **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.

4.1.3 Fire Prevention and Suppression Programs and Regulations

There are several fire prevention and suppression programs that communities can implement to reduce their wildland fire hazard. Some of these programs aim to control the type, density and continuity of fuel (vegetation) available for a fire to burn; others are directed at the strengthening of structures to be more fire resistant. Given that the increase in catastrophic, human-caused wildland fires is associated with an increased number of people living and playing in wildland areas, limiting human-wildland interaction during periods of heightened fire risk can also help reduce the likelihood of human-caused fires in an area. Finally, the effective containment of a wildland fire before it impacts vulnerable structures is in great part the result of the suppression resources available to the agencies fighting the fire, and the fire department's accessibility to the impacted area. Some of these programs are described in more detail below.

4.1.3.1 Vegetation Management

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 a Wildland-Urban Interface Code under the direction of the California State Fire Marshal. The first draft of this code was published in October 1995. Then, in 2003, the International Fire Code Institute consolidated into the International Code Council. The 2012 Wildland-Urban Interface Code issued by the International Code Council contains provisions addressing fire spread, accessibility, defensible space, and water supply for buildings constructed near wildland areas.

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 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 dying 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 communities or developments 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 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.

The Town of Yucca Valley recommends the clearance of all flammable vegetation (creating a defensible space) within a minimum distance of 30 feet from any flammable building materials or finished structures. If sitting on a hill, the downhill defensible area should be wider than 30 feet, as fire travels upslope very quickly. Fire-resistant shrubs and trees are preferred, especially near structures.

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; the increased visibility and access this provided helped them hunt and forage. It is thought that as much as 12% of the State was burned every year by various tribes (Coleman, 1994). European settlers, on the other hand, considered wildfires unacceptable, and in the early 20th century, as development started to encroach onto the foothills, the Fire Service began campaigns to prevent wildfires from occurring. Over time this has led to an increased volume of fuel per acre, that, combined with longer periods between fires, has resulted in an increase in fire risk as wildfires that impact areas with fuel buildup are more intense and significantly more damaging to the ecosystem than periodic, low-intensity fires. This makes it harder for firefighters to suppress fires, increases safety issues and reduces productivity for fire crews on perimeter lines, and increases taxpayer costs while increasing losses of life, property and resources.

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 California alone. 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 a century of common practice and beliefs. Prescribed fire does carry a risk, as relatively recent experiences in New Mexico, Arizona, and Orange County have shown. In 2000, in Los Alamos, New Mexico, the Cerro Grande fire began when a prescribed burn escaped, destroying several hundred homes and burning more than 50,000 acres. This fire triggered revisions in the guidelines for performing prescribed burns. In Orange County, the U.S. Forest Service lost control of a prescribed burn in the Santa Ana Mountains. The Sierra Fire burned for about ten days in February 2006 causing road and highway closures and resident evacuations, but no damaged structures. In all, the Sierra Fire burned 10,584 acres of land and cost about $6.9 million. 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.

Joshua Tree National Park prefers the use of manual and mechanical methods for hazard fuel reduction for the sole purpose of maintaining defensible space areas around structures (National Park Service, 2005).

4.1.3.2 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. *The Town of Yucca Valley addresses the issue of weeds and other vegetation as a potential fire hazard and identifies the steps that the Town takes to abate this hazard in the Town's Municipal Code, Chapter 6.04.* Specifically, the Town considers it unlawful and a nuisance for a property to have weeds, dry grass, rubble, brush, litter, or any flammable material which by its volume, extent or nature endangers the public safety by creating a fire hazard. The Town Manager, code enforcement officer or his/her designee has the authority to give the property owner of record a notice of violation requiring him/her to abate the hazard. If the owner does not abate the hazard during the time period specified in the notice, the Town may take further action to reduce the fire hazard in the form of tax liens and fines. San Bernardino County Fire Department personnel are planning to conduct courtesy home inspections in the urban-wildland interface areas to educate homeowners on being fire safe and maintaining a defensible space.

4.1.3.3 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. The portion of a structure most susceptible to ignition from a wildland fire is its roof, which is exposed to burning cinders (or brands) generally carried by winds far in advance of the actual fire. 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 (Class C roof coverings 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). 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 (see Plate 4-2).

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 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.

Roofing materials can also be:

- **Non-Combustible**: Roof made of non-combustible materials like metal. Although metal roofs don't burn, they are excellent heat conducts, and during an intense fire, heat can be conducted through the metal to the underlying, combustible materials.

- **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 Town of Yucca Valley accepts construction with Class A, B and C roofs. Most new construction uses Class A (Battalion Chief Dave Benfield, written communication, June 2012).

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. To prevent this, it is important that all ventilation openings be properly screened. 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 latest version of the California Building Code (2010) has specific construction requirements for new buildings located in State Responsibility Areas, any Local Agency Very High Fire Hazard Severity Zone, and any Urban-Wildland Interface Fire Area (Chapters 7A and 15 of Title 24, California Code of Regulations,). The California Building Code also has specific fire-resistance-rated construction requirements for all types of construction, based on occupancy type and construction type. *The Town of Yucca Valley has adopted and enforces the most recent edition (currently the 2010) of the California Building Code for all new construction (Town Ordinance 220 and Municipal Code Title 8).*

4.1.3.4 Restricted Public Access

In addition to the fire-susceptibility conditions described before, the wildfire susceptibility of an area changes throughout the year, and from year to year in response to local variations in precipitation, temperature, vegetation growth, and other conditions. To map these changes, the EROS Data Center (EDC) in Sioux Falls, South Dakota, has produced since the early 1990s 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 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 (for more information see http://edc.usgs.gov/greenness/index.html). 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.

Having said the above, Joshua Tree National Park is always open and may be visited anytime of the year, consistent with the 1916 National Park Service Organic Act that directs the U.S. Parks Service to provide for the "public enjoyment of the scenery, wildlife

and natural and historical resources of national parks." The Park Service recognizes, however, that a severe fire can affect operations, and may require temporary closure of the park to protect the public from the threat of an approaching fire and the effects of smoke (National Park Service, 2005).

4.1.3.5 Fire Safety Education

Individuals can make an enormous contribution to fire hazard reduction if provided with the information and tools to do so. In addition to the specific code requirements and guidelines mentioned in the sections above regarding defensible space and appropriate landscaping and construction materials, homeowners can take on several measures to reduce their fire risk. Some of these tasks are listed below:

- Do not mow or use gas-powered landscaping tools during the hottest time of the day.
- Use care when refueling garden equipment and maintain it regularly.
- Dispose of cuttings and debris promptly, according to local regulations.
- Store firewood away from structures.
- If an irrigation system is used, keep it well maintained.
- 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, cliffs, or drainage embankments. Keep a single-story structure at least 30 feet away from the edge of a cliff or ridge; increase this distance if the structure exceeds one story.
- Use construction materials that are fire-resistant or non-combustible whenever possible.
- For roof construction, the Town of Yucca Valley follows the requirements of the California Building Code. Class A, B and C roofing materials are permissible, but Class A is used preferentially for new construction. Class A asphalt shingles, slate or clay tile, metal, cement and concrete products, or terra-cotta tiles have the highest fire-resistant ratings.
- Install an approved automatic fire sprinkler system. The California Building Code has fire sprinkler requirements for new buildings according to occupancy and construction type, but all types of structures can benefit from having a fire sprinkler system installed. This is particularly true of older construction.
- Driveways should provide easy access for fire engines. Driveways and access roads should be well maintained, clearly marked, and include ample turnaround space near houses.
- 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 roofs 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.

4.2 Structure Fires

Based on the 2010 census, the Town of Yucca Valley has a permanent population of about 20,700 (U.S. Census Bureau, 2010 at http://2010.census.gov/2010census). A large percentage of the housing stock in the Town of Yucca Valley area consists of single-family, detached structures, but approximately 11.5% of the housing stock in town consists of apartments, condominiums, and other multi-occupancy structures. Multiple-family and multiple-occupancy 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 Town's Building and Fire Codes. Given that only since January 2011 has the State required one- and two-family dwellings and townhouses to be fitted with fire sprinklers, most of Yucca Valley's residential stock is likely to be un-sprinklered.

In the United States, deaths from fires and burns are the third leading cause of fatal injury, and four out of five fire deaths in 2008 occurred in homes (Karter, 2009, as reported by the Center for Disease Control and Prevention at http://www.cdc.gov/HomeandRecreationalSafety/FirePrevention/fires-factsheet.html). Smoking is the leading cause of fire-related deaths, and cooking is the primary cause of residential fires (Ahrens, 2009a, as reported by the Center for Disease Control and Prevention). Although the number of fatalities and injuries caused by residential fires has declined in the last decades, residential fire-related deaths and injuries still pose a significant public health issue. The good news is that residential fire-related deaths and injuries can be prevented.

When a fire develops in a newer, single-family residential structure constructed of fire-resistant materials and with internal fire sprinklers, the fire can generally be contained to the room of origin, unless the building contents are highly flammable. 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 rooms, and even adjacent structures, unless there is ample distance between structures, there are no strong winds, and the local fire department is able to respond quickly. Fire losses, as a percentage of the total area of the building, are thus potentially higher in older buildings not built with fire-resistant materials (such as gypsum wallboard) that help slow down the spread of fire from the ignition source to other rooms in the

structure. Older structures are also less likely to have the redundant exits and window-height requirements that allow occupants to more easily evacuate the building if needed.

In high-density residential areas, especially in older neighborhoods, fire can easily spread from one structure or unit to the next, and the narrow spaces between structures and property lines provide limited room for emergency access, hindering fire suppression and evacuation efforts. Emergency access and exits may also be compromised if obstructions, such as bay windows and roof awnings, project into the setback between structures, or if non-structural items, such as garbage cans or sheds are stored in those areas. Newer multiple-family units typically meet special fire protection requirements, including automatic fire sprinklers and smoke detectors, and fire-resistant construction materials, in conformance with the more recent California Building and Fire Codes. These improvements help retard the spread of fire between dwelling units.

Post-fire forensic data show that fire safety in structures is controlled to a great degree by the contents in the structure: upholstered furniture, bedding, curtains, mattresses and floor coverings (such as carpets and rugs) allow for quick fire spread and fire growth, and ignition of these materials is responsible for more deaths and injuries than the collapse of structures due to fire (Canadian Wood Council, 2000). Most injuries or deaths due to fire are in fact the result of smoke or toxic fumes inhalation, and not burns (Hall, 2001), so smoke detectors and/or fire alarm systems, combined with window and door openings that allow the occupants to evacuate safely, are very important in managing the impact of a structure fire. Approximately 40% of the home fire deaths occur in homes without smoke alarms (Ahrens, 2009b as reported by the Center for Disease Control and Prevention).

Data provided by the San Bernardino County Fire Department shows that between 2009 and 2012, only about 2.5% of the incident calls received by Fire Stations 41 and 42 were for fires. How many of these were structural or vegetation fires is unknown. Response activity statistics for Stations 41 and 42 for the years 2009-2012 are summarized further in Table 4-1 below. The data show that the number of calls received by the local fire department has increased from one year to the next, at an average rate of just under 4% per year, roughly consistent with the population growth during the same time period.

Table 4-1: Response Statistics for the Yucca Valley Fire Stations for Fiscal Years 2009 to 2012

Station No.	Year	Fires	Medical Calls	Other*	Total Calls
41	2009-2010	74	2,664	657	3,395
	2010-2011	56	2,662	737	3,455
	2011-2012	69	2,828	764	3,661
42	2009-2010	22	711	215	948
	2010-2011	31	704	231	966
	2011-2012	36	736	252	1,024

Data provided by the San Bernardino County Fire Department, written communication from Battalion Chief Dave Benfield, June 2012.

* Other calls include issues like downed power lines, false alarms, smoke investigations, carbon dioxide and smoke alarm investigations, etc.

These statistics are for two stations only and limited to calls within the Town of Yucca Valley.

Losses due to fires, as the data in Table 4-1 show, vary from year to year. The reality is that one fire incident in a high consequence structure (see below) could alter the yearly statistics significantly. Although mostly residential, some of the businesses and land-uses in and around Yucca Valley could result in chemical fires. Issues associated with the storage, use and disposal of hazardous materials are discussed in more detail in Chapter 5, whereas a discussion of chemical fires is provided in Section 4.4 below. Finally, fires after earthquakes are a real concern in southern California, given the region's seismic potential. This is discussed further in Section 4.5.

4.2.1 Target Fire Hazards and Standards of Coverage

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. As mentioned above, in newer residential areas where construction includes fire-resistant materials and internal fire sprinklers, most structure 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 structure fire impacting adjacent structures, unless there is ample distance between buildings, there are no strong winds, and the Fire Department is able to respond in a timely manner.

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:

- Their 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 fire-resistant construction materials;
- 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 its 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:** such as multi-family dwellings and residential buildings like apartments and condominiums, single-family residential homes in the older sections of the Town, hazardous materials occupancies, and large shopping stores and high-occupancy facilities like movie theaters, convention centers, and meeting halls.
- **Low Probability/High Consequences:** such as the medical offices, mid-size shopping centers, industrial occupancies, and large office complexes.
- **High Probability/Low Consequences:** such as older, detached single-family dwellings.
- **Low Probability/Low Consequences:** such as newer, detached single-family dwellings, and small office buildings.

The Fire Department (Battalion Chief Benfield, written communication, June 2012) has indicated that the largest target hazards in Yucca Valley include the following facilities:

- Wal-Mart / Stater Bros. Shopping Center on Hilton Road and Highway 62,
- Stater Bros. Shopping Center on Highway 62, east of Barberry Avenue,
- The Home Depot on Highway 62, east of Avalon Avenue,
- The Best Western Motel at 56525 Highway 62, east of Palm Avenue,
- Amerigas Propane on Old Woman Springs Road and Buena Vista Drive,
- Ferrelgas located at Yucca Trail and Cherokee Trail,
- G&K Propane located at Yucca Trail and Wall Street,
- Santa Fe Assisted Living at 55475 Santa Fe Trail, west of Shawnee Trail,
- Sky Harbor Convalescent at 57333 Joshua Lane, east of Hardesty Drive, and
- Desert Manor Convalescent at 8515 Cholla Avenue, off of Golden Bee Drive.

Other high probability/high consequence risks of concern include 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. 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. There are currently no high-rise buildings meeting those criteria in Yucca Valley. The tallest structure in the Town of Yucca Valley is currently the Best Western Hotel & Suites on Highway 62, which is three stories high.

4.2.2 Regulatory Context

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 Town of Yucca Valley has adopted the 2010 California Fire Code as amended by the County, a modification of the International Fire Code. These provisions include 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 San Bernardino County Fire Department Chief is authorized and directed to enforce the provisions of the California Fire Code throughout the Town. The Town has also adopted the most recent (currently 2010) version of the California Building Code that includes sections on fire-resistant construction material requirements based on building use and occupancy. The construction requirements are a function of building size, purpose, type, materials, location, proximity to other structures, and the type of fire suppression systems installed.

Some of the more significant Fire Code items that help reduce the hazard of structural fire include requirements regarding fire-extinguishing systems such as automatic fire sprinklers. 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 most recent version of the California Fire Code requires fire sprinklers in all new one- and two-family residential structures built after January 1, 2011.

Fire apparatus access to a burning structure is critical to the rapid containment of a fire. Given the size and weight configurations of fire engines, access roads need to comply with minimum width, maximum grade and surface requirements. Approved fire apparatus access roads need to be provided for every facility or building in Town. Fire apparatus roads need to extend to within 150 feet of all of the facility and all portions of the exterior walls of the first story of the building. In some areas, more than one road may be required if and when it is determined that access by a single road may be impaired by vehicle congestion, difficult terrain, weather conditions which could result in dangerous situations or other factors that could limit access. Furthermore, appropriate signage is important to identify the emergency access roads, and to identify the street number of a property, and the buildings therein.

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; equal to 138 kPa) residual pressure. Available fire flow is the total water flow available at the fire hydrants, also measured in gallons per minute. The California Fire Code lists the minimum required fire-flow and flow duration for buildings of different floor areas and construction types; a reduction in required fire flow of 50 to 75% is allowed when the building is provided with an approved automatic sprinkler system. Fire flow requirements within commercial projects are based on square footage and type of construction of the structures. Minimum fire flow for any commercial structure is 1,500 gallons per minute (gpm) at a residual pressure of 20 psi, and can rise to 8,000 gpm, per Table A-III of the California Fire Code. For additional information regarding the required fire-flow for your building, contact the Town's Building and Safety Department and the San Bernardino County Fire Department. The Fire Department conducts inspections of all public fire hydrants in the Town of Yucca Valley to make sure that they are working properly at the appropriate flows for the area.

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 (Platte and Brazil, Los Angeles Times, 1993), primarily because of dwindling water pressure, inadequate pipeline connections and insufficient pumping capacity: most water reservoirs in Laguna Beach were located at lower elevations than the fire, and the water district could not supply water to the higher elevations as fast as the fire engines were using it.

Many of the sixteen existing water tanks owned by Hi-Desert Water District in Yucca Valley are located at higher surface elevations than the neighborhoods that they serve. This allows for a gravity-fed mechanism for water distribution. Nevertheless, regional gravity-fed water distribution systems can still be compromised, especially as a result of an earthquake. While the majority of pipeline failures during earthquakes occur due to fault rupture and lateral spreading, about 40% of the failures are due to wave propagation effects, such as amplification in sedimentary basins (O'Rourke and Liu, 1999). 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. Thus, municipalities that have an older utilities system that includes some of these more vulnerable pipe types should consider upgrading their systems to prevent significant pipeline failures during an earthquake.

Furthermore, as the Town grows to the south and north, and onto higher elevations, the existing water storage tanks may not be able to provide water to all these structures, unless the water is pumped. During and after an earthquake, if there is loss of electric power with a resultant failure of the water pumps, and there are substantial breaks in the water mains due to surface fault rupture, other types of surface failure, and ground shaking, large portions of Town may be left without water for days or weeks. Also important to consider is the fact that more than half of the existing water reservoirs in Yucca Valley do not have the seismic valves, flexible joints and other seismic upgrades that are now required in newer tanks (see Chapter 3, Section 3.2.2), based on lessons learned from the 1992 Landers and 1994 Northridge earthquakes. Damage to these tanks during an earthquake, in addition to leaking irrigation lines and open valves in damaged homes can reduce the amount of water available to fire fighters. A minimum seven-day emergency storage supply is recommended, especially in areas likely to be impacted by fires after earthquakes, due to the anticipated damage to the main water distribution system as a result of ground failure and/or weaknesses in the pipes due to corrosion or age.

4.3 Fire Suppression Services

Fire suppression services in the Town of Yucca Valley are provided by the San Bernardino County Fire Department, Division 5. The Fire Department provides all fire services including fire suppression, inspection, fire safety, rescue and emergency response (emergency medical and paramedic ambulance transportation). The San Bernardino County Fire Department also monitors the fire hazard in the Town, and has ongoing programs for public education, and the investigation and mitigation of hazardous situations. Fire-fighting resources in Yucca Valley include the fire

stations listed in Table 4-2 below. Stations 41 and 42 provide year-round service, whereas Station 38 is only manned when necessary, typically during the high-fire season months. The general telephone number for the Yucca Valley Fire Department is **760-365-3335. For emergencies, dial 911.**

Table 4-2: Fire Stations In and Near the Town of Yucca Valley

Station No.	Address, Phone, Service Area	Equipment, Personnel
41	57201 Twentynine Palms Hwy. (Hwy. 62), Yucca Valley, CA 92284 760-228-2160 Services the valley and southern portion of the Town, and responds to incidents as needed in Joshua Tree, Twentynine Palms, Morongo Valley. Assists the CDF with fire response in Joshua Tree National Park.	1 Type I engine, 1 Type III brush engine, 2 paramedic ambulances, 1 swift water rescue unit. The Type I engine and ambulances are regularly staffed. The brush engine and swift water unit are cross-staffed with the regular duty crew when necessary. Between the hours of 8AM and 8PM, the station is staffed with 6 people. At night, between 8PM and 8AM, the station is staffed with 4 people, with one of the ambulances taken out of service.
42	58612 Aberdeen Road Yucca Valley, CA 92284 760-228-1991 Services the Yucca Mesa area north of town, and responds to incidents in Landers, Johnson Valley, Pioneertown and Joshua Tree. Assists the CDF on all State Responsibility Areas west of Highway 247.	1 Type I Engine, 1 Water Tender, 1 Paramedic Ambulance, and 1 OES-rated light duty rescue unit. The water tender and rescue unit are cross-staffed as needed by the regular crew. Also houses 1 Type I reserve engine and 2 reserve ambulances.
38	5380 Mountain View Lane, Pioneertown, CA 92268 760-365-3650	1 utility unit staffed by one paid local firefighter that lives in the area.

San Bernardino County Fire Department's Division 5 administration, operations and community safety functions are located at 6942 Airway Avenue, Suite A, in Yucca Valley.

4.3.1 Response Objectives and Statistics

The National Fire Protection Association (NFPA Standard 1710, 2010) recommends the following objectives for fire departments:

- An alarm answering time of not more than 15 seconds for at least 95% of the alarms received, and not more than 40 seconds for at least 99% of the alarms received;
- When the alarm is received at a public safety answering point (PSAP) and transferred to a secondary answering point (or communication center), the agency responsible for the PSAP should have an alarm transfer time of not more than 30 seconds for at least 95% of all alarms processed;
- The responding fire department should have an alarm processing time (the time interval from when the alarm is acknowledged at the communication center until response information begins to be transmitted via voice or electronic means to emergency response facilities and emergency response units) of not more than 60 seconds for at

least 90% of the alarms, and not more than 90 seconds for at least 99% of the alarms;

- Turnout time for fire and special operations of 80 seconds, and turnout time for Emergency Medical Service (EMS) response of 60 seconds;
- Travel time of 240 seconds (4 minutes) or less for the arrival of the first arriving engine company at a fire suppression incident and 480 seconds (6 minutes) or less travel time for the deployment of an initial full alarm assignment at a fire suppression incident;
- Travel time of 240 seconds (4 minutes) or less for the arrival of a unit with first responder with automatic external defibrillator (AED) or higher level capability at an emergency medical incident;
- Travel time of 480 seconds (6 minutes) or less for the arrival of an advanced life support unit at an emergency medical incident, where this service is provided by the fire department, provided that a first responder with AED or basic life support unit arrived in 240 seconds (4 minutes) or less travel time.

The time recommendations for fire suppression incidents are based on the demands created by a structure fire: It is critical to attempt to arrive and intervene at a fire scene prior to the fire spreading beyond the room of origin, and this typically occurs within 8 to 10 minutes after ignition. In reality however, response times are going to vary depending on the distance between the responding fire stations and the incident location, the setting (urban, rural or outlying), traffic density and patterns, and conditions specific to the area that may hamper fire response times.

According to the San Bernardino County Fire Department, average response time for Station 41 is 6 minutes, 42 seconds. Average response time for Station 42 is 12 minutes, 20 seconds (Battalion Chief Benfield, written communication, June 2012). These averages include both response to calls close to the stations, and calls to the extreme limits of the stations' response areas, including areas outside of the Town of Yucca Valley. Station 42 services an extremely large area. As a result, response times can actually take 20 minutes or more because of the distance from the fire station to the incident. In addition to the large response area serviced by the Fire Department, response times in the Town of Yucca Valley can be impacted by a number of conditions. The most significant of these include congestion on Highway 62 during the late afternoons and early evenings, and the numerous unpaved (dirt) roads that limit driving speeds. Weather can impact response times too. Some of the Town roads are prone to flooding during storms. For example, Yucca Mesa Road and Old Woman Springs Road are the main arteries providing connection between the areas serviced by Station 42 (in northern Yucca Valley) and Station 41 (southern Yucca Valley). However, the intersection of Yucca Mesa Road and Barron Drive is typically closed due to flooding during storms, forcing all traffic between the two areas onto Old Woman Springs Road. Deep snow at higher elevations during the winter can also hinder or slow down emergency response.

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. The Town of Yucca Valley currently has a Class 5 ISO rating in the developed portions of the Town, and a rating of 9 in its outlying areas. As development in the area increases, additional fire stations will be required to serve the increasing population in a timely manner.

Another potential issue that can impact emergency response is multiple emergency alarms. These do occur occasionally, and when this happens, and simultaneous or numerous calls are received, the Fire Department dispatches the next closest available resource to the new incident. If necessary, the Fire Department relies on its Automatic and Mutual Aid Agreements with neighboring communities, as discussed further in Section 4.3.2.

In addition to the response time, 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 large apartment complex. Structure fire response requires numerous critical tasks to be performed simultaneously, and the number of firefighters required to perform the tasks varies based upon the risk.

The number of firefighters needed at a maximum high-risk occupancy, such as a shopping mall or large industrial occupancy is 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. These agreements are discussed further below.

4.3.2 Automatic and Mutual Aid Agreements

Although Stations 41 and 42 are tasked with the responsibility of fire prevention and fire suppression in Yucca Valley, 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 require 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 the Town 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.

The Town of Yucca Valley is one of 24 cities and towns (in addition to several self-governed Special Districts) that are part of the San Bernardino County Operational area. The Operational Area is part of the Standardized Emergency Management System (SEMS), further described below, which promotes effective disaster management, response and cooperation across jurisdictional boundaries. As a result of being part of an Operational Area group, all of the jurisdictions have mutual aid agreements that allow them to obtain additional emergency resources as needed from non-affected members in the group. Given their geographic locations, the fire stations in Joshua Tree and Landers (County Stations 36 and 19, respectively) are the first responders to mutual aid requests from the Town of Yucca Valley. 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 or jurisdiction. The automatic aid agreements provide for automatic dispatch of surrounding agencies when needed to replace units that are already responding to other calls (multiple alarms), in areas where two or more agencies border each other, or when the call type requires more units than the local area can provide. Mutual aid calls for units over and above what a first alarm assignments provide, generally on large incidents (like a fire in a large shopping center or apartment complex). In both automatic aid and mutual aid agreements, fire units are provided free of charge for the first 12 hours. After 12 hours, the agency with jurisdiction reimburses the assisting agencies for their costs.

Automatic aid and mutual aid agreements with other surrounding agencies include Morongo Valley Fire, CalFire, the Bureau of Land Management (BML), the National Park Service, Twentynine Palms Fire Department, and the Combat Center (Twentynine Palms Marine Base) Fire Department. Numerous other agencies are available to assist the San Bernardino County Fire Department if needed. These include the San Bernardino County Sheriff's Office 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 observe Fire Department operations, as this can hinder fire suppression and emergency response efforts. In addition to the agencies mentioned above, several other 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 and

open areas, agencies that provide fire suppression services include the National Park Service, U.S. Forest Service, National Association of State Foresters, Fish and Wildlife Service, and the Department of Agriculture. Private companies and individuals may also be asked to provide assistance in some cases.

4.3.3 Standardized Emergency Management System (SEMS) and National Incident Management System (NIMS)

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.

Emergency response in every jurisdiction in the State of California is handled in accordance with SEMS. 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. The responsibilities of individual city agencies and personnel are typically defined in the city's Emergency Plan, a document that every jurisdiction is required to have. These documents describe 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; and
- All agencies must complete after-action reports within 120 days of each declared disaster.

The September 11, 2001 terrorist attacks, and later, the 2004 and 2005 hurricane seasons demonstrated the need for improve the country's emergency management, incident response capabilities and coordination processes. On February 28, 2003, the President issued Homeland Security Presidential Directive 5 (HSPD-5), and in response, on March 1, 2004, the Department of Homeland Security unveiled the basic framework guiding the development and administration of the ***National Incident Management System*** (**NIMS**). NIMS provides a nationwide template that is meant to enable Federal, State, tribal, and local governments, in addition to non-governmental organizations and the private sector, to work together to "prevent, protect against, respond to, recover from, and mitigate the effects of incidents, regardless of cause, size, location, or complexity." NIMS is a core set of doctrines, concepts, principles, terminology and organizational processes that enable effective, efficient and collaborative incident management. NIMS works hand in hand with the National Response Framework (NRF), which provides the structure and mechanisms for national-level policy for incident management.

NIMS is the following:

- A comprehensive, nationwide systematic approach to incident management, including the Incident Command System, Multiagency Coordination Systems, and Public Information;
- A set of preparedness concepts and principles for all hazards;
- Essential principles for a common operating picture and interoperability of communications and information management;
- Standardized resource management procedures that enable coordination among different jurisdictions and organizations;
- Scalable, so that it may be used for all incidents (from day-to-day to large-scale); and
- A dynamic system that promotes ongoing management and maintenance.

NIMS components include:

- Preparedness;
- Communications and Information Management;
- Resource Management;
- Command and Management; and
- Ongoing Management and Maintenance.

HSPD-5 requires all Federal departments and agencies to adopt NIMS and use it in all their individual incident management and activities. *Furthermore, the directive requires Federal departments and agencies to make adoption of NIMS by State, tribal and local (i.e., cities) organizations a condition for receiving Federal preparedness assistance.* Given that the basic framework for NIMS was put together in short order, it was understood that it would be a work in progress. In the years since 2004, the NIMS process has been reviewed continuously to incorporate best practices and lessons learned from recent incidents. In 2005, all state, local and tribal jurisdictions were to adopt NIMS for all Departments/Agencies, and were to revise and update their emergency operations plans, standard operating procedures, and standard operating guidelines to incorporate NIMS and National Response Framework components, principles and policies. In 2008, local jurisdictions were to use existing resources, such as programs, personnel and training facilities to coordinate and deliver NIMS training requirements. These training requirements are based on a group of training courses at different levels have been developed and that all appropriate emergency response personnel at all levels of government are required to take to satisfy the NIMS objectives. The most recently published NIMS compliance metrics can be obtained from the Federal Emergency Management Agency (FEMA) website at http://www.fema.gov/emergency/nims/ and from the California Emergency Management Agency (CalEMA) at http://www.calema.ca.gov/PlanningandPreparedness/Pages/National-Incident-Management-System.aspx.

Consistent with both SIMS and NIMS requirements, San Bernardino Fire County personnel are required to train regularly. In fact, training is mandated to be a minimum of two hours per day, per person, at each station, time permitting. Each employee trains either individually and/or in groups, and participates in a formalized program of instruction (with a lesson plan, instructor, or instructional device) to acquire the skills and knowledge necessary to improve the employee's performance in his or her current position. Once a month, multiple crews train together in multi-company drills. Other annual training requirements that they meet include classes on confined-space entry, wildland fire training annual refreshers, etc. The County's training facility, at the Richard Sewell Training Center, provides continuing education courses, both online and in the classroom, for medical and hazardous materarials certifications, and a variety of specialized skills, such as knots and ropes equipment, thermal imaging, firefighter self survival, inspection and maintenance of fire extinguishers, swift water awareness, structural fireground strategy and tactics, fire behavior and fire weather, fire shelter deployment, etc.

4.4 Chemical Fires

Chemical substances are often unstable under high temperatures. Other chemicals are reactive to water or oxygen, and can self-ignite if exposed to water or air. For example, sulfuric acid, one of the most abundant and widely distributed chemicals produced in the U.S., is highly reactive when exposed in its concentrated form to water. Other substances if mixed together can also generate a fire. Therefore, when dealing with chemical fires it is important to know what type of chemicals are present in the area and where they are being stored or used. 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 that they will react violently, increasing the severity of the fire. Fire fighters can better respond to a situation with the appropriate equipment if they have the information needed to make these decisions immediately available to them. This is what the business plans and the Material Safety Data Sheets (MSDS) discussed in Chapter 5 – Hazardous Materials Management – 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 that contain ammonium phosphate.
- **CO_2 (carbon dioxide) extinguishers** are for class B and C fires. They do not work very well on class A fires because the material usually re-ignites. CO_2 extinguishers have an advantage over dry chemical extinguishers in that they leave behind no harmful residue – a good choice for an electrical fire on a computer or other delicate instrument. Note that

CO_2 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 storm drains or leach fields. Containing the water runoff from a fire is difficult but possible, especially if the special equipment to do so is available.

4.5 Fires Following Earthquakes

Although wildland fires can be devastating, history shows that 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, with the potential to severely tax the local fire suppression agencies. Furthermore, if fire fighters are involved with search and rescue operations, they are less available to fight fires. Fire suppression efforts can also be limited by a water distribution system that has been impaired by the earthquake. Thus, 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. 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).

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, M6.7 Northridge earthquake of 1994 caused 15,021 natural gas leaks that resulted in three street fires, 51 structure 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; as a result, 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.

Closer to home, the 1992 Landers earthquake caused two residential fires in Landers, most likely the result of propane gas leaks from overturned appliances; both structures burned down completely. In Yucca Valley, two mobile homes fell off their supports and ignited, also most likely as a result of severed propane gas lines or overturned gas appliances. One of these mobile homes was completely destroyed. Despite multiple breaks in the water distribution system, the San Bernardino County Fire Department reported sufficient water supply to fight these fires (EERI, 1992).

As the examples above indicate, fires following earthquakes can cause severe losses. In some instances, these losses can outweigh the losses from direct damage, such as the collapse of buildings and disruption of lifelines. This potential hazard is particularly applicable to the southern California area given its high seismic potential, and to the Town of Yucca Valley, given its location near several major active faults. Some of the faults that could cause significant ground shaking in Yucca Valley include the Pinto Mountain, Burnt Mountain, Eureka Peak, the South Johnson Valley and other faults that ruptured in the Landers earthquake, to mention a few. A strong earthquake on any of these faults could trigger multiple fires and disrupt lifelines services (such as the water supply) in Yucca Valley. The first four faults in the list above could also cause surface fault rupture in or near Yucca Valley, in addition to other forms of ground failure that could disrupt the local and regional infrastructure. For additional information regarding these seismic hazards, refer to Chapter 1.

The potential impact of fire following an earthquake in the Town of Yucca Valley could be evaluated using the loss-estimation software HazUS, a program developed for FEMA that estimates the losses that could occur as a result of a given earthquake scenario. This program uses a Monte Carlo simulation model to estimate the number of ignitions and the potential burn area resulting from a fire-after-earthquake scenario. Although a complete fire-following-earthquake model requires extensive input about the readiness of the local fire department and the types and availability (functionality) of the local water system, a simplified approach can be used to obtain a rough estimate of the potential losses associated with this hazard. The forecasting ability of the software is expected to improve as data garnered after future earthquakes provides a better understanding of the fire damage associated with different levels of ground shaking, differences in building construction type, and other factors.

A regional earthquake scenario that involves rupture of the entire southern section of the San Andreas fault was conducted in 2008 for the ShakeOut Scenario (Jones and others, 2008; Scawthorn, 2008). The scenario estimates that as a result of a magnitude 7.8 earthquake on the southern San Andreas, a total of 234 ignitions would occur in San Bernardino County. This estimate does not include ignitions that are suppressed by responding citizens. Of the estimated

234 ignitions that will require fire department response, 151 would develop into large fires, each requiring the response of more than one fire engine company. The estimated ultimate burnt area in the County would be equivalent to about 1,000 single-family dwellings (Scawthorn, 2008). Using the 1994 Northridge earthquake as proxy, about half of the ignitions are expected to be electric related, about a quarter would be gas related, and the rest would be the result of a variety of causes, including chemical reactions. Also based on the Northridge earthquake, about 70% of all ignitions will occur in residential structures. Although city-specific estimates were not computed as part of the ShakeOut scenario, the data clearly highlight the hazard associated with earthquake-induced fires. Response to these fires will be hindered by a damaged water distribution system, overwhelmed local fire department resources, overwhelmed 911 centers, and extremely delayed response from strike teams coming in from outlying areas due to damage to the transportation system and traffic disruption (Scawthorn, 2008).

Rupture of the Pinto Mountain fault through the heart of Yucca Valley could result in a significant number of earthquake-induced fires due to damage to the natural gas system. This is especially true if the natural gas system in Town includes several older sections that have not been seismically retrofitted. In support of this argument consider the following example from the Los Angeles area: In 1988 the California Division of Mines and Geology (now the California Geological Survey; Toppozada and others, 1988) published a study that identified projected damages in the Los Angeles area as a result of an earthquake on the Newport-Inglewood fault, a near-surface fault similar to the Pinto Mountain fault that extend across Yucca Valley. The Newport-Inglewood 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, which occurred on a buried thrust fault that did not cause surface fault rupture, the Southern California Gas Company reported 35 breaks in its natural gas transmission lines and 717 breaks in its distribution lines. About 74% of the leaks were corrosion related. Thus, in an area like Yucca Valley where the local gas and water distribution systems have the potential to be impacted by surface fault rupture, a high percentage of breaks can be expected if the Pinto Mountain or any of the other faults through Town ruptures.

The San Bernardino County Fire Department (Battalion Chief Benfield, written communication, June 2012) has standard operating procedures immediately following an earthquake that include pulling all units out of the stations, checking the stations for damage, and then driving the local area to conduct damage surveys. If an earthquake is more severe, the local stations call for more resources as needed, including the activation of emergency operations centers, and the County's Office of Emergency Services. All County fire stations are equipped with emergency generators, and all have the ability to draft water from swimming pools and other bodies of water, a capability of great value, especially if the water distribution system has been damaged and the Fire Department has to resort to alternative water sources to fight fires.

4.6 Summary and Recommended Programs

The San Bernardino County Fire Department manages the fire hazard in the Town of Yucca Valley by providing fire prevention, suppression and public education programs, in addition to medical emergency response and transport. The Town and the County have invested and continue to

invest on infrastructure and equipment that help the Fire Department be as responsive as possible. However, their coverage area is large, and traffic congestion and bad weather at times hinder the Fire Department's response time to emergency calls. Yucca Valley's ISO ratings of 5 for the developed area and 9 for the outlying areas reflect the Insurance Services Office's assessment that fire suppression capabilities, especially in the outlying areas, are still in need of improvement. Mutual aid agreements with neighboring communities to the east, west and north help with response times, but additional fire resources will be necessary as the Town continues to grow.

Wildland fires have been and continue to pose a threat to the outlying areas of the Town, both to west-northwest and south. Several significant fires have encroached onto Yucca Valley from the Sawtooth Mountains and Joshua Tree National Park. As a result, the California Department of Forestry and Fire Protection (CDF) has identified the hillside areas of the Town as having a high to very high fire threat. The Town is also in the list of Communities at Risk, in part due to its location adjacent to or within Federal responsibility areas with a high to very high fire hazard. The National Park Service indicates that the potential future arrival of invasive, non-native grasses, such as buffelgrass, could result in a substantial change in the fire regime of the region, with an increase in the number and size of wildland fires, and an increase in the fire danger due to the high temperatures at which these grasses burn.

Several historical wildland fires have impacted the Yucca Valley area and surrounding communities (Plate 4-1). Cal FIRE has delineated several different areas in Town and surrounding areas as Federal, State or Local Responsibility Areas. The boundaries of these regions are shown on Plate 4-2. Residents of and near these high and very high fire hazard areas should be encouraged to practice fire-safe procedures, including maintaining a fire-safe landscape, and keeping combustibles (such as fire wood) a safe distance away from all structures. Similarly, the County and the Town of Yucca Valley should continue to enforce the weed abatement and notification program, to reduce the potential for vegetation fires to occur in vacant or poorly maintained lots.

Based on data provided by the San Bernardino County Fire Department for the years 2009 to 2012, fires in Yucca Valley account for about 2% of the annual emergency calls that the Fire Department receives. These data do not distinguish between vegetation fires and structure fires. Nevertheless, because of the potential losses, structure fires are considered a significant threat, and the Fire Department has identified several target hazards in Yucca Valley. These include the larger stores and shopping centers where a fire could result in high consequences. Other target hazards of concern include multi-family residential structures, especially older structures not fitted with internal fire sprinklers, and mobile homes, as these buildings typically do not perform well in fires. Thus, structure fires can represent a large percent of the total annual fire losses, especially if these are the result of an earthquake (see below). Programs that can be continued or implemented to reduce these losses should be encouraged.

An earthquake centered in the Town of Yucca Valley, especially if on the Pinto Mountain fault, has the potential to cause substantial damage to the Town and its infrastructure. Extensive damage to the water distribution system would result in substantial reduction in water available to fight fires immediately following the earthquake. Fire Station 41 is located near the Pinto Mountain fault, and although surface fault rupture is not likely to impact the station itself, damage to the surrounding streets and main arteries is expected to hinder the fire station's response, especially to the northern half of Yucca Valley, north of the Pinto Mountain fault zone. Structure fires caused by

an earthquake, the result of electric malfunctions, gas leaks, or toppled-over heat or flame sources, can occur simultaneously at several different locations throughout the Town. The multiple ignitions could severely tax the Fire Department, especially if the damaged roads hinder emergency response. Given the length and extent of the Pinto Mountain fault, other fire stations in adjacent communities (such as Joshua Tree, Twentynine Palms and Morongo Valley) that would normally provide support to the stations in Yucca Valley would find themselves responding to emergencies within their own service areas, further limiting response to impacted areas in Yucca Valley.

Specific actions that the Town of Yucca Valley and the San Bernardino County Fire Department can implement to increase their resiliency to fires are discussed below:

- Encourage residents in areas identified as having a high fire threat to continue fire-safe practices, including the maintenance of a fire-safe landscape, keeping combustibles a safe distance from all structures, etc. The Town and County Fire Department should also continue to enforce the weed abatement program to reduce the potential for vegetation fires.
- 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.
- The Town should coordinate with Joshua Tree National Park to develop abatement procedures to control the spread of buffelgrass and other non-native invasive plant species before they take hold in the region.
- Encourage owners of non-sprinklered properties, especially high-occupancy structures, to retrofit their buildings and include internal fire sprinklers.
- 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 also, 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 systems (SEMS and NIMS).
- The Town should encourage the local gas purveyors and the owners of the high-pressure gas lines that extend through the Town to review and retrofit their pipelines, especially those sections that cross the Pinto Mountain, Burnt Mountain or Eureka Peak faults. The pipelines should be retrofitted, replaced or relocated where necessary. Shut-off valves and/or other mitigation measures designed to limit the release of gas or other products in the event of pipe breakage should be considered for those sections of pipelines that extend across, or overlie the faults that extend across the Town.
- The Hi-Desert Water District should review and improve as needed the adequacy of their water storage capacity and distribution network considering that surface fault rupture and ground failure can impact their systems during an earthquake. Priority should be given to older water lines that may be partially corroded and may therefore be more susceptible to breakage during an earthquake. Redundant systems should be considered and implemented in the downtown, developed portion of the Town on or near the Pinto Mountain fault, where ground failure could result in breaks to both the water and gas

mains, with the potential for significant fire damage.

- Continue to conduct regular assessments of the Fire Department's response objectives, to identify those areas that, because of increasing population and associated congestion, will require an increase in fire department presence and improved responsiveness. Specifically, as the Town's population increases, additional fire stations may be required, their locations to be selected based on population demands, and sited so as to avoid areas with a potential for surface fault rupture, landsliding, or flooding. Funding for the construction of these new fire stations could be supported in part by developers of proposed large-scale master-planned communities.

CHAPTER 5: HAZARDOUS MATERIALS MANAGEMENT

5.1 Setting and Definitions

A high standard of living has driven our increasing dependence on chemicals. Chemicals like hydrocarbon fuels, chlorine, pesticides and herbicides are used on a daily basis and in large quantities. Because of the high demand for these types of chemicals, their storage and transportation is necessary. Some industrial, commercial, manufacturing and military facilities also use hazardous materials, and releases of these compounds onto the environment, either intentionally or accidentally, even if it was years or decades ago, can still pose a threat to public health. Compounds that were used extensively decades ago, when regulations regarding the manufacture, use and storage of these substances were lax, have been found to be hazardous to human health and to the environment. In response to these concerns, which began in the late 1960s, Federal, State, and local regulations have been implemented to dictate the use, storage, transportation, handling and clean-up of hazardous materials and wastes. It is the aim of these regulations to minimize the risk of exposure to hazardous materials by the general public.

The United States Environmental Protection Agency (herein referred to as the EPA) has defined hazardous waste as substances: 1) that may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness; 2) that pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed; and 3) whose characteristics can be measured by a standardized test or reasonably detected by generators of solid waste through their knowledge of their waste. Hazardous waste is also ignitable, corrosive, or reactive (explosive) (EPA 40 CFR 260.10). A material may also be classified as hazardous 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 agencies.

The State of California further defines hazardous materials as substances that are toxic, ignitable or flammable, reactive, and/or corrosive. The State also defines an extremely hazardous material as a substance that shows high acute or chronic toxicity, carcinogenity, bioaccumulative properties, is persistent in the environment, or is water reactive (California Code of Regulations, Title 22).

5.2 Regulatory Context and Lists of Sites

Various Federal and State programs regulate the use, storage, and transportation of hazardous materials. These will be discussed in this section as they pertain to the Town of Yucca Valley area and the Town's 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 the town's residents and visitors, both in normal, day-to-day conditions, and as a result of a regional disaster, such as an earthquake.

Several of the existing Federal and State programs are summarized in the subsections below.

5.2.1 Federal Clean Water Act (33 U.S.C. §1251 et seq., 1972) and California Water Code

In decades past, "out of sight, out of mind" used to be the traditional approach to dealing with trash, sediment, fertilizer-laden irrigation water, used motor oil, unused paint and

thinner, and other hazardous substances that people would dump onto the ground, or into the sewer and storm drains. What we now know is that substances dumped into the storm drain system will make their way into drainages, lakes, rivers, and eventually the ocean. Contaminants in these waterways can endanger aquatic organisms and wildlife dependent on these water sources, and can impact human health and the environment. Some substances dumped onto the ground will eventually make their way into the groundwater, with the potential for contamination of our drinking water resources. Soils contaminated with hazardous substances also require cleanup, as these soils are unacceptable as growing medium for crops, or as a foundation for buildings.

In part to deal with these issues, the Federal government enacted the Clean Water Act in 1972. This Act establishes the framework by which discharges of pollutants into the waters of the United States are regulated, including the establishment of quality standards for surface waters. One of the earliest programs established under the Act was the National Pollutant Discharge Elimination System (NPDES) to control wastewater discharges from various industries and wastewater treatment plants known as a "point sources." A point source is defined by the EPA as a discrete, easily discernible source of pollution, such as a smokestack or sewer. Then, in 1987, the Water Quality Act amended the NPDES permit system to include "non-point source" (NPS) pollution. NPS pollution refers to the introduction of bacteria, sediment, oil and grease, heavy metals, pesticides, fertilizers and other chemicals from less well-defined sources into our rivers, lakes, bays and oceans. These pollutants are not released at one specific, identifiable point, but rather, from a number of points that are spread out and are thus difficult to identify and control. The pollutants are washed away from roadways, parking lots, yards, farms and other areas by rain and dry-weather urban runoff into the storm drain system (if there is one), from where they are ultimately conveyed to the area's water bodies and the ocean. Contaminants can also be carried directly into the soil and the underlying groundwater basin by water infiltrating the soil. 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 NPDES program is handled at the State-level by the California State Water Resources Control Board, with regional offices of the Board overseeing implementation and enforcement of the program at the local level. The regional office of the Board that oversees the Town of Yucca Valley area is Region 7 – Colorado River Basin, with their main office located at 73-720 Fred Waring Drive, Suite 100, Palm Desert, California 92260. Their general telephone number is (760) 346-7491. In accordance with the Clean Water Act, and the Porter-Cologne Water Quality Control Act (contained in Division 7 of the California Water Code), the Water Resources Control Board is responsible for the formulation and adoption of state policy for water quality control. This includes the development of water quality principles and guidelines for ground waters, surface waters and the use of reclaimed water; the formulation, adoption and periodic review and revision of water quality control plans; and the formulation and enforcement of waste discharge requirements (WDRs).

The Federal Clean Water Act states that individual households that are connected to a municipal system, use a septic system, or do not have a surface discharge, do not need an NPDES permit, but cities and facilities must obtain a permit if their discharges go directly to surface waters. Given that currently all wastewater in the Yucca Valley region is disposed through septic systems, and that discharges do not go to surface waters, the Town is not required to have a NPDES permit. However, the California Water Code states that anyone who is discharging or proposing to discharge wastewater onto land shall file a report with the Regional Water Quality Control Board. After review, and following any necessary hearings, the Board may impose waste discharge requirements on that individual or facility. All dischargers, except for small, residential, on-site systems, are required to complete and submit to the Regional Board a Report of Waste Discharge. The appropriate forms, including descriptions and instructions for each, can be obtained at http://www.waterboards.ca.gov/coloradoriver/water_issues/programs/permits.shtml.

Given that Yucca Valley obtains all of its drinking water from water wells in the area, protecting the groundwater from contamination is a priority. However, at this time all residents and businesses in the Town of Yucca Valley "use septic systems and subsurface disposal systems to treat and dispose of . . . wastewater" (Hi-Desert Water District 2010 Urban Water Management Plan by Kennedy/Jenks, 2011). This has contributed to an increase in the concentration of nitrates in the groundwater. A study conducted by the U.S. Geological Survey, in cooperation with the Hi-Desert Water District and the Mojave Water Agency (Nishikawa and others, 2003), showed that septage from septic tanks is the primary source for the high concentration of nitrate detected in several local wells after the Hi-Desert Water District began a groundwater recharge program in 1995. Recognizing the impact that septic systems can have on groundwater quality, the Regional Water Quality Control Board, in its 2004 Triennial Review and Workplan (final published in 2005), identified the Town of Yucca Valley, together with Twentynine Palms, Joshua Tree, Coachella Valley and Pinyon Pines, as areas of concern where they needed to evaluate and revise the Board's guidelines for sewage disposal from land developments. The workplan specifically discusses the need to consider sewer versus septic wastewater disposal, and the need to prohibit or limit the density of septic systems.

Starting in 2003, the Hi-Desert Water District used nitrate removal systems at some of its wells to reduce, to levels below the State's regulatory limits, the concentration of nitrates in the drinking water in its service area. Having achieved those goals, the program has been discontinued, but the equipment is still in place if needed again (M. Ban, Hi-Desert Water District, personal communication, July 2012). Following the U.S. Geological Survey's (Nishikawa and others, 2003) study, and recognizing that a long-term solution to the contamination of the regional groundwater resources was necessary, the Colorado River Basin office of the California Regional Water Quality Control Board, the Hi-Desert Water District, and the Town of Yucca Valley have developed plans for wastewater treatment and water reclamation of the basin. Specifically, in 2009, the Hi-Desert Water District adopted a revised Sewer Master Plan that includes a three-phase development of new sewer collection and treatment systems. The treated wastewater would then be used for groundwater recharge. The District plans to construct a water reclamation facility that will use a tertiary advanced treatment system to treat wastewater and generate effluent that

would then be delivered to recharge basins where it would percolate into and recharge the Warren Valley groundwater basin.

Phase 1 of this plan, which involves the construction of the water treatment facility and sewer connections in the central portion of Town, along the 29 Palms Highway corridor, is scheduled to be completed by 2016 to comply with the California Regional Water Quality Control Board's Resolution No. R7-2011-0004. This resolution stipulates certain prohibitions against the use of septic systems in the Town of Yucca Valley. For additional information and progress reports on the District's Water Reclamation Facility, Wastewater Treatment Plant and Sewer Collection System Project, refer to the Hi-Desert Water District's website at http://www.hdwd.com.

The Regional Board also monitors development projects during the construction stage. Specifically, all dischargers whose projects will disturb one or more acres of soil, or whose projects are less than one acre in size but that are part of a larger development that in total will disturb one or more acres of land are required to obtain a General Permit for Discharges of Storm Water Associated with Construction Activity, under Construction General Permit Order 2009-0009-DWQ adopted on September 2, 2009, and amended by Order No. 2010-0014-DWQ, effective February 14, 2011. Construction activity includes clearing, grading and disturbances such as stockpiling or excavation. The Construction General Permit requires the development of a Storm Water Pollution Prevention Plan (SWPPP). For additional information regarding this program, copies of the appropriate forms, and specifics regarding the contents of a SWPPP, refer to http://www.waterboards.ca.gov/water_issues/programs/stormwater/construction.shtml.

5.2.2 Comprehensive Environmental Response, Compensation and Liability Act

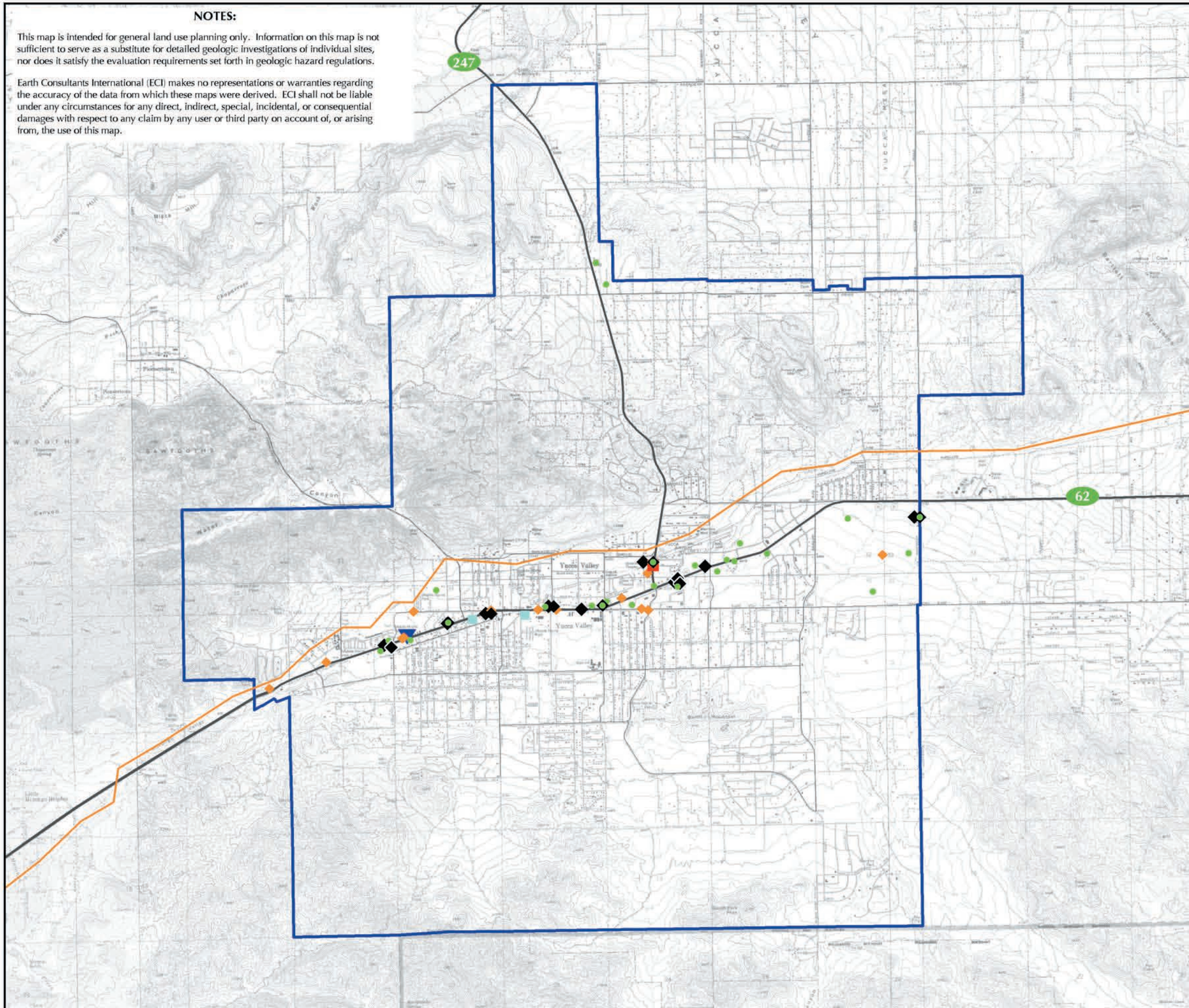
The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) is a regulatory or statute law developed to protect the water, air, and land resources from the risks created by past chemical disposal practices. This act is also referred to as the Superfund Act and contains the National Priority List (NPL) of sites, which are referred to as Superfund sites. Superfund is the name of the environmental program and fund established by CERCLA to address abandoned hazardous waste sites. The fund allows the EPA to clean up these sites and compel responsible parties to do the cleanup or to reimburse the government for the EPA-led cleanup. There are two main types of response actions authorized under CERCLA: 1) removal actions, and 2) remedial actions. Removal actions are short-term responses, often to address emergency situations that require a prompt response, such as the finding of abandoned drums containing hazardous materials or soils contaminated with a substance that poses an acute risk to human health or the environment. Remedial actions are typically long-term responses at sites in the National Priorities List (NPL) with the objective of permanently and significantly reducing the risk associated with the past release of hazardous substances at these sites.

According to the EPA (http://cfpub.epa.gov/supercpad/cursites/srchsites.cfm), there are no Superfund sites in the Town of Yucca Valley. However, in the EPA CERCLIS database (CERCLIS EPA ID CAN000908491), the Yucca Mercury Spill site at 7050 La Contenta

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.



Hazardous Materials Site Map

Yucca Valley, California

Explanation

- EPA-Registered Large Quantity Hazardous Waste Generator (LQG) Facility
- EPA-Registered Small Quantity Hazardous Waste Generator (SQG) Facility
- EPA-Registered Hazardous Waste Generator Facility (size unknown)
- Leaking Underground Storage Tank (LUST) Site (closed cases shown in black)
- Permitted Underground Storage Tank (UST) Site
- Land Disposal Site
- Gas Transmission Line
- Yucca Valley Town Boundary

N
W E
S

Scale: 1:60,000

5000 0 5000
Feet

1200 0 1200
Meters

Base Map: USGS Topographic Map from Sure!MAPS RASTER, 1997
Source: http://iaspub.epa.gov/enviro; http://cfpub.epa.gov/supercpad/cursites/srchrslt.cfm; http://www.epa.gov/tri; http://www.dtsc.ca.gov/database/Transporters/trans_cnty.cfm; http://iaspub.epa.gov/enviro; http://geotracker.swrcb.ca.gov; http://nhdgeo.usgs.gov/viewer.htm

Earth Consultants International

YUCCA VALLEY GENERAL PLAN

Project Number: 3114
Date: 2011

Plate 5-1

Road, in Yucca Valley 92284 is listed as a Superfund site, although not included on the National Priority List. The site is also known as La Contenta Middle School, and was cleaned up with EPA fund-financed monies on an emergency basis on March 24-25, 2007. The cleanup consisted of removal of the contaminant, in this case, mercury. Given the one-time release and that the spill was cleaned up, this site is not included in Plate 5-1.

5.2.3 Emergency Planning and Community Right-To-Know Act

The primary purpose of the Federal Emergency Planning and Community Right-To-Know Act (EPCRA) of 1986 is to inform communities and citizens of chemical hazards in their area. Sections 311 and 312 of EPCRA require businesses to report the locations and quantities of chemicals stored on-site to state and local agencies. These reports help communities prepare to respond to chemical spills and similar emergencies.

The EPA maintains and publishes a database that contains information on toxic chemical releases and other waste management activities that are reported annually by certain industry groups and federal facilities. The database is referred to as the Toxics Release Inventory (TRI), and it was first established under the EPCRA and expanded by the Pollution Prevention Act of 1990. EPCRA's power has allowed for the mandate that Toxic Release Inventory (TRI) reports be made public. TRI reports provide information about potentially hazardous chemicals and their uses 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 3131 of EPCRA requires manufacturers to report releases to the environment 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/tri/. The facilities are required to report on releases of toxic chemicals to the air, soil, and water. They are also required to report on 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. Reporting by facilities is based on the following factors:

- If the facility has ten or more full-time employees;
- If the facility manufactures or processes over 25,000 pounds of approximately 600 designated chemicals, or 28 chemical categories specified in the regulations, or uses more than 10,000 pounds of any designated chemical or category; and
- If the facility engages in certain manufacturing operations in the industry groups specified in the U.S. Government Standard Industrial Classification Codes (SIC) 20 through 39; or
- If the facility is a Federal facility.

A search of the TRI database on November 10, 2011 showed that there are no records of on-site or off-site disposed or otherwise released chemicals in zip codes 92284 and 92286,

the two zip codes that encompass the Town of Yucca Valley area. The database includes the most recent data released to the public on December 2010 with data for the year 2009. The EPA web site (http://www.epa.gov/tri/) should be reviewed periodically for updates to this information, including the potential future presence of other TRI sites in the Town of Yucca Valley area.

5.2.4 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 waste materials. 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 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 the storage period. Disposal is the permanent placement of the waste into or on the land. Disposal facilities are usually designed to contain the waste permanently and to prevent the release of harmful pollutants to the environment.

Many different 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. The EPA (Title 40 of the Code of Federal Regulations) defines a small quantity generator as a facility that produces 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). A “conditionally exempt” small quantity generator is a business that generates 220 pounds (27 gallons) or less of hazardous waste per month.

Since some of these facilities are often small, start-up businesses that come and go, the list of small-quantity generators in a particular area typically changes over time. Sometimes, a facility remains, but the name of the business changes with new ownership. For this reason, please contact the San Bernardino County Fire Department, Hazardous Materials Division, or the EPA website for up-to-date information about generators of hazardous materials in the Town of Yucca Valley. As of November 10, 2011, there were 26 facilities in the Yucca Valley area reported as small-quantity generators. In addition, two sites are on the EPA list but their handler type (small-quantity generator, large quantity generator, or transporter) is unspecified. These facilities are included in Table 5-1, below, and their locations are depicted on Plate 5-1.

Larger businesses are sometimes generators of large quantities of hazardous waste. These generally include some gas stations, chemical manufacturers, large electroplating facilities, petroleum refineries, and military installations. 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 EPA identifies one large-quantity generator in the Yucca Valley area as of November 2011 (see

top of Table 5-1 and Plate 5-1). Please note that these lists can change; therefore, to determine whether the list has been updated, and to obtain a more recent list, if available, contact the San Bernardino County Fire Department, Hazardous Materials Division, or refer to the EPA website.

Table 5-1: EPA-Registered Small- and Large-Quantity Generators of Hazardous Materials in the Town of Yucca Valley

Facility Name, Address	EPA ID	Type Facility
SCE Twentynine Palms Service Center 6999 Old Woman Springs Road, Yucca Valley 92284	CAR000195958	Large-Quantity Generator
Airway Surgicenter, Inc. 57463 29 Palms Highway, Suite 206, Yucca Valley 92284	CAD983651324	Small-Quantity Generator
Arco Facility No. 05215 57858 29 Palms Highway, Yucca Valley 92284	CAR000103549	Small-Quantity Generator
Arco Facility No. 09720 56888 29 Palms Highway, Yucca Valley 92284	CAR000104091	Small-Quantity Generator
Big K Mart No. 3811 57725 29 Palms Highway, Yucca Valley 92284	CAR000129478	Small-Quantity Generator
Bills Diesel Repair 4695 Old Woman Springs Road, Yucca Valley 92284	CAR000085654	Small-Quantity Generator
Blairs Body & Paint 56806 29 Palms Highway, Yucca Valley 92284	CAD982031486	Small-Quantity Generator
CALTRANS District 8 Paradise Valley 6690 La Contenta Road, Yucca Valley 92284	CAD982417784	Small-Quantity Generator
Circle K Store #902 6940 Old Woman Springs Rd., Yucca Valley 92284	CAD981679400	Small-Quantity Generator
City of Yucca Valley 58928 Business Center Drive, Yucca Valley 92284	CAR000069328	Small-Quantity Generator
George's Radiator Shop 56448 29 Palms Highway, Yucca Valley 92284	CAD982348559	Small-Quantity Generator
Hi Desert Disposal 7112 Miami Trail, Yucca Valley 92284	CAD982337933	Small-Quantity Generator
Hi Desert Disposal 4878 Newton Lane, Yucca Valley 92284	CAD983619560	Small-Quantity Generator
Home Depot USA HD 6971 58705 29 Palms Highway, Yucca Valley 92284	CAR000187336	Small-Quantity Generator
Laidlaw Transit 59267 Sunny Slope, Yucca Valley 92284	CAR000070995	Small-Quantity Generator
Norge Village Cleaners 56438 29 Palms Highway, Yucca Valley 92284	CAD981631393	Small-Quantity Generator
Oasis Cleaners 57109 29 Palms Highway, Yucca Valley 92284	CAD982488025	Small-Quantity Generator
Palm Springs Oil No. 15 55716 29 Palms Highway, Yucca Valley 92284	CAD981661135	Small-Quantity Generator
Phelps Chevrolet Nissan 57909 29 Palms Highway, Yucca Valley 92284	CAR000174698	Small-Quantity Generator
Phelps Chevrolet Nissan 56916 29 Palms Highway, Yucca Valley 92284	CAD98200261	Small-Quantity Generator

Facility Name, Address	EPA ID	Type Facility
Rite Aid No. 5686 57646 29 Palms Highway, Yucca Valley 92284	CAR000107680	Small-Quantity Generator
Truck and Equipment Service 4695 Old Woman Springs Road, Yucca Valley 92284	CAR000085654	Small-Quantity Generator
Valley Cleaner 55435 29 Palms Highway, Yucca Valley 92284	CAD981623531	Small-Quantity Generator
Walgreens No. 6399 58133 29 Palms Highway, Yucca Valley 92284	CAR000108894	Small-Quantity Generator
Walmart No. 1915 57980 29 Palms Highway, Yucca Valley 92284	CAR000206607	Small-Quantity Generator
Yucca Valley Chrysler Center 55288 29 Palms Highway, Yucca Valley 92284	CAD983588617	Small-Quantity Generator
Yucca Valley Ford Lincoln Mercury 55189 29 Palms Highway, Yucca Valley 92284	CAD981615495	Small-Quantity Generator
Circle K Store #539 55899 29 Palms Highway, Yucca Valley 92284	CAD981679897	Unknown
CQ of Yucca Valley, No. 7714 56315 29 Palms Highway, Yucca Valley 92284	CAR000216036	Unknown

Source: EPA's EnviroMapper data search performed November 10, 2011.

According to the RCRA database, there is one facility in the Town of Yucca Valley listed as a transporter (Scott Crane at 56826 Mountain View Trail, Yucca Valley 92284). However, this company is not registered in the Department of Toxic Substances Control (DTSC) official database of hazardous waste transporters in the state of California (http://www.dtsc.ca.gov/database/Transporters/trans_city.cfm). Since all transporters of hazardous waste have to be registered with the DTSC in order to operate in the state, this company is most likely no longer in business or operating as a transporter. For this reason, this company is not included in Plate 5-1. The DTSC database does not include any transporters registered in Yucca Valley. Notwithstanding the fact that there are no transporters of hazardous waste registered in Yucca Valley, hazardous waste is being transported through the area by transporters registered or based elsewhere. This is discussed further in Section 5.6.

5.2.5 Cortese List

This California legislation (Government Code § 65962.5) was originally enacted in 1985, and became effective on January 1, 1992. The code required several different State agencies to compile and update annually a list of hazardous materials sites as indicated below, and submit these lists to the Secretary for Environmental Protection. The Secretary was to consolidate all the information received and then forward the complete list of sites to each city and county with sites on the composite list.

1. The California Department of Toxic Substances Control (DTSC) [Subsection 65962.5. (a)] was to compile information on:

- All hazardous waste facilities subject to corrective action pursuant to Section 25187.5 of the Health and Safety Code;
- All land designated as hazardous waste property or border zone property pursuant to Article 11 (commencing with Section 25220) of Chapter 6.5 of Division 20 of the Health and Safety Code;
- All information received by the Department of Toxic Substances Control pursuant to Section 25242 of the Health and Safety Code on hazardous waste disposals on public land;
- All sites listed pursuant to Section 25356 of the Health and Safety Code; and
- All sites included in the Abandoned Site Assessment Program.

2. The State Department of Health Services [Subsection 65962.5. (b)] was to compile data on:

   - All public drinking water wells that contain detectable levels of organic contaminants and that are subject to water analysis pursuant to Section 116395 of the Health and Safety Code.

3. The State Water Resources Control Board [Subsection 65962.5. (c)] was to compile:

   - All underground storage tanks for which an unauthorized release report is filed pursuant to Section 25295 of the Health and Safety Code (this list is now available from GeoTracker, see Section 5.3);
   - All solid waste disposal facilities from which there is a migration of hazardous waste and for which a California Regional Water Quality Control Board office has notified the Department of Toxic Substances Control pursuant to subdivision (e) of Section 13273 of the Water Code; and
   - All cease and desist orders issued after January 1, 1986, pursuant to Section 13301 of the Water Code, and all cleanup or abatement orders issued after January 1, 1986, pursuant to Section 13304 of the Water Code, that concern the discharge of wastes that are hazardous materials.

4. The local enforcement agency, as designated pursuant to Section 18051 of Title 14 of the California Code of Regulations, shall submit to the California Integrated Waste Management Board [Subsection 65962.5. (d]:

   - All solid waste disposal facilities from which there is a known migration of hazardous waste.

Most of this information is now available directly from the various individual state agencies that make the data available on their respective websites. Furthermore, some of the activities required under this code are no longer being implemented, and in some cases, the information to be contained in the Cortese list does not exist (http://www.calepa.ca.gov/sitecleanup/corteselist/Background.htm). There are no sites in Yucca Valley listed in the Cortese List. The closest site is the Twentynine Palms Marine Air

to Ground Combat Center north of Twentynine Palms and, at a minimum, 20 miles to the northeast of the Town of Yucca Valley.

5.2.6 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/Contingency Plan (also known as the Hazardous Materials Business Plan) to its local Certified Unified Program Agency (CUPA). The CUPA with responsibility for the Town of Yucca Valley is the Hazardous Materials Division of the San Bernardino County Fire Department (SBCFD-HMD). The Business Plan includes the Business Owner/Operator Identification page, Hazardous Materials Inventory – Chemical Description page, and an Emergency Response Plan and Training Plan.

According to the guidelines spelled out in the website of the San Bernardino County Fire Department – Hazardous Materials Division (http://www.sbcfire.org/hazmat/forms_guidelines.aspx#Hazardous), the preparation, submittal and implementation of a Business Activity Form is required by all businesses that handle a hazardous material or a mixture containing a hazardous material in quantities equal to, or greater than, those outlined below:

- All hazardous waste generators, regardless of quantity generated or size of container.
- Any business that uses, generates, processes, produces, treats, stores, emits, or discharges a hazardous material in quantities at or exceeding:
  - 55 gallons or more of a liquid;
  - 500 pounds or more of a solid; or
  - 200 cubic feet (compressed) of gas

  at any one time in the course of a year.
- Any business that handles, stores, or uses Category (I) or (II) pesticides, as defined by the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), regardless of amount.
- Any business that handles Department of Transportation (DOT) Hazard Class 1 (Explosives, as defined in Title 49 of the Code of Federal Regulations) regardless of amount.
- Any business that handles extremely hazardous substances in quantities exceeding the threshold planning quantity, as listed in Title 40 of the Federal Code of Regulations, Part 355.
- Any business subject to the EPCRA (also known as SARA Title III; see Section 5.2.3 above). Generally EPCRA includes facilities that handle hazardous substances above 10,000 pounds, or extremely hazardous substances above threshold

planning quantities. Some exceptions include retail gas stations with up to 75,000 gallons of gasoline or 100,000 gallons of diesel if their underground storage tanks meet the 1998 upgrade requirements.

- Any business that handles radioactive materials in quantities for which an emergency plan is required to be adopted, pursuant to Parts 30, 40 or 70 of Chapter 10, Title 10, Code of Federal Regulations (CFR), or pursuant to any regulations adopted by the State in accordance with those regulations.

All Business Plans need to be updated by March 1st of each year (beginning January 1, 2013, all CUPA forms will have to be submitted electronically), or within 30 days of a substantial change. Businesses are required to submit an amendment to their business plan to the CUPA if any of the following events occur:

- A change in inventory;
- Any change in site conditions that may significantly impact emergency response;
- Change of mailing address, phone number or business location; change of emergency contact person;
- Change of ownership; or
- Change of business name.

Business plans must include an inventory of the hazardous materials at the facility. The entire Business Plan needs to be reviewed and re-certified every three years. Business plans are required to include emergency response plans and procedures to be used in the event of a significant or threatened significant release of a hazardous material. These plans need to identify the procedures to follow for immediate notification to all appropriate agencies and personnel of a release, identification of local emergency medical assistance appropriate for potential accident scenarios, contact information for all 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. All facilities must keep a copy of their plan on site.

Additional and specific information regarding business plans and the CUPA forms required by the San Bernardino County Fire Department are available at http://www.sbcfire.org/hazmat/forms_guidelines.aspx#Hazardous. The offices of the Hazardous Materials Division are located at 620 South "E" Street, San Bernardino, California 92415-0153, and they are available by phone at (909) 386-8401 between 8:00 AM and 5:00 PM, Monday through Friday.

Business plans are designed to be used by responding agencies, such as the San Bernardino County Fire Department, during a release or spill to allow for a quick and accurate evaluation of each situation for appropriate response. Businesses that handle hazardous materials are required by law to provide an immediate verbal report of any release or threatened release of hazardous materials if there is a reasonable belief that the release or threatened release poses a significant present or potential hazard to human

health and safety, or to property or the environment. Fines of up to $25,000 per day and one year in prison may be awarded to an individual or business if a release or threatened release is not reported. If a release involves a hazardous substance listed in Title 40 of the Code of Federal Regulations in an amount equal to or exceeding the reportable quantity for that material, a notice must be filed with the California Office of Emergency Services within 15 days of the incident.

The San Bernardino County Fire Department Hazardous Materials Division is charged with the responsibility of conducting compliance inspections of regulated facilities in San Bernardino County (with the exception of Victorville). Specialists are assigned countywide to address the wide variety of complex issues associated with hazardous substances. For example, all new installations of underground storage tanks require an inspection, along with the removal, under strict chain-of-custody protocol, of the old tanks (see Section 5.3 below).

5.2.7 Hazardous Materials Incident Response

There are thousands of different chemicals available today, each with unique physical characteristics; what might be an acceptable mitigation practice for one chemical could be totally inadequate for another. Therefore it is essential that agencies responding to a hazardous material release have as much available information as possible regarding the type of chemical released, the amount released, and its physical properties to effectively and quickly evaluate and contain the release. The EPA-required business plans are an excellent resource for this type of information. Other sources of information are knowledgeable facility agents or 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) that is responsible for developing an emergency plan to prepare for and respond to chemical emergencies in their 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 San Bernardino County Office of Emergency Services (OES), the San Bernardino County Fire Department, the Hazardous Materials Division, and the Town of Yucca Valley Emergency Preparedness Division are all responsible for coordinating hazardous material and disaster preparedness planning and appropriate response efforts with other Town of Yucca Valley departments, as well as local and State agencies. The goal is to improve public and private sector readiness, and to mitigate local impacts resulting from natural or man-made emergencies. The OES is a branch of the San Bernardino County Fire Department that deals with the planning for and response to natural and technological disasters in the County, whereas the Fire Department's Hazardous Materials Division deals with the coordination and inspection of hazardous materials facilities in the County and in the Town of Yucca Valley. The San Bernardino County Fire Department has developed and teaches a Community Emergency Response Team (CERT) training program to help county residents prepare for potential disasters. The CERT training generally consists of seven sessions, one evening a week over a seven-week period, for a total of 20 hours of instruction. The program is certified by the Federal Emergency Management Agency (FEMA) and the State OES. For more information on the CERT program, contact the San Bernardino County Office of Emergency Services CERT Program at (909) 356-3998 or visit http://www.sbcfire.org/oes/csc_cert.aspx. Information on CERT training held locally in Yucca Valley is also available at Town Hall. The Town of Yucca Valley is one of nine jurisdictions within the County currently supporting a Citizens Corps Program. This program is designed to engage residents in community and family safety programs by helping families and neighbors prepare for a disaster. For additional information, refer to the California Service Corps website at http://www.csc.ca.gov.

In 1984, San Bernardino County formed a regional hazardous materials emergency response team through a joint effort of the San Bernardino County Fire Chiefs Association, the San Bernardino County Department of Environmental Health Services, and the County's Communications Center (http://www.sbcfire.org/hazmat/ER.aspx). The formation of this response team was motivated by the need for highly trained personnel and expensive, specialized equipment to respond to hazardous materials incidents. The County's Hazardous Materials Response team now has more than 100 personnel, all trained to the State Fire Marshal-approved Hazardous Material Specialist level, and 19 response vehicles equipped to respond to hazardous release incidents. The County's Hazardous Materials Response Team is divided into three geographic locations, allowing them to quickly respond to hazardous materials incidents anywhere within the county. County Fire Station 36 in Joshua Tree has trained HazMat technicians and equipment, allowing them to make quick assessments and provide resource and mitigation recommendations to the incident commander in real time. The Twentynine Palms Combat Center Fire Department also has fully trained hazardous materials technicians and a large compliment of equipment. They are available to assist on any and all hazardous materials incidents in the Town of Yucca Valley. Finally, the County's Hazardous Materials Response Team in San Bernardino can and will respond to incidents in Yucca Valley (Battalion Chief Benfield, written communication, June 2012).

San Bernardino County Fire Department Hazardous Materials Team members are capable of monitoring unknown atmospheres, identifying unknown chemicals, plugging, patching

and intervening in large chemical leaks, conducting mass decontamination, and handling confined space entry rescue operations. The hazardous materials team members often also assist local fire stations with medical emergencies, structural fires and mass casualty incidents.

5.2.8 Hazardous Material Spill/Release Notification Guidance

All significant spills, releases, or threatened releases of hazardous materials must be immediately reported. **To report all significant releases or threatened releases of hazardous materials, first call 911** (or the local emergency response agency), and then call the Governor's OES Warning Center at 1-800-852-7550.

This guidance summarizes pertinent emergency notification requirements and applies to all significant releases of hazardous materials. 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.

State notification requirements for a spill or threatened release include (at a minimum):

- Identity of caller,
- Location, date and time of spill, release, or threatened release,
- Substance and quantity involved,
- Chemical name (if known; also report whether or not chemical is extremely hazardous), and
- Description of what happened.

Federal notification requires additional information for spills (CERCLA chemicals) that exceed Federal-reporting requirements. This information includes:

- 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 for more information.

Many State statutes require emergency notification of a hazardous chemical release. These statutes include:

- Health and Safety Codes §25270.7, 25270.8, and 25507,
- Vehicle Code §23112.5,
- Public Utilities Code §7673, (PUC General Orders #22-B, 161),
- Government Code §51018, 8670.25.5 (a),

- Water Codes §13271, 13272, and
- California Labor Code §6409.1 (b)10.

In addition, all releases that result in injuries, or workers harmfully exposed, must be immediately reported to Cal/OSHA (CA Labor Code §6409.1 (b)). For additional reporting requirements, also refer to the Safe Drinking Water and Toxic Enforcement Act of 1986, better known as Proposition 65, and §9030 of the California Labor Code.

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 must adopt implementing regulations and seek delegation of the program from the EPA. The CalARP aims to be proactive and therefore 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 in working directly with businesses in this program. The County of San Bernardino Fire Department, Hazardous Materials Division is designated as the Administering Agency for hazardous materials in the Town of Yucca Valley.

5.3 Leaking Underground Storage Tanks

Leaking underground storage tanks (LUSTs) have been recognized since the early 1980s as the primary cause of groundwater contamination by gasoline compounds and solvents. In California, regulations aimed at protecting against underground storage tank (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. These Federal laws 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, Division 20, Chapter 6.7, and in the California Code of Regulations Title 23, Division 3, Chapter 16, commonly referred to as the "Underground 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 ground water 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.

Older tanks were typically single-walled steel tanks. Many of these leaked as a result of corrosion and detached fittings. As a result, the state of California required the replacement of older tanks with new double-walled, fiberglass tanks with flexible connections and monitoring systems. 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. Nevertheless, in that RUST loan funds are still available in 2011 indicates that there are still UST owners, typically small, independent operators that have yet to comply with the RUST requirements. RUST loans, ranging from $10,000 to $750,000 (maximum per person or entity), can be used to finance up to 100% of the costs to upgrade USTs by installing containment sumps, double-walled piping, dispensers, under-dispenser containment boxes or pans, electronic monitoring systems, and enhanced vapor recovery systems. The funds can also be used to conduct enhanced leak detection tests. For additional information on this program, refer to http://www.swrcb.ca.gov/water_issues/programs/ustcf/rust.shtml.

The California legislature established the Barry Keene Underground Storage Tank Cleanup Fund Act of 1989 to provide a means for petroleum UST owners and operators to meet the Federal and state requirements, and to assist small businesses and individuals by providing reimbursement for unexpected and catastrophic expenses associated with the cleanup of leaking petroleum USTs. The fund also provides money to the Regional Water Quality Control Boards to cleanup abandoned sites or abate emergency situations that pose a threat to human health, safety and the environment as a result of a petroleum release from an UST (http://www.swrcb.ca.gov/water_issues/programs/ustcf/). Revenues for the Fund are generated by a storage fee for every gallon of petroleum product placed into a UST. The State Board of Equalization collects these fees on a quarterly basis from owners of active USTs. In the last few years, the fund has experienced a cash shortage. As a result, in May 2009, the State Water Resources Control Board passed Resolution No. 2009-0042 that defines specific actions that the Regional Boards are to take to improve administration of the UST Cleanup Fund and the UST Cleanup Program. The most significant decision in this resolution is that the Regional Boards are to review the open UST cleanup cases and identify those where continued investigation, remediation or monitoring poses little to no environmental benefit. Those sites open for more than five years that are found to not pose a threat to water quality or sensitive receptors, will be recommended for closure.

Recently, the State Water Resources Control Board received a federal grant from the U.S. Environmental Protection Agency using American Recovery and Reinvestment Act funds to cleanup leaks from underground storage tanks. The funds are available to eligible applicants under a new program called the Orphan Site Cleanup Fund (OSCF) or Orphan Site Fund. Orphan sites are sites contaminated by leaking petroleum underground storage tanks where there is no financially responsible party. Additional information on this program, including eligibility requirements and copies of the application for funding can be obtained at http://www.swrcb.ca.gov/water_issues/programs/ustcf/oscf.shtml.

The California Regional Water Quality Control Board (CRWQCB), in cooperation with the Office of Emergency Services, maintains an inventory of leaking underground storage tanks (LUSTs) in a Statewide database called GeoTracker, which is available at http://geotracker.swrcb.ca.gov/. The database lists ten reported LUST cases in the Yucca Valley area. According to the LUST database, all ten sites have been remediated and closed. The ten cases are listed in Table 5-2, below, and their approximate location is shown on Plate 5-1. Given that there are at least 13 permitted underground storage tank (UST) locations in the Town of Yucca Valley area (see Plate 5-1), new

leaks from these USTs could be reported in the future. Therefore, the GeoTracker list should be reviewed periodically for information regarding any new leaks.

Because of the deep groundwater table in the Town of Yucca Valley area, all ten reported leaks listed in Table 5-2 reportedly impacted the soil only; that is, none of the leaks impacted groundwater. In cases like these, the stained soils are generally excavated and replaced with clean soil, and the contaminated soil is then shipped to a facility that accepts hazardous materials. Specific information about each of these sites, including any reports submitted to the Regional Board by the consultants that conducted the cleanups, if available, can be found at the GeoTracker site (http://geotracker.swrcb.ca.gov/).

Table 5-2: Leaking Underground Fuel Tanks Reported in the Town of Yucca Valley

Site Name	Address	State Case No.	Case Type	Status, Contaminant (Date Case Closed)	Date Leak Discovered
7-11 Station	55277 29 Palms Highway	T0607100988	S	5, G (7/23/1999)	11/23/1998
Arco #9720	56888 29 Palms Highway	T0607161914	S	5, G (5/9/2003)	7/3/2001
Bills Service	56504 29 Palms Highway	T0607100990	S	5, FO, G (8/26/2004)	4/14/1999
Caltrans Paradise Valley	6690 La Contenta Road	T0607100985	S	5,G (9/21/1990)	4/28/1987
Circle K #902	6940 Old Woman Springs Road	T0607100984	S	5, G (2/24/1988)	6/11/1987
EZ Serve Station	56079 29 Palms Highway	T060710987	S	5, G (9/9/1999)	8/15/1995
Goodyear Tire	57672 29 Palms Highway	T0607100986	S	5, O (4/21/1995)	11/16/1994
Mag Gas	55716 29 Palms Highway	T0607100989	S	5, G (8/25/1999)	11/9/1998
San Bernardino Co. Yucca Valley Forest Fire	7105 Airway Avenue	T0607100983	S	5, G (7/16/1984)	7/16/1984 & 9/9/1999
Thrifty Oil Station #350	56888 29 Palms Highway	T0607125003	S	5, G (9/19/1990)	7/12/1989

Source: GeoTracker (http://geotracker.swrcb.ca.gov/), based on search conducted November 10, 2011.

Abbreviations Used for Case Type: S = **Soil contaminated, groundwater not impacted**; **G** = Aquifer used for drinking water supply impacted; **O** = Other groundwater (uses other than drinking water); **U** = Under investigation.
Abbreviations Used for Status: 1 = Case Opened; **2** = Site Assessment; **3** = Remediation; **4** = Assessment and Interim Remedial Action; **5 = Case Closed.**
Abbreviations Used for Contaminant: D = Diesel; G = Gasoline; **S** = Other Solvent or Non-Petroleum Hydrocarbon; **O = Waste Oil / Motor / Hydraulic / Lubricating**; **P** = Petroleum / Fuels / Oils, Volatile Organic Compounds; **FO = Fuels Oxygenate**.

5.4 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 behind-the-scene individuals that continually monitor the water supplies for contaminants, in accordance with the drinking water standards set by the EPA. Primary authority for EPA water programs was established by the 1986 amendments to the Safe Drinking Water Act (SDWA) and the 1987 amendments to the Clean Water Act (CWA).

The National Primary Drinking Water Standard protects drinking water quality by limiting the levels of specific contaminants that are known to occur or have the potential to occur in water and can adversely affect public health. All public water systems that provide service to 25 or more people 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, based on new research or new case studies, revised MCLs for some contaminants are issued.

The principal drinking water provider for residents of the Town of Yucca Valley and adjacent portions of unincorporated San Bernardino County is the Hi-Desert Water District (HDWD or District). The HDWD estimates that they serve a population of approximately 24,000 people through approximately 10,000 connections (www.hdwd.com). Other smaller water systems are likely to occur in the area, but these would serve less than 25 people, as they are not listed in the EPA Safe Drinking Water Information System (SDWIS) database (www.epa.gov/enviro/html/sdwis/sdwis_ov.html). Groundwater is the primary water source type used by the HDWD, which owns and operates 18 groundwater wells (13 of which are active), ten booster stations, and 16 reservoirs. The District extracts approximately 3,000 acre-feet of groundwater per year, with its wells having a combined pumping capacity of about 6,200 gallons per minute (Hi-Desert Water District 2010 Urban Water Management Plan by Kennedy/Jenks, 2011). The District supplements its groundwater output with State Water Project (SWP) water as needed, and also uses SWP water to recharge the groundwater basins. The HDWD has a SWP maximum allocation of 4,282 acre-feet per year (http://www.hdwd.com/LinkClick.aspx?fileticket=2cbTAxlFQZc%3d&tabid=106&mid=664). Once the Wastewater Treatment Plant and Water Reclamation Facility is completed (see Section 5.2.1), treated wastewater will also be used to recharge the groundwater basin.

5.4.1 Contaminants of Concern in Groundwater

5.4.1.1 Coliform

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 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 5% tested positive for Total Coliform, or
- For those systems testing less than 40 samples, more than one sample tested positive for Total Coliform.

According to the EPA Safe Drinking Water Information System (SDWIS), the HDWD has had only one monitoring violation since 2000 (www.epa.gov/enviro/html/sdwis/sdwis_ov.html based on data extracted on October 15, 2011 and accessed December 13, 2011). This monitoring, repeat minor violation occurred between March 1 and March 31, 2008, and had to do with the reporting of coliform sampling. Essentially, monitoring and reporting violations occur when the water system fails to complete all samples, or the sampling is not done in a timely manner. The HDWD has had no health-based violations in the last ten years. This record compares well with the national record, as the EPA indicates that in 2005, the last fiscal year for which the EPA has complete data, 24% of all water purveyors had a reporting/monitoring violation, 6.1% reported a maximum contaminant level (MCL) violation, and 1.5% reported a treatment technique violation.

5.4.1.2 Perchlorate

A contaminant that California water agencies are increasingly testing for is perchlorate. Perchlorates are negatively charged molecules that are highly persistent in the environment, lasting decades under typical groundwater and surface conditions. Perchlorate salts are used extensively in several industries. For example, ammonium perchlorate is used as a booster or oxidant for solid fuel powering rockets and missiles, in explosives, and for chemical processes and pyrotechnics. Ammonium perchlorate typically constitutes 60 to 75% of missile propellant and about 70% of space shuttle rocket motors. Potassium perchlorate is also used as a solid rocket fuel oxidizer, and in flares and pyrotechnics. Sodium perchlorate is used as a precursor to potassium and ammonium perchlorate, and in explosives. Magnesium perchlorate is used in military batteries (Rogers, 1998). Perchlorate salts are used in automobile air bags, as a component of air bag inflators, and in nuclear reactors and electronic tubes. Other commercial and industrial uses of perchlorate salts include: as additives in lubricating oils; as fixatives (mordants) for fabrics and dyes, in the production of paints and enamels, tanning and finishing of leathers; electroplating; aluminum refining; and the manufacture of rubber (Siddiqui and others, 1998).

Humans exposed to perchlorate are likely to absorb this compound primarily through ingestion, either by drinking water with perchlorate, or possibly by ingesting produce (such as lettuce or other vegetables that store water) that has been irrigated with water containing perchlorate. Although studies indicate that most ingested perchlorate is eliminated rapidly in the urine without being metabolized (Eichler and Hackenthal, 1962; Anbar and others, 1959), small amounts of perchlorate can displace iodide in the thyroid gland. In adults,

this can lead to hypothyroidism and goiter (enlarged thyroid). Symptoms and effects of hypothyroidism include depression and slow metabolism. In children, the thyroid plays a major role in proper development. Impairment of thyroid function in expectant mothers and newborns can result in delayed development and decreased learning capability. Even temporary disruptions in thyroid function can cause permanent physical and mental impairment, including mental retardation, speech impairments, deafness and/or mutism, impaired fine motor skills, delayed reflexes and gait disturbances.

In 2004, the California's Office of Environmental Health Hazard Assessment (OEHHS) established a public health goal (PHG) of 6.0 micrograms per liter (µg/L) for perchlorate (www.dhs.ca.gov/ps/ddwem/chemicals/perchl/perchlorateMCL.htm). Effective October 2007, perchlorate became a regulated drinking water contaminant in California, with a maximum contaminant level (MCL) of 6 µg/L. In January 2011, and following the review of new data on environmental exposures to and possible effects of perchlorate primarily on infants, the OEHHS submitted a proposal to reduce perchlorate's Public Health Goal (PHG) from 6 µg/L to 1 µg/L.

High levels of perchlorate have been found in hundreds of water wells in San Bernardino County, including in the cities of Rialto, Barstow, Fontana, San Bernardino, Redlands, Ontario, and Loma Linda. High levels have also been detected in Lake Havasu. Perchlorate at low concentrations, significantly below the PHG, have been detected in water samples from some of the wells at the Marine Corps Air Ground Combat Center north of the city of Twentynine Palms (https://www.denix.osd.mil/portal/pls/portal/DENIX_CHLORINE.RPT_PERCH_SUMM.SHOW?p_arg_names=ps_id&p_arg_values=349), and in other parts of the western Mojave Desert (where it is now believed to be naturally occurring; Jackson and others, 2010). To date, perchlorate has not been detected in any of the wells in the Yucca Valley area.

5.4.1.3 Arsenic

Arsenic is a naturally occurring, toxic element that occurs in rocks, soils and groundwater. Because it can cause skin, bladder and other cancers, the Environmental Protection Agency and the California Department of Public Health limit the amount of arsenic that can be present in drinking water. The current (as of July 2011) maximum contaminant level (MCL) allowed for arsenic in drinking water is 10 micrograms per liter (µg/L), equivalent to 10 parts per billion (ppb). However, arsenic at concentrations above this regulatory level occurs in groundwater in several parts of the United States, especially in the southwest and California.

Naturally occurring arsenic at concentrations that intermittently exceed the MCL has been detected in two of the Hi-Desert Water District wells that tap into the deeper aquifer in the Warren Valley groundwater basin. According to the District's 2010 Urban Water Management Plan (Kennedy/Jenks, 2011), one of these wells has been taken off-line until a solution to reduce the arsenic levels is implemented. Water from the other well is blended with water from two other water wells that have low arsenic levels. Both wells produce less than 250 gallons per minute (gpm) of water and are not considered critical producing production wells (Kennedy/Jenks, 2011).

5.4.1.4 Nitrate and Nitrite

Nitrate and nitrite are nitrogen-oxygen combinations that occur in several organic and inorganic compounds. Nitrates are used extensively in fertilizers and are thus found in agricultural areas and landscaped areas where fertilizers are used extensively. Other sources of nitrates include leaks from septic tanks and leaching fields, and erosion of natural deposits. Nitrate does not bind well with soil and typically makes its way into the groundwater where it can impact the drinking aquifers. Drinking water with high concentrations of nitrates can have a serious health hazard, especially to infants. The maximum contaminant level for nitrate is 10 parts per million (ppm or mg/L) as nitrogen, and 45 mg/L as nitrate (http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm).

Prior to the groundwater recharge program started by the Hi-Desert Water District in 1995, background nitrate levels in the water wells in the area averaged about 10 ppm as nitrate. By 1997, nitrate at concentrations above the MCL was detected in water from some wells in Yucca Valley, especially in the midwest and mideast hydrogeologic units (with the water in at least one well containing as much as 150 ppm nitrate; Nishikawa and others, 2003). Nitrate removal systems were emplaced at those wells to reduce the concentrations to levels below the MCL. The nitrates concentration has since been reduced so significantly that the removal systems no longer need to be used, although the equipment is available if high nitrate levels are detected again. The District's Consumer Confidence Report for 2010 (the most current report available when this document was finalized) indicates that in 2010 nitrate was detected in the District's groundwater at a concentration of 15.2 mg/L (approximately equivalent to ppm) as nitrate, with a range of between less than 2 and 40 mg/L.

5.4.1.5 Hexavalent Chromium

Hexavalent chromium has been detected in hundreds of wells in San Bernardino County, including several wells in the Hi-Desert Water District service area. The 2009 Consumer Confidence Report issued by the Hi-Desert Water District reports a total chromium concentration of 3.6 ppb (with a range of between 1.2 and 7.7 ppb) in its drinking water. These concentrations are significantly below the maximum contaminant level of 50 ppb for total chromium. In December 2010, however, the California Office of Environmental Health Hazard Assessment proposed a Public Health Goal for hexavalent chromium of 0.02 µg/L, with a maximum contaminant level for hexavalent chromium (independent of total chromium) expected to be established in the near future. This means that the hexavalent chromium levels in groundwater in Yucca Valley (and many other jurisdictions in the region) exceed this PHG value. In January 2011, the U.S. Environmental Protection Agency recommended that public water systems conduct enhanced testing and monitoring for hexavalent chromium, in addition to total chromium, to better inform their users (the consumers) about the presence of chromium-VI in their drinking water (http://water.epa.gov/drink/info/chromium/guidance.cfm).

5.5 Household Hazardous Waste and Recycling

According to The American Red Cross (1994), most victims of chemical accidents are injured at home. These accidents usually result from ignorance or carelessness in using flammable, combustible or corrosive materials. This is not surprising considering that households do use environmentally significant quantities of hazardous materials. For example, FEMA estimates that 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 the sewer and storm drain systems each month (http://www.fema.gov/hazard/hazmat/backgrounder.shtm). However, with the development of new, "greener" products, and recognizing that sensitive individuals can react to many of the chemicals used in these products, many people find themselves with unused household hazardous waste that they need to dispose off properly. Good, usable leftovers of these products can be donated to willing recipients, such as family members, neighbors and community organizations like churches. But others will want to deliver these substances to an appropriate collection center.

The San Bernardino County Solid Waste Management Department has adopted a Household Hazardous Waste and Oil-Recycling program free to residents, in accordance with the California Integrated Solid Waste Management Act of 1989 (AB 939). The County has established several regional household hazardous waste collection centers, in addition to regional Antifreeze, Batteries, Oil (and Filters), and Paint (Latex only) (ABOP) only collection centers. Those facilities within approximately 50 miles of the Town of Yucca Valley are listed in Table 5-3 below. Personnel who have been trained in hazardous waste handling and emergency response procedures operate these facilities.

At the permanent waste collection centers, a variety of household toxics are accepted, including: chlorine bleach, disinfectants, hair dyes, fiberglass and epoxy resins, paint stripper, paint thinner and turpentine, chemicals used in photo processing, insecticides, pesticides and herbicides, motor oils, rodent poisons, pool/spa chemicals, camp propane tanks, outdated medications, etc. The waste needs to be in its original container or labeled properly. Containers also need to be in good condition, sealed, and not leaking, and the total amount of waste cannot exceed 15 gallons or 125 pounds per trip. Container volume cannot exceed 5 gallons. Materials not accepted include radioactives, explosives, medical waste and asbestos. Also, waste from businesses and non-profit organizations are not accepted at these collection centers. Proof of residency in San Bernardino County may be required. For a complete list of acceptable and non-acceptable materials and tips on how to transport these materials, refer to **http://www.sbcfire.org/hazmat/hhwcollection.aspx#Desert%20Region or call the Household Hazardous Waste Information Hotline at (1-800) OILY CAT (645-9228)**. At the ABOP only centers, they accept only Antifreeze, Batteries (various kinds, including vehicle batteries), Oil (used motor oil and oil filters), and Paint (latex only).

Several other businesses in and around the Town of Yucca Valley, such as The Home Depot, UPS Mailing Centers, Office Depot and similar stores may receive and recycle certain kinds of materials such as used batteries, spent light bulbs, and old electronics. To obtain additional information regarding these facilities, their hours of operation, and the types of waste that they receive, call them directly.

Table 5-3: Regional Household Hazardous Waste Collection Centers

Type	Name	Address	Other Information
Collection Facility	Joshua Tree	62499 29 Palms Hwy.	West of Solid Management Building 3rd Saturday of the month 9:00 AM to 1:00 PM
Collection Facility	Apple Valley	13450 Nomwaket Rd.	Saturdays 10:00 AM to 2:00 PM
ABOP only	Lucerne Valley	33269 Old Woman Springs Road	Behind Fire Station 3rd Saturday of the month 9:00 AM to 12 Noon

Waste collection, in the form of curbside pick-up and recycling services, in the Town of Yucca Valley is provided by **Burrtec**. Their phone number is **(760) 365-2015**, and their website is http://www.burrtec.com/yucca-valley. Burrtec has a series of programs designed to reduce the amount of waste that is taken to the landfill. Their waste reduction and recycling programs include separate containers for recyclable materials (paper, glass, aluminum, cardboard, etc.), and non-recyclable trash. Additional residential services provided by Burrtec include pick-up of bulky items, Christmas tree recycling, pick-up of electronic waste, and used motor oil collection. Information on which items are recyclable and which are non-recyclable, motor oil recycling and the recycling of electronic waste is provided on Burrtec's website.

Burrtec operates three material recovery facilities (MRFs), six transfer stations and seven landfills in southern California. In a material recovery facility, workers sort and process recyclables. All three material recovery facilities operated by Burrtec are more than 50 miles from Yucca Valley. Transfer stations are facilities that serve as local collection points prior to the final disposal site, where waste is separated into types, and sent to the appropriate final destinations. The transfer station closest to Yucca Valley is located in Twentynine Palms, and the closest landfill is located in Landers (see Table 5-4).

There is one land disposal site in the Yucca Valley area listed in GeoTracker. This site is also summarized in Table 5-4 below, and its location is shown on Plate 5-1.

Table 5-4: Active Landfills, Transfer Stations, and Land Disposal Sites Near the Town of Yucca Valley

Name	Address	GeoTracker ID No.	Comments
Landers Sanitary Landfill	59200 Winters Road, Landers, CA 92285 (909) 386-8701	Not in GeoTracker	Operated by Burrtec. Accepts solid waste, household refuse, yard trimmings, furniture, appliances, televisions and computers, and electronic waste. Open 8:00 AM to 4:30 PM, Monday through Saturday.
29 Palms Transfer Station	7501 Pinto Mountain Rd., Twentynine Palms, CA	Not in GeoTracker	Operated by Burrtec. Open 8:00 AM to 4:30 PM, Monday through Saturday.
Trail's End	10780 Malibu Trail,	Not in	Owned and operated by the San Bernardino

Name	Address	GeoTracker ID No.	Comments
Transfer Station	Morongo Valley	GeoTracker	County Solid Waste Management Department. For unincorporated County residents only. Open 8:00 AM to 4:30 PM Thursday through Sunday.
Hi-Desert Water District Land Disposal Site	55439 29 Palms Hwy., Yucca Valley 92284	L10001524666	Land disposal site listed as an open case by the Colorado Basin Regional Water Quality Control Board. No site history or cleanup history provided.

Sources: http://www.burrtec.com/; http://www.sbcounty.gov/dpw/solidwaste/sites.asp; http://geotracker.swrcb.ca.gov/

5.6 Releases due to Transportation Accidents and Pipeline Failures

State Route 62 (Twentynine Palms Highway) traverses the Town of Yucca Valley from west to east, whereas State Route 247 (Old Woman Springs Road) extends across the north-central portion of the Town in a north to northwesterly direction. According to the National Hazardous Materials Route Registry maintained by the Federal Motor Carrier Safety Administration, a division of the U.S. Department of Transportation, both State Routes 62 and 247 are prescribed or permitted to carry hazardous materials. All types of hazardous materials are permitted on both of these roads, and they are both recommended for the transport of Class 1 Explosives. Other roads identified by the U.S. Department of Transportation that are within about 50 miles of Yucca Valley are also included in Table 5-5 below.

Table 5-5: Routes Through Yucca Valley and Surrounding Areas Used to Transport Hazardous Materials and Explosives

Route	Comments / Restrictions	Designation Date
State 62 from Interstate 10 to Arizona	Recommended for Class 1 – Explosives. All types of hazardous materials permitted.	1/1/1995
State 247 from State 18 to State 62	Recommended for Class 1 – Explosives. All types of hazardous materials permitted.	1/1/1995
Adobe Road from Amboy Road to State 62	Recommended for Class 1 – Explosives. All types of hazardous materials permitted.	1/1/1995
Amboy Road from National Trails Highway (near Amboy) to Adobe Road	Recommended for Class 1 – Explosives. All types of hazardous materials permitted.	1/1/1995
Interstate 10 from Arizona to Interstate 405	Recommended for Class 1 – Explosives. All types of hazardous materials permitted.	10/28/1992
Interstate 10 from Arizona to State Route 60	Poisonous Inhalation Hazard.	4/16/1992
Interstate 40 from Arizona to Interstate 15	Preferred route for Class 1 – Explosives, Poisonous Inhalation Hazard, and Radioactive materials. All types of hazardous materials permitted.	1/1/1995; radioactive route designated on 10/25/1994

As a result, these roads pose a potential for spills or leaks from non-stationary sources to occur within the area. Vehicles 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, the San Bernardino County Fire Department – Hazardous Materials Division and local sheriffs providing additional resources as needed.

Train accidents or derailments can result in a release of hazardous substances. However, there are no railroad tracks extending across the Yucca Valley area, so this hazard is not applicable to the study area.

One Southern California Gas Company transmission pipeline extends in an easterly direction across and near the Town of Yucca Valley (https://www.npms.phmsa.dot.gov/searchp/Application.asp) (see Plate 5-1). This gas transmission pipeline crosses and runs over sections of the Pinto Mountain fault zone along a good portion of the Town of Yucca Valley study area, especially in the central portion of town. Given the large displacements expected along the Pinto Mountain fault when this fault ruptures next (an average of about 5 meters of left-lateral displacement could occur if the fault ruptures along its entire length), the pipeline can be expected to rupture where it crosses or overlies the fault. Gas would be released into the air, and if there are ignition sources nearby, fires could ensue.

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 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** (http://www.digalert.com or www.call811.com). Their telephone number is **8-1-1.** 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 and power line failures during an earthquake are more often the result of permanent ground deformations, including fault rupture, liquefaction, landslides, and consolidation of loose granular soils. Tectonic uplift or subsidence can also impact a pipeline. Seismic shaking typically has less of an impact on buried utilities than it does on aboveground structures. The Town of Yucca Valley is underlain by several active faults, so the hazard of surface fault rupture and its potential impact on the town's utilities distribution system is high. In addition, Yucca Valley is located near several other major seismic sources, including the San Andreas fault and other faults of the Eastern California Shear Zone (see Chapter 1), any of which could generate significant ground shaking in the area. Earthquake-induced settlement as a result of an earthquake on any of these seismic sources has the potential to locally impact pipelines, power lines, communication towers, and other lifelines that service the town.

5.7 Earthquake-Induced Releases of Hazardous Materials

Isolated unauthorized releases of hazardous materials can occur at any time, but natural disasters, such as an earthquake or flood, have the potential to cause several incidents at the same time. Strong seismic shaking can lead to the release of hazardous materials by damaging storage facilities and transport infrastructure. During an earthquake, chemical storage tanks could buckle or, if improperly secured and fastened, could easily be punctured and/or tipped over. Improperly segregated chemicals could react forming a toxic gas cloud. Even small amounts of chemicals, if kept in breakable containers and stored together (like in the same chemical closet at a high school chemistry lab or the same aisle at the grocery store), could result in a potentially hazardous situation if the containers break and the chemicals react with each other. As discussed in the section above, pipelines are especially vulnerable to damage as they can be pulled apart or ruptured by strong ground motion and surface ground deformation. Natural gas lines pose a significant hazard due to the high number of pipelines in urban environments and because gas leaks from ruptured lines can lead to secondary fires.

As a result of the Northridge earthquake, 134 locations reported hazardous materials issues, 60 of which required emergency responses. 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 pipeline system and half a dozen leaks in a 10-inch crude oil pipeline (Hall, 1994). A train derailment following the Northridge earthquake included a train with 29 cars and one locomotive. One of the cars spilled an estimated 2,000 gallons of sulfuric acid, and 1,000 gallons of diesel fuel spilled from the locomotive.

The M5.9 Whittier Narrows earthquake in 1987 was nearly 100 times smaller than the ShakeOut earthquake scenario on the San Andreas fault mentioned in Chapter 1, and yet, 22 hazardous materials release incidents were reported as a result of the shaking. The most significant of these incidents was the release, from a collapsed tank in a chlorine re-packaging facility, of nearly one ton of chlorine gas (FEMA, 1997; Eguchi and Ghosh, 2008). This leak caused the evacuation of a neighborhood in Santa Fe Springs. The Whittier Narrows earthquake also caused over 1,400 natural gas leaks, three of which caused subsequent fires. At least 5,000 pounds of anhydrous ammonia were released in 1989, during the Loma Prieta earthquake, at a food processing plant in Watsonville (ABAG, 1990; Seligson and others, 1992).

The facilities listed in previous sections of this report that manufacture, use or store hazardous materials are for the most part using chemical substances that occur in a liquid or solid state at normal temperatures and pressures. A leak of any of these substances (such as gasoline, diesel and motor oil used at gas stations and vehicle repair centers, and solvents used in dry cleaners) could impact the underlying soils. While such a release and subsequent contamination would be unfortunate and would require extensive resources to cleanup, it would not pose an immediate danger to the surrounding population. Past studies of hazardous materials release scenarios as a result of an earthquake have concentrated on the two substances that are thought to pose the biggest threat to a community during an earthquake: Chlorine and anhydrous ammonia. These substances, under normal temperature and pressures, occur in a gas state, and thus if released to the atmosphere, form clouds that can spread to adjacent areas, posing a threat to the surrounding community.

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

Ammonia is a compound of hydrogen and nitrogen that is used extensively, either directly or indirectly, in several different types of applications, including the manufacture of pharmaceuticals, fertilizers, and commercial cleaning products. The colorless gas has a strong pungent odor, an unlike chlorine gas, is lighter than air. Exposure to high concentrations of ammonia can lead to lung damage and death. Solutions of ammonia can be irritating to the eyes and mucous membranes, and to a lesser extent, the skin. Mixture of an ammonia solution with a chlorine-containing compound, such as bleach, can result in the formation of a highly poisonous gas.

Chlorine pellets, chlorine solutions and ammonia solutions can be found at supermarkets, hardware stores and other locations that sell pool supplies and cleaning products. Bleach and ammonia 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, ammonia, or worse, a mixture of the two. Chlorine and/or ammonia may be used at the wastewater treatment plants proposed to be built in Yucca Valley. Chlorine is also likely to be used by the Hi-Desert Water District at its water storage facilities to treat the municipal supply of drinking water. Proper operations and maintenance procedures are required at these facilities to prevent equipment and process failures that could lead to the unauthorized release of these substances at concentrations that could impact the surrounding areas. These facilities are required to maintain a comprehensive program of personnel training, security enforcement and equipment monitoring to reduce the risk of an accidental or intentional (terrorist) release.

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 material 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 happen coincidently, the challenges of managing each are greatly increased. During an earthquake response, hazardous material emergencies become an additional threat that must be integrated into the response management system.

5.8 Other Potential Hazardous Materials Release Incidents

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 is 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).

According to records from the California Division of Oil, Gas and Geothermal Resources (CDOGGR; http://www.conservation.ca.gov/dog/maps/Pages/index_map.aspx), no oil or geothermal wells have been drilled in the Yucca Valley area. Thus, no issues associated with oil and gas production are anticipated in the region.

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 substance, especially if a toxic gas is involved. The best way to reduce the risk posed by a hazardous material release is enforcement of stringent regulations governing the storage, use, manufacturing, and handling of hazardous materials.

The Town of Yucca Valley, like all of San Bernardino County, observes the most current version of the California Fire Code (currently the 2010 edition that was adopted in January 2011) for 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.

There is currently one reported Significant Hazardous Materials Site in the Town of Yucca Valley. A Significant Hazardous Materials Site, as used herein, includes facilities identified in Federal and/or State databases as Superfund-Active or Archived Sites (CERCLIS), Cortese List, RCRA/RCRIS-EPA registered Large-Quantity Hazardous Waste Generators, and Toxic Release Inventory Sites (TRIs). There are also 26 reported Small-Quantity Generators of hazardous materials in the Town, and two facilities whose classification as either small- or large-quantity generators were not identified. Compared to other cities in southern California, Yucca Valley at this time has a relatively small number of facilities that use or store hazardous materials. Nevertheless, several of the existing hazardous materials generators are located within about 1 mile of schools in the community. As the town continues to grow, more, especially small-quantity generators of hazardous materials are expected to be located in the area. Town planners are advised to encourage the establishment of future significant hazardous materials sites in areas far away from

critical facilities with evacuation constraints, such as schools and nursing homes. Facilities that use, store, generate or transport hazardous materials are also expected to come and go; so these lists, or comparable lists, should be updated at least once a year. Residents and property and business owners that are interested in obtaining current data for a particular area or site should request it from the San Bernardino County Fire Department, Hazardous Materials Division, or by visiting the appropriate websites referenced herein.

The Town of Yucca Valley is underlain by the Pinto Mountain, Burnt Mountain, Eureka Peak and southern extension of the Johnson Valley faults. The Town is also located near the San Andreas fault and several faults of the Eastern California Shear Zone. The San Andreas fault especially, is thought to have a relatively high probability of generating an earthquake in the next 30 years (see Chapter 1). Therefore, all hazardous materials sites in Yucca Valley could be subject to moderate to severe seismic shaking. Their business plans should address, provide 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 building does not suffer significant damage. Hazardous material containers not properly secured and fastened could easily be punctured and/or tipped over, pipes 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. The one large-quantity generator of hazardous waste in Yucca Valley is located very close to the mapped surface trace of the Pinto Mountain fault. Surface fault rupture at this facility could result in structural damage and release of the chemical substances stored therein.

The large-quantity generator of hazardous waste, and some of the small-quantity hazardous waste generators are also located within the FEMA-defined 100-year flood zone, or between the limits of the 100- and 500-year flood zones (see Chapter 3). This is generally not recommended, unless all standards of elevation, anchoring and flood proofing have been satisfied, and the hazardous materials are stored in watertight containers designed to not float. Avoidance of the 100-year flood zones by facilities using or storing hazardous materials should be considered in the future.

5.10 Summary of Findings

Federal Clean Water Act and California Water Code

Given that currently all wastewater in the Yucca Valley region is disposed through septic systems, and that discharges do not go to surface waters, the Town of Yucca Valley is not required to have a National Pollutant Discharge Elimination System (NPDES) permit. However, anyone who is discharging or proposing to discharge wastewater onto land needs to file a report with the Regional Water Quality Control Board. The Board can impose waste discharge requirements on that individual or facility. All dischargers, except for small, residential, on-site systems are required to complete and submit to the Board a Report of Waste Discharge. Furthermore, and more importantly, releases from septic tanks in the Yucca Valley area have been shown to have degraded the groundwater quality of the Warren Valley groundwater basin. Specifically, in the 1990s nitrate concentrations in the groundwater increased from a background level of about 10 parts per million (ppm) to as much as about 150 ppm in at least one well. The Hi-Desert Water District has successfully used nitrate removal systems at some of its wells, but to further reduce the

impact of septage on the groundwater resources of the region, the Board passed Resolution No. R7-2011-0004 which phases out, over the next several years, the use of septic systems in the Town of Yucca Valley. The Hi-Desert Water District has developed a plan to construct a water treatment and water reclamation facility that will also involve the construction of sewer connections in town. The first phase of this plan is scheduled for 2016.

Superfund, Hazardous Waste, and Toxic Release Inventory Sites

According to EPA data, there are no Superfund (CERCLIS) sites in the Yucca Valley area, although the La Contenta Middle School is included in the National Priority List due to a mercury release that was cleaned-up with EPA fund-financed monies on an emergency basis in March 2007. The EPA reports that there is one permitted Large-Quantity Generator of hazardous materials (SCE Twentynine Palms Service Center). There are no sites listed in the Toxic Release Inventory (TRI) database, and no sites are included in the CORTESE list. These databases should be reviewed periodically to obtain the most recent information for the area. As of November 10, 2011, there were 26 permitted Small-Quantity Generators of hazardous materials located throughout the town, and two sites listed as unknown. The number of hazardous waste generators is expected to increase as Yucca Valley grows. There is also one business listed in the RCRA database as a transporter of hazardous waste in the Yucca Valley area, but this facility is not listed in the Department of Toxic Control Substances official database of registered transporters of hazardous waste in California.

Hazardous Materials Disclosure Program

Both the Federal government and the State of California require businesses that handle more than a specified amount of hazardous materials or extremely hazardous materials, termed a reporting quantity, to submit a business plan to the local Certified Unified Program Agency (CUPA). In the Town of Yucca Valley, the local CUPA is the San Bernardino County Fire Department, Hazardous Materials Division (SBCFD-HMD). They are responsible for reviewing the annually submitted business plans. For more information refer to their website (http://www.sbcfire.org/hazmat), or contact them by phone at (909) 386-8401.

Leaking Underground Fuel Tanks

According to data from the State Water Quality Control Board, ten leaking underground storage tank (LUST) sites were reported in Yucca Valley between 1984 and 2001. All ten sites have been remediated and/or are not considered to pose a risk to human health and the environment; their cases have been closed by the appropriate regulatory agency. None of the leaks reportedly impacted the groundwater given that groundwater in the region occurs at significant depth. The California Regional Water Quality Control Board (CRWQCB), in cooperation with the County of San Bernardino Fire Department– Hazardous Materials Division provides oversight and conducts inspections of all underground tank removals and installation of new ones. Given that there are at least 13 permitted underground storage tanks in the town, future leaks could be reported. The GeoTracker database should be reviewed periodically for updates.

Water Quality

The Hi-Desert Water District provides drinking water to the residents of the Town of Yucca Valley and unincorporated areas nearby. According to the EPA Safe Drinking Water Violation Report, in the last ten years, the Hi-Desert Water District has had only one minor reporting violation, and no

health-based violations. The monitoring violation occurred in March 2008, and had to do with the reporting of coliform sampling. Compared to State statistics for drinking water violations, the Hi-Desert Water District's record is good.

Substances that have the potential to impact the drinking water aquifers that provide water to the residents of the Town of Yucca Valley include coliform and other bacteria present in human and animal wastes, arsenic (which in this area is naturally occurring), nitrates, hexavalent chromium (which may also be naturally occurring in this area), and man-made contaminants such as pharmaceuticals that are present in septic tanks septage. The concentrations of all these compounds in the groundwater used for drinking purposes are monitored on a regular basis by the Hi-Desert Water District. In the late 1990s and early 2000s, nitrates were detected in water samples from the Warren Valley groundwater basin at levels above the maximum contaminant level. The presence of nitrates in the groundwater is attributed to leakage from the septic tanks. The levels of nitrates in groundwater have since decreased substantially, to concentrations below the State-defined Maximum Contaminant Level for nitrate in drinking water.

Household Hazardous Waste

San Bernardino County has adopted a Household Hazardous Waste and Oil-Recycling program that is free to county residents, in accordance with the California Integrated Solid Waste Management Act of 1989. There are a few facilities in the region where residents from Yucca Valley can drop off their unwanted household hazardous waste; the closest site is located in Joshua Tree, at 62499 29 Palms Highway. For a list of collection sites, their schedules of operation, and types of materials accepted, refer to the San Bernardino County Solid Waste Management Department at http://www.sbcfire.org/hazmat/hhwcollection.aspx#Desert%20Region or call the Household Hazardous Waste Information Hotline at (1-800) OILY CAT (645-9228).

The Town of Yucca Valley, together with Burrtec, their trash hauler, have programs designed to reduce the amount of waste taken to the landill. Waste reduction and recycling programs include: curb-side collection service with separate containers for grass clippings and composting materials, recyclables, and non-recyclable trash. For additional information regarding the services provided by Burrtec refer to their website at http://www.burrtec.com/yucca-valley, or call (760) 365-2015. Burrtec operates a transfer station in Twentynine Palms (at 7501 Pinto Mountain Road), and the closest landfill to Yucca Valley is the Landers landfill at 59200 Winters Road. There is one site in the Town of Yucca Valley identified as a land disposal site in the GeoTracker database; information on this site, referred to as the Hi-Desert Water District land disposal site, was not available.

Releases due to Transportation Accidents and Pipeline Failures

Both State Rout 62 and State Route 247 are permitted to transport hazardous materials, including Class I explosives. Other routes in the region, within about 50 miles of the Town of Yucca Valley are also used to transport hazardous material, including Interstates 10 and 40, and internal roads leading to the Twentyine Palms Air to Ground Combat Training Center north of Twentynine Palms. Spills or leaks from a non-stationary source could occur on these roads in the event of an accident involving a vehicle carrying hazardous substances. All transportation of hazardous materials needs to be conducted under strict protocol. Material data sheets for each substance being transported need to be carried by the conductor. These data sheets are designed to help

emergency response personnel identify the most appropriate action to contain the specific substances involved in the spill. The California Highway Patrol is in charge of spills that occur in or along freeways, with Caltrans, the San Bernardino County Fire Department – Hazardous Materials Division and local sheriffs providing additional resources as needed.

One gas transmission line extends across the Town of Yucca Valley in an easterly direction, generally extending across or along mapped traces of the Pinto Mountain fault. Rupture of any portion of this pipeline could adversely impact the surrounding area. Pipeline operators are responsible for the continuous maintenance and monitoring of their pipelines, including the repair, when necessary, of corroded sections of pipe. All excavations or drilling operations near pipelines should be conducted only after proper clearance by the appropriate utility agencies or companies. California law requires that all excavations be cleared – this is done by the Underground Service Alert of California or DigAlert (http://www.digalert.com or www.call811.com). Their telephone number is **8-1-1.** Calls need to be made at least two (2) working days before digging, and the proposed excavation area needs to be delineated or marked.

Oil Fields

There are no oil or gas fields in or near Yucca Valley. Environmental issues associated with oil and gas fields are not anticipated in the study area.

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 materials released. The best way to reduce the possibility for a hazardous material release is by implementing and enforcing stringent regulations governing the storage, use, manufacturing and handling of hazardous materials. Given that the Pinto Mountain, Burnt Mountain, Eureka Peak and Southern Johnson Valley faults extend across the Town of Yucca Valley, the hazards of surface fault rupture, ground deformation and strong ground shaking, and the impact that these geologic conditions may have on the structural integrity of the storage containers and pipelines carrying hazardous materials need to be considered and planned for.

The entire area will be subjected to intense ground shaking as a result of an earthquake on the southern segment of the San Andreas fault, or on the Pinto Mountain, Burnt Mountain, Eureka Peak or Southern Johnson Valley faults that extend across the planning area (for more information refer to Chapter 1). It has been observed in previous urban earthquakes that hazardous materials spills can occur even when the building housing the materials does not suffer significant damage. Hazardous material containers not properly secured and fastened can easily be punctured and/or tipped over. Improperly segregated chemicals could react, forming a toxic gas cloud. In a worst-case scenario, several hazardous materials releases could occur simultaneously. Therefore, hazardous material sites in Yucca Valley should be designed with secondary containment systems, tank bracing systems, and other engineering solutions to reduce the potential for tanks and containers to tip over during an earthquake. All business plans for sites within the city should address the hazard of intense ground shaking and identify specific measures to be taken to reduce this hazard to an acceptable level.

The one significant hazardous materials site identified in Yucca Valley is located within the flood zone; several of the small-quantity generators of hazardous materials are also located within either the 100- or 500-year flood zones. It is recommended that future hazardous materials sites in Yucca Valley not be located in the 100-year floodplain, unless very specific containment measures are implemented to reduce the potential for hazardous materials to leak during a flood. Furthermore, street flooding as a result of intense storms and inadequate storm drain capacity could result in the flooding of some of the hazardous materials facilities. Therefore, the business plans for all hazardous materials businesses should address the hazards of flooding and of strong ground shaking during an earthquake, and provide for mitigation measures to be implemented to reduce the potential for hazardous materials to leak during a natural disaster.

Several of the existing hazardous materials sites are also located within 1 mile of schools and other facilities with populations with special evacuation needs. It is advisable to encourage the establishment of any future significant hazardous materials sites in areas far away from critical facilities with evacuation concerns. Furthermore, these critical facilities should have plans that include protocol to be followed in the event of a leak of hazardous materials that would require them to evacuate.

CHAPTER 6: SEVERE WEATHER HAZARDS

Severe weather, including high winds, hail, excessive precipitation, wildfires, blizzards, snowstorms and ice storms, dust storms, heat spells and drought, have the potential to cause significant damage to property and infrastructure, cause serious social disruption, and result in injuries and/or loss of life. Many of these hazards can create conditions that disrupt essential systems such as public utilities, telecommunications, and transportation routes. Flooding associated with excessive precipitation and wildfires are discussed in other chapters, although wildfires fanned by winds are also included herein. This chapter discusses primarily high winds, hail, snow storms, heat spells and drought. Historical occurrences of these conditions in the high deserts and San Bernardino Mountains region are summarized as background information, in addition to definitions and terminology associated with each. Finally, where appropriate, based on the historical data presented, mitigation measures that can reduce the potential impacts of these hazards are provided.

6.1 High Winds

This section discusses the specific hazards associated with unusual and potentially damaging wind activity based on scientific data and historical records. In southern California, strong winds may be associated with Santa Ana conditions, thunderstorm-related strong winds and tornadoes, and macrobursts and microbursts. Each of these strong wind conditions is discussed further in the subsections below. In addition, strong wind activity combined with loose soil in an arid or semi-arid environment such as southern California's can result in dust storms. These are also discussed below.

6.1.1 Definitions and Setting

Wind is air that is in motion relative to the earth. It generally has both horizontal and vertical components, but the horizontal component generally dominates (National Research Council, Committee on Natural Disasters – NRC, CND, 1993). Due to friction, wind speed drops off at the ground surface, with approximately 50% of the transition in wind speed due to the frictional forces exerted by the ground surface occurring in the first six feet above the ground. As a result, "near-surface wind is the most variable of all meteorological events" (NRC, CND, 1993), and it generally consists of a combination of high-frequency oscillations in both speed and direction superimposed on a more consistent flow with a prevailing speed and direction. With an increase in wind speed, the high-frequency oscillations can become more abrupt and of greater amplitude – these are referred to as wind gusts. Because wind speeds vary as a function of height, time and the terrain upwind, it is difficult to obtain a value that is representative of the wind speeds over a large region. The recommended convention for measuring wind speed is at a height of 33 feet (10 m), in flat, open terrain, such as that provided by an airport field. Temporal variations are taken into account by averaging speed and direction over a given time, typically 1-minute averages for sustained wind, and 2- to 5-second averages for peak or extreme winds. The mean annual wind speed for the contiguous 48 states is 8 to 12 miles per hour (mph), with most areas of the country frequently experiencing 50-mph winds (NRC, CND, 1993).

To better appreciate the impact that wind has on the sea and land, and the wind speeds required to move different objects, refer to the Beaufort Scale in Table 6-1, below. This

scale was developed by Sir Francis Beaufort in 1805 to illustrate and measure the effect that varying wind speed can have on sea swells and structures. Note that the highest wind speeds in the Beaufort Scale approach the lowest wind speed on the Fujita Scale presented in Table 6-2.

Table 6-1: The Beaufort Scale

Beaufort Force	Wind Speed (mph/ knots)	Wind Description – State of Sea – Effects on Land
0	< 1; <1	Calm – Mirror-like – Smoke rises vertically.
1	1 - 3 / 1 - 3	Light – Scaly ripples; no foam crests – Smoke drifts show direction of wind, but wind vanes do not.
2	4 - 7 / 4 - 6	Light Breeze – Small but pronounced wavelets; crests do not break – Wind vanes move; leaves rustle; you can feel wind on face.
3	8 - 12 / 7 - 10	Gentle Breeze – Large wavelets; crests break; glassy foam; a few whitecaps – Leaves and small twigs move constantly; small, light flags are extended.
4	13 - 18 / 11 - 16	Moderate Breeze – Small (1-4 ft) waves; numerous whitecaps – Wind lifts dust and loose paper; small tree branches move.
5	19 - 24 / 17 - 21	Fresh breeze – Moderate (4-8 ft) waves taking longer to form; many whitecaps; some spray – Small trees with leaves begin to move.
6	25 - 31 / 22 - 27	Strong Breeze – Some large (8-13 ft) waves; crests of white foam; spray – Large branches move; wires whistle.
7	32 - 38 / 28 - 33	Near Gale – Sea heaps up; waves 13-20 ft; white foam from breaking waves blows in streaks with the wind – Whole trees move; resistance felt walking into the wind.
8	39 - 46 / 34 - 40	Gale – Moderately high (13-20 ft) waves of greater length; crests break into spin drift, blowing foam in well-marked streaks; Twigs and small branches break off trees; difficult to walk.
9	47 - 54 / 41- 47	Strong Gale – High waves (20 ft) with wave crests that tumble; dense streaks of foam in wind; poor visibility from spray – Slight structural damage; shingles blow off roofs.
10	55 - 63 / 48 - 55	Storm – Very high (20-30 ft) waves with long, curling crests; sea surface appears white from blowing foam; heavy tumbling of sea; poor visibility – Trees broken or uprooted; considerable structural damage.
11	64 – 73 / 56 - 63	Violent Storm – Waves high enough (30-45 ft) to hide small and medium-sized ships; sea covered with patches of white foam; edges of wave crests blown into froth; poor visibility – Seldom experienced inland; considerable structural damage.
12	> 74 / > 64	Hurricane – Sea white with spray; foam and spray render visibility almost non-existent; waves over 45 ft high – Widespread damage; very rarely experienced on land.

Sources: www.spc.noaa.gov/faq/tornado/beaufort.html; http://www.stormfax.com/beaufort.htm

6.1.2 Types of High Winds in Southern California

6.1.2.1 Santa Ana Winds

Most incidents of high wind in southern California are the result of ***Santa Ana wind*** conditions. Santa Anas are generally dry, often dust-bearing, winds that blow from the east or northeast toward the coast, and offshore (Figure 6-1). These winds commonly develop when a region of high atmospheric pressure builds over the Great Basin – the arid high plateau that covers most of Nevada and parts of Utah, between the Sierra Mountains on

the west and the Rocky Mountains to the east. Clockwise circulation around the center of this high-pressure area forces air downslope from the plateau. As the air descends toward the California coast, it warms at a rate of about 5 degrees Fahrenheit per 1,000 feet elevation. Since the air originates in the high deserts of Utah and Nevada, it starts out already very low in moisture; as it is heated, it dries out even further. The wind picks up speed as it hits the canyons and passes in the coastal ranges of southern California, blowing with exceptional speed through the Santa Ana Canyon (from where these strong winds derive their name). Forecasters at the National Weather Service usually reserve the use of "Santa Ana" winds for those with sustained speeds over 25 knots (1 knot = 1.15 mph); as they move through canyons and passes, these winds may reach speeds of 35 knots, with gusts of up to 50 to 60 knots (see Table 6-1).

Santa Ana winds are common in the southern California area, with Santa Ana conditions expected yearly in the region, typically in the fall through early spring. For the most part these winds are a nuisance, bringing dust indoors, breaking tree branches, and causing minor damage. For people with respiratory ailments, however, Santa Ana winds often mean headaches, sinus pain, difficulty breathing, and even asthma attacks. Strong Santa Ana winds can cause extensive damage to trees, utility poles, vehicles and structures, and can even be deadly. In 2003, for example, two deaths were blamed on these strong winds: a downed tree struck and killed a woman in San Diego, and a passenger in a vehicle was struck by a flying pickup truck cover (http://cbsnews.com/ January 8, 2003 article). Wildfires in the region often occur during Santa Ana wind conditions, when the air humidity is low to very low. Because the winds fan and help spread these fires, Santa Ana wind conditions always are serious concerns to fire fighters.

6.1.2.2 Thunderstorm-Related Tornadoes

A variety of mechanisms give rise to ***thunderstorms***, but most often these develop when warm, moist air meets a cold front, producing strong winds, and sometimes tornadoes, and hail. More than 100,000 thunderstorms occur every year in the United States, and more than 10,000 of these are considered severe, resulting in annual property losses in excess of $1 billion (National Research Council's Committee on Natural Disasters, 1993). Most of these occur in the central Great Plains and the southeastern coastal states, but thunderstorms do occur in every state. A thunderstorm is officially labeled as severe if: 1) it produces a tornado, 2) has winds in excess of 58 mph, or 3) produces surface hail greater than 0.75 inch in diameter. An exceptionally severe thunderstorm can generate several tornadoes and downbursts.

Tornadoes are "violently rotating columns of air extending from a thunderstorm to the ground (http://www.nssl.noaa.gov/edu/safety/tornadoguide.html; see Figure 6-2). Although tornadoes occur in many parts of the world, they are most common during the spring and summer months in the Central Plains of the United States, east of the Rocky Mountains. In the spring, tornadoes often form where warm, moist air from the east meets hot, dry air from the west (this boundary is called a "dryline"). In the winter and early spring, tornadoes can form when strong frontal weather systems originating in the Central states move eastward. Thunderstorms, and associated tornadoes, can also form at the range front, where near-ground air is forced to move "upslope" along the ascending mountain slopes. In California, tornadoes are occasionally generated by strong storms. Although the number of tornadoes reported in California is only a fraction of those reported in the

central states, California does get its share of these. In the 30 years between 1959 and 1988, 133 tornadoes were reported in California, for an average of 4 tornadoes a year (NRC-CND, 1993).

Tornadoes can also accompany tropical storms and hurricanes as they move on land, where they usually occur ahead of the path of the storm center as it comes onshore (http://www.nssl.noaa.gov/edu/safety/tornadoguide.html). Weak tornadoes that form over warm water are called ***waterspouts***. Occasionally, waterspouts can move on land and become tornadoes. ***Funnel clouds*** are cone-shaped or needle-like clouds that extend downward from the main cloud base but do not extend to the ground surface. If a funnel cloud touches the ground, it becomes a tornado; if it touches or moves across water, it is a waterspout. Waterspouts that have moved onto land are more often reported in southern California in the fall and winter, but some have also been reported in the spring. For example, on April 6, 1926, a waterspout that came on land at National City, near San Diego, unroofed several homes and injured eight people; one on February 12, 1936 unroofed two homes, blew down five oil derricks and injured six people.

Figure 6-1: View From Space of Smoke from the October 2003 Fires in Southern California, Carried Offshore by Strong Santa Ana Winds

Source: Image by Jacques Descloitres, MODIS Rapid Response Team at NASA/GSFC, obtained from the archives at http://visibleearth.nasa.gov/

Figure 6-2: View of a Tornado

Source:
http://www.photolib.noaa.gov/700s/nssl0123.jpg

To measure the intensity, area and strength of a tornado, in 1973 Dr. Ted Fujita (then with the University of Chicago) and Allen Pearson (at the time director of the National Severe Storm Forecast Center) introduced the Fujita-Pearson Tornado Intensity Scale (see Table 6-2). An improvement over the scale first published by Dr. Fujita in 1971, this scale

compared the estimated wind velocity with the corresponding amount of damage to human-built structures and vegetation (a component first introduced by Fujita) and the width and length of the tornado path (the component added by Pearson). The scale classified tornadoes into six levels (from F0 to F5) with larger numbers indicating more damaging and larger tornadoes (the Fujita scale smoothly divided wind speed between the highest Beaufort level and Mach 1.0 into 12 levels – F0 through F12, but recognized that an F6 tornado would be inconceivable, and indeed no tornado above F5 has ever been measured. The Fujita-Pearson scale was used to classify all tornadoes reported after its introduction, in addition to retroactively classify all tornadoes reported since 1950 that were listed in the National Oceanic and Atmospheric Administration's (NOAA) national tornado database.

Table 6-2: The Fujita-Pearson Tornado Damage Scale

Scale	Wind Speed Estimate (mph)	Average Damage Path Width (feet)	Typical Damage
F0	40 - 72	30 - 150	**Light** damage (gale tornado). Some damage to chimneys and television antennas; twigs and branches break off trees; winds push over shallow-rooted trees; sign boards are damaged.
F1	73 – 112	100 - 500	**Moderate** damage (weak tornado). Winds peel off roofs; windows break; light trailer homes are pushed off their foundations or overturned; some trees are uprooted or snap; moving autos are pushed off the road; attached garages may be destroyed. Hurricane speed starts at 74 mph.
F2	113 – 157	360 - 820	**Considerable** damage (strong tornado). Roofs are torn off frame houses, leaving strong walls upright; weak rural buildings are demolished; trailer homes are destroyed; large trees snap or are uprooted; railroad boxcars are pushed over; light objects become airborne missiles; cars are blown off highways.
F3	158 – 206	650 – 1,650	**Severe** damage (severe tornado). Roofs and some walls are torn off well-constructed frame structures; some rural buildings are completely demolished; trains are overturned; steel-framed hangars and warehouse-type structures are torn; cars are lifted off the ground; most trees are uprooted, snapped or leveled.
F4	207 – 260	1,300 – 3,000	**Devastating** damage (devastating tornado). Well-constructed frame houses are leveled, leaving piles of debris; steel structures are badly damaged; trees are de-barked by small flying objects; cars and trains are thrown some distances or roll considerable distances; large objects become missiles.
F5	261 – 318	~ 3,600	**Incredible** damage (incredible tornado). Strong, whole-frame houses are lifted off their foundations and carried considerable distances; steel-reinforced concrete structures are badly damaged; automobile-sized missiles are generated and carried through the air >100 meters; trees are debarked.
F6	319 – 379		**Inconceivable** damage: These winds are unlikely. Should a tornado with maximum speed in excess of F5 occur, the extent and type of damage may not be conceived. A number of airborne missiles, such as refrigerators, water heaters, storage tanks, automobiles, etc. create serious secondary damage on structures.

Fujita's wind estimates have since been found to be inaccurate, with the original wind speed estimates higher than the wind speeds actually required to incur the damage described in each category, especially for tornadoes classified as F3 or larger. In response to these criticisms, a new **Enhanced Fujita** (EF) **Scale** for tornado damage was developed between 2004 and 2006. The EF scale, which was officially implemented in the United States on February 1, 2007, is considered an improvement over the old scale: engineers and meteorologists estimated the wind speeds in the new scale (although actual speed winds have not been empirically measured), and records of past tornadoes were reviewed to better equate the wind speeds with the storm damage reported. The new scale also includes more types of structures and vegetation in the damage assessment, and better accounts for differences in construction quality. Similar to the original Fujita scale, the EF Scale also has six levels of tornado damage, EF-0 to EF-5 (see Table 6-3). A researcher assigning a level of damage to a tornado using the EF scale needs to refer to a list of 28 different damage indicators (DI) or types of structures and vegetation, and then the degree of damage (DoD) for each. Damage indicators include barns or farm outbuildings, residences, manufactured homes (with distinctions made for single-wide and double-wide), apartments, masonry buildings, strip malls, automobile lots, elementary schools, low-, middle- or high-rise buildings (each a different category of indicator), electrical transmission lines, free-standing towers, and softwoods or hardwood trees. The new scale is likely to be modified or updated as new tornado data become available.

Table 6-3: Enhanced Fujita Scale

Scale	Wind Speed Estimate		Relative Frequency (%)
	mph	Km/h	
EF-0	65 - 85	105 - 137	53.5
EF-1	86 - 110	138 - 178	31.6
EF-2	111- 135	179 – 218	10.7
EF-3	136 – 165	219 – 266	3.4
EF-4	166 – 200	267 – 322	0.7
EF-5	> 200	> 322	< 0.1

6.1.2.3 Macrobursts and Microbursts

Storm researcher Dr. Ted Fujita first coined the term "***downburst***" to describe a strong, straight-direction surface wind in excess of 39 miles per hour (mph) caused by a small-scale, strong downdraft from the base of a thundershower and thunderstorm cell. Unlike tornadoes, the origin of a downburst is downward-moving air from a thunderstorm's core (as opposed to the upward movement of air associated with tornadoes). Downbursts are further classified into macrobursts and microbursts.

Macrobursts are downbursts with winds up to 117 mph that spread across a path greater than 2.5 miles wide at the surface, and which last from five to 30 minutes. ***Microbursts*** are confined to smaller areas, less than 2.5 miles in diameter from the initial point of downdraft impact. An intense microburst can result in winds near 170 mph but often lasts less than five minutes. Like tornadoes, microbursts can do significant damage: When a microburst hits a tree, the winds strip the limbs and branches off it; a microburst that hits a house has the potential to flatten the structure. After striking the ground, a powerful

outward-running gust can generate significant damage along its path. Damage associated with a microburst appears to have been caused by a tornado, except that the damage pattern away from the impact area is characteristic of straight-line winds, rather than the twisted pattern typical of tornado damage.

Microbursts are particularly dangerous to aircraft landing or taking off, and have caused several planes to crash, with resultant loss of life. Microbursts have also been responsible for capsizing and sinking ships, causing structural damage in many communities, lifting roofs off structures, downing electrical lines, and generally causing millions of dollars in damage. Most of the microbursts reported have occurred in the northeastern and central parts of the United States, including New York, New Jersey, Massachusetts, Ohio, and Kansas, but microbursts have also been reported in Arizona and Utah (http://en.wikipedia.org/wiki/Microburst#Danger_to_aircraft), and in southern California. On March 29, 1998, in a Lake Elsinore neighborhood, an apparent microburst uprooted a tree and ripped two 20-foot sections of roofing tiles from a home. A funnel cloud was also spotted that afternoon near Dulzura, to the east-southeast of San Diego.

6.1.2.4 Dust Storms

Dust storms are high wind events common in arid and semi-arid regions. Strong winds pick up sand and other particulates and transport them by saltation and suspension to another location, where they are deposited. Dust storms are significant erosive agents, with both short- and long-term impacts on people, structures and other property, and on the environment. In the short-term, a dust storm causes reduced visibility, which can affect motorists and aircraft. Fine particulates in the air will enter the respiratory pathways and can cause serious health conditions, including nose, ear and eye infections, sinus infections, asthma, dry eyes (a condition that if left untreated can led to blindness), silicosis, and even premature death. Dust storms can also spread virus spores and contaminants that can result in skin rashes and other infections. Long-term impacts of dust storms include loss of productivity from agricultural fields that have had their organic-rich, topsoil removed, whereas the deposition of sand and dirt elsewhere can bury and destroy crops and landscaping. Sandblasting of buildings, signs, fences, and vehicles can have both an aesthetic and structural impacts; in the long term the damage due to continuous pitting may require the replacement of a structure. For additional information regarding blowing sand refer to Chapter 2.

6.1.3 Historic Southern California Windstorms

As mentioned above, Santa Ana winds are common in the southern California region, typically in the fall through spring. Some of the strong winds in the winter are associated with winter storms emanating from Alaska and Canada. The high desert areas are also subjected to high winds associated with short-duration tropical thunderstorms emanating from the south. These storms typically occur in the summer months, between July and September.

As of the writing of this document, the National Climatic Data Center (NCDC) listed 134 high wind events and thunderstorms in San Bernardino County between 1996 and March 20, 2011 (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms). Those storms in the NCDC database that impacted the San Bernardino Mountains and high desert are included below. Previously, the database included storms dating back to 1973; many of

these are also included in Table 6-4. Events that have occurred since March 2011 were culled from online local newspapers. Table 6-4 also includes exceptional historical storms that impacted the southern California area, causing extensive damage either directly, or indirectly, by fanning wildfires that consumed thousands of acres and destroyed many homes. Please note that this list will most likely not include all damaging windstorms that have impacted the Town of Yucca Valley, as some events may have been so localized as to have not made it into the National Climatic Data Center database.

Table 6-4: Major Southern California Windstorms (1858 - 2011) and Strong Winds Reported in the Yucca Valley Area (1973 - October 2011)

Date	Description, Including Location and Damage Reported
October 2, 1858	Category 1 hurricane hits San Diego. Sustained winds to 75 mph are estimated based on the extensive damage to property reported.
May 23, 1932	Strong winds and low humidity; 12 serious brush fires, blackening nearly 2,000 acres in San Diego County were reported. The biggest fire was in Spring Valley.
September 24-25, 1939	Tropical storm that lost hurricane status shortly before moving onshore at San Pedro had sustained winds of 50 mph. At least 48 people died from sinking boats.
November 19-29, 1956	Strong and prolonged Santa Ana winds fanned a fire north of Descanso that burned 44,000 acres and killed 11. Two wooden bridges and a power plant were destroyed. A 100 mph gust was recorded on November 20 at a forest lookout near Sagus.
November 21-22, 1957	Extremely destructive Santa Ana winds fan a 28,000-acre brush fire west of Crystal Lake. Flying debris forced people indoors in some areas. Extreme turbulence due to a downdraft injured 12 out of 33 people on an airplane near Ontario.
November 5-6, 1961	Strong Santa Ana winds fan fires in Topanga Canyon, Bel Air and Brentwood; 103 firemen are injured; $100 million in economic losses, including 484 buildings (mostly residential) and 6,090 acres scorched.
August 20, 1962	A severe thunderstorm struck Twentynine Palms, blowing down many trees and breaking several windows.
July 13, 1967	Strong thunderstorm produced damaging winds in the high desert. Telephone and power poles were knocked down, causing widespread power outages.
January 18-28, 1969	Strong storm winds cause power outages and falling trees in southern California; 4 killed by downed trees.
September 26-29, 1970	Gusts to 60 mph in Cuyamaca Rancho State Park. Fires from Cuyamaca to Alpine, including the Laguna Fire, resulted in 400 homes destroyed, 185,000 acres burned, and 8 killed.
August 15, 1971	Heavy thunderstorms strike the Joshua Tree region, causing flash floods that cause extensive damage to the roads in the area.
September 10, 1976	Hurricane Kathleen brought to the Southwest US the highest sustained winds associated with an eastern Pacific tropical cyclone; sustained winds of 57 mph at Yuma, Arizona.
November 30 – December 1, 1982	Widespread strong winds associated with a big storm result in 1.6 million homes without power.
March 26, 1984	Winds of 60-90 mph in the Mojave Desert cause power outages and road closures. Car had its windows blown out; another had a door ripped off. Peak gust of 103 mph at Mojave; 66 mph in Daggett.
November 23, 1986	Strong Santa Ana winds hit Los Angeles, its foothills and mountains. Gusts to 54 mph recorded; gusts to 70 mph estimated. An unfinished house in Glendale is blown to bits; numerous beach rescues needed for sailors and windsurfers. Two sailboat masts were snapped in a boat race in the Channel Islands.

Date	Description, Including Location and Damage Reported
January 20, 1987	Wind gusts to 80 mph below Cajon Pass, 70 mph in San Bernardino, 60 mph in Mt. Laguna, and 40 mph at El Toro. Winds cause thick dust clouds; trucks blown over; trees toppled. 100 power poles downed in the Inland Empire. Numerous power outages force school closures. Brush fires started.
March 15, 1987	Widespread strong storm winds; winds of 25-35 mph sustained all day, gusts to 40 mph in San Diego. Result in power outages all over the San Diego metropolitan area; motor homes toppled in the desert; light standard fell over onto cars in Coronado; boats flipped over in harbors; a 22-foot boat turned over at Mission Beach jetty; Catalina cruise ships delayed, stranding 1,200 tourists there.
December 12-13, 1987	Strong Santa Ana winds in San Bernardino, with 60-80 mph gusts. 38-mph winds recorded in San Diego. 80 power poles blown down within a ½-mile stretch in Fontana and Rancho Cucamonga; downed tree limbs damaged cars, homes and gardens; 1 injured when tree fell on truck; power poles and freeway signs damaged; parked helicopter blown down a hillside in Altadena; trees downed and power outages in San Diego County. In Spring Valley, 1 dead when eucalyptus tree fell on truck.
December 15, 1987	Strong storm winds of 100 mph at Wheeler Ridge, 80 mph in San Bernardino County; up to 70-mph gusts at Point Arguello; 60-mph gusts in Orange County and the San Gabriel Mountains. One truck overturned.
January 21-22, 1988	Strong offshore winds following major Pacific storm with gusts to 80 mph at the Grapevine, 60 mph in Ontario, and 80 mph in San Diego County. Power poles, road signs and big rigs knocked down in the Inland Empire. In San Diego County, 6 injured; roofs blown off houses, trees toppled, and crops destroyed. Barn demolished and garage crushed by tree in Pine Valley; 20 buildings damaged or destroyed at Viejas; avocado and flower crops destroyed at Fallbrook and Encinitas, respectively, with 5 greenhouses damaged in Encinitas.
February 16-19, 1988	Very strong Santa Ana winds with gusts to 90 mph in Newport Beach, 70+ mph in the San Gabriel Mountain foothills; gusts to 76 mph at Monument Peak – Mt. Laguna; 63 mph at Ontario, and 50 mph at Rancho Cucamonga. Numerous trees and power lines downed resulting in power outages along the foothills of the San Gabriel and San Bernardino mountains. Mobile home overturned and shingles torn off roofs in Pauma Valley; Fontana schools closed due to wind damage; 3 killed when truck overturned and burned; 1 killed when stepped on downed power line. Power outages impacted 200,000 customers in Los Angeles and Orange counties. Grass fires. Roof damage widespread in communities around Glendale and Burbank, and at John Wayne Airport. Boats torn from moorings at Newport Harbor.
December 8, 1988	Strong Santa Ana winds across southern California, with gusts to 92 mph at Laguna Peak. Winds fanned several major fires; buildings were unroofed; trees and power lines downed. $20 million in estimated damages.
November 28, 1989	Strong Santa Ana winds with gusts to 70 mph at Rialto Airport. Several tractor-trailer trucks were overturned east of Los Angeles.
December 11, 1989	Strong Santa Ana winds with gusts to 100 mph near the Grapevine. Winds reduced visibility to near zero in the desert areas and closed major interstate highways east of Ontario.
August 4, 1993	Thunderstorms and strong winds reported in the central portion of San Bernardino County.
October 26-27, 1993	Strong Santa Ana winds with gusts to 62 mph at Ontario. Twenty fires in the southern California area, including the Laguna Hills Fire. 4 dead, 162 injured, $1 billion in property losses alone; 194,000 acres destroyed.
June 30, 1994	Thunderstorms and strong winds reported in Barstow. The winds reportedly caused about $1K in property damage.

Date	Description, Including Location and Damage Reported
July 28, 1996	Thunderstorms and strong winds to 50 knots reported in Barstow, Daggett and Twentynine Palms airport. In Twentynine Palms, the winds caused about $50K in property damage.
November 22, 1996	Thunderstorms and strong winds in the San Bernardino County desert caused about $20K in property damage.
November 25, 1996	Thunderstorms and strong winds throughout the southern California area, from San Diego to Ventura counties, and inland in the San Bernardino County mountains and valleys, with winds to 85 knots.
November 28, 1996	Strong northwest winds ahead of a cold front impacted the entire southern California area, with sustained winds of about 40 mph, and gusts up to 60 mph. Many downed trees and power lines were reported.
December 14, 1996	Strong Santa Ana winds with gusts to 111 mph at Fremont Canyon and 92 mph in Rialto, toppled trees and electric poles, smashed windows, knocked out power to tens of thousands across southern California. Two deaths in Fontana; one man killed by a live power line that was blown on him; the second died when a tree branch fell onto his van. Minor injuries (3 total) in Orange and San Diego counties. In Crestline, a radio tower was blown down and the roof blown off the transmitter building. I-15 near Devore closed for 15 hours where two trailers flipped.
December 17, 1996	Santa Ana winds with gusts to 66 knots downed trees and power poles. In Rancho Cucamonga, winds toppled a 500,000 kilovolt electric power, sparking a fire that burning 250 acres and forced evacuation of 80 homes.
January 6, 1997	High winds to 86 knots throughout southern California injured four: Three students at the CSU campus at San Bernardino, and a man that suffered cuts when his trailer overturned. Fourteen tractor trailer rigs tipped over in the I-15 between Devore and Corona forcing closure of the freeway; over 900,000 customers lost power; vehicle pile-ups in the Coachella Valley.
January 29, 1997	Santa Ana winds with gusts to 100 mph in Fremont Canyon, 87 mph in Rialto, cause big rigs on the freeway to topple over.
February 13, 1997	Strong Santa Ana winds uprooted trees, downed power lines and toppled rigs. One firefighter suffered minor injuries when the winds blew boards off a truck and onto him while he was trying to extinguish a fire. The Interstate 10/15 transition roads were closed for hours. Sporadic power outages were reported due to downed power lines.
February 24-25, 1997	Gusty Santa Ana winds occurred below selected passes and canyons, with gusts to 80 mph measured in Fremont Canyon. The winds knocked down power lines, fanned several small fires, and forced closure of the I-215 in San Bernardino County for one hour. One of the fires destroyed an abandoned house in San Bernardino.
May 11, 1997	Thunderstorm activity spawned a tornado in Apple Valley and produced strong winds in the high desert areas. The twister destroyed a metal shed, uprooted trees and ripped shingles off of roofs. Strong winds to 70 knots, lightning and rain caused additional property damage in Apple Valley and Hesperia.
May 18, 1997	Thunderstorm produced two tornadoes and a wet microburst north of the Apple Valley airport. First tornado flattened a few buildings; second tornado blew down several power poles and destroyed several small structures. The damage caused was sporadic as it did not contact the ground continuously. The microburst ripped a 55-foot awning from a mobile home and blew it against a car, pinning, and slightly injuring a girl.
June 6, 1997	Cluster of thunderstorms produced strong winds with 60-mph gust at Twentynine Palms airport. No damage reported.
August 3, 1997	Severe thunderstorms dropped hail and heavy rains in **Landers**, flooded and closed five roads around **Joshua Tree** and produced 50 mph sustained winds with a gust of 85 mph at Twentynine Palms airport.
September 1,	Thunderstorm generates several strong winds throughout the day, with three gusts of

Date	Description, Including Location and Damage Reported
1997	90 knots (104 mph) recorded at Twentynine Palms airport. No damage reported.
October 13-14, 1997	Santa Ana winds of 30-40 mph with frequent gusts over 60 mph developed below Cajon Pass, in Orange County, and valley areas of San Bernardino County. Fire in Orange County burned almost 6,000 acres and destroyed two buildings. Trees and power lines blown down in Rialto and Fontana; a shed was destroyed at the Banning/Beaumont border.
December 10-12, 1997	Santa Ana winds with gusts to 96 mph at Pine Valley; 87 mph in Upland. Flying debris killed 2 construction workers, one in Riverside, another in Irvine. Fish farm in Sun City reported more than $1 million in structural damages; extensive damage to the avocado crop; boats damaged and sunk at Coronado and Avalon.
December 18-22, 1997	Gusts to 60 mph in Rialto; 67 mph at Idyllwild and below Cajon Pass. Driver near Pedley killed when he lost control of his van because of strong wind gust; his passenger was injured. Fires; downed trees; and widespread wind damage. More than 9,500 homes and businesses without power in Ontario, Rancho Cucamonga, Fontana, and Chino. On the 22nd, strong winds toppled at least 6 trucks on the I-15 and 60 freeways. In the Coachella Valley, winds uprooted many trees in Palm Desert and overturned several big-rig trucks near Indio. Several trees and signs downed in Desert Hot Springs.
December 28, 1997	Santa Ana winds with gusts to 80 mph snapped a dozen power poles near Corona, cutting power to dozens of rural customers. A downed tree crushed a car in Riverside. In Mira Loma, a dozen power poles were downed, leaving hundreds without power and closing Hamner Avenue for two days. Heavy blowing dust and restricted visibility created hazardous driving conditions on the Interstate 15.
February 3-4, 1998	Strong storm winds with gusts to 60 mph and heavy downpours. The strongest winds were clocked in Orange County and the mountains of San Bernardino County in advance of the storm. Wind gusts to 60 mph downed trees and caused scattered power outages. Moderate to heavy rain flooded intersections in coastal areas; snow fell as low as 4,500 feet. Two young illegal immigrants near Campo died, and 12 others suffered from exposure to strong winds, cold temperatures and rain.
July 28, 1998	Thunderstorm winds in Twentynine Palms snapped two power poles knocking out electricity in a two-block area. A storage shed was blown onto the roof of a nearby house and got caught in electrical wires. $10K in property damage reported.
August 31, 1998	Strong thunderstorm-related winds with gust to 63 mph were recorded at Twentynine Palms Marine Corps Base, and a gust to 58 mph was recorded at the Twentynine Palms airport. No damage was reported.
December 9-10, 1998	Santa Ana winds with 101-mph gusts at Modjeska Canyon, 93-mph gusts at Fremont Canyon, 52-mph gusts in Santa Ana, and 83-mph gusts at Ontario disrupted transportation, power and daily activities. Winds toppled trees and power lines, overturned vehicles, and caused property damage. 180,000 customers without electric power; 17 trucks were blown over along I-15 and Highway 60. 7 students at CSU in San Bernardino were knocked down and injured. Trees fell on passing motorists in Fontana. A total of 24 injuries reported, with property damage amounting to $1.1 million.
January 8, 1999	Strong Santa Ana winds to 61 knots in San Bernardino and Riverside counties broke tree braches, downed power lines and blew dust across freeways. $10K in property damage.
January 20-21, 1999	80-mph gust in the Salton Sea area; 70-mph gust in the Coachella Valley; 47-mph gust in Palm Springs; and 36-mph gust in Thermal.
February 10-12, 1999	Santa Ana winds with gusts to 85 mph at Rialto; gusts to 80 mph on the I-8, forcing the closure of several major roads and interstates. Extensive property damage throughout and west of San Gorgonio Pass. Freshly plowed field west of San Gorgonio Pass was

Date	Description, Including Location and Damage Reported
	stripped of its top soil; 30 Beaumont residents treated for breathing problems and skin rashes associated with the dust storm. Trees and signs were blown down; large commercial building in Lake Elsinore was blown down; 150-foot tall tree was blown over and crushed a trailer home. $950K in property damages reported.
April 8, 1999	Strong winds to 54 knots reported in Apple and **Yucca valleys**, the Coachella Valley, San Bernardino County mountains, San Diego County mountains, and Santa Ana mountains and foothills. $10K in property damage reported.
May 3, 1999	Strong winds to 65 knots reported in Apple and **Yucca valleys**, San Bernardino County mountains, and San Diego County deserts and mountains. Five miles east of Jacumaba, along I-8, a semi tractor-trailer rig and a motor home were blown over. $150K in property damage.
July 10, 1999	Thunderstorms dumped moderate to heavy rain for about 1 hour in the **Joshua Tree** area. Runoff caused road closures but no significant damage. Gusty winds associated with the storm destroyed a large sun porch in one residence. $3K in property damages reported.
July 11, 1999	Wind gusts to 55 mph were recorded at the Twentynine Palms Marine Corps Base where power poles were downed and two buildings were damaged. Strong thunderstorms produced heavy rain and gusty winds across the desert. Travel along I-15 and I-40 affected as heavy rain reduced visibility to near zero in some areas, and runoff covered sections of the roads. $15K in property damage reported.
July 28, 1999	Strong wind gusts associated with nearby thunderstorm ripped the roof off a house just east of Twentynine Palms, causing $10K in damages.
October 17, 1999	Santa Ana winds caused wind damage in the mountains and valleys of Orange, Riverside, and San Bernardino counties. In San Bernardino, 40 mph wind gusts caused a fire that damaged 11 houses and a 12-plex apartment building; other fires in the Inland Empire fanned by the gust winds. $30K in property damage reported.
November 21-22, 1999	Santa Ana winds with gusts to 54 knots caused power outages throughout the Inland Empire and the Santa Ana mountains and foothills. A semi-tractor trailer was toppled over at the I-15 and Highway 60 intersection. Farther south on I-15, tumbleweeds caused traffic hazards. $190K in property damage and 1 injury reported.
December 3-4, 1999	Strong Santa Ana winds with gusts to 90 mph at San Bernardino and 68 mph in Fontana. Ten power poles knocked down just below Cajon Pass, and in Muscoy, Rialto, Fontana, Murrieta and Lake Elsinore. Most major highways in the Inland Empire and through the Santa Ana Mountains were closed due to semi-tractor trailers overturned, blowing dust reduced visibility and road signs and debris blown around. Two barns were destroyed when their roofs were lifted off; six horses received minor injuries. $210K in property damages reported.
December 10-11, 1999	Strong winds in the Coachella Valley, valleys in Riverside and San Bernardino counties, and Santa Ana mountains and foothills. Winds downed power lines and traffic signs. Gust to 60 mph clocked in Palm Springs. Blowing sand and dust caused poor visibility and forced road closures and cancellation of outdoor events. Several trees were knocked over. $50K in property damage, $10K in crop damages, and one injury reported.
December 21-22, 1999	Strong Santa Ana winds; 68-mph gust at Campo, 53-mph gust at Huntington Beach; 44-mph gust in Orange. Widespread power and phone outages due to fallen trees knocking down lines and snapped poles. Large dust cloud over the San Jacinto Valley that reached height of 500 feet closed highways and sandblasted cars. Gusty winds spread a fire in Glendale to an adjacent house, causing two injuries and $50K in damages. Three wildfires in San Diego County. $227K in property damage reported throughout the region.
January 5-6,	Santa Ana winds with 93-mph gust at Fremont Canyon; 60-mph gust at Ontario; 58-

Date	Description, Including Location and Damage Reported
2000	mph gust at Devore. Winds blew over four semi-tractor trailer rigs on I-10, I-15, I-215 and Highway 60 causing 10-hour delay between Apple Valley and the Inland Empire. Elsewhere in the Inland Empire, blowing sand and dust reduced visibilities to near zero. Roof damage in Rialto. Power outages to 10,000 customers due to downed power lines and poles. Two injuries and $400K in property damage reported.
February 12, 2000	Wind gusts 50 mph or greater were recorded at Horse Thief Springs, Squaw Springs and Twentynine Palms.
March 20-21, 2000	Santa Ana winds in the Coachella Valley, valleys in Riverside and San Bernardino counties, San Diego County and Santa Ana Mountains and foothills. Winds downed power poles, felled trees on cars and houses, knocked fruit off trees, and blew sand and dust, lowering visibility to near zero. Semi-tractor trailer was blown over near Pedley. $425K in property damage and $865K in crop damage reported.
March 31- April 1, 2000	Strong Santa Ana winds caused $375K in property damage in the Inland Empire area. Twenty-five power poles were toppled in the Sun City area; several others fell in Yucaipa. A large tree was blown down in Beaumont. Blowing dust reduced visibility along most highways.
June 22, 2000	Fierce thunderstorm winds damaged a hangar at Barstow-Daggett Airport and knocked out the electricity for runway lights. $25K in property damage reported.
August 26, 2000	A dry microburst (large dust devil) swept through a demolition project in **Yucca Valley** causing a roof to collapse and injuring one worker. $1K in property damage.
November 7, 2000	Santa Ana winds with 82-mph gust at Fremont Canyon caused damage in Orange, San Bernardino and Riverside counties. In San Bernardino County, strong winds knocked power lines together causing them to spark; the sparks ignited wildfires. In Colton, blowing sand covered the I-215. Two semi-tractor trailers overturned at the intersection of the I-15 and Highway 60. $167K in property damages reported.
December 25-26, 2000	Santa Ana winds; 87-mph gust at Fremont Canyon. Damage and injuries reported in Mira Loma, and in Orange and Riverside counties. 50-mph winds in northern Orange County toppled utility poles leaving about 25,000 customers in Tustin, Garden Grove, Orange, Santa Ana and Westminster without power for a few hours. Across the Inland Empire, winds knocked down power poles, trees, signs and fences at 23 separate locations. Many trees were uprooted. Power disrupted to 9,000 homes and businesses. Four injuries and $665K in property damage reported.
May 12, 2001	Downdraft winds associated with thunderstorms impacted the north slopes of the San Bernardino mountains and across the Apple Valley floor, blowing dust and reducing visibility to near zero. Gusts to 82 mph were recorded at Granite Mountain just north of Apple Valley.
August 7, 2001	Strong thunderstorm winds in Twentynine Palms knocked down several power lines near City Hall and the local library; both buildings had to be evacuated. One of the power lines also fell onto a car, trapping the woman inside. The woman was not injured but the car was damaged slightly. $5K in property damage reported.
December 7-8, 2001	Santa Ana winds with gust to 87-mph at Fremont Canyon affected most of southern California. Trees, power lines and signs were toppled. Two construction workers were injured when a 20-foot-high brick wall they were working next to collapsed. Several major freeways were closed to high profile vehicles. Power outages affected about 40,000 customers. Three injuries and $250K in property damage. Winds fanned the Potrero Fire.
January 23-24, 2002	Santa Ana winds throughout the mountains and valleys of Riverside, San Bernardino, San Diego and Orange counties. Semi-tractor trailer rig blown over in Fontana. Strong winds fanned several wildfires. In San Bernardino, one house was damaged and a few outlying structures were destroyed by the wind-fanned flames. $190K in property damage.

Date	Description, Including Location and Damage Reported
February 8-13, 2002	Santa Ana winds with 80-mph gust at Descanso, 78-mph gust at Fremont Canyon, and 76-mph gust at San Bernardino. Blown-over semi-tractor trailer rigs forced closure of I-15, I-215 and I-8 for a day. Twelve million pounds of avocados blown off of trees. Winds fanned several fires caused by downed power lines. In Orange County, fire that started in Corona burned 2,400 acres. In Tijuana, fire destroys 50 buildings, and kills one woman. Gavilan fire spreads from Fallbrook to Camp Pendleton, torching 5,783 acres, destroying 44 houses and damaging 14 others, destroying 40 vehicles and injuring 19. $2 million in property damage and $7.8 million in crop damage.
March 18, 2002	Thunderstorm-related winds to 56 knots in San Bernardino County valleys; whiteout conditions in the High Desert areas with snow down to the 2,500 foot level; hail in Apple Valley; lightning in San Diego struck an aircraft on final approach to the San Diego International Airport.
November 8, 2002	Strong winds associated with the first winter storm of the season reported in Apple and **Yucca valleys**, Coachella Valley, and San Bernardino mountains and valleys. Winds downed power lines and caused damage to roofs and signs. $550K in property damage.
December 16, 2002	Strong winds in Apple and **Yucca valleys**, San Bernardino County mountains, and San Diego coastline. Car windows blown out at Cajon Pass; power lines and trees blown down at Arrowhead and Big Bear City; motor home blown over in Hesperia. Tractor trailer blown over west of Phelan. Visibility reduced to zero due to blowing dust in local highways. Two injuries and $750K in property damage reported.
January 5-7, 2003	Strong, widespread Santa Ana winds with 100-mph gust at Fremont Canyon, 90-mph gust at Ontario; 80-mph gust at Upland. Winds toppled power poles in Orange; blew over a mobile derrick in Placentia, crushing two vehicles; and delayed Metrolink rail service. Interstates 8, 10 and 15 were blocked for several hours due to large trucks blown over. Dust storms forced closure of I-215. One commercial plane sustained damage at Ontario Airport; others had to be diverted. As a result of the winds and toppled poles, thousands of people in northeastern Orange County were without power. Two dead, 11 injured. Widespread property damage, road closures, wildfires, 20 million pounds of avocado lost. $3.3 million in property damage and $28 million in crop damage.
February 2, 2003	High winds blew down trees in Redlands, Jurupa and Riverside. Blowing sand and dust disrupted traffic in the Coachella Valley.
March 26, 28-29, 2003	Area of low pressure off the California coast brought strong winds to portions of the Mojave Desert. Winds with gusts to nearly 50 mph blew shingles off several roofs in Twentynine Palms, causing $5K in property damage. Elsewhere, wind blew trees over, falling on cars and power lines. A semi-tractor trailer was blown over in I-8 in the San Diego County mountains. A total of $140K in property damages reported.
September 4, 2003	Tornado-like winds associated with a series of powerful thunderstorms ripped off the roof from a house and damaged about ten other houses near **Yucca Valley**. Funnel clouds, heavy rain and hail the size of walnuts were reported.
October 25-27, 2003	Strong Santa Ana winds; 45-mph at Ontario, 43-mph at Fremont Canyon. Extensive wildfires consumed hundreds of thousands of acres; killed more than 20 people, and caused more than $1 billion in damage.
November 22, 2003	High winds knocked down trees, power lines and signs, causing about $175K in damages.
December 25, 2003	High winds to 56 mph knocked down many trees that then fell on power lines, cars, houses and roads in Crestline and Forest Falls. $500K in property damage.
February 26, 2004	Winter storm moving southeasterly from the Gulf of Alaska picked up moisture before moving onshore. Strong winds occurred in the mountains, and heavy rains reported throughout southern California. Most roads along the foothills of the San Bernardino

Date	Description, Including Location and Damage Reported
	Mountains, both on the north and south sides were closed due to flooding and mudslides.
April 27, 2004	Low-pressure system pushing through the Mojave Desert produced strong winds with gusts to 67 mph recorded at Squaw Springs and 53 mph in the Opal Mountains.
December 16, 2004	Santa Ana winds with sustained speeds of 51 mph and 78-mph gusts at Fremont Canyon; gusts to 69-mph northwest of San Bernardino and 66 mph near Pine Valley. At least five big rigs were blown over in Inland Empire roads; the I-15 was closed temporarily. Trees were blown over and power lines were downed. $150K in property damage reported.
January 7, 2005	Strong winds and thunderstorms throughout the southern California area, including Apple and **Yucca valleys**. Very saturated soils and wind gusts in excess of 50 mph knocked down hundreds of trees. The felled trees knocked out power, blocked roads, and damaged many cars and property. One woman injured when tree fell onto her car. $600K in property damage reported throughout the region.
February 3, 2005	Strong storm-related winds to 70-mph impacted the region. At least 15 homes in Idyllwild were damaged by felled trees; downed power lines in the Inland Empire; big rig was overturned on the I-8. $1 million in property damage.
March 28-31, 2005	Strong southwest winds reported across the San Bernardino County deserts with wind gusts to 52 mph. $50K in property damage.
July 22, 2005	Strong thunderstorm winds cause major damage to three houses in Twentynine Palms. Described as either a tornado or a microburst, the winds also broke the window of a parked car and lifted a trampoline into the air and slammed it into a utility pole. Other utility poles were knocked down, forcing road closures.
January 2, 2006	Post-frontal 50+-mph winds widespread throughout the region. Winds downed trees, power lines, and power poles onto houses and cars. In Crestline, 20 houses were so damaged as to be uninhabitable. In San Diego Bay, boats broke loose from their moorings. In Apple Valley, winds toppled power poles, downed trees and caused damage to numerous homes. A trailer home was knocked off its supports in Hesperia. $210K in property damage reported.
January 22-24, 2006	Santa Ana winds; peak winds of 71 mph at Fremont Canyon on the 24th; gusts exceeded 60 mph on 19 hourly observations. Seven big rigs overturned in Fontana; downed power lines and trees caused power outages and property damage. Dust storm closed the Ramona Expressway.One fatality when spooked horse threw off its rider. $80K in property damage.
October 26, 2006	Offshore winds blew to 40-mph in the Banning Pass. An arsonist started the Esperanza Fire; it burned 40,200 acres from Cabazon to San Jacinto, destroying 43 homes and killing 5 firefighters.
November 29, 2006	Offshore winds with sustained speeds of 54 mph and 73-mph gust at Fremont Canyon; 58-mph gust at Ontario, caused widespread property damage and power outages as a result of downed power lines, poles and trees. Caltrans reported more than 100 calls in 4 hours reporting downed street signs, trees and power lines. About 15,000 people lost power in Orange County. $30K in property damage.
January 5 & 7, 2007	Strong winds across southern California. Damaged or downed power poles; damage to trees or tree limbs; blowing dust reduced visibility to near zero along I-215 and the Ramona Expressway; small, wind-driven wildfires along I-15. In the mountains, high winds forced vehicles to slide across icy stretches of road near Rim Forest. Large trees fell on homes and cars in the Lake Arrowhead area. $700K in property damage.
February 27, 2007	Widespread wind activity on the desert slopes of the San Bernardino Mountains; strong winds caused property damage to three homes in Palm Springs. One house had its roof ripped off; the others reported broken fences, damaged solar panels and downed trees. Poor visibility due to blowing dust forced closure of several roads in

Date	Description, Including Location and Damage Reported
	the Coachella Valley. Gust to 52 mph recorded at Thermal Airport; gust to 57 mph recorded at a golf course in La Quinta.
March 20, 2007	Strong winds caused extensive damage in North Palm Springs, where 14 power poles were knocked down; several snapped in half. This affected nearly 500 SCE customers. Isolated gust at 81 mpg was measured at the Burns Canyon Remote Automated Weather Station (RAWS) located a few miles to the northwest of **Yucca Valley**.
March 27, 2007	Strong down-slope winds and mountain wave activity caused a palm tree to fall on a home in Indian Wells and leaving 79,000 customers in the valley without power. Peak wind of 53 mph was measured in Thermal, and gust to 48 mph was measured in Palm Springs. A 60-mph gust was measured at the Burns Canyon RAWS.
July 24-30, 2007	Thunderstorms, strong winds and flash flooding in the Mojave Desert. Strong winds to 52 knots reported in Twentynine Palms on the 26th.
October 21-22, 2007	Strong Santa Ana winds caused widespread damage across the Inland Empire, with gusts in excess of 70 mph snapping power poles, toppling trees, overturning big rigs and damaging roofs. Sustained winds over 50 mph were recorded at several locations for several hours. Winds fanned the flames of several large wildfires. $35 million in property damage reported.
December 25, 2007	Gusty winds in the Inland Empire downed power lines, uprooted trees, and overturned several semi-tractor trailer rigs. $50K in property damage reported.
January 17, 2008	Strong Santa Ana winds caused widespread tree and property damage in the Inland Empire area. Numerous tractor-trailers were blown over, one hangar at Corona airport sustained major damage; power was knocked out, $250K in property damages reported.
January 30 - February 1, 2008	High winds with gusts to 80 mph caused widespread property damage and knocked out power to thousands of homes in the **Morongo Basin**. Hundreds of homes were impacted with damage to roofs, fences, storage sheds and other structures. Two power poles were toppled on Twentynine Palms Highway near Indio Avenue, **Yucca Valley**, blocking traffic for hours.
July 12, 2008	Monsoon moisture from the southeast brought severe storms and flash flooding to the Mojave Desert, including Twentynine Palms.
August 3-4, 2008	Monsoon moisture from the southeast brought severe storms and flash flooding to the Mojave Desert. In Twentynine Palms, the winds blew down three power poles and broke off several large tree limbs. Flash flooding reported throughout the area. $25K in property damage.
December 13-17, 2008	Strong winds with gusts to 72 mph accompanied a pair of winter storms that brought rain and snow to the region. Blizzard conditions forced closure of mountain highways.
December 25, 2008	Winds that gusted to nearly 70 mph caused extensive damage in the Morongo Basin, knocking down 10 to 12 power poles and 38 circuits in the Twentynine Palms area, leaving nearly 8,000 customers without power for several hours. An additional 8 to 10 power poles, a billboard and a sign were downed in **Yucca Valley**.
February 16, 2009	High winds, with gusts to 68 mph, were caused by a low pressure cell and cold front that swept through the southern California area.
March 22, 2009	High winds with gusts up to 73 mph knocked down trees, freeway signs and power lines in the mountains and deserts of southern California. Winds fanned two fires in the region that damaged structures and trees.
April 3, 2009	Wind gusts in excess of 58 mph were measured in the afternoon at the Burns Canyon Remote Automated Weather Station (RAWS) located about 13 miles to the northwest of **Yucca Valley**. The high winds downed power lines and caused minor roof damage. A fire fanned by the winds burned at least two homes in Palm Springs.
April 14, 2009	High winds with peak gusts of 64 mph were measured at the Burns Canyon RAWS.

Date	Description, Including Location and Damage Reported
	The winds, caused by a low-pressure trough combined with a surface cold front, caused damage to power lines, trees, and overturned tractor-trailers in the mountains and deserts.
May 29, 2009	Strong thunderstorms in the Hesperia – Victorville area caused damage to four horse shelters and downed power lines. Lightning from the thunderstorm set a brush fire near **Yucca Valley**.
October 27, 2009	High winds with gusts of 60 mph at the Burns Canyon RAWS were felt throughout the mountains and deserts of southern California. The strong winds downed several eucalyptus trees and caused a few power outages in the region.
December 9, 2009	A powerful winter storm brought high winds, rain and some snow to the region. Gusts to 62 mph were measured at the Burns Canyon RAWS. Due to the rain-soaked ground and gust winds, several trees throughout the region were uprooted, damaging vehicles and buildings. Over 100,000 customers lost electric power during the storm.
December 12, 2009	Powerful winter storm with sustained winds near 50 mph, and gusts up to 100 mph measured in the high desert, in the Lucerne and Apple valleys, impacted the region. The strong winds blew shingles off roofs, damaged a trailer, and downed several trees. Power lines arched and some were knocked down, resulting in power outages. Heavy rain caused minor roadway flooding and a flash flood. Parts of Highway18 were closed due to large rocks on the roadway. Two motorists had to be rescued from a vehicle that was trapped in a flooded intersection in Perris.
December 22, 2009	Wind gusts in excess of 58 mph were measured at the Burns Canyon RAWS, with a peak wind gust of 68 mph. The strong winds associated with this winter storm affected the mountains and deserts.
January 18, 2010	In the early afternoon, strong winds tore down about 20 road signs along Interstate 15 in the Cajon Pass area. A peak wind gust of 65 mph was measured at the Burns Canyon RAWS. The storm also brought heavy rain and mountain snow. The winds and rain caused widespread damage, estimated at about $50K, including urban flooding, a few flash floods and minor debris flows.
January 19, 2010	A strong southerly jet stream ahead of a cold front contributed to moderate low-level wind shear with high winds and a peak wind gust of 73 mph measured at Burns Canyon RAWS. The thunderstorms brought in waterspouts, at least one tornado, and hurricane-force winds in Orange County. In San Diego County, the winds contributed to structural damage and one fatality.
January 20, 2010	The third storm of the week brought widespread heavy rain, snow in the mountains, and strong winds with a peak gust of 85 mph measured at Burns Canyon RAWS.
April 27-29, 2010	Multiple upper level low pressure areas brought winter-like weather to southern California during the last part of April, between the 21st and the 29th. Rain and mountain snow were common, with strong gusty winds reported between the 27th and the 29th. Gusts between 58 and 62 mph were measured at the Burns Canyon RAWS in the afternoon and early evening of the 28th.
January 14, 2011	Moderately high Santa Ana winds estimated at between 40 and 50 mps downed three power lines and a transformer in San Bernardino. Three residents that stepped outside to try to extinguish spot fires caused by sparks were electrocuted and died. A water line also ruptured in one of the houses and 2,700 customers lost power because of the downed lines. Gusty winds were also reported in the mountains.
February 2-4, 2011	A strong cold upper level, low-pressure system moved southward from the Four Corners region into northern Mexico. A strong surface high pressure settled over the region and brought strong offshore winds. The winds knocked over a 70- to 75-foot tall tree with a 30-inch diameter trunk over three units in an apartment development in Glen Avon. No injuries were reported, but the units were declared uninhabitable and the residents were relocated. Strong winds were also helpful in knocking over five big

Date	Description, Including Location and Damage Reported
	rigs near the Interstate 10-15 interchanged and contributed to a crash on Highway 60 near the Interstate 15. No injuries were reported. Other downed trees and power lines were reported. About $60K in property damage reported.
March 20, 2011	A strong low pressure system brought strong winds, heavy rain and heavy snow, with blizzard conditions in the mountains. Wind exceeded 110 mph at times in the high deserts, causing considerable damage in the Apple Valley area. Several inches of rain, hail and a few waterspouts were reported, causing some minor urban flooding.
March 28, 2011	Strong winds destroyed a barn at a horse-rescue facility in **Yucca Valley**.
August 27-28, 2011	Thunderstorms hit the Joshua Tree, Twentynine Palms area ripping roofing material off several businesses in Joshua Tree, and knocking down a line of power lines in Twentynine Palms that left hundreds of customers without power. Weather spotter clocked sustained winds up to 60 mph, with stronger gusts.
October 5, 2011	Non-thunderstorm winds with gusts up to 65 mph (at the Burns Canyon RAWS) were reported in the high desert and mountains of San Bernardino County. One mile NNW of **Yucca Valley**, a trained spotter reported that 3-inch diameter trees had been blown over, and that visibility was 40 to 50 yards due to blowing dust. An aluminum shed in **Yucca Valley** was blown over, and several power lines were downed in Lucerne Valley. The strong winds also forced a big rig with empty trailer onto incoming traffic on Highway 18; three vehicles were involved in the incident.

Sources: NCDC database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf), newspaper accounts in the archives of the High Desert Star (www.hidesertstar.com), and Los Angeles Times (http://articles.latimes.com/keyword/yucca-valley-ca).

As discussed above, although most tornado activity in the United States occurs in the Midwest states, ***tornadoes*** can and do occur in California. The Tornado Project, a company that researches, compiles and makes tornado information available on the web at www.tornadoproject.com, indicates that 24 tornadoes have been reported in San Bernardino County between 1914 and 1998; the National Oceanic and Atmospheric Agency (NOAA) lists 29, including six between 1999 and August 2008. In Riverside County, The Tornado Project list includes nine tornadoes between 1955 and 1998; NOAA includes an additional ten tornadoes between 1999 and January 2010, with the majority of these near Hemet and Temecula. A list compiled by the San Diego office of the National Weather Service includes a few additional tornadoes in both San Bernardino and Riverside County. Table 6-5 lists the tornadoes reported in San Bernardino County, and two tornadoes in Riverside County that occurred relatively close to the San Bernardino County line. The data available indicate that in the last about 60 years, tornadoes have caused five injuries and about $4 million in property damage in San Bernardino and Riverside counties. Table 6-5 also includes funnel clouds reported in the mountains and high deserts of San Bernardino County, which appear to occur primarily near Hesperia and Victorville, to the northwest of Yucca Valley.

Table 6-5: Tornadoes and Funnel Clouds Reported In and Near San Bernardino County Between 1914 and 2011

Date and Location	Time	Dead	Injured	Fujita Scale	Damage Description
San Bernardino County					
January 27, 1914	NA	0	0	F1	
November 11, 1944	21:00	0	0	F2	

Date and Location	Time	Dead	Injured	Fujita Scale	Damage Description
June 25, 1954 NE of Victorville	12:00	0	1	F2	
April 2, 1958 in San Bernardino	NA	0	0	NA	Roof was ripped off a garage at Baseline and Sterling
November 25, 1965	16:30	0	0	F1	$35K in property damage
July 22, 1966 in Victorville	18:45	0	0	F1	
October 22, 1974 in **Yucca Valley**	15:55	0	0	F1	$3K in property damage
September 4, 1976	19:45	0	0	F1	$25K in property damage
September 5, 1976	19:19	0	0	F1	
September 6, 1976	18:00	0	0	F1	
September 6, 1976	19:19	0	0	F1	
September 6, 1976	19:25	0	0	F1	
September 6, 1976	19:30	0	0	F1	
September 7, 1982 in Landers	15:30	0	2	F2	$25K in property damage.
August 1, 1983 in Landers	12:50	0	1	F0	$250K in property damage
July 21, 1986	13:45	0	0	F0	
July 27, 1987 in Twentynine Palms	18:51	0	0	F0	
August 14, 1990	18:45	0	0	F0	
September 29, 1990	18:00	0	0	F0	
March 20, 1991 in Muscoy	14:45	0	0	F0	
May 11, 1997 in Apple Valley	13:30	0	0	F1	Tornado destroyed a metal shed, knocked down several fences, uprooted trees, and ripped shingles off roofs. Part of thunderstorm that spawned strong winds, a dust storm, intense rain, and thunder and lightning.
May 18, 1997 in Apple Valley	15:37	0	0	M, F1	Thunderstorm caused two tornadoes and a wet microburst. First tornado moved through mostly open country, flattening a few buildings on its 3.5-mile path. Power lines arced and produced fires.
May 18, 1997 in Apple Valley. Estimated 130-140 mph winds	15:50	0	0	F1	Second tornado in sequence; moved east through Apple Valley south of Waalew Road. Caused sporadic damage as it did not make continuous contact with ground. Several power poles were blown down, small structures destroyed, and the roof was ripped off a garage. The wet microburst that followed ripped the awning off a mobile home and blew it against a car, pinning and slightly injuring a young girl.
June 6, 1997 in Hesperia	17:00	0	0	F0	Tornado overturned and destroyed a 300-pound fountain.
August 7, 1997 in	17:33	0	0	F0	Tornado touched down on open country

Date and Location	Time	Dead	Injured	Fujita Scale	Damage Description
Needles					near the Interstate 40.
March 14, 1998 in Hesperia	12:57	0	0	NA	A low-pressure center drifting over southwestern California spawned a funnel cloud near Hesperia that was visible for about 20 miles.
May 5, 1998 in San Bernardino and Rialto	NA	0	0	NA	"Apparent" tornado shredded metal siding in Rialto.
August 25, 1998 in Nipton	11:20	0	0	F0	Small tornado caught on video about 5 miles SW of Nipton. At about same time a hood was ripped off a dump truck and a truck was blown off Interstate 15 near Highway 164 (Nipton Road).
July 10, 1999 in Hesperia	17:30	0	0	NA	Funnel cloud reported 3 miles north of Hesperia. No damage reported.
June 23, 2000 in Hesperia	12:20 & 13:40	0	0	NA	Two funnel clouds reported near and in Hesperia. The first one was reported 7 miles west of Hesperia. No damage reported.
July 14, 2000 in Phelan	13:15	0	0	NA	Funnel cloud reported near Phelan. No damage reported.
April 21, 2001 in Needles airport	11:35	0	0	F1	
July 3, 2001 in Hesperia	NA	0	0	NA	Dust devil (possibly a microburst or other thunderstorm-generated wind) blows off roof.
July 7, 2001 in **Joshua Tree** and **Twentynine Palms**	12:45	0	0	F0	Caused minor damage to homes and businesses in Joshua Tree, including a roof torn off an abandoned house and a patio cover torn off another home. $10K in property damage reported
September 4, 2003 in **Joshua Tree – Yucca Valley**	NA	0	0	NA	Extensive damage to one residence and minor damage to eleven others, for $25K in property damage. No injuries reported.
August 14, 2004 in **Yucca Valley**	11:18	0	0	F0	Tornado with very intense rotation reported 14 miles NNW of Yucca Valley. No damage reported from tornado.
August 14, 2004 in Phelan	11:40	0	0	F0	Tornado occurred in open fields – no damage reported.
February 22, 2005 in Victorville	15:00	0	0	NA	Funnel cloud reported 15 miles north of Victorville. No damage reported.
March 4, 2005 in Fontana	12:20	0	0	F0	$20K in property damage; blew shingles off three homes, ripped the roof off a water-well building, felled several trees and downed power lines. Accompanied by hail.
July 30, 2005	11:38	0	0	NA	Funnel cloud was seen in the San Gorgonio Wilderness, about 5 miles east of Angelus Oaks. No damage was reported.
August 4, 2008 in Lucerne Valley (Johnson Valley)	13:00	0	0	F1	$10K in property damage; bent two flag poles, blew off a roof and uprooted a tree.

Date and Location	Time	Dead	Injured	Fujita Scale	Damage Description
August 6, 2008 in Yucaipa	13:55	0	0	NA	Funnel cloud associated with a severe thunderstorm near the Banning Pass was observed near Yucaipa. Tree damage was reported in Banning and Yucaipa.
May 29, 2009 in Hesperia	NA	0	0	NA	Strong thunderstorms produced a microburst or tornado that damaged four horse shelter roofs. One roof was completely removed. Winds also knocked down power lines in Hesperia and Victorville.
August 28, 2011 in Twentynine Palms and Joshua Tree	NA	0	0	NA	Possibly a microburst, it tore off sections of the roof of the Joshua Tree Branch Library; toppled a large billboard, and stripped off the aluminum roofs and siding from several metal sheds at Bargain Alley. Other structural and tree damage reported.
Riverside County					
December 22, 1996 in Cabazon	09:00	0	0	F1	Tornado was first noticed near the corner of Dell and Lemon; it moved northeastward for about 700 feet before dissipating. Lifted a 5-ton mobile home and deposited it 30 feet from its foundation, its roof and contents removed. Six other mobile homes suffered minor damage.
February 13, 2001	NA	0	0	NA	Funnel clouds in Palm Desert.

Sources: NCDC database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), The Tornado Project (http://www.tornadoproject.com/), compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf); online newspaper accounts in the archives of the Hi Desert Star (www.hidesertstar.com).

The NCDC database lists eight ***dust storm*** events in San Bernardino County between 1998 and 2004. At least sixteen more events were culled from the windstorm descriptions provided in Table 6-4. Given the many instances of strong winds reported in the region, this list is very likely under-representing the hazard of dust storms in the region.

Table 6-6: Dust Storms Reported in San Bernardino County Between 1989 and 2011

Date	Description, Including Location and Damage Reported
December 11, 1989	Strong Santa Ana winds with gusts to 100 mph reduced visibility to near zero in the desert areas and closed major interstate highways east of Ontario.
December 28, 1997	Santa Ana winds with gusts to 80 mph resulted in heavy blowing dust and restricted visibility on the I-15, creating hazardous driving conditions.
November 8, 1998	Blowing sand and dust reported throughout the valleys to the north and east of the San Bernardino Mountains. Strong winds were reported from Hesperia, Twentynine Palms, Joshua Tree, Lucerne Valley, with the most severe wind events occurring between about 10:20 AM and 1:30 PM. Tents and portable toilets were knocked over at the Girl Scouts Campground. $40K in property damage reported.
December 9, 1998	Strongest Santa Ana wind event in two years. Blowing dust forced closure of the Ontario International Airport for several hours.
February 11, 1999	Santa Ana winds with gusts to 85 mph forced the closure of several major roads

Date	Description, Including Location and Damage Reported
	and interstates. Winds stripped the topsoil off a freshly plowed field west of San Gorgonio Pass and tracked it downstream for 15 miles; 30 Beaumont residents were treated for breathing problems and skin rashes associated with the dust storm.
December 3-4, 1999	Strong Santa Ana winds with gusts to 90 mph; blowing dust reduced visibility.
December 10-11, 1999	Strong winds with gusts to 60 mph resulted in blowing sand and dust. Forced the closure of roads and cancellation of outdoor events in the Coachella Valley and other areas.
December 22, 1999	Strong Santa Ana winds caused a large dust cloud that closed the San Jacinto Valley highways, sand-blasted cars, and reached a height of 500 feet. Winds carrying sand and dirt, and cross winds forced the cancellation of three flights and re-routing of two commercial airplanes from Ontario International Airport.
March 20-21, 2000	Santa Ana winds blew sand and dust, reducing visibility to near zero.
March 31 – April 1, 2000	Strong Santa Ana winds blew dust reducing visibility along most highways in the Inland Empire area.
May 12, 2001	Downdraft winds associated with thunderstorms impacted the north slopes of the San Bernardino Mountains and across the Apple Valley floor, blowing dust and reducing visibility to nearly zero.
August 17, 2001	Thunderstorms moved northwest across the Imperial Valley and Salton Sea. The 30-mph sustained winds caused a dust storm that reduced visibility to less than 1 mile over eastern San Diego County, the Coachella Valley and the Banning Pass.
October 12. 2001	Santa Ana winds blew dust and debris across several freeways between Fontana and Rialto, stopping traffic at times during the morning commute.
February 10, 2002	Santa Ana winds blew dust and sand, disrupting traffic by reducing visibility to near zero and sandblasting windshields. Signs, trees, power poles and fences were blown down in several communities in the Inland Empire.
March 13, 2002	Strong winds over 50 mph caused visibility to drop to near zero on Interstate 15 near Yermo. The low visibility caused two seven-car pileups, injuring several motorists. The interstate had to be closed for an hour due to the visibility issues and damaged vehicles.
November 25, 2002	Blowing dust caused visibility to be near zero from Perris to Moreno Valley; small rocks were blown across Highway 74 in the San Jacinto Valley. Strong winds reported throughout the southern California area.
December 16, 2002	Strong winds in Apple and Yucca valleys, San Bernardino Mountains and San Diego coastline. Visibility reduced to zero in local highways due to blowing dust.
January 6-7, 2003	Santa Ana winds impacted at least 60 communities in southern California. Blowing dust and sand reduced visibility to zero, forcing the closure of I-215. Planes were diverted from landing at Ontario International Airport; one large commercial transport airplane sustained damage.
August 24, 2003	Thunderstorm downdraft winds caused a dust storm in eastern Moreno Valley, north of Highway 60, with sustained winds to 40 mph.
November 27, 2003	Ash and soot from burned areas were picked up by east winds gusting between 40 and 60 mph. Visibility was reduced across the valleys, coasts, and the coastal waters out to San Clemente Island. Unhealthy air was measured in several cities in San Diego County. Hospitals reported twice the number of patients normally seen for breathing difficulties. 40 injuries reported.
March 10, 2004	Blowing sand and dust reduced visibility to within 50 feet in Rancho Cucamonga.
August 12, 2004	Dust storm reduced visibility to near zero on the Interstate 10 between Blythe and Desert Center.
February 27, 2007	Widespread wind activity on the desert slopes of the San Bernardino Mountains. Poor visibility due to blowing dust forced closure of several roads in the Coachella

Date	Description, Including Location and Damage Reported
	Valley.
October 5, 2011	Visibility to the north-northwest of **Yucca Valley** reported at 40 to 50 yards due to blowing dust.

Sources: NCDC database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf), and data presented in Table 6-4 above.

6.2 Other Extreme Weather Events

6.2.1 Hail

Hail is solid precipitation consisting of fragments of water ice called hailstones. These can be irregular in shape, oval or rounded, and can vary in size from 0.2 inch (5 mm) in diameter, to nearly 8 inches (20 cm), although hail more than 4 inches in diameter is unusual. The stones can range from soft to very hard. Hail is produced in thunderstorms with strong upward motion of the air, similar to a tornado, and freezing levels at relatively low elevations. A hailstone forms as a result of super-cooled water that freezes around an ice-condensing particle, such as a grain of sand, a bit of compacted snow, or even a particle of pollen or other debris carried up into the atmosphere by the thunderstorm updrafts. The resulting hailstone may be carried upward into colder sections of the atmosphere, all the while collecting additional super-cooled water droplets. Once it gets too heavy for the wind to keep it aloft, it either falls to the ground as hail. Hailstones have rings like an onion, with translucent ice layers alternating with white, opaque layers. It is believed that the translucent layers are formed in those sections of clouds where water occurs as droplets, whereas the opaque, white sections form in areas where water vapor predominates. Hailstones also form by accretion, with smaller stones sticking together to form larger, irregular stones. These are often lumpy or even spiky on the outside.

With current weather detection methods, such as weather satellites and radar, it is possible to detect thunderstorms that will produce hail. Severe weather warnings are generally issued in the United States for hail that is more than about 1 inch (2.5 cm) in diameter.

The NOAA website lists 54 hail events in San Bernardino County between 1966 and 2010. Twelve of those events specifically impacted Yucca Valley or nearby communities and are therefore listed in Table 6-7 below, together with two other events listed in the National Weather Service list issued by the San Diego office (last updated in February 2010). The data suggest that hail storms in the region have generated minor to moderate damage to property. No injuries or deaths were reported as a result of the hail storms listed, but the data may be incomplete.

Table 6-7: Hail Events In the Yucca Valley Area Between 1956 and 2011

Date	Description, Including Location and Damage Reported
July 24, 1956	Severe thunderstorm dropped hail "almost the size of baseballs" at Joshua Tree National Monument and vicinity, pelting a Marine Corps party.
September 2, 1960	Largest known hail to hit southern California; hail more than 2.75-inches in diameter and over 1 pound in weight reported in the San Diego and Riverside areas, causing considerable damage to structures. A severe thunderstorm also hit San Bernardino, blowing roofs off houses, smashing windows, and blowing down

Date	Description, Including Location and Damage Reported
	dozens of power poles.
July 18, 1985	Hail 1.75 inches in diameter reported in Twentynine Palms.
July 28, 1987	Hail to 1.00 inch in diameter reported in Twentynine Palms area.
May 19, 1997	Hail 0.75 inch in diameter was spotted in Twentynine Palms. No damage reported.
August 3, 1997	Severe thunderstorms dropped dime-sized hail and heavy rain in Landers, closed five roads around Joshua Tree, and caused 50-mph sustained winds at Twentynine Palms airport.
August 11, 1998	Golf-ball sized hail (up to 1.75 inches in diameter) was reported by the San Bernardino County Sheriff on Highway 62, near Twentynine Palms.
July 10, 1999	Thunderstorms dumped moderate to heavy rain (and hail) for over an hour around Joshua Tree. Runoff forced the closure of some roads and produced gusty winds that destroyed a sun porch, for property damage estimated at $3K.
July 11, 1999	Thunderstorm brought rain, gusty winds and hail to the San Bernardino county deserts, from Barstow south to Twentynine Palms. Travel along interstates 15 and 40 was significantly affected as the heavy rain reduced visibility to near zero and runoff covered road sections.
March 17-18, 2002	Small hail reported in Apple Valley. Part of a late-season winter storm that dropped snow down to the 2,500-foot elevation level.
September 4, 2003	Severe thunderstorm dropped golf-ball sized hail in Twentynine Palms. $50K in property damage reported.
August 12, 2004	Three-quarter inch hail was reported at the north entrance to Joshua Tree National Park. $5K in property damage reported.
August 14, 2004	Monsoon thunderstorms in the valleys, mountains and deserts produced a tornado north of **Yucca Valley** and dropped golf-ball sized (1.75 inch diameter) hail that dented several vehicles. About $10K in property damage reported.
August 1, 2005	Hail up to 0.75-inch in diameter reported in **Yucca Valley**.
August 26, 2007	Thunderstorms over the Mojave Desert dropped dime-sized hail over Twentynine Palms. The hail shower lasted about 15 minutes.
March 20-21, 2011	Strong low-pressure system that brought snow, heavy rains and strong winds to the southern California area, including the high desert. Hail and a few waterspouts were reported behind the front.
July 5, 2011	Thunderstorms brought heavy rain, lightning, high winds and hail to the southern California desert, about 15 miles north of **Yucca Valley**.
August 28, 2011	A 30-minute long thunderstorm hit the Joshua Tree area bringing pea-sized hail, nearly 1 inch of rain and strong winds.

Sources: NOAA database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf), http://www.kcdzfm.com/news/fullstory070611.html; http://www.kesq.com/news/28453825/detail.html; http://www.hidesertstar.com/news/article_d2d3f24a-0e2a-551b-aad1-0ec71209e9fb.html.

6.2.2 Heavy Snow and Ice

Snow and ice normally do not come to mind at the mention of southern California, but some of the mountain communities do receive substantial precipitation in the form of snow and ice during the winter months. Sudden drops in temperature, combined with reduced visibility due to the snow, have stranded hikers in the mountains of San Diego, Riverside and San Bernardino counties. The NCDC site lists 58 snow and ice events between 1994 and 2011 that have impacted the mountains in San Bernardino County. Additional events extending back to 1847 are included in the database maintained by the National Weather Service office in San Diego (last updated in 2010), although this list is not to be considered

comprehensive. The Town of Yucca Valley, given its location, occasionally receives sufficient snow and/or ice to hinder commuting and other activities. Those events listed in the NCDC and the National Weather Service databases that are known or inferred to have impacted the Yucca Valley area and vicinity are listed in Table 6-8. Since 1994, snow storms in San Bernardino County have directly contributed to at least four deaths and 102 injuries, in addition to more than $2 million in property damage.

Table 6-8: Significant Heavy Snow and Ice Events in Southern California That Likely Impacted the Yucca Valley Area Between 1848 and 2010

Date	Description, Including Location and Damage Reported
1848	Snow fell "to the depth of several feet, and covered the plains for a long time," with the plains referring to San Bernardino Valley. Thousands of cows died.
January 12-14, 1882	Fifteen inches of snow reported in San Bernardino, 25 inches in outlying San Diego, 5 inches in Riverside. Birds and livestock died; telegraph lines downed; citrus trees were damaged.
January 15, 1932	Extensive snow fall impacted the southern California area. Up to 2 inches of snow all over the Los Angeles Basin, including 1 inch at the Los Angeles Civic Center; beaches were whitened. Elsewhere, 18 inches in Julian, 17 inches at Mt. Laguna, 14 inches at Cuyamaca, and 6 inches at Descanso.
February 21, 1944	A heavy snowstorm struck the San Bernardino Mountains. Several snow slides, some 50 to 60 feet high, obliterated parts of the Rim of the World highway.
January 9-11, 1949	Another extensive snowstorm blanketed the region, with snow 4 to 8 inches deep down to the 1,000-foot elevation. Fourteen inches in Woodland Hills, 8 inches in La Canada and Catalina Island, 4 inches in Pasadena, 1 inch in Laguna Beach and Long Beach. Transportation throughout the area was greatly impacted. Power outages and emergencies throughout. A plane crash near Julian kills five and injures one. Camping group stranded at Cuyamaca.
January 13-18, 1952	Heavy snow in several waves impacts the San Bernardino Mountains. Forty inches of snow fell in Lake Arrowhead, 37 inches in Big Bear Lake. All mountain roads were blocked and closed because of snow slides.
January 20-22, 1962	Big snow storm extended to lower elevations, dropping 2 inches in Victorville, Barstow and Yucaipa, 27 inches in Big Bear Lake and 24 inches at Lake Arrowhead. Many highways closed.
December 9, 1963	Heavy snow in the mountains blocked highways and caused vehicular accidents. Five killed and 6 injured.
April 7-11, 1965	Strong late-season storm dropped heavy snow in the mountains, including 50 inches at Lake Arrowhead, 24 inches at Idyllwild, and 13 inches at Palomar Mountains, forcing the closure of many mountains roads.
December 13-19, 1967	Fifty inches of snow in 24 hours reported at Mt. Laguna, 38 inches in Idyllwild, 6 inches in Temecula, 4.5 inches at Anza Borrego State Park, and 2 inches in Carlsbad. Mt. Laguna recorded a total of 96.5 inches in 8 days. Numerous schools and highways closed. Transportation was disrupted, extensive power outages. One freezing death reported.
December 17-22, 1970	A series of storms dropped heavy snow in the San Bernardino Mountains; 32 inches at Idyllwild, 28 inches at Big Bear Lake, 26 inches at Palomar Mountain, and 24 inches at Lake Arrowhead.
December 26-28, 1971	Series of heavy storms that produced up to 2 feet of snow at Lake Arrowhead, 20 inches at Palomar Mountain, 15 inches at Big Bear Lake, and 13 inches at Idyllwild. Snow closed the Morongo Pass at **Yucca Valley** for some time.
January 3-5, 1974	Over 18 inches of snow in the San Bernardino Mountains; 17 inches in Victorville, the greatest daily amount on record. Flurries reported in Palm Springs on the 4th.

Date	Description, Including Location and Damage Reported
	Structures and a few roofs collapsed due to the weight of snow. Power lines and trees snapped.
January 30 – February 2, 1979	Widespread snow event; 56 inches in Big Bear Lake, the greatest snowfall on record. On January 31, snow fell heavily on Palm Springs, snow drifts shut down the I-10 on both sides of Palm Springs, isolating the city. Schools were closed and hundreds of cars were abandoned. All major interstates into Los Angeles were closed.
December 18-19, 1984	Major snowstorm brings up to 16 inches of snow to the mountains and upper deserts, including 13 inches to Lancaster. Edwards Air Force Base and the I-5, from Castaic to the San Joaquin Valley, were both closed.
February 2, 1985	Up to 2 inches of snow reported in Palm Springs.
November 11-13, 1985	A cold, slow-moving storm dropped 14 inches of snow in Mt. Laguna, 5 inches in Julian, and through the San Gabriel Mountains. Snow fell as low as Alpine (1,800-foot elevation). Interstates were closed for some time.
December 10-11, 1985	Cold storm brought heavy snow to the mountains and high desert; 17 inches in Mt. Laguna, 15 inches in Julian, 12 inches in Palomar Mountain, and up to 4 inches in Victorville and Warner Springs. The highways and schools were closed in the mountains and high desert.
February 22-25, 1987	Snow reported throughout the southern California area, with 24 inches at Mt. Laguna, 12-17 inches in the San Bernardino Mountains, 4 inches in one hour at Lake Hughes. Snow pellets reported in coastal areas, including 2 to 3 inches in Huntington Beach. Slight snow reported on the 25th in Tarzana, Northridge, Torrance, Fontana and Redlands. Roads and schools closed in the mountain areas. An aircraft accident due to a snow squall near Anza killed four.
December 16-17, 1987	Snow fell throughout southern California, including for two minutes at Malibu Beach. One foot of snow fell in the mountains north and east of Los Angeles, 24 inches in Julian. Disneyland closed due to weather; other theme parks and stretches of the I-5 and I-15 closed through the mountains. Numerous accidents resulted in fatalities. Due to the snow, all schools closed in the mountains of San Diego County and 16,000 students were sent home in the Santa Clarita Valley.
February 7-9, 1989	Snow reported from the beaches in Los Angeles to the desert in Palm Springs; 15 inches in the mountains, 3 inches at Palmdale. Major road closures and numerous traffic accidents reported.
March 17-20, 1991	Snow 2 to 5 feet deep in the mountains; on the 19th, 1 foot of snow fell on Mr. Laguna, 6 inches at Palomar Mountain and Cuyamaca. Schools and roads closed in the mountains, including the section of I-8 between Alpine and Imperial County. Many downed trees and power outages.
January 5-7, 1992	Six to 20 inches of snow in the mountains, 2 to 8 inches in the foothills and high desert floors.
January 3-4, 1995	Six to 12 inches of snow in the mountains, 2 inches of heavy, wet snow at 2,300-foot elevation in the high desert.
December 23, 1995	Up to 12 inches of snow in the San Bernardino Mountains, and up to 8 inches on the high desert floors.
February 25-28, 1996	Ten inches of snow at Idyllwild, 2 inches in Yucaipa a dusting at Hemet and Corona; 1-2 feet in the mountains, and up to 6 inches in the high desert.
January 5, 1997	Winter storm in southern California brought snow and strong winds to the mountains and high deserts. Snow was reported as low as 3,200 feet. Sleet, snow pellets and thunder accompanied the snow at several locations. Two to 3 inches of snow reported in the Apple and Lucerne valleys, 5 inches in the mountains.
January 12-15, 1997	Snowfall 1.5 to 3 feet deep common on elevations above 2,500 feet. In the San Gorgonio Wilderness, a blizzard accompanied by single-digit temperatures and 4 feet

Date	Description, Including Location and Damage Reported
	of snow stranded a family of hikers that were later rescued. In the high deserts around **Yucca Valley**, hundreds lost power and cable service when a relay tower was damaged by strong winds. Thirteen illegal immigrants died due to exposure near Pine Valley.
February 23, 1998	Snow levels dropped down to 1,400 foot elevation in the high deserts of San Bernardino County. Strong winds downed power lines, leaving thousands without power. In Apple Valley and Hesperia, flooding caused damage to many homes and businesses. In Apple Valley, two dozen families had to be evacuated and flooding caused $10 million in property damage.
March 28-29, 1998	Late season winter storm dropped 4 to 8 inches of snow between the 3,000- and 5,000-foot levels, and 1 to 3 feet above 5,000 feet. Strong winds with gusts to 60 mph accompanied the snow fall, causing snowdrifts that forced closure of some roads. Considerable damage to crops.
March 31-April 1, 1998	Cold front caused strong winds in the Victor Valley area, with heavy snow in the San Bernardino Mountains. Snow fell as low as 2,000 feet locally, while elevations above 5,500 feet saw 8 to 18 inches of snow. Strong winds caused occasional white-out conditions.
May 12, 1998	Unusual late season winter storm dropped snow down to the 4,000-foot level. Measured amounts ranged from about 6 inches at 5,800 feet to 2 feet above 8,000 feet. Thunder and lightning accompanied some of the heavier snow and ice-pellet showers. Weight of the snow snapped tree branches causing sporadic power outages.
December 4-6, 1998	First heavy snow storm of the season. Total snowfall at the 6,000-foot elevation was 9 to 10 inches; 4 to 6 inches were reported in the passes. The high valleys north of the San Bernardino mountains received 1 to 3 inches. This caused closure of 70 to 90% of the major roads and nearly 100% of the minor roads. Highway crews used 22 person-days of overtime to clear the roads in San Bernardino County alone. Several traffic accidents in Hesperia occurred as a result of the snow.
January 26, 1999	Eighteen inches of snow reported in the Angelus Oaks area at 5,600 feet elevation, and 22 inches of snow was reported between 6,200 and 7,200 feet levels, in the Green Valley, Arrow Bear, and Running Springs areas. Eighty percent of the primary roads and 90% of secondary roads were closed.
April 1-6, 1999	Eighteen inches of snow fell in 12 hours at Mt. Laguna, 7-9 inches at Pine Valleyand Descanso; heavy snow reported at Cherry Valley (3,000-foot elevation). By the 6th, snow level down to the 2,600-foot elevation. Eight illegal immigrants found dead near Descanso; 50 survived wearing only light clothing and tennis shoes, having been on foot for 3 days, and having never experienced snow.
March 4-6, 2000	Winter storm brought snow at high elevations and rain and flooding at lower elevations. The night of the 5th, the snow level lowered dramatically, with up to 17 inches of snow in 24 hours in the mountains. At least 30 people were trapped in the wilderness areas of San Diego County; three died and another 13 were hospitalized for hypothermia. Blizzard conditions were reported throughout the southern California mountains. $50K in property damage reported.
January 10-12, 2001	Second of three strong winter storms that week, snow between 3 and 19 inches deep reported between 2,600 and 4,500 foot elevation. Gusty winds the night of the 10th created blizzard conditions. Forty-five people were stranded in the snow; 15 suffered from hypothermia. $60K in property damage reported.
February 11-14, 2001	Winter storm caused near blizzard conditions throughout the southern California mountains, forcing the closure of all roads. The Wrightwood area received between 27 and 60 inches of snow; other areas in the mountains reported 18 to 31 inches. The Apple Valley received 5 to 12 inches of snow. Twenty-six people suffering from mild hypothermia were rescued by the Border Patrol. At lower elevations there was

Date	Description, Including Location and Damage Reported
	extensive flooding. Thirty-one injuries and $150K in property damage reported, including the rof of an ice rink that caved in at Blue Jay.
January 27-29, 2002	Cold Pacific storm brought snow to the mountains of southern California, with traces of snow reported down to the 1,000-foot elevation. Several semi-tractor trailers and trucks jackknifed or overturned in the snow and rain, forcing the closure of several major highways.
March 17-18, 2002	Whiteout conditions were reported over the high desert areas, with the snow down to the 2,500-foot-elevation level. Small hail reported in Apple Valley; 3 inches of snow in Apple Valley, 1 inch in Hesperia. Five different groups of people who were lightly clad were rescued from the San Diego Mountains near Pine Valley.
October 27, 2004	An storm brought 2 feet of snow to Big Bear, with most of this falling within a 12-hour period. Roads became impassable and the weight of the snow broke several tree branches and knocked out power to the area. Intense rain at lower elevations. Rainfall for the month totaled between 1,000 to 2,000% above normal in the coast, valley and deserts, while snow levels in the mountains were 500 to 900% above normal.
November 20-22, 2004	Snow storm that lasted for two days with snow level down to 1000-foot elevation. A spotter in **Yucca Valley** reported 12 inches of snow on the ground in under 6 hours. Eighteen to 20 inches of snow reported in the foothills south of **Yucca Valley**, 9-12 inches in Hesperia and Apple Valley. Nine inches of wet snow in Yucaipa and Calimesa caused tree limbs to snap and fall over cars, houses and roadways. Snow lined the sides of Interstate 10 for about 2 days after the storm.
January 3-4, 2005	Cold storm brought snow and wind to the local mountains; snow fell down to the 3,000-foot level in places like Hesperia, Descanso, Campo, Cajon Pass, and Warner Springs. Temperatures dropped significantly, down to 9 degrees in Big Bear, where the lake completely froze over by the end of the storm.
January 7, 2005	Strong storm dumped several feet of snow at higher elevations on the mountains. Nearly 200 motorists had to be rescued when hundreds of cars became stranded in near white-out conditions on Highway 18, in an area known as the Artic Circle. The rescue operation, using snowcats, took nearly 10 hours. Warm air in the afternoon changed the snow to rain, causing rocks and mud to start falling from the cliffs along the highway. $135K in property damage reported.
March 10-11, 2006	A very large, cold, low-pressure system brought strong winds and heavy snow accumulation to the mountain areas of southern California, and down to the 1,500-foot elevation. Numerous traffic accidents forced the closure of several roads, including the I-8, Highway 18, Highway 38, and Highway 243. Snowfalls ranged from about 1 to 3 feet. Light snow was reported in Hemet, Temecula, Devore, Sage, Yucaipa and Alpine. One person died and 7 were injured when their party became lost near Pine Valley in the storm. $160K in property damage reported.
January 12-13, 2007	Light snow was reported throughout the Inland Empire on the morning of the 12th, down to the 500-foot elevation. In most areas, the snow was about ½-inch deep, but up to 1 inch was reported in Highland and Redlands, and 3 inches were reported in Yucaipa.
January 23-25, 2008	Significant winter storm hit the western part of the San Bernardino mountains, with 24 to 38 inches of snow reported. Periods of heavy snow and whiteout conditions forced closure of sections of the I-15 and Highway 138. $150K in property damage reported.
December 13-17, 2008	Series of significant winter storms that dumped 2-3 feet of snow on the San Bernardino Mountains. Most highways were closed because of heavy snow and trapped motorists. Storm on the 17th dumped 18 inches of snow in Hesperia, Lucerne Valley, Palomar Mountain and Julian; 14 inches in Victorville and even 4 inches in Shelter Valley. Big Bear received an impressive 54 inches over the 5 day period. Heavy

Date	Description, Including Location and Damage Reported
	snow caused significant tree damage at the 3,500 to 4,000-foot elevation, especially to live oak trees. Many tree limbs snapped and fell on vehicles and structures. Significant flooding and mudslides reported at lower elevations. $100K in property damage.
February 5-10, 2009	Winter storm brought significant precipitation to the southern California area. Snow began to fall especially on the night of the 9th, with 20 inches reported in Big Bear by 14:00 the next day. Twelve inches of snow fell in 2 hours in Forest Falls. The heavy snow snapped tree limbs and power lines, leaving approximately 10,000 residents without power. Many mountain roads had to be closed, including Highway 18 where a pair of avalanches buried part of the road. About $50K in property damage reported.
February 16, 2009	A new storm brought additional snow, gusty winds, heavy rain and small hail to the southern California area. Snowfall up to 18-inches deep was reported in the mountains. Heavy rain in the foothills and coastal areas caused flooding along highways and areas with poor drainage.
January 21-22, 2010	The fourth and strongest in a series of storms that brought heavy rain, thunderstorms, several feet of snow in the mountains, and flooding in the foothills and coastal areas. Some areas received as much as 3 to 4 feet of snow in a 36-hour period. The weight of the snow caused damage to several mobile homes. $150K in property damage reported.
February 25-26, 2011	Very cold storm system from the Gulf of Alaska dropped south impacting the southern California area with snow down to the 1,000-foot elevation. Snow accumulations reported above 1,500 feet. Two feet of snow reported in Forest Falls, 24.5 inches in Wrightwood and 21 inches in Lake Arrowhead. Gusty winds contributed to areas of blowing snow, reducing visibility.
March 20-21, 2011	Strong low-pressure system brought very strong winds, heavy rain and heavy snow to southern California. Up to 20 inches of snow was reported in the San Bernardino Mountains, with heavy rain in the foothills. Very strong winds with gusts to 110 mph were reported in the high deserts, with considerable damage reported in the Apple Valley area. Hail and a few waterspouts were also reported behind the front.

Sources: NOAA database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), and compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf.

6.2.3 Temperature Extremes

Temperature extremes are responsible for more deaths in the United States on a yearly basis than all other extreme weather events combined, including flooding. Based on data collected by the Centers for Disease Control and Prevention (CDC, as reported in Goklany, 2007), between 1979 and 2002, an average of 358 people were killed annually by excessive heat. Extreme cold is even more deadly; an average of 680 people died in the United States each year due to cold weather between 1979 and 2002 (Goklany, 2007). In addition to the significant loss of life and injuries, temperature extremes also cause significant economic losses in agricultural production, and in transportation, energy and infrastructure costs.

Heat waves, which are periods of excessive heat, typically exceeding 95 degrees Fahrenheit, often with high levels of humidity, and lasting more than three days, can be deadly by pushing the human body beyond its limits. The heat itself is not deadly, but dehydration and loss of salts through sweating can lead to blood clots that can result in

heart attacks or strokes; people with weak hearts may not be able to deal with the increased blood flow necessary to keep the body cool. Sensitive populations include older adults, children, and those that are sick or overweight. Those at greatest risk of dying during a heat wave are city-dwelling seniors that don't have access to an air-conditioned environment for at least part of the day. [Urban areas, due to the heat-absorbing properties of asphalt and concrete, are generally hotter than rural areas.] Athletes that don't take extra precautions or don't decrease their usual exercise routine in response to the high heat can also be impacted by a life-threatening, heat-induced illness such as heat exhaustion or heat stroke. These heat-induced illnesses can also impact outdoor workers, such as those in the agricultural or construction fields, that are not acclimatized, and do not have access to water and shade, or do not slow down and take cool-down breaks in the shade. Poor air quality often occurs during heat waves if a stagnant atmospheric condition develops, trapping dust and air contaminants near the ground surface. The resulting brown haze can cause serious respiratory problems in the elderly, infants, asthmatics, and others with compromised immune systems.

In addition to the potential injuries and loss of life brought on by heat waves, excessive heat can impact agricultural production, both of livestock and crops. Poultry, in particular, do poorly during heat waves. Millions of birds died during a severe heat wave that impacted the Midwestern states in 1980. Crops can also be adversely impacted by excessive heat and/or drought. Increased irrigation, with concurrent increased production costs, is generally necessary to prevent permanent damage to certain crops, such as vegetables and leafy greens.

High heat and ***excessive heat*** events that have occurred historically in the southern California area and that are known or inferred to have impacted the Yucca Valley area are listed in Table 6-9. High heat events are periods of high heat that either did not last for at least three days, or where the heat and/or humidity levels were not sufficiently high to be defined as an excessive heat event. The data provided in Table 6-9 is most likely not comprehensive, but it does suggest that periods of temperature extremes have occurred historically in the region, and thus, that periods of excessive heat can be anticipated in the future.

The definition and effects of ***extreme cold*** vary across different areas of the country. In southern California, where we are not generally accustomed to cold weather, temperatures near freezing are considered "extreme cold." A cold wave, where temperatures drop rapidly within a 24-hour period, can be devastating to susceptible and unprotected populations, crops, livestock and wildlife. Exposure to extreme cold can lead to several life-threatening health conditions, including frostbite and hypothermia. ***Frostbite*** is an injury to the body, typically to the extremities such as fingers, toes, ear lobes or nose, caused by freezing body tissue. The main symptoms include a loss of feeling in the affected area, often combined with a pale, gray, white or yellow, and possibly waxy, appearance. Immediate medical attention is generally required, and the affected area should be slowly re-warmed to avoid further tissue damage. ***Hypothermia*** is an abnormally low body temperature (typically below 95 degrees Fahrenheit). Warning signs include uncontrollable shivering, disorientation, memory loss, slurred speech, drowsiness, and apparent exhaustion. Medical attention should be provided immediately if at all possible, and the body should be slowly warmed.

Populations vulnerable to cold weather include (but are not limited to) the homeless, older adults, persons with medical conditions, including heart disease, diabetes, high blood pressure, mental illness, and cognitive disorders, infants and small children under the age of five, pregnant women, persons of limited economic resources that cannot afford to keep their home warm, people who are socially isolated, and people who are caught outside in the storm, unprepared. The use of space heaters, barbeques, and fireplaces to keep structures warm increase the potential for structural fires and the risk of carbon monoxide poisoning.

Crop damage and livestock kills due to cold weather have historically cost the southern California area billions of dollars. For example, the December 1990 winter storms cost the state of California $3.4 billion in direct and indirect losses, whereas the 2002 winter caused more than $2 million in crop and property damage to the southern California area alone. Extreme cold events that are known or inferred to have impacted the Yucca Valley area are listed in Table 6-9.

Table 6-9: Historical High Heat, Excessive Heat and Extreme Cold Events Reported in Southern California that Impacted or Are Inferred to Have Impacted the Yucca Valley Area

Date	Description, Including Location and Damage Reported
January 9, 1888	**Extreme cold:** Cold wave with freezing temperatures impacted the citrus-growing areas with substantial loss of the citrus crop.
December 23-30, 1891	**Extreme cold:** Cold wave impacted the southern California area; 1-inch thick ice on oranges on trees in Mission Valley, 0.5-inch thick ice in San Diego pools.
January 6-7, 1913	**Extreme cold:** 25 degrees at San Diego on the 7th, the lowest temperature on record. Killing freeze that caused extreme damage to the citrus crop all over California. Many other crops lost. Water pipes frozen, trolley lines disrupted. The damage directly led to the establishment of the U.S. Weather Bureau's Fruit Frost forecast program.
June 16, 1917	**Excessive heat:** The most destructive heat wave of record in California history climaxes at Mecca with a temperature of 124 degrees.
January 22, 1937	**Extreme cold:** 19 degrees at Palm Springs.
September 18-22, 1939	**Excessive heat:** Heat wave with 95-degree plus readings in San Diego, 106 degrees on the 21st. Los Angeles experienced 100-degree weather for seven consecutive days, with a peak of 107 degrees on the 20th. Eight heat-related deaths.
August 31 to September 7, 1955	**Excessive heat:** On September 1st, it was 110 degrees in Los Angeles, and all-time record, and 104 degrees in San Diego.
September 26, 1963	**High heat:** Hot weather throughout the southern California region, including the coastline, with 112 degrees at El Cajon, 109 degrees at Imperial Beach, 113 degrees at El Toro (the hot spot in the nation for that date), 108 degrees in Carlsbad. Crop damage and animal deaths reported. Schools dismissed; workers sent home early.
October 20-29, 1965	**Excessive heat:** Very long heat wave, with a peak of 104 degrees in San Diego on the 22nd. Los Angeles had ten consecutive days with afternoon highs reaching 100 degrees.
September 25-30, 1970	**Excessive heat:** Drought in southern California came to a climax, with hot Santa Ana winds that sent the temperature soaring to 105 degrees in Los Angeles, and 97 degrees in San Diego on the 25th. The Laguna Fire consumed entire communities in eastern San Diego County. Half a million acres burned, with $50 million in property damage.
January 29, 1979	**Extreme cold:** -25 degrees in Big Bear Lake, the lowest temperature ever recorded in southern California.

Date	Description, Including Location and Damage Reported
September 4-19, 1984	**High heat:** Tropical air from weakening hurricane Marie brought hot temperatures and high humidity to the region. 100 degrees in San Diego on the 8th and 9th. Numerous health problems reported due to the poor air quality and high humidity.
January 16-18, 1987	**Extreme cold:** Very cold air mass remained over the region, 22 degrees at Valley Center, 24 degrees in Poway, 26 degrees in El Cajon, 36 degrees in San Diego. Substantial avocado crop loss in the millions of dollars. Two homeless men died of hypothermia on the 17th.
October 3-4, 1987	**High heat:** Dry, hot weather, with 108 degrees both days in Los Angeles (a record for October), 109 degrees in El Cajon, 106 degrees in Chula Vista, Fallbrook and Santee, 104 degrees in San Diego on the 3rd. The dry weather and winds fueled the Palomar Mountain fire.
December 25-26, 1987	**Extreme cold:** Low temperatures caused extensive damage to the avocado and citrus crop. 9 degrees at Mt. Laguna and 22 degrees in Valley Center on the 25th; 15 degrees in Julian and Mt. Laguna, 16 degrees in Campo, 26 degrees in El Cajon, 30 degrees in Del Mar and 37 degrees in San Diego on the 26th.
March 25-26, 1988	**High heat:** Santa Ana conditions brought temperatures into the 90s all over the region, with record heat, and fanning of several brush fires. 102 degrees reported in Santee on the 25th, 97 degrees throughout the San Diego valleys, 95 degrees in Los Angeles and Santa Maria, 90 degrees in San Diego.
December 24-30, 1988	**Extreme cold:** A week of sub-freezing temperatures in southern California; 5 people died directly from the cold weather.
April 6-7, 1989	**Excessive heat:** Record high heat reported at all recording stations in southern California, including 112 degrees in Palm Springs, 106 degrees in Los Angeles, 104 degrees in Riverside, 103 degrees in Escondido, 101 degrees in Tustin, 95 degrees in Victorville, and 76 degrees in Big Bear Lake. Part of a major heat wave that lasted from late March into early April.
December 21-23, 1990	**Extreme cold:** An artic air mass produced record cold temperatures in the region, such as a low of 29 degrees at Redondo Beach on the 22nd. Throughout the state, December 1990 brought record-low temperatures to many areas, causing $3.4 billion in damages to public buildings, utilities, residential burst pipes, and especially, crop and fruit tree damage. Thirty-three counties were included in a disaster declaration, and as a result, the State established the State Agency Freeze Disaster Task Force, and the development of the State Agency Freeze Disaster Action Plan of 1991.
August 17, 1992	**High heat:** Tropical air brought high temperatures and heat index values to Los Angeles and vicinity the entire week. On the 17th, it was 99 degrees, with a heat index of 110 degrees.
August 1, 1993	**High heat:** 123 degrees in Palm Springs.
July 27-29, 1995	**Excessive heat:** Heat wave in the region; 123 degrees at Palm Springs on the 28th and 29th, 120 degrees in Coachella, 113 degrees in San Jacinto, 112 degrees in Riverside, 111 degrees in Banning, Moreno Valley and Sun City; 110 degrees in Yucaipa on the 27th.
August 2-7, 1997	**Excessive heat**: Dangerously hot weather across all of southern California except in the coastal areas. Riverside and Ontario both peaked at 110 degrees Fahrenheit. Intense heat also felt at higher elevations. Beaumont hit 113 degrees, Julian hit 101 degrees. Five deaths were directly attributed to hyperthermia. One female died near Dulzura on the 5th; an elderly female collapsed in her yard in Cabazon on the 6th. On the 7th, a man collapsed in a parking lot in Riverside, and another died at a residence in Flowing Wells. A woman from Campo was hospitalized on the 8th and died several days later. The heat made brush fires difficult to control.
December 26, 1997	**Extreme cold:** 0 degrees reported at Big Bear Lake, 4 degrees at Big Bear Airport.

Date	Description, Including Location and Damage Reported
July 27, 1998	**High heat:** 120 degrees at Palm Springs, 118 degrees at Borrego Springs, 127 degrees at Death Valley.
August 29-31, 1998	**Excessive heat:** Record heat in the region, with 112 degrees in Yorba Linda and the Wild Animal Park, 110 degrees at El Cajon, Hemet and Riverside; 108 degrees at Ramona, 106 degrees in Vista and Escondido, over 100 degrees in most of Orange County, 114 degrees in Dulzura on the 29th. Blazes at Camp Pendleton and Lake Jennings.
June 3, 1999	**Extreme cold:** Unseasonably cold air mass brings record low temperatures this late in the season to the southern California area. The high temperature of 38 degrees at Mt. Wilson became the lowest high temperature on record for June.
May 7-9, 2001	**Excessive heat:** Heat wave with 109 degrees at Palm Springs, Thermal and Borrego Springs, 103 degrees at Hemet, 102 degrees in San Bernardino.
January 28-31, 2002 February 1-3, 2002	**Extreme cold**: Very cold weather reported throughout the southern California area caused water pipes to freeze and burst, damaged vegetable and flower crops, and caused homeless shelters to fill to capacity. $230K in property damage and $1.8M in crop damage reported. One death directly attributed to cold spell. Most freezing damage occurred in January, but the hard freezes continued in the valleys and deserts into early February. Overnight lows in the single digits were common at mountain resort locations.
July 8-11, 2002	**Excessive heat**: Temperatures over 100 degrees Fahrenheit reported in the San Bernardino Mountains for three days. On the third day nine people were admitted to local hospitals for heat exhaustion. A smog alert was also issued due to the hot stagnant air over the area.
September 1, 2002	**High heat:** Tropical heat wave; 118 degrees in Dulzura, 113 degrees in Temecula, 112 degrees in Riverside and Menifee. Sharp temperature gradients, with areas adjacent to the coastline 10 to 30 degrees cooler than areas slightly farther inland (77 degrees at Newport Beach vs. 107 degrees in Santa Ana, 10 miles away; 72 degrees at Oceanside Harbor vs. 87 degrees at Oceanside Airport, 2 miles away).
July 20, 2003	**Excessive heat**: A truck a man and a woman were riding in became stuck near the Twentynine Palms Air-Ground Combat Center. They tried to walk for help, but were overcome by the heat and died.
April 26-27, 2004	**High heat:** Record highs for April set, with 103 degrees at the Wild Animal Park, 100 degrees at Yorba Linda on the 26th.
December 1-3, 2004	**Extreme cold:** 30s in the coast, 20s in the inland valleys and deserts, teens and single digits in the mountains, 8 degrees on all three mornings at Big Bear. Wrightwood reported a low of 9 degrees. Crop damage.
July 10-20, 2005	**Excessive heat**: Record heat reported throughout the area due to a strong high pressure, with temperatures soaring to 121 degrees at Thermal, 120 degrees at Palm Springs, and 116 degrees at Hesperia. No relief was to be found in the mountains either, where even at elevations above 7,000 feet temperatures reached into the mid and upper 90s. Big Bear Lake tied an all high record high of 94 degrees on the 18th, while Idyllwild hit a high of 98 degrees. Daytime temperatures in the inland valleys hit 100 degrees or higher on most days, with a slew of record high minimums reported. One teen died of heat exposure when he and his father went looking for help after their dune-buggy broke down in Anza-Borrego Desert State Park. Near record high power consumption.
July 21-27, 2006	**Excessive heat**: A strong high pressure centered over the SW US and monsoon moisture during the second half of July led to numerous daily high minimums and high maximum temperature records. Desert locations reported the all-time warmest month on record. Heat wave reached its peak on the 22nd; several highs were tied or broken that day. Temperature rose to 105 degrees in Julian, 114 degrees at Ontario, 120

Date	Description, Including Location and Damage Reported
	degrees at Indio and Thermal, and 121 degrees at Palm Springs. There were at least 16 deaths and 27 injuries reported as a result of the heat wave, but these numbers, especially the injuries, are thought to be underestimated. Some power outages occurred.
January 12-18, 2007	**Extreme cold:** A cold snap peaked on the 15th with -7 degrees at Fawnskin, -2 degrees at Big Bear Lake and Wrightwood, 5 degrees at Hesperia, 6 degrees at Mt. Laguna, 18 degrees at Thermal, 19 degrees in Hemet, and 20 degrees at Camp Pendleton. San Diego, Riverside and San Bernardino counties declared disaster areas. $114.7 million in crop damage in San Diego County, $86 million in Riverside County, and $11.1 million in San Bernardino County. $600K in damage from frozen pipes in San Bernardino County.
July 3-6, 2007	**Excessive heat**: A significant heat wave occurred in the mountains and the Coachella Valley, with high temperatures generally around 115 degrees reported in the lower deserts, 105 degrees in the mountains between 3,000 and 5,000 feet, 100 degrees between 5,000 and 6,000 feet, and 95 degrees between 6,000 and 7,000 feet. Most valleys and coastal cities west of the mountains were not affected because of a persistent marine layer, and as a result, there was little media coverage regarding the heat wave. The heat wave likely made many people ill, but the number is unknown.
September 1-4, 2007	**Excessive heat**: A strong high pressure and easterly flow brought hot, humid weather to much of southern California. Temperatures exceeded 110 degrees in the Inland Empire and high deserts, and 115 degrees in the lower deserts. Humidity levels were quite high for the region. At least six people died of heat-related causes; the actual number is probably higher.
June 20, 2008	**High heat**: High temperatures were recorded in the Inland Empire area, including 105-111 degrees in the valleys and 115-118 degrees in the lower deserts. The relatively short duration of the heat spell and the lack of humidity kept this episode from meeting the excessive heat criteria. News reports indicated that several people were treated for heat-related illnesses, but no specifics were provided.

Sources: NOAA database (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms), and compilation by the National Weather Service office in San Diego (http://www.wrh.noaa.gov/sgx/document/weatherhistory.pdf).

6.3 Community Vulnerability to Severe Weather Damage

6.3.1 Hazards Assessment Summary

The previous sections describe the various extreme weather conditions that have impacted and are likely to impact again the Yucca Valley area. By reviewing the historical record we can better understand the geographic extent of the hazard, the intensity of the events likely to impact the study area, and their probability of occurrence. Each of the hazards covered above is discussed further in the paragraphs below, addressing these issues, with an emphasis on how they pertain specifically to the Yucca Valley area.

6.3.1.1 Windstorms

Windstorms are significant chronic events that cumulatively cause extensive damage, with property losses in the millions of dollars, in addition to injuries and loss of life. A windstorm event in the region can range from a short-term microburst or tornado lasting only a few minutes, to either Santa Ana or thunderstorm-related wind conditions that can last for several days.

The data in Table 6-4 show that high winds can occur in Yucca Valley almost any time during the year, but primarily in January, July, August, and December. More specifically, **Santa Ana wind** conditions occur most often in the fall and winter months, occurring as early as September, and as late as March, but mostly between December and January. These winds tend to impact a large geographic area. Similarly, high winds accompanying **winter storms** approaching from the north or northeast also occur most often between November and March, with most equally distributed between December, January and February. **Tropical storms** that make landfall in Baja California and move north into Arizona and California generally occur between May and September, with most taking place in July and August.

The data presented in Table 6-4 may give the impression that windstorm events have increased in frequency over time. However, this is most likely the result of an incomplete historical record rather than a change in wind frequency. The records are likely missing data because: 1) there were less people in the area that could be impacted by these natural hazards, and 2) only unusually damaging storms would be recorded in newspapers, journals and other sources. Using the record from the last decade only, the study area is impacted by windstorms approximately five times per year, on average, but there is significant variability from year to year. For example, in the years 2001 and 2004, only three high wind events were reported in the area, whereas in 2009, there were nine wind events, and in the year 2000, eight.

The records (see Table 6-5) indicate that **tornadoes** can occur in San Bernardino County at any time of the year, but that they do occur more often in July, followed by August and September. The tornado numbers also vary significantly from year to year. Using only the records between 1990 and 2011, which are deemed to be more complete than those for previous decades, we find that in some years there is substantial tornado activity, while in others, there is none. For example, several tornadoes were reported in the region in 1990, 1997, 1998, 2000, 2001, 2004, 2005, 2008, but no tornadoes were reported in 1992 through 1996, 2002, 2006, 2007, or 2010. Tornadoes and microbursts usually impact a relatively small geographic area. Tornadoes in the southern California area have for the most part been size F0 or F1, but even these tornadoes are capable of causing extensive property damage, injuries and loss of life.

Based on the data presented in Table 6-6, winds in San Bernardino County producing **dust storms** are for the most part the result of Santa Ana conditions, and occurring primarily between October and March. Less than 20% of the dust storms reported are the result of thunderstorms in May and August. For dust storms to occur, there has to be a source of sand, dirt, or ash present, generally the result of vegetation stripping either as a result of man-made activities (such as farming, grading during construction), an antecedent natural disaster (drought, forest fire, a flood event depositing loose sand and silt), or a natural condition (desert). Depending on the availability of sand and other debris, and the regional extent of the wind event responsible for picking up and transporting the dust, a dust storm will be either local or regional in extent. Santa Ana wind conditions, given their regional extent and their wind strength, have the capacity to move large amounts of dust, if there is a source available, great distances (see the Photo on Figure 6-1 showing ash and smoke from wildfires being transported hundreds of miles out to sea).

Unlike flooding hazards, which are generally confined to a discrete area that can be mapped, windstorms may travel in any direction, and are only partly affected by topography (with stronger winds usually observed in canyons and passes, where the winds are funneled by the surrounding topographic highs). Given that we cannot predict when or where a windstorm will occur, nor its intensity, the conservative approach is to assume that a windstorm event can take place anywhere in the Yucca Valley area anytime during the year, but preferentially in the summer (July and August) and winter (December and January).

6.3.1.2 Hail

The data presented in Table 6-7 suggest that most hail events in the Yucca Valley region are caused by late spring and summer thunderstorms, with most of these occurring between July and September. Based on the damage descriptions, these events are typically localized, impacting a relatively small area, most often around Twentynine Palms and Joshua Tree, and generally lasting 30 minutes or less. A few of the hail events reported have been associated with late-season winter storms, with most of these occurring in March. The hailstones produced by these storms have been relatively small in diameter, generally less than 1 inch, but the area impacted by the storm appears to be larger. No deaths or injuries as a result of these hail events were reported, with property damage generally amounting to less than $10,000. The one exception is a thunderstorm reported in 1960 that impacted a large regional area, with hail reported in San Diego, Riverside, and San Bernardino. The large hailstones produced by this storm (2.75 inches in diameter and over 1 pound in weight) caused significant property damage, although a dollar amount was not assigned. This particular event indicates that the southern California area can be affected by severe but unusual (low probability) thunderstorms with the right atmospheric conditions to produce large hailstones.

6.3.1.3 Heavy Snow and Ice

Winter storms that bring snow and ice to the San Bernardino Mountains occur on a yearly basis, with most storms occurring between December and March. However, a few autumn storms as early as October and November have been reported, and Table 6-8 also lists a few late-season storms in April and May. The storms that impact the high desert, including the Yucca Valley area, tend to be regional in scale, generally affecting a large portion of southern California, if not the entire region. Heavy snow and ice accumulation on roof-tops, overhead utility lines, and on tree branches, has been the primary cause of property damage in these events. Traffic accidents caused by unsafe road conditions and road closures due to slope failures and snowdrifts add to the property loss. Most property losses reported to date for an individual storm event vary between a few thousands dollars, to $160,000 (March 2006), but these numbers most likely don't capture all of the losses and are thus not misleading. If the storm impacts low-lying agricultural areas, the losses to crops and livestock can amount to millions of dollars.

6.3.1.4 Temperature Extremes

Table 6-9 includes fifteen **extreme cold** events that have impacted or are inferred to have impacted the Yucca Valley area between 1888 and 2010. Since 1987, eight deaths in the region have been directly attributed to cold weather. Most of these events, as expected, occurred in December, January and February, during the winter months. One extreme cold event was interestingly reported in early June (1999), when a winter storm brought

unseasonably low temperatures to the southern California area, with up to 3 inches of snow reported in the mountains above the 5,500-foot elevation in San Bernardino, Los Angeles, Riverside and San Diego counties. Property and crop damage is not well accounted for, but it amounts in the millions of dollars (the 2007 freeze alone caused $600 thousand in property damage and $11.1 million in crop damage in San Bernardino County).

Table 6-9 also includes 17 **extreme heat** and 10 **high heat** events between 1917 and 2008. At least 30 people reportedly died from high heat between 1997 and 2010, although this number may be underestimated. Most extreme and high heat events occurred between July and September, but at least one high heat event was reported as early as March, one extreme heat event occurred in April, and two events (one high heat and one extreme heat), were reported as late as October. Property and crop losses associated with these events amount to billions of dollars, especially if the damage as a result of the fires associated with these heat waves is included in the loss count.

Temperature extreme events tend to be regional in scale, although to some extent they are controlled by elevation, with high and extreme heat impacting low-lying inland areas preferentially, and extreme cold more likely to impact the higher elevation areas. Given that the Town of Yucca Valley is located at an approximate elevation of 3,300 feet above mean sea level, it enjoys cooler summers than the communities to the south, in the Coachella Valley, and generally milder winters than the mountain communities to the west and northwest.

6.3.2 Damage Assessment

As past events show, storms in the Yucca Valley area and elsewhere have the potential to impact life, property, utilities, infrastructure and transportation systems, causing damage to trees, power lines, utility poles, road signs, cars, trucks, and building roofs and windows. Structures and facilities can be impacted directly by high winds and/or can be struck by air-borne debris or downed trees and power poles. Windstorms can disrupt power to facilities and disrupt land-based communications as well. In fact, historically, trees downed during a windstorm have been the major cause of power outages in the southern California area. Uprooted trees and downed utility poles can also fall across the public right-of-way disrupting transportation.

Hail can and will cause significant damage to structures, vehicles, aircraft, and livestock (not to mention people that don't find cover). Hail can also cause significant damage to crops. The structural components most often damaged by hail include roofs (including glass roofs), skylights, window awnings, and windows. Vehicular accidents as a result of reduced visibility, and hail stones on the pavement acting as ball bearings, can be expected during these kinds of storms.

Extreme cold is typically only one of the hazards associated with winter storms. Thus, in addition to cold temperatures, residents and visitors to the area impacted by a storm have to deal with other potential hazards including icy roadways, strong winds, and power outages. Vehicular accidents and falls on icy sidewalks are two leading causes of injuries during winter storms.

These events can be major hindrances to emergency response and disaster recovery. For example, if transportation routes are compromised by fallen debris, and loss of power occurs in the area, emergency response facilities like hospitals, fire stations, and police stations may find it difficult to function effectively. Falling or flying debris, downed trees and power lines can also injure or kill motorists and pedestrians. As discussed previously, windstorms, especially Santa Ana winds, are often also associated with wildfires, which, if they occur in or near a populated area, can result in enormous losses to property, in addition to injuries and loss of life. Such an event may require the involvement of Town maintenance personnel responding to cleanup and repairs during and following the windstorm. Similarly, maintenance crews may be required to secure certain facilities ahead of a potential storm, provided sufficient advanced notice is available, and that municipal crews are available to respond on short notice.

6.3.2.1 Structural Damage

Depending on its age, condition, and structural design, any structure may be susceptible to windstorm damage. However, buildings with weak reinforcements are most susceptible. Wind pressure can create a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Conversely, passing currents can create lift suction forces that pull building components and surfaces outward and/or upward. Under extreme wind forces, the roof or entire building can fail or sustain considerable damage. Mobile homes are particularly susceptible to windstorm damage. Debris carried by the wind may also contribute to loss of life and, indirectly, to the failure of building envelopes, sidings or walls.

A windstorm also has the potential to displace residents, which may require the Town to provide short-term and/or long-term shelters to accommodate these individuals, in addition to providing for other emergency response activities such as cleanup and repair. This has the potential to impact Yucca Valley economically, as Town funds would have to be tapped into to respond adequately to the needs of the impacted members of the community.

Heavy snow and ice can also cause structural damage. Flat roofs in particular, are susceptible to this hazard, given that as the snow or ice accumulates on the roof, the extra weight stresses the structural supports, causing the roof to collapse, or even damaging the whole structure. A roof collapse as a result of snow accumulation occurred in the Big Bear Lake area in January 2010, pinning down and injuring a teenager. Mobile homes in particular are susceptible to roof collapse due to snow accumulation. As a result of the same snow storm in 2010, four mobile homes in Big Bear Lake and two in Big Bear City suffered roof damage (http://www.bigbearcityfire.org/news_archives.php?id=71).

6.3.2.2 Lifelines and Critical Facilities

Historically, downed trees have been a major cause of power outages in the region during windstorms and winter storms. Some tree limbs can break in winds of about 45 mph, and the broken limbs can be carried by the wind more than 75 feet from their source. Thus, overhead power lines can be damaged even in relatively minor windstorm events. Downed trees can also bring electric power lines down to the pavement or ground, where they become serious, life-threatening, sources of electric shock. Winter storms often do

substantial damage to overhead utilities, usually the result of ice and snow breaking tree branches and limbs that then down power and telephone lines.

Lifelines and critical facilities should remain accessible, if at all possible, during a natural hazard event. The impact of closed transportation arteries may be increased if a blocked road or bridge is critical to access a hospital or other emergency facilities. Population growth and new infrastructure in the region could result in a higher probability for damage to occur from windstorms and winter storms as more lives and property are exposed to these hazards.

Cold waves can cause poorly insulated water pipes to freeze, which in turn can result in substantial property damage. Fires can become more hazardous in extreme cold conditions, especially if the water supply has become unreliable due to water main breaks that hinder firefighting efforts.

6.3.2.3 Infrastructure

As mentioned above, windstorms may damage buildings, power lines, and other property and infrastructure due to falling trees and branches. During wet winters, saturated soils cause trees to become less stable and more vulnerable to uprooting from high winds. Windstorms can also result in damaged or collapsed buildings, blocked roads and bridges, damaged traffic signals and streetlights, and damaged park facilities. Roads blocked by fallen trees during a windstorm may severely impact people attempting to access emergency services. Emergency response operations can be compromised when roads are blocked or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric services and from extended road closures. They can also sustain direct losses to buildings, personnel and other vital equipment.

In addition to the problems caused by downed trees and electrical wires blocking streets and highways, storms can also force the temporary closure of roads to vehicular traffic. This is especially true during extremely strong Santa Ana winds and winter storms, and as a result of microbursts or tornadoes associated with summer thunderstorms. Cold weather can also impact the transportation of goods, especially of produce and livestock, cause significant engine wear and tear, and the freezing and thawing can damage roadways.

The high demand for air-conditioning during a heat wave has a significant impact on the electric transmission system. The heat itself can cause overhead electric lines to sag and short-out. As a result of demand exceeding supply, in addition to the physical damage to the electric transmission lines, it is not uncommon for electric companies to institute or be forced to establish rolling black-outs during periods of excessive heat. Excessive heat can also buckle roads, stress engines, and distort rail lines. All of these conditions add up, increasing the costs of transporting goods. Heat waves also have an impact on the water resources and water infrastructure, with increased demand for water. If wildfires occur during a heat wave, there will be increased use of water for fire-fighting purposes, which can tax the available resources, reducing water supply and water pressure.

Widespread weather observation stations and networks, in addition to great advancements in computer modeling and a better, if not yet comprehensive understanding of atmospheric processes, have greatly facilitated the forecasting of meteorological events such as winter

storms, windstorms, and extreme temperature events. Weather forecasts, combined with an increased use of internet and media resources, permit the wide dissemination of weather warnings in real time, with the potential to greatly reduce the effect of extreme weather events on people and property. Utility companies, relief organizations, and government officials can and should use weather warnings to anticipate an increase in demand for electricity, heating oil or gas, shelters for the homeless, and maintenance and emergency response personnel.

Date	Description, Including Location and Damage Reported
	Structures and a few roofs collapsed due to the weight of snow. Power lines and trees snapped.
January 30 – February 2, 1979	Widespread snow event; 56 inches in Big Bear Lake, the greatest snowfall on record. On January 31, snow fell heavily on Palm Springs, snow drifts shut down the I-10 on both sides of Palm Springs, isolating the city. Schools were closed and hundreds of cars were abandoned. All major interstates into Los Angeles were closed.
December 18-19, 1984	Major snowstorm brings up to 16 inches of snow to the mountains and upper deserts, including 13 inches to Lancaster. Edwards Air Force Base and the I-5, from Castaic to the San Joaquin Valley, were both closed.
February 2, 1985	Up to 2 inches of snow reported in Palm Springs.
November 11-13, 1985	A cold, slow-moving storm dropped 14 inches of snow in Mt. Laguna, 5 inches in Julian, and through the San Gabriel Mountains. Snow fell as low as Alpine (1,800-foot elevation). Interstates were closed for some time.
December 10-11, 1985	Cold storm brought heavy snow to the mountains and high desert; 17 inches in Mt. Laguna, 15 inches in Julian, 12 inches in Palomar Mountain, and up to 4 inches in Victorville and Warner Springs. The highways and schools were closed in the mountains and high desert.
February 22-25, 1987	Snow reported throughout the southern California area, with 24 inches at Mt. Laguna, 12-17 inches in the San Bernardino Mountains, 4 inches in one hour at Lake Hughes. Snow pellets reported in coastal areas, including 2 to 3 inches in Huntington Beach. Slight snow reported on the 25th in Tarzana, Northridge, Torrance, Fontana and Redlands. Roads and schools closed in the mountain areas. An aircraft accident due to a snow squall near Anza killed four.
December 16-17, 1987	Snow fell throughout southern California, including for two minutes at Malibu Beach. One foot of snow fell in the mountains north and east of Los Angeles, 24 inches in Julian. Disneyland closed due to weather; other theme parks and stretches of the I-5 and I-15 closed through the mountains. Numerous accidents resulted in fatalities. Due to the snow, all schools closed in the mountains of San Diego County and 16,000 students were sent home in the Santa Clarita Valley.
February 7-9, 1989	Snow reported from the beaches in Los Angeles to the desert in Palm Springs; 15 inches in the mountains, 3 inches at Palmdale. Major road closures and numerous traffic accidents reported.
March 17-20, 1991	Snow 2 to 5 feet deep in the mountains; on the 19th, 1 foot of snow fell on Mr. Laguna, 6 inches at Palomar Mountain and Cuyamaca. Schools and roads closed in the mountains, including the section of I-8 between Alpine and Imperial County. Many downed trees and power outages.
January 5-7, 1992	Six to 20 inches of snow in the mountains, 2 to 8 inches in the foothills and high desert floors.
January 3-4, 1995	Six to 12 inches of snow in the mountains, 2 inches of heavy, wet snow at 2,300-foot elevation in the high desert.
December 23, 1995	Up to 12 inches of snow in the San Bernardino Mountains, and up to 8 inches on the high desert floors.
February 25-28, 1996	Ten inches of snow at Idyllwild, 2 inches in Yucaipa a dusting at Hemet and Corona; 1-2 feet in the mountains, and up to 6 inches in the high desert.
January 5, 1997	Winter storm in southern California brought snow and strong winds to the mountains and high deserts. Snow was reported as low as 3,200 feet. Sleet, snow pellets and thunder accompanied the snow at several locations. Two to 3 inches of snow reported in the Apple and Lucerne valleys, 5 inches in the mountains.
January 12-15, 1997	Snowfall 1.5 to 3 feet deep common on elevations above 2,500 feet. In the San Gorgonio Wilderness, a blizzard accompanied by single-digit temperatures and 4 feet

APPENDIX A: REFERENCES and USEFUL WEBSITES

References and Other Useful Sources

Abrahamson, N.A. and Silva, W.J., 1997, Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes: *Seismological Research Letters*, Vol. 68, No.1, pp. 94-127.

Ahrens M., 2009a, Home structure fires: National Fire Protection Association, Quincy, MA.

Ahrens M., 2009b, Smoke alarms in U.S. home fires: National Fire Protection Association, Quincy, MA.

Ahrens M., 2003, The U.S. fire problem overview report: leading causes and other patterns and trends: National Fire Protection Association, Quincy MA.

Allen, C.R., 1957, San Andreas fault zone in San Gorgonio Pass, southern California: *Geological Society of America Bulletin*, Vol. 68, No. 3, pp. 315-350.

Alquist-Priolo Earthquake Fault Zoning Act, California Public Resources Code, Chapter 7.5 Earthquake Fault Zones, Section 2621 et seq., last updated October 2, 2007.

American Red Cross, 1994, Your Guide to Home Chemical Safety and Emergency Procedures, 24p.

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

Anbar, M., Guttmann, S., and Lewitus, Z., 1959, The mode of action of perchlorate ions on the iodine uptake of the thyroid gland: *International Journal on Application of Radiating Isotopes*, Vol. 7, pp. 87-96.

Anderson, K., 2006, The Use of Fire by Native Americans in California; *in* Sugihara, N.G., van Wagtendonk, J.W., Shaffer, K.E., Fites-Kaufman, J., and Thode, A.E., (editors), 2006, Fire in California's Ecosystems: University of California Press, Berkeley and Los Angeles, California, pp. 417-430.

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.

Andrews, R., 1995, Emergency response and recovery after the Northridge earthquake; *in* Woods, M.C., and Seiple, W.R., (editors), The Northridge, California, Earthquake of 17 January 1994: California Department of Conservation, Special Publication 116, pp. 241-245.

Association of Bay Area Governments (ABAG), 1990, Database of Hazardous Materials Releases Which have Occurred Due to Earthquakes: Oakland, California (as referenced in Seligson et al., 1992).

Bacheller, J., III, 1978, Quaternary geology of the Mojave Desert – eastern Transverse Ranges boundary in the vicinity of Twentynine Palms, California: Unpublished M.S. thesis, University of California – Los Angeles, 157p. + map at 1:24,000 scale.

Bader, J.S., and Moyle, W.R., 1960, Data on water wells and springs in the Yucca Valley – Twentynine Palms area, San Bernardino and Riverside Counties, California: California Department of Water Resources Bulletin No. 91-2, 163p., map scale 1:62,500.

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., 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.

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.

Behr, J., Bilham, R., Bodin, P., and Gross, S., 1994, Eureka Peak fault afterslip following the 28 June 1992 Landers earthquake: Bulletin of the Seismological Society of America, Vol. 84, No. 3, pp.826-834.

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

Blake, T.F., Hollingsworth, 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., 1999, Earthquakes: W.H. Freeman and Company, New York, Fourth Edition, 320p.

Bonilla, M.G., 1973, Trench exposures across surface fault ruptures associated with the San Fernando Earthquake; *in* Geological and Geophysical Studies, Vol. 3 of San Fernando, California, earthquake of February 9, 1971: U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, pp. 173-182.

Boore, D.M., Joyner, W.B., 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, plus erratum.

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

Bortugno, E.J., and Spittler, T.E., 1986, Geologic Map of the San Bernardino Quadrangle: California Division of Mines and Geology Regional Geologic Map Series, Map No. 3A, scale 1:250,000.

Bozorgnia, Y., Campbell, K.W., and Niazi, M., 1999, Vertical Ground Motion: Characteristics, Relationship with Horizontal Component, and Building Code Implications: Proceedings of the SMIP99 Seminar on Utilization of Strong-Motion Data, Oakland, California, pp. 23-50.

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.

Brooks, M.L., and Minnich, R.A., 2006, Southeastern Deserts Bioregion; *in* Sugihara, N.G., van Wagtendonk, J.W., Shaffer, K.E., Fites-Kaufman, J., and Thode, A.E., (editors), 2006, Fire in California's Ecosystems: University of California Press, Berkeley and Los Angeles, California, pp. 391-414.

Bryan K. A., and Rockwell, T. K., 1995, Holocene character of the Helendale fault zone, Lucerne Valley, San Bernardino County, California: Geological Society of America, Abstracts with Programs, Vol. 27, pp. 7.

Bryant, W.A., 1986a, Fault Evaluation Report for the Pinto Mountain, Mesquite Lake, Copper Mountain, and related faults, Southern San Bernardino County, California: California Division of Mines and Geology FER-181, 16p. + figures.

Bryant, W.A., 1986b, Fault Evaluation Report for the Western North Frontal Fault Zone and Related Faults, San Bernardino County, California: California Division of Mines and Geology FER-186, 16p. + figures.

Bryant, W.A., 1987, Fault Evaluation Report for the Recently active traces of the Harper, Blackwater, Lockhart and related faults near Barstow, San Bernardino County, California: California Division of Mines and Geology FER-189.

Bryant, W.A., 1988, East Airfield fault, Mesquite Lake fault, and western segment of the Pinto Mountain fault, San Bernardino County, California: California Division of Mines and Geology Supplement No. 2 to FER-181, dated January 8, 1988, 5p. + figures.

Bryant. W.A., 1992, Surface fault rupture along the Johnson Valley, Homestead Valley, and related faults associated with the Ms 7.5 28 June 1992 Landers earthquake: California Division of Mines and Geology Fault Evaluation Report FER-234, 21p., scale: 1:24,000.

Bryant, W.A., compiler, 2000, Fault number 118, Pinto Mountain fault zone (includes Morongo Valley fault) in Quaternary fault and fold database of the Unites States: U.S. Geological Survey website, http://earthquakes.usgs.gov/regional/qfaults

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.

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.

Cadena, A.M., Rubin, C.M., Rockwell, T.K., Walls, C., Lindvall, S., Madden, C., Khatib, F., and Owen, L., 2004, Late Quaternary activity of the Pinto Mountain Fault at the Oasis of Mara: Implications for the Eastern California Shear Zone: Geological Society of America Abstracts with Programs, Vol. 36, No. 5, pp. 137. [Paper presented at the Annual Meeting in Denver, Colorado, Paper No. 51-5, Nov. 7-10, 2004.]

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

California Building Standards Commission (CBSC), 2010, California Building Code, Title 24, Part 2, 2 Volumes, 1,600p.

California Building Standards Commission (CBSC), 2010, California Historical Building Code, Title 24, Part 8.

California Building Standards Commission (CBSC), 2010, California Existing Building Code, Title 24, Part 10.

California Building Standards Commission (CBSC), 2001, California Building Code.

California Department of Forestry and Fire Protection (CDF), Fire and Resource Assessment Program (FRAP), 2005a, Fire Threat Map, Scale: 1:1,100,000 at 34″ x 44″; Map ID: FTHREAT_MAP v05_1, published October 20, 2005.

California Department of Forestry and Fire Protection (CDF), Fire and Resource Assessment Program (FRAP), 2005b, Fuel Rank Potential Fire Behavior Map, Scale: 1:1,100,000 at 34" x 44"; Map ID: FRNK_MAP v05_2, published July 07, 2005.

California Department of Forestry and Fire Protection (CDF), 2007, San Bernardino County (South East) Fire Hazard Severity Zones Map, State Responsibility Area (SRA), adopted November 2007, available from www.fire.ca.gov/fire_prevention/fhsz_maps/fhsz_maps_sanbernardinose.php.

California Department of Forestry and Fire Protection (CDF), 2008, San Bernardino County (South East) Fire Hazard Severity Zones Map, Local Responsibility Area (LRA), recommended November 2008; available from www.fire.ca.gov/fire_prevention/fhsz_maps/fhsz_maps_sanbernardinose.php.

California Department of Forestry and Fire Protection, 2009, Fire Perimeters Map, Version 08_2, from http://frap.fire.ca.gov/data/frapgisdata/select.asp and http://frap.cdf.ca.gov/projects/fire_data/fire_perimeters/, last updated on January 09, 2009.

California Department of Water Resources, 1960, Data on water wells and springs in the Yucca Valley-Twentynine Palms Area, San Bernardino and Riverside Counties, California, Bulletin No. 91-2, dated June, 1960.

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

California Department of Water Resources, 2004, California's Groundwater, Bulletin 118, last updated February 27, 2004.

California Division of Mines and Geology (now California Geological Survey), 1988, Earthquake Fault Zones map for Joshua Tree North Quadrangle, Official Map effective March 1, 1988; Scale: 1:24,000.

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

California Division of Mines and Geology (now California Geological Survey), 1993a, Earthquake Fault Zones map for Joshua Tree South Quadrangle, Official Map effective July 1, 1993; Scale: 1:24,000.

California Division of Mines and Geology (now California Geological Survey), 1993b, Earthquake Fault Zones map for Yucca Valley South Quadrangle, Official Map effective July 1, 1993; Scale: 1:24,000.

California Division of Mines and Geology (now California Geological Survey), 1993c, Earthquake Fault Zones map for Yucca Valley North Quadrangle, Official Map effective July 1, 1993; Scale: 1:24,000.

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 fault near-source zones in California and adjacent portions of Nevada, to be used with the 1997 Uniform Building Code: International Conference of Building Officials.

California Environmental Quality Act, California Public Resources Code, Section 21000 et seq.

California Geological Survey, 2008, Guidelines for Evaluating and Mitigating Seismic Hazards in California: Special Publication 117A, Revised and Re-adopted September 11, 2008 by the State Mining and Geology Board, 98p. Available from http://www.conservation.ca.gov/cgs/shzp/webdocs/Documents/sp117.pdf

California Governor's Office of Planning and Research (OPR), 1998, General Plan Guidelines.

California Governor's Office of Planning and Research (OPR), 2011, Planning, Zoning and Development Laws.

California Regional Water Quality Control – Colorado River Basin Region, 2005, 2004 Triennial Review Workplan, final dated May 4, 2005, 19p.

California Regional Water Quality Control Board – Colorado River Basin Region, 2008, Final Draft 2007 Triennial Review List, 4p., released on January 18, 2008.

California Regional Water Quality Control Board – Colorado River Basin Region, 2010, Staff Report in Support of a Basin Plan Amendment to Prohibit Septic Tank Discharges in the Town of Yucca Valley, dated December 2010.

California Regional Water Quality Control Board – Colorado River Basin Region, 2011, Resolution No. R7-2011-004: Amending the Water Quality Control Plan for the Colorado River Basin Region to Prohibit Septic Tank Discharges in the Town of Yucca Valley, San Bernardino County.

California Seismic Safety Commission (CSSC), 2000, Status of the Unreinforced Masonry Building Law (Government Code Section 8875 *et. seq.*), 2000 Year Report to the Legislature, Adopted April 13, 2000, SSC 00-02.

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

California Seismic Safety Commission (CSSC), 2006, Status of the Unreinforced Masonry Building Law, 2006 Report to the Legislature, Adopted November 9, 2006, SSC Publication No. 2006-04, 12p. + 2 appendices.

Campbell, K.W., 1997, Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, Vol. 68, pp. 154-179.

Campbell, K.W., and Bozorgnia, Y., 2000, New empirical models for predicting near-source horizontal, vertical, and V/H response spectra: Implications for design, in Proceedings, 6th International Conference on Seismic Zonation, Palm Springs, California.

Campbell, K.W., and Bozorgnia, Y., 2003a Erratum, Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra: Bulletin of the Seismological Society of America, Vol. 93, No. 4., pp. 1872.

Campbell, K.W., and Bozorgnia, Y., 2003b, Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra: Bulletin of the Seismological Society of America, Vol. 93, No. 1., pp. 314-331.

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

Campbell, R.H., Fleming, R.W., Prior, DB., Nichols, D.R., Varnes, D.J., Hampton, M.A., Sangrey, D.A. and Brabb, E.E., 1989, Landslide Classification and Identification of Mud Flows and Other Landslides; *in* Sadler, P.M., and Morton, D.M., (editors), Landslides in a Semi-Arid Environment with Emphasis on the Inland Valleys of Southern California: The Inland Geological Society, Volume 2, pp. 1-27.

Canadian Wood Council, 2000, Fire Safety in Residential Buildings: Building Performance Series, Bulletin No. 2, 11p.

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

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

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.

Dawson, T.E., Weldon, R.J., II, and Biasi, G.P., 2008, Appendix B: Recurrence Interval and Event Age Data for Type A Faults: U.S. Geological Survey Open File Report 2007-1437B, California Geological Survey Special Report 203B, Southern California Earthquake Center Contribution #1138B, Version 1.0, 38p.

Deng, J., and Sykes, L.R., 1996, Triggering of 1812 Santa Barbara earthquake by a great San Andreas shock: implications for future seismic hazards in southern California: Geophysical Research Letters, Vol. 23, pp. 1155-1158.

Dibblee, T.W., Jr., 1967a, Geologic map of the Deadman Lake quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Field Investigation Map I-488.

Dibblee, T.W., Jr., 1967b, Geologic map of the Joshua Tree quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-516, 3p. pamphlet + map at 1:62,500 scale.

Dibblee,T.W., Jr., 1967c, Geologic Map of the Morongo Valley quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Geologic Investigations, Map I-517, 4p. pamphlet + map at 1:62,500 scale.

Dibblee, T.W., Jr., 1968a, Geologic Map of the Twentynine Palms quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Miscellaneous Field Investigation Map -561, at 1:62,500 scale.

Dibblee, T.W., Jr., 1968b, Evidence of major lateral displacement on the Pinto Mountain fault, southeastern California (abstract): Geological Society of America Special Paper 115, 322p.

Dibblee, T.W. Jr., 2008a, Geologic map of the Deadman Lake & Lead Mountain 15 minute quadrangles, San Bernardino County, California: Dibblee Geology Center Map #DF-388, Scale 1:62,500.

Dibblee, T.W. Jr., 2008b, Geologic map of the Joshua Tree & Twentynine Palms 15 minute quadrangles, Riverside and San Bernardino Counties, California: Dibblee Geology Center Map #DF-390, Scale 1:62,500.

Earth Consultants International, 2009, Chapter 4: Safety | City of Twentynine Palms General Plan Update Technical Report, dated October 2009 (Updated March 2010), available at http://29palmsgeneralplan.com

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

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

Eichler, O., and Hackenthal, E., 1962, Uber Ausscheidung und Stoffwechsel von Perchlorat gemessen mit 36ClO4 [Secretion and metabolism of perchlorate measured with 36ClO4]: Naunyn-Schmidedberg's Arch. Exp. Pathol. Pharmakol., Vol. 243, pp. 554-565.

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.

Fakhoury, E., and Patton, K.R., 1992, A Practical Approach for Environmental Site Assessment of Oilfield Properties Prior to Redevelopment; *in* Stout, M.L. (editor), Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, October 2-9, 1992, p. 268.

Federal Emergency Management Agency (FEMA), 1985, Comprehensive Earthquake Preparedness Planning Guidelines: City: Earthquake Hazard Reduction Series 2, FEMA-73, 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), 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), 1994, (Second Edition), Typical Costs for Seismic Rehabilitation of Existing Buildings: Volume 1: Summary: Prepared for FEMA by the Hart Consultant Group, Inc., Santa Monica, California, 70p., supersedes 1988 version.

Federal Emergency Management Agency (FEMA), 1995, (Second Edition), Typical Costs for Seismic Rehabilitation of Existing Buildings: Volume 2: Supporting Documentation. Second Edition: Prepared for FEMA by the Hart Consultant Group, Inc., Santa Monica, California, 102p., supersedes 1988 version.

Federal Emergency Management Agency (FEMA), 1996, Flood Insurance Rate Maps (FIRMs) for the Town of Yucca Valley, California; Community Panel Nos. 06071C8120H, 06071C8140H, 06071C8855H, 06071C8860H, 06071C8195H, and 06071C8880H.

Federal Emergency Management Agency (FEMA), 1997, Flood Insurance Study, San Bernardino County, California and Unincorporated Areas, Vol. 1 of 4, revised January 17, 1997.

Federal Emergency Management Agency (FEMA), 1998, Home Builder's Guide to Seismic Resistant Construction: Earthquake Hazard Reduction Series, FEMA-232, 75p.

Federal Emergency Management Agency (FEMA), 1998, Seismic Rehabilitation of Buildings: Strategic Plan 2005: Earthquake Hazard Reduction Series FEMA-315, 40p.

Federal Emergency Management Agency (FEMA), 2008, Flood Insurance Study, San Bernardino County, California, and Incorporated Areas, FIS No. 06071CV001A, Revised August 28, 2008.

Federal Emergency Management Agency (FEMA), 2009, NEHRP (National Earthquake Hazards Reduction Program) Recommended Seismic Provisions for New Buildings and Other Structures: FEMA P-750, 388p.

Fife, D.L., 1978, Airfield fault, Mesquite Playa, San Bernardino County, California: California Geology, Vol. 31, No. 3, pp. 51-53.

Fife, D.L., 1980, Giant dessication polygons and playa features; in Fife, D.L., and Brown, A.R., (editors), Geology and Mineral Wealth of the California Desert: South Coast Geological Society, published in conjunction with the October 11-12, 1980 field trip to the California Desert, pp. 414-429.

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: U.S. 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.

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.

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., Rymer, M.J., and Seitz, G.G., 2002, Timing of large earthquakes since A.D. 800 on the Mission Creek strand of the San Andreas fault at Thousand Palms Oasis, near Palm Springs: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, Vol. 92, No.7 , pp. 2841-2860.

Fumal, T.E., Weldon II, R.J., Biasi, G.P., Dawson, T.E., Seitz, G.G., Frost, W., and Schwartz D.P., 2002, Evidence for large earthquakes on the San Andreas fault at the Wrightwood, California, Paleoseismic site: A.D. 500 to present: Bulletin of the Seismological Society of America, Special Issue on Paleoseismology of the San Andreas Fault System, Vol. 92, No. 7, pp. 2726-2760.

Ganev, P.N., Dolan, J.F., Blisniuk, K., Oskin, M., and Owen, L.A., 2010, Paleoseismologic evidence for multiple Holocene earthquakes on the Calico fault: Implications for earthquake clustering in the Eastern California shear zone: Lithosphere, Vol. 2, No. 4, pp. 287-298; doi:10.1130/L82.1

Garrison, T., 2002, Oceanography – An Invitation to Marine Science: Wadsworth Publishing House, Belmont, California, 4th Edition.

Glowacka, E., Nava, F.A., Díaz de Cossío, G., Wong, V., Farfán, F., 2002, Fault slip, seismicity, and deformation in Mexicali Valley, Baja California, Mexico, after the M 7.1 1999 Hector Mine earthquake: Bulletin of the Seismological Society of America, Vol. 92, No. 4, pp. 1290-1299.

Goklany, I.M., 2007, Death and Death Rates Due to Extreme Weather Events | Global and U.S. Trends, 1900-2006: International Policy Press, a division of International Policy Network, London, 15p.

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.

Greenlee, J., and Sapsis, D., 1996, Prefire effectiveness in fire management: A summary and a review of the state-of-knowledge: International Association of Wildland Fire, Fairfield, WA, dated August 1996.

Greenwood, R.B., 1998, Section 1 - Liquefaction Evaluation Report: Liquefaction zones in the Long Beach 7.5-Minute Quadrangle, Los Angeles County, California: California Division of Mines and Geology Seismic Hazard Zone Report for the Long Beach 7.5-Minute Quadrangle, Los Angeles County, California, Open File Report No. 98-19, pp. 3-20.

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.

Grimes, G.J., 1987, Geology at the convergence of the Pinto Mountain fault and Morongo Valley fault, southern California: unpublished M.S. thesis, California State University, Los Angeles, 102p., map scale 1:12,000.

Grimes, G.J., 1981, Geologic map of part of the Yucca Valley area: Unpublished map for the California Division of Mines and Geology Data Base Augmentation Program, Scale 1:24,000.

Grimes, G.J., 1992, Sediments in Yucca Valley adjacent to the Pinto Mountain fault: San Bernardino County Museum Association, Special Publication 92-2, prepared in conjunction with the 1992 Mojave Desert Quaternary Research Center Symposium, May 15-18, 1992, pp. 28-30.

Hall, J.R., 2001, Burns, toxic gases, and other hazards associated with fires: Deaths and injuries in fire and non-fire situations: National Fire Protection Association, Fire Analysis and Research Division, Quincy, MA.

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.

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.

Hart, E.W., and Bryant, W.A., 2007 Interim Revision, 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, 42p., available from the web at http://www.consrv.ca.gov/cgs/rghm/ap/Pages/disclose.aspx.

Hart, E.W., Bryant, W.A., and Treiman, J.A., 1993, Surface faulting associated with the June 1992 Landers earthquake, California: California Geology, Vol. 46, pp. 10-16.

Haukson, E., Jones, L.M., and Hutton, K., 2002, The 1999 Mw 7.1 Hector Mine, California, earthquake sequence: Complex conjugate strike-slip faulting: Bulletin of the Seismological Society of America, Vol. 92, No. 4, pp. 1154-1170.

Hauksson, E., Stock, J., Hutton, K., Yang, W., Vidal-Villegas, J.A., and Kanamori, H., 2010, The 2010 Mw 7.2 El Mayor-Cucapah Earthquake Sequence, Baja California, Mexico and Southernmost California, USA: Active Seismotectonics along the Mexican Pacific Margin: Pure and Applied Geophysics, printed online 16 November 2010, 23p., doi: 10.1007/s00024-010-0209-7.

Hawkins, H.G., and McNey, J.L., 1979, Homestead Valley earthquake swarm, San Bernardino County, California: California Geology, Vol. 31, No. 10, pp. 222-224.

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.

Hereford and Longpre, 2009, Climate History of the Mojave Desert Region, 1982-1996, Including Data from 48 Long-Term Weather Stations and an Overview of Regional Climate Variation, U.S. Geological Survey, http://mojave.usgs.gov/climate-history/.

Herzberg, M., 1996, The Neotectonic History of the Johnson Valley fault, San Bernardino County, California: M.S. Thesis, San Diego State University, 68p.

Hi-Desert Water District (HDWD), 2012, District Facts, www.hdwd.com/AboutUs/District Facts.aspx

Hill, R.T., 1928, Southern California geology and Los Angeles earthquakes: Southern California Academy of Sciences, Los Angeles, 232p.

Hill, R.L., Pechman, J.C., Treiman, J.A., McMillan, J.R., Given, J.W., and Ebel, J.E., 1980, Geologic study of the Homestead Valley earthquake swarm of March 15, 1979: California Geology, Vol. 32, No. 3, pp. 60-67.

Hopson, R.F., 1996, Basement rock geology and tectonics of the Pinto Mountain fault, San Bernardino County, southern California: Unpublished M.S. thesis, California State University, Los Angeles, 132p.

Hough, S. E., Moil, J., Sembera, E., Glassmoyer, G., Mueller, C. and Lydeen, S., 1993, Southern surface rupture associated with the 1992 M 7.4 Landers earthquake: did it all happen during the mainshock?: Geophysical Research Letters, Vol. 20, pp. 2615-2618.

Howard, K.A., Bacheller, J. III, Fitzgibbon, T.T., Powell, R.E., and Allen, C.M., 1995, Geologic map of the Valley Mountain 15-minute quadrangle, San Bernardino and Riverside Counties, California: U.S. Geological Survey Open-File Report 95-528, scale: 1:62,500.

Huff, J.A., Clark, D.A., and Martin, P., 2002, Geologic and ground-water data for monitoring sites in the Mojave River and Morongo Ground-Water basins, San Bernardino County, California, 1992-98: U.S Geological Survey Open-File Report 02-354.

Institute for Local Self Government, 1992, Fire Retardant Roofing: How we can save lives and property: A guide for enacting local ordinances for fire and retardant roofing, 69p.

Insurance Services Office, Inc. (ISO), 1997, The Wildland/Urban Fire Hazard: ISO, New York, December 1997.

International Code Council (ICC), 2006, International Building Code.

International Code Council (ICC), 2009, International Building Code.

International Code Council (ICC), 2012, International Wildland-Urban Interface Code.

International Conference of Building Officials (ICBO), 2001, California Historical Building Code, California Building Standards Commission, Part 8, Title 24, California Code of Regulations.

International Conference of Building Officials (ICBO), 1997, Uniform Building Code.

International Conference of Building Officials (ICBO), 1998, California Building Code.

Jackson, W.A., Bohlke, J.K., Gu, B., Hatzinger, P.B., and Sturchio, N.C., 2010, Isotopic composition and origin of indigenous natural perchlorate and co-occurring nitrate in the Southwestern United States: Environmental Science Technology, Vol. 44, No. 13, pp. 4869-4876, DOI:10.1021/es903802j.

Jacoby, G.C. Jr., Sheppard, P.R., and Sieh, K.E., 1988, Irregular Recurrence of Large Earthquakes along the San Andreas Fault: Evidence from Trees: Science, Vol. 241, No. 4862, pp. 196-199.

James, H., 1986, Report of subsurface Alquist-Priolo investigation of Assessor's Parcel No. 615-221-03, 04, and 05, located northeast of the intersection at 29 Palms Highway and Sunrise Road, Twentynine Palms, California: Unpublished consulting report by Southern California Soil and Testing, Inc., of Palm Desert, California, for Warner Engineering; Project No. SCS&T 8531123, 4p. + 2 plates; dated February.

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. (CD-2000-06: Digital Database of Fault Activity Map of California and Adjacent Areas).

John M. Tettemer & Associates, Inc., 1999, Yucca Valley Master Plan of Drainage, Final Report, prepared for the San Bernardino County Flood Control District, February 1999.

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.

Jones, L.M., Bernknopf, R., Cox, D., Goltz, J., Hudnut, K., Mileti, D., Perry, S., Ponti, D., Porter, K., Reichle, M., Seligson, H., Shoaf, K., Treiman, J., and Wein, A., 2008, The ShakeOut Scenario: U.S. Geological Survey Open File Report 2008-1150, California Geological Survey Preliminary Report 25, version 1.0, 308p.

Karter, M.J., 2009, Fire loss in the United States during 2008: National Fire Protection Association, Fire Analysis and Research Division, Quincy, MA.

Keefer, D.K., 1984, Landslides caused by earthquakes: Geological Society of America Bulletin, Vol. 95, No. 4, pp. 406-421.

Keefer, D.K., and Wilson, R.C., 1989, Predicting earthquake-induced landslides with emphasis on arid and semi-arid environments; *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 of Southern California, Volume 2, pp. 118-149.

Kennedy/Jenks Consultants, 2011, Final 2010 Urban Water Management Plan, prepared for the Hi-Desert Water District; K/J Project No. 1089057*00, dated June 2011.

Kennedy/Jenks/Chilton, 1991, Final Draft Report, Warren Valley Basin Management Plan; unpublished consulting report for the Warren Valley Basin Watermaster, K/J/C Project No. 904619.00, dated January 30, 1991.

Kohler, S., 2006, Aggregate Availability in California – Fifty-Year Aggregate Demand Compared to Permitted Aggregate Resources, Map Sheet 52: Department of Conservation, California Geological Survey, dated December 2006.

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.

Langenheim, V.E., and Powell, R.E., 2009, Basin geometry and cumulative offsets in the Eastern Transverse Ranges, southern California: Implications for transrotational deformation along the San Andreas fault system: Geosphere (a publication of the Geological Society of America), Vol. 5, No. 1 (February edition), pp. 1-22; DOI: 10.1130/GES00177.1.

Larson, L., 2009, How Certain Are We About Our Flood Risk?: Natural Hazards Observer, Vol. XXXIII, No. 6, dated July 2009.

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.

Lewis, R.E., 1972, Ground-water Resources of the Yucca Valley – Joshua Tree Area, San Bernardino County, California: U.S. Geological Survey Water Resources Division, Open-File Report prepared in cooperation with the Mojave Water Agency, 51p.

Louderback, G.D., 1949, Seismological Notes, Desert Hot Springs Earthquake: Bulletin of the Seismological Society of America, Vol. 39, No. 1, pp. 57-65.

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.

Madden, C.L., Rubin, C.M., and Streig, A., 2006, Holocene and latest Pleistocene activity on the Mesquite Lake Fault near Twentynine Palms, Eastern California Shear Zone: Implications for Fault Interaction: Bulletin of the Seismological Society of America, Vol. 96, No. 4A, pp. 1305-1320, DOI 10.1785/0120020120.

Manson, M.W., 1986, Homestead Valley fault, Johnson Valley fault, and associated faults, San Bernardino County, California: California Division of Mines and Geology Fault Evaluation Report FER-180, Open-File Report 90-14, scale: 1:24,000.

Matti, J.C., and Morton, D.M., 1993, Paleogeographic evolution of the San Andreas fault in southern California: a reconstruction based on a new cross-fault correlation; *in* Powell, R.E., Weldon, R.J., II, and Matti, J.C., (editors), The San Andreas Fault System: Displacement, Palispastic Reconstruction, and Geologic Evolution: Geological Society of America Memoir, Vol. 178, pp. 107-159.

Matti, J.C., Morton, D.M., and Cox, B.F., 1992, The San Andreas fault system in the vicinity of the central Transverse Ranges province, southern California: U.S. Geological Survey Open-File Report No. 92-354, 40p., map at 1:250,000 scale.

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., and Vorhis, R. C., 1968, Seismic Seiches from the March 1964 Alaska earthquake: U.S. Geological Survey Professional Paper 544-E, 43p.

McGill, S.F., Dergham, S., Barton, K., Berney-Ficklin, T., Grant, D., Hartling, C., Hobart, K., Minnich, R. Rodriguez, M., Runnerstrom, E., Russell, J., Schmoker, K., Stumfall, M., Townsend J., and Williams J., 2002, Paleoseismology of the San Andreas Fault at Plunge Creek, near San Bernardino, Southern California: Bulletin of the Seismological Society of America, Vol. 92, pp. 2803-2840, doi:10.1785/0120000607.

McJunkin, R.D., 1980, Strong-motion data for the Homestead Valley Earthquake Swarm, San Bernardino County, California, 15 March 1979: California Geology, Vol. 32, No. 1, pp. 11-13.

Meisling, K.E., 1984, Neotectonics of the north frontal fault system of the San Bernardino Mountains, southern California; Cajon Pass to Lucerne Valley: California Institute of Technology, unpublished Ph.D. dissertation.

Meltzner, A.J., Rockwell, T.K., and Owen, L.A., 2006, Recent and long-term behavior of the Brawley Fault Zone, Imperial Valley, California: An escalation in slip rate?: Bulletin of the Seismological Society of America, Vol. 96, No. 6, pp. 2304-2328; DOI: 10.1785/0120050233.

Messaros, Karin, 2009, Staff with the Joshua Tree National Park, e-mail communication on October 8, 2009.

Miller, W.J., 1938, Pre-Cambrian and associated rocks near Twentynine Palms, California: Geological Society of America Bulletin, Vol. 49, No. 3, pp. 417-446.

Morton, D.M., Miller, F.K., and Smith, C.C., 1980, Photo-reconnaissance maps showing young-looking fault features in the southern Mojave Desert, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1051, 7 sheets, Scale: 1:24,000.

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.

Morton, D.M., Matti, J.C., and Tinsley, J.C., 1987, Banning fault, Cottonwood Canyon, San Gorgonio Pass, southern California: Geological Society of America Centennial Field Guide-Cordilleran Section.

Morton, D.M., and Sadler, P.M., 1989, Landslides flanking the northeastern Peninsular Ranges and the San Gorgonio Pass area of southern California; *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, Vol. 2, pp. 338-255.

Murphy, Sean, 2009, GIS Specialist with the Joshua Tree National Park, e-mail communication via Karin Messaros on October 8, 2009.

MWH, 2007, Water System Master Plan, prepared for the HI-Desert Water District, July 2007.

National Climatic Data Center, 2010, Various Event Record Details, www4.ncdc.noaa.gov.

National Earthquake Information Center (NEIC) USGS Earthquake Hazards Program http://neic.usgs.gov/neis/epic/epic_rect.html

National Oceanic & Atmospheric Administration (NOAA), 2005a, NOAA identifies causes for latest wet weather in west, NOAA News Online (Story 2395) at www.noaanews.noaa.gov.

National Oceanic & Atmospheric Administration (NOAA), 2005b, Worsening drought in northwest, record rain in the southwest in January, NOAA News Online (Story 2389), at www.noaanews.noaa.gov.

National Park Service, Joshua Tree National Park, 2005, Fire Management Plan Environmental Assessment: document prepared by Mangi Environmental Group, McLean, VA, dated April 2005.

National Research Council, Committee on Natural Disasters, Commission on Engineering and Technical Issues, 1993, Wind and the Built Environment: U.S. Needs in Engineering and Hazard Mitigation: National Academy Press, Washington D.C., 230p.

National Research Council, Committee on Alluvial Fan Flooding, 1996, Alluvial Fan Flooding, ISBN: 0-209-5542-3, 182p.

National Research Council, Committee on FEMA Flood Maps, 2009, Mapping the Zone – Improving Flood Map Accuracy: National Academies Press, ISBN: 0-309-13058-1, 136p.

Nishikawa, T., Densmore, J.N., Martin, P., and Matti, J., 2003, Evaluation of the Source and Transport of High Nitrate Concentrations in Ground Water, Warren Subbasin, California: U.S. Geological Survey, Water-Resources Investigations Report 03-4009, prepared in cooperation with the Hi-Desert Water District and the Mojave Water Agency, 133p.

O'Rourke, Michael J., and X. Liu, 1999, Response of Buried Pipelines Subject to Earthquake Effects: American Society of Civil Engineers, Multidisciplinary Center for Earthquake Engineering Research Monograph #3, Buffalo, New York, 249p.

Oskin, M., Perg, L., Blumentritt, D., Muckopadhyay, S., and Iriondo, A., 2007, Slip rate of the Calico fault: implications for geologic versus geodetic rate discrepancy in the Eastern California Shear Zone: Journal of Geophysical Research - Solid Earth, Vol. 112, DOI:10.1029/2006JB004451.

Perry, R.W., and Lindell, M.K., 1995, Earthquake-initiated hazardous materials release: Lessons Learned from the Northridge Earthquake: George Washington University and Arizona State University.

Person, W. J., 1986, Earthquakes: July - August 1986: Earthquakes and Volcanoes, Vol. 19, No. 1, pp. 32-35.

Person, W. 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., and Reichle, M.S., (California Division of Mines and Geology), Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., (U.S. Geological Survey), 1996, Probabilistic seismic hazard assessment for the State of California: California Division of Mines and Geology Open-File Report 96-08 and U.S. Geological Survey Open-File Report 96-706, 64 p.

Petersen, 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.

Philibosian, B., Fumal, T.E., and Weldon, R.J., 2011, San Andreas Fault Earthquake Chronology and Lake Cahuilla History at Coachella, California: Bulletin of the Seismological Society of America, Vol. 101, No. 1, pp. 13-38, doi: 10.1785/0120100050

Phillips, Clinton B., 1983, Instructions for Zoning Fire Hazard Severity in State Responsibility Areas in California: California Department of Forestry, dated December 1983.

Platte, M., and Brazil, J., 1993, Water Pressure Burned Laguna – Fire Distribution Problems, and Not Low Supply – Hindered Fight, Records Show: Los Angeles Times article, November 14, 1993; http://articles.latimes.com/1993-11-14/news/mn-56930_1_low-water-pressure.

Porter K., Wein, A., Alpers, C., Baez, A., Barnard, P., Carter, J., Corsi, A., Costner, J. Das, T., Dettinger, M., Done, J., Eadie, C., Eymann, M., Ferris, J., Gunturi, P., Hughes, M., Jarrett, R., Johnson, L., Le-Griffin, H., Mitchell, D., Morman, S., Neiman, P., Olsen, A., Perry S., Plumlee, F., Ralph, M., Reynolds, D., Rose, A., Schaefer, K., Serakos, J., Siembieda, W., Stock, J., Strong, D., Wing, I., Tang, A., Thomas, P., Topping, K., and Wills, C., Jones, L. (chief scientist), and Cox, D. (project manager), 2011, Overview of the Arkstorm Scenario, U.S. Geological Survey Open File Report 2010-1312, 183p. plus appendices.

Ralph, F.M., and Dettinger, M.D., 2011, Storms, Floods, and the Science of Atmospheric Rivers, in EOS, Transactions, American Geophysical Union, Vol. 92, No. 32, dated 9 August 2011.

Rasmussen, Gary S., & Associates, Inc., 1992, Subsurface Engineering Geology Investigation, Tract No. 10682-1 and -2, Lots 1-76 Immediately South of Onaga Trail, West of Palomar Avenue, Yucca Valley, California: unpublished consulting report for Redlands Financial Services, Inc., Project No. 3141, dated December 3, 1992.

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.

Rockwell, T.K., Lindvall, S., Herzberg, M., Murbach, D., Dawson, T., and Berger, G., 2000, Paleoseismology of the Johnson Valley, Kickapoo and Homestead Valley faults: clustering of earthquakes in the Eastern California Shear Zone: Bulletin of the Seismological Society of America, Vol. 90, pp. 1200-1237.

Rogers, D. E., 1998, Perchlorate user and production information [memorandum with attachments to Annie M. Jarabek], Wright-Patterson Air Force Base, OH: Department of the Air Force, Air Force Materiel Command Law Office; October 30.

Rogers, J.J.W., 1954, Geology of a portion of Joshua Tree National Monument, Riverside County, in Jahns, R.H., ed., Geology of Southern California, California Division of Mines and Geology Bulletin 170, map sheet no. 24, 1:84,000.

Rogers, J.J.W., 1958, Textural and spectrochemical studies of the White Tank quartz monzonite, California, Geological Society of America Bulletin, v.69, no. 4, p. 449-464.

Rogers, J.J.W., 1961, Igneous and metamorphic rocks of the western portion of the Joshua Tree National Monument, Riverside and San Bernardino Counties, California, California Division of Mines and Geology Special Report 68.

Rubin, C.M., and Sieh, K., 1997, Long dormancy, low slip rate, and similar slip-per-event for the Emerson fault, eastern California shear zone: Journal of Geophysical Research, Vol. 102, pp. 15,319-15,333.

Rymer, M.J., 2000, Triggered surface slips in the Coachella Valley area associated with the 1992 Joshua Tree and Landers, California, earthquakes: Bulletin of the Seismological Society of America, Vol. 90, No. 4, pp. 832-848; DOI: 10.1785/0119980130.

Rymer, M.J., Boatwright, J., Seekins, L.C., Yule, J.D., and Liu, J., 2002, Triggered surface slips in the Salton Trough associated with the 1999 Hector Mine, California, earthquake: Bulletin of the Seismological Society of America, Vol. 92, No. 4, pp. 1300-1317.

Sadigh, K., Chang, C.Y., Egan, J.A., Makdisi, F., and Youngs, R.R., 1997, Attenuation Relations for Shallow Crustal Earthquakes Based on California Strong Motion Data: Seismological Research Letters, Vol. 68, No.1, pp. 180-189.

San Bernardino County, 2009, Land Use Plan, General Plan, Hazard Overlay Maps for Yucca Valley.

San Bernardino County Flood Control District, 2006, Flood History, updated October 5, 2006, http://www.co.san-bernardino.ca.us/flood.

San Bernardino County Flood Control District, 2009, Flood History, http://www.co.san-bernardino.ca.us.

San Bernardino County Flood Control District, 2011, Yucca Valley Flood Control System, 6-4054-00 through 6-486-00, SBCFCD file no. RM-D4-8, dated October 2011.

Scawthorn, C.R., 2008, The ShakeOut Scenario Supplemental Study: Fire Following Earthquake: U.S. Geological Survey Open File Report 2008-1150, dated March 3, 2008.

Seismic Hazards Mapping Act, California Public Resources Code, Section 2690 et seq., last updated May 13, 2003.

Seligson, H.A., Eguchi, R.T., and Tierney, K.J., 1992, A methodology for assessing the risk of hazardous materials release following earthquakes – a demonstration study for the Los Angeles area: Proceedings of the 4th U.S.-Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems, U.S. Government Printing Office, Washington D.C., pp. 437-450.

Seligson, H.A., Eguchi, R.T., Tierney, K.J., and Richmond, K., 1996, Chemical Hazards, Mitigation and Preparedness in Areas of High Seismic Risk: A Methodology for Estimating the Risk of Post-Earthquake Hazardous Materials Release: National Center for Earthquake Engineering Research (NCEER) Technical Report 96-0013, dated November 7, 1996.

Siddiqui, M., LeChevallier, M. W., Ban, J., Phillips, T., and Pivinski, J., 1998, Occurrence of perchlorate and methyl tertiary butyl ether (MTBE) in groundwater of the American water system: American Water Works Service Company, Inc., Vorhees, NJ, September 30.

Sieh, K., 1986, Slip rate across the San Andreas fault and prehistoric earthquakes at Indio, California: Eos, Transactions of the American Geophysical Union, Vol. 67, No. 55, p. 1200.

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.

Sieh, K., Stuiver, M. and Brillinger, D., 1989, A more precise chronology of earthquakes produced by the San Andreas fault in southern California: Journal of Geophysical Research, Vol. 94, pp. 603-623.

Sieh, K. and Williams, P., 1990, Behavior of the southernmost San Andreas fault during the past 300 years: Journal of Geophysical Research, Vol. 95, pp. 6629-6645.

Sneed, M., Ikehara, M.E., Stork, S.V., Amelung, F., and Galloway, D.L., 2003, Detection and measurement of land subsidence using interferometric synthetic aperture radar and global positioning system, San Bernardino County, Mojave Desert, California: U.S. Geological Survey Water-Resources Investigations Report 03-4015.

Southern California Earthquake Center (SCEC), 2001, Southern California Faults and Earthquakes, World-Wide Web Site: www.scecdc.scec.org.

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

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.

Stamos, C.L., Glockhoff, C.S., McPherson, K.R., and Julich, R.J., 2009, Water-level and land-subsidence studies in the Mojave River and Morongo groundwater basins: U.S. Geological Survey Scientific Investigations Report 2007-5097, unpaginated.

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 Knopp, 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 on October 23-27, 1995, San Diego, California.

Stewart, J.P., Bray, J.D., Seed, R.B., and Sitar, N., (editors), 1994, Preliminary report on the principal geotechnical aspects of the January 17, 1994 Northridge earthquake: University of California at Berkeley, College of Engineering Report No. UCB/EERC 94-08, 245p.

Stierman, D.J., Lee, T-C., Zappe, S.O., Seamount, D., 1980, Aftershocks of the Homestead Valley Earthquakes of March 15, 1979: California Geology, Vol. 32, No. 1, pp. 14-17.

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.

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.

Taylor, W.L., and Taylor, R.W., 2007, The Great California Flood of 1862: The Fortnightly Club of Redlands, California.

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.

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.

Toppozada, T.R., Real, C.R., and D.L. Parke, 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.

Townley, S.D., 1939, Earthquakes in California, 1769 to 1928: Bulletin of the Seismological Society of America, Vol. 29, No. 1, pp. 21-252.

Treiman, J.A., 1992, Eureka Peak and Burnt Mountain faults, two "new" faults in Yucca Valley, San Bernardino County, California: Southern California Section of the Association of Engineering Geologists Field Trip Guidebook, pp. 19-22.

Treiman, J.A., Kendrick, K.J., Bryant, W.A., Rockwell, T.K., and McGill, S.F., 2002, Primary surface rupture associated with the Mw 7.1 16 October 1999 Hector Mine earthquake, San Bernardino County, California: Bulletin of the Seismological Society of America, Vol. 92, No., 4, pp. 1171-1191.

Troxell, H.C., 1942, Floods of March 1938 in southern California: U.S. Geological Survey Water-Supply Paper 844.

Tsihrintzis, V.A, Murillo, B.N., Mulvihill, M.E., Trott, W.J., Baine, J.T., Tiamzon, N., 1991, Flood control design for development on alluvial fans: Hydraulic Engineering: Proceedings of the National Conference on Hydraulic Engineering, pp. 417-422.

Unreinforced Masonry Law, California Public Resources Code, Chapter 12.2 Building Earthquake Safety, Section 8875 et seq.

URS Corporation, 2007, County of San Bernardino 2007 General Plan, Adopted March 13, 2007, Effective April 12, 2007.

U.S. Geological Survey, 1994, Joshua Tree North quadrangle, 7.5 Minute Series (Topographic) Scale 1:24,000.

U.S. Geological Survey, 1994, Joshua Tree South quadrangle, 7.5 Minute Series (Topographic) Scale 1:24,000.

U.S. Geological Survey, 1994, Rimrock quadrangle, 7.5 Minute Series (Topographic) Scale 1:24,000.

U.S. Geological Survey, 1994, Yucca Valley North quadrangle, 7.5 Minute Series (Topographic) Scale 1:24,000.

U.S. Geological Survey, 1994, Yucca Valley South quadrangle, 7.5 Minute Series (Topographic) Scale 1:24,000.

U.S. Geological Survey, 2000, Landslide hazards, USGS Fact Sheet FS-071-00, available at http://pubs.usgs.gov/fs/fs-0071-00.

van Wagtendonk, J.W., and Cayan, D., 2008, Temporal and spatial distribution of lightning strikes in California in relation to large-scale weather patterns: Fire Ecology, Vol. 4, No. 1, pp.34-56.

Varnes, D.J., 1978, Slope movement types and processes; in Schuster, R.L. and Krizek, R.J. (editors), Landslides – Analysis and Control: National Academy of Sciences Transportation Research Board Special Report 176, pp. 12-33.

Vaughan, F.F., 1922, Geology of San Bernardino Mountains north of San Gorgonio Pass: University of California, Berkeley, Bulletin of the Department of Geological Sciences, Vol. 13, No. 9, pp. 319-411.

Waananen, A.O., 1969, Floods of January and February 1969 in central and southern California: U.S. Geological Survey, Water Resources Division, Open-File Report.

Wald, D.J., Quitorino, 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.

Wei, M., Sandwell, D., Fialko, Y., and Bilham, R., 2011, Slip on faults in the Imperial Valley triggered by the 4 April 2010 Mw 7.2 El Mayor-Cucapah earthquake revealed by InSAR: Geophysical Research Letters, Vol. 38, L01308, doi:10.1029/2010GL045235.

Weldon, R.J., 2010, communication to the Southern California Earthquake Center's El Mayor – Cucapah Earthquake response team; available on the web at http://response.scec.org/node/273.

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: Geological Society of America, Reviews in Engineering Geology, Vol. VII, pp. 105-114.

Wesnousky, S.G., 1986, Earthquakes, Quaternary faults, and seismic hazards in southern California: Journal of Geophysical Research, Vol. 19, No. B12, pp. 12587-12631.

Williams, F.J., and McWhirter, J., 1980, Landers Area Magnetometer Survey: California Geology, Vol. 32, No. 1, pp. 18-19.

Williams, P.L., McGill, S., Sieh, K., Allen, C.R., and Louie, J.L., 1986, North Palm Springs earthquake: Bulletin of the Seismological Society of America, Vol. 78, pp. 1112-1122.

Wills, C.J., Weldon II, R.J., and Bryant, W.A., 2008, Appendix A: California fault parameters for the National Seismic Hazard Maps and Working Group on California Earthquake Probabilities 2007: U.S. Geological Survey Open File Report 2007-1437A, California Geological Survey Special Report 203A, Southern California Earthquake Center Contribution #1138A, Version 1.0, 48p.

Wilson, R.C., and Keefer, D.K., 1985, Predicting areal limits of earthquake-induced landsliding; *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. 316-345.

2007 Working Group on California Earthquake Probabilities, 2008, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): USGS Open File Report 2007-1437, CGS Special Report 203, SCEC Contribution #1138, Version 1.0.

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.

Yule, D., Maloney, S., and Cummings, S., 2006, Using pollen to constrain the age of the youngest rupture of the San Andreas fault at San Gorgonio Pass: Seismological Research Letters, Vol. 77, No. 2, p. 245.

Yule, D., and Sieh, K., 2003, Complexities of the San Andreas fault near San Gorgonio Pass: Implications for large earthquakes: Journal of Geophysical Research, Vol. 108, No. B11, pp. 2548.

Zappe, D.P., 1997, Testimony of David P. Zappe, General Manager-Chief Engineer, Riverside County Flood Control and Water Conservation District, Impact of the Endangered Species Act of Flood Control Activities; available online at www.House.gov/resources/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.

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/cgs/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://gmw.consrv.ca.gov/shmp/

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/cgs/rghm/quakes/index.htm

List of California earthquakes (date, magnitude, latitude longitude, description of damage).

http://geohazards.cr.usgs.gov/eq/html/canvmap.html

Website at the USGS Earthquake Hazard's Program that lists seismic acceleration maps available for downloading.

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.

http://neic.usgs.gov/

Homepage of the National Earthquake Information Center. Maintains an extensive global seismic database on earthquake parameters. Its mission is to rapidly determine the location and size of all destructive earthquakes worldwide, and disseminate that information as quickly as possible to concerned national and international agencies, scientists, and the public in general.

http://www.scsn.org/

Site where Shakemaps for actual and scenario earthquakes can be obtained.

Landslides and Debris Flows

http://landslides.usgs.gov/index.html
USGS Landslide webpage. Links to their publications, recent landslide events, and bibliographic databases.

http://gmw.consrv.ca.gov/shmp/
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/hazards/landslides/landslif.shtm
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/fima/
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.

Others

http:// www.bsc.ca.gov
Site of the California Building Standards Commission. Provides information regarding the status of the building codes being considered for future approval in California.

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 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 by the National Academy of Sciences (1988) is "a fault that on the basis of historical, seismological, or geological evidence has the finite probability of producing an earthquake." The American Geological Institute (1972) defines an active fault as one along which there is recurrent movement, usually indicated by small, periodic displacements or seismic activity.

Acute – Quick, one-time exposure to a chemical.

Adjacent grade – Elevation of the natural or graded ground surface, or structural fill, abutting the walls of a building.

Aftershocks – Minor earthquakes following a greater one and originating at or near the same location.

Aggradation – The building up of earth's surface by deposition of sediment.

Alluvial – Pertaining to, or composed, of alluvium, or deposited by a stream or running water.

Alluvial fan – A low, outspread relatively flat to gently sloping surface consisting of loose sediment that is shaped like an open fan, deposited by a stream at the place where the stream comes out of a narrow canyon onto a broad valley or plain. Alluvial fans are steepest near the mouth of the canyon, and spread out, gradually decreasing in gradient, away from the stream source.

Alluvium – Surficial sediments of poorly consolidated gravels, sand, silts, and clays deposited by flowing water.

Amplitude – The height of a wave between its crest (high point) and its mid-point.

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.

Apparatus – Fire apparatus includes firefighting vehicles of various types.

Aquifer – A body of rock or sediment that contains sufficient saturated permeable material to allow the flow of ground water and to yield economically significant quantities of ground water to wells and springs.

Argillic – Alteration in which certain minerals of a rock or sediments are converted to clay. Also said of a soil horizon characterized by the illuvial accumulation of clay.

Armor – To protect slopes from *erosion* and *scour* by *flood* waters. Techniques of armoring include the use of riprap, gabions, or concrete.

Arsenic – A naturally occurring, toxic element that occurs in rocks, soils and groundwater. Above certain concentrations, it can cause skin, bladder and other cancers.

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 referred to as a "flowing" **artesian** well.

Aspect – The direction a slope faces.

Atmospheric river – Narrow streams of water vapor transported in the lower atmosphere that are thought responsible for most of the storms on the west coast of the United States.

Attenuation – The reduction in amplitude of a wave with time or distance traveled.

Automatic aid agreement – An agreement between two or more agencies whereby such agencies are automatically dispatched simultaneously to predetermined types of emergencies in predetermined areas.

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).

Basalt – Dark, fine-grained volcanic rock consisting primarily of plagioclase, pyroxene and olivine, with less than 20% quartz, that formed from rapid cooling of lava exposed at or near the ground surface (extrusive).

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*.)

Beaufort Scale – A scale devised in 1805 by Admiral Francis Beaufort of the British Navy to classify wind speed based on the wind's effect on the seas and vegetation. The scale goes from 0 (calm) to 12 (hurricane).

Bedding – The arrangement of a sedimentary rock or deposit 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. A bench is also a long, narrow, relatively level or gently inclined platform of land or rock bounded by steeper slopes above and below.

Bioregion – A major, regional ecological community characterized by distinctive life forms and distinctive plant and animal species.

Biotite – A general term to designate all ferromagnesian micas. More specifically, biotite is a widely distributed and important rock-forming mineral that is usually black, brown or dark green, and that is an original constituent of igneous and metamorphic rocks, or a detrital constituent of sedimentary rocks.

Blind thrust fault – A thrust fault is a low-angle reverse fault (where the top block is being or has been pushed over the bottom block). A "blind" thrust fault refers to one that does not reach the surface.

Braided stream – A stream that divides into or follows an interlacing or tangled network of several, small, branching and reuniting shallow channels separated from each other by channel bars. Also referred to as an **anastomosing** stream.

Brush – A collective term that refers to stands of vegetation dominated by shrubby, woody plants, or low-growing trees.

Brushfire – A fire burning in vegetation that is predominantly shrubs, brush, and scrub growth.

Building code – Regulations adopted by local governments that establish standards for construction, modification, and repair of buildings and other structures.

Carcinogen – Material capable of causing cancer in humans.

Cast-in-place concrete – Concrete that is poured and formed at the construction site.

CEQA – The California Environmental Quality Act (Chapters 1 through 6 of Division 13 of the Public Resources Code). A state statute that requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible.

Chronic – Continual or repeated exposure to a hazardous material.

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 inch). Term is commonly applied to any soft, adhesive, fine-grained deposit.

Climate – The average condition of weather over time in a given region.

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.

Coliform – A group of rod-shaped bacteria that are found in water, soil, and on vegetation, and are present in large numbers in the feces of warm-blooded animals. The coliform count is used as an indicator of the sanitary conditions of foods and water. Most genera of coliform are not harmful to humans, but a few kinds, including some strains of Escherichia coli (E. coli) can be debilitating to sensitive individuals, including children, seniors, and those with compromised immune systems.

Collapse – A relatively sudden change in the volume of a soil mass resulting in the local settlement of the ground surface, with the potential to cause significant damage to overlying structures. If due to strong ground shaking, the soil grains in the soil column are re-arranged by the shaking so that the pore space between grains is reduced and the grains become more tightly packed, resulting in the overall reduction of the thickness of the soil column. This is referred to as earthquake-induced subsidence. Collapse can also occur in certain types of sediments, where with the introduction of water (due to an increase in irrigation, for example), the cement between soil grains dissolves, allowing the soil particles to become more tightly packed, again resulting in the local settlement of the ground surface. This process is also referred to as **hydro-collapse** or **hydroconsolidation**.

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.

Compressible soil – Geologically young unconsolidated sediment of low density that may compress under the weight of a proposed fill embankment or structure.

Community at Risk – Wildland interface community in the vicinity of Federal lands that is at high risk from wildfire.

Complex (Fire) –Two or more individual incidents located in the same general area and assigned to a single incident commander or unified command.

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.

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 about 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.

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 burning – Any fire originally set for the purpose of clearing land or for burning rubbish, garbage, range, stubble, or meadow burning.

Debris impact loads – Loads imposed on a structure by the impact of flood-borne debris. These loads are often sudden and large. Though difficult to predict, debris impact loads must be considered when structures are designed and constructed.

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.

Defensible space – An area, either natural or manmade, where material capable of causing a fire to spread has been treated, cleared, reduced, or changed in order to provide a barrier between an advancing wildland fire and the loss to life, property, or resources. In practice, defensible space is defined as an area with a minimum of 100 feet around a structure that is cleared of flammable brush or vegetation. Distance from the structure and the degree of fuels treatment vary with vegetation type, slope, density, and other factors.

Deflected canyons – A relatively spontaneous diversion in the trend of a stream or canyon caused by any number of processes, including folding and faulting.

Deformation - A general term for the process of folding, faulting, shearing, compression, or extension of rocks.

Design flood – The greater of either (1) the *base flood* or (2) the *flood* associated with the *flood hazard area* depicted on a community's flood hazard map, or otherwise legally designated.

Design Flood Elevation (DFE) – Elevation of the *design flood*, or the flood protection elevation required by a community, including wave effects, relative to the *National Geodetic Vertical Datum*, *North American Vertical Datum*, or other datum.

Development – Under the *National Flood Insurance Program*, any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations or storage of equipment or materials.

Differential settlement – Non-uniform settlement; the uneven lowering of different parts of an engineered structure, often resulting in damage to the structure. Sometimes included with liquefaction as ground failure phenomenon.

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.

Dispatch – The implementation of a command decision to move a resource or resources from one place to another.

Displacement - The length, measured in kilometers (km), of the total movement that has occurred along a fault over as long a time as the geologic record reveals.

DMA 2000 - Disaster Mitigation Act of 2000. Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended by Public Law 106-390, October 30, 2000. DMA 2000 is intended to establish a continuing means of assistance by the Federal Government to State and local governments in carrying out their responsibilities to alleviate the suffering and damage which result from disasters by (1) revising and broadening the scope of existing disaster relief programs; (2) encouraging the development of comprehensive disaster preparedness and assistance plans, programs, capabilities, and organizations by the States and by local governments; (3) achieving greater coordination and responsiveness of disaster preparedness and relief programs; (4) encouraging individuals, States, and local governments to protect themselves by obtaining insurance coverage to supplement or replace governmental assistance; (5) encouraging hazard mitigation measures to reduce losses from disasters, including development of land use and construction regulations; and (6) providing Federal assistance programs for both public and private losses sustained in disasters .

Dust storms – High wind events common in arid and semi-arid regions; strong winds pick up sand and other particulates and transport them by saltation and suspension to another location.

Dynamic analysis – A complex earthquake-resistant engineering design technique 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% 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*.

El Niño – Phenomenon that originates, every few years, typically in December or early January, in the southern Pacific Ocean, off of the western coast of South America, characterized by warmer than usual water. This warmer water is statistically linked with increased rainfall in both the southeastern and southwestern United States, droughts in Australia, western Africa and Indonesia, reduced number of earthquakes in the Atlantic Ocean, and increased number of hurricanes in the Eastern Pacific.

Emergency Planning and Community Right to Know (EPCRA) – The portion of SARA that specifically outlines how industries report chemical inventory to the community.

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.

Environmental Protection Agency (EPA) – Federal agency tasked with ensuring the protection of the environment and the nation's citizens.

Ephemeral stream – A stream or reach of a stream that flows only briefly in direct response to precipitation.

Epicenter – The point at the Earth's surface directly above where an earthquake originated.

Erodible soil – Soil subject to wearing away and movement due to the effects of wind, water, or other geological processes during a flood or storm or over a period of years.

Erosion – Under the *National Flood Insurance Program*, the process of the gradual wearing away of landmasses. In general, erosion involves the detachment and movement of soil and rock fragments, during a flood or storm or over a period of years, through the action of wind, water, or other geologic processes.

Erosion analysis – Analysis of the short- and long-term *erosion* potential of soil or strata, including the effects of wind action, *flooding* or *storm surge*, moving water, wave action, and the interaction of water and structural components.

Evacuation – Movement of people from an area, typically their homes, to another area considered to be safe, typically in response to a natural or man-made disaster that makes an area unsafe for people.

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.

Extremely hazardous substance – A substance that shows high acute or chronic toxicity, carcinogenity, bioaccumulative properties, is persistent in the environment, or is water reactive (California Code of Regulations, Title 22).

Fanglomerate – A sedimentary rock consisting of a heterogeneous mix of fragments of all sizes, originally deposited in an alluvial fan and subsequently cemented into a firm rock. Generally said of the coarser, consolidated rock material that occurs in the upper part of an alluvial fan.

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.

Fault strand – A fault that is mappable as a single, fairly continuous feature.

Federal Emergency Management Agency (FEMA) – Independent agency created in 1979 to provide a single point of accountability for all Federal activities related to disaster mitigation and emergency preparedness, response and recovery. FEMA administers the *National Flood Insurance Program*.

Federal Insurance Administration (FIA) – The component of the *Federal Emergency Management Agency* directly responsible for administering the flood insurance aspects of the *National Flood Insurance Program*.

Feldspar – The most widespread of any mineral group; constitutes ~60% of the earth's crust. Feldspars occur as components of all kinds of rocks and, on decomposition, yield a large part of the clay of a soil.

Fill – Material such as soil, gravel, or crushed stone placed in an area to increase ground elevations or change soil properties.

Fire behavior – The manner in which a fire reacts to the influences of fuel, weather and topography.

Fire flow – The flow rate of a water supply expressed in gallons per minute (gpm), measured at 20 pounds per square inch (psi) residual pressure, that is available for fire fighting.

Fire frequency – The number of fires occurring within a defined area in a given time period.

Fire regime – The long-term fire pattern characteristic of a region or ecosystem described using a combination of seasonality, fire return interval, size, spatial complexity, intensity, severity, and fire type.

Fire resistant – A characteristic of a plant species that allows individuals to resist damage or mortality during a fire. Also used to describe construction materials that resist damage to fire.

FIRESCOPE – **FI**refighting **RES**ources of **C**alifornia **O**rganized for **P**otential **E**mergencies. A cooperative effort involving all agencies with fire fighting responsibilities in California. The goal of this group is to create and implement new applications in fire service management, technology and coordination, with an emphasis on incident command and multi-agency coordination. This dynamic state-wide program serves the needs of California fire service management as an ongoing program.

First responders – A group designated by the community as those who may be first to arrive at the scene of a fire, accident, or chemical release.

Fire weather – The weather conditions that influence fire behavior, including air temperature, atmospheric moisture, atmospheric stability, clouds and precipitation.

Five-hundred (500)-year flood – *Flood* that has as 0.2% probability of being equaled or exceeded in any given year.

Flash flood – A local and sudden flood or torrent overflowing a stream channel in an usually dry valley, carrying an immense load of mud and rock fragments, and generally resulting from a rare and brief but heavy rainfall over a relatively small area having steep slopes.

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.

Floodway – 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.

Flow failure – A type of liquefaction-induced failure that generally occurs in slopes greater than 3 degrees, and that is characterized by the displacement, often over tens to hundreds of feet, of blocks of soil riding on top of the liquefied substrate.

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.

Frostbite – Injury, typically to the extremities, such as fingers and toes, caused by freezing body tissue.

Fuel – The source of heat that sustains the combustion process. In wildland fires, fuel is the combustible plant biomass, including grass, leaves, ground litter, shrubs, plants and trees.

Fuel load – The amount of fuel that is potentially available for combustion.

Fuel moisture – The moisture content expressed as a percentage of the dry weight of the fuel.

Fuel modification zone – 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.

Funnel clouds – Cone-shaped or needle-like clouds that extend down from the main cloud base but do not extend to the ground surface. If a funnel cloud touches the ground surface, it becomes a tornado.

Gabbro – A group of dark-colored, coarse-grained intrusive igneous rocks composed principally of plagioclase. These rocks cooled slowly, deep under the Earth's crust, allowing the minerals to form large crystals. The approximate intrusive equivalent of basalt.

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.

Gneiss – A metamorphic rock in which bands of granular minerals alternate with bands in which mineral have a flaky or prismatic habit, with less than 50 percent of the minerals showing preferred parallel orientation.

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 lurching – A form of earthquake-induced ground failure where soft, saturated soils move in a wave-like manner in response to intense seismic ground shaking, forming ridges or cracks at the surface.

Ground oscillations – A type of liquefaction-induced failure where liquefaction occurs at depth, in an area where the ground surface is too level to permit the lateral displacement of the overlying soil blocks. The blocks instead separate from one another and oscillate above the liquefied layer. This may result in the opening and closing of fissures or cracks, and the formation of sand boils or volcanoes.

Ground rupture – Displacement of the earth's surface as a result of fault movement associated with an earthquake.

Hail – Solid precipitation consisting of fragments of ice water called hailstones.

Hazardous material (HAZMAT) – Substance that has the ability to harm humans, property or the environment. The United States Environmental Protection Agency defines hazardous waste as substances that:

1) may cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness;
2) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed; and
3) whose characteristics can be measured by a standardized test or reasonably detected by generators of solid waste through their knowledge of their waste.

Hazardous waste is also ignitable, corrosive, or reactive (explosive) (EPA 40 CFR 260.10). A material may also be classified as hazardous if it contains defined amounts of toxic chemicals.

Hazardous Waste Operations and Emergency Response (HAZWOPER) – The Occupational Safety and Health Agency (OSHA) regulation that covers safety and health issues at hazardous waste sites and response to chemical incidents.

Hazard reduction – Any treatment of a hazard that reduces the threat of ignition and fire intensity or rate of spread.

Heat wave – Periods of excessive heat, typically exceeding 95 degrees Fahrenheit, often with high levels of humidity, and lasting more than three days.
Hexavalent chromium – Compounds that contain the element chromium in its +6 (hexa) oxidation state. These compounds are used extensively in several different industries; however, it is a known human carcinogen and thus its use is now regulated. Groundwater in many parts of the country has been contaminated with varying levels of hexavalent chromium.

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 (the past about 11,000 years).

Hornblende – The most common mineral of the amphibole group. It is a primary constituent in many intermediate igneous rocks.

Hydrocompaction – Settlement of loose, granular soils that occurs when the loose, dry structure of the sand grains held together by a clay binder or other cementing agent collapses upon the introduction of water.

Hydrodynamic loads – Loads imposed on an object, such as a building, by water flowing against and around it. Among these loads are positive frontal pressure against the structure, drag effect along the sides, and negative pressure on the downstream side.

Hydrostatic loads – Loads imposed on a surface, such as a wall or floor slab, by a standing mass of water. The water pressure increases with the square of the water depth.

Hypocenter – The earthquake focus, that is, the place at depth, along the fault plane, where an earthquake rupture started.

Hypothermia – Abnormally low body temperature (typically below 95 degrees Fahrenheit) that is accompanied by any of several signs, including uncontrollable shivering, disorientation, memory loss, slurred speech, drowsiness, and apparent exhaustion.

Igneous – Type of rock or mineral that formed from molten or partially molten magma.

Ignition point – The location of the ignition.

Ignition source – The origin or source of a fire.

Infiltration – The process by which water seeps into the soil, as influenced by soil texture, soil structure, and vegetation cover.

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.

Invasive plants – Plants that aggressively expand their ranges over the landscape, typically at the expense of native plants that are displaced or destroyed by the newcomers. Invasive species are typically considered a major threat to biological diversity.

ISO – Insurance Services Office. Private organization that formulates fire safety ratings based on fire threat and responsible agency's ability to respond to the threat. ISO ratings from one (excellent) to ten (no fire protection). Many insurance companies use ISO ratings to set insurance premiums. ISO may establish multiple ratings within a community, such as a rating of 5 in the hydranted areas and one of 8 in the non-hydranted areas.

Jet stream – A relatively narrow stream of fast-moving air in the middle and upper troposphere. Surface cyclones develop and move along the jet stream.

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.

Ladder fuels – Fuels that provide vertical continuity between strata, allowing fire to move from the surface fuels to the crowns of shrubs and trees with relative ease.

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.

Level-of-service standard (LOS standard) – Quantifiable measures against which services being delivered by a service provider can be compared. Standards based upon recognized and accepted professional and county standards, while reflecting the local situation within which services are being delivered. Levels-of-service standards for fire protection may include response times, personnel per given population, and emergency water supply. LOS standards can be used to evaluate the way in which fire protection services are being delivered, for use in countywide fire planning efforts.

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.

Litter – Recently fallen plant material that is only partially decomposed, forming a surface layer on some soils.

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.

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.

Local Responsibility Area (LRA) – Lands in which the financial responsibility of preventing and suppressing fires is primarily the responsibility of the local jurisdiction.

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.

Macroburst – A strong downdraft over 2.5 miles in diameter that can cause damaging winds lasting 5 to 20 minutes. Formed by an area of significantly rain-cooled air that after hitting ground levels spreads out in all directions.

Magnitude – A measure of the size of an earthquake, as determined by measurements from seismograph records. Also refers to both a fire's intensity and severity.

Main shock – The biggest earthquake of a sequence of earthquakes that occur fairly close in time and space. Smaller shocks before the main shock are called **foreshocks**; smaller shocks that occur after the main shock are called **aftershocks**.

Major earthquake – Capable of widespread, heavy damage up to 50+ miles from epicenter; generally near Magnitude range 6.5 to 7.0 or greater, but can be less, depending on rupture mechanism, depth of earthquake, location relative to urban centers, etc.

Manufactured home – Under the *National Flood Insurance Program*, a *structure*, transportable in one or more sections, which is built on a permanent chassis and is designed for use with or without a permanent foundation when attached to the required utilities. The term "manufactured home" does not include a "recreational vehicle."

Masonry – Built-up construction of combination of building units or materials of clay, shale, concrete, glass, gypsum, stone, or other approved units bonded together with or without mortar or grout or other accepted methods of joining.

Mass casualty – Incident in which the number of victims exceeds the capability of the emergency management system to manage the incident effectively.

Material Safety Data Sheets (MSDS) – Information sheets for employees that provide specific information about a chemical that they may come in contact at their place of work, with attention to health effects, handling, and emergency procedures.

Maximum Considered Earthquake (MCE) – Starting with the 2006 International Building Code, a probabilistic analysis used for seismic design that calculates the earthquake size that would generate ground motions with a 2% probability of being exceeded in 50 years (approximately equivalent to a 2,500-year return period).

Maximum Contaminant Level (MCL) – Federal drinking water standard: "the maximum permissible level of a contaminant in water which is delivered to any user of a public water system" (Code of Federal Regulations [CFR], Title 40, Part 141.2).

Maximum Magnitude Earthquake (M_{max}) – 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.

Mediterranean climate – The climate characteristic of the Mediterranean region and most of California, characterized by hot, dry summers, and cool, wet winters.

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*.

Microburst – A very localized zone of sinking air, less than 2.5 miles in diameter, producing damaging, straight-line, divergent winds at or near the ground surface lasting 2 to 5 minutes.

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.

Modified Mercalli Intensity – A qualitative measure of the size of an earthquake based on people's description of how strongly the earthquake was felt, and the damage it caused to the built environment. The scale has 12 divisions, ranging from I (felt by only a very few people) to XII (total damage).

Moment magnitude (seismic moment, M_w) – A measure of earthquake size that is based on the amount of energy released when a fault ruptures. Considered the most meaningful and thus preferred measure of earthquake size.

Monsoon – A seasonal reversing wind that is accompanied by precipitation. In North America, the monsoon occurs between late June and early September; starts in Mexico and spreads northward into Arizona, New Mexico, West Texas, Nevada, Utah, Colorado and eastern California.

Mutual Aid Agreement – A reciprocal aid agreement between two or more agencies that defines what resources each will provide to the other in response to certain predetermined types of emergencies. Mutual aid response is provided upon request.

National Fire Protection Association (NFPA) – A group that issues fire and safety standards for industry and emergency responders.

National Fire Incident Reporting System (NFIRS) – A database of fire incident reports compiled at the local fire department level. NFIRS was an outgrowth of the 1974 National Fire Prevention and Control Act, Public Law 93–498. The U.S. Fire Administration (USFA), an entity of the Department of Homeland Security, developed NFIRS as a means of assessing the nature and scope of the fire problem in the United States.

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*.

Natural Attenuation – Reduction in mass or concentration of a compound in groundwater over time or distance from the source of constituents of concern due to naturally occurring physical, chemical, and biological processes, such as biodegradation, dispersion, dilution, adsorption, and volatilization. (American Society for Testing and Materials, 2003).

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.

Nitrite and nitrate – Nitrogen-oxygen combinations that occur in several organic and inorganic compounds. High concentrations of nitrites in drinking water can pose serious health hazards, especially to infants.

Non-coastal A zone – The portion of the *Special Flood Hazard Area* in which the principal source of *flooding* is runoff from rainfall, snowmelt, or a combination of both. In non-coastal A zones, *flood* waters may move slowly or rapidly, but waves are usually not a significant threat to buildings. See *A zone* and *coastal A zone*. (Note: the *National Flood Insurance Program* regulations do not differentiate between non-coastal A zones and *coastal A zones*.)

Non-load-bearing wall – Wall that does not support vertical loads other than its own weight. See *Load-bearing wall*.

North American Vertical Datum (NAVD) – Datum used as a basis for measuring flood, ground, and structural elevations. NAVD is used in many recent *Flood Insurance Studies* rather than the *National Geodetic Vertical Datum*.

Oblique-reverse fault – A fault that combines some strike-slip motion with some dip-slip motion in which the upper block, above the fault plane, moves up over the lower block.

Offset ridge – A ridge that is discontinuous on account of faulting.

Offset stream – A stream displaced laterally or vertically by faulting.

One hundred (100)-year flood – See *Base flood*.

Orthoclase – One of the most common rock-forming minerals; colorless, white, cream-yellow, flesh-reddish, or grayish in color.

Paleoseismic – Pertaining to an earthquake that happened decades, centuries, or millennia ago.

Peak flood – The highest discharge or stage value of a flood.

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 that are 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.

Perennial stream – A stream that flows continuously throughout the year.

Perchlorates – Negatively charged molecules highly persistent in the environment that can displace the iodide molecule in the thyroid gland, leading to hypothyroidism in adults, and impaired development in infants.

Plagioclase – One of the most common rock forming minerals.

Playa – Term used in the Southwestern US to describe a flat-floored, typically unvegetated area composed of thin, stratified sheets of fine clay, silt or sand that represent the bottom or central part of a shallow, completely closed or undrained desert lake basin where water accumulates after a rainstorm and quickly evaporates, leaving behind deposits of soluble salts.

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 – According to the Alquist-Priolo Earthquake Fault Zone Act guidelines, a fault showing evidence of movement within the last 1.6 million years but that has not been shown conclusively whether or not it has ruptured in the past about 11,000 years ago. The U.S. Geological Survey considers a fault potentially active if it has moved in the time period between about 11,000 years ago (the Holocene) and 750,000 years ago, and that is thought capable of generating damaging earthquakes.

Precast concrete – Structural concrete element cast elsewhere than its final position in the structure. See *Cast-in-place concrete*.

Prescribed fire – A fire ignited under known conditions of fuel, weather, and topography to achieve specific objectives.

Primary fault rupture - Fissuring and displacement of the ground surface along a fault that breaks in an earthquake.

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 approximately 1.6 to 2 million years.

Rain shadow – A reduction in precipitation in an area on the leeward side of a mountain or range of mountains, caused by the release of moisture on the windward side.

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.

Remote shutoff – Valve that can be used to shut off the flow of a substance or chemical from a location away from the spill or break.

Reportable quantity – A term used by the EPA and the Department of Transportation (DOT) to denote a quantity of chemicals that require some kind of action, such as reporting an inventory or reporting an accident involving a certain amount of chemicals.

Response spectra – The range of potentially damaging frequencies of a given earthquake applied to a specific site and for a particular building or structure.

Response Time – The time that elapses between the moment a 911 call is placed to the emergency dispatch center and the time that a first-responder arrives on scene. Response time includes dispatch time, turnout time (the time it takes firefighters to travel to the fire station, don their personal protection equipment, and prepare the apparatus), and travel time.

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.

Rhyolite – A group of extrusive igneous rocks, generally exhibiting flow texture, with large crystals (phenocrysts) of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass. The approximate extrusive equivalent of granite.

Ridgetop shattering – An earthquake-induced type of ground failure that occurs along at or along the top of ridges, forming linear, fault-like fissures, and leaving the area looking like it was plowed.

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.

Rockfall – Free-falling to tumbling mass of bedrock that has broken off steep canyon walls or cliffs.

Sand boil – An accumulation of sand resembling a miniature volcano or low volcanic mound produced by the expulsion of liquefied sand to the sediment surface. Also called sand blows, and sand volcanoes.

Sandstone – A medium-grained, clastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in a fine-grained matrix and more or less firmly united by a cementing material.

Santa Ana (or Santana) wind – Strong, typically extremely dry offshore winds that characteristically blow through southern California and northern Baja California in late fall and winter. They typically originate in the Great Basin or upper Mojave Desert, and can be either hot or cold. The winds tend to funnel down the valleys and canyons, where gusts can attain speeds of 60 to 90 miles per hour (mph). Several devastating wildfires in southern California have been associated with Santa Ana winds.

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*.

Secondary fault rupture - Ground surface displacements along faults other than the main traces of active regional faults.

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.

Sedimentary rock – Type of rock composed of material deposited at the Earth's surface or at the bottom of bodies of water by the actions of water, wind, gravity, or ice. Sedimentary rocks generally differ from sediment in that the individual particles have been partially or fully cemented together by clay, silica, calcium carbonate or some other material, giving the rock strength.

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.

Seismic Moment – A measure of the size of an earthquake that is associated with the amount of energy released (the force that was necessary to overcome the friction along the fault plane), the area of the fault rupture, and the average amount of slip.

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.

Sheet flow – An overland flow or downslope movement of water taking the form of a thin, continuous film over relatively smooth soil or rocks surfaces and not concentrated into channels larger than rills.

Shutter ridge – That portion of an offset ridge that blocks or "shutters" the adjacent canyon.

Sidehill fill – A wedge of artificial fill typically placed on the side of a natural slope to create a roadway or a level building pad.

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.

Slip Rate – The speed at which a fault is moving, typically expressed in millimeters per year (mm/yr), and generally estimated by measuring the amount of offset that has occurred in a given, known amount of time.

Slope creep – Deformation and movement of the outer soil or rock that cover a slope due to the forces of gravity overcoming the shear strength of the material.

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.

Soft-story building – Building with a story, generally the ground or first floor, lacking adequate strength or toughness due to too few shear walls. Examples of this type of structure include apartments above glass-fronted stores, and buildings perched atop parking garages.

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.

Spot fire – Ignition resulting from embers from the fireline transported aerially in front of the fireline and often increasing fire spread.

Standardized Emergency Management System (SEMS) – (Government Code § 8607). The group of principles developed for coordinating state and local emergency response in California. SEMS provides for organization of a multiple-level emergency response, and is intended to structure and facilitate the flow of emergency information and resources within and between the organizational levels--the field response, local government, operational areas, regions and the state management level. SEMS incorporates by reference: the Incident Command System (ICS); multi-agency or inter-agency coordination; the State's Mutual Aid Program; and Operational Areas.

State Responsibility Area (LRA) – Per California Public Resources Code 4125-4127, the lands in which the State has primary financial responsibility for preventing and suppressing fires.

Storage capacity – Dam storage measured in acre-feet or decameters, including dead storage.

Strike-slip fault – A fault with a vertical to sub-vertical fault surface that displays evidence of horizontal and opposite displacement.

Structural concrete – All concrete used for structural purposes, including *plain concrete* and *reinforced concrete*.

Structural engineer – A licensed civil engineer certified by the State as qualified to design and supervise the construction of engineered structures.

Structural fill – Fill compacted to a specified density to provide structural support or protection to a *structure*. See *Fill*.

Structure – Something constructed, such as a building, or part of one. For *floodplain management* purposes under the *National flood Insurance Program*, a walled and roofed building, including a gas or liquid storage tank, that is principally above ground, as well as a manufactured home. For insurance coverage purposes under the NFIP, structure means a walled and roofed building, other than a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a *manufactured home* on a permanent foundation. For the latter purpose, the term includes a building while in the course of construction, alteration, or repair, but does not include building materials or supplies intended for use in such construction, alteration, or repair, unless such materials or supplies are within an enclosed building on the premises.

Subsidence – The sudden sinking or gradual downward settling of the Earth's surface with little or no horizontal motion.

Superfund Amendments and Reauthorization Act (SARA) – Law that regulates a number of environmental issues, predominantly for the chemical inventory reporting by industry to the local community.

Surficial failure – Type of slope failure that impacts the near-surface soil and weathered rock face, typically in response to the effects of gravity and precipitation.

Swale – In hillside terrace, a shallow drainage channel, typically with a rounded depression or "hollow" at the head.

Talus – The cone-shaped accumulation of angular fragments of rock or soil at the base of a cliff that has experienced rockfalls.

Target fire hazard – A facility or structure within a fire department's jurisdiction that if it caught fire, it could overwhelm the fire department's fire response capabilities. Target hazards typically include industrial buildings, facilities that use, store or manufacture hazardous materials, high-occupancy facilities, and structures that house sensitive populations, like schools and hospitals.

Tectonic plate – Any of several large pieces, or blocks, of the Earth's lithosphere that are slowly moving relative to each other as part of the process called plate tectonics.

Thrust fault – A fault, with a relatively shallow dip, in which the upper block, above the fault plane, moves up over the lower block.

Thunderstorm – A weather condition that develops when warm, moist air meets a cold front, producing strong winds, and sometimes tornadoes and hail.

Tornado – A localized but violently destructive windstorm occurring over land (at sea it is called a waterspout) characterized by a funnel-shaped cloud extending toward the ground.

Transform system – A system in which faults of plate-boundary dimensions transform into another plate-boundary structure when it ends.

Transpression – In crustal deformation, an intermediate stage between compression and strike-slip motion; it occurs in zones with oblique compression.

Tsunami – Great sea wave produced by submarine earth movement, volcanic eruption, oceanic meteor impact, or underwater nuclear explosion.

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.

Underground Storage Tank (UST) – Tank, commonly used to store gasoline, diesel or other chemical, that is buried under the ground.

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.

Unreinforced Masonry (URM) structure – Building without adequate anchorage of the masonry walls to the roof and floor diaphragms and lack of steel reinforcement, of limited strength and ductility, and as a result, that tends to perform poorly when shaken during an earthquake.

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.

Urban-wildland interface area (UWI) – The area where wildland approaches or interfaces with the urban environment. Important in fire hazard studies where wildland fires have the potential to impact the built environment.

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 river or lake.

Waterspout – Tornado that forms over warm water.

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.

Water year – The 12-month period from October 1 through September 30 of the following year.

Weather – The short-term state of the air or atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness, or any other meteorologic phenomena.

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.