3.7 GEOLOGY AND SOILS

This section of the Program Environmental Impact Report (PEIR) describes geology and soils in the SCAG region, discusses the potential impacts of the proposed 2016 Regional Transportation Plan/Sustainable Communities Strategy ("2016 RTP/SCS," "Project," or "Plan") related to hazards to people or property from geology and soils, identifies mitigation measures for the impacts, and evaluates the residual impacts. The potential for hazards to people and property from geology and soils were evaluated in accordance with Appendix G of the 2015 State California Environmental Quality Act (CEQA) Guidelines. Geology and soils within the SCAG region were evaluated at the programmatic level of detail, in relation to the general plans of the six counties and the 191 cities within the SCAG region, review of general information characterizing geology and soils from the Dibblee Maps and maps of Alquist-Priolo zones and mapping of seismic zones and movement that has occurred along mapped earthquake faults, review of published and unpublished literature germane to the SCAG region, and review of SCAG's 2012 RTP/SCS PEIR.[1]

The geology and soils of the SCAG region were defined by major forces that continue to shape the physical environment, including mountain building, faulting, erosion, deposition, and volcanic activity. These events occur both gradually and in potentially catastrophic episodes. The region that is now Southern California slowly "assembled" over a billion years from older materials recycled through the lithosphere (Earth's crust and mantle) or accumulated from precipitation and biological activity in the oceans, or carried in as ash and dust in the atmosphere.[2] Tectonic forces and volcanism built up the landscape, and sediments eroded and deposited along the margin of the North American continent, later to be uplifted and recycled over again. Much of the continental crust that is now southern California was derived or recycled from crust that formed beneath the Pacific Ocean region and later subducted or accreted onto the margin of the North American continent.

Definitions

Alluvium: An unconsolidated accumulation of stream deposited sediments, including sands, silts, clays or gravels.

Extrusive Igneous Rocks: Rocks that crystallize from molten magma on earth's surface.

Fault: A fracture or fracture zone in rock along which movement has occurred.

Formation: A laterally continuous rock unit with a distinctive set of characteristics that make it possible to recognize and map from one outcrop or well to another. The basic rock unit of stratigraphy.

Holocene: An interval of time relating to, or denoting the present epoch, which is the second epoch in the Quaternary period, from approximately 11,000 years ago to the present time.

1 Southern California Association of Governments. April 2012. *Final Program Environmental Report: 2012-2035 Regional Transportation Plan/Sustainable Communities Strategy*. Available at: http://rtpscs.scag.ca.gov/Pages/Final-2012-PEIR.aspx

2 U.S. Geological Survey. Accessed 7 September 2015. *Geologic History of Southern California*. Available at: http://geomaps.wr.usgs.gov/archive/socal/geology/geologic_history/index.html

Liquefaction: The process by which water-saturated sandy soil materials lose strength and become susceptible to failure during strong ground shaking in an earthquake. The shaking causes the pore-water pressure in the soil to increase, thus transforming the soil from a stable solid to a more liquid form.

Miocene: An interval of time relating to, or denoting the fourth epoch of the Tertiary period, between the Oligocene and Pliocene epochs, from approximately 23 to 5.5 million years ago.

Oligocene: An interval of time relating to, or denoting the third epoch of the Tertiary period, between the Eocene and Miocene epochs, from approximately 34 to 23 million years ago.

Outcrop: A rock formation that is visible on earth's surface.

Paleocene: An interval of time, relating to, or denoting the earliest epoch of the Tertiary period, between the Cretaceous period and the Eocene epoch.

Paleozoic: An interval of time relating to, or denoting the era between the Precambrian eon and the Mesozoic era.

Pleistocene: An interval of time relating to, or denoting the first epoch of the Quaternary period, between the Pliocene and Holocene epochs, from approximately 2.6 million years ago to 11,000 years ago.

Pliocene: An interval of time relating to, or denoting the last epoch of the Tertiary period, between the Miocene and Pleistocene epochs, from approximately 5.5 to 2.6 million years ago.

Plutonic Igneous Rocks: Igneous rocks that have crystallized beneath the earth's surface.

Pore water pressure: Refers to the pressure of groundwater held within a soil or rock, in gaps between particles (pores).

Quaternary: The most recent period in geological time; includes the Pleistocene and Holocene Epochs.

3.7.1 REGULATORY FRAMEWORK

Federal

Earthquake Hazards Reduction Act

The Earthquake Hazards Reduction Act of 1977 (Public Law 95-124) established the National Earthquake Hazards Reduction Program which is coordinated through the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), the National Science Foundation, and the National Institute of Standards and Technology. The purpose of the Program is to establish measures for earthquake hazards reduction and promote the adoption of earthquake hazards reduction measures by federal, state, and local governments; national standards and model code organizations; architects and engineers; building owners; and others with a role in planning and constructing buildings, structures, and lifelines through (1) grants, contracts, cooperative agreements, and technical assistance; (2) development of standards, guidelines, and voluntary consensus codes for earthquake hazards reduction for buildings, structures, and lifelines; and (3) development and maintenance of a repository of information, including technical data, on seismic risk and hazards reduction. The Program is intended to improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines through interdisciplinary research that involves engineering, natural sciences, and social, economic, and decisions sciences.

Disaster Mitigation Act (2000)

The federal Disaster Mitigation Act (DMA; Public Law 106-390) provides the legal basis for FEMA mitigation planning requirements for state, local, and Indian Tribal governments as a condition of mitigation grant assistance. DMA 2000 amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act by repealing the previous mitigation planning provisions and replacing them with a new set of requirements that emphasize the need for state, local, and Indian Tribal entities to closely coordinate mitigation planning and implementation efforts. The requirement for a state mitigation plan is continued as a condition of disaster assistance, adding incentives for increased coordination and integration of mitigation activities at the state level through the establishment of requirements for two different levels of state plans. DMA 2000 also established a new requirement for local mitigation plans and authorized up to 7 percent of Hazard Mitigation Grand Program funds available to a state for development of state, local, and Indian Tribal mitigation plans.

Uniform Building Code (UBC)

The UBC is published by the International Conference of Building Officials and forms the basis for California's building code, as well as approximately half of the state building codes in the United States. It has been adopted by the California Legislature to address the specific building conditions and structural requirements for California, as well as provide guidance on foundation design and structural engineering for different soil types. The UBC defines and ranks the regions of the United States according to their seismic hazard potential. There are four types of regions defined by Seismic Zones 1 through 4, with Zone 1 having the least seismic potential and Zone 4 having the highest.

U.S. Geological Survey Landslide Hazard Program

The USGS Landslide Hazard Program provides information on landslide hazards including information on current landslides, landslide reporting, real time monitoring of landslide areas, mapping of landslides through the National Landslide Hazards Map, local landslide information, landslide education, and research.

Farmland Protection Program (1996)

The Farmland Protection Program was enacted in 1996, directing the Secretary of Agriculture to establish and carry out a farmland protection program under which the Secretary shall purchase conservation easements or other interests in not less than 170,000, nor more than 340,000, acres of land with prime, unique, or other productive soil that is subject to a pending offer from a state or local government for the purpose of protecting topsoil by limiting nonagricultural uses of the land. The Natural Resources Conservation Service (NRCS) maps soils and farmland uses to provide comprehensive information necessary for understanding, managing, conserving and sustaining the nation's limited soil resources. In addition to many other natural resource conservation programs, the NRCS manages the Farmland Protection Program, which provides funds to help purchase development rights to keep productive farmland in agricultural uses. Working through existing programs, the United States Department of Agriculture (USDA) joins with state, tribal, and local governments to acquire conservation easements or other interests from landowners.

State

Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act)

The Alquist-Priolo Act (California Code of Regulations, Section 3603(f)) provides policies and criteria to assist cities, counties, and state agencies in the development of structures for human occupancy across the trace of active faults. The Alquist-Priolo Act was intended to provide the citizens of the state with increased safety and to minimize the loss of life during and immediately following earthquakes by facilitating seismic retrofitting to strengthen buildings, including historical buildings, against ground shaking.

Alquist-Priolo Special Study Zones

The Alquist-Priolo Act requires that special geologic studies be conducted to locate and assess any active fault traces in and around known active fault areas prior to development of structures for human occupancy. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. The Alquist-Priolo Act's main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. This Act addresses only the hazard of surface fault rupture and is not directed toward other earthquake hazards.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 (Public Resources Code, Chapter 7.8, Sections 2690–2699.6) addresses non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Act.

California Building Code

The California Building Code is another name for the body of regulations contained in Title 24, Part 2, of the California Code of Regulations (CCR), which is a portion of the California Building Standards Code (CBSC; 1995). Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable. Published by the International Conference of Building Officials, the UBC is a widely adopted model building code in the United States. The California Building Code incorporates by reference the UBC with necessary California amendments. Approximately one-third of the text within the California Building Code has been tailored for California earthquake conditions. Although widely accepted and implemented throughout the state, local jurisdictions can adopt the UBC either in whole or in part.

California Department of Transportation (Caltrans) Regulations

Caltrans' jurisdiction includes rights-of-way (ROWs) of state and interstate routes within California. Any work within the ROW of a federal or state transportation corridor is subject to Caltrans' regulations governing allowable actions and modifications to the ROW. Caltrans issues permits to encroach on land within their jurisdiction to ensure encroachment is compatible with the primary uses of the State Highway System, to ensure safety, and to protect the state's investment in the highway facility. The encroachment permit requirement applies to persons, corporations, cities, counties, utilities, and other government agencies. A permit is required for specific activities including opening or excavating a state highway for any purpose, constructing, or maintaining road approaches or connections, grading within rights-of-way on any state highway, or planting or tampering with vegetation growing along any state highway. The encroachment permit application requirements relating to geology, seismicity and soils include information on road cuts, excavation size, engineering and grading cross-sections, hydraulic calculations, and mineral resources approved under Surface Mining Area Reclamation Act (SMARA).

Caltrans Seismic Design Criteria

Caltrans Seismic Design Criteria was initiated through the recognition that past earthquakes in California have shown the vulnerability of some older structures, designed with non-ductile design standards to earthquake-induced force sand deformations. As a result, Caltrans initiated an extensive seismic retrofit program to strengthen the state's inventory of bridges to ensure satisfactory performance during anticipated future earthquakes. Caltrans has funded an extensive research program as well as developed design procedures that have furthered the state of practice of earthquake bridge engineering. The Seismic Design Criteria (SDC) are an encyclopedia of new and currently practiced seismic design and analysis methodologies for the design of new bridges in California. The SDC adopts a performance-based approach specifying minimum levels of structural system performance, component performance, analysis, and design practices for ordinary standard bridges. Bridges with non-standard features or operational requirements above and beyond the ordinary standard bridge may require a greater degree of attention than specified by the SDC.

Southern California Catastrophic Earthquake Preparedness Plan

The Southern California Catastrophic Earthquake Preparedness Plan, adopted in 2008, examines the initial impacts, inventories resources, cares for those wounded and homeless and develops a long-term recovery process. The process of Long-Term Regional Recovery (LTRR) provides a mechanism for coordinating federal support to state, tribal, regional, and local governments, nongovernmental organizations (NGOs), and the private sector to enable recovery from long-term consequences of extraordinary disasters. The LTRR process accomplishes this by identifying and facilitating the availability and use of recovery funding sources, and providing technical assistance (such as impact analysis) for recovery and recovery planning support. "Long term" refers to the need to reestablish a healthy, functioning region that would sustain itself over time. Long-term recovery is not debris removal and restoration of utilities, which are considered immediate or short-term recovery actions. The LTRR's three main focus areas are housing, infrastructure (including transportation), and economic development.

Local

County and City General Plans

A safety element is required in county and city general plans for the protection of the community from any unreasonable risks associated with the effects of seismically induced surface rupture, ground shaking, ground failure, tsunami, seiche, and dam failure; slope instability leading to mudslides and landslides; subsidence; liquefaction; and other seismic hazards identified in Division 2 of the Public Resources Code, and other geologic hazards known to the legislative body. The safety element shall include mapping of known seismic and other geologic hazards (Government Code Section 65302 (g)). As part of the safety element, county and city governments typically identify goals, objectives, and implementing actions to minimize the loss of life, property damage, and disruption of goods and services from man-made and natural disasters including floods, fires, non-seismic geologic hazards, and earthquakes. County and City governments may provide policies and develop ordinances to ensure acceptable protection of people and structures from risks associated with these hazards. Ordinances may include those addressing unreinforced masonry construction, erosion, or grading.

3.7.2 EXISTING CONDITIONS

Geologic hazards are natural geologic events that can endanger human lives and threaten property. Potential geologic hazards include rupture of a known earthquake fault, seismic ground shaking, seismic ground failure including liquefaction, and landslides. Other hazards in relation to geology and soils include soil erosion or loss of topsoil, and development of structures and buildings in locations with geologic units or soils that are unstable or expansive soils. Similarly, not all areas within the SCAG region are served by sewer systems or have soils that are capable of adequately supporting septic tanks or alternative waste water disposal systems.

Topographic and Geologic Structures

The SCAG region extends primarily over four[3] California geomorphic provinces: the Mojave Desert, the Transverse Ranges, the Peninsular Ranges, and the Colorado Desert.[4] These provinces are naturally defined geologic regions that display a distinct landscape or landform (**Figure 3.7.2-1, *Geomorphic Provinces***).

Mojave Desert

The Mojave Desert geomorphic province occupies approximately 25,000 square miles. It is a broad interior region of isolated mountain ranges separated by expanses of desert. There are two important fault trends that control topography a prominent northwest-southeast trend and a secondary east-west

3 A small sliver of the northwest corner of San Bernardino County is located in the Basin and Range province, and a small area in northern Ventura County is located in the Southern Coastal Ranges province.

4 California Geological Survey. 2002. *California Geomorphic Provinces*. Sacramento, CA.

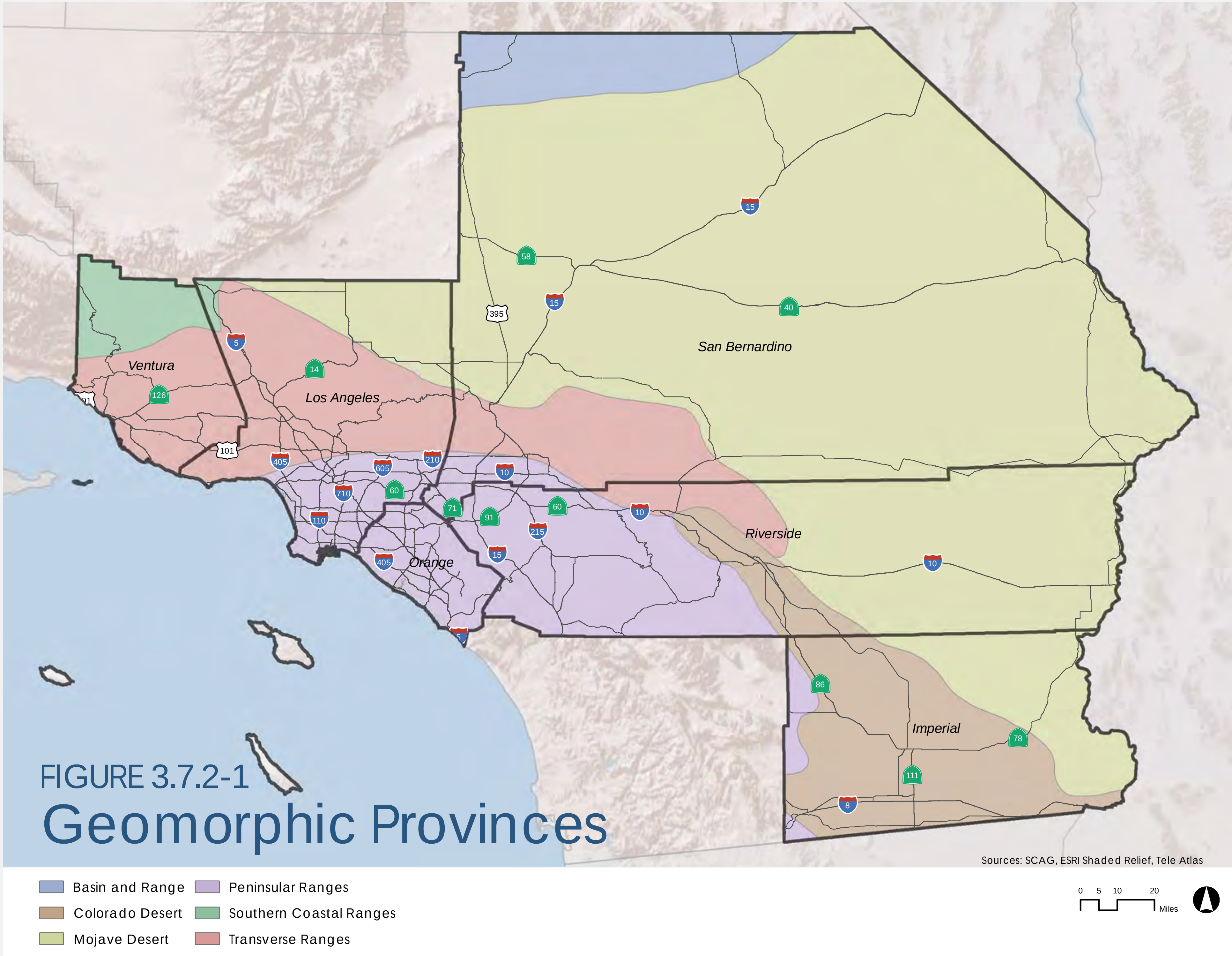

FIGURE 3.7.2-1

Geomorphic Provinces

Q:\1315\SCAG\ArcProjects\GeomorphicProvinces.mxd | Date: 10/14/2015 trend. The Mojave province is wedged in a sharp angle between the Garlock Fault to the north (southern boundary Sierra Nevada) and the San Andreas Fault to the west (where it bends east from its northwest trend). The Nevada state line defines its eastern boundary, and the San Bernardino/Riverside county line defines its southern boundary. Portions of Los Angeles and San Bernardino Counties lie within this province.

Erosional features such as broad alluvial basins that receive non-marine sediments from the adjacent uplands dominate the Mojave Desert region. Numerous playas, or ephemeral lakebeds within internal drainage basins, also characterize the region. Throughout this province, small hills—some the remnants of ancient mountainous topography—rise above the valleys that are surrounded by younger alluvial sediments. The highest elevation approaches 4,000 feet above mean sea level (MSL), and most valleys lie between 2,000 to 4,000 feet above MSL.

Transverse Ranges

The Transverse Ranges are an east-west trending series of steep mountain ranges and broad alluvial valleys that extends approximately 320 miles from Point Arguello in the west to the Little San Bernardino Mountains in the east. The east-west structure of the Transverse Ranges is oblique to the normal northwest trend of coastal California, hence the name “Transverse.” This geomorphic province includes Ventura County and portions of Los Angeles, San Bernardino, and Riverside Counties. It also extends offshore to include San Miguel, Santa Rosa, and Santa Cruz islands.

There is intense north-south compression squeezing the Transverse Ranges and resulting in the prominent basins and ranges found in this province, including the Ventura Basin and the San Gabriel and San Bernardino Mountains. This is one of the most rapidly rising regions on earth. Several active faults, such as the San Andreas Fault Zone, are located in the Transverse Ranges. Other faults in the province include the Santa Clara River Valley Fault, the San Gabriel Fault Zone, the Santa Cruz Island Faults, the Santa Rosa Island Faults, and the Soledad Faults. This province is one of the most geologically diverse in California, containing a wide variety of bedrock types and structures. California’s highest peaks south of the central Sierra Nevada and the only Paleozoic rocks in the coastal mountains in the United States are found here. Because of the great lithological diversity, the province is further subdivided into eight subprovinces, each displaying its own geologic signature. Broad alleviated valleys, narrow stream canyons, and prominent faults separate these subprovinces.

Peninsular Ranges

The Peninsular Ranges province consists of a series of ranges separated by northwest trending valleys, subparallel to faults branching from the San Andreas Fault. This province is bounded on the northwest by the Transverse Ranges, on the east by the Colorado Desert, and extends south, encompassing the Los Angeles Basin and terminating 775 miles south of the United States–Mexico border.

The Peninsular Ranges includes the southern portion of Los Angeles County, the southwest corner of San Bernardino County, all of Orange County, and the San Jacinto Mountains and the Coachella Valley in the central portion of Riverside County. The ranges are composed of a series of northwest-southeast trending mountains that are separated by several active faults, including the San Jacinto and Elsinore Fault zones. The Peninsular Ranges is one of the largest geologic units in western North America. Its highest elevations are found in the San Jacinto-Santa Rosa Mountains, with San Jacinto Peak reaching

10,805 feet above MSL. The orientation and shape of the Peninsular Ranges is similar to the Sierra Nevada, in that the west slope is gradual and the eastern face is steep and abrupt. Drainage from the province is typically by the San Diego, San Dieguito, San Luis Rey, and Santa Margarita Rivers.

Colorado Desert (Salton Trough)

The Colorado Desert geomorphic province (also referred to as the Salton Trough) is a depressed block between active branches of alluvium-covered San Andreas Fault with the southern extension of the Mojave Desert province in the east. Its roughly triangular shape is bounded to the east by the Chocolate Mountains, to the west by the Peninsular Ranges, and extends south into Mexico. The area is a low-lying, barren desert basin dominated by the Salton Sea. This province includes a large portion of Imperial County and a small portion of central Riverside County. The Colorado Desert is divided into two main valleys: the deep Imperial Valley to the south and the narrower and shallower Coachella Valley to the north. A good portion of both valleys lie below sea level with the lowest elevation found in the Salton Basin at 235 feet below MSL. The area is characterized by the ancient beach lines and silt deposits of extinct Lake Cahuilla. Geologic features include playas separated by sand dunes and the occurrence of seismic and a seismic subsidence due to the San Andreas Fault system.

Earthquake Faults

The SCAG region is located in an area that has historically experienced high seismicity. In the past 100 years, several earthquakes of magnitude 5.0 or larger have been reported on the active San Andreas, San Jacinto, Elsinore, and Newport-Inglewood fault systems. These four fault systems are concentrated in the western portion of the SCAG region, running in a northwest to southeast direction. The San Andreas Fault lies furthest to the east, extending just above the northern border of Ventura County and the San Gabriel Mountains, eventually terminating at the Salton Sea. As a result, significant earthquake hazards exist in the region.[5] Injury to people and damage to structures during earthquakes can be caused by actual surface rupture along an active fault, by ground shaking from a nearby or distant fault, liquefaction, or dam failure. In Southern California, the last earthquake exceeding Richter magnitude 8.0 occurred in 1857. Much more frequent are smaller temblors, like the relatively moderate (but still exceedingly damaging) 1971 San Fernando and 1994 Northridge earthquakes, both classified as magnitude 6.7 earthquakes.[6]

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5 It should be noted that new faults continue to reveal themselves, such as in the case of the Northridge earthquake of 1994, and the potential seismic threats posed by these faults also continue to be reevaluated on the basis of new geologic information and analysis, as in the recent case of the Puente Hills Fault.

6 The human and economic damage caused by earthquakes tends to increase with time, as more and more people and property come to occupy more and more of the land, thus cumulatively increasing the exposure of human habitation to seismic hazard. The 1994 Northridge earthquake, though hardly the most severe experienced by Southern California, was deemed the most expensive, in terms of its economic cost and its damage to human property. The California Office of Emergency Services claimed a $15 billion total damage estimate.

A fault is a fracture in the crust of the earth along which there has been displacement of the sides relative to one another parallel to the fracture. Most faults are the result of repeated displacements over a long period of time. Numerous active and potentially active faults have been mapped in the region (**Table 3.7.2-1, *Characteristics of Major Faults in the SCAG Region*,** and **Figure 3.7.2-2, *Potentially Active Faults in the SCAG Region***). The SCAG region contains lateral strike slip faults similar to the San Andreas and various identified and hidden blind thrust faults. A fault trace is the surface expression of a particular fault. Buried or blind thrust faults are thought to underlie much of the SCAG region. These "buried" faults do not exhibit readily identifiable traces on the earth's surface and are typically at considerable depth within the underlying geologic formation. Although these faults typically do not offset surface deposits, they can generate substantial ground shaking. The California Geological Survey (CGS) defines active faults as those that have exhibited evidence of displacement during Holocene (10,000 years ago to present) period. Potentially active faults are defined as faults that have exhibited evidence of displacement during the Pleistocene period (10,000 years to 1.8 million years ago). Class A faults have slip rates greater than 5 millimeters per year (mm/yr) and generally have substantial historic seismic data available, while Class B faults have slip rates smaller than 5 mm/yr and, as a rule, historic seismic data on which to develop reliable recurrence intervals of large events is lacking.

TABLE 3.7.2-1
CHARACTERISTICS OF MAJOR FAULTS IN THE SCAG REGION

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
Class A Faults				
San Andreas	Los Angeles San Bernardino Riverside Imperial	Historic	25.0–34.0	7.2–7.5
San Jacinto – Imperial Fault Zone	San Bernardino Riverside Imperial	Holocene Later Quaternary	4.0–20.0	6.6–7.1
Elsinore Fault Zone	Riverside Imperial	Holocene	2.5–5.0	6.8–7.1
Class B Faults				
Elsinore and San Jacinto Fault Zones (Non A Faults)				
Brawley Seismic Zone	Imperial		25.0	6.4
Chino	San Bernardino Riverside		1.0	6.7
Earthquake Valley	—		2.0	6.5
Elmore Ranch	Imperial		1.0	6.6
Garlock Fault Zones				
Garlock – west	San Bernardino		6.0	7.3
Garlock – east	San Bernardino		7.0	7.5
Owl Lake	San Bernardino		2.0	6.5
Transverse – Ranges and Los Angeles Basin				
Clamshell-Sawpit	Los Angeles		0.5	6.5
Cucamonga	San Bernardino		5.0	6.9
Hollywood	Los Angeles		1.0	6.4
Holser	Ventura		0.4	6.5
Malibu Coast	Los Angeles Ventura		0.3	6.7

FIGURE 3.7.2-2:
Potentially Active Faults in the SCAG Region

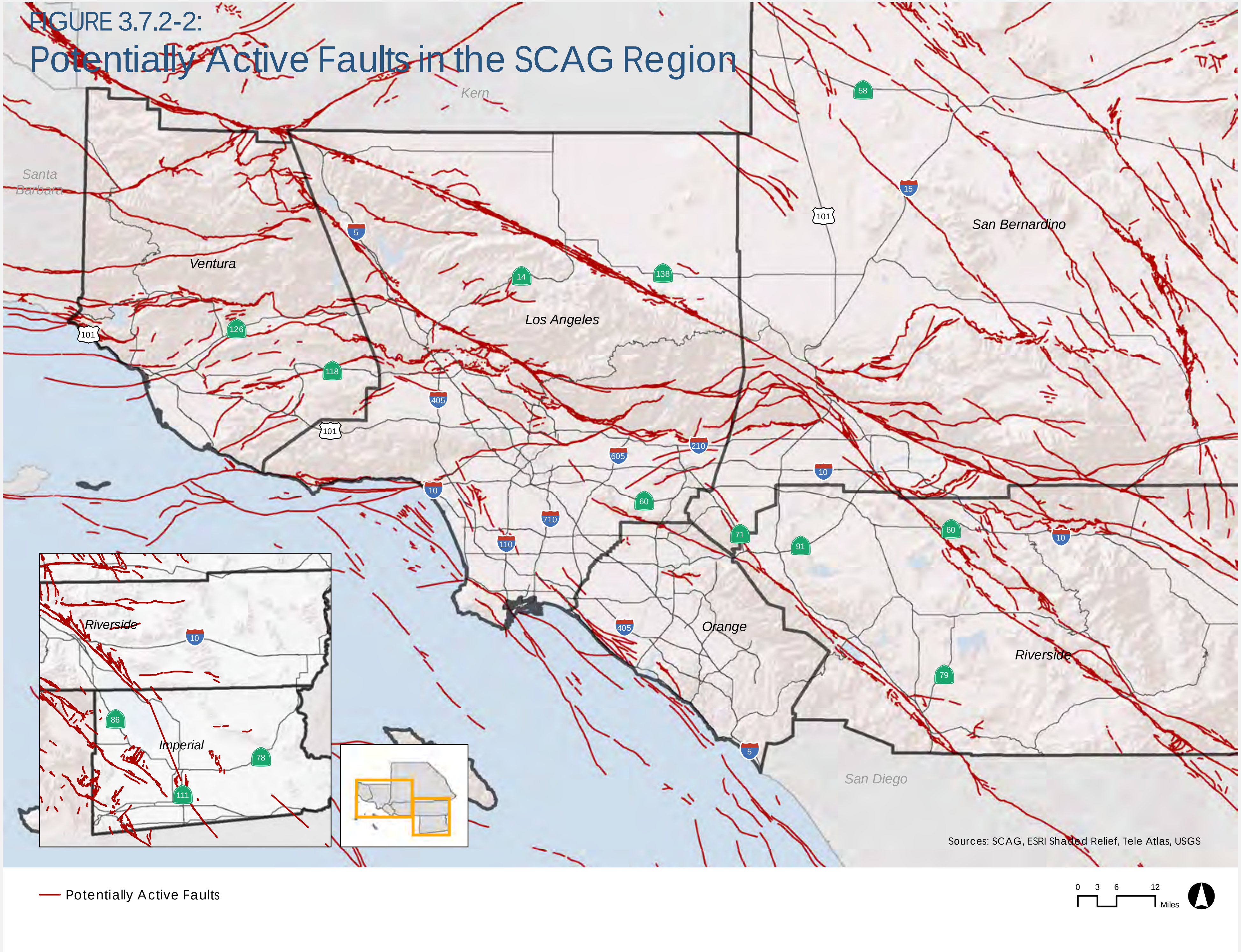


TABLE 3.7.2-1
CHARACTERISTICS OF MAJOR FAULTS IN THE SCAG REGION

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
Mission Ridge – Arroyo Parida – Santa Ana	Los Angeles		0.4	7.2
Newport-Inglewood	Los Angeles Orange	Late Quaternary (?)	1.0	7.1
Oak Ridge	Ventura	Holocene Late Quaternary	4.0	7.0
Palos Verdes	Los Angeles		3.0	7.3
Pleito	—		2.0	7.0
Raymond	Los Angeles		1.5	6.5
Red Mountain	San Bernardino		2.0	7.0
San Cayetano	Ventura		6.0	7.0
San Gabriel	Ventura Los Angeles	Holocene	1.0	7.2
San Jose	San Bernardino Los Angeles		0.5	6.4
Santa Monica	Los Angeles		1.0	6.6
Santa Ynez (West)	Ventura		2.0	7.1
Santa Ynez (East)	Ventura		2.0	7.1
Santa Susana	Ventura Los Angeles	Historic Late Quaternary	5.0	6.7
Sierra Madre (San Fernando)	Los Angeles		2.0	6.7
Sierra Madre	Los Angeles	Holocene Late Quaternary	2.0	7.2
Simi-Santa Rosa	Ventura		1.0	7.0
Ventura-Pitas Point	Ventura		1.0	7.0
Verdugo	Los Angeles Ventura		0.5	6.9
White Wolf	—		2.0	7.3
Los Angeles Blind Thrusts				
Upper Elysian Park	—		1.3	6.4
Northridge	Ventura Los Angeles		1.5	7.0
Puente Hills blind thrust	Los Angeles		0.7	7.1
San Joaquin Hills	Orange		0.5	6.6
Transverse – Ranges and Mojave				
Blackwater	—		0.6	7.1
Burnt Mountain	—		0.6	6.5
Calico-Hidalgo	San Bernardino		0.6	6.5
Cleghorn	San Bernardino		3.0	6.5
Eureka Peak	—		0.6	6.4
Gravel Hills – Harper Lake	San Bernardino		0.6	7.1
Helendale – S. Lockhart	San Bernardino		0.6	7.3
Johnson Valley (Northern)	San Bernardino		0.6	6.7
Landers	—		0.6	7.3
Lenwood – Lockhart – Old Woman Springs	San Bernardino		0.6	7.5
North Frontal Fault zone (Western)	San Bernardino		1.0	7.2
North Frontal Fault zone (Eastern)	San Bernardino		0.5	6.7
Pinto Mountain	San Bernardino		2.5	7.2

TABLE 3.7.2-1
CHARACTERISTICS OF MAJOR FAULTS IN THE SCAG REGION

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
Pisgah – Bullion Mountain – Mesquite Lake	San Bernardino		0.6	7.3
S. Emerson – Copper Mountain	San Bernardino		0.6	7.0

NOTE:
Recency of fault movement: Refers to the time period when the fault is believed to have last moved. The age is expressed in terms of the Geologic Time Scale. Generally, the older the activity on a fault, the less likely it is that the fault will produce an earthquake in the near future. For assessing earthquake hazard, usually only faults active in the Late Quaternary or more recently are considered. These include the following three non-overlapping time periods: Historic: Refers to the period for which written records are available (approximately the past 200 years, in California and Nevada).
Holocene: Refers to a period of time between the present and 10,000 years before present. Faults of this age are commonly considered active. For the purpose of classifying faults, C.W. Jennings defined Holocene to exclude the Historic; that is, from 200 to 10,000 years before the present).
Late Quaternary: Refers to the time period between the present and approximately 700,000 years before the present. Here too, for the purpose of classifying faults, Jennings defined Late Quaternary to exclude the Holocene and the Historic website, http://quake.wr.usgs.gov/info/faultmaps/slipage.html, accessed May 11, 2015.
Where no recency data are given, no determination has been made.
The Maximum Moment Magnitude is an estimate of the size of a characteristic earthquake capable of occurring on a particular fault. Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event [CGS, 2002b]. Richter magnitude estimations can be generally higher than moment magnitude estimations.
SOURCE:
Southern California Probabilistic Seismic Hazard Assessment Maps (PSHA). Accessed 25 August 2015. Website. Available at: http://www.conservation.ca.gov/cgs/rghm/psha/ofr9608/Pages/Index.aspx
U.S. Geological Survey. Accessed 25 August 2015. Website. Available at: http://quake.wr.usgs.gov/recenteqs/FaultMaps/118-34.htm
Petersen, M.D., W.A. Bryant, and C.H. Cramer. 1996. *Probabilistic Seismic Hazard Assessment for the State of California, California Department of Conservation, Division of Mines, 1996*. Geology Open-File Report issued jointly with U.S. Geological Survey, CDMG 96-08.
U.S. Geological Survey. Accessed 11 May 2015. 96-706. Available at: http://www.conservation.ca.gov/cgs/rghm/psha/ofr9608/Pages/Index.aspx

Seismic Hazards

Movements on the previously identified faults would likely cause future earthquakes in the SCAG region. Earthquakes can originate in areas where potential seismic energy has built up along a fault over time, but has not yet been released in the form of an earthquake. Studies supported by the National Earthquake Hazards Reduction Program enable scientists to evaluate the hazard level in different areas. In Southern California, scientists estimate that the probability of a magnitude 7.0 or greater earthquake by the year 2024 approaches 80 to 90 percent.

The four major hazards generally associated with earthquakes are ground shaking, surface fault rupture (ground displacement), liquefaction ground failures, and settlement. A detailed discussion of these types of hazards is found below.

Ground Shaking

Ground shaking may affect areas hundreds of miles distant from the earthquake's epicenter. Historic earthquakes have caused strong ground shaking and damage in many areas of the SCAG region. The composition of underlying soils in areas located relatively distant from faults can intensify ground shaking. Areas that are underlain by bedrock tend to experience less ground shaking than those underlain by unconsolidated sediments such as artificial fill.

Ground shaking is commonly described in terms of peak ground acceleration as a fraction of the acceleration of gravity (g), or by using the Modified Mercalli (MM) Intensity Scale, a common metric for characterizing intensity. The MM Intensity Scale is a more descriptive method involving 12 levels of intensity denoted by Roman numerals (**Table 3.7.2-2, *Modified Mercalli Intensity Scale***). MM intensities range from level I (shaking that is not felt) to level XII (total damage). MM intensities ranging from IV to X could cause moderate to significant structural damage. The degree of structural damage, however, would not be uniform. Not all buildings perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a building all affect its performance.

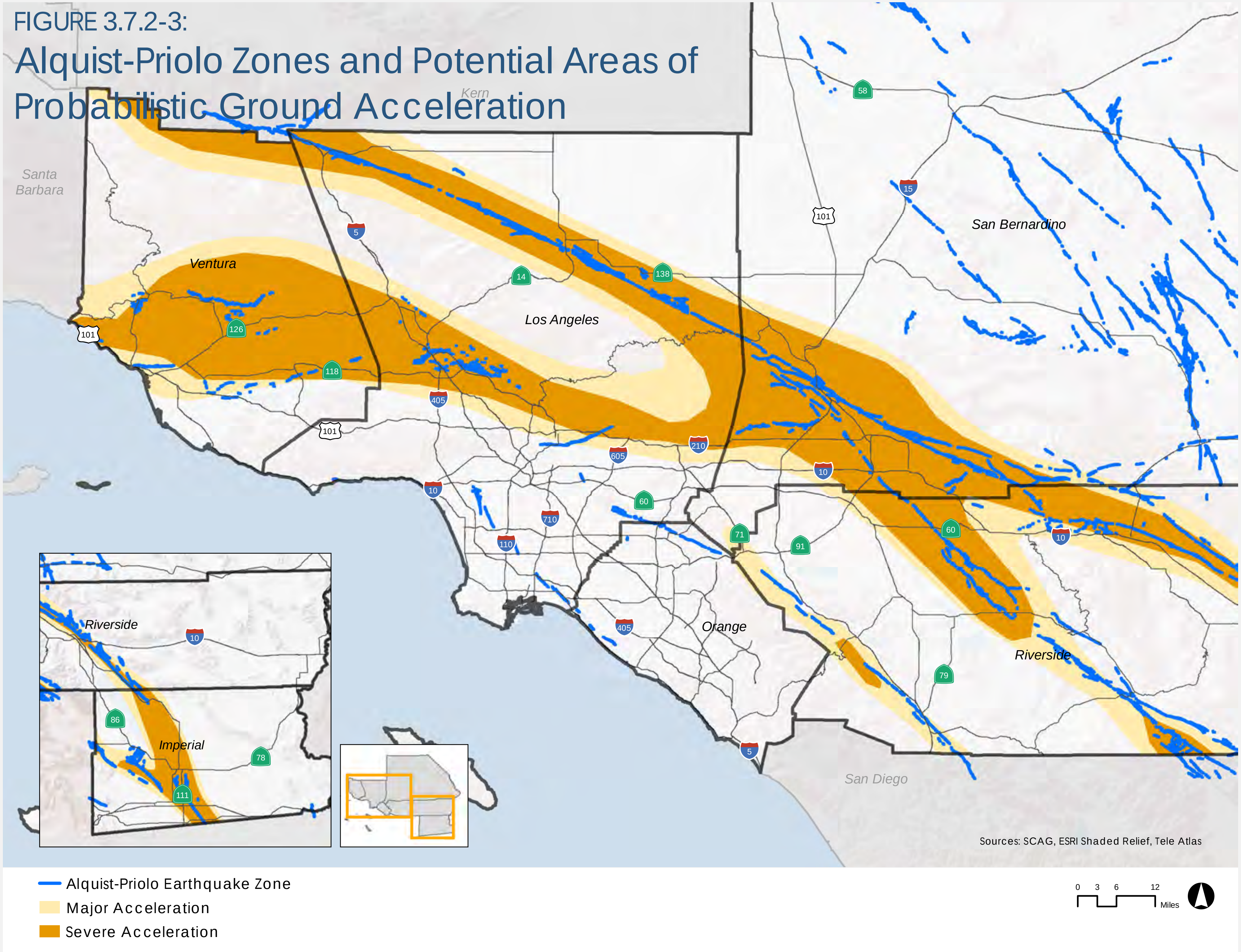
TABLE 3.7.2-2
MODIFIED MERCALLI INTENSITY SCALE

I.	Not felt except by a very few under especially favorable conditions.
II.	Felt only by a few persons at rest, especially on upper floors of buildings.
III.	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV.	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V.	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI.	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII.	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII.	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI.	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII.	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

SOURCE: U.S. Geological Survey, Earthquake Hazards Program. Accessed 11 May 2015. Website. Available at: http://earthquake.usgs.gov/learn/topics/mag_vs_int.php

Earthquakes on the various and potentially active fault systems are expected to produce a wide range of ground shaking intensities in the SCAG region (**Figure 3.7.2-3, *Alquist-Priolo Zones and Potential Areas of Probabilistic Ground Acceleration***). The estimated maximum moment magnitudes represent

FIGURE 3.7.2-3:
Alquist-Priolo Zones and Potential Areas of Probabilistic Ground Acceleration



Q:\1315\SCAG\ArcProjects\Faults_Ground_Acceleration.mxd | Date: 11/19/2015 characteristic earthquakes on particular faults.[7] While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the ground shaking effects at a particular location. Shaking intensity can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and characteristics of geologic media. Generally, intensities are highest at the fault and decrease with distance from the fault.

Surface Fault Rupture

The surface expression of earthquake fault rupture typically occurs in the immediate vicinity of the originating fault. The magnitude and nature of the rupture may vary across different faults, or even along different segments of the same fault.[8] Rupture of the surface during earthquake events is generally limited to the narrow strip of land immediately adjacent to the fault on which the event is occurring. Surface ruptures associated with the 1992 Landers earthquake in San Bernardino County extended for a length of 50 miles, with displacements varying from 1 inch to 20 feet.

The Alquist-Priolo Earthquake Fault Zoning Act was passed in 1972 to mitigate the risk to human habitation of seismically induced ground-surface ruptures. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. Surface rupture is the most easily avoided seismic hazard, provided regulatory stipulations embedded in this law are met.

The law requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults, and to issue appropriate maps. Numerous active and potentially active earthquake faults are mapped throughout the SCAG region (**Figure 3.7.2-1**).[9] Detailed maps are distributed to all affected cities, counties, and state agencies for their use in planning new or renewed construction. Local agencies must regulate most development projects within the zones, including all land divisions and most structures intended for human habitation. Fault surface rupture almost always follows preexisting faults, which are zones of weakness. Rupture may occur suddenly during an earthquake, or slowly in the form of fault creep. Sudden displacements are more damaging to structures because they are accompanied by ground shaking. Fault creep is the slow rupture of the earth's crust. Not all earthquakes result in surface rupture (e.g., the 1994 Northridge earthquake). Potentially active faults have demonstrated movement within Pleistocene period (approximately 1.6 million years ago). According to the CDMG, active and potentially active faults must be considered as potential sources of fault rupture.

Liquefaction and Ground Failure

Liquefaction has been responsible for ground failures during almost all of California's large earthquakes. The depth to groundwater can control the potential for liquefaction; the shallower the groundwater, the higher the potential for liquefaction. Earthquake-induced liquefaction most often occurs in low-lying

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7 Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event. See Table 4.6-1 for the moment magnitudes associated with particular faults.

8 California Geological Survey. 2002. *Guidelines for Evaluating the Hazard of Surface Fault Rupture*. CGS Note 49. Sacramento, CA.

9 "Earthquake Fault Zones" were called "Special Studies Zones" prior to January 1, 1994.

areas with soils or sediments composed of unconsolidated, saturated, clay-free sands and silts, but can also occur in dry, granular soils, or saturated soils with some clay content.

Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength. A lateral spread is a horizontal displacement of surficial blocks of sediments resulting from liquefaction in a subsurface layer. Lateral spread occurs on slopes ranging between 0.3 and 3 percent and commonly displaces the surface by several meters to tens of meters. Flow failures occur on slopes greater than 3 degrees and are primarily liquefied soil or blocks of intact material riding on a liquefied subsurface zone. Ground oscillation occurs on gentle slopes when liquefaction occurs at depth and no lateral displacement takes place. Soil units that are not liquefied may pull apart from each other and oscillate on the liquefied zone. Ground fissures can accompany ground oscillation and sand boils and damage underground structures and utilities. The loss of bearing pressure can occur beneath a structure when the underlying soil loses strength and liquefies. When this occurs, the structure can settle, tip, or even become buoyant and "float" upwards.

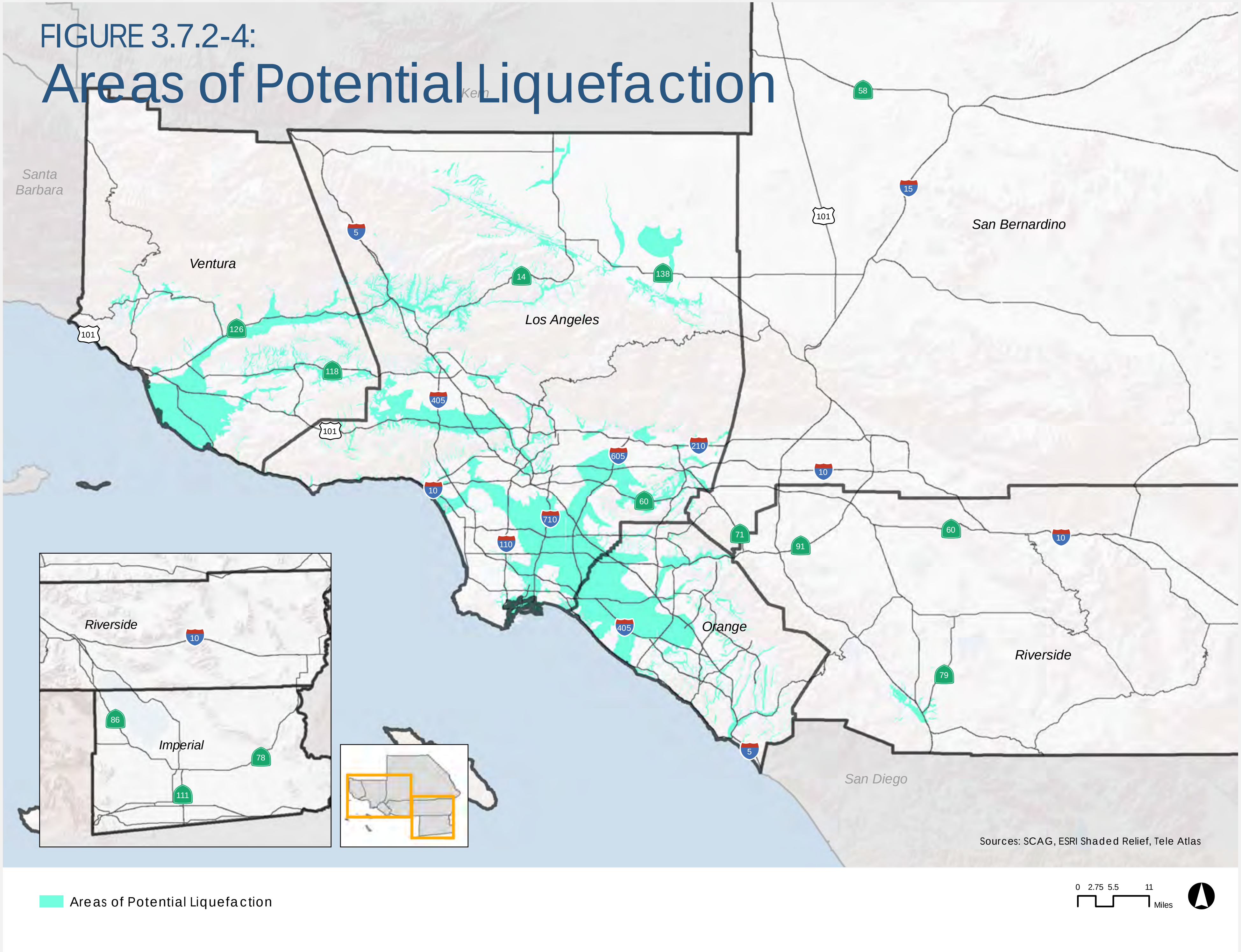
Within the SCAG region, liquefaction potential is a function of the potential level of ground shaking at a given location and depends on the geologic material at that location (**Figure 3.7.2-4, *Areas of Potential Liquefaction***). Structural failure often occurs as sediments liquefy and cannot support structures that are built on them. Alluvial valleys and coastal regions are particularly susceptible to liquefaction. These areas can include but are not limited to flood plains and former wetlands such as Marina Del Rey, Playa Del Rey and areas near the Los Angeles River, the Santa Monica Bay, and Los Alamitos Bay in Los Angeles County, Areas in the vicinity the Santa Clara River, and Calluguas Creek outlets to the ocean in Ventura County. Additionally, there are areas in northern Los Angeles County that are susceptible to liquefaction as a result of existing geological conditions (**Figure 3.7.2-4**). Unconsolidated alluvial deposits in desert region deposits are rarely saturated because of the depth to the water table, and are thus, less susceptible to liquefaction than unconsolidated alluvium adjacent to stream channels.

Earthquake-Induced Subsidence

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments) due to the rearrangement of soil particles during prolonged ground shaking. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Within the SCAG region, artificial fills, unconsolidated alluvial sediments, slope washes, and areas with improperly engineered construction-fills typically underlie areas susceptible to this type of settlement. In the past five years, there have been several earthquakes in the SCAG region, none exceeding a magnitude of 6. The March 2014 M5.1 earthquake was felt throughout the Los Angeles Metropolitan area, specifically near the cities of La Habra, Brea, and Rowland Heights. No major subsidence or landslide incidents were reported as a result of this earthquake. Additional earthquakes occurred in Imperial County, with three occurring in 2010 and two occurring in 2012; similarly, no major damages were reported.[10] Explanations of earthquake-induced subsidence are discussed further below.

[10] U.S. Geological Survey. Accessed 25 August 2015. Website. Available at: http://earthquake.usgs.gov/earthquakes/map/

FIGURE 3.7.2-4:
Areas of Potential Liquefaction



Seismically Induced Landslides

Strong ground shaking during earthquake events can generate landslides and slumps in uplands or coastal regions near the causative fault. Seismically induced land sliding has typically been found to occur within 75 miles of the epicenter of a magnitude 6.5 earthquake. Seismically induced landslides would be most likely to occur in areas that have previously experienced landslides or slumps, in areas of steep slopes, or in saturated hillside areas. Areas of the SCAG region are susceptible to seismically induced land sliding because of the abundance of active faults in the region and the existing landslide hazards (**Figure 3.7.2-5, *Areas of Potential Landslides***). Specifically, areas with high susceptibility to earthquake-induced landslides are concentrated along mountain ranges in the SCAG region: Santa Ana Mountains, San Gabriel Mountains, Santa Susanna Mountains, Santa Monica Mountains, Sulphur Mountain, San Jacinto Mountains, and the San Bernardino Mountains.

Earthquake-Induced Inundation and Tsunamis

Because the West Coast of the United States is seismically active, California is subject to flood hazard from tectonic activity capable of generating submarine earthquakes, volcanic eruptions, and landslides. Considering its proximity to the Pacific Ocean, the inundation by tsunamis (seismic sea waves) or seiches (oscillating waves in enclosed water bodies) can occur along the California coast in the event of significant earthquake. The SCAG region consists of approximately 150 miles of coastline. The coastline of SCAG region has been mapped as being in a location potentially subject to tsunamis and the existing tsunami warning system (**Figure 3.7.2-6, *Areas Susceptible to Tsunamis***).[11] Additionally, several large water impoundments in the SCAG region also have the potential to induce seiche inundation. For purposes of a relative comparison, an earthquake with its epicenter in Alaska and with a magnitude of 8.5 (Richter scale) generated a seismically induced sea wave with a maximum wave height of 11 feet in the Monterey Harbor, on the central coast of California north of the SCAG region. The most recent historical tsunami to affect the coast of the SCAG region was in 2012, when a magnitude 7.5 earthquake struck the Queen Charlotte Islands of the west coast of Canada. The resulting tsunami was 0.08 meter or 0.26 foot.[12]

Soils and Geologic Materials

Soils within the SCAG region are classified by distinguishing characteristics and are arranged within soil associations.[13] Soils throughout the region differ in origin, composition, and slope development. Individual soil characteristics are important in determining the suitability of the soil for agricultural use or urbanized development. The formation of surficial soil depends on the topography, climate, biology, local vegetation, and the material on which the soil profile is developed. Although many soils in the SCAG region are suitable for agricultural uses, each soil type may have properties that could limit its uses and represent an agricultural or development hazard.[14] These limitations are listed and discussed

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11 California State Department of Conservation. Accessed 19 July 2015. Website. Available at: http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Statewide_Maps.aspx

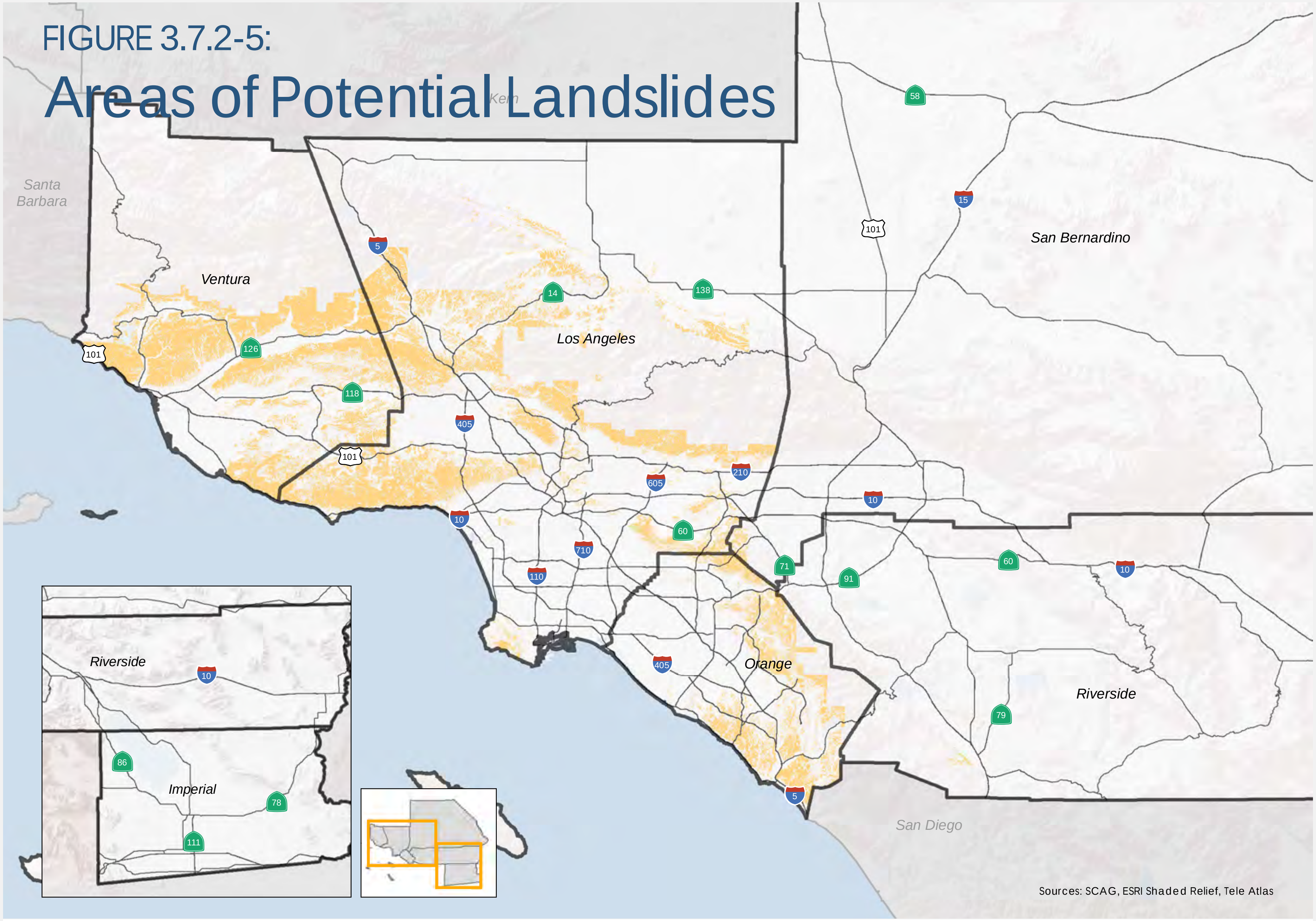
12 California Geological Survey. Accessed 19 July 2015. Website. Available at: http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Pages/About_Tsunamis.aspx#historic

13 Soil Association: A mapping unit consisting of a group of defined and taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region.

14 U.S. Department of Agriculture, Soil Conservation Service. 1970. *Soil Survey of Ventura Area, California*. Washington, DC.

FIGURE 3.7.2-5:

Areas of Potential Landslides



Earthquake-Induced Landslide Zone

0 2.75 5.5 11 Miles

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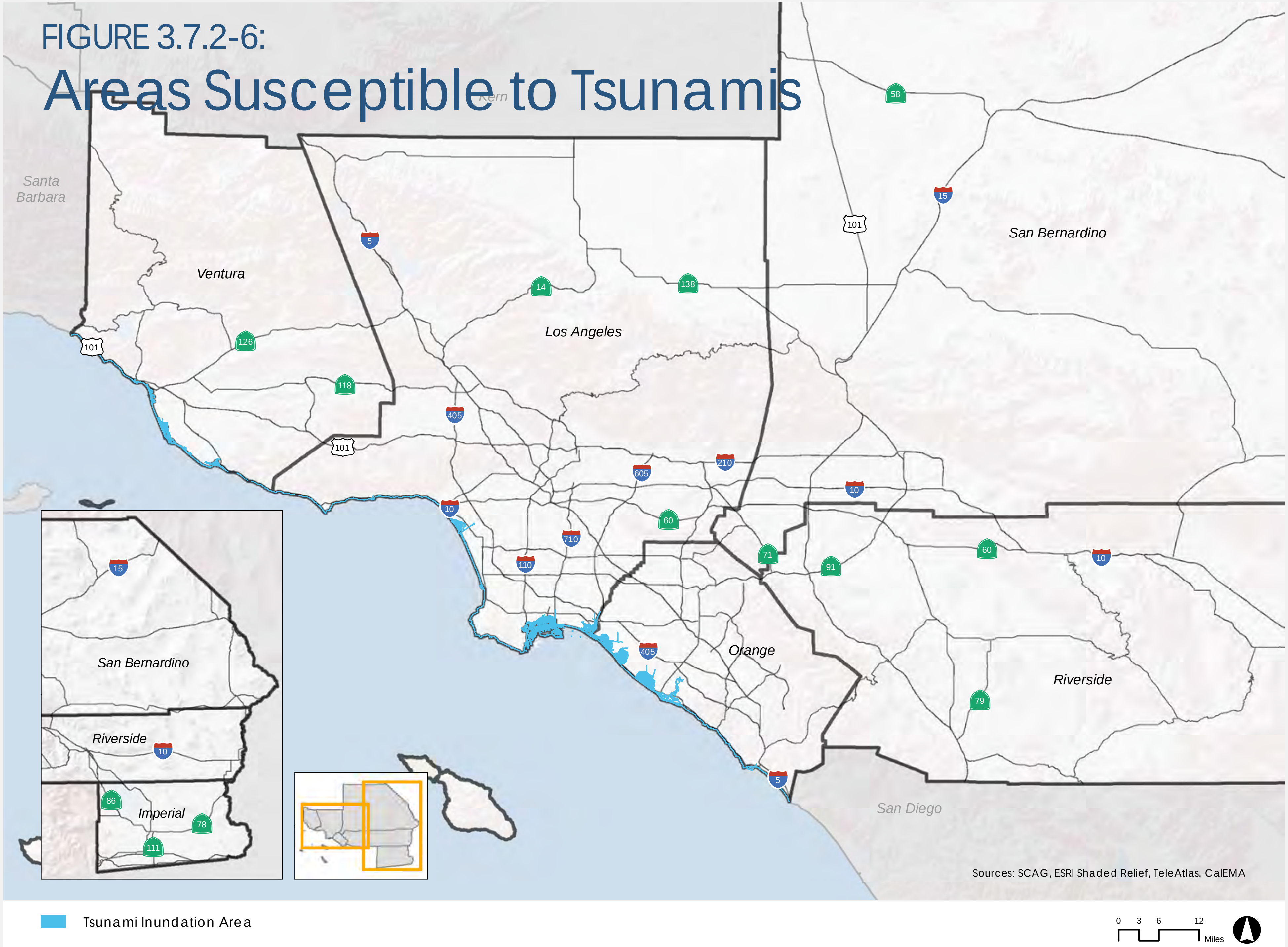
FIGURE 3.7.2-6:

Areas Susceptible to Tsunamis



Sources: SCAG, ESRI Shaded Relief, TeleAtlas, CalEMA

Tsunami Inundation Area

below. **Figure 3.7.2-7, *General Soil Types***, shows the general location of soil types contained within the SCAG region. Applicable USDA NRCS soil surveys for specific counties provide the classification and description of each soil type encountered in the SCAG region.

Erosion

Soil erosion is also a natural ongoing process that transports, erodes, and displaces soil particles through a transport mechanism such as flowing water or wind. Erosion is the physical detachment and movement of soil materials through natural processes or human activities. The determination of soil erosion potential is a complex process generally applied to site specific areas using the soil erodibility K-factor index and the Universal Soil Loss Equation (USLE). Determining areas of potential erosion is made more complex due to the substantial geomorphic diversity in the SCAG region. Generally, there is a high potential for erosion in mountainous areas and areas along the margins of mountainous areas, where there is a high intensity of rainfall and where the soils are considered erosive. Clay soils typically have low erodibility because the soil particles are resistant to detachment. Soils having a high silt content are the most erosive as the particles are easily detached, tend to crust, and produce high rates of runoff.[15]

Soil

Three soil factors are strongly associated with soil erosion potential: texture, compactness, and structure. Of these, texture plays the most dominant role. Intermediate textured soil types, such as silt, tend to be most erodible, whereas clay and particles coarser than sand are more resistant to erosion. Slopes influence the rate and amount of runoff, and in turn these influence erosion. Loose texture and steep slopes primarily result in high wind erosion potential in soils. Data on Soil Erodibility (K Factor) from the State Water Resources Control Board indicates there are areas within the SCAG region with both moderate (K factor 0.25–0.45) and high susceptibility (K factor > 0.45) of erosion. The K factor combines the detachability of soil, runoff potential of the soil, and transportability of the sediment eroded from the soil into one measure for soil erodibility. The K factor is just one element of the RUSLE (Revised Universal Soil Loss Equation), which is used by government agencies to make erosion predictions for regulatory and conservation planning uses. In Ventura County, most of the Santa Monica Mountains and Topatopa Mountains are characterized by soils that are moderately susceptible to erosion. In Los Angeles County, most soils within the urbanized areas south of the San Gabriel Mountains are moderately susceptible to erosion. These soils continue southeast into Orange County where almost all of the land area is covered by soils moderately susceptible to erosion. In San Bernardino County, the majority of soils are not moderately or highly susceptible, however several pockets of moderately erodible soils exist throughout the county, particularly surrounding the Ivanpah and Piute Mountains and Lanfair and Ivanpah Valleys; one small area of highly erodible soil exists in the northeast corner of the county within the Mesquite Valley. Riverside County also features both moderately and highly susceptible erodible soils that are mainly concentrated in the western portion of the county immediately adjacent to the east and west of the Lakeview Mountains. Finally, Imperial County is covered by moderately erodible soils on its west side, surrounding the Salton Sea and extending south.[16]

15 Michigan State University, RUSLE Online Soil Erosion Assessment Tool. Accessed 8 September 2015. Available at: http://www.iwr.msu.edu/rusle/kfactor.htm

16 California Water Resources Control Board. Accessed 25 August 2015. Website. Available at: http://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/constpermits/guidance/k_factor_map.pdf

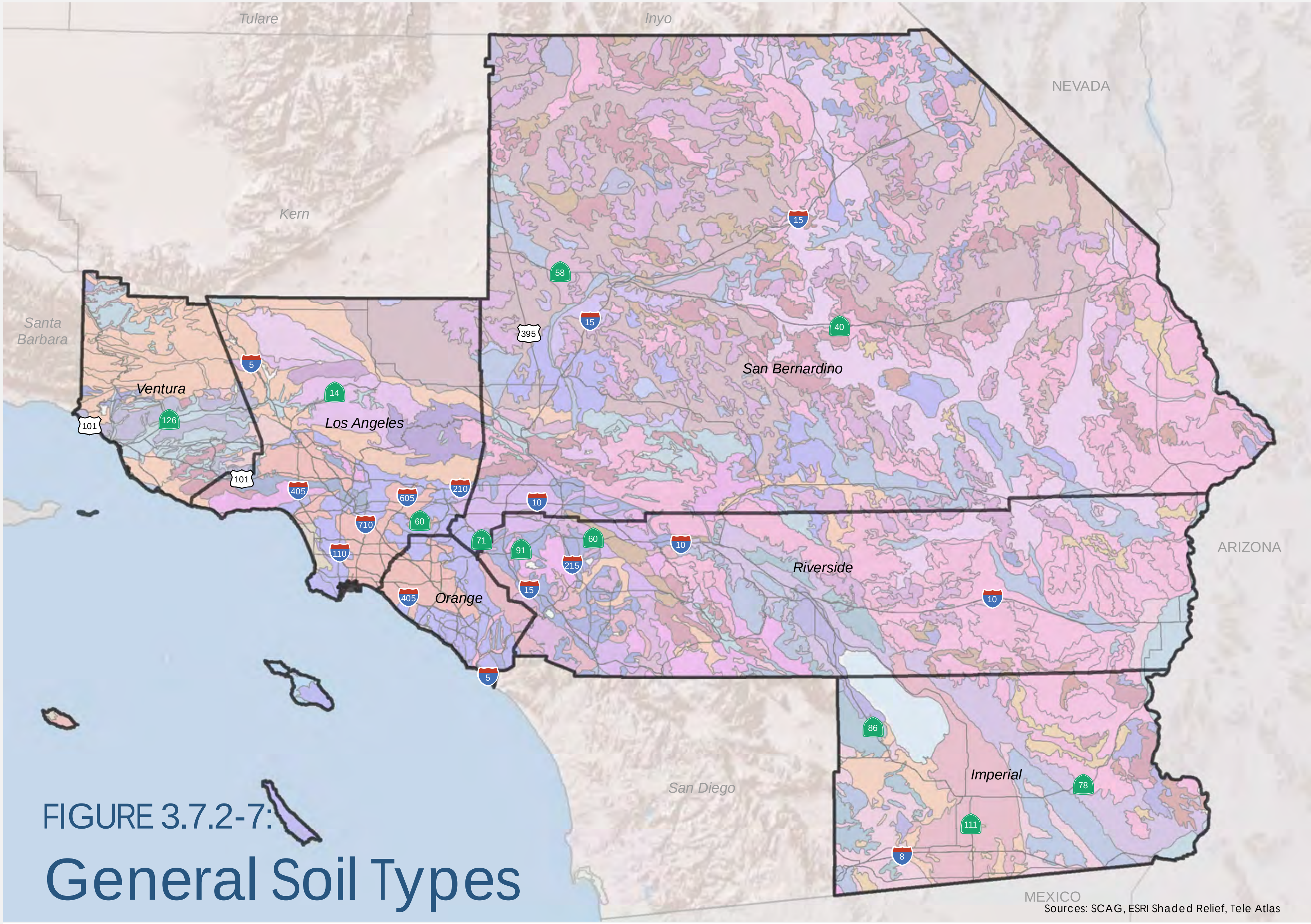


FIGURE 3.7.2-7:

General Soil Types

Sources: SCAG, ESRI Shaded Relief, Tele Atlas

- channery clay loam, CN-CL
- channery loam, CN-L
- clay loam, CL
- clay, C
- coarse sand, COS
- coarse sandy loam, COSL
- cobbly sand, CB-S
- extremely channery loam, CNX-L
- extremely gravelly fine sandy loam, GRX-FSL
- extremely gravelly loam, GRX-L
- fine sand, FS
- fine sandy loam, FSL
- gravelly clay loam, GR-CL
- gravelly coarse sandy loam, GR-COSL
- gravelly fine sand, GR-FS
- gravelly loam, GR-L
- gravelly loamy sand, GR-LS
- gravelly sand, GR-S
- gravelly sandy loam, GR-SL
- loam, L
- loamy fine sand, LFS
- loamy sand, LS
- sand, S
- sandy loam, SL
- silt loam, SIL
- silty clay, SIC
- unweathered bedrock, UWB
- variable, VAR
- very channery loam, CNV-L
- very cobbly sandy loam, CBV-SL
- very cobbly silt loam, CBV-SIL
- very fine sandy loam, VFSL
- very gravelly fine sandy loam, GRV-FSL
- very gravelly loam, GRV-L
- very gravelly loamy sand, GRV-LS
- very gravelly sandy clay loam, GRV-SCL
- very gravelly sandy loam, GRV-SL
- weathered bedrock, WB

0 5 10 20 Miles

Erosion caused by wind is most severe in arid regions where sandy or loamy sediments are not covered by vegetation and exposed to severe wind conditions, such as the eastern portions of San Bernardino, Riverside, and Imperial Counties. Human intervention can accelerate the natural erosion process. For instance, typical consequences of development increase erosion potential due to the removal of vegetative cover and reduction of overall permeable area. These activities can lead to increased water runoff rates and concentrated flows that have greater potential to erode exposed soils. The effects of excessive erosion range from nuisance problems that require additional maintenance, such as increased siltation in storm drains, to instances of more severe damage where water courses are down-cut and gullies develop. These processes can eventually undermine adjacent structures or topography. Human activities that disturb soils in arid regions also increase wind erosion potential. Many of the desert areas in the SCAG region are susceptible to blowing sand, a severe form of wind erosion that damages property and accumulates soil on roadways. The majority of the soils in the SCAG region exhibit moderate to high erosion potential, which can be compounded by development. **Figure 3.7.2-8, *Soils with Moderate to High Erosion Potential***, shows the general location of soils within the SCAG region that exhibit moderate to high erosion potential.

Coastal

Coastal erosion is a natural process that is typically the most visible during storm events. Beach sand is replenished by sediment loads in rivers and gentler waves after storm events or during summer months. Erosion rates of 1 inch per year are considered moderate. However, depending on the severity and duration of storm events and the degree of human intervention with natural coastline or riverine processes, coastal erosion can proceed at considerable rates, resulting in rapid visible coastline recession. In areas of extreme coastal erosion, such as the cities of Rancho Palos Verdes and Malibu, slopes have been undercut by waves during storm events, causing slope failure and resulting in property damage and risks to human health and safety. The coastal regions of Los Angeles, Orange, and Ventura Counties are susceptible to wave erosion hazards.

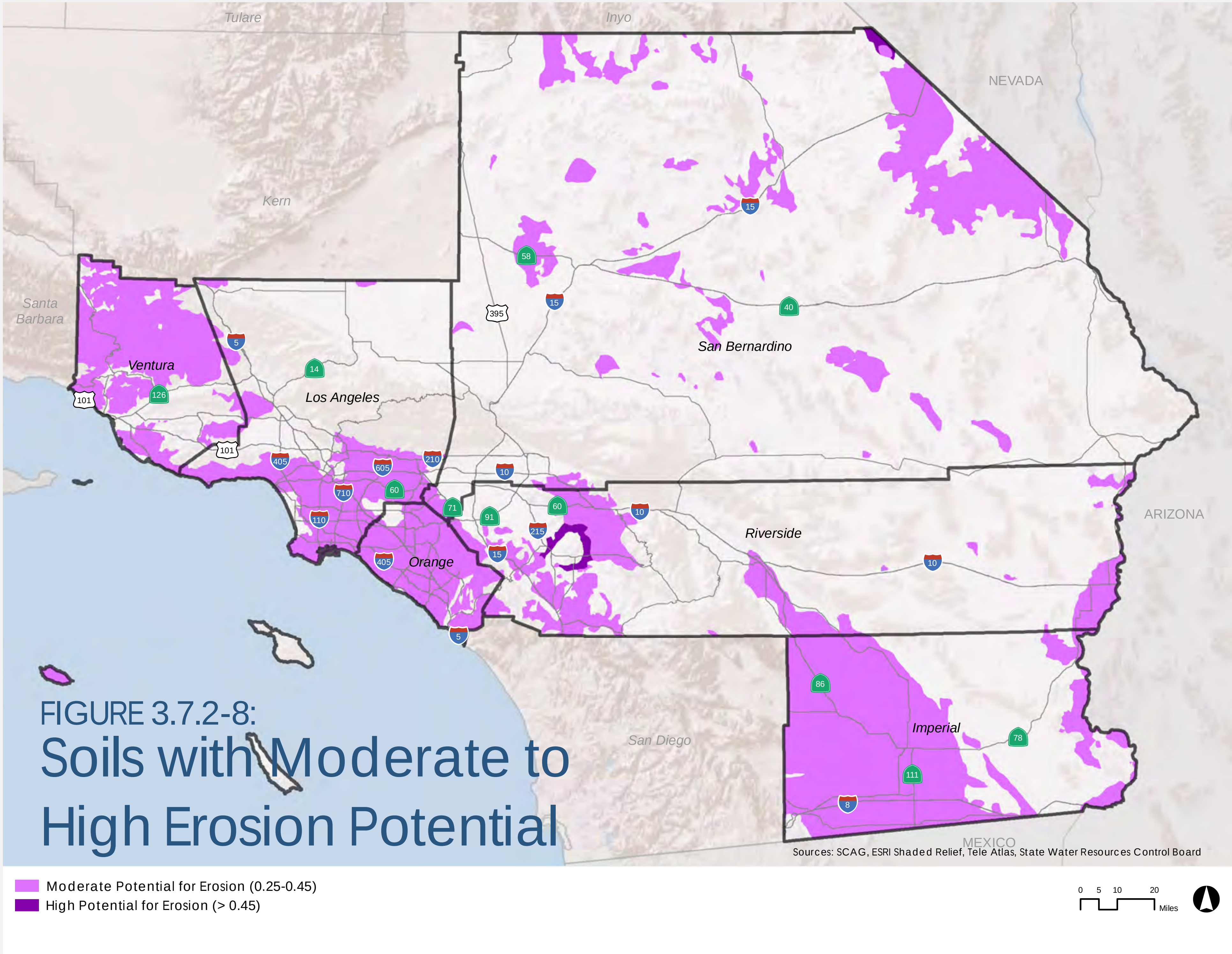
The Pacific Ocean borders the Peninsular Ranges province and the Transverse Ranges Province on the west. Nearly all the sea cliffs along the coast display some sign of coastal erosion. Coastal retreat is attributable to various processes, including undercutting from wave action, weathering and erosion of rocks and cliffs, emergence of groundwater at the cliff face, rain-wash, and land sliding. Additionally, these naturally occurring forces can be assisted by human activity such as coastal road construction, channelization of surface water flows, or development on marine terraces.

Expansive Soils

Expansive soils possess a “shrink-swell” behavior. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Structural damage may result over a long period of time, usually the result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils. Typically, soils that exhibit expansive characteristics comprise the upper 5 feet of the surface. The effects of expansive soils could damage foundations of aboveground structures, paved roads and streets, and concrete slabs. Expansion and contraction of soils, depending on the season and the amount of surface water infiltration, could exert enough pressure on structures to result in cracking, settlement, and uplift.

FIGURE 3.7.2-8:

Soils with Moderate to High Erosion Potential



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Locations of expansive soils are site-specific and can generally be remedied through standard engineering practices.

Unstable Soil Conditions

Settlement

Loose, soft soil material comprised of sand, silt and clay, if not properly engineered, has the potential to settle after a building is placed on the surface. Settlement of the loose soils generally occurs slowly but over time can amount to more than most structures can tolerate. Building settlement could lead to structural damage such as cracked foundations and misaligned or cracked walls and windows. Settlement problems are site-specific and can generally be remedied through standard engineering applications.

Land Subsidence

Land subsidence is caused by a variety of agricultural, municipal or mining practices that contribute to the loss of support materials within a geologic formation. Agricultural practices can cause oxidation and subsequent compaction and settlement of organic clay soils or hydro-compaction allowing land elevations to lower or sink. Agricultural and municipal practices can result in the overdraft of a groundwater aquifer thereby causing aquifer settlement. Groundwater overdraft occurs when groundwater pumping from a subsurface water-bearing zone (aquifer) exceeds the rate of aquifer replenishment. The extraction of mineral or oil resources can also result in subsidence from removal of supporting layers in the geologic formation. Substantial subsidence occurs in the SCAG region due to groundwater extraction and subsequent lowering of the groundwater surface, typically beneath a confining clay stratum. The impact of subsidence could include lowering of the land surfaces, increased potential for flooding, potential disturbance or damage to buried pipelines and associated structures, and damage to structures designed with minimal tolerance for settlement. Historic occurrences of land subsidence due to groundwater extraction are reported in the SCAG region within Antelope Valley, Coachella Valley, and the Mojave River Basin Area. With groundwater level declines as high as 300 feet in some areas, subsidence has caused permanent damage to many of these landscapes.[17]

Landslides

Landslides are the rapid downslope movement of a mass of material that moves as a unit and carries with it all the loose material above bedrock. Landslides occur more frequently on steep slopes or after periods of heavy rain due to the additional weight of water and its lubricating qualities. The material in the slope and external processes such as climate, topography, slope geometry, and human activity can render a slope unstable and eventually initiate slope movements and failures. Changes in slope material such as improperly engineered fill slopes can alter water movement and lead to chemical and physical changes within the slope. Unfavorable fracture or joint orientation and density may develop as a rock material responds to reduced weight or strain relief, resulting in a decreased ability of the rock material to resist movement. Removing the lower portion (the toe) decreases or eliminates the support that opposes lateral motion in a slope. This can occur by man-made activity such as excavations for road-

[17] California Water Foundation. Accessed 25 August 2015. Website. Available at: http://www.californiawaterfoundation.org/uploads/1397858208-SUBSIDENCEFULLREPORT_FINAL.pdf

cuts located along a hillside. Oversteepening a slope by removing material can also reduce its lateral support. Placement of buildings on slopes can increase the amount of stress that is applied to a potential failure surface. Shaking during an earthquake may lead materials in a slope to lose some cohesion, cause liquefaction, or change pore water pressures. Landslide-susceptible areas within the SCAG region are those with low-strength soil material on hilly topography, for example, the Portuguese Bend and Point Fermin areas of the Palos Verdes Peninsula, and the Blackhawk slide area on the north slope of the San Bernardino Mountains. Factors that decrease resistance to movement in a slope include pore-water pressure, material changes, and structure.

Soils Capable of Supporting Septic Tanks or Alternative Waste Water Disposal Systems

The California State Water Resources Control Board has specific guidelines and requirements with regard to soil suitability for septic tanks and alternative waste water disposal systems in their publication 3.2C-Construction Practices – Onsite Wastewater Treatment Systems (OWTS).[18] Soils with poorly or excessively drained soils are generally not suitable for septic tanks or alternatives waste water disposal systems.[19] According to the U.S. Environmental Protection Agency, is it recommended that onsite wastewater disposal systems incorporate native soil knowledge into system design to prevent groundwater contamination and ensure long-term performance. Most often, a percolation test is performed to assess the infiltration rate and soil texture, both of which determine the site suitability for a waste water disposal system. As it is difficult to assess site suitability without on-site testing, suitability in the SCAG region would be determined on a per project basis according to all local, regional, and state requirements.[20]

3.7.3 THRESHOLDS OF SIGNIFICANCE

The 2016 RTP/SCS would have a significant impact related to geology or soils if it would expose people or property to unacceptable risks in relation to the seven criteria identified in the State CEQA Guidelines:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - (i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.
  - (ii) Strong seismic ground shaking.
  - (iii) Seismic-related ground failure, including liquefaction.
  - (iv) Landslides.

- Result in substantial soil erosion or the loss of topsoil.

18 California State Water Resources Control Board. Accessed 19 July 2015. Website. Available at: http://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia/3_2c_const_owts.shtml

19 California State Water Resources Control Board. Accessed 19 July 2015. Website. Available at: http://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia/3_2c_const_owts.shtml

20 U.S. Environmental Protection Agency. Accessed 25 August 2015. Website. Available at: http://water.epa.gov/aboutow/owm/upload/2004_07_07_septics_septic_2002_osdm_all.pdf

- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.
- Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

Methodology

The methodology for determining the significance of potential risk to people and property in relation hazards posed by geology and soils compares the existing conditions to the future 2040 conditions under the Plan, as required by CEQA Guidelines Section 15126.2(a).

To assess potential impacts to residences and businesses adjacent to transportation corridors, geographic information systems (GIS) was used to assess seismic and geologic impacts by overlaying data in GIS format on the location of areas known to pose seismic or geologic hazards in the SCAG region. Specifically, the Major Transportation Projects[21] and urban development patterns from land use strategies included in the Plan were plotted on maps that identify potential hazards, such as known faults, high ground acceleration areas, areas exhibiting landslide potential, and areas with highly erodible soils in the SCAG region. A 500-foot-wide buffer was created along transportation project segments to identify potential seismic and geologic hazards and to determine whether such hazards could impact transportation projects included in the 2016 RTP/SCS. **Table 3.7.3-1, *SCAG 2016 RTP/SCS Potential Impacts from Geologic Hazards***, and **Figure 3.7.3-1, *SCAG 2016 RTP/SCS Projects in Relation to Geologic Hazards***, show the results of this analysis.

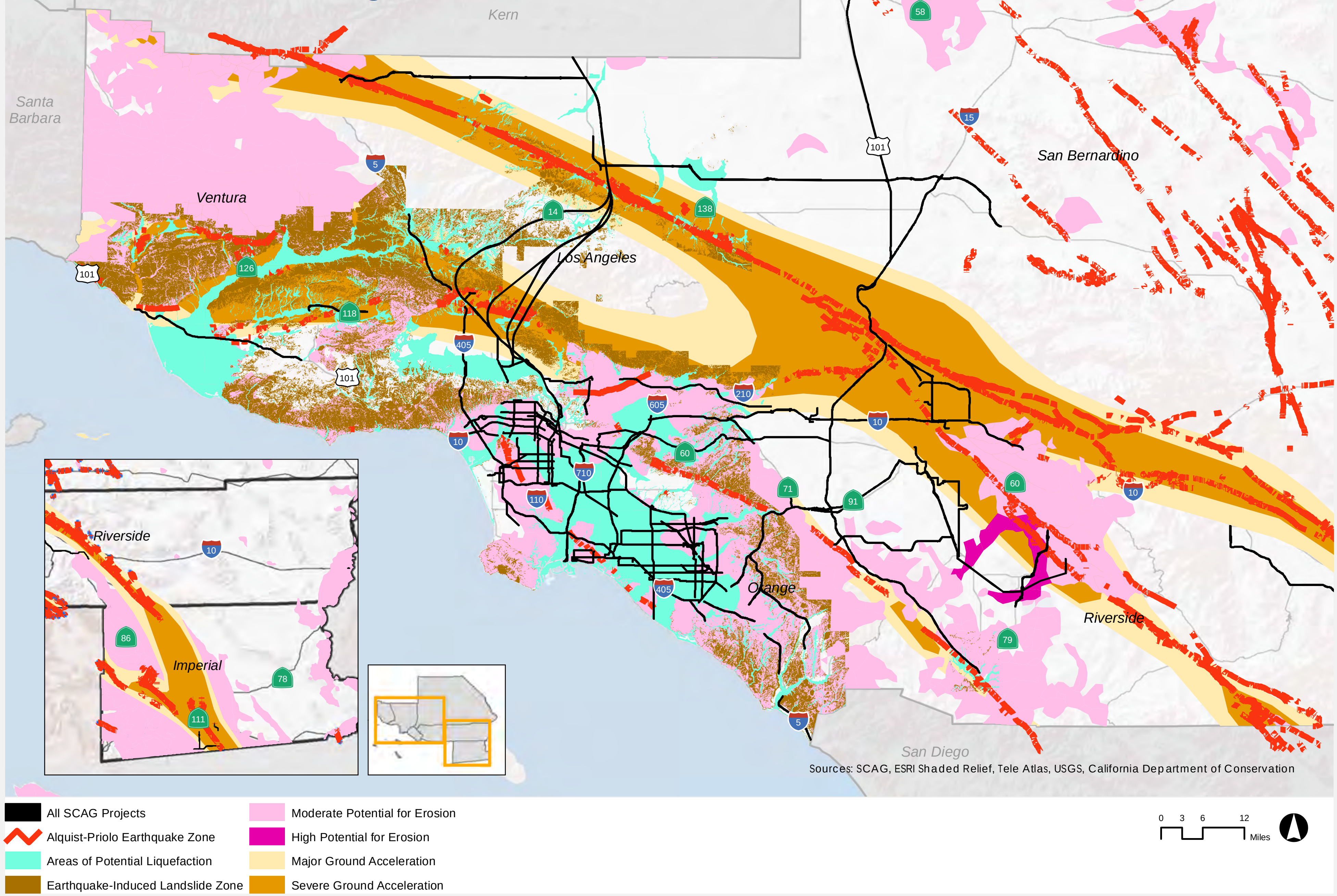
TABLE 3.7.3-1
SCAG 2016 RTP/SCS POTENTIAL IMPACTS FROM GEOLOGIC HAZARDS

County	Soil Erosion Potential (acres)		Potential Liquefaction (acres)	Potential Earthquake Induced Landslides (acres)	Peak Ground Acceleration (acres)		Alquist Priolo Earthquake Zone (linear miles)
	Moderate	High			Major	Severe	
Imperial	2,451	0	0	0	548	1,409	0.24
Los Angeles	43,862	0	26,902	2,759	9,645	11,312	12.39
Orange	26,755	0	15,458	1,027	25	0	0.27
Riverside	5,494	2,133	52	3	4,757	2,384	1.03
San Bernardino	1,000	1,000	2	0	2,245	10,708	1.39
Ventura	517	0	2,064	103	1,842	1,247	0.82
Total SCAG area	**80,079**	**3,133**	**44,477**	**3,892**	**19,061**	**27,061**	**16**

SOURCE: SCAG GIS analysis and data, 2015.

21 Major Transportation Projects include but are not limited to projects that involve ground disturbing activities and projects outside of existing rights-of-way such as projects that require new rights-of-way, adding traffic lanes, and grade separation.

FIGURE 3.7.3-1:
SCAG 2016 RTP/SCS Projects in Relation to Geologic Hazards



Q:\1315\SCAG\ArcProjects\PEIR\ProjectGeoHazards.mxd | Date: 10/24/2015

3.7.4 IMPACT ANALYSIS

IMPACT GEO-1: Potential to expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; (ii) strong seismic ground shaking; (iii) seismic related ground-failure, including liquefaction; (iv) landslides.

Significant Impact

Transportation projects included in the 2016 RTP/SCS that involve large-scale ground disturbance during construction, such as grade separation projects, mixed flow lane projects, and rail projects, may expose people or structures to substantial risk or hazards from seismic activity, constituting a significant impact. Development encouraged by land use strategies that directs more growth into existing suburban town centers, walkable mixed-use communities, transit-oriented development, and other areas well-served by transit such as high-quality transit areas (HQTAs) may also result in exposure of people and structures to hazards and risks from seismic activity, including earthquakes and seismically induced landslides, constituting a significant impact. As shown on **Table 3.7.3-1**, the entire SCAG region is susceptible to impacts from seismic activity. Seismic events can damage transportation infrastructure and urban development through surface rupture, ground shaking, liquefaction, and landslides. As shown in **Table 3.7.2-1**, numerous active faults are known to exist in the SCAG region that could potentially generate seismic events capable of significantly affecting existing structures and transportation facilities analyzed in the Plan. Therefore, transportation projects and development encouraged by land use strategies included in the 2016 RTP/SCS would be exposed to both direct and indirect effects of potential earthquakes.

Transportation projects included in the 2016 RTP/SCS are affected by Alquist Priolo Fault Zones and areas of major and severe ground acceleration (**Table 3.7.3-1)**. Transportation projects and potential development patterns encouraged by land use strategies reflected in the 2016 RTP/SCS have the potential to expose people and structures to risk due to the potential for seismic ground-shaking that is inherent to the SCAG region (**Figure 3.7.3-1**). Potential direct impacts from surface rupture and severe ground shaking could cause catastrophic damage to transportation infrastructure, particularly overpasses and underground structures. Indirect impacts from seismic events could damage ancillary transportation facilities such as port facilities, traffic control equipment, and train stations.

The 2016 RTP/SCS identifies new rail transit routes, extensions and development encouraged by land use strategies in Los Angeles and San Bernardino Counties. Other transit-related projects that would involve the construction of transit stations and other appurtenant infrastructure. The High Speed Rail project and proposed alternatives are an example of rail transit routes that would require the acquisition of new rights-of-way. All existing highways and rail lines in the SCAG region are subject to seismic or geologic influences to some degree. Similarly, new highways, arterials, bus rapid transit (BRT) routes, express high occupancy toll (HOT), high occupancy vehicle (HOV), goods movement (freight), heavy and light rail routes, and other capacity enhancements identified in the 2016 RTP/SCS would be susceptible to impacts from seismic activity for at least some portion of its length.

Some transportation projects and development influenced by the land use strategies as included in the 2016 RTP/SCS would be located within or across Alquist-Priolo Fault Zones. These zones are identified as areas directly over faults that are susceptible to surface rupture (**Figure 3.7.2-3**). For example, the proposed High Speed Rail transit system would cross several Alquist-Priolo Zones including the San Andreas Fault Zone (**Figure 3.7.3-1**). Other transportation projects and development patterns encouraged by land strategies may potentially be located in areas known to experience severe ground acceleration during earthquakes making these areas susceptible to severe ground shaking and earth movement. Many transportation projects would be located in areas prone to landslide, liquefaction or erosion (such as the High Desert Corridor project) areas. Indirect impacts could also promote additional delays and breaks in service while repairs are made. The potential for transportation projects and strategies to be significantly affected by liquefaction would be higher in areas exhibiting shallow groundwater levels and unconsolidated soils such as fill material, some alluvial soils, and coastal sands.

Specifically, with respect to urban development patterns encouraged by land use strategies, earthquakes can occur within previously undetected fault zones. For example, the Northridge Earthquake occurred within previously undetected fault zones and caused $13 billion in damages. Additionally, a catastrophic earthquake within the entire SCAG region would have the potential to damage approximately 1,800 facilities, displace 9 million people, and cause $200 billion in damage cost.[22] Future seismic activity from previously unknown faults could present catastrophic impacts to the transportation network. Similarly, liquefaction potential can change over time in heavily landscaped areas such as parks and agricultural areas, as soil saturation is altered.

Seismic activity can cause damage to existing structures designed due to substandard construction. However, new or seismically retrofitted structures designed with current state of the art engineering knowledge and compliance with local or state building codes (California Building Code, Uniform Building Code[23]) could reduce potential damage to these structures and minimize the seismic impacts to the public.

Individual transportation projects and development patterns encouraged by land use strategies would require additional CEQA review and impact analysis on a project-by-project basis. Nevertheless, new transportation infrastructure and facilities associated with implementation of transportation projects included in the 2016 RTP/SCS could expose additional people and infrastructure to the effects of earthquakes and seismically-induced landslides. Similarly, the 2016 RTP/SCS includes a set of regional land use strategies that are intended to guide future land development patterns to focus new growth in HQTAs, existing suburban town centers, and walkable mixed-use communities. While the specific impact of this pattern of development relative to seismic risk is unknown, it could result in more people being exposed to the effects of earthquakes and seismically induced landslides.

Therefore, transportation projects and development patterns encouraged by land use strategies included in the 2016 RTP/SCS could expose people or structures to impacts involving known faults,

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22 United States Geological Survey. 2008. *The Shake Out Scenario*. Available online at: http://pubs.usgs.gov/of/2008/1150/of2008-1150.pdf

23 California Building Standards Commission. 2013. 2013 California Building Standards Code. Available at: http://www.bsc.ca.gov/Home/Current2013Codes.aspx

strong seismic ground shaking, and seismic related ground-failure including liquefaction and landslides. Impacts would be potentially significant, requiring the consideration of mitigation measures.

IMPACT GEO-2: Potential to result in substantial soil erosion or the loss of topsoil.

Significant Impact

Development of transportation projects included in the 2016 RTP/SCS, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, in addition to urban development patterns encouraged by land use strategies that direct more growth into existing suburban town centers, walkable mixed-use communities, and areas well-served by transit such as HQTAs, may result in significant impacts from soil erosion or the loss of topsoil, constituting a significant impact.

Several transportation projects and strategies included in the 2016 RTP/SCS would involve major construction of new facilities that may involve rail lines, highway segments, or other urban development patterns that would be within previously undisturbed areas. The high speed rail projects and alternative routes identified in the 2016 RTP/SCS are examples of these types of projects. **Figure 3.7.3-1** shows the location of projects identified in the 2016 RTP/SCS in relation to geologic hazards including areas with soils subject to moderate and high potential for soil erosion. Therefore, the projects included in the 2016 RTP/SCS have the potential to result in soil erosion and loss of topsoil in previously undisturbed areas. Some of these transportation projects and development patterns encouraged by land use strategies would require significant earthwork including cuts into hillsides, which could become unstable over time, increasing long-term erosion potential. Improvements and modifications to existing rights-of-way, such as HOV lanes, HOT lanes, new bus-ways and capacity enhancement facilities, mixed flow lanes, and ROW maintenance, would have less potential to impact topsoil because these project locations have previously been disturbed. However, road cuts could expose soils to erosion over the life of the project, creating potential landslide and falling rock hazards. Engineered roadways could be undercut over time by storm water drainage and wind erosion. Some areas would be more susceptible to erosion than others due to the naturally occurring soils with high erosion potential.

Notwithstanding natural soil types, engineered soils can also erode due to poor construction methods and design features or lack of maintenance. As shown in **Table 3.7.3-1**, transportation projects included in the 2016 RTP/SCS are in areas susceptible to geologic hazards including high soil erodibility. Construction of additional lanes on freeways, other transportation facilities or development patterns encouraged by land use strategies could potentially result in the loss of topsoil, if it involves grading, trenching, excavation, and/or soil removal of any kind, in an area not previously used as a paved transportation facility. In addition, ROW maintenance has the potential to impact topsoil depending on activities involved.

The 2016 RTP/SCS includes coordinated and integrated regional strategies for transportation investments and land use growth that aims to focus more development in urbanized areas such as HQTAs, livable corridors, neighborhood mobility areas, suburban town centers and walkable, mixed-used communities. This focus on compact development would not be expected to result in an increase in slope instability as much of the anticipated development would be in already developed areas served by transit and other existing infrastructure. However, some of the anticipated development could require earthwork or otherwise result in soil erosion or slope failure, thus creating a significant impact. Since the 2016 RTP/SCS also guides nearly one-third of growth near the new transit infrastructure, it is recommended that the additional earthwork be considered for the new development in both existing and future HQTAs.

As such, development of transportation projects included in the 2016 RTP/SCS, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, in addition to regional land use strategies included in the 2016 RTP/SCS that encourage compact development within the SCAG region, could result in significant impacts from soil erosion or the loss of topsoil, requiring the consideration of mitigation measures.

IMPACT GEO-3: Potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.

Significant Impact

Development of transportation projects, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, in addition to regional land use strategies included in the 2016 RTP/SCS that encourage compact development, may expose people and structure to geologic hazards and risks due subsidence, slope failure, and the presence of expansive soils where transportation projects and development patterns encouraged by land use strategies are located in these types of soils, constituting a significant impact. Potentially significant impacts to property and public safety could occur due to subsidence, slope failure, and the presence of expansive soils. Subsidence has historically occurred within the SCAG region due to groundwater overdraft and petroleum extraction. **Table 3.7.3-1** shows the number of acres within each County where 2016 RTP/SCS transportation projects and strategies are affected by liquefaction and earthquake-induced landslides. **Figure 3.7.3-1** shows the location of the 2016 RTP/SCS transportation projects and potential development patterns encouraged by land use strategies in relation to these areas. Unconsolidated soils containing petroleum or groundwater often compress when the liquids are removed causing the surface elevation to decrease. Improperly abandoned oil wells or underground hard rock mining can also cause localized subsidence. Areas of historic subsidence within the SCAG region exist in the Santa Clara River Valley and in the historic oil and gas fields of Los Angeles County including the Baldwin Hills, Long Beach, Pomona Chino, Puente Hills, and Antelope Valley areas. Subsidence has also occurred in the Coachella Valley and Murrietta/Temecula areas in Riverside County, Troy Lake, Lucerne Lake, Lucerne Valley, Harper Dry Lake, and Fort Irwin in San Bernardino County, the Santa Ana basin in Orange County, and the Oxnard Plan and Santa Clarita Calleguas Basin in Ventura County. The Port of Long Beach has also experienced subsidence due to the placement of fill along the original coast-line.[24] Subsidence can also occur in areas with unconsolidated soils that have not historically shown elevation changes. Transportation infrastructure designs must include appropriate

[24] State of California Department of Water Resources. 2014. *Summary of Recent Historical Potential Subsidence in California*. Available at: http://www.water.ca.gov/groundwater/docs/Summary_of_Recent_Historical_Potential_Subsidence_in_CA_Final_with_Appendix.pdf

reinforcement to minimize potential impacts from subsidence in areas where such activity has not been witnessed.

Soils with high percentages of clay can expand when wet, causing structural damage to surface improvements. These clay soils could occur in localized areas throughout the SCAG region, making it necessary to survey transportation project and/or strategy areas extensively prior to construction. Each new project location would have the potential to contain expansive soils, although they are more likely to be encountered in lower drainage basin areas. Expansive soils are generally removed during foundation work to avoid structural damage. However, individual new projects (transportation or development under land use strategies) would also require additional CEQA review and impacts would be determined by the assigned lead agency on a project by project basis. Additionally, the 2016 RTP/SCS assumes 47 percent of new residential growth and 56 percent of new employment growth would occur within existing HQTAs where expansive soils may have already been removed.

Slope failure results in landslides and mudslides from unstable soils or geologic units. As discussed above, construction of transportation projects and development pattern encouraged by land use strategies, as included in the Plan, may require substantial earthwork and road cuts, increasing the potential for slope failure.

Development of projects that involve large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, in addition to regional land use strategies included in the 2016 RTP/SCS that encourage compact development, may result in significant impacts from subsidence, slope failure, and the presence of expansive soils where transportation projects and development patterns encouraged by land use strategies are located in these types of soils, requiring the consideration of mitigation measures.

IMPACT GEO-4: Potential to be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

Significant Impact

Development of transportation projects, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, and regional land use strategies included in the 2016 RTP/SCS that encourage compact development, may expose people and structures to risks where transportation projects and development patterns encouraged by strategies are located within expansive soils, constituting a significant impact. Soils with high percentages of clay can expand when wet, causing structural damage to surface improvements. These clay soils can occur in localized areas throughout the SCAG region, making it necessary to survey project areas extensively prior to construction. A total of 1,675 acres of the 2016 RTP/SCS transportation projects and other potential development patterns encouraged by strategies, within Los Angeles County are located on channery clay loam soil (**Figure 3.7.2-7**). Each new project would need to be evaluated on a project-specific basis to determine if the project location would have the potential to contain expansive soils. Expansive soils are generally removed during foundation work to avoid structural damage. The 2016 RTP/SCS assumes 47 percent of the new residential growth and 56 percent of new employment growth would occur within the existing HQTAs, where expansive soils may have already been removed. However, expansive soils are present in many parts of the SCAG region.

As such, the development of transportation projects, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, and regional land use strategies included in the 2016 RTP/SCS that encourage compact development, may result in significant impacts where transportation and potential development projects are located within expansive soils, requiring the consideration of mitigation measures.

IMPACT GEO-5: Potential to have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

Less than Significant Impact

The 2016 RTP/SCS includes transportation investments and regional land use strategies that aim to produce more compact development in well-served transit areas. These land use strategies encourage compact development in HQTAs, existing suburban town centers, and more walkable, mixed-use communities to accommodate the anticipated growth of 3.8 million people by 2040. The 2016 RTP/SCS does not encourage or anticipate residential development in areas where sewers are not available for the disposal of waste water or where densities would not support the provision of sanitary sewers. Therefore, impacts from having soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water would be less than significant, and no mitigation measures are required.

3.7.5 CUMULATIVE IMPACTS

The 2016 RTP/SCS includes coordinated transportation investments and land use growth strategies to increase mobility, promote sustainability, and improve the economy. The RTDM used for this analysis captures pass-through traffic that does not have an origin or destination in the region, but does impact the region. As a result, this pass-through traffic is included in the project analysis. Although development is anticipated to occur within the region even without the 2016 RTP/SCS, this Plan includes regional land use growth policies that could influence growth, including distribution patterns, throughout the region. To address this, the analysis covers overall impacts of transportation projects included in the 2016 RTP/SCS and land development strategies described in the 2016 RTP/SCS. Potentially hazardous geological and seismic conditions are found throughout the SCAG region and Southern California in general, and are generally site specific. The 2016 RTP/SCS encompasses all development (both transportation and land use changes) that would occur in the region through 2040. As a result, the Plan would be expected to contribute to a cumulatively considerable increase in risk associated with geologic hazards.

IMPACT GEO-1: Potential to expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; (ii) strong seismic ground shaking; (iii) seismic related ground-failure, including liquefaction; (iv) landslides.

Significant Cumulative Impact

Implementation of the transportation projects included in the 2016 RTP/SCS, when taken into consideration with related development and infrastructure projects within the SCAG region and surrounding areas, and anticipated growth and land use development patterns, would contribute to cumulative significant impacts with regard to the potential to expose additional people and infrastructure to the effects of earthquakes, seismic related ground-failure, liquefaction, and seismically induced landslides. The 2016 RTP/SCS includes a set of regional land use strategies that are intended to guide future land development patterns to focus new growth in HQTAs, existing suburban town centers, and walkable mixed-use communities. While the specific impact of this pattern of development relative to seismic risk is unknown, it could result in cumulative significant impacts with regard to more people being exposed to the effects of effects of earthquakes, seismic related ground-failure, liquefaction, and seismically induced landslides. **Appendix B, *2016 RTP/SCS Project List***, shows the related transportation projects for each county and major cities in the SCAG region that would be expected to contribute to the cumulative impacts from the 2016 RTP/SCS. **Table 3.7.3-1** shows that 27,061 acres are subject to severe peak ground acceleration, 16 linear miles are within an Alquist-Priolo Earthquake zone, 44,477 acres are subject to potential liquefaction, and 3,892 acres are subject to potential earthquake induced landslides within 500 feet of major SCAG projects. Therefore, the Plan would result in cumulative significant impacts with regard to the potential to expose additional people and infrastructure to the effects of earthquakes, seismic related ground-failure, liquefaction, and seismically induced landslides, requiring the consideration of mitigation measures.

IMPACT GEO-2: Potential to result in substantial soil erosion or the loss of topsoil.

Significant Cumulative Impact

Implementation of the transportation projects included in the 2016 RTP/SCS, when taken into consideration with related development and infrastructure projects within the SCAG region and surrounding areas, and anticipated growth and land use development patterns, would contribute to cumulative significant impacts with regard to the potential to the potential to result in substantial soil erosion or the loss of topsoil. The 2016 RTP/SCS includes a set of regional land use strategies that are intended to guide future land development patterns to focus new growth in HQTAs, existing suburban town centers, and walkable mixed-use communities. While the specific impact of this pattern of development relative to seismic risk is unknown, it could result in cumulative significant impacts with regard to the potential to result in substantial soil erosion or the loss of topsoil. **Appendix B** shows the related transportation projects for each county and major cities in the SCAG region that would be expected to contribute to the cumulative impacts from the 2016 RTP/SCS. **Table 3.7.3-1** shows that 83,212 acres are subject to moderate or high soil erosion potential within 500 feet of major SCAG projects. Therefore, the Plan would result in cumulative significant impacts with regard to the potential to result in substantial soil erosion or the loss of topsoil, requiring the consideration of mitigation measures.

IMPACT GEO-3: Potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.

Significant Cumulative Impact

Implementation of the transportation projects included in the 2016 RTP/SCS, when taken into consideration with related development and infrastructure projects within the SCAG region and surrounding areas, and anticipated growth and land use development patterns, would contribute to cumulative significant impacts with regard to the potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse. The 2016 RTP/SCS includes a set of regional land use strategies that are intended to guide future land development patterns to focus new growth in HQTAs, existing suburban town centers, and walkable mixed-use communities. While the specific impact of this pattern of development relative to seismic risk is unknown, it could result in cumulative significant impacts with regard to the potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse. **Appendix B** shows the related transportation projects for each county and major cities in the SCAG region that would be expected to contribute to the cumulative impacts from the 2016 RTP/SCS. **Table 3.7.4-1** shows that 27,061 acres are subject to severe peak ground acceleration, 16 linear miles are within an Alquist-Priolo Earthquake zone, 44,477 acres are subject to potential liquefaction, and 3,892 acres are subject to potential earthquake induced landslides within 500 feet of major SCAG projects. Therefore, the Plan would result in cumulative significant impacts with regard to the potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse, requiring the consideration of mitigation measures.

IMPACT GEO-4: Potential to be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

Significant Cumulative Impact

Implementation of the transportation projects included in the 2016 RTP/SCS, when taken into consideration with related development and infrastructure projects within the SCAG region and surrounding areas, and anticipated growth and land use development patterns, would contribute to cumulative significant impacts with regard to the potential to be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property. The 2016

RTP/SCS includes a set of regional land use strategies that are intended to guide future land development patterns to focus new growth in HQTAs, existing suburban town centers, and walkable mixed-use communities. While the specific impact of this pattern of development relative to seismic risk is unknown, it could result in cumulative significant impacts with regard to on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property. **Appendix B** shows the related transportation projects for each county and major cities in the SCAG region that would be expected to contribute to the cumulative impacts from the 2016 RTP/SCS. A total of 1,675 acres of the 2016 RTP/SCS transportation projects within Los Angeles County are located on channery clay loam soil (**Figure 3.7.2-7**). Expansive soils are generally removed during foundation work to avoid structural damage. The 2016 RTP/SCS assumes 47 percent of the new residential growth and 56 percent of new employment growth would occur within the existing HQTAs, where expansive soils may have already been removed. However, expansive soils are present throughout the SCAG region. As a result, the development of transportation improvement projects, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, and regional land use strategies included in the 2016 RTP/SCS that encourage compact development the direction of more growth into HQTAs within the SCAG region, may result in significant impacts where transportation and potential development projects are located within expansive soils, requiring the consideration of mitigation measures.

IMPACT GEO-5: Potential to have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

Less than Significant Cumulative Impact

The 2016 RTP/SCS does not encourage or anticipate residential development in areas where sewers are not available for the disposal of waste water or where densities would not support the provision of sanitary sewers. Therefore, cumulative impacts from having soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water would be less than significant.

3.7.6 MITIGATION MEASURES

Mitigation measures as they pertain to each CEQA question related to geology and soils are described below. Mitigation measures are categorized into two categories: SCAG mitigation and project-level mitigation measures. SCAG mitigation measures shall be implemented by SCAG over the lifetime of the 2016 RTP/SCS. Project-level mitigation measures can and should be implemented by Lead Agencies for transportation and development projects, as applicable and feasible.

IMPACT GEO-1: Potential to expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; (ii) strong seismic ground shaking; (iii) seismic related ground-failure, including liquefaction; (iv) landslides.

SCAG Mitigation Measures

MM-GEO-1(a): SCAG shall facilitate minimizing future impacts to geological resources from exposure of people or structures to potential substantial adverse effects involving including the risk of loss, injury, or death involving rupture of a known earthquake fault, strong seismic ground shaking, seismic-related ground failure including liquefaction, landslides; substantial soil erosion or loss of topsoil; off-site landslide, lateral spreading, subsidence, liquefaction, or collapse; and being located on an expansive soil through cooperation, information sharing, and regional program development as part of SCAG's ongoing regional planning efforts. Such efforts shall include web-based planning tools for local government including CA LOTS, and other GIS tools and data services, including, but not limited to, Map Gallery, GIS library, and GIS applications, and direct technical assistance efforts such as Toolbox Tuesday Training series and sharing of associated online training materials. Resource agencies, such as the U.S. Geology Survey, shall be consulted during this update process.

Project-Level Mitigation Measures

MM-GEO-1(b): Consistent with the provisions of Section 15091 of the State CEQA Guidelines, SCAG has identified mitigation measures capable of avoiding or reducing the significant effects on the potential for projects to result in the exposure of people and infrastructure to the effects of earthquakes, seismic related ground-failure, liquefaction, and seismically induced landslides, that are in the jurisdiction and responsibility of public agencies, regulatory agencies, and/or Lead Agencies. Where the Lead Agency has identified that a project has the potential for significant effects, the Lead Agency can and should consider mitigation measures to ensure compliance with County and City Public Works and Building and Safety Department Standards, the Uniform Building Code (UBC) and the California Building Code (CBC), and other applicable laws and regulations governing building standards, as applicable and feasible. Such measures may include the following, or other comparable measures identified by the Lead Agency:

- Consistent with Section 4.7.2 of the Alquist-Priolo Earthquake Fault Zoning Act, conduct a geologic investigation to demonstrate that proposed buildings would not be constructed across active faults. An evaluation and written report of a specific site be prepared by a licensed geologist. If an active fault is found and unfit for human occupancy over the fault, place a setback of 50 feet from the fault.
- Use site-specific fault identification investigations conducted by licensed geotechnical professionals in accordance with the requirements of the Alquist-Priolo Act, as well as any applicable Caltrans regulations that exceed or reasonably replace the requirements of the Act to either determine that the anticipated risk to people and property is at or

below acceptable levels or site-specific measures have been incorporated into the project design, consistent with the CBC and UBC.

- Ensure that projects located within or across Alquist-Priolo Zones comply with design requirements provided in Special Publication 117, published by the California Geological Survey, as well as relevant local, regional, state, and federal design criteria for construction in seismic areas.
- Consistent with the CBC and local regulatory agencies with oversight of development associated with the Plan, ensure that projects are designed in accordance with county and city code requirements for seismic ground shaking. With respect to design, consider seismicity of the site, soil response at the site, and dynamic characteristics of the structure, in compliance with the appropriate California Building Code and State of California design standards for construction in or near fault zones, as well as all standard design, grading, and construction practices in order to avoid or reduce geologic hazards.
- Consistent with the CBC and local regulatory agencies with oversight of development associated with the Plan, ensure that site-specific geotechnical investigations conducted by a qualified geotechnical expert be required prior to preparation of project designs. These investigations shall identify areas of potential expansive soils and recommend remedial geotechnical measures to eliminate any problems. Recommended corrective measures, such as structural reinforcement and replacing soil with engineered fill, shall be implemented in project designs. Geotechnical investigations identify areas of potential failure and recommend remedial geotechnical measures to eliminate any problems.
- Adhere to design standards described in the CBC and all standard geotechnical investigation, design, grading, and construction practices to avoid or reduce impacts from earthquakes, ground shaking, ground failure, and landslides.
- Consistent with the CBC and local regulatory agencies with oversight of development associated with the Plan, projects avoid geologic units or soils that are unstable, expansive soils and soils prone to lateral spreading, subsidence, liquefaction, or collapse wherever feasible.

IMPACT GEO-2: Potential to result in substantial soil erosion or the loss of topsoil.

SCAG Mitigation Measures

MM-GEO-1(a).

Project-Level Mitigation Measures

MM-GEO-2(b): Consistent with the provisions of Section 15091 of the State CEQA Guidelines, SCAG has identified mitigation measures capable of avoiding or reducing the significant effects on the potential for projects to result in substantial soil erosion or the loss of topsoil, that are in the jurisdiction and responsibility of public agencies, regulatory agencies, and/or Lead Agencies. Where the Lead Agency has identified that a project has the potential for significant effects, the Lead Agency can and should consider mitigation measures to ensure compliance with County and City Public Works and Building and Safety Department Standards, the Uniform Building Code (UBC) and the California Building Code (CBC), and other applicable laws and regulations governing building standards, as applicable and feasible. Such measures may include the following, or other comparable measures identified by the Lead Agency:

- Consistent with the CBC and local regulatory agencies with oversight of development associated with the Plan, ensure that site-specific geotechnical investigations conducted by a qualified geotechnical expert are conducted to ascertain soil types prior to preparation of project designs. These investigations can and should identify areas of potential failure and recommend remedial geotechnical measures to eliminate any problems.
- Consistent with the requirements of the State Water Resources Control Board (SWRCB) for projects over one acre in size, obtain coverage under the General Construction Activity Storm Water Permit (General Construction Permit) issued by the SWRCB and conduct the following:
    - File a Notice of Intent (NOI) with the SWRCB.
    - Prepare a stormwater pollution prevention plan (SWPPP) and submit the plan for review and approval by the Regional Water Quality Control Board (RWQCB). At a minimum, the SWPPP should include a description of construction materials, practices, and equipment storage and maintenance; a list of pollutants likely to contact stormwater; site-specific erosion and sedimentation control practices; a list of provisions to eliminate or reduce discharge of materials to stormwater; best management practices (BMPs); and an inspection and monitoring program.
    - Submit to the RWQCB a copy of the SWPPP and evidence of submittal of the NOI to the SWRCB. Implementation of the SWPPP should start with the commencement of construction and continue through the completion of the project.
    - After construction is completed, the project sponsor can and should submit a notice of termination to the SWRCB.
- Consistent with the requirements of the SWRCB and local regulatory agencies with oversight of development associated with the Plan, ensure that project designs provide adequate slope drainage and appropriate landscaping to minimize the occurrence of slope instability and erosion. Design features should include measures to reduce erosion caused by storm water. Road cuts should be designed to maximize the potential for revegetation.
- Consistent with the CBC and local regulatory agencies with oversight of development associated with the Plan, ensure that, prior to preparing project designs, new and abandoned wells are identified within construction areas to ensure the stability of nearby soils.

IMPACT GEO-3: Potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.

SCAG Mitigation Measures

MM-GEO-1 (a).

Project-Level Mitigation Measures

MM-GEO-1(b)

IMPACT GEO-4: Potential to be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

SCAG Mitigation Measures

MM-GEO-1 (a).

Project-Level Mitigation Measures

MM-GEO-1(b)

3.7.7 LEVEL OF SIGNIFICANCE AFTER MITIGATION

IMPACT GEO-1: Potential to expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; (ii) strong seismic ground shaking; (iii) seismic related ground-failure, including liquefaction; (iv) landslides.

Implementation of Mitigation Measures **MM-GEO-1(a)** and **MM-GEO-1(b)** would reduce potential impacts to the seismically active areas and Alquist-Priolo fault zones. However, because of the regional scale of the Plan, the direct, indirect, and cumulative impacts would remain significant and unavoidable..

IMPACT GEO-2: Potential to result in substantial soil erosion or the loss of topsoil.

Implementation of Mitigation Measures **MM-GEO-1(a)** and **MM-GEO-2(b)** would reduce potential impacts from soil erosion and loss of topsoil. However, because of the regional scale of the Plan, the direct, indirect, and cumulative impacts would remain significant and unavoidable..

IMPACT GEO-3: Potential to be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.

Implementation of Mitigation Measures **MM-GEO-1(a)** and **MM-GEO-1(b)** would reduce potential impacts from off-site landslide, lateral spreading, subsidence, liquefaction, or collapse. However, because of the regional scale of the Plan, the direct, indirect, and cumulative impacts would remain significant and unavoidable.

GEO-4: Potential to be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.

Implementation of Mitigation Measures **MM-GEO-1(a) and MM-GEO-1(b)** would reduce potential impacts from expansive soils. However, because of the regional scale of the Plan, the direct, indirect, and cumulative impacts would remain significant and unavoidable.