3.7 GEOLOGY AND SOILS

This section of the Program Environmental Impact Report (PEIR) describes the geological characteristics of the SCAG region, identifies the regulatory framework with respect to laws and regulations that govern geology and soils, and analyzes the significance of the potential impacts that could result from development of the Connect SoCal Plan ("Connect SoCal"; "Plan"). In addition, this PEIR provides regional-scale mitigation measures as well as project-level mitigation measures to be considered by lead agencies for subsequent, site-specific environmental review to reduce identified impacts as appropriate and feasible. Information regarding paleontological resources was largely obtained from the Paleontological Resources Report prepared by SWCA and included as Appendix 3.7 of this PEIR.

3.7.1 ENVIRONMENTAL SETTING

3.7.1.1 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.

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.

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.

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.

Unique geologic feature: An important and irreplaceable geological formation. Such features may have scientific and/or cultural values.

Unique paleontological resource: A fossil that meets one or more of the following criteria:

- It provides information on the evolutionary relationships and developmental trends among organisms, living or extinct.
- It provides data useful in determining the age(s) of the rock unit or sedimentary stratum, including data important in determining the depositional history of the region and the timing of geologic events therein.
- It provides data regarding the development of biological communities or interaction between plant and animal communities.
- It demonstrates unusual or spectacular circumstances in the history of life.
- The fossils are in short supply and/or in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and are not found in other geographic locations.

3.7.1.2 Existing Conditions

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.[1] 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.[2]

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.

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 3.7-1, 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 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.

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1 U.S. Geological Survey. *Information by Region – California*. Available online at: https://earthquake.usgs.gov/earthquakes/byregion/california.php, accessed July 22, 2019.

2 Geologycafe.com. *Geologic History of California*. Available online at: https://geologycafe.com/geologic_history/index.html, accessed August 30, 2019.

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*. Available online at: https://www.conservation.ca.gov/cgs/Documents/Note_36.pdf, accessed June 12, 2019.

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.

Paleontological Setting

Given the diversity of geologic units found in the SCAG region, the paleontology is equally diverse, and, in some areas, fossils are quite abundant. A detailed analysis of the paleontological sensitivity of each geologic formation in the SCAG region is beyond the scope of this analysis and should be the subject of project-specific paleontological assessments (see recommendations below). The SVP (2010) defines fossils as being over 5,000 years in age, while the BLM (2009, 2016) generally considers fossils to be Pleistocene in age or older (11,700 years in age). Therefore, sediments younger than middle or early Holocene are too young to preserve fossil resources and have low (SVP) or PFYC 2 (BLM) paleontological sensitivity. Other types of geologic units with low sensitivity are moderately metamorphosed rocks, as the heat and pressure associated with metamorphism is likely to destroy fossils. High grade metamorphic rocks, as well as igneous rocks, have no paleontological sensitivity.

Some generalizations about the primary types of fossil bearing rocks can be made, based on the 1:750,000 scale geologic mapping by Jennings et al. (2010), as discussed below.

Cenozoic Marine Deposits

Cenozoic marine deposits date from the Paleocene to the Pliocene and were deposited on the ancient seafloor. These geologic formations are well known for being highly fossiliferous in southern California and may preserve a wide variety of marine fauna: invertebrates such as mollusks, crustaceans, echinoderms, and others; marine vertebrates such as shark and other fish, whales, seals, sea lions, and others; and even terrestrial vertebrates such as horse, camel, bison, and others that washed out to sea and where buried in the near-shore marine deposits.

These deposits are particularly common at the surface in the Transverse Ranges in Ventura County, where Eocene and Miocene units are prevalent, coastal Orange County, central Imperial County as scattered outcrops around the Salton Sea, and central Los Angeles County. In the subsurface, these deposits are likely to be encountered underlying the younger surficial alluvium across large parts of the Los Angeles and San Bernardino basins.

Some of these units with the highest paleontological sensitivity (BLM PFYC class 4 or 5, SVP high potential) are discussed below:

Shallow Marine Deposits. Shallow marine deposits such as the San Pedro Sand and the Palos Verdes Sand have a strong record of preserving Pleistocene-aged marine and terrestrial fossils. The San Pedro Sand has yielded a diverse fauna of nearshore marine invertebrates such as crabs, snails, bivalves, gastropods, and echinoids and vertebrates such as sharks, bony fish, amphibians, reptiles, birds, whales, antelopes, mammoth, dire wolves, rodents, and bison. These units are common along coastal southern California, including Ventura, Los Angeles, and Orange Counties in the SCAG region. Many abundant fossil localities have been collected from excavations in San Pedro around the Port of Los Angeles, where the setting is very similar to that of the program area, with artificial fill covering old marine deposits. These deposits have yielded thousands of specimens of marine invertebrates that are significant for reconstructing changes in shallow marine ecosystems as the climate has changed since the Pleistocene.[5]

Fernando Formation. The Fernando Formation dates to the Pliocene and consists of marine siltstone, sandstone, pebbly sandstone, and conglomerate. The Fernando is common in the Transverse Ranges, particularly in Los Angeles County, where it is found extensively in the subsurface throughout the Los Angeles Basin. The lower part of the Fernando Formation consists of a pebble-cobble conglomerate in a sandstone matrix that fines upwards into a coarse sandstone and then a silty sandstone. The upper Fernando Formation consists of coarse-grained sandstone with conglomerate lenses. The Fernando

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5 SWCA Environmental Consultants. 2019. *Draft Paleontological Resources Technical Report for the 2020-2045 Regional Transportation Plan and Sustainable Communities Strategy for the Southern California Association of Governments*.

Formation has an extensive record of preserving scientifically significant fossils, including invertebrates such as mollusks, echinoids, and bryozoans, fish, squid, and a number of unidentified megafossils.[6]

Bouse Formation. The Bouse Formation spans the early Pliocene to the late Miocene and has been interpreted to represent either a marine estuarian or lacustrine depositional environment. The Bouse Formation is found in the Mojave Desert Geomorphic Province and consists of calcareous clay, silt, and sand. Abundant common invertebrate fossils such as gastropods, ostracodes, barnacles, and foraminifera, as well as fish and plants are known from the Bouse Formation.[7]

Puente Formation. The Puente Formation, often synonymous with the Modelo Formation, consists of marine sandstone, siltstone, and shale that dates from the early Pliocene to the Miocene. The Puente Formation has a history of preserving both invertebrate and vertebrate marine fossils, such as cephalopods, crustaceans, fishes, and other marine and terrestrial vertebrates. The Puente Formation is common in the Peninsular Ranges and Transverse Ranges provinces.[8]

Monterey Formation. The Monterey Formation records the filling of a deep basin formed by tectonism along the California margin and constitutes one of the major elements of California geology and can range up to several thousands of feet thick. The Monterey ranges in age from the Pliocene to middle Miocene and can be found throughout the basins of the Peninsular Ranges and Transverse Ranges provinces in the subsurface. The Monterey has yielded a diverse fauna consisting of some mollusks and common fish skeletons, and remains of larger marine macrofauna such as whales and the giant extinct Desmostylus, as well as birds, crocodiles and rare land organisms such as horse and land plants.[9]

Vaqueros Formation. The Vaqueros Formation consists of predominately limey sandstone interbedded with siltstone and shale deposited in an offshore basin. The Vaqueros Formation is common in the Peninsular Ranges and Transverse Ranges provinces and dates from the early Miocene to the late Eocene. Common fossils in the Vaqueros include marine invertebrates such as barnacles, ostreids, pectinids and marine ichnofossils, as well as terrestrial vertebrates and marine megafauna.[10]

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[6] SWCA Environmental Consultants. 2019. Draft Paleontological Resources Technical Report for the 2020-2045 Regional Transportation Plan and Sustainable Communities Strategy for the Southern California Association of Governments.

[7] Ibid.

[8] Ibid.

[9] Ibid.

[10] Ibid.

Cenozoic Terrestrial Deposits

Cenozoic terrestrial deposits date from the Paleocene to the Pleistocene and were deposited in terrestrial environments as alluvial sediments, fluvial sediments, and lacustrine deposits. These geologic formations are well known for being highly fossiliferous in southern California and may preserve a wide variety of terrestrial fauna: invertebrates such as mollusks; plants; and abundant terrestrial vertebrates such as horse, camel, bison, and others.

These deposits are particularly common at the surface in the Mojave and Colorado Desert provinces but are found scattered across the entire SCAG region. Some of these units with the highest paleontological sensitivity (BLM PFYC class 4 or 5, SVP high potential) are discussed below.

Pleistocene Alluvium. Pleistocene alluvium consists of sand, silt, and gravel deposited in terrestrial environments as the result of erosion of surrounding highlands and dates to the Pleistocene (11,000–2.58 ma). Pleistocene sediments have a rich fossil history in southern California.[11]

The most common Pleistocene terrestrial mammal fossils include the bones of mammoth, horse, bison, camel, and small mammals, but other taxa, including lion, cheetah, wolf, antelope, peccary, mastodon, capybara, and giant ground sloth, have been reported, as well as birds, amphibians, and reptiles such as frogs, salamanders, snakes, and turtles. In addition to illuminating the striking differences between Southern California in the Pleistocene and today, this abundant fossil record has been vital in studies of extinction, ecology, and climate change.[12]

An excellent example of the striking abundance and diversity of these Pleistocene sediments comes from Riverside County, just south of San Bernardino County, where nearly 100,000 identifiable fossil specimens representing 105 vertebrate, invertebrate, and plant species were collected from more than 2,000 individual localities during the construction of the dam at Diamond Valley Lake and are now housed at the Western Science Center in Hemet, California. This site represents the second largest late Pleistocene fossil assemblage known from the American Southwest after the La Brea Tar Pits in Los Angeles. Other Ice Age fossils have been found throughout the inland valleys and the Mojave Desert.[13]

Manix Formation. The Manix Formation consists of around 40 m of lacustrine, fluvial, and alluvial sediments deposited in and around the Middle to late Pleistocene Lake Manix. This formation occurs to the east of Barstow in the Mojave Desert. The lacustrine and fluvial deposits in this formation have

11 Ibid.

12 Ibid.

13 Ibid.

yielded a diverse fauna, preserving invertebrates such as mollusks and ostracods as well as aquatic and terrestrial vertebrates such as fish, birds, and numerous Ice Age mammals.[14]

San Timoteo Formation. The San Timoteo Formation dates from the Pleistocene to the Pliocene and consists of stream-deposited alluvial sediments that are made up of detritus eroded from the San Bernardino Mountains in the Mojave Desert and southeastern Transverse Ranges provinces. A number of significant fossil deposits have been discovered in the San Timoteo. The construction of the El Casco Substation in San Timoteo Canyon between September 2009 and January 2011 produced numerous fossils, including riparian and aquatic plants, insects, slugs and snails, fish, tortoise, lizards, snakes, small mammals, birds, a giant camel, a llama, two ground sloths, and two different types of saber tooth cats. The Shutt Ranch fauna is a collection of hundreds of significant fossils belonging to 37 species of small mammals, as well as larger macrofauna such as sloth, camel, deer, horse, and others, found in the San Timoteo beds. The scientific literature records a rich fossil history from this unit that includes fossils of more than 30 plant taxa and over forty animal taxa, including camels, deer, sloth, elephants, bears, rabbits, and rodents. This fauna has been the subject of study for almost 100 years.[15]

Avawatz Formation. The Avawatz Formation consists of four members: conglomerate, siltstone and sandstone, breccias, and sandstone, siltstone, and tuff deposited in alluvial fans, floodplains, and lakes, spanning a period of around 40 Ma, during the late Miocene. The Avawatz Formation is found in the Avawatz Mountains in the Mojave Desert province. The Avawatz preserves a typical Miocene mammalian fauna of early ancestors of horses and camels, as well as abundant rodents and some reptiles. In addition, the Avawatz is known for preserving exceptional fossil trackways from dozens of different types of animals, including birds, camels, and cats. Trackways are significant fossil resources, and provide valuable information on not only foot morphology, but also how an animal moved and potentially whether it was part of a herd. The Raymond M. Alf Museum in Claremont, California, has more than 100 fossil trackways collected from the Avawatz in San Bernardino County.[16]

Topanga Group. The Topanga Group is predominantly composed of sandstone but also some siltstone, breccia, and shale. Formations within the Topanga Group are common across the basins of the Peninsular Ranges and Transverse Ranges provinces. The Topanga is interpreted to represent wave-dominated coastal deposits grading into river-dominated deltaic deposits and fluvial deposits in the upper parts of the formation. The Topanga Formation dates to the middle Miocene, around 20 to 16 Ma. Fossils from the Topanga Formation include numerous invertebrate and vertebrate remains from both

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14 Ibid.

15 Ibid.

16 Ibid.

marine and terrestrial settings, including sharks, bony fishes, birds, whales, dolphins, and land mammals.[17]

Barstow Formation*.* The Barstow Formation is composed of fluvial and lacustrine sediments interbedded with air-fall tuff beds deposited in lakes from around 14.8 to 19.3 ma. This formation crops out across the Mojave Desert province. The fossil mammal fauna of the Barstow is so abundant it has been used to define a biostratigraphic portion of the middle Miocene called the Barstovian North American Land Mammal Age. The University of California, Berkeley, conducted extensive excavations of the mammal fossils shortly after they were first discovered in the Mud Hills. The most common fossils from the Barstow Formation include early ancestors of horses, antelope, and camels, as well as small mammals such as mice and rabbits, with birds, fish, invertebrates, reptiles, and early ancestors of canines and elephants less common but well represented. In addition to the vertebrate fauna, an extensive record of exceptionally preserved small organisms, such as insects and arthropods, are known from the Barstow. These fossils have been extensively studied and reported on in the scientific literature, leading to a better understanding of the early evolution of many modern animals ranging from horses and camels to insects, as well as paleoecology.[18]

Earthquake Faults

The SCAG region is seismically active. 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.[19] 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

17 Ibid.

18 Ibid.

19 It should be noted that new faults continue to reveal themselves, such as in the case of the Ridgecrest quake of 2019, and the potential seismic threats posed by these faults also continue to be reevaluated on the basis of new geologic information and analysis.

earthquakes, both classified as magnitude 6.7 earthquakes.[20] In July 2019, a magnitude 7.1 earthquake struck on a previously unnamed fault system near Ridgecrest in San Bernardino County. Two foreshocks of 5.4 and 6.1 preceded the larger 7.1 earthquake.

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 3.7-1, Characteristics of Major Faults in the SCAG Region,** and **Figure 3.7-2, Alquist-Priolo Zones and Areas of Probabilistic Ground Acceleration**). 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.[21]

Table 3.7-1
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 Late Quaternary Latest Quaternary	24.0–34.0	7.2–7.5

[20] 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.

[21] United States Geological Survey. 2000. *Quaternary Fault and Fold Database Background*. Available online at: https://earthquake.usgs.gov/hazards/qfaults/background.php, accessed July 15, 2019.

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
San Jacinto – Imperial Fault Zone	San Bernardino Riverside Imperial	Historic Holocene Late Quaternary Latest Quaternary	4.0–20.0	6.6–7.2
Elsinore Fault Zone	Los Angeles Orange Riverside Imperial San Bernardino	Historic Holocene Late Quaternary Latest Quaternary	2.5–5.0	6.8–7.1
Class B Faults				
Elsinore and San Jacinto Fault Zones (Non A Faults)				
Brawley Seismic Zone	Imperial	Historic	25.0	6.4
Chino	San Bernardino Riverside	Latest Quaternary	1.0	6.7
Elmore Ranch	Imperial		1.0	6.6
Garlock Fault Zones				
Garlock – west	Los Angeles San Bernardino	Latest Quaternary	6.0	7.3
Garlock – east	San Bernardino	Late Quaternary Latest Quaternary	7.0	7.5
Owl Lake	San Bernardino	Latest Quaternary	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	Late Quaternary Latest Quaternary	1.0	6.4
Holser	Los Angeles Ventura	Late Quaternary	0.4	6.5
Malibu Coast	Los Angeles Ventura	Late Quaternary Latest Quaternary	0.3	6.7
Mission Ridge – Arroyo Parida – Santa Ana	Ventura	Late Quaternary Latest Quaternary	0.4	7.2
Newport-Inglewood	Los Angeles Orange	Historic Late Quaternary Latest Quaternary	1.0	7.1
Oak Ridge	Ventura	Holocene Late Quaternary Latest Quaternary	4.0	7.0
Palos Verdes	Los Angeles	Late Quaternary Latest Quaternary	3.0	7.3
Raymond	Los Angeles	Late Quaternary Latest Quaternary	1.5	6.5
Red Mountain	Ventura	Late Quaternary Latest Quaternary	2.0	7.0
San Cayetano	Ventura	Late Quaternary Latest Quaternary	6.0	7.0

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
San Gabriel	Ventura Los Angeles San Bernardino	Holocene Late Quaternary Latest Quaternary	1.0	7.2
San Jose	Los Angeles	Late Quaternary	0.5	6.4
Santa Monica	Los Angeles	Late Quaternary Latest Quaternary	1.0	6.6
Santa Ynez (East)	Ventura	Late Quaternary	2.0	7.1
Santa Susana	Ventura Los Angeles	Historic Late Quaternary	5.0	6.7
Sierra Madre	Ventura Los Angeles San Bernardino	Holocene Historic Late Quaternary Latest Quaternary	2.0	7.2
Simi-Santa Rosa	Ventura Los Angeles	Late Quaternary Latest Quaternary	1.0	7.0
Ventura-Pitas Point	Ventura	Latest Quaternary	1.0	7.0
Verdugo	Los Angeles	Late Quaternary Latest Quaternary	0.5	6.9
Los Angeles Blind Thrusts				
Upper Elysian Park	Los Angeles	Quaternary	1.3	6.4
Northridge	Ventura Los Angeles	Historic	1.5	7.0
Puente Hills blind thrust	Los Angeles Orange	Historic Quaternary	0.7	7.1
San Joaquin Hills	Orange	Latest Quaternary	0.5	6.6
Transverse – Ranges and Mojave				
Blackwater	San Bernardino	Latest Quaternary Undifferentiated Quaternary	0.6	7.1
Burnt Mountain	San Bernardino Riverside	Historic Latest Quaternary	0.6	6.5
Calico-Hidalgo	San Bernardino	Historic Latest Quaternary Undifferentiated Quaternary	0.6	7.3
Cleghorn	San Bernardino	Late Quaternary Undifferentiated Quaternary	3.0	6.5
Eureka Peak	San Bernardino Riverside	Historic Latest Quaternary	0.6	6.4
Gravel Hills – Harper Lake	San Bernardino		0.6	7.1
Helendale – S. Lockhart	San Bernardino	Late Quaternary Latest Quaternary	0.6	7.3
Johnson Valley (Northern)	San Bernardino	Historic Latest Quaternary	0.6	6.7

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
Lenwood – Lockhart – Old Woman Springs	San Bernardino	Historic Late Quaternary Latest Quaternary	0.6	7.5
North Frontal Fault zone (Western)	San Bernardino	Late Quaternary Latest Quaternary	1.0	7.2
North Frontal Fault zone (Eastern)	San Bernardino	Latest Quaternary	0.5	6.7
Pinto Mountain	San Bernardino	Late Quaternary Latest Quaternary	2.5	7.2
Pisgah – Bullion Mountain – Mesquite Lake	San Bernardino	Historic Late Quaternary Latest Quaternary	0.6	7.3
S. Emerson – Copper Mountain	San Bernardino	Latest Quaternary	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 150 years).
Latest Quaternary: Refers to a period of time between the present and 15,000 years before present. Faults of this age are commonly considered active.
Late Quaternary: Refers to the time period between the present and approximately 130,000 years before the present.
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). Available online at: https://www.conservation.ca.gov/cgs/Pages/PSHA/shaking-assessment.aspx, accessed 13 May 2019.
U.S. Geological Survey, Quaternary Fault and Fold Database. Available online at: https://earthquake.usgs.gov/cfusion/qfault/query_main_AB.cfm?CFID=1322837&CFTOKEN=66fceb6a140aa938-F82CC7E1-A43F-D9BB-AC8B50A1C3900752, accessed 13 May 2019.
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.

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 2045 is 75 percent.[22]

22 United States Geological Survey, *Uniform California Earthquake Rupture Forecast*, *Version 3*, March 2015.

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.

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, Alquist-Priolo Zones and Potential Areas of Probabilistic Ground Acceleration)**. The estimated maximum moment magnitudes represent characteristic earthquakes on particular faults.[23] 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. 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 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).** Detailed maps are distributed to all affected cities, counties, and state agencies for their use in planning new or

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23 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.

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 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. 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 3.7-3, 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 3.7-3).** 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. The July 2019 M7.1 Ridgecrest Earthquake and its preceding M6.4 and M5.4 foreshocks were felt across much of Southern California and into parts of Arizona, Nevada, and the San Francisco Bay Area. The M7.1 mainshock was the strongest earthquake to occur in the state in nearly 20 years. Although mobile homes, chimneys, and gas lines suffered damage, no major subsidence or landslide incidents were reported as a result of this earthquake.

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 3.7-4 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 3.7-5, Areas Susceptible to Tsunamis**).[24] 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

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24 California State Department of Conservation. *California Official Tsunami Inundation Maps*. Available online at: https://www.conservation.ca.gov/cgs/tsunami/maps#Interactive, accessed June 24, 2019.

struck the Queen Charlotte Islands of the west coast of Canada. A resulting tsunami was 0.08 meter or 0.26 foot and occurred in Santa Monica.[25]

Soils and Geologic Materials

Soils within the SCAG region are classified by distinguishing characteristics and are arranged within soil associations.[26] 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.[27] These limitations are listed and discussed below. **Figure 3.7-6, General Soil Types**, shows the general location of soil types contained within the SCAG region.

Erosion

Soil erosion is a natural ongoing process that transports, erodes, and displaces soil particles through a transport mechanism such as flowing water or wind. In addition, erosion results from manmade activity when soil coverings are stripped leaving the underlying soil exposed to the elements. 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. 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.

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

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[25] California State Department of Conservation. *List of Historic Tsunamis in California*. Available online at: https://www.conservation.ca.gov/cgs/tsunami, accessed June 24, 2019.

[26] 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.

[27] U.S. Department of Agriculture, Soil Conservation Service. 1970. Soil Survey of Ventura Area, California. Washington, DC.

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.[28]

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 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. 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.[29]

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

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28 Michigan State University, RUSLE Online Soil Erosion Assessment Tool. Available online at: http://www.iwr.msu.edu/rusle/kfactor.htm, accessed June 24, 2019.

29 California State Water Resources Control Board. RUSLE K Values. Available online at: https://www.waterboards.ca.gov/water_issues/programs/stormwater/docs/constpermits/guidance/k_factor_map.pdf, accessed June 24, 2019.

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 3.7-7, 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. 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. Land subsidence can also result from persistent and prolonged drought. Prolonged drought can also exacerbate the above causes of subsidence as in the case of groundwater extraction for agricultural purposes. As there is less surface water available, more groundwater is extracted, thus increasing the potential for subsidence.[30]

The impact of subsidence could include lowering of the land surfaces, increased potential for flooding, potential disturbance or damage to transportation infrastructure, 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

30 U.S. Geological Survey. n.d. Areas of Land Subsidence in California. Available online at: http://ca.water.usgs.gov/land_subsidence/california-subsidence-areas.html, accessed July 23, 2019.

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.[31]

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-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).[32] Soils with poorly or excessively drained soils are generally not suitable for septic tanks or alternative waste water disposal

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31 California Water Foundation. April 2014. Land Subsidence from Groundwater Use in California. Available online at: https://water.ca.gov/LegacyFiles/waterplan/docs/cwpu2013/Final/vol4/groundwater/13Land_Subsidence_Groundwater_Use.pdf, accessed June 24, 2019.

32 California State Water Resources Control Board. 3.2C – Construction Practices – Onsite Wastewater Treatment Systems (OWTS). Available online at: https://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia/3_2c_const_owts.html, accessed June 24, 2019.

systems.[33] According to the U.S. Environmental Protection Agency, it is 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.[34]

3.7.2 REGULATORY FRAMEWORK

3.7.2.1 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

33 Ibid.

34 U.S. Environmental Protection Agency. Website. Available at: http://water.epa.gov/aboutow/owm/upload/2004_07_07_septics_septic_2002_osdm_all.pdf, accessed July 22, 2019.

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.

Clean Water Act Section 402

Section 402 of the Clean Water Act (33 U.S. Code Section 1251 et seq.) establishes a framework for regulating municipal and industrial stormwater discharges under the National Pollutant Discharge Elimination System (NPDES) program. The NPDES program controls water pollution by regulating point sources that discharge pollutants, including rock, sand, dirt, and agricultural, industrial, and municipal waste, into waters of the United States. The Environmental Protection Agency has delegated to the State Water Resources Control Board the authority for the NPDES program in California, which is implemented by the State's nine Regional Water Quality Control Boards. Under the NPDES Phase II Rule, construction activity disturbing 1 or more acres must obtain coverage under the State's General Permit for Discharges of Storm Water Associated with Construction Activity (General Construction Permit). As described further in **Section 3.10, Hydrology and Water Quality,** the Construction General Permit requires that applicants develop and implement a Stormwater Pollution Prevention Plan (SWPPP), which specifies best management practices (BMPs) that reduce pollution in stormwater discharges to the Best Available Technology Economically Achievable/Best Conventional Pollutant Control Technology standards and perform inspections and maintenance of all BMPs.

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.

3.7.2.2 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.

In addition to the Seismic Hazards Mapping Act, the CGS provides guidelines (Guidelines for Evaluating and Mitigating Seismic Hazards in California) for evaluating seismic hazards other than surface fault rupture, and for mitigation measures as required by PRC Section 2695(a). The most current guidelines are provided in Special Publication 117A of 2008.

California Building Code

The California Building Code (CBC) is a compilation of building standards codified in the California Code of Regulations, Title 24, Part 2. The provisions of the CBC apply to the construction, alteration, movement, replacement, location, and demolition of every building or structure in California. The CBC is published on a triennial basis, and supplements and errata can be issued throughout the cycle. The 2016 edition of the CBC became effective on January 1, 2017, and is based on the 2015 International Building Code (IBC) of the International Code Council, with California amendments. The 2016 CBC incorporates the latest seismic design standards for structural loads and materials, as well as provisions from the National Earthquake Hazards Reduction Program to mitigate losses from an earthquake.

CBC standards are based on the following:

- Building standards that have been adopted by state agencies without change from a national model code such as the IBC;
- Building standards based on a national model code that have been changed to address conditions specific to California; and
- Building standards authorized by the California legislature but not covered by the national model code.

The CBC includes provisions for demolition and construction, as well as regulations regarding building foundations and soil types to protect people and property from hazards associated with falling debris or construction processes. Seismic standards within the CBC are among the strictest in the world due to California's susceptibility to earthquakes and other seismic events.

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, based on the California Geological Survey and USGS's ShakeOut Scenario of 2008, was released in 2010 and 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.

3.7.2.3 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)). **Table 3.7-1** and **Figure 3.7-2** above show the potentially active faults in the SCAG region. 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.

3.7.3 ENVIRONMENTAL IMPACTS

3.7.3.1 Thresholds of Significance

For the purposes of this PEIR, SCAG has determined that adoption and/or implementation of the Plan could result in significant adverse impacts related to geology and soils if the Plan would result in any of the following:

- Directly or indirectly cause 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.

- 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 direct or indirect 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.
- Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.

3.7.3.2 Methodology

This section evaluates 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 was evaluated in accordance with Appendix G of the 2019 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 and review of published and unpublished literature germane to the SCAG region.. 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 2045 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[35] and urban development patterns from the 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 Plan. **Table 3.7-2, Potential Geologic Hazards Impacts from the Plan**, and **Figure 3.7-8, Connect SoCal Projects in Relation to Geologic Hazards**, show the results of this analysis.

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[35] 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.

Table 3.7-2
Potential Geologic Hazards Impacts from the Plan

County	Potential Liquefaction (acres)	Potential Earthquake Induced Landslides (acres)
Imperial	n/a	N/a
Los Angeles	14,343.88	736.34
Orange	4,197.14	152.85
Riverside	46.02	6.16
San Bernardino	0.15	
Ventura	2591.39	106.51
Total SCAG Area	**21,179**	**1,002**

Source: SCAG GIS analysis and data, 2019
Note: data for Imperial County is not available

In 2015, the California Supreme Court in *California Building Industry Association v. Bay Area Air Quality Management District (CBIA v. BAAQMD* (2015) 62 Cal.4th 369), held that CEQA generally does not require a lead agency to consider the impacts of existing environmental conditions on the future residents or users of a project. However, if a project risks exacerbating preexisting environmental hazards or conditions, the lead agency is required to analyze the impact of that exacerbated condition on the environment, which may include future residents and users within the project area. Generally, transportation and land use projects under the Plan would not exacerbate existing environmental hazards related to geological and soil conditions, nonetheless, consistent with past practice, information is presented on geologic hazards at the regional level that may be of use to local jurisdictions or other readers of the Plan or PEIR.

The mitigation measures in the PEIR are divided into two categories: SCAG mitigation and project-level mitigation measures. SCAG mitigation measures shall be implemented by SCAG over the lifetime of the Plan. For projects proposing to streamline environmental review pursuant to SB 375, SB 743, or SB 226 (as described in **Section 1.0, Introduction**), or for projects otherwise tiering off this PEIR, the project-level mitigation measures described below (or comparable measures) can and should be considered and implemented by Lead Agencies and Project Sponsors during the subsequent, project- or site-specific environmental reviews for transportation and development projects as applicable and feasible. However, SCAG cannot require implementing agencies to adopt mitigation, and it is ultimately the responsibility of the implementing agency to determine and adopt project-specific mitigation.

3.7.3.3 Impacts and Mitigation Measures

Impact GEO-1 **Directly or indirectly cause 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.**

Less than Significant Impact.

Connect SoCal identifies new transit and rail routes, expansion highway routes and other facilities, all of which are subject to seismic events to some degree (See **Table 3.7-1**). Seismic events can damage transportation infrastructure and urban development through surface rupture, ground shaking, liquefaction, and landslides. As illustrated in **Table 3.7-1**, 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 projects analyzed in the Plan. Also, as described in the existing setting, it is expected there are unknown faults that could also significantly damage transportation infrastructure or the built environment. The plan contains transportation projects that would be located in areas prone to landslide, liquefaction and/or erosion. Indirect impacts could also promote additional delays and breaks in service while repairs are made. The potential for transportation projects and anticipated development projects 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. As shown in **Table 3.7-2**, **Potential Geologic Hazards Impacts from the Plan,** approximately 21,000 acres of land are within 500 feet of Plan transportation projects. Potential hazards associated with liquefaction would be addressed through site-specific geotechnical studies required by local jurisdictions in accordance with standard industry practices and state-provided guidance, such as CGS Special Publication 117A, which specifically address liquefaction.

The land use strategies would have the potential to direct more growth into existing urban centers, walkable mixed-use communities, transit-oriented development, and other areas well-served by transit such as high-quality transit areas (HQTAs). Increased density could increase the number of people and structures exposed to potential fault rupture at a given location. For example, if a fault were to rupture adjacent to an urban center more people would be affected than if fault rupture were to occur in a remote area of the region with few people (as was the case with the Ridgecrest earthquake). Strength of a particular earthquake and proximity to the fault would also be factors in how many people are affected by an earthquake.

Implementation of the Plan would result in projects exposed to both direct and indirect effects of seismic activities compared to existing conditions. However, the Plan would neither cause nor exacerbate existing geologic hazards, including the likelihood of fault rupture. This condition exists throughout the SCAG region as it is a seismically active area.

Transportation projects would be in proximity to known faults, increases in population would also result in people being located near known faults. Potential direct impacts from surface rupture and severe ground shaking could cause catastrophic damage to transportation infrastructure, including overpasses and underground structures. Indirect impacts from seismic events could damage ancillary transportation facilities such as port facilities, traffic control equipment, and train stations. With regard to land use development, seismic activity can cause damage to existing structures designed due to substandard construction. Further, as noted above, earthquakes can occur within previously undetected fault zones. For example, the July 2019 Ridgecrest earthquakes occurred within previously undetected fault zones and caused an excess of $100 million in damages.[36] A catastrophic earthquake on the San Andreas Fault would have the potential to cause 1,800 fatalities, displace 9 million people, and cause more than $200 billion in damages.[37]

The Alquist-Priolo Act prohibits the location of structures for human occupancy across active faults. Local jurisdictions require a surface fault rupture hazard investigation for any development project that would be located within an Alquist-Priolo Earthquake Fault Zone. This is to ensure that proposed development would not be located astride an active fault. In addition, the CBC contains numerous regulations designed to address seismic hazards.

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[38]) also reduce potential damage to structures and minimize the seismic impacts to the public. For example, the City of Los Angeles has issued mandatory retrofitting notices to owners of soft-story buildings under

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36 CBS News, *Recent California Earthquakes a Stark Warning for Los Angeles, July 8, 2019.* Available online at: https://www.cbsnews.com/news/california-earthquakes-a-stark-warning-for-los-angeles-ridgecrest-trona/, accessed September 5, 2019.

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

38 California Building Standards Commission. 2016. *2016 California Building Standards Code*. Available online at: https://www.dgs.ca.gov/BSC/Codes, accessed May 21, 2019.

Ordinance 183893 and 184081. As of October 2019, approximately 82 percent of property owners receiving notices have submitted plans to retrofit or provide proof of a past retrofit.[39]

As discussed above, implementation of the Plan would not exacerbate existing geologic hazards including fault rupture because the SCAG region is a seismically active area, and this condition exists throughout the region. Furthermore, there are numerous regulations in place to reduce such risks to any planned development or transportation project, and therefore, the potential impacts of the Plan with regard to fault rupture are less than significant. No mitigation measures are necessary.

Impact GEO-2 Result in substantial soil erosion or the loss of topsoil.

Significant and Unavoidable Impact – Mitigation Required.

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

Soil erosion and its subsequent loss are the result of the actions of water and wind. The likelihood of erosion is higher with an increase in slope, the narrowing of runoff channels, and the removal of groundcover such as vegetation. Human activities associated with development such as grading, particularly on slopes, increase the risk for erosion in affected areas. Erosion also increases the risks of dust storms which can degrade air quality.

Several transportation projects included in the Plan 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 which may result in soil erosion and the loss of topsoil. Some transportation projects and anticipated development projects may also require significant earthwork including cuts into hillsides, which could become unstable over time, increasing long-term erosion potential. Strategies that encourage denser development could also contribute to loss of topsoil through construction of underground parking garages.

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[39] City of Los Angeles. *Soft Story Retrofit Program.* Available online at: http://www.ladbs.org/services/core-services/plan-check-permit/plan-check-permit-special-assistance/mandatory-retrofit-programs/soft-story-retrofit-program, accessed October 23, 2019.

Improvements and modifications to existing rights-of-way, such as HOV lanes, HOT lanes, new busways 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.

Figure 3.7-8, Connect SoCal Projects in Relation to Geologic Hazards, shows the location of projects identified in the Plan in relation areas with soils subject to moderate and high potential for soil erosion.

Notwithstanding natural soil types, engineered soils can also erode due to poor construction methods and design features or lack of maintenance. Transportation projects included in the Plan are in areas susceptible to geologic hazards including high soil erodibility. Construction of additional lanes on freeways, other transportation facilities or development could also potentially result in the loss of topsoil, through grading, trenching, excavation, and/or soil removal.

The Plan includes coordinated and integrated regional strategies for transportation investments and land use growth that aim to focus more development in urbanized areas such as HQTAs, livable corridors, neighborhood mobility areas, 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.

Throughout California, the Regional Water Quality Control Boards (RWQCB) set erosion control standards because one of the major effects of grading is sedimentation of receiving waters. These control standards are administered via the NPDES permit process for storm drainage discharge. One of the requirements of this permit is the implementation of nonpoint source control of stormwater runoff through the application of Best Management Practices (BMPs). A Storm Water Pollution Prevention Plan (SWPPP) is required by the RWQCB to describe the BMPs that would control both the quality and amount of stormwater runoff on a project site. Erosion and sedimentation issues are addressed more fully in **Section 3.10, Hydrology and Water Quality**. Transportation projects and development that would occur under the Plan would be required to comply with this process.

Because projects would be required to comply with existing state and local jurisdiction permitting, regulatory, and grading processes as well as the application of BMPs, impacts may be reduced. However, given the large number of projects in the Plan and wide variety of project conditions including soil types and slopes, this impact is considered significant.

Mitigation Measures

SCAG Mitigation Measure

SMM-GEO-1: SCAG shall facilitate the minimization of substantial soil erosion or loss of topsoil 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 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 Mitigation Measures

PMM-GEO-1: In accordance with provisions of sections 15091(a)(2) and 15126.4(a)(1)(B) of the *State CEQA Guidelines*, a Lead Agency for a project can and should consider mitigation measures to reduce substantial adverse effects related to historical resources. Such measures may include the following or other comparable measures identified by the Lead Agency:

a) 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.

b) 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 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.

c) 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.

d) 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.

Level of Significance after Mitigation

As previously discussed, regulations and policies would reduce impacts but given the regional scale of the analysis in this PEIR, it is not possible to determine if all impacts would be fully mitigated by existing regulations and policies. Therefore, this PEIR identifies project-level mitigation measures consistent with applicable regulations and policies designed to reduce impacts. Lead Agencies may choose to include project-level mitigation measures in environmental documents as they determine to be appropriate and feasible. However, because of the regional nature of the analysis and the lack of project specific-detail, including project components and locations, and SCAG's lack of authority to impose project-level mitigation measures, this PEIR finds impacts related to erosion could be significant and unavoidable even with implementation of mitigation.

Impact GEO-3 **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.**

Less than Significant Impact.

Lateral spreading is a phenomenon where large blocks of intact soil move downslope in a rapid fluid-like flow movement. This is usually associated with liquefaction events. The mass moves towards an unconfined area, such as downslope on slopes as small as one degree. Lateral spreading often occurs along riverbanks, where soft soils are often present, as well as in other areas prone to liquefaction.

Subsidence has historically occurred within the SCAG region due to groundwater overdraft and petroleum extraction. **Table 3.7-2, Potential Geologic Hazards Impacts from the Plan,** shows the acres of land within each County (except Imperial) where transportation projects in the Plan intersect with areas prone to liquefaction and earthquake-induced landslides. **Figure 3.7-8, Connect SoCal Projects in Relation to Geologic Hazards,** shows the location of the Plan transportation projects 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 Murrieta/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 coastline.[40] Subsidence can also occur in areas with unconsolidated soils that have not historically shown elevation changes.

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

Section 1613 of the CBC states that projects located in liquefaction zones shall incorporate seismic design features into both grading and construction plans. Any on-site grading and site preparation activities must comply with the CBC, described above, which addresses grading and excavations. The requirements laid out therein are considered minimum standards for the design and construction of buildings, particularly for those located on soils that are unstable or that have the potential to be unstable. Additionally, local jurisdictions require that the recommendations contained within the geotechnical report to be implemented by the individual project applicant.

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40 State of California Department of Water Resources. 2014. *Summary of Recent, Historical, and Estimated Potential for Future Land Subsidence in California*. Available online at: https://water.ca.gov/LegacyFiles/groundwater/docs/Summary_of_Recent_Historical_Potential_Subsidence_in_CA_Final_with_Appendix.pdf, accessed May 21, 2019.

Hazards associated with unstable soils or geologic units are dependent on site-specific conditions, as well as the specific nature of the individual project proposed. However, implementation of transportation projects and development projects anticipated to occur under the Plan would not be expected to exacerbate existing conditions with respect to geologic units and existing soils. With adherence to grading permit and building code requirements, including seismic design criteria as required by the CBC, transportation projects and anticipated development projects would be designed to minimize potential risks related to unstable soils and geologic units. Therefore, the potential for landslide, lateral spreading, subsidence, liquefaction, or other collapse impacts related to the implementation of transportation projects and anticipated development projects under the Plan, is considered less than significant and no mitigation is required.

Impact GEO-4 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.

Less than 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 compact development strategies, may expose people and structures to risks where located on expansive soils. 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. Expansive soils are generally removed during foundation work to avoid structural damage. The Plan assumes 60 percent of the new residential growth and 73 percent of new employment growth would occur within Growth Priority Areas, where expansive soils may have already been removed. However, expansive soils may remain in many parts of the SCAG region.

Transportation projects and anticipated development under the Plan would not be expected to exacerbate existing conditions with respect to expansive soils. Expansive soil conditions would be addressed through the integration of geotechnical information in the design process for development projects to determine whether a site is suitable for a project. Industry practice and state-provided guidance would minimize risk associated with geologic hazards. Compliance with CBC requirements as well as adherence to local building codes and ordinances would reduce hazards relating to expansive soils, and as such, impacts remain less than significant.

Impact GEO-5 **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 Plan includes transportation investments and the regional land use strategies that are intended to produce more dense development in well-served transit areas. These land use strategies encourage compact development in HQTAs, and more walkable, mixed-use communities to accommodate the anticipated growth of 3.2 million people by 2045. The Plan does not encourage or anticipate residential development in areas where sewers are not available for the disposal of wastewater or where densities would not support the provision of sanitary sewers. the Plan's transportation projects would not require septic tanks or alternative wastewater disposal systems. Moreover, the Growth Priority Areas are well served by sanitary sewer systems. To the extent septic tanks and alternative wastewater disposal systems may be required in more rural areas, septic tanks and alternative wastewater disposal systems are heavily regulated at the state, regional, and local level. Local jurisdictions also have general plans that contain policies and implementation measures, including BMPs relevant to the use of septic tanks or alternative water disposal system. County environmental health departments regulate septic tanks through measures such as requiring a Sewage Disposal Permit for construction, reconstruction, repair, or abandonment of septic tanks. Therefore, impacts from having soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater would be less than significant, and no mitigation measures are required.

Impact GEO-6 **Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.**

Significant and Unavoidable Impacts - Mitigation Required.

As discussed in the environmental setting section of this chapter, geologic units considered sensitive for paleontological resources are widespread in the Plan area. These units, such as the shallow marine deposits, such as the San Pedro Sans and the Palos Verdes Sand may yield marine and terrestrial fossils. These units are common along coastal southern California, including Ventura, Los Angeles, and Orange Counties in the SCAG region. Many abundant fossil localities have been collected from excavations in San Pedro around the Port of Los Angeles, where the setting is very similar to that of the program area, with artificial fill covering old marine deposits. These deposits have yielded thousands of specimens of marine invertebrates that are significant for reconstructing changes in shallow marine ecosystems.

Potential impacts to paleontological resources would be more likely to occur from ground-disturbing activities associated with transportation projects and development projects anticipated to occur under the Plan rather than during ongoing operations. Direct permanent impacts to paleontological resources as a result of the Plan may result from ground disturbance associated with construction. Ground-disturbing activities such as excavation for building foundations and bridges, trenching for utility lines, tunneling, and grading, could damage or destroy sensitive paleontological resources on or near the surface or at depth. Construction in previously undisturbed areas and deep excavation activities would have the greatest probability to impact intact buried paleontological resources. The potential for direct impacts to paleontological resources may be comparatively less for improvements to existing facilities and modifications to existing rights-of-way since these areas have been previously disturbed. However, any construction in geologic units sensitive for paleontological resources could result in potentially significant damage to or destruction of unique paleontological resources.

Direct permanent impacts may arise if paleontological resources cannot be completely avoided by project design. Substantial damage to or destruction of significant paleontological resources would represent a significant impact. Excavation of the sediments and any significant fossils could destroy or degrade the condition of the fossils; additionally, the nature of project excavation would cause any fossils to be removed from their stratigraphic context, thereby reducing the scientific usefulness of the fossil. The extensive distribution and presence of rock units below the ground surface that may contain significant fossilized remains makes it difficult to predict the location of paleontological resources during the project planning phase, and thus increases the likelihood of inadvertent discovery of significant paleontological resources during construction and ground-disturbing activities.

Therefore, the potential direct impacts on paleontological resources related to implementation of transportation projects and development projects anticipated to occur under the Plan, could result in substantial alteration or removal of a significant paleontological resource from construction activities, and is considered significant.

Mitigation Measures

SCAG Mitigation Measure

SMM-GEO-3: Impacts to paleontological resources shall be minimized through cooperation, information sharing, and SCAG's ongoing regional planning efforts such as web-based planning tools for local governments including CA LOTS, and other GIS tools and data services, including, but not limiting to, Map Gallery, GIS library, and GIS applications; and direct technical assistance efforts such as training series and sharing of associated online training materials. SCAG shall consult with resource agencies such as the National Park Service, United States Forest Service, and Bureau of Land Management to identify opportunities for early and effective consultation to identify unique paleontological resources and unique geological features to avoid such resources wherever practicable and feasible and reduce or mitigation for conflicts in compatible land use to the maximum extent practicable.

<u>*Project Level Mitigation Measures*</u>

PMM-GEO-1: In accordance with provisions of sections 15091(a)(2) and 15126.4(a)(1)(B) of the *State CEQA Guidelines*, a Lead Agency for a project can and should consider mitigation measures to reduce substantial adverse effects related to paleontological resources. Such measures may include the following or other comparable measures identified by the Lead Agency:

a) Ensure compliance with the Paleontological Resources Preservation Act, the Federal Land Policy and Management Act, the Antiquities Act, Section 5097.5 of the Public Resources Code (PRC), adopted county and city general plans, and other federal, state and local regulations, as applicable and feasible, by adhering to and incorporating the performance standards and practices from the 2010 Society for Vertebrate Paleontology (SVP) standard procedures for the assessment and mitigation of adverse impacts to paleontological resources.

b) Obtain review by a qualified paleontologist (e.g. who meets the SVP standards for a Principal Investigator or Project Paleontologist or the Bureau of Land Management (BLM) standards for a Principal Investigator), to determine if the project has the potential to require ground disturbance of parent material with potential to contain unique paleontological or resources, or to require the substantial alteration of a unique geologic feature. The assessment should include museum records searches, a review of geologic mapping and the scientific literature, geotechnical studies (if available), and potentially a pedestrian survey, if units with paleontological potential are present at the surface.

c) Avoid exposure or displacement of parent material with potential to yield unique paleontological resources.

d) Where avoidance of parent material with the potential to yield unique paleontological resources is not feasible:

1) All on-site construction personnel receive Worker Education and Awareness Program (WEAP) training prior to the commencement of excavation work to understand the regulatory framework that provides for protection of paleontological resources and become familiar with diagnostic characteristics of the materials with the potential to be encountered.

2) A qualified paleontologist prepares a Paleontological Resource Management Plan (PRMP) to guide the salvage, documentation and repository of unique paleontological resources encountered during construction. The PRMP should adhere to and incorporate the performance standards and practices from the 2010 SVP Standard procedures for the assessment and mitigation of adverse impacts to paleontological resources. If unique paleontological resources are encountered during construction, use a qualified paleontologist to oversee the implementation of the PRMP.

3) Monitor ground disturbing activities in parent material, with a moderate to high potential to yield unique paleontological resources using a qualified paleontological monitor meeting the standards of the SVP or the BLM to determine if unique paleontological resources are encountered during such activities, consistent with the specified or comparable protocols.

4) Identify where ground disturbance is proposed in a geologic unit having the potential for containing fossils and specify the need for a paleontological monitor to be present during ground disturbance in these areas.

e) Avoid routes and project designs that would permanently alter unique geological features.

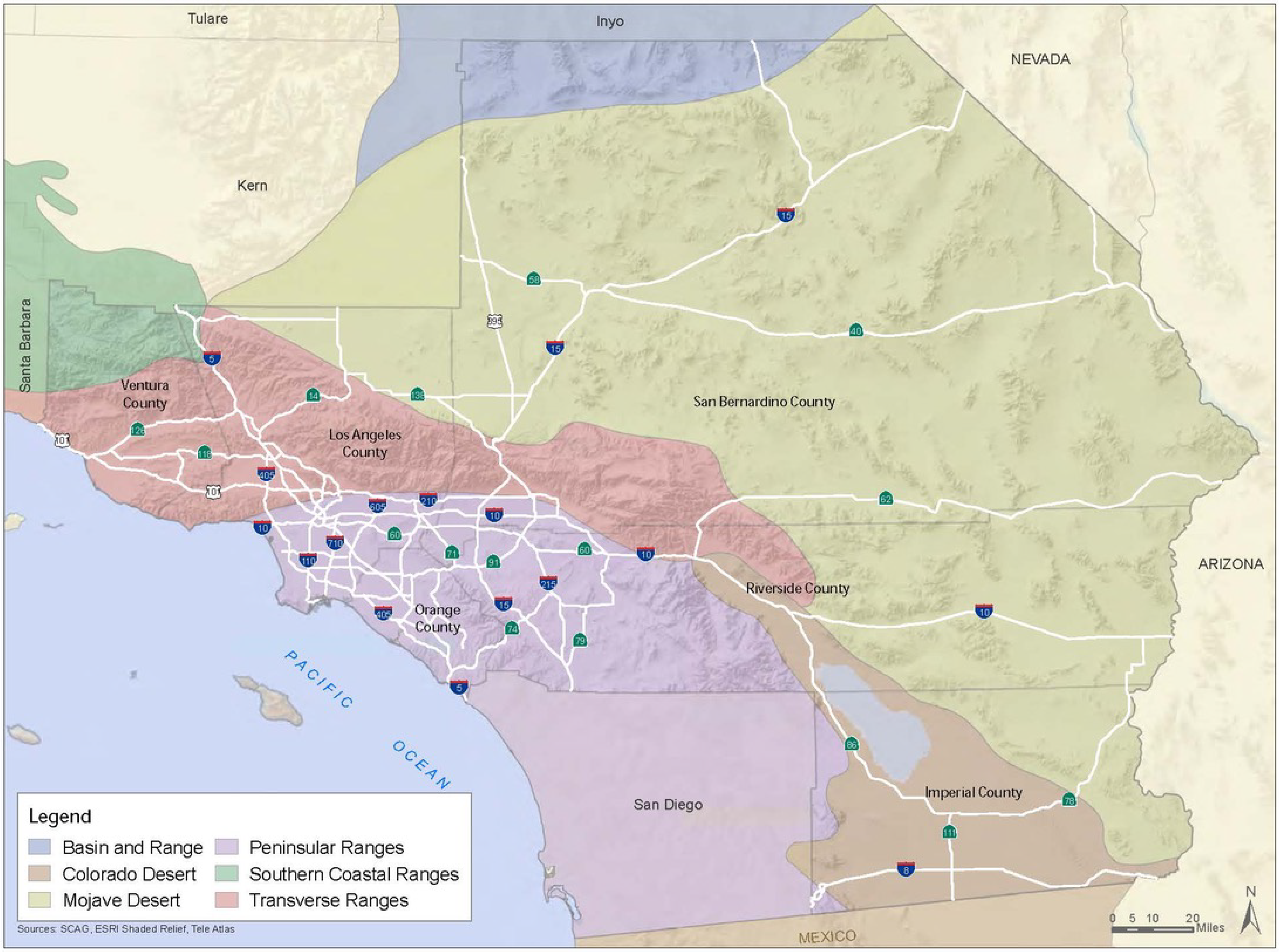
f) Salvage and document adversely affected resources sufficient to support ongoing scientific research and education.

g) Significant recovered fossils should be prepared to the point of curation, identified by qualified experts, listed in a database to facilitate analysis, and deposited in a designated paleontological curation facility.

h) Following the conclusion of the paleontological monitoring, the qualified paleontologist should prepare a report stating that the paleontological monitoring requirement has been fulfilled and summarize the results of any paleontological finds. The report should be submitted to the lead CEQA and the repository curating the collected artifacts, and should document the methods and results of all work completed under the PRMP, including treatment of paleontological materials, results of specimen processing, analysis, and research, and final curation arrangements.

Level of Significance after Mitigation

As discussed above, regulations and policies would reduce each of the impacts but given the regional scale of the analysis in this PEIR, it is not possible to determine if all impacts would be fully mitigated by existing regulations and policies. Therefore, this PEIR identifies project-level mitigation measures consistent with applicable regulations and policies designed to reduce impacts. Lead Agencies may choose to include project-level mitigation measures in environmental documents as they determine to be appropriate and feasible. However, because of the regional nature of the analysis and lack of project-specific detail, including project components and locations, and SCAG's lack of authority to impose project-level mitigation measures, this PEIR finds impacts to paleontological resources could be significant and unavoidable even with implementation of mitigation.



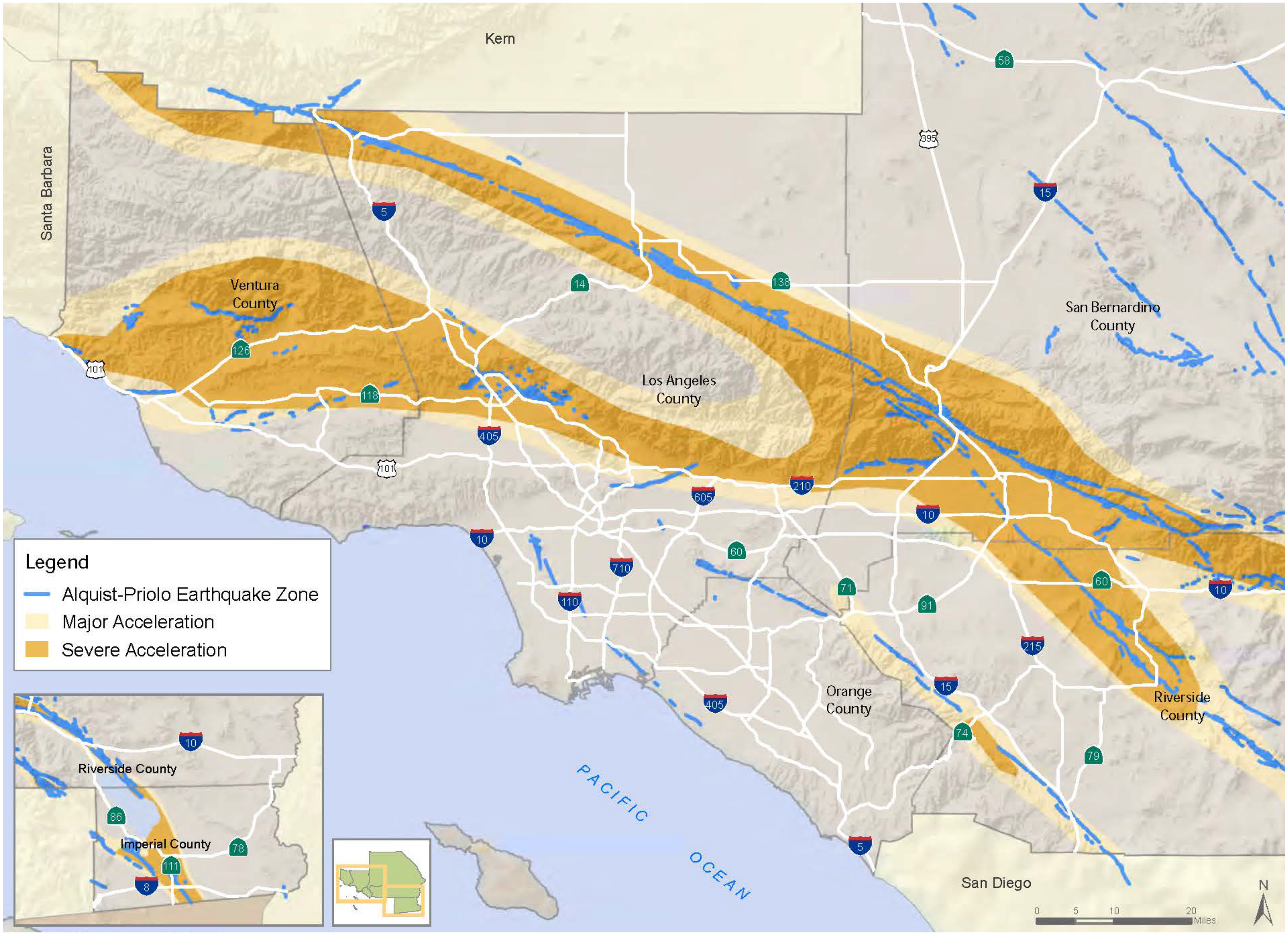
SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2019

FIGURE **3.7-1**

IMPACT SCIENCES

Geomorphic Provinces

1329.001•10/19



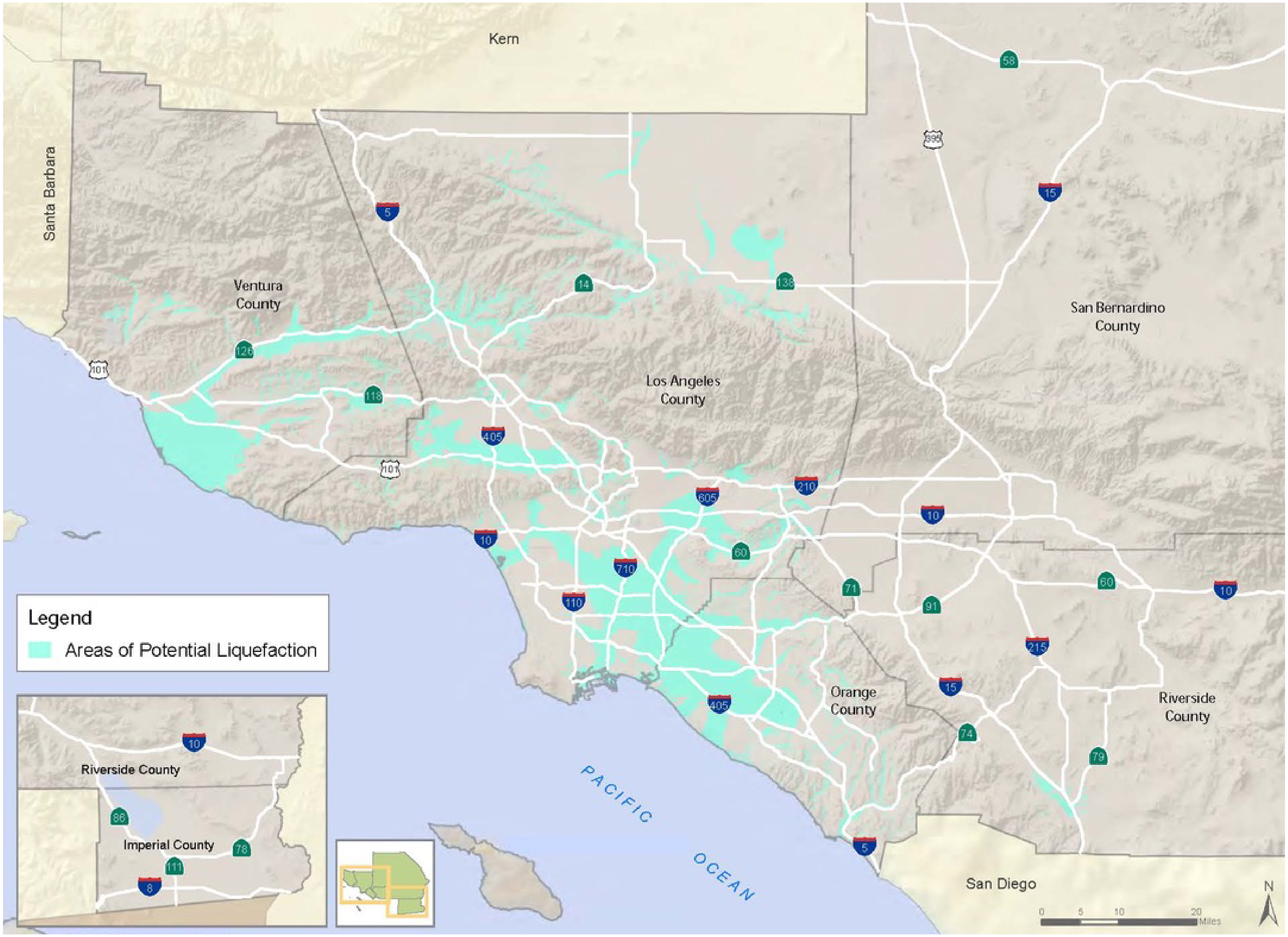
SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2012

FIGURE 3.7-2

IMPACT SCIENCES

Alquist-Priolo Zones and Potential Areas of Probabilistic Ground Acceleration

1329.001•10/19



SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2015

FIGURE 3.7-3

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Areas of Potential Liquefaction

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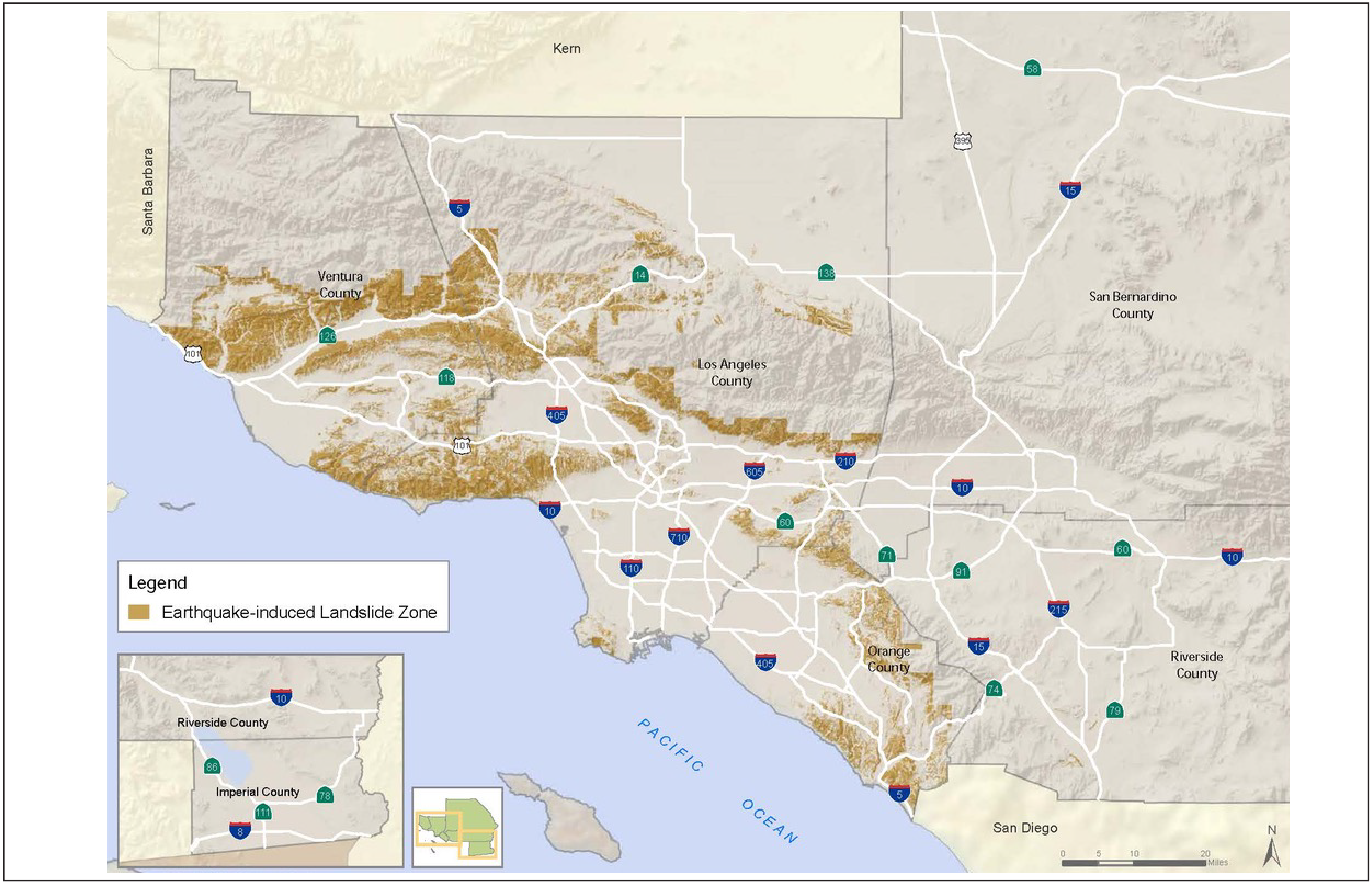

SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2015

FIGURE 3.7-4

Areas of Potential Landslides

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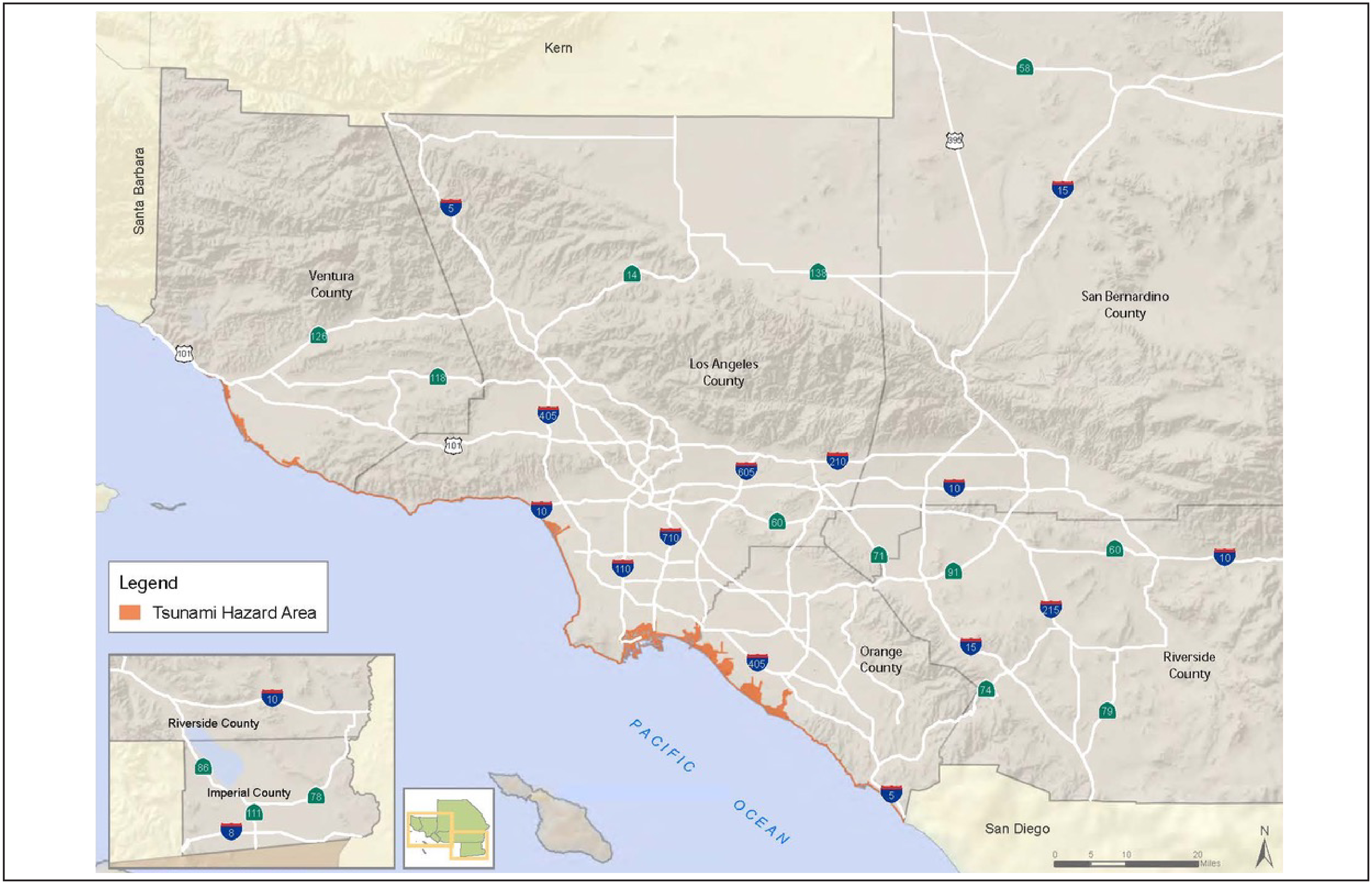

SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, CalEMA, 2015

FIGURE 3.7-5

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Areas Susceptible to Tsunamis

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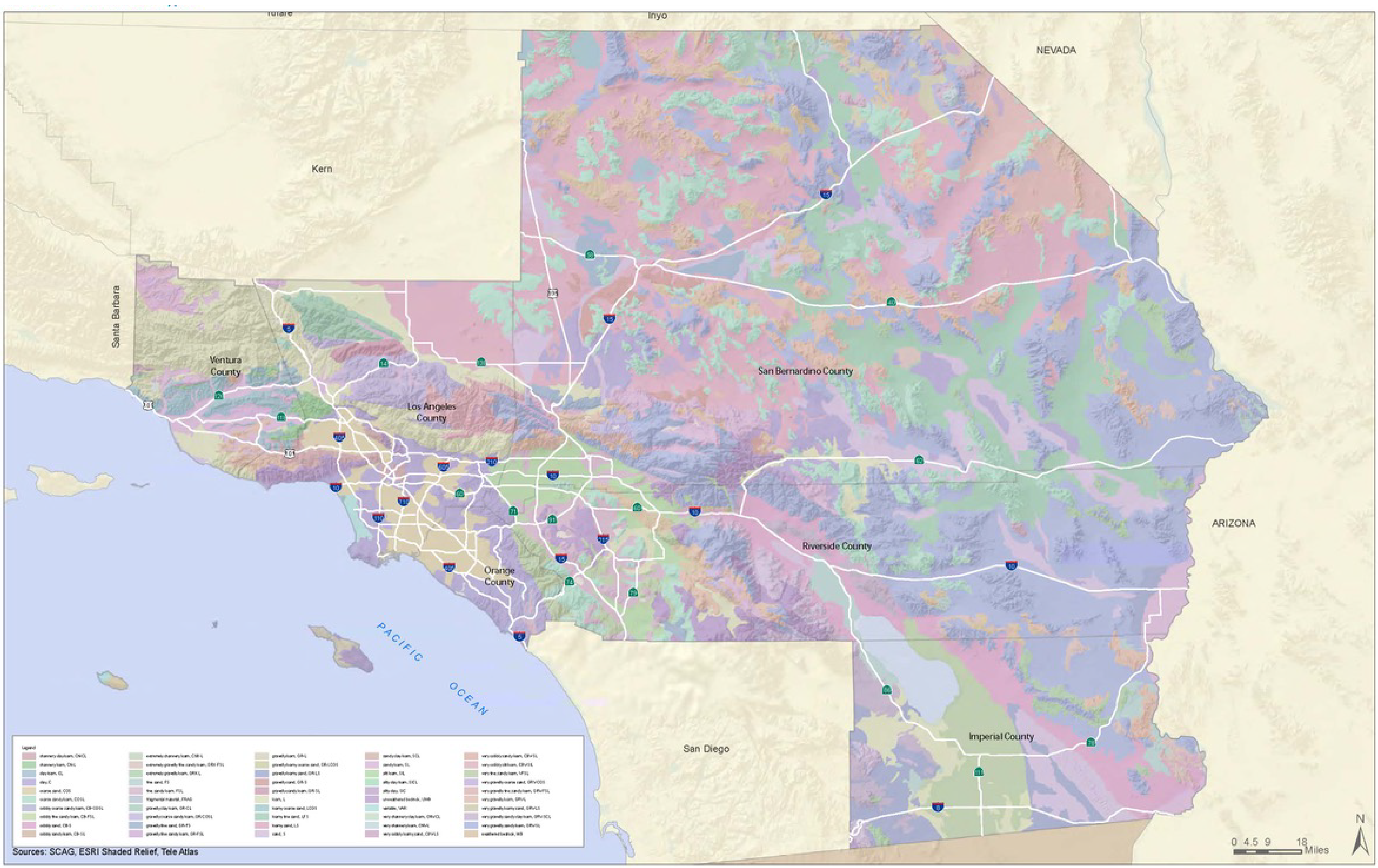

SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2015

FIGURE **3.7-6**

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General Soil Types

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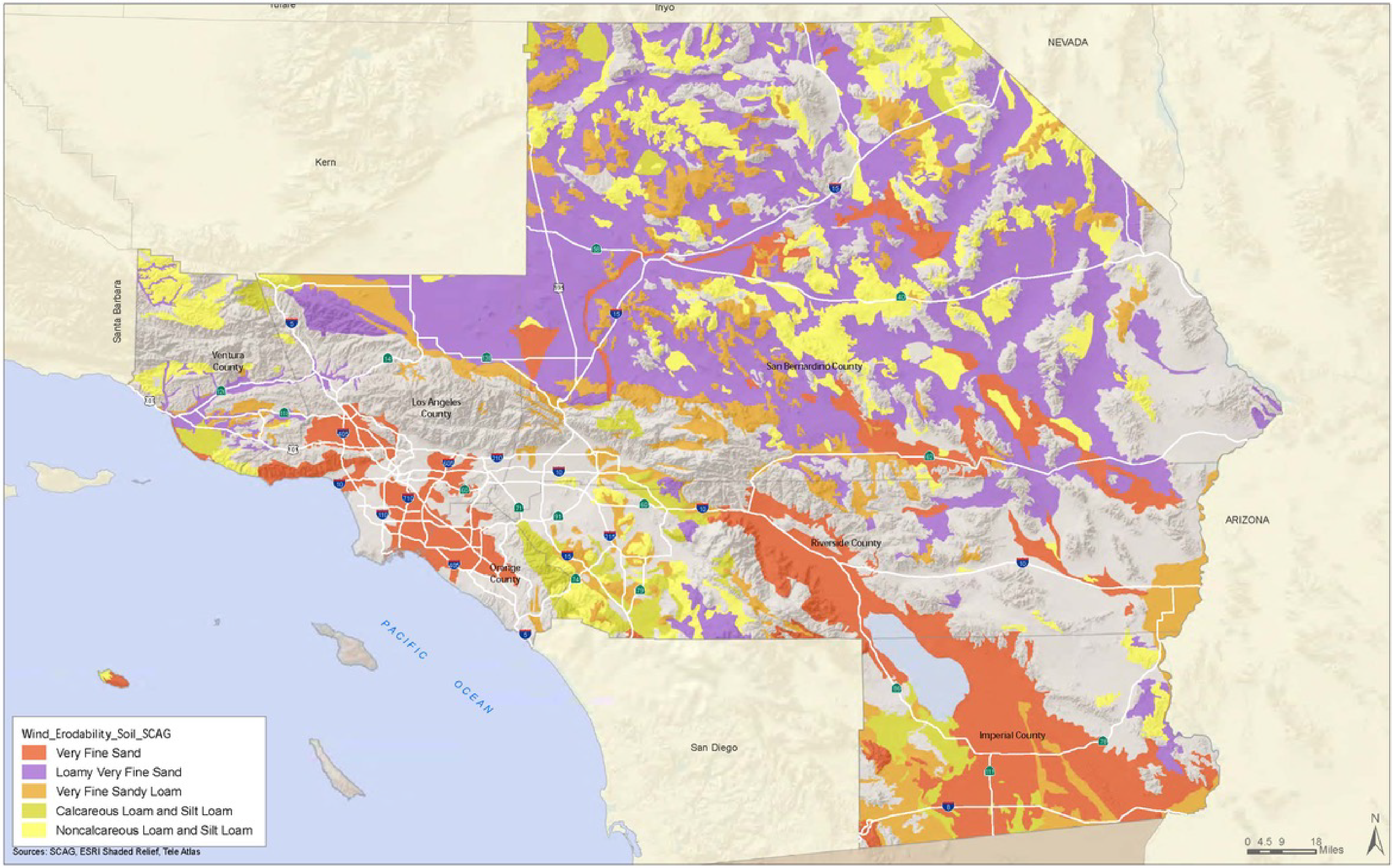

SOURCE: SCAG, ESRI Shaded Relief, Tele Atlas, 2015

FIGURE **3.7-7**

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Soils with Moderate to High Erosion Potential

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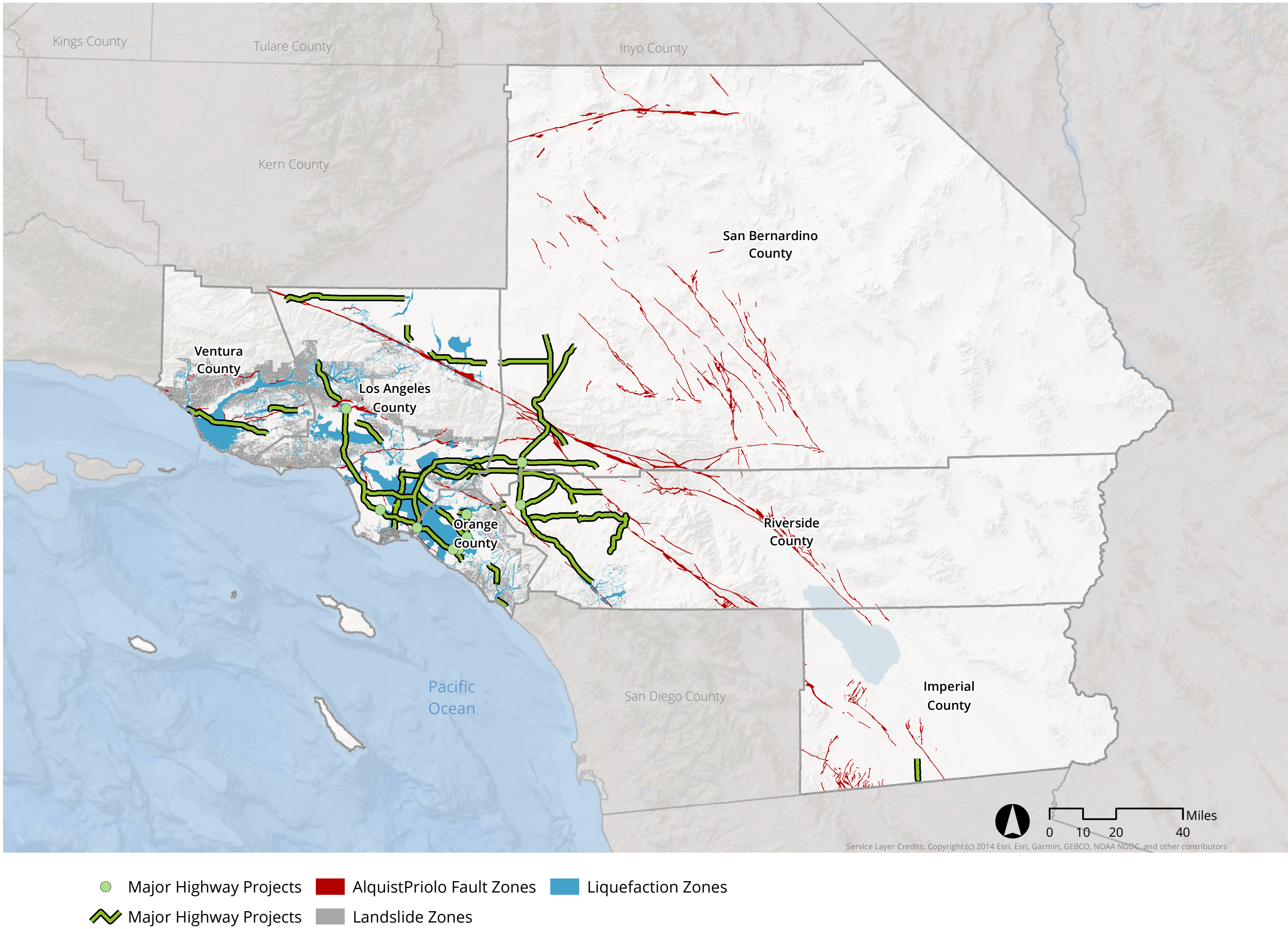

SOURCE: USGS. 2000, 2016 and 2018; SCAG, 2019

FIGURE **3.7-8**

IMPACT SCIENCES

Connect SoCal Projects in Relation to Geologic Hazards

1329.001•10/19

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