7.15 GEOLOGIC HAZARDS AND RESOURCES

This section of the AFC presents information on the geological and tectonic setting of the region and site vicinity. Following this discussion, geologic hazards and resources are described to provide background information on the conditions surrounding the proposed project and its related facilities, including linear features. The discussion of geologic hazards includes surface fault rupture, strong ground shaking, liquefaction, mass wasting/slope stability, subsidence, and expansive soils. Potential impacts of the project on the geologic resources at the site are also addressed. Based on this evaluation, measures are recommended to mitigate potential impacts from the proposed project.

The final portion of this section describes laws, ordinances, regulations, and standards (LORS) relevant to geologic impacts of the project as well as the contacts in cognizant regulatory agencies. Required permits are also discussed.

7.15.1 Affected Environment

The proposed project site, including the power plant, construction laydown area, transmission lines, pipelines and access road, is located in the Coachella Valley, near Devers Hill. The facilities are situated on a portion of a large alluvial fan that emanates from the base of the San Bernardino Mountains, approximately 5 miles northwest of the site which is covered with a near-surface veneer of silt and sand. The alluvial deposits overlie formations of conglomerate and fanglomerate, estimated to be at a depth of 100 feet or greater below the surface, as presented in Appendix R.

The project site is in the northwestern portion of the Coachella Valley, which forms the northwest part of the Colorado Desert region and merges into the Imperial Valley. Coachella Valley is roughly 50 miles long and from 10 to 20 miles wide. The area of the site and its linear features contains gentle sloping topography ranging from an elevation of approximately 770 feet above sea level (asl) to 1,140 feet asl, moving from northwest to southeast. It is bordered by the foothills of the San Bernardino Mountains, some spurs of the San Jacinto Mountains, and the westernmost 4-mile extension of the Indio Hills. The site, as well as much of southern California, is within a highly active seismic region.

7.15.1.1 Regional Geology

The site lies at the boundary of the San Gorgonio Pass to the west, and the Coachella Valley to the east. The Desert Hot Springs area is in the upper Coachella Valley at the juncture of three natural geomorphic provinces of California—the Transverse Ranges, the Peninsular Ranges, and the Colorado Desert. The San Gorgonio Pass forms the boundary between the Transverse Ranges geomorphic province to the north, and the Peninsular Ranges province to the south. The Transverse Ranges are characterized by east-west trending mountain ranges which include the San Bernardino Mountains, located to the north of the site. The Peninsular Ranges are characterized by northwest-southeast trending mountain ranges and valleys. The San Jacinto Mountains to the south of the site are part of the Peninsular Ranges province. The Coachella Valley is located immediately to the east of the site. The Coachella Valley is part of the tectonically active Salton Trough, which is an internally draining basin that extends from the San Gorgonio Pass southeast to the Colorado River delta near the Mexican border. The project site is located about 100 miles east of Los Angeles and is principally in north central Riverside County (Proctor, 1968).

The San Bernardino Mountains north of the site are mostly comprised of Precambrian San Gorgonio gneisses. These rocks and the Early Cretaceous igneous rock masses intruded into them are collectively termed the Chuckwalla complex. Schists, gneisses, and recrystallized limestone rocks, probably late Paleozoic in age, compose the metamorphic rocks of the San Jacinto Mountains (Figure 7.15-1) (Proctor, 1968).

The foothills of these mountains, including the vicinity of the site, are underlain by alluvial deposits of various ages, ranging from recent stream channel deposits, to Pleistocene and older alluvium, to Tertiary sandstones and conglomerates. All unmetamorphosed sedimentary and igneous deposits are late Cenozoic in age, ranging from Late Miocene fanglomerate and basalts to recent alluvium and sand accumulations. Only the lower Pliocene Imperial Formation is marine; it affords the best clues to the ages of the unconformably underlying Coachella/Split Mountain Formation and the conformably overlying Palm Springs and Canebrake/Painted Hill Formations. Unconformably above these last-named rock units are the upper Pleistocene Cabezon Fanglomerate/Ocotillo Conglomerate. Figure 7.15-2 summarizes the nomenclature and correlation of Cenozoic sedimentary rocks in the Coachella Valley (Proctor, 1968).

The San Andreas Fault Zone is the most significant potential seismic source in the vicinity of the proposed project. In the eastern San Gorgonio Pass and the upper portion of the Coachella Valley, the San Andreas Fault Zone is comprised of the Garnet Hill, the Banning, and the Mission Creek Faults. The Garnet Hill Fault is the least well understood of these faults. It is located along the base of Whitewater Hill just south of the site. All of these branches of the San Andreas Fault are included within the Alquist-Priolo Earthquake Fault Zones (A-P Zones) as established by the California Geological Survey.

7.15.1.2 Local Geology

Previous geologic studies by Proctor (1968), as well as seismic refraction and trenching performed in February and March 2001 for a previous, similar project (Appendix R), indicate that the site is covered by a thin layer of recent sand and silt, underlain by Pleistocene alluvium, overlying the Pleistocene Cabezon Fanglomerate at an assumed depth of 80 to 100 feet, north and south of the Banning Fault (see Figure 7.15-3). The uplifted alluvial and terrace deposits are derived from the erosion of the San Bernardino Mountains to the north of the sites and consist of fine- to coarse-grained sand with gravel, cobbles, and some boulders. Depth to groundwater is estimated to be greater than 160 feet north of the Banning Fault (RCS, 2000) and greater than 300 feet south of it (Rasmussen, 1981).

Structure

Local geologic structure is generally subhorizontal and generally flat lying. Local surface materials are alluvial and colluvial. Within the nearby desert area, several “islands” or inliers project through the alluvium. Devers Hill, northeast of the site, is a dissected mound of Cabezon Fanglomerate which is an inlier of the eroded old alluvial fans which form the foothills 2 miles to the west. Recent aggradation is slowly burying this old fan remnant. The absence from Devers Hill of the orange terrace mantle that is conspicuous in the low hills to the west and on the long tongue extending eastward from Whitewater Hill is believed to be due to erosion. Devers Hill is also characterized by the presence of the “Devers Hill fault” (Kahle et al., 1987), which has a mapped length of one mile and trends northeast-southwest (California Division of Mines and Geology, 1980).

Garnet Hill, to the southeast, is a low anticline faulted up by the now buried Garnet Hill Fault. It is believed to be much older than Devers Hill and to have existed as a low mound when the fanglomerate was being deposited (Proctor, 1968).

Stratigraphy

Stratigraphically, the area of the proposed project is underlain by 900 to 1,000 feet of unconsolidated alluvial fan deposits of Quaternary age (up to 2 million years old). These materials are underlain by basement granitic and metamorphic rock. A generalized geologic description of the units follows.

The oldest rocks in the area are Precambrian amphibolitic and migmatized paragneisses of the San Gorgonio igneous-metamorphic (Chuckwalla) complex. They are intruded by Cretaceous diorite porphyry, Cactus granite, quartz monzonite, intrusive breccia, and basic plutonic rocks. The metamorphic

rocks of the San Jacinto Mountains form spurs projecting into San Gorgonio Pass and Coachella Valley. They are probably of late Paleozoic age.

Cenozoic formations were noted by Proctor (1968). They are, from oldest to youngest:

- Coachella Fanglomerate/Split Mountain Formation (Late Miocene),
- Painted Hill Formation/Canebrake Conglomerate,
- Palm Springs Formation (mid-Pliocene to early Pleistocene), and
- Cabezon Fanglomerate/Ocotillo Conglomerate (late Pleistocene).

The local geologic units are presented in a stratigraphic column in Figure 7.15-2. The formations date from the pre-Cambrian, late Paleozoic, Cretaceous, Upper Miocene, Lower Pliocene, Middle and Upper Pliocene, Pleistocene, and Recent.

The Quaternary formations of immediate concern at the site are the Cabezon Fanglomerate/Ocotillo Conglomerate (Pleistocene), Terrace Deposits/Sand (Pleistocene), and alluvium (Recent).

Quaternary System – Cabezon Fanglomerate and Ocotillo Conglomerate (Pleistocene)

The Quaternary Cabezon Fanglomerate is exposed at Whitewater Hill and forms the base of the foothills of the Little San Bernardino Mountains, and beyond into Morongo Valley. Garnet Hill is a folded outlier in the middle of the Coachella Valley southeast of the site and Devers Hill is a remnant of a fan partially covered by Recent alluvium (Proctor, 1968). Trenching near the site indicates Pleistocene terrace deposits are at a shallow depth beneath a few feet of sand and alluvium (see Appendix R and Rasmussen, 1981).

Stratigraphy of the Cabezon Fanglomerate (Pleistocene)

Based on the exposures at Whitewater Hill, the fanglomerate consists of ill-sorted, poorly bedded, pebbly and bouldery, tan, arkosic sandstone with clasts of gneiss (50 percent), granitic rocks and pegmatite (45 percent), and a minor amount of basalt (Proctor, 1968). The granitic clasts were evidently derived from far within the northern San Bernardino Mountains.

Most of the fanglomerate clasts suggest that drainage from the northern San Jacinto Mountains has only rarely extended to the north, and has since late Tertiary time dominantly drained eastward, as it does at present. The size of the clasts in the Cabezon Fanglomerate ranges from large boulders to sand, but averages about 6 inches. The largest boulder observed on Garnet Hill, resting on Imperial Sandstone, measured 19 feet in maximum diameter. On Whitewater Hill in Long Canyon and in Dry Morongo Wash, clasts larger than 10 feet were found, all showing extreme desert varnish and polish. Most clasts in the fanglomerate are subrounded, but on Garnet Hill they are generally angular.

The Cabezon Fanglomerate is similar to the Ocotillo Conglomerate in general lithology, color, degree of induration, and degree of deformation. The Cabezon beds also have similar stratigraphic position, being unconformably underlain by the Canebrake Conglomerate (Proctor, 1968).

Stratigraphy of Ocotillo Conglomerate (Pleistocene)

The light tan Ocotillo Conglomerate, as exposed in the Indio Hills, is generally sandier than the typical Cabezon Fanglomerate and the clasts are smaller, averaging pebble and cobble size. They are subrounded

and consist of locally derived gneisses (70 percent), granite (20 percent), with the remainder of basic volcanic rocks, impure limestone and pegmatite.

The Ocotillo Conglomerate is considerably more folded toward the south than in the north, and the attitudes are generally much flatter than those in the underlying Imperial Formation.

The "Edom" well intersected approximately 2,400 feet of Ocotillo beds, which may be approximately the maximum thickness of the formation.

The Ocotillo Conglomerate unconformably overlies the Canebrake and Palm Springs Formations.

Terrace Deposits (Pleistocene)

The stream terrace deposits shown on Figure 7.15-3 are thin mantles and patches capping older rocks. In most places, terrace deposits weather to form a bright orange-colored soil. Usually these patches are a few inches to a few feet thick with large boulders standing out above the gravel and sand of the matrix. Most smaller fragments are subangular and resemble recent alluvium, which is pale gray-brown. The large boulders, the last vestige of once-extensive terrace deposits, are generally well-rounded and polished, mainly as a result of mechanical weathering caused by strong desert winds and extremes in temperature.

Alluvium (Recent)

The contact between alluvium and superficial sand deposits in some places is sharp, as around the San Jacinto Mountain spurs, but more commonly it is a gradational boundary. It is certainly a shifting boundary, due to fluctuations in intensity and direction of the winds, which distribute the superficial materials. Towards the valley from the washes and arroyos, which tend to be sandy in their lower reaches, the alluvium is more compact and has a marked increase of silt. This alluvium eventually weathers to form a desert soil.

In the alluvium of the uppermost Coachella Valley are pebbles of crystalline limestone that must have come from the Furnace Limestone, which is now being eroded by the headwaters of the Little Morongo and Mission Creeks. The origin of the crystalline limestone is believed to be from the high east flank of the San Bernardino Mountains, where precipitation rates are relatively high.

Superficial Sand (Recent)

Wind-blown sand is very common at the site and in the Coachella Valley in general, especially on Garnet Hill. It is commonly found on the windward slopes, where it is caught and held by vegetation. Also present is stream-deposited sand, mainly in the numerous washes.

Proctor (1968) evaluated the mineralogy of superficial sand samples and found that quartz is surprisingly second in abundance to feldspar. Biotite commonly appears to be even more abundant. Epidote, sphene, zircon, garnet, and especially hornblende are also prevalent. Commonly the larger grains consist of gneiss, with many minerals visible in a single grain. All grains are angular or subangular, indicating that the sands are immature and freshly supplied. Windward slopes expose gravel and pebble surfaces characterized by abrasive erosion. Many sandy surfaces are covered with grains averaging 0.12 inch (3 millimeters [mm]) in diameter, but a few inches deep smaller grains are found, accompanied by much silt and biotite flakes; the average grain diameter is 0.08 inch (2 mm). The Whitewater River, 2 miles south of the site, and its tributaries supply the area with alluvial sand, which is mostly derived from the intermediate to basic gneisses and igneous rocks.

7.15.1.3 Plate Tectonic Setting

Southern California is within the boundary zone between the North American and Pacific tectonic plates. The relative motion between these two plates has been determined from paleomagnetic lineations in the Gulf of California, from global solutions to known slip rates along plate boundaries, from geology, and from geodesy (Minster and Jordan, 1978; DeMets et al., 1987; Wallace, 1990) to be primarily horizontal at a rate of about 50 mm/yr (DeMets et al., 1987). On a broad scale, the North American–Pacific plate boundary in California is a transform fault that extends from the Gulf of California to Cape Mendocino. The San Andreas Fault and the transform plate boundary end to the north at the Mendocino Triple Junction in northernmost California. North of Cape Mendocino, the spreading center and subduction zone of the Juan de Fuca plate lie between the North American and Pacific plates. At the southern end, another spreading center lies in the Gulf of California, creating parts of the Pacific and Rivera plates. The transform faults of that spreading center merge into the San Andreas fault system near the Imperial Valley and the Salton Sea (Hutton et al., 1991). Atwater (1970) and more recently Irwin (1990) describe the evolution of the Pacific–North American plate boundary.

Whereas the relative plate motion is concentrated near the San Andreas Fault in northern California, the San Andreas Fault in southern California makes a notable bend within the Transverse Ranges north of the Los Angeles basin. From this point southward and extending to the site area, the plate motion is spread over a wide area of deformation, encompassing normal, strike-slip, and reverse faults. While the majority of the plate motion appears to be accommodated by the San Andreas Fault itself, the rest of the motion is distributed among a dozen or so other major faults (Weldon and Humphreys, 1986; Bennett et al., 1996). The diffuse deformational pattern leads to the high level of seismic activity and to a complicated tectonic setting.

Hutton et al. (1991) describe the complicated tectonic structure of southern California by addressing the four major tectonic divisions — the San Andreas fault system, the Transverse Ranges, the Mojave desert, and the Sierra Nevada and southern Basin and Range. The proposed project falls within the San Andreas Fault System (see Figure 7.15-4). The San Andreas Fault itself is the easternmost member of this system and the fault on which the largest Quaternary displacements have been recorded (Allen, 1981). In addition to the San Andreas Fault, the other major faults include the Imperial Fault, the San Jacinto Fault, the Elsinore Fault, and the faults of the coastal zone and the Continental Borderland, including the Newport-Inglewood-Rose Canyon Fault (Hutton et al., 1991). Hirabayashi et al. (1996) describe a number of faults in Baja California that appear to be continuous with, or splays off of, the faults of the San Andreas Fault System, including the San Miguel-Vallecitos Fault Zone that appears to be a possible landward extension of Continental Borderland faults. As discussed below, the proposed project site is located less than a kilometer away from the Banning segment of the San Andreas Fault.

7.15.1.4 Regional Seismotectonic Setting and Seismicity

Figure 7.15-5 shows the historical seismicity in the site region. Within the project region, defined to incorporate the area from 114.5°W to 118.5°W and 32.5°N to 35.5°N, earthquakes of measured or estimated magnitude 6 or greater occurring within the period from 1769 to June 2000 are shown in Table 7.15-1. Major faults in the vicinity of the proposed project site are indicated on Figure 7.15-4.

The project earthquake catalog was compiled from several primary catalogs, as discussed below.

The catalog of historical earthquakes occurring in California from 1735 to 1974 of the California Geological Survey (CGS) (formerly known as the California Division of Mines and Geology [CDMG]) was compiled by Real et al., (1978) and Toppozada et al., (1984). This file includes epicenters from catalogs of the Seismological Laboratory of the California Institute of Technology (PAS) and the Seismological Stations of the University of California at Berkeley (BRK). This catalog was updated

through December 1993 and used in the development of the 1996 USGS/CDMG probabilistic seismic hazard maps. The updated catalog includes events of magnitude 4 or greater and is available at the CGS website (2007). A modification of the on-line catalog for the epicenter of the M 7.3 February 24, 1892 event was suggested following personal communication with Tousson Toppozada of the CDMG (Toppozada, 2000; Toppozada et al., 2000). In concurrence with work by Mueller and Rockwell (1995), Dr. Toppozada now places this event in the vicinity of the Laguna Salada fault in northern Baja California, Mexico. Only events up through 1931 were used from this catalog, as the catalog of the Southern California Seismic Network (SCSN), discussed below, is preferred over the CGS catalog for recent seismicity.

Patterns of historical seismicity (Figure 7.15-5) and microearthquakes in the region show that the right-stepping and left-stepping en echelon faults thrust faults, and reverse faults are active. Slip rates along segments of the San Andreas Fault Zone in Southern California range between 1 and 1.3 inches per year (in/yr) (24 to 34 millimeters per year [mm/yr]). For segments of the San Jacinto Fault Zone Slip in the area slip rates are approximately 0.16 to 0.79 in/yr (4 to 20 mm/yr); for the Elsinore Fault Zone Slip rates are 0.16 to 0.2 in/yr (4 to 5 mm/yr) (Cao et al., 2003).

Significant Quaternary Faults

Figure 7.15-6 shows the principal Quaternary faults in the site region. Fault data have been obtained mainly from Jennings (1992). Included below is a brief discussion of these significant Quaternary faults in the region of the site. A lineament analysis that was performed to evaluate potential active faulting in the vicinity of the project site is also described.

San Andreas Fault

The San Andreas Fault extends 370 miles (600 km) in southern California and is responsible for the largest earthquake of the region — the 1857 M 7.8 Fort Tejon earthquake. In northern and central California, the San Andreas Fault is clearly delineated, striking northwest approximately parallel to the direction of plate motion, N35°W (Hill et al., 1991). Near Fort Tejon, along the northern edge of the Transverse Ranges, the fault changes strike to N70°W, referred to as the "Big Bend." Southward, at Cajon Pass, at the southeast end of the 1857 rupture zone, the San Andreas Fault Zone splits into the San Jacinto and main San Andreas Fault segment. The San Andreas Fault here is generally referred to as the San Bernardino Fault. Near Highland (east of San Bernardino), the San Bernardino Fault splits again into several strands, and the names given to various segments become complex, variously named in different studies. For example, Jennings (1992) shows Banning and Mission Creek strands and Matti et al., (1985) talk about these as the two most recently active features. Finally, southeast of the town of Thousand Palms, the multiple strands rejoin to form the Coachella segment of the San Andreas Fault, and the strike of the fault resumes its southeast trend toward the east shore of the Salton Sea (Hutton et al., 1991). These faults are shown in Figure 5.3-6 in Appendix R along with the proposed project site location.

The proposed project is located approximately 1 mile (1.7 km) from the mapped surface trace of the Banning segment of the San Andreas Fault as characterized by Jennings (1992) and the Alquist-Priolo Earthquake Fault Zones Desert Hot Springs map (CDMG, 1980). This fault last ruptured on July 8, 1986 during the North Palm Springs earthquake (M 6.0). Relocation of aftershocks from this earthquake indicated that the section of the fault that ruptured, dips to the northeast at about 45 degrees (Magistrale and Sanders, 1996). Based on the fault geometry, the proposed project site is located on the foot wall of the fault. The aftershocks were limited to a depth range of about 3 to 9 miles (5 to 15 km), which corresponds to the range of significant subsurface strike-slip motion determined from inversions of the recorded strong ground motion time histories (Mendoza and Hartzell, 1988). Surface cracking and fractures were mapped after the earthquake in the epicentral region. A zone of surface fracturing was mapped along the surface trace of the Banning Fault from Whitewater Canyon to the intersection of

Dillon Road and the Banning Fault. However, these surface fractures were not continuous over this entire 5.6-mile (9-km) length. The largest fracture exhibited 0.35 inch (9 mm) of right lateral displacement (Sharp et al., 1986). Other secondary ground fractures were noted for this earthquake along with other earthquakes in the region (Williams et al., 1988).

Prior to the North Palm Springs earthquake, the Banning section of the San Andreas was estimated to be creeping at a rate of 0.07 in/yr (2 mm/yr) (Louie et al., 1985). This estimate was based on a creep meter station located at Devers Hill east of the project site location and operated by the California Institute of Technology, and was consistent with other estimates of creep for other segments of the San Andreas fault in this region. The North Palm Springs earthquake showed that this section of the San Andreas Fault could exhibit coseismic rupture as well as aseismic creep.

The CDMG (1996), U.S. national seismic hazard maps (Frankel et al., 1996), and the 2000 International Building Code (International Code Council, 2000) Maximum Considered Earthquake maps model the San Andreas Fault in the project site region as a single fault which connects the San Bernardino and Coachella segments of the San Andreas. The mapped location of the San Andreas Fault for these studies is between the Mission Creek and Banning Fault Traces and is shown in Figure 7.15-6 as the solid black line labeled UBC97: San Andreas Fault (Southern). This simplified representation of this complex section of the San Andreas Fault does not correspond to an actual geologic mapped surface trace of the fault, but rather is a simplified representation of the location of the surface trace of the fault. For the proposed project site, the closest distance from the site to this simplified representation of the San Andreas Fault is about 0.22 mile (0.36 km). However, the actual distance from the project site to the Banning Fault is 0.26 mile (0.42 km) as determined from the Alquist-Priolo and Jennings (1994) fault maps.

The simplified CDMG (1996) model of the San Andreas Fault in the project site region is modeled with two segments. The intersection of these segments is located near the project site. The Coachella segment extends toward the south of the site and has a length of 59 miles (95 km) and a slip rate of 0.94 in/yr (25 mm/yr). CDMG (1996) estimates the maximum magnitude for this segment of the San Andreas Fault at 7.1 with no estimated recurrence interval. The San Bernardino segment extends toward the north of the site and has a length of 66 miles (107 km) and a slip rate of 0.94 in/yr (24 mm/yr). CDMG (1996) estimates the maximum magnitude for this segment of the San Andreas Fault at 7.3 with an estimated recurrence interval of 433 years. The CDMG model also considers the coincident rupture on both of these fault segments, referred to as the San Andreas (southern) segment. This combination of the Coachella and San Bernardino segments has a length of 126 miles (203 km) and a slip rate of 0.94 in/yr (24 mm/yr). CDMG (1996) estimates the maximum magnitude for this fault segment combination of the San Andreas Fault at 7.4 with an estimated recurrence interval of 220 years. As the CDMG (1996) fault model is the one used for the Uniform Building Code (UBC) fault atlas, the distance from the site to this representation of the San Andreas Fault is about 0.22 mile (0.36 km).

The Working Group on California Earthquake Probabilities (WGCEP, 1995) also considers a simplified model for the San Andreas Fault in this area, one that emphasizes the San Bernardino-Mission Creek-Coachella Valley segments. Similar to the CDMG model, the San Andreas Fault is comprised of various fault segments, including, again, variations of the San Bernardino and Coachella Valley segments. The WGCEP Coachella Valley segment extends toward the south of the site and has a length of 71 miles (114 km) and a slip rate of 0.98 in/yr (25 mm/yr). WGCEP (1995) estimates the maximum magnitude for this segment of the San Andreas Fault at 7.5 with an estimated recurrence interval of 220 years. The San Bernardino segment extends toward the north of the site and has a length of 48 miles (78 km) and a slip rate of 0.94 in/yr (24 mm/yr). WGCEP (1995) estimates the maximum magnitude for this segment of the San Andreas Fault at 7.3 with an estimated recurrence interval of 146 years. The WGCEP model also considers the coincident rupture on both of these fault segments, resulting in an estimated maximum magnitude of 7.6. The WGCEP further considers the coincident rupture of the San Bernardino and Coachella Valley segments along with additional San Andreas segments to the north, including the

portion of the San Andreas fault that ruptured in 1857, resulting in a maximum scenario magnitude of 7.9. The closest approach of the San Andreas fault, as modeled by WGCEP (1995), to the site under this model is approximately 6 miles (9.6 km).

The near-site segment of the San Andreas Fault is classified as a Type A 1997 UBC seismic source based on the maximum magnitude and slip rate.

Imperial Fault

The Imperial Fault is the southern extension of the San Andreas Fault System in the Salton Sea region . The fault is approximately 43 miles (70 km) long and trends in a northwest-southeast direction. The Imperial Fault is located approximately 90 miles (145 km) from the project site. Historically, two significant earthquakes are associated with the Imperial Fault. The 1940 (M 6.7) earthquake initiated in Brawley and ruptured southeast to Saltillo, Mexico. There were field reports of 16 feet (5 meters) of right lateral offset and reports of normal slip along the southern end of the Imperial Fault (Thomas and Rockwell, 1996). The 1979 (M 6.5) earthquake started south of the international border and ruptured to the northwest. Surface offsets of 6½ feet (2 meters) were observed in this event (Thomas and Rockwell, 1996).

Thomas and Rockwell (1996) estimate the slip rate of the Imperial Fault to be 0.6 to 0.8 in/yr (15 to 20 mm/yr) over the last 300 to 550 years. The CDMG (1996) estimated a slip rate of 0.8 in/yr (20 mm/yr) for the state seismic hazard map. These estimated slip rates, however, are substantially below the more global geodetic slip rate estimates of 1.4 to 1.6 in/yr (35 to 40 mm/yr) for the combined San Andreas and San Jacinto Faults located north of the international border. One possible explanation for the slip rate deficiency is the presence of previously unmapped northwest-trending faults in the region, which are accommodating the additional regional slip. Thomas and Rockwell (1996) postulate the extension of the Cerro Prieto Fault as an additional fault in the region, which could be taking up the additional slip. Another theory is that the slip rate on the Imperial Fault is episodic in nature. Thomas and Rockwell (1996) prefer the model where a previously unmapped fault is accommodating the additional regional slip.

The CDMG (1996) assessed a maximum magnitude of 7.0 for this fault. The WGCEP (1995) models this fault as greater in length (56 miles [90 km]), and assigns a maximum magnitude of 7.4. Based on the maximum magnitude and corresponding slip rate, the Imperial Fault is classified as a 1997 UBC Type A seismic source. The closest distance from the proposed project site to this fault is approximately 91 miles (147 km).

San Jacinto Fault

The San Jacinto Fault has produced moderate to large historic earthquakes in the Southern California region and is a major tectonic feature both structurally and seismically (see Figure 7.15-4). The fault strikes in a northwest-southeast direction with a total length of approximately 186 miles (300 km) and is predominantly right-lateral strike-slip (WGCEP, 1995). The most recent large historical earthquakes associated with the San Jacinto Fault were the Elmore Ranch (M 6.1) and Superstition Hills (M 6.5) earthquakes of November 24, 1987. The San Jacinto Fault has an average recurrence interval of 10 years for magnitude 6.0 and larger events (Hutton et al., 1991).

Although the San Jacinto Fault is a continuous mapped feature, recent probabilistic analysis for the Southern California region (WGCEP, 1995) has subdivided the fault into seven distinct segments: San Bernardino Valley, San Jacinto Valley, Anza, Coyote Creek, Borrego Mountains, Superstition Hills, and Superstition Mountains, going from the north to south. The estimated slip rates of the individual fault segments vary from between 4 in/yr for the southern segments to a high of 0.5 in/yr (12 mm/yr) for the Anza segment (WGCEP, 1995). The WGCEP (1995) assigns a maximum magnitude of 7.45 for a rupture

of the entire San Jacinto Fault System. The CDMG (1996) considers each segment individually with the largest magnitude of 7.2 assessed for the Anza segment. The closest distance from the project site location to the San Jacinto Fault System is approximately 23 miles (37 km). The San Jacinto Fault is classified as a 1997 UBC Type A seismic source.

Elsinore Fault

The Elsinore Fault extends from the southern Los Angeles basin (Whittier segment) to the California–Mexico border (Coyote Mountain segment) in a southeasterly direction. The length of this segment is approximately 143 miles (230 km). Northwest of latitude 33.5°N, the Elsinore Fault can be characterized by a simple linear segment. However, southeast between a latitude of 33.5°N and approximately 33.0°N, the Elsinore Fault consists of two parallel linear fault strands (Magistrale and Rockwell, 1996). The western strand is identified as the Elsinore Fault, while the eastern strand (offset to the east by 4 to 7.5 miles [7 to 12 km]) is a combination of the Aguanga, Agua Tibia, and Earthquake Valley Faults. South of the latitude of 33.0°N, the Elsinore Fault consists of only one mapped strand.

The Elsinore Fault is characterized by right-lateral motion. The estimated slip rate along the fault varies from a value of 0.1 in/yr (2.5 mm/yr) at the northern end to a range of slip rate estimates between 0.16 and 0.19 in/yr (4 and 5 mm/yr) for the southern section. Based on the estimates of slip rate for the Elsinore Fault, the segment-specific repeat times range from 240 to 760 years with an average repeat time of approximately 400 years (WGCEP, 1995). The maximum credible earthquake for the Elsinore Fault system is an M 7.4 event (WGCEP, 1995). Various individual segments of the Elsinore Fault Zone have associated maximum magnitudes ranging from 6.8 to 7.1, according to the CDMG (1996). In the last 200 years the Elsinore Fault has not generated an earthquake with observed surface faulting. The Elsinore Fault is a Type A UBC seismic source. The closest distance from the proposed project site is approximately 45 miles (73 km).

Garnet Hill Fault

The Garnet Hill Fault extends roughly from Whitewater Canyon to the vicinity of Edom Hill, although it is mapped as an inferred and concealed fault as it approaches Edom Hill. Its northwesterly orientation and proximity to the San Andreas Fault Zone suggest that the Garnet Hill Fault may be associated with, and perhaps may even be an ancestral branch of the San Andreas Fault. The Garnet Hill Fault is not considered an "active" fault by the CGS, and may not be capable of generating an earthquake. However, ground fractures associated with the 1986 North Palm Springs earthquake were reported along this fault, and it has the potential to move coseismically during an earthquake on another nearby fault.

Devers Hill Fault

The Devers Hill Fault, to the east of State Highway 62 in Desert Hot Springs, extends for a relatively short distance in a northeast-southwest trending direction. Given its orientation, the fault appears to be a secondary fault that ruptures in response to earthquakes on the San Andreas Fault. Its scarp ranges from 3 to 12 feet in height and is moderately dissected. For this reason, the fault is considered an "active" fault and is subject to the development review process described in the California Alquist-Priolo Earthquake Fault Zoning Act.

Lineaments

In 2001, in preparation of the AFC for the proposed Ocotillo Energy Plant (OEP) located approximately 0.6 mile (1 km) south of this project, CPV Sentinel conducted an engineering geologic evaluation of the mapped Banning Fault splays (Appendix R). The fault evaluation work was performed in accordance with CDMG Special Publication 117 (1997): *Guidelines for Seismic Evaluation and Mitigation of Seismic Hazards in California*. The work included two seismic refraction profiles, as well as a 1,435-

foot-long, north-south trending fault exploration trench. The trench extended approximately 440 feet north of the northern limits of the proposed OEP plant site. The trench was extended north of the plant site to cross the southernmost of two of the three Banning Fault splays that were mapped by the CDMG (1980). The northernmost end of the trench was designated as Station 00+00. The trench exposed several faults between Stations 90 and 215, a distance of approximately 235 feet from the northern boundary of the proposed OEP site.

Aerial photographs were investigated to assess the requirements for field investigations for identifying previously mapped faults from published maps. The photos were also reviewed to determine whether there were any lineaments in the area that could potentially be unmapped faults, and to compare the location of mapped faults and lineaments (Smith, 1979; Kahle et al., 1987; Treiman, 1994).

Imagery Acquisition

The availability of aerial photographs was investigated and digital orthophoto quadrangle maps of the Desert Hot Springs, California, topographic quadrangle were ordered and purchased. The color aerial photography was acquired in 1996. The entire area of interest, a 1.2 mile by 1.2 mile (2-km by 2-km) area encompassing the proposed site (Figure 5.3-8 within Appendix R), was covered by the digital orthophoto quadrangle maps.

Image Processing

The orthophoto images were enhanced to accentuate geologic features. Individual geologic maps were scanned and georeferenced. The mapped faults were placed on a vector layer which could be overlaid on the photo image.

An orthophoto map was produced (Figure 5.3-9 in Appendix R) showing published faults from the Desert Hot Springs Alquist-Priolo Earthquake Fault Zone map near the site, where the original published map was at a scale of 1:24,000. The fault segments that appear on this figure all belong to the Banning segment of the San Andreas Fault. The faults shown are all considered to have been active during Quaternary time. Long dashed lines represent fault segments approximately located, short dashed lines are inferred fault segments, and dotted lines represent concealed fault segments.

Lineament Analysis

A lineament analysis was performed using the orthophoto imagery. One lineament that was identified is adjacent to the proposed site and is shown in Figure 5.3-10 (within Appendix R). Lineaments are linear features that may have structural significance and can indicate geological faults. Trenching performed at the site is discussed in Appendix R.

Interpretation of Lineaments

High-angle faults are expressed on the surface as straight lines and lower-angle faults as arcs because of truncation of geologic structures and formations. Over time, erosion causes sediments to be transported and the fault trace may become less distinct. Hence, the more distinct and straighter the truncation, the greater the potential for a more recent fault.

The orientation of the one lineament found is west-northwest. This is the same orientation as the San Andreas Fault in this area and is close to the location of a segment of the San Andreas Fault as mapped by CGS in the Alquist-Priolo Earthquake Fault Zone and shown in Figure 5.3-9 within Appendix R. The aerial photo lineament truncates a geomorphic feature.

Relation of Lineaments to Known Faults

The Alquist-Priolo Fault Zone containing a segment of the San Andreas Fault is shown on Figure 5.3-10 within Appendix R along with the lineament. The lineament falls within the Alquist-Priolo Zone and both are within a kilometer of the proposed site.

It should be noted that the location of the San Andreas Fault varies between the Jennings map (1994) (scale 1:750,000) and the Alquist-Priolo map (scale 1:24,000). This may be related in part to the differences in scale of the original maps.

Southern California as a region is considered very seismically active largely due to the abundance of active faults. The State of California, under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant, 1997), considers a fault segment active if it has experienced a displacement in the historical record (last 200 years) or during the Holocene (last 11,000 years). A fault segment is considered potentially active if there is evidence of a displacement during the Late Quaternary (last 700,000 years) or the Quaternary (last 1.6 million years) (Jennings, 1994; Hart, 1994).

Fifty-two active faults are within 100 miles of the project site as listed in Table 7.15-2. This table also provides the estimates of the maximum earthquake for each fault and the closest distance from each fault to the proposed project (Blake, 2004). Maximum earthquake magnitude (Mmax) estimates are based on EQFAULT, a computer program for the deterministic prediction of peak horizontal acceleration from digitized California faults. Figure 7.15-6 illustrates the location of the proposed project with respect to the major Quaternary faults in the site region.

Historical Seismicity

Estimates of historic earthquakes are frequently referenced to Richter Magnitude, designated by the Symbol M. In recent years seismologists have used the moment magnitude, designated Mw, to more accurately reflect the energy released by an earthquake as a function of its seismic movement. The most frequent historical seismicity in northern California is largely associated with the San Andreas Fault System, although infrequent moderate magnitude earthquakes occur outside of this system. Several of the faults within the San Andreas System have produced large-magnitude historical events that caused damage to buildings and structures in the region. Because a number of the earthquakes occurred before modern instruments were developed, the magnitude and distribution of damage can only be surmised from written historical documents. Figure 7.15-5 illustrates historic earthquakes in the site vicinity that occurred in the period from 1864 to 2000.

There have been approximately 56 historical earthquakes of M 5.5 or greater in the Southern California region. Historically, several major earthquakes have occurred in the region, such as the 1857 Mw 7.9 Fort Tejon and the 1982 Mw 7.8 Imperial Valley earthquakes. Earthquakes of this magnitude can pose significant ground-shaking hazard in the project area. The following paragraphs discuss a few of these historic earthquakes that are considered of relevance to the proposed project site.

October 16, 1999, Hector Mine Earthquake. This earthquake was centered in such a remote part of the Mojave Desert that, instead of being named for the nearest town or the community which suffered the greatest damage, it was named after the closest spot in the list of reference points used by the Southern California Seismic Network: the Hector Mine, an open pit quarry 14 miles (22 km) northwest of the epicenter. This is the largest earthquake to strike the area since the M 7.3 Landers earthquake of June 28, 1992 (see below).

The location of the earthquake was so remote that it caused relatively negligible damage for a magnitude Mw 7.1 earthquake. The 25-mile (41-km) surface rupture along the Lavic Lake Fault and central section of Bullion Fault was located entirely within the boundaries of the Twentynine Palms Marine Corps Base,

and crossed neither paved roads nor structures (unlike the Landers rupture of 1992). The Southern California Earthquake Center (SCEC) lists this earthquake's location as 34.59º N, 116.27º W.

January 17, 1994, Northridge Earthquake. The Mw 6.7 earthquake occurred on a blind thrust fault (the Northridge Thrust—also known as the Pico Thrust), and produced the strongest ground motions ever instrumentally recorded in an urban setting in North America. Damage was widespread: sections of major freeways collapsed, parking structures and office buildings collapsed, and numerous apartment buildings suffered irreparable damage. Damage to wood-frame apartment houses was very widespread in the San Fernando Valley and Santa Monica areas, especially to structures with "soft" first floor or lower-level parking garages. The high accelerations, both vertical and horizontal, lifted structures off of their foundations and/or shifted walls laterally. The SCEC lists this earthquake's location as 34° 12.80' N, 118° 32.22' W.

June 28, 1992, Landers Earthquake. The Mw 7.3 quake was preceded by the Joshua Tree M 6.3 earthquake on April 22 and followed by the Big Bear M 6.4 earthquake later the same day. A robust aftershock sequence followed, which consisted of thousands of tremors, including 143 quakes registering M 4.0 or stronger — 19 of which measured M 5.0 or stronger. The most recent moderate aftershock was the Joshua Tree M 5.0 earthquake on May 14, 1999.

Vigorous shaking was felt 100 miles away in Los Angeles and the earthquake was felt as far away as Central California and Las Vegas, Nevada. One person was killed, 25 were seriously injured, and another 372 were treated for earthquake-related injuries. The total property damage value was on the order of $56 million and included collapsed buildings, ruptured utility lines, and widespread nonstructural damage.

Three items regarding this earthquake are notable: (1) the quake ruptured disconnected surface traces of several known faults (Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock) and several other unknown faults for a distance of 53 miles; (2) the displacement was two to three times larger than generally anticipated for these faults, with maximum horizontal offsets of 15 to 20 feet across a zone 30 to 60 feet wide; and as a consequence, (3) the magnitude was much larger than envisioned by seismologists and geologists for these individual faults. The SCEC lists this earthquake's location as 34° 13' N, 116° 26' W.

June 28, 1992, Big Bear Earthquake. While technically an aftershock of the Landers earthquake (indeed, the largest aftershock), the Mw 6.4 Big Bear earthquake occurred more than 25 miles (40 km) west of the Landers rupture, on a fault with a different orientation and sense of slip than those involved in the main shock — an orientation and slip which could be considered "conjugate" to the faults that slipped in the Landers rupture. The Big Bear earthquake rupture did not break the surface; in fact, no surface trace of a fault with the proper orientation has been found in the area. However, the earthquake produced its own set of aftershocks, and from these, we know the fault geometry — left-lateral slip on a northeast-trending fault.

Following the Landers mainshock by three hours (it occurred while television news coverage of the Landers earthquake was being broadcast live from Caltech), the Big Bear earthquake caused a substantial amount of damage in the Big Bear area, but fortunately claimed no lives. Landslides triggered by the jolt blocked roads in the San Bernardino Mountains, however, aggravating the cleanup and rebuilding process. The SCEC lists this earthquake's location as 34° 12' N, 116° 49.6' W.

April 22, 1992, Joshua Tree Earthquake. Preceded by a magnitude 4.6 foreshock — which, by itself, caused a stir — the Mw 6.1 Joshua Tree earthquake raised some alarms due to its proximity to the San Andreas Fault. A San Andreas Hazard Level B was declared following this quake, meaning that a 5 to 25 percent chance existed for an even larger earthquake to happen along the San Andreas Fault within 3 days. That never happened, of course, but roughly two months and 6,000 aftershocks later, the Landers

earthquake broke the surface of the Mojave desert in the largest quake to hit southern California in 40 years, showing that the concern caused by the Joshua Tree earthquake was warranted, though not in quite the way anticipated.

The aftershocks of the Joshua Tree earthquake suggested that the fault which slipped in the shock was a north-northwest-trending, right-lateral strike-slip fault at least 9 miles (15 km) long. From this and the location of the shocks, one can infer that the Eureka Peak fault may have been responsible for this earthquake.

Damage caused by the Joshua Tree earthquake was slight to moderate in the communities of Joshua Tree, Yucca Valley, Desert Hot Springs, Palm Springs, and Twentynine Palms. Thirty-two people were treated for minor injuries. Though somewhat forgotten in the wake of the Landers earthquake, the Joshua Tree earthquake was a significant event on its own, and was felt as far away as San Diego, Santa Barbara, Las Vegas, Nevada, and even Phoenix, Arizona. The SCEC lists this earthquake's location as 33° 57.6' N, 116° 19' W.

7.15.1.5 Geologic Hazards

The following sections discuss potential geologic hazards that may occur at the proposed project site.

Surface Fault Rupture

The Banning segment of the San Andreas Fault is assessed a maximum magnitude of 7.4 by the CDMG (1996). For a strike-slip fault Wells and Coppersmith (1994) estimate a mean maximum displacement of about 4 meters from an earthquake of this magnitude.

No faults are mapped at the proposed project site. The San Andreas (Banning Fault) and Devers Hill Fault are within a 2-mile radius of the site and are zoned under the Alquist-Priolo Act. The San Andreas Fault, about 0.26 mile (0.42 km) to the south and the Devers Hill Fault, about 0.21 mile (0.33 km) to the northeast are the fault zones closest to the site which could produce surface fault rupture and has demonstrated Holocene activity.

The Alquist-Priolo Special Studies Zone Act requires the CGS to designate faults considered active or potentially active, and to establish zones within which studies are required for structures involving human occupancy.

The Alquist-Priolo-zoned faults cross linear features in the project proposed project area, and the hazard from ground rupture is considered moderate.

Earthquake Ground Shaking

In this section the seismic design ground motion at the proposed project location is assessed under the provisions of the 1997 UBC. Ground shaking is a significant geologic hazard at this site.

The California Energy Commission (1989) recommends that nonnuclear power plants be designed to the level of conservatism implied by the UBC. The proposed project is located in 1997 UBC Seismic Zone 4.

The 1997 UBC design spectra are, to the first order, a function of seismic zone and site soil classifications. As part of the site subsurface investigation that was performed for a nearby site in February and March 2001 (Appendix R), site-specific soil characteristics were developed and the UBC soil class was determined to be Sc. As discussed further below, for Seismic Zone 4 the seismic design spectrum is also a function of nearby active faults, as specified by the seismic source type and the distance of the fault to the site.

Active faults within 9 miles (15 km) of a site located in UBC Seismic Zone 4 may modify the shape and amplitude of the first-order UBC spectrum, as defined by the so-called near-fault factors. The Banning segment of the San Andreas Fault is close enough to the project to affect the UBC design spectrum and is classified as a type A fault. Based on the Alquist-Priolo Zone, the proposed project site is located 0.26 mile (0.42 km) from the mapped surface trace of the Banning segment. However, as was discussed earlier, the seismic source modeling of this section of the San Andreas Fault for the 1997 UBC Atlas, CDMG (1996) state hazard map, and the national hazard maps (Frankel et al., 1996) places the San Andreas Fault at a distance of about 0.22 mile (0.36 km) from the project. For the 1997 UBC design spectrum, the near-source amplification factor (Na) is constant for distance of less than 1.2 miles (2 km) so the difference estimates of the closest distance from the site to the fault results in the same Na of 1.5.

Site stability aspects due to seismic shaking, such as slope stability, will be evaluated using the guidelines of Special Publication 117 of the California Division of Mines and Geology.

The most significant geologic hazard at the proposed project site is strong ground shaking due to an earthquake. The site has experienced at least moderate ground motions in the past and will in the future. Blake (2004) estimates that the ground shaking of an M 7.4 earthquake along the San Andreas fault could produce a peak bedrock acceleration of up to 0.70 g (rounded up, g = acceleration due to gravity) in the vicinity of the proposed project site. This is the maximum considered earthquake (MCE) event with ground motions associated with a 2,500-year mean return period or a 2 percent probability of exceedance in 50 years. This would affect the plant site.

Based on the potential earthquake shaking in the proposed project's vicinity depicted on Figure 7.15-7, Figure 7.15-8 shows that the ground motions with a 10 percent probability of being exceeded within the next 50 years are estimated at about 0.08 g (Campbell and Bozorgnia, 1997).

Liquefaction

Liquefaction is the phenomenon during which loose, saturated, cohesionless soils temporarily lose shear strength during strong ground shaking. Significant factors known to affect the liquefaction potential of soils are the characteristics of the materials such as grain-size distribution, relative density, degree of saturation, the initial stresses acting on the soils, and the characteristics of the earthquake, such as the intensity and duration of the ground shaking. Liquefaction typically occurs when the water table is shallow (generally less than 40 feet below ground surface) and the soils are predominantly granular and unconsolidated. The potential for liquefaction increases as the groundwater approaches the surface. Groundwater in the vicinity occurs at an approximate depth greater than 300 feet. Accordingly, the potential for liquefaction at the site is considered negligible.

Based on the geologic observations, site investigations, and laboratory testing, the foundation materials at the proposed project site are not expected to be subject to liquefaction for the following reasons:

- The low groundwater table.
- High density foundation materials.
- The presence of highly heterogeneous materials with high fines particle size content.
- Improbable development of pore pressures necessary to develop the liquefaction phenomenon.

This conclusion is supported by data contained in Appendix R.

Seiches and Tsunami

Seiches are oscillations in an enclosed body of water (e.g., lake, pond, water tank) that may be caused by an earthquake. The proposed project will include a retention basin and water tanks, so seiches could occur in this area. The retention basin is located along the southern boundary of the proposed power plant

site south of all the project facilities. The degree of damage that would occur in the event of a seiche would be less than significant.

Tsunamis are seismic sea waves that can be triggered by submarine earthquakes, landslides, or volcanic eruptions. Because no large bodies of water are adjacent to the proposed project site, the occurrence of a tsunami off the coast of California would have no impact on the proposed project.

Mass Wasting and Slope Stability

Slope instability depends on steepness of the slope, underlying geology, surface soil strength, and pore pressures in the soil. Based on general screening criteria, the site topography does not meet the categories for geologic environments likely to produce earthquake-induced landslides. Cut slopes and fills constructed for the planned site facilities would consider stability against slides.

The site is generally flat. There are no surface features of significant relief near the site that could develop a landslide hazard. Devers Hill and Garnet Hill are the only nearby features and both are incapable of a landslide of any significance to the site. Several minor ephemeral stream channels that cross the site are too shallow to pose a landslide hazard. The site does not exhibit a geologic environment nor topographic features likely to produce earthquake-induced landslides (CDMG, 1997). Slope stability associated with any cut slopes required for the site development of the project are discussed in Appendix R. Site stability aspects due to seismic shaking, such as slope stability, will be evaluated using the guidelines of Special Publication 117 of the California Division of Mines and Geology. The lack of significant slopes on or near the site indicates that the hazard from slope instability, both landslides and debris flows, is negligible.

Subsidence

Subsidence of the land surface can be attributed to natural phenomena, e.g., tectonic deformation, consolidation, hydrocompaction, collapse of underground cavities, oxidation of organic-rich soils, or rapid sedimentation, and also by the activities of man, e.g., the withdrawal of groundwater or hydrocarbons. Soil collapse (hydrocompaction) is a phenomenon that results in relatively rapid settlement of soil deposits due to addition of water. This generally occurs in soils having a loose particle structure cemented together with soluble minerals or with small quantities of clay. Water infiltration into such soils can break down the interparticle cementation, resulting in collapse of the soil structure. Collapsible soils are usually identified with index tests, such as dry density and liquid limit, and consolidation tests where soil collapse potential is measured after inundation under load.

The potential for seismically induced ground subsidence is considered to be low at the site. Dry sands tend to settle and consolidate when subjected to strong earthquake shaking. The amount of subsidence is dependent on relative density of the soil, ground motion, and earthquake duration. Uncompacted fill areas may be susceptible to seismically induced settlement. Loosely cemented, silty fine sand similar to that described in Section 7.3 of Appendix R has the potential to be collapsible when subjected to moisture increase. However, based on the data collected during the investigation, this sand is extremely dense and only occurs in localized, thin seams that are less than 1 foot thick. Most of the physical conditions responsible for areal land subsidence are not known to exist at the proposed project. Subsidence caused by groundwater withdrawals is not expected to be a significant problem at the proposed project. Therefore, the potential for soil collapse or settlement from inundation at the site is remote.

Expansive Soils

Soil expansion is a phenomenon in which clayey soils expand in volume as a result of an increase in moisture content, and shrink in volume upon drying. Expansive soils are usually identified with index tests, such as percentage of clay particles and liquid limit. It is generally accepted that soils with liquid

limits larger than about 50 percent, i.e., soils that classify as high plasticity clays (CH) or high plasticity silts (MH), may be susceptible to volume change when subjected to moisture variations.

Laboratory test results for representative soil samples indicated that the upper, near surface soils at the site generally classify as coarse-grained with percent fines lower than 20 percent. These soils are considered nonswelling and the potential for soil expansion at the site and its linear features is virtually nil.

Erosion and Sedimentation

The primary causes of erosion at the site are wind and water. Although considered to be a secondary hazard, wind erosion is anticipated due to the extremely windy conditions combined with fine windborne silt particles. Water is expected to be a more prevalent hazard than wind and would cause erosion in the stream drainages that cross the site. Based on reports of flooding during the winter of 1979/1980, attention to surface water diversion is important.

7.15.1.6 Geologic Resources

The project is not expected to cause a cumulative impact to geologic resources from construction or operation of the proposed project and associated linear components. There are no known petroleum reserves beneath the site property. There are no aggregate mining operations or mines within 2 miles of the site. No collectable or marketable minerals are known to be present in the proposed project area. The presence of naturally hot mineral water in the vicinity of the town of Desert Hot Springs is controlled by faults and is not expected to be influenced by construction or operation of the power plant (Proctor, 1968).

Mineral extraction is an important component of Riverside County's economy. The county has extensive deposits of clay, limestone, iron, sand, and aggregates. The SMGB established Mineral Resources Zones (MRZ) to designate lands that contain mineral deposits and has also designated Aggregate Mineral Resource areas within the county. Cities and counties are responsible for establishing policies and programs for the management of land uses in and around designated mineral deposit zones.

According to the California Geological Survey, the area to the north of I-10 in the project vicinity is located within a classified MRX-3 mineral resource zone, which indicates areas of mineral deposits that cannot yet be evaluated for significance according to the County of Riverside General Plan (County of Riverside, 2003). The construction of the proposed project could cause some reduction of the area available for surface mining activities, but does not preclude the ability of future mining in the site vicinity and is generally considered a compatible land use adjacent to a surface mine.

7.15.2 Environmental Consequences

Appendix G of the CEQA Guidelines provides examples of impacts that could be considered significant for geology and soils. Based on these examples, a project could result in a significant impact if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - 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,
  - Strong seismic ground shaking,
  - Seismic-related ground failure including liquefaction, or
  - Landslides.

- Results 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, creating substantial risks to life or property.
- Have 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.

Potential impacts of the proposed project on the geologic environment and potential impacts of the environment on the proposed project can be divided into those involving construction activities and those related to plant operation.

The geotechnical investigations conducted to develop the preliminary evaluation of the geological hazards at a adjacent site are described in Appendix R. A comprehensive investigation of the Banning Fault Zone was performed as part of the geologic characterization of the site. The results of this investigation are described in Appendix R.

The Banning Fault is active (Holocene) and occurs near the site. However, detailed site fault investigations show that the proposed power plant structures do not cross the fault. The hazard from ground rupture is negligible on the basis of this information. Site-specific characterization of the site foundation materials and depth to groundwater indicate that, at the shaking levels anticipated, secondary ground failure effects will not be expected to occur.

Linear features of the project will necessarily cross traces or splays of the active Banning Fault as indicated on Figure 7.15-6. This includes:

- A gas transmission/potable water line running in a north-south direction from the plant site to Dillon Road;
- An east-west gas transmission corridor along the Dillon Road right-of-way to an unpaved road (about one mile long); and
- A north-south gas transmission corridor from Dillon Road to the Indigo Power Plant.

Dominantly horizontal surface displacements associated with large future earthquakes along the Banning Fault could affect these utility lines and mitigation measures will be required to offset the consequences of such ruptures as described in Section 7.15.4.

Potential impacts of the proposed plant on the geologic environment and potential impacts of the environment on the project can be divided into those involving construction activities and those related to plant operation.

7.15.2.1 Construction

Grading of the proposed project site will include a balanced cut and fill to terrace the site to accommodate the eight combustion turbines generators. Over excavation and recompaction will be required in the temporary construction laydown area. Site grading is not expected to result in significant adverse impacts to the geologic environment.

7.15.2.2 Operations

Seismically induced ground shaking presents a moderate hazard to the proposed project facility. This impact is potentially significant. Liquefaction and slope failure are not hazards at the site. No other geologic hazards with the potential to significantly affect the proposed project were identified. With implementation of the mitigation measures proposed in Section 7.15.4, all geologic hazards will be reduced to a less-than-significant level.

No significant impacts on the geologic environment are expected from the operation of the proposed plant.

7.15.3 Cumulative Impacts

Based on proximity to the project site, the following future projects in the area are considered under cumulative impacts:

- Indian Avenue/I-10 Interchange Project: This proposed project involves reconstruction of the I-10 Freeway/Indian Avenue interchange and is located south of the proposed project. This reconstruction is expected to occur in 2008.

- Dillon Wind Farm: Installation of 45 wind turbines located in three separate areas, including (1) an area west of Devers substation, (2) an area 2,000 feet east of the project site, and (3) an area 4,500 feet to the southeast of the project site. The Environmental Impact Report for this project was recently certified by Riverside County.

- Wind Energy Conservation System (WECS) 20 Permit Project: This project would consist of 8 new GE 1.5 MW wind turbine generators in the existing WECS 20 Wind Park. This site is located approximately 0.5 mile west of State Route 62 and 2 miles north of I-10; about 2 miles northwest of the proposed project site.

- Green Path Project: The main feature of the Green Path project is a new 100-mile, 500kV line planned to extend from the Devers-Palo Verde transmission corridor north to a new Upland substation in the northeastern sector of Los Angeles Department of Water and Power (LADWP) service territory. The project would increase the reliability and voltage support of existing system by upgrading to 230kV standards of existing corridors. Planned construction is 2007 to 2009; planned in-service date is 2010.

- Oasis Annexation: Mixed-use development (including residential) on 155 acres located approximately 3.2 miles northeast of the project site.

- Alpine Group Development: Mixed-use development (including schools and high-density residential) on 160 acres located 1 mile northwest of the project site. The City Desert of Hot Springs is expecting to annex and approve this project.

- Palmwood Specific Plan and Outparcels Development: Mixed-use development (including 1,853 residential units) on 1,926-acres located 6.5 miles north of the site.

No impacts of a geologic hazard or geologic resources nature are anticipated at the project site due to the cumulative effects of the above listed projects or other possible projects to be constructed in the vicinity of the site.

7.15.4 Mitigation Measures

The following measures are proposed to mitigate potentially significant geologic hazards to less-than-significant levels for the proposed project. These mitigation measures are more accurately described as project design features. No unavoidable adverse impacts that cannot be mitigated to less than significant levels have been identified.

Final design for the proposed project will incorporate features that consider the strong shaking hazard and surface rupture potential to gas and water utilities crossing the Banning Fault. Erosion would be considered in surface water diversion measures. Wind erosion is expected to be of relatively less significance, but safeguards against wind loading will be considered in the design.

The proposed project will be designed in accordance with California Building Code (CBC) 1998 requirements and considering the results of the project-specific geotechnical and geologic studies. The CBC provision incorporating recent probabilistic, deterministic, and near-fault factors indicates that 0.70 g will provide an appropriate level of conservatism for design against the effects of earthquake shaking at the site.

The potential adverse impact from erosion or sedimentation (see Erosion and Sedimentation in Section 7.15.1.5) is low at this site. Design measures can mitigate the possible erosion or sedimentation that might occur in drainages on or immediately adjacent to this site. Project design measures to reduce potential impacts to soils are discussed in Section 7.9, Soils.

GEO-1: Prior to the start of construction, the project owner shall assign to the project an engineering geologist(s), certified by the State of California, to carry out the duties required by the 1998 edition of the California Building Code (CBC) Appendix, Chapter 33, Section 3309.4. The certified engineering geologist(s) assigned must be approved by the Compliance Project Manager (CPM). The functions of the engineering geologist can be performed by the responsible geotechnical engineer, if that person has an appropriate California license.

Verification: At least 15 days before the start of construction (or a lesser number of days mutually agreed to by the project owner and the Chief Building Official (CBO) prior to the start of construction) the project owner shall submit to the CPM for approval the name(s) and license number(s) of the certified engineering geologist(s) assigned to the project. The submittal should include a statement that CPM approval is needed. The CPM will approve or disapprove of the engineering geologist(s) and will notify the project owner of its findings within 7 days of receipt of the submittal. If the engineering geologist(s) is subsequently replaced, the project owner shall submit for approval the name(s) and license number(s) of the newly assigned individual(s) to the CPM. The CPM will approve or disapprove of the engineering geologist(s) and will notify the project owner of the findings within 7 days of receipt of the notice of personnel change.

GEO-2: The assigned engineering geologist(s) shall carry out the duties required by the 1998 CBC, Appendix Chapter 33, Section 3309.4 Engineered Grading Requirement, and Section 3318.1 – Final Reports. Those duties are:

1. Prepare the Engineering Geology Report. This report shall accompany the Plans and Specifications when applying to the CBO for the grading permit.

2. Monitor geologic conditions during construction.

3. Prepare the Final Engineering Geology Report.

Protocol: The Engineering Geology Report required by the 1998 CBC Appendix Chapter 33, Section 3309.3 Grading Designation, shall include an adequate description of the geology of the site, conclusions and recommendations regarding the effect of geologic conditions on the proposed development, and an opinion on the adequacy of the site for the intended use as affected by geologic factors.

The Final Engineering Geology Report to be completed after completion of grading, as required by the 1998 CBC Appendix Chapter 33, Section 3318.1, shall contain the following: A final description of the geology of the site and any new information disclosed during grading; and the effect of same on recommendations incorporated in the approved grading plan. The engineering geologist shall submit a statement that, to the best of his or her knowledge, the work within their area of responsibility is in accordance with the approved Engineering Geology Report and applicable provisions of this chapter.

Verification: (1) Within 7 days after submittal of the application(s) for grading permit(s) to the CBO, the project owner shall submit a signed statement to the CPM stating that the Engineering Geology Report has been submitted to the CBO as a supplement to the plans and specifications and that the recommendations contained in the report are incorporated into the plans and specifications. (2) Within 90 days following completion of the final grading, the project owner shall submit copies of the Final Engineering Geology Report required by the 1998 CBC Appendix Chapter 33, Section 3318 Completion of Work, to the CBO, and to the CPM on request.

GEO-3: Final project design must take into account potential surface ruptures associated with future large earthquakes on the Banning Fault that could adversely affect utility lines (specifically gas transmission and potable water) crossing the fault. These techniques are well known to engineers and could involve special design at fault crossings, e.g., providing pipeline flexibility by means of "loops" in the alignment coupled with the installation of automatic shutoff valves on either side of fault crossings.

7.15.5 Compliance with Laws, Ordinances, Regulations, and Standards

The County of Riverside Department, Building Division, was contacted to determine the building code that is currently in use and to inquire about any other pertinent issues regarding the design or construction of an "industrial facility."

The County of Riverside currently uses UBC 1997 to govern the design of buildings. It also uses the 1997 issue of the Uniform Mechanical Code and the 1996 issue of the National Electric Code. The city is within UBC Seismic Zone 4. Information on the ordinances and other requirements is available on the county website (County of Riverside, 2007). Of interest to this project is Ordinance No. 547.7 which implements the Alquist-Priolo Earthquake Fault Zoning Act for the county.

The proposed project will be constructed and operated in accordance with all laws, ordinances, regulations, and standards (LORS) applicable to geologic hazards and resources. LORS relevant to this project are discussed in the following sections, and listed in Table 7.15-3.

7.15.5.1 Federal

Acceptable design criteria for excavations and structures for static and dynamic loading conditions are specified by the Uniform Building Code (1997).

7.15.5.2 State

California Public Resources Code Section 25523(a): 20 CCR Section 1752(b) and (c)

The project site is located outside of the Alquist-Priolo Earthquake Fault Zone and is not subject to requirements for construction within that zone. For certain building design and requirement elements, the California Building Code Title 24 (2001) would supersede the UBC as discussed above.

The California Seismic Hazard Mapping Act requires the CGS to map seismic hazards other than surface faulting in designated areas. The recently of the proposed project is not within such an area, thus the Seismic Hazard Mapping Act is not applicable.

7.15.5.3 Local

The project site is located within an unincorporated area of Riverside County and would be subject to the LORS for the County of Riverside.

California Building Code, Appendix Chapter 33

This element sets forth rules and regulations to control excavation, grading, and earthwork construction, including fills and embankments. It establishes basic policies to safeguard life, limb, property, and public welfare by regulating grading on private property.

The geotechnical engineer and engineering geologist will certify the placement of fills and the adequacy of the site for structural improvements in accordance with the California Building Code, Appendix Chapter 33.

The geotechnical engineer will address Sections 3309 (Grading Permit Requirements), 3312 (Cuts), 3315 (Drainage and Terracing), 3316 (Erosion Control), 3317 (Grading Inspection), and 3318 (Completion of Work) of the California Building Code, Appendix Chapter 33. Additionally, the engineering geologist will present findings and conclusions pursuant to Public Resources Code, Section 25523(a) and 20 CCR, Section 1752(b) and (c).

California Building Code 1998, Volume 2, Chapter 16

This element sets forth rules and regulations that address potential seismic hazards. The administering agency for the above authority is the Riverside County Building Department. Riverside County has defined faults and study areas regarding geologic hazards would be applicable to the proposed activities at the site, other than the building permit review process.

7.15.6 Involved Agencies and Agency Contacts

Agencies with jurisdiction to issue applicable permits and enforce LORS related to geologic hazards and resources, and the appropriate contact person are shown below.

Agency	Contact/Title	Telephone
California Energy Commission	Steve Baker	(916) 654-3915
State of California, California Geological Survey	Bill Bryant	(916) 323-9672
County of Riverside, Planning Department	Jay Olivas	(760) 863-7579

7.15.7 Permits Required and Permit Schedule

The following local permit will be required; however no applicable permits specifically related to geological hazards are required.

Responsible Agency	Permit/Approval	Schedule
Riverside County Department of Public Works	Construction and Grading Permit	To be obtained before construction begins.

7.15.8 References

Allen, C. R., 1981. The modern San Andreas fault. W. G. Ernst (ed.). *The Geotectonic Development of California*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc. Rubey Vol. 1: 511-534.

Atwater, T., 1970. Implications of plate tectonics for the Cenozoic tectonic evolution of western North America. *Bull. Geol. Soc. Am.* Vol. 81: 3513-3536.

Bennett, R., W. Rodi, and R. Reilinger, 1996. Global positioning system constraints on fault slip rates in southern California and northern Haja, Mexico. *J. Geophys. Res.* Vol. 101: 21943-21960.

Blake, T. F., 2004. EQFAULT, A Computer Program for the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults.

Campbell, K. W. and Y. Bozorgnia, 1997 revised 2003. "Updated near–source ground motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra." *Bulletin of the Seismological Society of America*, Vol. 93, no. 1, February 2003 issue, pp. 314–331.

Cao, Tianqing, W. A. Bryant, B. Rowshandel, D. Branum, and C. J. Wills, 2003. The Revised 2002 California Probabilistic Seismic Hazard Maps, California Geological Survey.

CDMG (California Division of Mines and Geology), 1980. Special Studies (Earthquake Fault) Zones: Desert Hot Springs Quadrangle, Revised Official Map, effective January 1, 1980, scale 1:24,000.

CDMG (California Division of Mines and Geology), 1996. Probabilistic seismic hazard assessment for the State of California. DMG Open-File Report 96-08, 59 pp.

CDMG (California Division of Mines and Geology), 1997. Guidelines for Evaluation and Mitigation of Seismic Hazards in California, Special Publication 117. Appendix E: Geologic Environments Likely to Produce Earthquake-Induced Landslides. March 13, 1997.

CDMG (California Division of Mines and Geology), 1999. Seismic Shaking Hazard Maps of California, MS 048.

CEC (California Energy Commission), 1989. Recommended Seismic Design Criteria for Non-nuclear Power Generating Facilities in California. Prepared by URS Corporation and John A. Blume and Associates.

CGS (California Geological Survey), 2007. CGS website. URL: http://www.consrv.ca.gov/dmg/rghm/psha/. Accessed May 2007.

County of Riverside, 2003. Riverside County General Plan.

County of Riverside, 2007. County of Riverside Transportation and Travel Management Agency webpage. URL: http://www.tlma.co.riverside.ca.us. Accessed May 2007.

DeMets, C., R. G. Gordon, S. Stein, and D. F. Argus, 1987. "A revised estimate of Pacific-North America motion and implications for western North America plate boundary zone tectonics." *Geophys. Res. Letters*. Vol. 14: 911-914.

Ellsworth, W.L., 1990, Earthquake history, 1769-1989, chap. 6 of Wallace, R.E., ed., The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515, p. 152-187.

Engdahl, E. R. and W. A. Rinehart, 1991. Seismicity map of North America Project. In D. B. Slemmons, E. R. Engdahl, M. D. Zoback, and D. D. Blackwell (eds.), *Neotectonics of North America*. Boulder, Colorado: Geological Society of America. Decade Map Vol. 1: 21-27.

Frankel, A., C. Mueller, T. Barnhard, D. Perkins, E. V. Leyendecker, N. Dickman, S. Hanson, and M. Hopper, 1996. National seismic-hazard maps: documentation June 1996. U.S. Geological Survey Open-file report 96-532.

Hart, E. W., revised 1994, Fault rupture hazard zones in California: California Division of Mines and Geology Special Publication 42.

Hart, E.W., and Bryant, W.A., 1997, Fault–rupture hazard zones in California, Department of Conservation, Division of Mines and Geology Special Publication, 42.

Hill, D. P., J. P. Eaton, W. L. Ellsworth, R. S. Cockerham, and F. W. Lester, 1991. The seismotectonic fabric of central California. In D. B. Slemmons, E. R. Engdahl, M. D. Zoback, and D. D. Blackwell (eds.), *Neotectonics of North America*. Boulder, Colorado: Geological Society of America. Decade Map Vol. 1: 107-132.

Hirabayashi, C. K., T. K. Rockwell, S. G. Wesnousky, M. W. Striling, and F. Suarez-Vidal, 1996. "A neotectonic study of the San Miguel-Vallecitos fault," Baja California, Mexico. *Bull. Seism. Soc. Am*. Vol. 86, no. 6: 1770-1783.

Hutton, L. K., L. M. Jones, E. Hauksson, and D. D. Given, 1991. "Seismotectonics of southern California." In D. B., Slemmons, E. R. Engdahl, M. D. Zoback, and D. D. Blackwell (eds.), *Neotectonics of North America*. Boulder, Colorado: Geological Society of America. Decade Map Vol. 1: 133-152.

ICBO (International Conference of Building Officials), 1997. Uniform Building Code, 1997. Vol. 2. Whittier, California.

ICC (International Code Council), 2000. 2000 International Building Code. Available through International Conference of Building Officials. Whittier, California.

Irwin, W. P., 1990. "Geology and plate-tectonic development." In R. E. Wallace (ed.). *The San Andreas Fault System, California*. U.S. Geological Survey. Professional Paper 1515: 60-80.

Jennings, C. W., 1992. Preliminary fault activity map of California. California Division of Mines and Geology. Open File Report 92-03.

Jennings, C. W., 1994. Fault activity map of California and adjacent areas with locations and ages of Recent volcanic eruptions. California Division of Mines and Geology. Geologic Data Map No. 6.

Kahle, J. E., E. W. Hart, G. Borchardt, and M. W. Manson, 1987. Surface Rupture Associated with the North Palm Springs Earthquake of July 8, 1986 – Banning and Related Faults, Riverside County; Fault Evaluation Report FER-185. Unpublished report. California Division of Mines and Geology. Page 6. August 7, 1987.

Louie, J. N., C. R. Allen, D. C. Johnson, P. C. Haase, and S. N. Cohn, 1985. "Fault slip in Southern California." *Bull. Seism. Soc. Am*. Vol. 75, No. 3, pp. 811-833.

Magistrale, H. and T. Rockwell, 1996. "The central and southern Elsinore fault zone, southern California." *Bull. Seism. Soc. Am.* Vol. 86, no. 6: 1793-1803.

Magistrale, H. and C. Sanders, 1996. "Evidence from precise earthquake hypocenters for segmentation of the San Andreas fault in the San Gorgonio Pass." *J. Geophys. Res*. Vol. 101, B2, pp. 3031-3044.

Matti, J. C., D. M. Morton, and B. F. Cox, 1985. Distribution and geologic relations of fault systems in the vicinity of the Central Transverse Ranges, southern California. U.S. Geological Survey. Open-File Report 85-365.

Mendoza, C. and S. H. Hartzell, 1988. "Inversion of slip distribution using Teleseismic P Waveforms: North Palm Springs, Borah Peak, and Michoacan Earthquakes." *Bull. Seism. Soc. Am.* Vol. 78, No. 3, pp. 1092-1111.

Minster, J. B., and T. H. Jordan, 1978. "Present-day plate motions." *J. Geophys. Res.* Vol. 83: 5331-5354.

Mueller, K. J., and T. K. Rockwell, 1995. "Late Quaternary activity of the Laguna Salada fault in Northern Baja California, Mexico." *Geol. Soc. Am.* Vol. 107, pp. 8-18.

Perez, O., 1999. "Revised world seismicity catalog (1950-1997) for strong ($M_S \geq 6$) shallow ($h \leq 70$ km) earthquakes." *Bull. Seism. Soc. Am*. 89: 335-341.

Pioneer Consultants, 1984. Geotechnical Investigation, Wind Energy Generation Farm, Desert Hot Springs Area, Riverside County, California, a Portion of Section 9, T3S, R4E, S.B.B.M.

Proctor, R. J., 1968. Geology of the Desert Hot Springs-Upper Coachella Valley Area, California. California Division of Mines and Geology Special Report 94, 50 pp.

Rasmussen, Gary, 1981. Engineering Geology Investigation, 1,171-foot (east-west) by 2,700-foot (north-south) rectangular parcel. Tentative Tract No. 16847, Lots 1-67, North Palm Springs, California. Project No. 1671. Unpublished consulting report (CDMG file AP-1551).

Real, C. R., T. R. Toppozada, and D. L. Parke, 1978. Earthquake catalog of California, January 1, 1900 – December 31, 1974. California Division of Mines and Geology. Special Publication 52.

Sharp, R. V., M. J. Rymer, and D. M. Morton, 1986. "Trace-Fractures on the Banning Fault Created in Association with the 1986 North Palm Springs Earthquake." *Bull. Seism. Soc. Am*. Vol. 76, No. 6, pp. 1838-1843.

Slade, Richard C. and Associates, LLC, 2000. Final Hydrogeologic Evaluation, Well Siting and Recharge Potential Feasibility Study, Mission Creek Groundwater Subbasin, Riverside County, California.

Smith, D. P., 1979. Fault Evaluation Report FER-86 (Faulting in the Desert Hot Springs Area): Unpublished report, California Division of Mines and Geology. Page 3-4, Figures 3 and 7.

SCEC (Southern California Earthquake Center), 2007. Southern California Earthquake Center website. URL: www.scec.org. Accessed January 15-21, 2007.

Thomas, A. P. and T. K. Rockwell, 1996. "A 300- to 550-year history of the Imperial Valley fault near the U.S.-Mexico border: Missing slip at the Imperial fault bottleneck." *J. Geophys. Res.* Vol. 101, No. B3, pp. 5987-5997.

Toppozada, T. R., C. R. Real, and D. L. Parke, 1981. Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes. California Department of Conservation Division of Mines and Geology Open-File Report 81-11.

Toppozada, T. R., C. R. Real, S. P. Bezore, and D. L. Parke, 1984. Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes. Contract Number: 14-08-0001-18243. California Division of Mines and Geology.

Toppozada, T. R., California Division of Mines and Geology, 2000. Personal communication with Gary Lay, URS Corporation.

Toppozada, T. R. et al., 2000. Epicenters of and areas damaged by M5 California earthquakes, 1800-1999. CDMG, in press.

Treiman, J. A., 1994. The San Gorgonio Pass, Banning and Related Faults, Riverside County, California. Fault Evaluation Report FER-235. Unpublished report. California Division of Mines and Geology. pp. 39-40. September 27, 1994.

Vaughan, F.E., 1922, Geology of the San Bernardino Mountains north of San Gorgonio Pass: California University Publications in Geological Sciences, v. 13. p. 319-411.

Wallace, R. E., 1990. "General features." In R. E. Wallace (ed.) *The San Andreas Fault System, California.* U.S. Geol. Surv. Prof. Pap. 1515: pp 3-12.

Weldon, R. J., and E. Humphreys, 1986. "A kinematic model of southern California." *Tectonics.* Vol. 5: 33-48.

Wells, D. L. and K. J. Coppersmith, 1994. "New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement." *Bull. Seism. Soc. Am.* V. 84, n. 4, 974-1002.

WGCEP (Working Group on California Earthquake Probabilities), 1995. "Seismic hazards in southern California: probable earthquakes, 1994 to 2024." *Bull. Seism. Soc. Am.* Vol. 85, no. 2: 379-439.

Williams, P. L., S. Fagerson McGill, K. E. Sieh, C. R. Allen, and John N. Louie, 1988. "Triggered slip along the San Andreas Fault after the 8 July 1986 North Palm Springs Earthquake." *Bull. Seis. Soc. Am.* Vol. 78, No. 3, pp. 1112-1122.

Table 7.15-1
Magnitude 6 and Greater Earthquakes Within 114.5°-118.5°W, 32.5°-35.5°N

Catalog	Year	Universal Time			Lat. N	Long. W	Depth (km)	Dist. (km)	Io	Magnitude		
		Mon	Day	Hr:Mn:Sec						Size	Type	Donor
CGS	1769	7	28	00:00	34.000	118.000		132.0		6.00		CGS
CGS	1800	11	22	21:30	33.000	117.300		122.9		6.50		CGS
CGS	1812	12	8	15:00	34.370	117.650		110.6		7.00		CGS
CGS	1852	11	29	20:00	32.500	115.000		215.6		6.50		CGS
CGS	1855	7	10	00:00	34.100	118.100		142.1		6.00		CGS
CGS	1858	12	16	00:00	34.000	117.500		86.0		6.00		CGS
CGS	1862	5	27	20:00	32.700	117.200		148.0		6.00		CGS
CGS	1875	11	15	22:30	32.500	115.500		187.1		6.25		CGS
CGS	1890	2	9	12:06	33.400	116.300		63.6		6.25		CGS
TOPPO	1892	2	24	07:20	32.550	115.650		175.2		7.30		CGS
CGS	1892	5	28	11:15	33.200	116.200		87.6		6.25		CGS
CGS	1894	7	30	05:12	34.300	117.600		103.2		6.00		CGS
CGS	1899	12	25	12:25	33.800	117.000		41.9		6.40		CGS
CGS	1906	4	19	00:30	32.500	115.500		187.1		6.20		CGS
CGS	1915	6	23	03:59	32.800	115.500		159.9		6.00		CGS
CGS	1916	11	10	09:11	35.500	117.000		178.4		6.10		CGS
CGS	1918	4	21	22:32:25.00	33.750	117.000		44.1		6.90		CGS
CGS	1923	7	23	07:30:26.00	34.000	117.250		63.0		6.00		CGS
SCSN	1933	3	11	01:54:07.80	33.617	117.967		133.5		6.40	ML	SCSN
SCSN	1937	3	25	16:49:01.83	33.409	116.262	10	64.2		6.00	ML	SCSN
SCSN	1940	5	19	04:36:40.90	32.733	115.500		165.8		6.70	ML	SCSN
SCSN	1942	10	21	16:22:13.00	32.967	116.000		118.9		6.60	ML	SCSN
SCSN	1947	4	10	15:58:06.00	34.983	116.550		116.9		6.50	ML	SCSN
SCSN	1948	12	4	23:43:17.00	33.933	116.383		17.5		6.00	ML	SCSN
SCSN	1954	3	19	09:54:29.00	33.283	116.183		80.0		6.40	ML	SCSN
SCSN	1968	4	9	02:28:59.06	33.190	116.129	11	91.4		6.50	ML	SCSN
SCSN	1971	2	9	14:00:41.83	34.411	118.401	8	176.6		6.60	ML	SCSN
PEREZ	1979	10	15	23:16:55.00	32.630	115.330	12	184.5		6.54	Mw	PEREZ
PEREZ	1986	7	8	09:20:45.00	34.000	116.610	12	8.8		6.04	Mw	PEREZ

Table 7.15-1
Magnitude 6 and Greater Earthquakes Within 114.5°-118.5°W, 32.5°-35.5°N

Catalog	Year	Universal Time			Lat. N	Long. W	Depth (km)	Dist. (km)	Io	Magnitude		
		Mon	Day	Hr:Mn:Sec						Size	Type	Donor
PEREZ	1987	11	24	01:54:15.00	33.080	115.780	4	119.3		6.06	Mw	PEREZ
PEREZ	1987	11	24	13:15:56.00	33.010	115.840	2	122.3		6.54	Mw	PEREZ
PEREZ	1992	4	23	04:50:23.00	33.960	116.320	12	23.6		6.18	Mw	PEREZ
PEREZ	1992	6	28	11:57:34.00	34.200	116.440	1	32.6		7.33	Mw	PEREZ
PEREZ	1992	6	28	15:05:31.00	34.200	116.830	5	38.4		6.52	Mw	PEREZ
SCSN	1999	10	16	09:46:44.10	34.594	116.271		78.9		7.10	ML	SCSN

Note: Distance is relative to 116.57°W, 33.92°N, CPV Sentinel Energy Project.

Table 7.15-2
Major Faults in the Vicinity of the CPV Sentinel Energy Project

Fault Name	Approximate Distance mi (km)	Maximum Earthquake Magnitude (Mw)	Peak Site Acceleration (g)	Estimated Site Intensity Modified Mercalli
San Andreas – Southern	0.4 (0.7)	7.4	0.698	XI
San Andreas – San Bernardino	0.4 (0.7)	7.3	0.662	XI
San Andreas – Coachella	6.0 (9.6)	7.1	0.351	IX
Pinto Mountain	10.0 (16.1)	7.0	0.238	IX
Burnt Mountain	11.2 (18.1)	6.4	0.160	VIII
Eureka Peak	13.7 (22.1)	6.4	0.139	VIII
Landers	18.0 (29.0)	7.3	0.182	VIII
North Frontal Fault Zone (East)	18.1 (29.2)	6.7	0.161	VIII
San Jacinto-Anza	23.1(37.2)	7.2	0.143	VIII
San Jacinto-San Jacinto Valley	24.0 (38.6)	6.9	0.119	VII
Emerson So. – Copper Mountain	26.3 (42.4)	6.9	0.111	VII
North Frontal Fault Zone (West)	26.7 (42.9)	7.0	0.140	VIII
Johnson Valley (Northern)	27.3 (43.9)	6.7	0.097	VII
Lenwood-Lockhart-Old Woman Springs	29.0 (46.7)	7.3	0.127	VIII
San Jacinto-Coyote Creek	33.4 (53.7)	6.8	0.087	VII
Calico – Hidalgo	34.1 (54.9)	7.1	0.101	VII
Helendale – S. Lockhardt	34.5 (55.5)	7.1	0.100	VII
Pisgah–Bullion Mtn.–Mesquite Lk	34.5 (55.6)	7.1	0.100	VII
San Jacinto–San Bernardino	38.5 (62.0)	6.7	0.074	VII
Cleghorn	43.4 (69.8)	6.5	0.061	VI
Elsinore–Temecula	45.4 (73.1)	6.8	0.069	VI
Elsinore–Julian	46.2 (74.3)	7.1	0.080	VII
Elsinore–Glen Ivy	48.9 (78.7)	6. 8	0.065	VI
Earthquake Valley	52.2 (84.0)	6.5	0.053	VI
Cucamonga	52.3 (84.1)	7.0	0.084	VII
San Jacinto – Borrego	55.3 (89.0)	6.6	0.053	VI
Chino–Central Ave. (Elsinore)	57.6 (92.7)	6.7	0.066	VI
San Andreas – 1857 Rupture	60.6 (97.6)	7.8	0.093	VII
San Andreas – Mojave	60.6 (97.6)	7.1	0.065	VI
Whittier	61.3 (98.7)	6.8	0.055	VI
Brawley Seismic Zone	64.2 (103.3)	6.4	0.043	VI
San Jose	65.2 (105.0)	6.5	0.054	VI

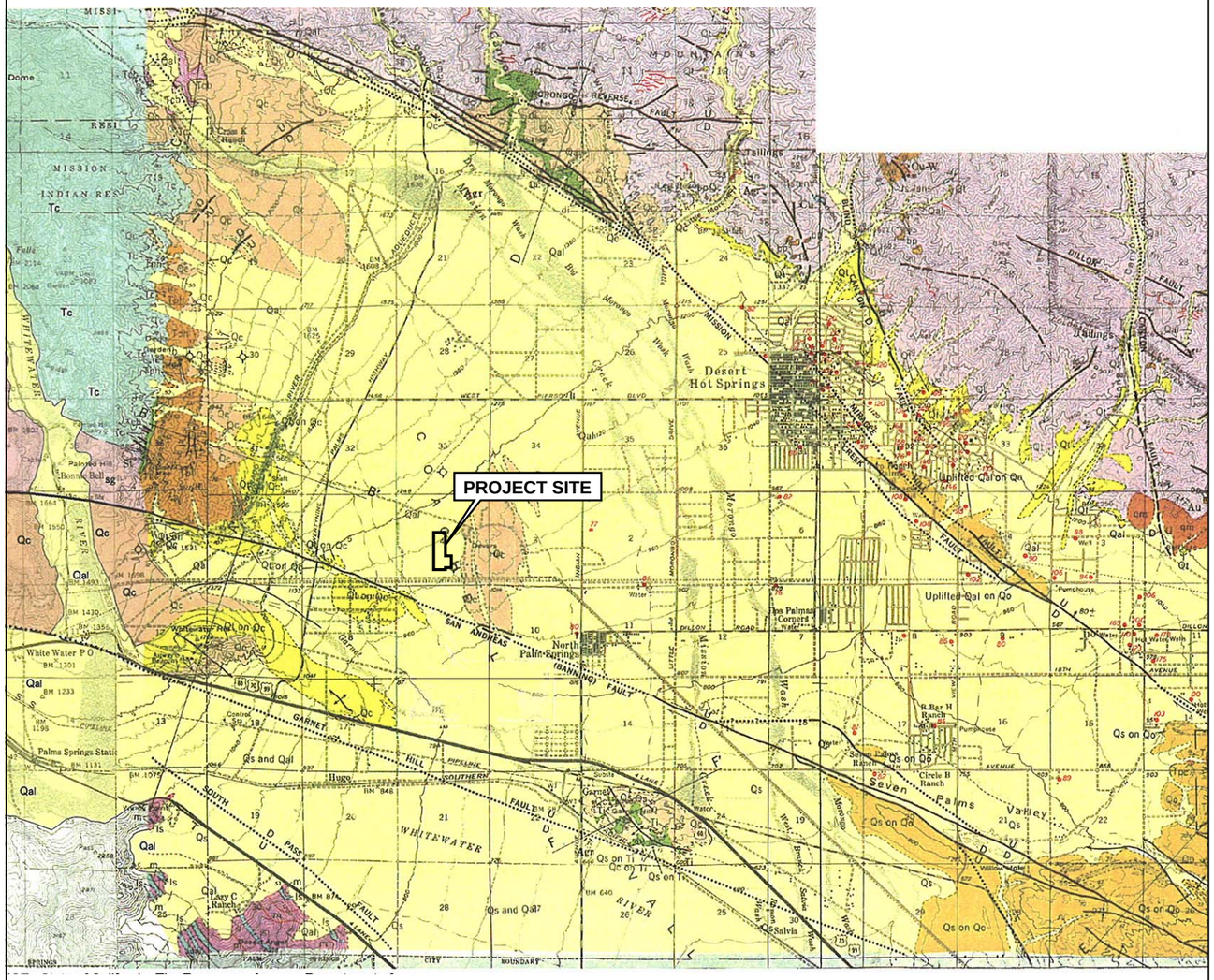
Table 7.15-2
Major Faults in the Vicinity of the CPV Sentinel Energy Project

Fault Name	Approximate Distance mi (km)	Maximum Earthquake Magnitude (Mw)	Peak Site Acceleration (g)	Estimated Site Intensity Modified Mercalli
Sierra Madre	67.4 (108.5)	7.0	0.069	VI
Gravel Hills – Harper Lake	67.6 (108.8)	6.9	0.053	VI
Elsinore–Coyote Mountain	68.2 (109.8)	6.8	0.050	VI
Elmore Ranch	71.7 (115.4)	6.6	0.044	VI
Elysian Park Thrust	72.3 (116.3)	6.7	0.056	VI
Newport–Inglewood (Offshore)	72.3 (116.4)	6.9	0.051	VI
Rose Canyon	74.1 (119.3)	6.9	0.050	VI
Superstition Mountain (San Jacinto)	75.1 (120.9)	6.6	0.042	VI
Clamshell-Sawpit	75.9 (122.2)	6.5	0.048	VI
Superstition Hills (San Jacinto)	76.4 (123.0)	6.6	0.041	V
Blackwater	79.3(127.7)	6.9	0.047	VI
Newport-Inglewood (L.A. Basin)	80.8 (130.1)	6.	0.046	VI
Compton Thrust	80.9 (130.2)	6.8	0.054	VI
Raymond	83.6 (134.6)	6.5	0.045	VI
Verdugo	88.5 (142.5)	6.7	0.047	VI
Coronado Bank	89.2 (143.6)	7.4	0.056	VI
Palos Verdes	90.5 (145.6)	7.1	0.047	VI
Imperial	91.2 (146.7)	7.0	0.045	VI
Laguna Salada	92.6 (149.0)	7.0	0.044	VI
Hollywood	95.9(154.3)	6.4	0.038	V

Source: Blake, 2004. EQFAULT, A Computer Program for the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults

Table 7.15-3
Laws, Ordinances, Regulations, and Standards

Laws, Ordinances, Regulations, and Standards	Applicability	Administering Agency	Conformance
Federal			
Uniform Building Code (UBC)	Design criteria for excavations and structures under static and dynamic loading conditions	Riverside County	7.15.5.1, Appendix C
State			
California Building Code, 2001	Superseded by UBC	California Building Standards Commission, State of California	7.15.5.2
Alquist Priolo Earthquake Fault Zoning Act;Title 14, Division 2, Chapter 8, Subchapter 1, Article 3, California Code of Regulations.	Identifies areas subject to surface rupture from active faults	California Geological Survey	7.15.5.2.1
Seismic Hazards Mapping Act Title 14, Division 2, Chapter 8, Subchapter 1, Article 10, California Code of Regulations.	Identifies nonsurface fault rupture earthquake hazards, including liquefaction and seismically induced landslides.	California Geological Survey	7.15.5.2.1
Regional			
None	N/A	N/A	7.15.5.3
Local			
California Building Code, 2001	Superseded by UBC Acceptable design criteria for structures with respect to seismic design and loadbearing capacity.	Riverside County	7.15.5.3
Alquist Priolo Earthquake Fault Zoning Act;Title 14, Division 2, Chapter 8, Subchapter 1, Article 3, California Code of Regulations.	Identifies areas subject to surface rupture from active faults	Riverside County	7.15.6.2
Seismic Hazards Mapping Act Title 14, Division 2, Chapter 8, Subchapter 1, Article 10, California Code of Regulations.	Identifies non–surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides.	Riverside County	7.15.6.2



EXPLANATION

QUATERNARY

Recent

Qs — Superficial Sand
Mainly blowsand; few dunes

Qal — Alluvium

Upper Pleistocene

Qt — Terrace Deposits
Thin orange mantle of gravels

Qc, Qo (ss) — Cabezon Fanglomerate and Ocotillo Conglomerate
Sandy ill-sorted light brown conglomerate; ss=resistant sandstone beds

TERTIARY

Middle Pliocene To Lower Pleistocene

Tph, Tpc (cg), Tps (b) — Painted Hill and Palm Springs Formations, Canebrake Conglomerate
Tph, Tpc=sandy well rounded conglomerate, Tps=siltstone; cg=resistant conglomerate bed; b-olivine basalt

Lower Pliocene

Ti — Imperial Formation
Marine sandstone and shale, fossiliferous

Upper Miocene(?)

Tcb, Tc, Ts — Coachella Fanglomerate and Split Mountain Formation
Red-brown conglomerate and coarse sandstone; Tcb-olivine basalt; Ts=(shown in sections only)

MAINLY PRE-MESOZOIC

m, ls — Metamorphic Rocks of the San Jacinto Mountains
Mica shist, gneiss and dikes; ls=recrystallized limestone large aplite dikes and sills shown in red

bp, sg, c, di, qm — San Gorgonio Complex (Chuckwalla Complex)
Mainly contorted migmatitic gneisses: c=Cactus Granite of Vaughn (1922); qm=quartz monzonite; di=diorite porphyry; bp=basic plutonic rocks (gabbroic); xe=xenolith breccia; large aplite dikes shown in red

SYMBOLS

Contact
(Dashed where approximately located, gradational or inferred)

U D — Fault, showing dip
(Dashed where approximately located; queried where uncertain; U, Upthrown side; D, downthrown side)

Concealed fault

Fault, showing relative movement

A T — Fault plane in section
(A=away; T=toward)

Strike and dip of beds

Strike and dip of foliation

Axis of syncline

Axis of anticline

Anticline showing direction of plunge

Abandoned oil well site

Landslump
(on Whitewater Hill)

Mine or quarry
Agr-aggregate
Au-gold
Cu-copper
St-building stone
W-tungsten

146 — Water well and water temperature (°F.)

0 8,000 16,000
Scale in Feet

State of California, The Resources Agency, Department of Conservation, Division of Mines and Geology, Desert Hot Springs Area, Riverside County, California, 1968, Special Report by R.J. Proctor

REGIONAL GEOLOGIC MAP

CPV Sentinel Energy Project
CPV Sentinel, LLC
Riverside County, California

June 2007
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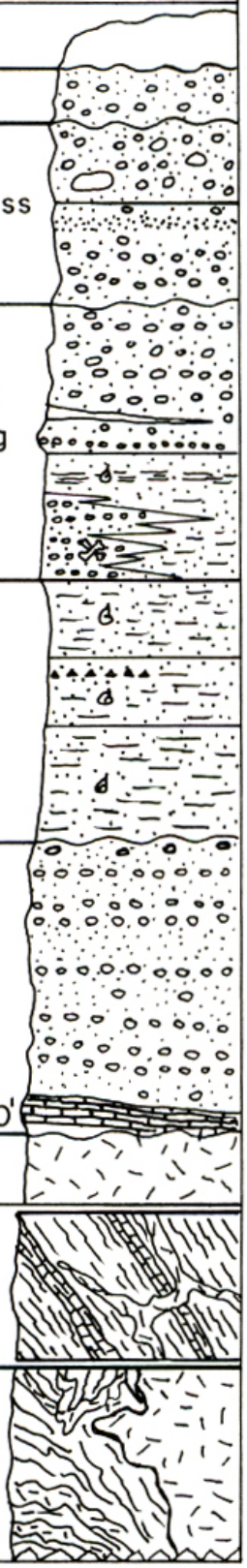
FIGURE 7.15-1

6/21/07 vsa ..T:\CPV Sentinel (Ocotillo)\7.15 Geohazards\7.15-1_Regional Geologic Map.ai

AGE	FORMATION	SYMBOL & THICKNESS
Recent	Sand and alluvium	Qs & Qal
	Terrace deposits	Qt <30'
Pleist.	Cabezon Fanglomerate and/or Ocotillo Conglomerate: Sandy, ill-sorted debris: ss = resistant sandstone.	Qc >1500' ss Qo >2400'
Middle & Upper Pliocene	Painted Hill Formation and/or Canebrake Conglomerate: Coarse, bouldery debris; b = basalt flow cg= resistant conglomerate bed Palm Spring Formation: Equus cf. (Plesippus) & brackish water fossils found near top of beds.	Tph >3400' b cg Tc >2000' Tps
Lower Pliocene	Imperial Formation: Near shore marine, fossiliferous sandy siltstone; 2 foot thick tuff bed on Garnet Hill.	Ti Painted Hill 0-100' Ti Garnet Hill >70' Ti Indio Hills 0-1660'
Upper Miocene	Coachella Fanglomerate: Red-brown well indurated conglomerate and sandstone; Tcb = olivine basalt flows. Split Mountain Formation (Not exposed on surface)	Tc >4600' Ts Tcb 300'
Cretac.	Cactus Granite and quartz monzonite diorite porphyry	c qm di
	contact not exposed	
Late Paleozoic	Metamorphic Rocks of the San Jacinto Mountains: Quartzite-mica-schists, recrystallized limestone and gneisses.	ls m >10,000'
	contact not exposed	
pre-Є(?)	San Gorgonio Complex (Chuckwalla Complex): Amphibolite and migmatitic paragneisses.	sg >20,000'



State of California, The Resources Agency, Department of Conservation, Divison of Mines ang Geology, Desert Hot Springs Area, Riverside County, California, 1968, Special Report by R.J. Proctor

GEOLOGIC UNITS IN THE PROJECT AREA

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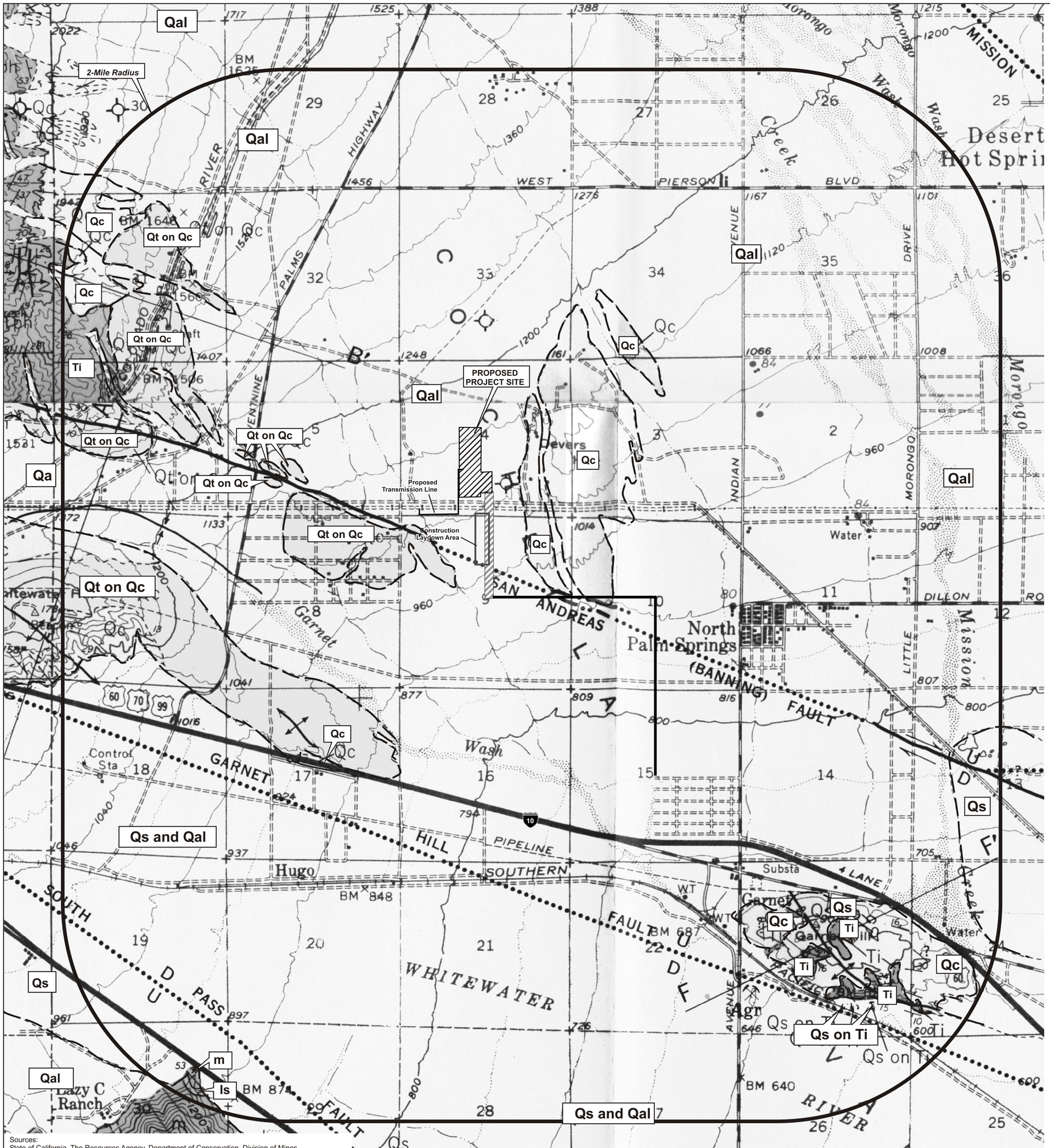
FIGURE 7.15-2

6/08/07 vsa ..T:\CPV Sentinel (Ocotillo)\7.15 Geohazards\7.15-2_Geologic units.ai



LEGEND

- Proposed Project Site
- Gas Transmission Corridor
- Gas Transmission/ Potable Water Line/ Access Road Corridor
- Construction Laydown Area
- Transmission Line

Qs	Superficial Sand
Qal	Alluvium
Qt	Terrace Deposits
Qc	Cabezon Fanglomerate
Ti	Imperial Formation
m	Metamorphic Rocks
ls	Recrystallized Limestone

SYMBOLS

Contact
(Dashed where approximately located, gradational or inferred)

Fault, showing dip
(Dashed where approximately located; queried where uncertain; U, Upthrown side; D, downthrown side)

Concealed fault

Fault, showing relative movement

Strike and dip of beds

Axis of anticline

Anticline showing direction of plunge

Abandoned oil well site

N

0 0.5 1
Scale in Miles

0 2000 4000
Scale in Feet
1:24,000

Sources:
State of California, The Resources Agency, Department of Conservation, Division of Mines and Geology, Desert Hot Springs Area, Riverside County, California 1968, Special Report by R.J. Proctor;
Base map: Topographic Division, U.S. Geological Survey

6/21/07 vsa..\CPV Sentinel (Ocotillo)\7.15 Geohazards\7.15-3 local geo_2mi.cdr

LOCAL GEOLOGIC MAP

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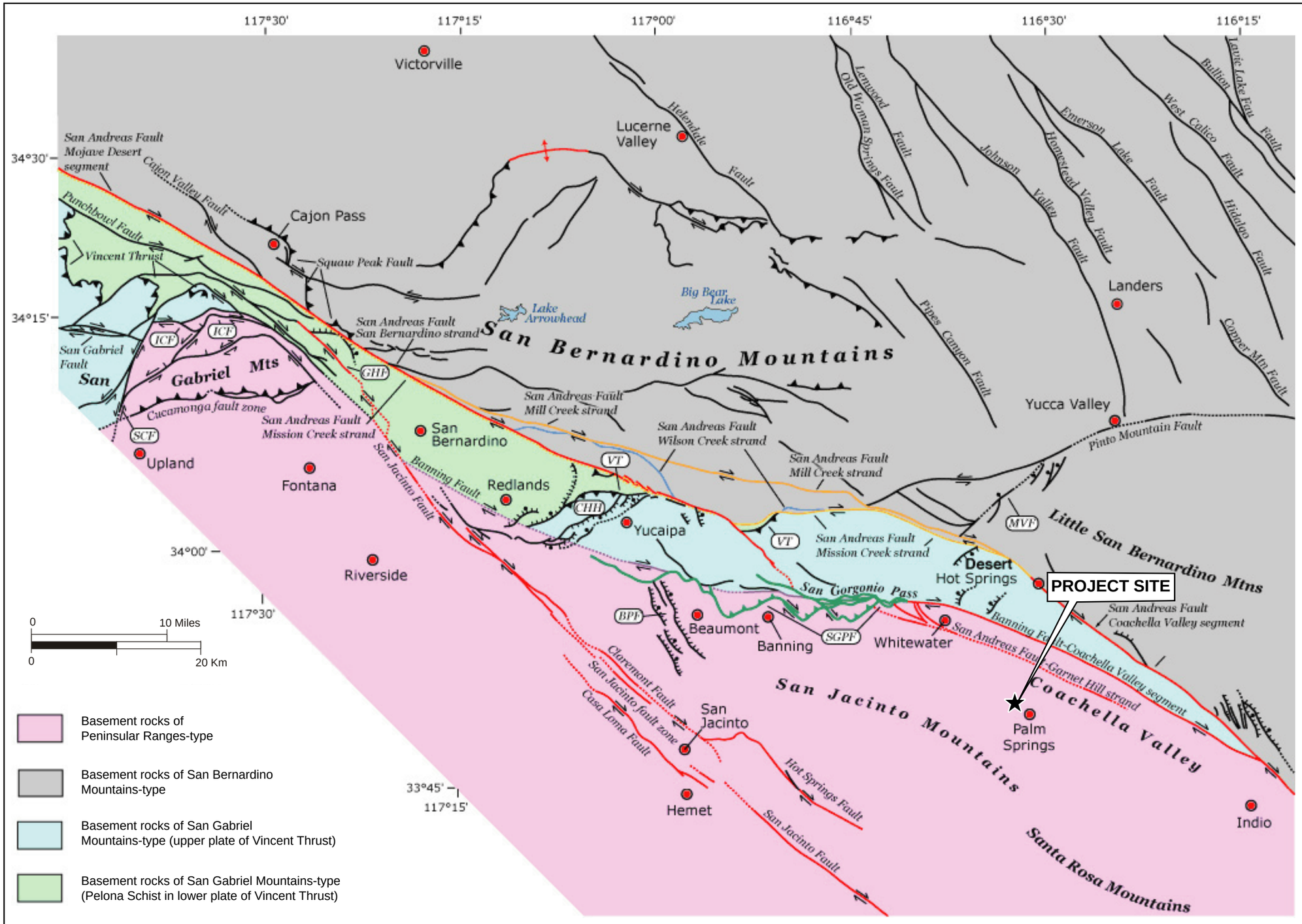
FIGURE 7.15-3



MAJOR FAULTS IN THE VICINITY OF THE PROPOSED PROJECT

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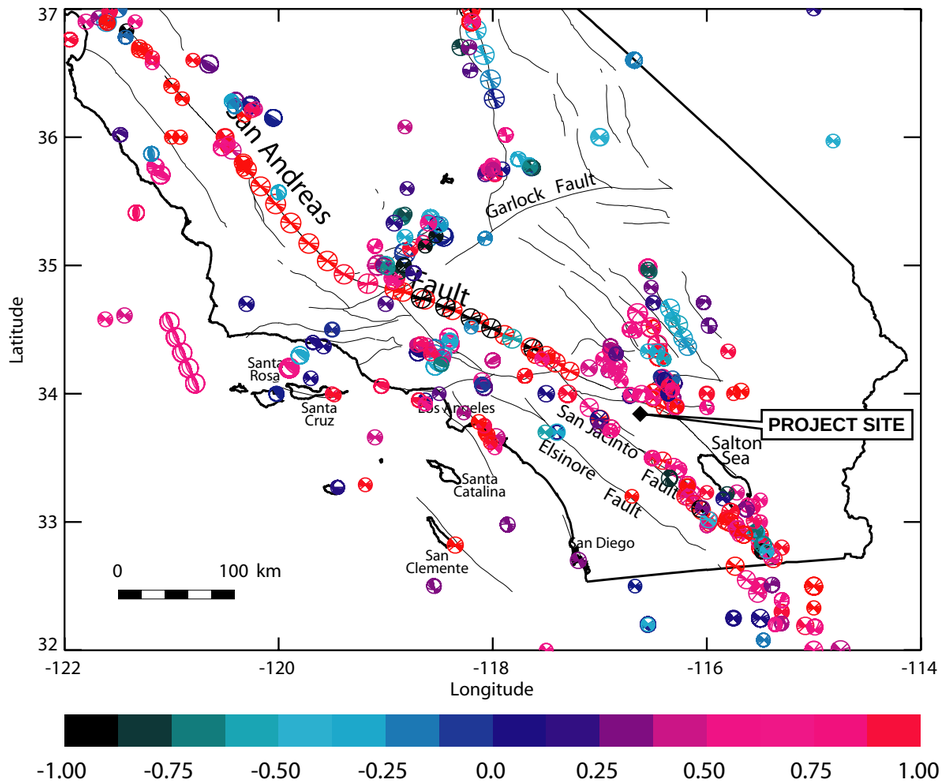
FIGURE 7.15-4

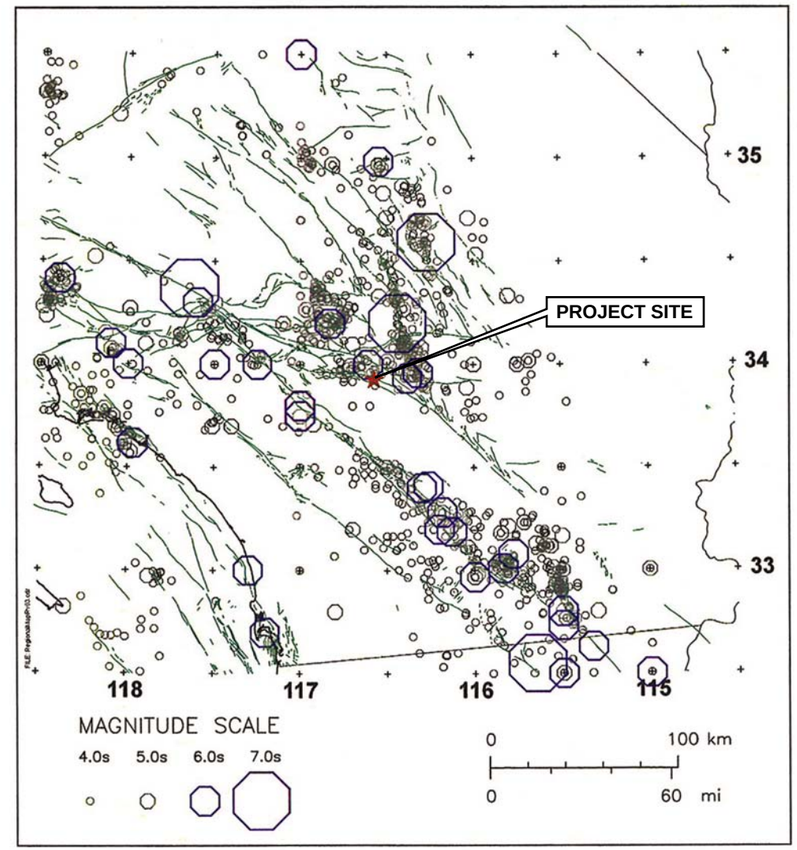
6/21/07 vsa/hk ..T:\CPV Sentinel (Ocotillo)\7.15 Geohazards\7.15-4_Major Faults.ai



Correlation: focal mechanism - stress

Focal mechanisms of earthquakes from 1800-2003 in the southern California area and major surface faults. Lower hemisphere diagrams of focal spheres are shown; the diagrams can be thought of as 3-D rotations of the mechanism. Modified Ellsworth (1990) and Toppozada et al. (2000) catalogs are used with addition of other data. Symbol size is proportional to earthquake magnitude. More dense "beachballs" correspond to point sources, striped symbols to extended sources. Stripes in beachballs are concentrated towards the assumed earthquake fault-plane. Diagrams are colored according to the consistency of the focal mechanisms with the tectonic andcoseismic static stress accumulated starting with 1850, by origin time of earthquake. Red means that focal mechanism is consistent (correlated) with the stress tensor, blue (black) signes the anticorrelation.

Source: Dept. of Earth and Space Sciences, University of California, Los Angeles



Plot of Regional Seismicity

HISTORICAL SEISMICITY (1864-2006)
IN THE VICINITY OF THE PROJECT

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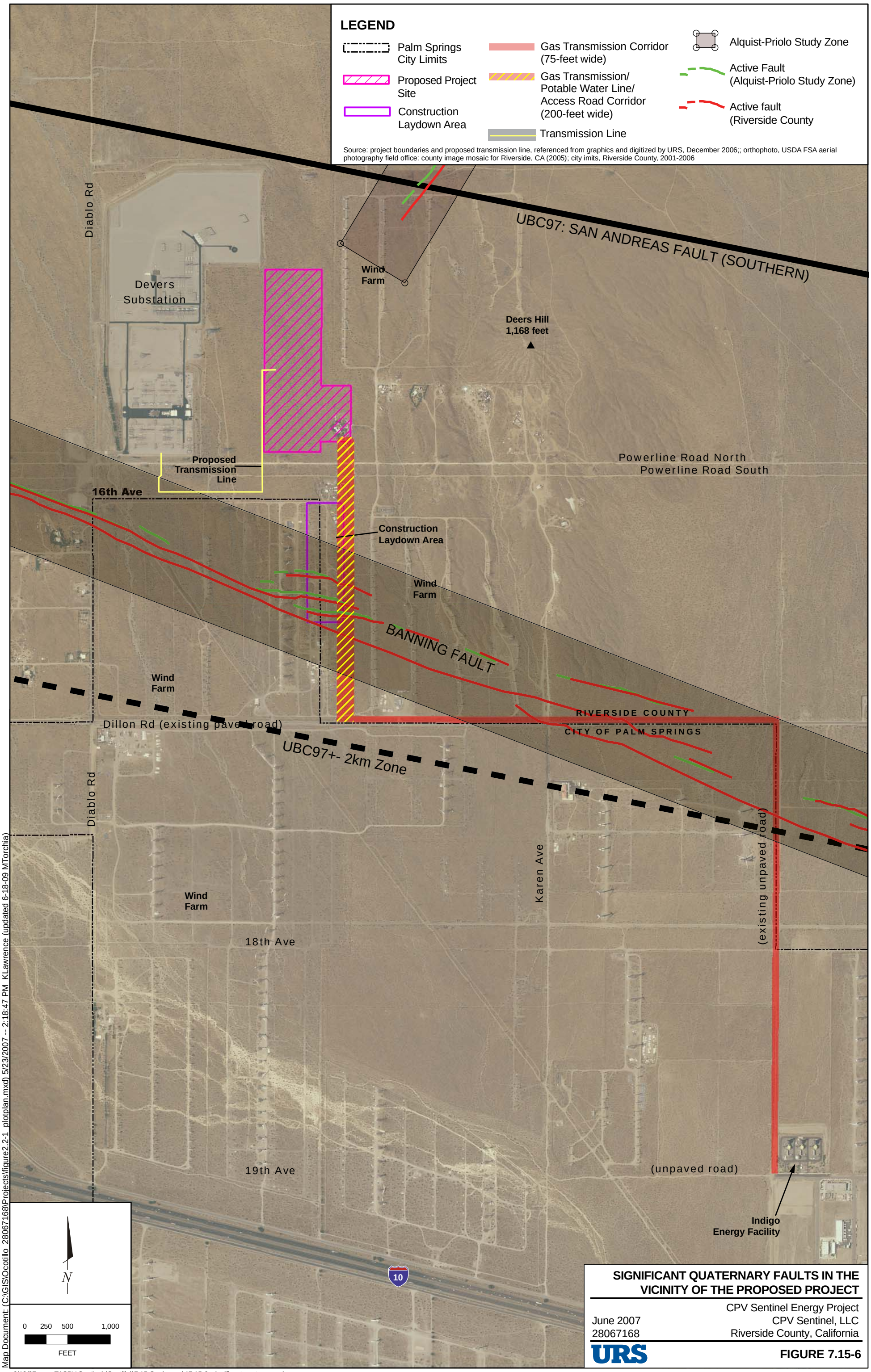
FIGURE 7.15-5



SIGNIFICANT QUATERNARY FAULTS IN THE VICINITY OF THE PROPOSED PROJECT

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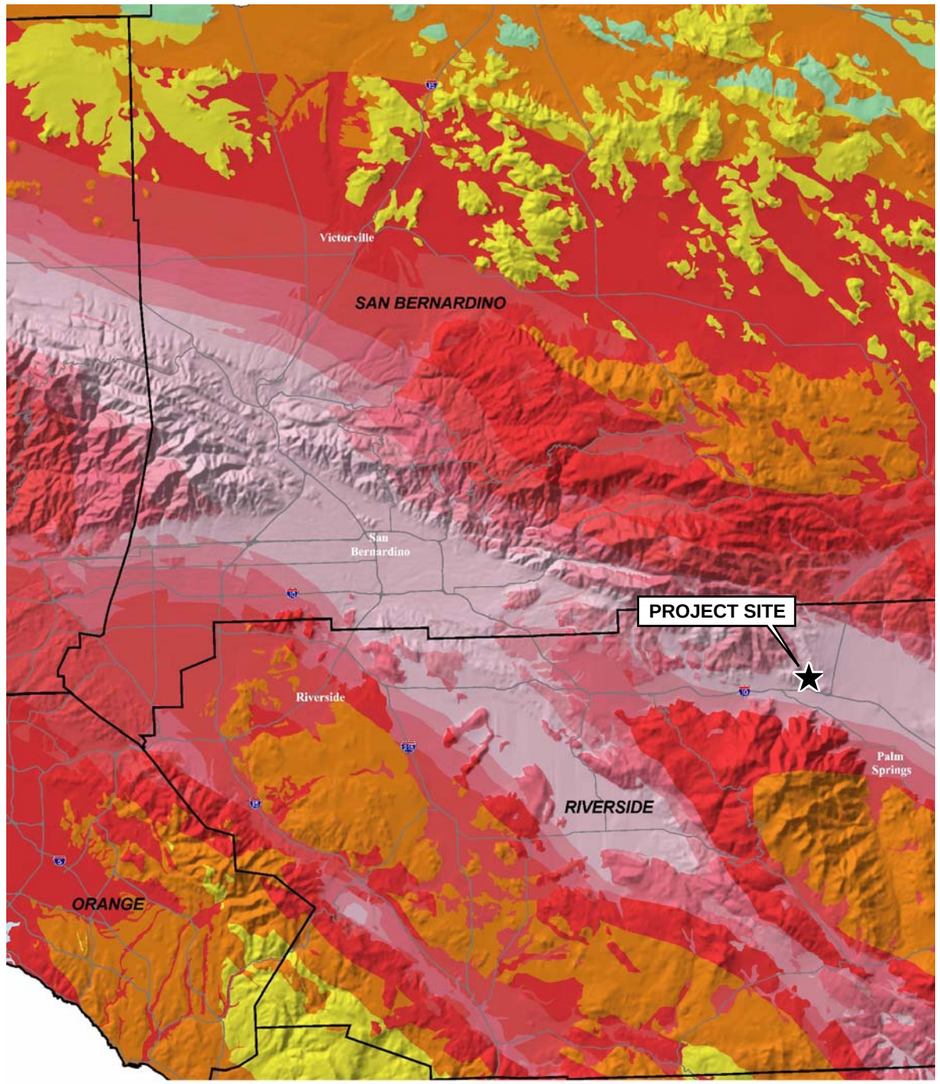
FIGURE 7.15-6

Map Document: (C:\GIS\Ocotillo_28067168\Projects\figure2.2-1_plotplan.mxd) 5/23/2007 -- 2:18:47 PM KLawrence (updated 6-18-09 MTorchia)

6/19/07 vsa ..T:\CPV Sentinel (Ocotillo)\7.15 Geohazards\7.15-6_significant quaternary.ai



Level of Earthquake Hazard

These regions are near major, active faults and will on average experience stronger earthquake shaking more frequently. This intense shaking can damage even strong, modern buildings.

Increasing intensity

These regions are distant from known, active faults and will experience lower levels of shaking less frequently. In most earthquakes, only weaker, masonry buildings would be damaged. However, very infrequent earthquakes could still cause strong shaking here.

County boundaries
Highways
Water

N W E S

0 5 10 Miles
0 5 10 Kilometers

Important messages about earthquakes for the Los Angeles metropolitan area:

- Earthquakes have produced over $55 billion in losses in California since 1971. The next large earthquake may produce even greater losses, especially if it affects a major urban area. If the Northridge or Loma Prieta earthquakes had occurred closer to a major population center, fatalities would have been much higher.
- A large earthquake in or near the Los Angeles metropolitan area will disrupt the economy of the entire State and much of the nation. Effective disaster planning by State and local agencies, and by private businesses, can dramatically reduce losses and speed recovery. (For information go to www.oes.ca.gov or www.seismic.ca.gov.)
- Current building codes will reduce damage but their objective is life safety, not continued operation of the facility.
- After a large earthquake, residents and businesses may be isolated from basic police, fire, and emergency support for a period ranging from several hours to a few days. Citizens must be prepared to survive safely on their own, and to aid others, until outside help arrives. (For information go to www.oes.ca.gov.)
- Maps of the shaking intensity after the next major earthquake will be available within minutes on the Internet. The maps available at http://www.cisn.org/shakemap, a cooperative effort of OES, CGS, USGS, Caltech and UC Berkeley, will help identify the areas most seriously affected and will guide emergency crews to the most damaged regions.

Source:
Earthquake Shaking Potential for the Los Angeles Region Counties,
Suumer 2003
Data Sources:
California Sesimic Safety Commision, California Geological Survey, Governor's Office of Emergency Services, and United States Geological Survey, April 2003, Earthquake Shaking Potential for California, California Seismic Safety Commission Publication No. 03-02.
Major roads from Thomas Brothers Maps, Inc., 2000, 2001. Shaded relief from U.S. Geological Survey meter DEMs.

EARTHQUAKE SHAKING POTENTIAL IN THE VICINITY OF THE PROPOSED PROJECT

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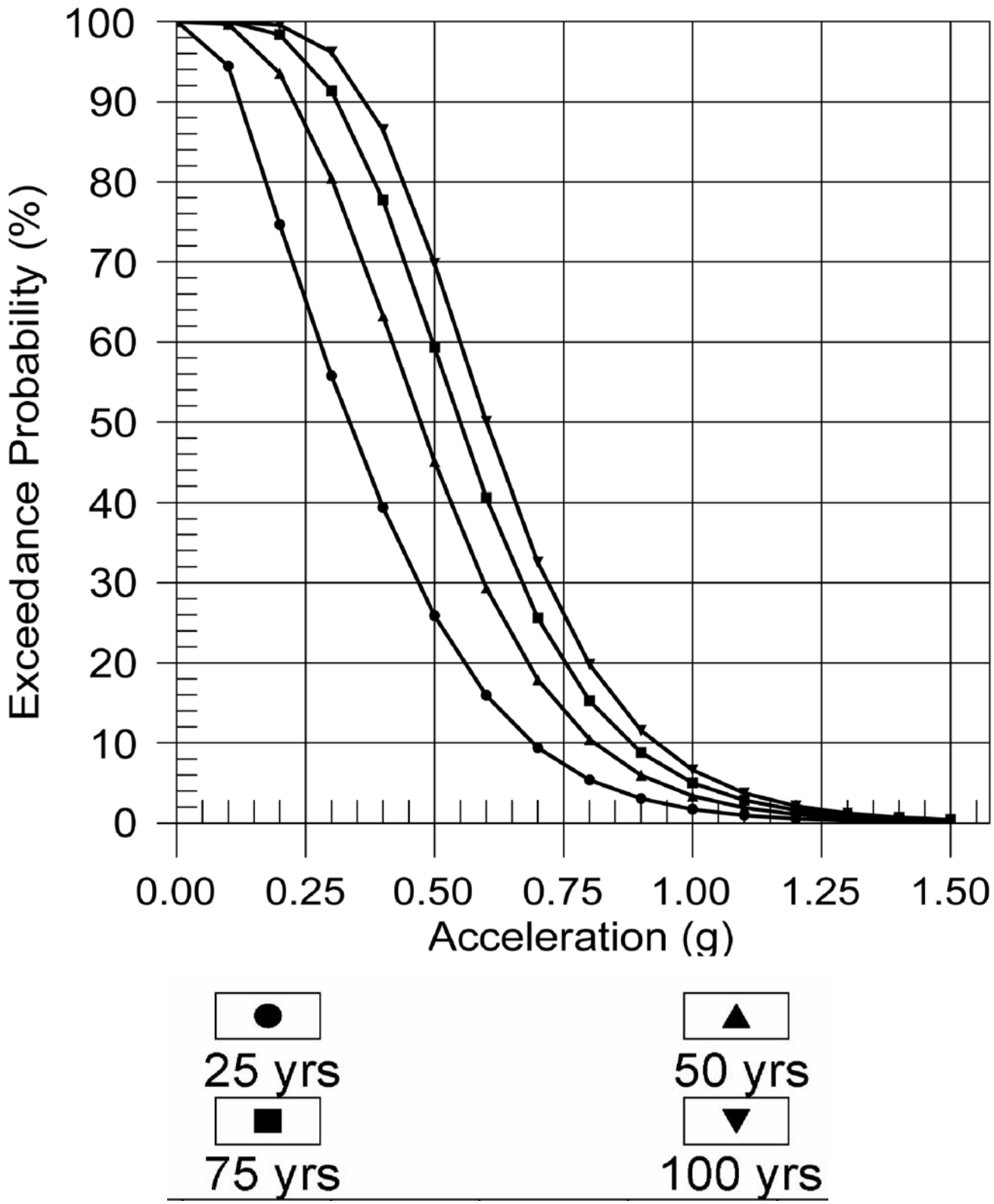
FIGURE 7.15-7



Campbell and Bozorgonia (1997 rev.)

PROBABILITY OF EXCEEDANCE FOR THE PROPOSED PROJECT

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FIGURE 7.15-8

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