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6.5 GEOLOGICAL RESOURCES AND HAZARDS

This section presents information on the general geology of the region, subsurface conditions at the Project, geologic hazards affecting the Project, and potential impacts of the Project on the geologic resources in the area.

Identification of geologic hazards and mineral resources is based on published literature and Project Site investigations. Regarding geologic resources, evaluations of impact significance are based on the type and the proximity of resource to the Project. Recommendations are provided for mitigation of geologic hazards and geotechnical issues at the Project Site. Figures are found at the end of this section.

The information provided in this section is based on a review of published geologic and mineral resource references and the Geotechnical Investigation prepared by Geotechnics Incorporated (2006). This report is found in Appendix C, Geotechnical Investigation.

6.5.1 Affected Environment

This SPPE Application is for the construction and operation of the ECGS Unit 3 Repower Project. The Project will be owned and operated by IID ("the Applicant") and will utilize the existing staffing at the ECGS. IID is an irrigation district established under Division 11 of the California water code, Sections 20500 et seq., that provides electrical power, non-potable water, and farm drainage services to the lower southeastern portion of the California desert, primarily in Imperial County. ECGS Unit 3 will continue to serve the growing electrical load demands of the region.

The Project consists of replacing the existing CE boiler with a GE Frame 7EA dry low NO_x CTG and HRSG to supply steam to the existing Westinghouse STG. The generator output from the Unit 3 Repower Project will be stepped-up to transmission voltage and interconnected to the existing IID El Centro Switching Station also located within the ECGS Site.

Most of the existing ECGS systems will continue to be used with only minor modifications. Systems that will continue to be used include the STG, cooling system, water treatment system, water supply system, control room, fire system, ammonia system, Project Site access during operations, and the El Centro Switching Station.

The Project consists of two major project areas:

- Project Site – new Unit 3 CTG/HRSG, minor modifications to the existing Unit 3 cooling tower, replacement of the Unit 3 condenser, and minor modifications to Unit 3 STG, the 92kV electrical interconnection and modifications to the existing gas interconnection facilities.
- Temporary Construction Area – construction parking, construction trailers, and construction laydown area.

The total Project disturbance will be 12.5 acres, all of which is within the ECGS Site.

The Project is located in the central portion of the Imperial Valley approximately 25 miles southeast of the Salton Sea and 7 miles north of the International Border with Mexico. This region of the Imperial Valley includes developed land associated with the City of El Centro, undeveloped land, and agricultural land. This section discusses the geologic conditions and geologic hazards for the Project (see Figure 6.10-1, Soils in Vicinity). The topography at the Project Site is characterized by relatively flat terrain lying at an elevation of approximately 50 feet below sea level. For reference, the Salton Sea lies at an elevation of approximately 228 feet below sea level.

The terrain rises gently to the southeast and west. The Project Site is located approximately 10 miles from the eastern and western margins of the ancient Lake Cahuilla. To the west and northwest lie the Yuha Desert and the Superstition Hills, respectively. To the east of the Project Site lie the East Mesa and Algodones Dune Field.

6.5.1.1 Tectonic Framework

The Project is within the southeastern portion of the Salton Trough, a topographic and structural depression within the Colorado Desert physiographic province, bounded to the north by the Coachella Valley and to the south by the Gulf of California. The Salton Trough may have originally formed as a major half-graben during the regional crustal extension that took place in much of western North America in the Miocene (Frost et al. 1997). Crustal attenuation during the Miocene may have helped to preferentially localize the faults of the San Andreas system within narrow zones, or blocks of rigid upper crust during the onset of transform faulting (Frost et al. 1997). The Salton Trough is now within a zone of transition from the ocean-floor spreading regime of the East Pacific Rise in the Gulf of California and the transform tectonic environment of the San Andreas Fault system (Elders 1979). Relative plate motion between the North American plate and Pacific plate is thought to be transferred to the San Andreas fault near the south end of the Salton Sea (Sharp 1972; Sylvester and Smith 1976). The three main fault zones that comprise the San Andreas fault system in this region form clear tectonic boundaries around the Salton Trough. Geophysical studies indicate the presence of a steep gravity gradient across the San Andreas fault along the eastern edge of the Trough (Biehler et al. 1964). This gravity gradient indicates that the northwest trending San Andreas fault is the principal structural boundary between the Salton Trough and the west edge of the North American plate (Sylvester 1976). The Orocopia and Chocolate mountains represent the broken edges of the plate along the eastern margin of the Salton Trough and are included in the southern Basin and Range physiographic province (Frost et al. 1997). The eastern edge of the Pacific plate is composed of intermediate composition granitic rocks of the Peninsular Ranges physiographic province. This eastern edge of the plate, which forms the western portion of the Salton Trough, has been offset along multiple strands of the San Andreas system, including the Elsinore and San Jacinto faults. The Salton Trough occupies the structurally weak zone between the strong, solid edges of the Pacific and North American plates. A zone of high seismicity connects the San Andreas fault north of the Salton Sea and the Imperial fault south of the City of Brawley. This structurally low area, called The Brawley Seismic Zone, may be the result of a tensional or releasing step between the San Andreas and Imperial faults (Figure 6.5-1, Geology Map, and Figure 6.5-1a, Legend for the Geology Map).

The basement of the Salton Trough is composed of Late Cenozoic and older crystalline igneous and metamorphic rocks. Extensive geophysical studies by the USGS in the Imperial Valley region indicate that the sub-basement, or lower crust beneath the axis of the Salton Trough, is composed of a mafic intrusive complex similar to oceanic middle crust (Fuis and Kohler 1984).

In contrast, the Peninsular Ranges to the west and Chocolate Mountains to the east of the Salton Trough are underlain by pre-Cenozoic crystalline rocks (Fuis and Kohler 1984).

Two north-south oriented tensional spreading centers have been identified in the Salton Trough based on geophysical surveys and recent volcanic activity (Kerr and Kidwell 1991; Fuis and Kohler 1984). One spreading center is in the southern end of the trough, approximately 18.5 miles south of the International Border in the Mexicali Valley of Baja California. The second spreading center is in the northern end of the trough and extends from the south part of the Salton Sea to the south under the City of Brawley. Volcanic activity associated with these spreading centers has reached the surface and formed the Cerro Prieto volcano in Baja California and the Salton Buttes near the Salton Sea (a group of five small extrusive domes with a northeast trend). Both are composed of rocks similar in origin to the volcanic rocks of the East Pacific Rise in the Gulf of California (Elders 1979). Younger intrusions associated with these spreading centers are the sources of high temperature (>350°Celsius [C]) hydrothermal systems of the Cerro Prieto and Salton Sea geothermal fields (Elders 1979). The Project Site lies southeast of the Salton Sea geothermal field. Several other areas in the Salton Trough, such as the Heber geothermal field near Calexico, are moderate-temperature hydrothermal systems (approximately 200°C). The heat source for these systems appears to be deep circulation of groundwater, possibly fault-controlled (Herber 1985).

6.5.1.2 Regional Stratigraphy

The oldest sedimentary units mapped by Dibblee (1954) in the Imperial Valley region are the Middle to Late Miocene Split Mountain and Mecca Formations, and the Pliocene Imperial Formation. The Split Mountain and Mecca Formations are composed chiefly of coarse-grained, locally derived detritus from the surrounding mountains (Sylvester 1976). These formations lie non-conformably on the crystalline basement rocks where they are observed in the western margin of the basin (Sylvester 1976). The Imperial Formation consists of mudstones and shales that record a major marine incursion into the basin during the late Miocene to early Pliocene. This marine embayment extended as far north as Whitewater in the Coachella Valley, indicating that the Salton Trough was already well defined during this time (Elders 1979). The upper parts of these formations record a gradual change to continental deposition as the Colorado delta developed. The marine waters of the gulf were cut off from the Salton Trough by growth of the Colorado River delta, resulting in the closed basin present today. The deltaic deposits consist of interbedded sands, silts, clays, and pebble conglomerates. The Pliocene Canebrake Conglomerate is composed of these coarse basin margin facies while the Pliocene to Pleistocene Palm Springs Formation is composed of finer-grained sandstones and mudstones deposited in the central portion of the basin. During the Late Pleistocene and Holocene, the basin was periodically inundated by floodwaters of the Colorado River to form lakes. The fine-grained silts and clays of the Brawley and Borrego formations represent the lacustrine sedimentation, which dominated the Pleistocene. Continued deposition of coarser sediments by the Colorado River along the basin margin during the Pleistocene resulted in the Ocotillo Conglomerate. Some of the most recent sediments deposited in the valley result from a series of fresh to brackish water lakes occupying the closed basin of the Salton Trough and comprise the Holocene Lake Cahuilla Beds. Alluvial deposits overlie or interfinger with the Lake Beds around the margins of the ancient lake region.

Minimal published information exists about the nature and age of the sedimentary deposits in the central part of the Salton Trough. Based on exploration well data, and geophysical survey information, these Cenozoic marine and nonmarine deposits may be as much as 20,000 feet thick. Pleistocene and Holocene alluvial and lacustrine deposits comprise the upper 3,000 feet of the section (Dibblee 1954; Kovach et al. 1962). The broad outlines of the stratigraphy of the Cenozoic rocks filling the trough have been summarized by Dibblee (1954) and Sharp (1972). Maximum marine submergence occurred during the Pliocene, and intermittent shallow marine environments existed within the western part of the valley until the middle Pleistocene (Woodard 1974). Correlation of stratigraphic units across the basin is particularly difficult both in outcrops and in the subsurface because of abrupt lateral facies changes, as is characteristic of these types of deposits. In general, the distribution of sedimentary facies is asymmetric as shown in Figure 6.5-2, Stratigraphy in the Salton Trough.

6.5.1.3 Local Geology

The Project is southeast of the southeast end of the Salton Sea, which covers an area of approximately 360 square miles, and is California's largest inland body of water. The latest flooding of the basin by the Colorado River in 1905 created the present-day Salton Sea (Sharp 1982). There are no natural outlets for the trapped water and it is slowly evaporating, becoming increasingly saline. The surface of the Salton Sea is currently at an elevation of approximately 228 feet below sea level.

The area within about a 10- to 15-mile radius of the Project is underlain by Lake Deposits Beds associated with ancient Lake Cahuilla as shown on Figure 6.5-3, Geologic Map of Project Vicinity. Geomorphic features near the Project are shown in Figure 6.5-1, Geology Map, and Figure 6.5-3, Geologic Map of Project Vicinity, and include the Salton Sea, Salton Buttes (Obsidian Butte), the Alamo and New rivers, the ancient Lake Cahuilla shorelines, the Superstition Hills, Superstition Mountain, and the Sand Hills.

The Project Site is underlain by a thick sequence of lacustrine deposits associated with ancient Lake Cahuilla. Lake Cahuilla was formed during the last 1,000 years and existed until approximately 300 years ago (Elders 1979). Evidence of its shoreline is still present around the Imperial Valley. In general, the lacustrine sediments in the Imperial Valley are estimated to be roughly 100 to 300 feet thick (Kovach et al. 1962). In general, the lacustrine deposits include sandy deltaic sediments and sandy beach deposits along ancient shorelines, and clay and silt deposited in deeper parts of the lake. The finer-grained sediments contain lenses of sand toward the lake margin.

Stiff to hard clays were encountered in the subsurface of the Project study area to depths of about 70 feet during the geotechnical investigations for the Project (Geotechnics 2006). At depths of 70 to 100 feet interbedded, thinly bedded sands, silt, and clay layers were encountered.

Subsurface conditions are described in greater detail in Appendix C, Geotechnical Investigation. Based on hollow-stem borings and cone penetration test (CPT) soundings conducted during the geotechnical investigation, the near surface deposits are composed of relatively massive fine-grained deposits consisting of lean to fat, firm to hard, clays (Unified Soil Classification CL to CH) with localized thin beds of sandy silt (ML).

The Project is in an area of shallow groundwater conditions because of the agricultural activities in the valley. The groundwater surface was encountered within 4 to 6 feet of the ground surface based on the geotechnical borings.

6.5.1.4 Geologic Hazards

The primary geologic hazards at the Project include strong ground motion from a seismic event centered on one of several nearby active faults, and liquefaction of the sandy soils that underlie the Project Site given strong ground shaking. The general geologic hazards and seismicity at the Project are discussed in detail below.

Seismicity

The Project is in one of the most seismically active areas in California. At least two-thirds of the relative motion between the North American and Pacific plates in California occur in the San Andreas fault system (Hutton et al. 1991; Sieh and Jahns 1984). In southern California, deformation on this complex fault system is spread over four major fault zones: the San Andreas fault zone, the Imperial fault zone, the San Jacinto fault zone, and the Elsinore fault zone. The Project Site is located approximately midway between the mapped terminations of the Imperial and San Jacinto fault (Superstition Mountain branch). Another prominent seismogenic structure in the Imperial Valley is a zone of high seismicity connecting the northwestern end of the Imperial fault and the southeastern end of the San Andreas fault called the Brawley Seismic Zone (Johnson and Hutton 1982). A map showing the primary seismic sources and earthquake epicenters greater than magnitude 4 is shown in Figure 6.5-4, Regional Fault and Epicenter Map. The following section discusses significant faults within a 62-mile radius of the Project in order of increasing distance.

<u>Imperial/Brawley Fault</u>

The Imperial fault zone is approximately 3 miles east of the Project. This northwest-trending fault is approximately 40 miles long and extends from just southwest of the City of Brawley southeast to the town of Saltillo, Mexico. The Brawley fault is the northeastern branch of the Imperial fault and was generally unrecognized until a series of small earthquakes causing surface rupture occurred in 1975 (Sharp 1976). Both faults ruptured together in the 1979 moment magnitude (M_w) 6.4 event, confirming its presence and relationship to the Imperial fault. The Imperial fault has been modeled as the transform fault between the two northernmost small spreading centers that characterize oblique spreading in the Gulf of California, the Brawley Seismic Zone, and the Cerro Prieto geothermal field in Mexico (Johnson and Hill 1982).

The Imperial fault is one of the most active faults in the region. In addition to the M_w6.4 earthquake in 1979, the fault also ruptured with an M_w6.9 event in 1940. The 1979 earthquake produced seismic intensities in the epicentral region of IV (Reagor et al. 1982), and caused widespread liquefaction. Moderate earthquakes (M_w5.5 to 6.3), which occurred in 1906, 1915, 1917, and 1927, are associated with the Imperial fault (Johnson and Hill 1982). California Geological Survey (CGS) fault parameters for the Imperial fault indicate a slip rate of 0.8 inches per year and a maximum moment magnitude of M_w7.0.

San Jacinto Fault Zone

The San Jacinto fault zone is approximately 4 miles west of the Project. This zone is a major tectonic and seismic structure, striking northwest for more than 124 miles. The San Jacinto fault zone is part of the San Andreas fault system. The southern segment of the San Jacinto fault zone is composed of the Coyote Creek fault and the Superstition Hills and Superstition Mountain faults. The Coyote Creek strand of the fault zone extends from just north of Borrego Springs to the northeast end of the Fish Creek Mountains north of Plaster City. The fault is not exposed at the surface to the south, as it is buried by young sediments. The Superstition Hills fault and the Superstition Mountain fault lie along a strike to the southeast of the Coyote Creek fault, and are generally considered to be the southern extension of the San Jacinto fault zone.

The San Jacinto fault zone is seismically the most active structure in southern California at all magnitude levels below M_w7.0 (Hutton et al. 1991). This fault zone has produced at least 10 earthquakes of M_w6.0 to 6.6 since 1890. This gives an average recurrence interval of approximately 10 years for a moment magnitude M_w6.0 and larger event (Hutton et al. 1991). The most recent large earthquakes to occur on the San Jacinto fault system were the M_w6.4 Arroyo Salada earthquake of 1954, the Borrego Mountain earthquake (M_w6.6) in 1968, and the Superstition Hills earthquake (M_w6.6) in 1987. CGS fault parameters for the San Jacinto fault zone are given for each segment: Coyote Creek; 0.16 inches per year slip rate and maximum moment magnitude of 6.8, Superstition Hills; 0.16 inches per year slip rate and maximum moment magnitude of 6.6, and Superstition Mountain; 0.2 inches per year slip rate and maximum moment magnitude of 6.6.

Brawley Seismic Zone

The Project Site is located approximately 11 miles south of the Brawley Seismic Zone. This structural depression lies between the San Andreas fault to the northeast and the Imperial fault to the southwest. The Brawley Seismic Zone was first recognized because of the number of earthquake swarms produced from 1973 through 1979 (Johnson and Hutton 1982). The swarm sequences and individual event clusters in the 1979 Imperial Valley earthquake aftershock sequence defined lineations transverse to the strike of the Imperial fault (Johnson and Hutton 1982). Two types of earthquake swarms occur in the Brawley Seismic Zone. Swarms that occur in the south end of the zone near the town of Brawley tend to occur in pairs, nucleating on the Imperial fault to the south and propagating away from it into the Seismic Zone. Swarms occurring in the northern part of the zone nucleate within the zone and do not occur in pairs (Hutton et al. 1991; Johnson 1982). Analysis of these swarms suggests they are triggered by creep events on the Imperial fault (Johnson 1982). The blind faulting controlling the geothermal resource geometry does not extend into recent sediments and, therefore is not considered a potential source of ground rupture. Following the 1940 Imperial Valley earthquake, swarm activity in the Brawley Seismic Zone ceased until the mid-1970s, most likely because of the drop in regional stress after the M_w6.9 event (Hutton et al. 1991).

The Brawley Seismic Zone is characterized by earthquake swarms, generally less than magnitude 3 or 4. CGS fault parameters for the Brawley Seismic Zone indicate a slip rate of 1 inch per year and a maximum moment magnitude of 6.4.

Laguna Salada Fault

The Laguna Salada fault trends northwest and is approximately 20 miles southwest of the Project in northern Baja California, Mexico. The fault is approximately 47 miles long and bounds the western margin of the Sierra Cucapa Mountains. The northern Laguna Salada fault may be linked to the Elsinore fault across a complex zone of northeast and northwest striking faults in the Yuha basin (Mueller and Rockwell 1995).

The most recent large earthquake along the Laguna Salada fault is most likely the earthquake in 1892. The estimated moment magnitude for this event, based on ground rupture lengths and measured offsets is M_W7.1 (Mueller and Rockwell 1995). CGS fault parameters for the Laguna Salada fault indicate a slip rate of 0.14 inches per year, and a maximum moment magnitude of 7.0.

Elmore Ranch Fault Zone

The Elmore Ranch fault zone is approximately 22 miles west of the Project. The fault zone is composed of six northeast-southwest trending parallel segments up to 7.5 miles long. These are commonly termed the Elmore Ranch fault, the West Elmore Ranch fault, the East Elmore Ranch fault, and the Lone Tree fault. Two smaller faults are in the northeast portion of the fault zone known as the Kane Spring fault and East Kane Spring fault. These left-lateral faults are conjugate faults, or cross-faults to the adjacent southern segment of the San Jacinto fault zone (the right lateral Superstition Hills fault), and the Brawley Seismic Zone to the east. The 1987 M_w6.2 Elmore Ranch earthquake ruptured these faults and triggered slip on the Superstition Hills fault, which followed with an M_w6.6 event approximately 12 hours later. Aftershocks of the Elmore Ranch earthquake extended into the Brawley Seismic Zone to the east (Magistrale et al. 1989). The nearly simultaneous activation of a conjugate fault pair is unique in the United States. Work by Hudnut et al. (1989) indicates that the fault has ruptured at least once prehistorically, within the past 330 years, possibly as a conjugate pair with the Superstition Hills fault. The earthquake sequence discussed above has generated an important point discussed in the literature, and that is potential cross-fault triggering of the San Andreas fault. As discussed below, the Coachella, or southern segment of the San Andreas fault has not ruptured historically. According to Hudnut et al. (1989) future slip on other known cross-faults would decrease normal stress across the southern San Andreas fault, potentially triggering an earthquake by a mechanism similar to that observed in the Superstition Hills sequence.

CGS fault parameters for the Elmore Ranch faults indicate a combined slip rate of 0.06 inches per year and a maximum moment magnitude of 6.1.

Elsinore Fault Zone

The Elsinore fault zone is approximately 27 miles west of the Project. The southern segment of the Elsinore fault is approximately 124 miles long and extends from the Los Angeles basin, where it splays into the Whittier and Chino faults, to the southwest end of the Imperial Valley, west of El Centro. This fault zone is the major structural boundary between the Peninsular Ranges and the west side of the Salton Trough (Frost et al. 1997).

The Elsinore fault zone is characterized by a moderate amount of seismicity, having experienced several earthquakes in the magnitude range M_w5.0 to 6.0. The only large earthquake to occur on the Elsinore fault in the historic record is the M_w6.0 earthquake along the central section in 1910.

CGS fault parameters for the Elsinore fault indicate a slip rate of 0.16 inches per year, and a maximum moment magnitude of 6.8.

Cerro Prieto Fault

The Cerro Prieto fault is approximately 29 miles south of the Project in northern Baja California, Mexico. This northwest striking fault is over 62 miles long and has been characterized as the southern extension of the San Andreas-Imperial fault system. Like the Imperial fault, the Cerro Prieto fault is adjacent to a structural depression and active spreading center.

The only historic earthquake to occur on the Cerro Prieto fault was in 1934 with an estimated moment magnitude of M_W6.5 to 7.5. Fault parameters for the Cerro Prieto fault include a slip rate of 0.78 inches per year and a maximum moment magnitude of 7.1.

San Andreas Fault Zone

The Coachella Valley segment of the San Andreas fault is approximately 59 miles long and extends from the town of Indio to Bombay Beach on the northeast shore of the Salton Sea, approximately 39 miles from the Project Site. North of Indio, the fault splays into two active strands, the Banning and the Mill Creek faults. The San Andreas fault has not been mapped south of the Salton Sea. Although a linear extension of the fault may exist under the Salton Sea or in the northern Imperial Valley, there has been no geologic or geophysical evidence to support it (Sharp 1982). It seems reasonable that the Imperial fault and Brawley Seismic Zone, which lie southwest of the San Andreas fault, may be linked together structurally with the San Andreas fault. Seismic activity along the Brawley Seismic Zone suggests that a major portion of the displacement observed on the Imperial Fault is being transferred to the San Andreas fault to the northeast (Hutton et al. 1991). Most of the aftershocks following the 1979 earthquake on the Imperial fault occurred within the Brawley Seismic Zone (Sharp 1982). The Imperial fault has a similar strike as the southern segment of the San Andreas fault and has been modeled as a releasing step with the Brawley Seismic Zone occupying the resulting structural depression (Frost et al. 1997). Dillon and Ehlig (1993) hypothesize the San Andreas fault may join the northeast corner of the Brawley Seismic Zone, and represents the most northerly spreading axis in a system of short spreading axes and interconnected transform faults that form the divergent plate boundary in the Gulf of California.

Although the San Andreas fault has generally produced few moderate-sized earthquakes in historic times, no large earthquake (M_w>7.0) has been documented in the historic record for the San Andreas south of San Bernardino (Hutton et al. 1991). This ‘locked’ southernmost section of the fault also lacks microseismicity and stands in sharp contrast to the northern sections of the fault that have ruptured with the largest historical earthquakes in California.

CGS fault parameters for the Coachella segment of the San Andreas fault indicate a slip rate of 1 inch per year and a maximum moment magnitude of 7.2.

Ground Shaking and Surface Rupture

To provide an estimate of the potential peak ground acceleration that structures found at the Project may experience, a probabilistic analysis of seismicity was performed (see Appendix C, Geotechnical Investigation). The probabilistic analysis incorporates the contribution of all known active faults within a 62-mile radius of the Project for which published data are available. The analysis attempts to account for uncertainty in rupture size, rupture location, magnitude, and frequency, as well as uncertainty in the attenuation relationship. Based on the results of the probabilistic analysis, the Upper Bound Earthquake for the Project Site, defined as the motion having a 10% probability of being exceeded in a 100-year period, is 0.60 force of gravity (g). *The Design Basis Earthquake* (10% probability of being exceeded in 50 years) has an associated peak ground acceleration of 0.52 g. For additional details on the Project Site specific seismic hazard analysis information see Appendix C, Geotechnical Investigation.

As discussed previously, the nearest active faults to the site are Imperial and San Jacinto faults at distances of approximately 3 to 4 miles. Therefore, the potential for ground rupture at the Project because of faulting is considered to be low.

Liquefaction

Liquefaction is a process in which soil grains in a saturated sandy deposit lose contact because of earthquakes or other sources of ground shaking. The soil deposit temporarily behaves as a viscous fluid; pore pressures rise, and the strength of the deposit is greatly diminished. Liquefaction is often accompanied by sand boils, lateral spreading, and post-liquefaction settlement as the pore pressures dissipate. Liquefiable soils typically consist of cohesionless sands and silts that are loose to medium dense, and saturated. The Project Site is within the Imperial Valley, an area that is generally susceptible to liquefaction. The 1940 and 1979 earthquakes on the Imperial fault caused widespread liquefaction in areas underlain by alluvium, areas adjacent to canals and drains, and in areas underlain by lake deposits. These liquefiable Project Sites contained predominantly loose sandy soils, or sequences of thick sandy layers within finer grained soils (Youd and Wieczorek 1982; Holtzer et al. 1989).

Based on the geotechnical investigation, localized sandy silt beds below the Project Site may liquefy during the *Design Basis Earthquake*. Such liquefaction could result in total post-liquefaction settlements estimated at 0 to ½ inch at the Project Site. For structural design, ¼ inch post-liquefaction differential settlement was estimated (Geotechnics 2006). Additional discussions of the liquefaction analysis are present in the Geotechnical Investigation.

Subsidence and Settlement

The Imperial Valley is subjected to subsidence from fluid withdrawal (generally associated with geothermal wells) and regional tectonic processes. The potential for damaging localized differential settlement from fluid subsidence is considered low, given the Project Site's relative distance to the geothermal areas.

The Project is within a region of active subsidence because of regional faulting. The Salton Trough is filled with up to 20,000 feet of Cenozoic-age sediments. Regional subsidence resulting from a combination of tectonic processes, including faulting and possible reservoir loading by the Salton Sea, may combine to produce roughly 1.6 inches of settlement per year across the entire Salton Trough (Lofgren 1978). Subsidence resulting from tectonic processes generally occur over large areas. Consequently, the potential for damaging localized differential settlement from regional subsidence is considered low.

As discussed in the previous section, the Project is subject to small liquefaction-related settlements. Such potential settlements represent a minor geologic hazard and will be addressed in Project design and construction.

Flooding

The Project is situated approximately 25 miles southeast of the Salton Sea and approximately 200 miles northeast of the Gulf of California. Rare seismic events could conceivably induce flooding in some areas of the Imperial Valley. These events include tsunamis within the Gulf of California, seiches within the Salton Sea, and flooding from failures along drain embankments. Given the distance of the Project from these hazards, it is very unlikely that any significant effects will be felt at the Project. The Project is located within an active alluvial floodplain. Extensive gullies and channels are present across the Project and throughout the Project study area. Surface water flow across the Project is likely to occur during periods of intense rainfall.

Tsunamis

The Project is situated roughly 50 feet below sea level. This suggests that the potential may exist for inundation in case of a tsunami (seismic sea wave) within the Gulf of California. However, the distance of the Project from the Gulf (approximately 200 miles) and the higher ground surface elevations to the south of the Project associated with the Colorado River delta, provide some measure of protection from such events, as there are no records (historic or geologic) which indicate that tsunamis have impacted the Imperial Valley in the last several hundred years. Therefore, the potential for flooding at the Project as a result of a tsunami is considered to be very low.

Seiches

A wave created by an earthquake shaking in an enclosed body of water is called a seiche. The potential for a seiche to occur is related to the natural frequency of vibration of the body of water, as well as the predominate frequencies of vibration in the seismic event. The possibility may exist for a seiche to occur in the Salton Sea. However, there are no records of seiches occurring during recent earthquakes in the Imperial Valley, and the Project Site is located 25 miles from the Salton Sea. Therefore, the potential for flooding at the Project Site as a result of a tsunami is considered to be very low.

Landslides and Lateral Spreading

Landsliding and lateral spreading usually occur in areas of relief, weak soil strength, and high groundwater. They are often triggered by earthquakes. The Project Site is in an area of low relief. The potential for localized landsliding or lateral spreading to occur within the Project study area is very low.

Volcanic Hazards

The Project is about 25 miles east of the extrusive rhyolite domes known as Salton Buttes. The USGS includes the "Salton Buttes rhyolite center" among its listed Potential Areas of Volcanic Hazards in California (USGS Bulletin 1847). According to the USGS, the most probable future potential hazard at the Project is explosive and extrusive rhyolitic eruptions, and/or phreatic and phreatomagmatic eruptions (volcanic eruptions or explosions of steam, mud, or other material caused by the heating of groundwater). No recurrence interval has been estimated, and the USGS has not qualified the potential hazard other than to say that it is present. Accordingly, the volcanic hazard potential at the Project is considered to be low.

Expansive Soils

The subsurface investigation (see Appendix C, Geotechnical Investigation) indicates that the surficial soils at the Project are composed of potentially expansive lean and fat clays (CL and CH) Laboratory testing of these soils indicate a low to moderate potential for expansion (Appendix C, Geotechnical Investigation).

6.5.1.5 Geologic Resources

Based on published information (California Department of Conservation 1977, Kohler 2002), there are no significant aggregate mining operations within 10 miles of the Project. The Project lies approximately 6 miles from the nearest known geothermal resource area at Heber. The Project does not represent a significant impact to the geologic resources of the region.

6.5.2 Environmental Consequences

Potential impacts of the Project on the geologic or mineral resources and potential impacts of geologic hazards on the Project can be divided into those related to construction activities and those related to plant operation.

6.5.2.1 Construction-Related Impacts

Construction-related impacts to the geologic or mineral resources primarily involve grading operations and operations for foundation support. The proposed improvements include excavation and minor grading for building pads, utility trenches, and for drainage of surface water flow. According to the Geotechnical Investigation (Appendix C), the Project slopes should be stable. Project Site development is not anticipated to result in significant adverse impacts to geologic or mineral resources. Potentially significant impacts by geologic conditions on the construction are not anticipated. With implementation of the mitigation measures outlined in Section 6.5.4, Mitigation Measures, impacts to Project construction by the geologic environment will be reduced to less than significant levels.

6.5.2.2 Operation-Related Impacts

No significant impacts to geologic resources have been identified as a result of operation. Potential impacts of geologic hazards on the Project and ancillary facility operations include seismic shaking and liquefaction-related settlement. With implementation of the measures outlined in Section 6.5.4, Mitigation Measures, impacts to Project operations from geologic hazards will be reduced to less than a significant level.

There would be no significant impacts to the geologic environment resulting from construction or operation of the Project.

6.5.3 Cumulative Impacts

Cumulative impacts to the geologic resources at the Project Site are considered to be negligible.

6.5.4 Mitigation Measures

6.5.4.1 Seismic Shaking

The potential exists for strong ground shaking from a variety of nearby sources, including the Brawley Seismic Zone, the San Andreas fault, the Imperial fault, and the San Jacinto fault.

Geo-1: Project facilities shall be designed in accordance with applicable building codes' seismic design criteria. Seismic design criteria, including Project Site-specific response spectra, are provided in Appendix C, Geotechnical Investigation.

6.5.4.2 Liquefaction and Settlement

Liquefaction related settlements are possible at the Project Site. In addition, heavy vibrating equipment proposed for the Project Site may settle on the order of 2 to 3 inches if constructed on mat foundations because of the thick clay deposits and shallow groundwater conditions.

Geo-2: To reduce the potential for adverse differential settlement beneath heavily loaded settlement-sensitive structures, deep foundations (driven piles) have been included in the Project design. Estimated settlement for various foundation loading conditions, as well as recommendations for foundation design, are provided in Appendix C, Geotechnical Investigation.

6.5.4.3 Flooding

Earthquake-induced flooding at the Project Site is not considered to be a significant hazard and no mitigations are suggested.

6.5.4.4 Landslides and Lateral Spreading

Landslides and lateral spread hazards are not present in the Project Site.

6.5.4.5 Expansive Soils

As discussed in Appendix C, Geotechnical Investigation, expansive soils are present at the Project Site however, the mitigation measure will provide adequate mitigation of any hazard related to expansive soils to less than significant.

Geo-3: To reduce the potential for heave of shallow foundations founded on the surficial clays, overexcavation of the surficial clays and replacement with low expansion sand or gravel is included in the grading plan for the Project. Minor structures and equipment pads will be underlain by at least 4 feet of select imported materials (expansion index of less than 50). To reduce the potential for heave related distress to proposed flatwork, the upper 2 feet of exterior slab and sidewalk subgrade will be replaced with low expansion sand or gravel. Details are provided in Appendix C, Geotechnical Investigation.

6.5.4.6 Geologic Resources

There are no significant impacts to geologic resources; therefore, no mitigation measures are required.

6.5.5 Laws, Ordinances, Regulations, and Standards

The Project will be constructed and operated in accordance with all LORS applicable to geologic hazards and resources discussed below and summarized in Table 6.5-1, Summary of Laws, Ordinances, Regulations, and Standards.

TABLE 6.5-1
SUMMARY OF LAWS, ORDINANCES, REGULATIONS, AND STANDARDS

Jurisdiction	LORS	Requirements	Conformance Section	Administering Agency
6.5. Geologic Hazards and Resources				
Federal				
No federal LORS are applicable				
State				
	Cal PRC 25523(a), Alquist-Priolo Earthquake Fault Zone	NA	Section 6.5.5.2, State	1 and 2
Local				
	City of El Centro; General Plan /Safety Element/Seismicity	Reduce risk from geotechnical hazards through appropriate planning, engineering and construction practices.	Section 6.5.5.3, Local	4
	California Building Code, Chapters 16, 18, and 33	Codes address excavation, grading and earthwork construction, including construction applicable to earthquake safety and seismic activity	Section 6.5.5.3, Local, and Appendix C, Geotechnical Investigation	4

NA = Not Applicable
LORS = Laws, Ordinances, Regulations, and Standards

6.5.5.1 Federal

There are no federal LORS for geological hazards and resources, or grading and erosion control.

6.5.5.2 State

California Public Resources Code 25523(a): 20 CCR § 1252 (b) and (c). None of the Project components are located within or cross an Alquist–Priolo earthquake zone. The Project will not be subject to requirements for construction within an earthquake fault zone.

UBC. The UBC 1997 edition with revisions specifically tailored to geologic hazards in California.

Chapter 16: Structural Design Requirements, Division IV Earthquake Design. This section requires structural designs to be based on geologic information for seismic parameters, soil characteristics, and Project Site geology.

Chapter 18: Foundations and Retaining Walls, Division I. This section sets requirements for excavations and fills, foundations, and retaining structures, with regard to expansive soils, subgrade bearing capacity, seismic parameters, and also addresses waterproofing and damp-proofing foundations. In Seismic Zones 3 and 4, as defined by the UBC, liquefaction potential at the Project Site should be evaluated. Division III contains requirements for mitigating effects of expansive soils for slab-on-grade foundations.

Chapter 33: Site Work, Demolition and Construction, and Appendix Chapter 33. These sections establish rules and regulations for construction of cut-and-fill slopes, fill placement for structural support, and slope setbacks for foundations.

CEQA of 1970. The CEC will be the lead agency for rules and regulations to implement the CEQA. Appendix G, Section VI of the CEQA guidelines contains the geologic hazards and resources related to the Project.

6.5.5.3 Local

City of El Centro: General Plan: Safety Element. The Safety Element of the El Centro General Plan provides an implementation program to reduce the threat of seismic and public safety hazards within the City of El Centro.

The Project would comply with all of the policies outlined in the Safety Element of the City of El Centro General Plan.

The City has adopted the UBC and will review the geologic information and geotechnical recommendations presented in the geotechnical report.

6.5.5.4 Involved Agencies and Agency Contacts

Agencies with jurisdiction to enforce LORS related to geologic hazards and resources, and the appropriate contact person are summarized in Table 6.5-2, Involved Agencies and Agency Contacts.

TABLE 6.5-2
INVOLVED AGENCIES AND AGENCY CONTACTS

Number	Agency	Contact/Title	Telephone
1	California Energy Commission Facilities Siting Division Engineering Office		
2	California Energy Commission Facilities Siting Division Siting Office		
4	City of El Centro Building Dept.	Bob Williams	760-337-4508

6.5.5.5 Permits Required

There are no applicable permits required for geologic hazards.

6.5.6 References

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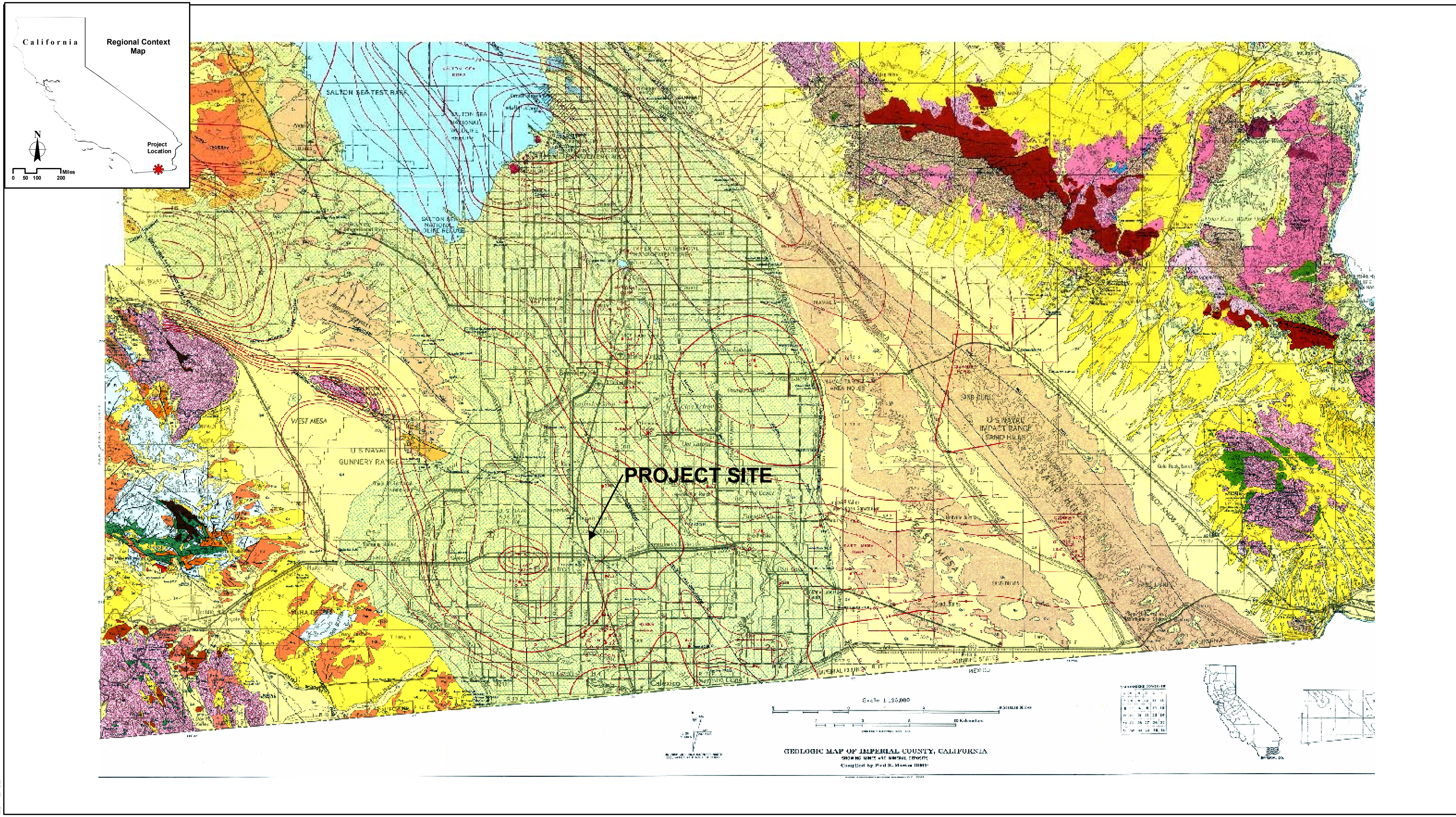

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SOURCE: State of California
Division of Mines and Geology
(Geologic Map of California)

Geology Map

El Centro Unit 3 Repower Project
Imperial Irrigation District

URS

FIGURE 6.5-1

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EXPLANATION

ROCKS OF COUNTY WIDE DISTRIBUTION

Qal

Alluvium

Unconsolidated clay, silt, sand, and gravel occurring primarily as valley fill and streamwash deposits.

Qc

Older alluvium

Partly dissected largely unconsolidated, poorly sorted silt, and gravel of alluvial fans, desert pavement areas, margins of larger canyons, and terraces. Includes Chemehuevis Formation.

CENOZOIC ROCKS OF IMPERIAL VALLEY AND WESTERN IMPERIAL COUNTY

Ql

Lake beds

Sediments of ancient lake Cahuilla and playa lakes. Tan and gray fossiliferous clay, silt, sand and gravel in conjunction with Qal (shown Ql/Qal).

Qv

Volcanic rocks

Rhyolite, pumice and obsidian occurring at and adjacent to volcanic domes near the southeast shore of the Salton Sea.

CENOZOIC ROCKS OF THE CHOCOLATE MOUNTAINS AND EASTERN IMPERIAL COUNTY

Tv

Volcanic rocks

Tv[i] = intrusive
Tv[p] = pyroclastic
Tv[r] = rhyolitic
Tv[a] = andesitic
Tvi[a] = intrusive andesite
Tv = undifferentiated

gr

Granitic rocks

Largely Mesozoic in age.

gr_1 = biotite granite
gr_2 = leucogranite
gr_3 = quartz diorite
gr_4 = quartz monzonite

mc

Chuckwalla Complex

Quartz diorite gneiss (mcgn), foliated hybrid granitic rocks, and granophyres, largely acidic to intermediate range in composition of Precambrian(?) age.

SYMBOLS

Contact
(dashed where approximately located; dotted where concealed; queried where inferred)

Fault
(dashed where approximately located; dotted where concealed; queried where inferred)

Thrust fault
(barb on upper plate)

CO_2 Field

Mill or abandoned mill

Steamwell

Mine or prospect

O115

Temperature wells by U.S.B.R. and others Numbers (115) are U.S.B.R. designation.

+90

88

Bouguer gravity contours*
(Contour interval 2 milligals)

Note: 1000 milligals have been added to all readings and the first digit is omitted; thus 84 is actually 984 - 1000 or -16 milligals. (Gravity by Shawn Biehler in Meidav and Rex, 1970)

● 11.9

Geothermal gradient in degrees Fahrenheit per 100 feet depth.*

3

Isothermal depth contours for a 300° C surface. (After Helgeson, 1968)

KGRA

KGRA = Known Geothermal Resources Area Designated by U.S.B.R.

SOURCE: State of California
Division of Mines and Geology
(Geologic Map of California)

Legend for the Geology Map

El Centro Unit 3 Repower Project
Imperial Irrigation District

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FIGURE 6.5-1A

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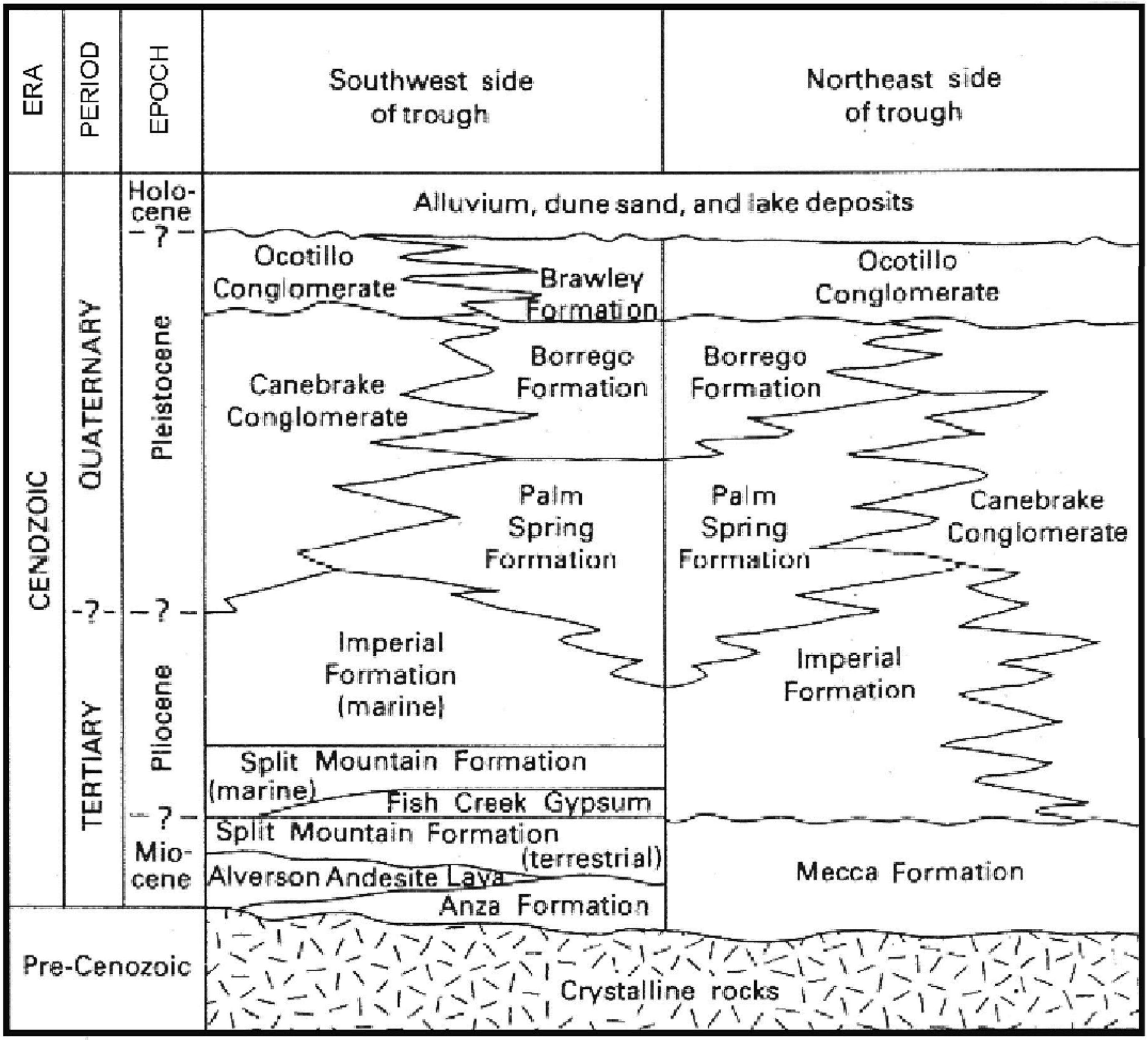

SOURCE: Sharp, 1982

Stratigraphy in the Salton Trough

El Centro Unit 3 Repower Project
Imperial Irrigation District

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FIGURE 6.5-2

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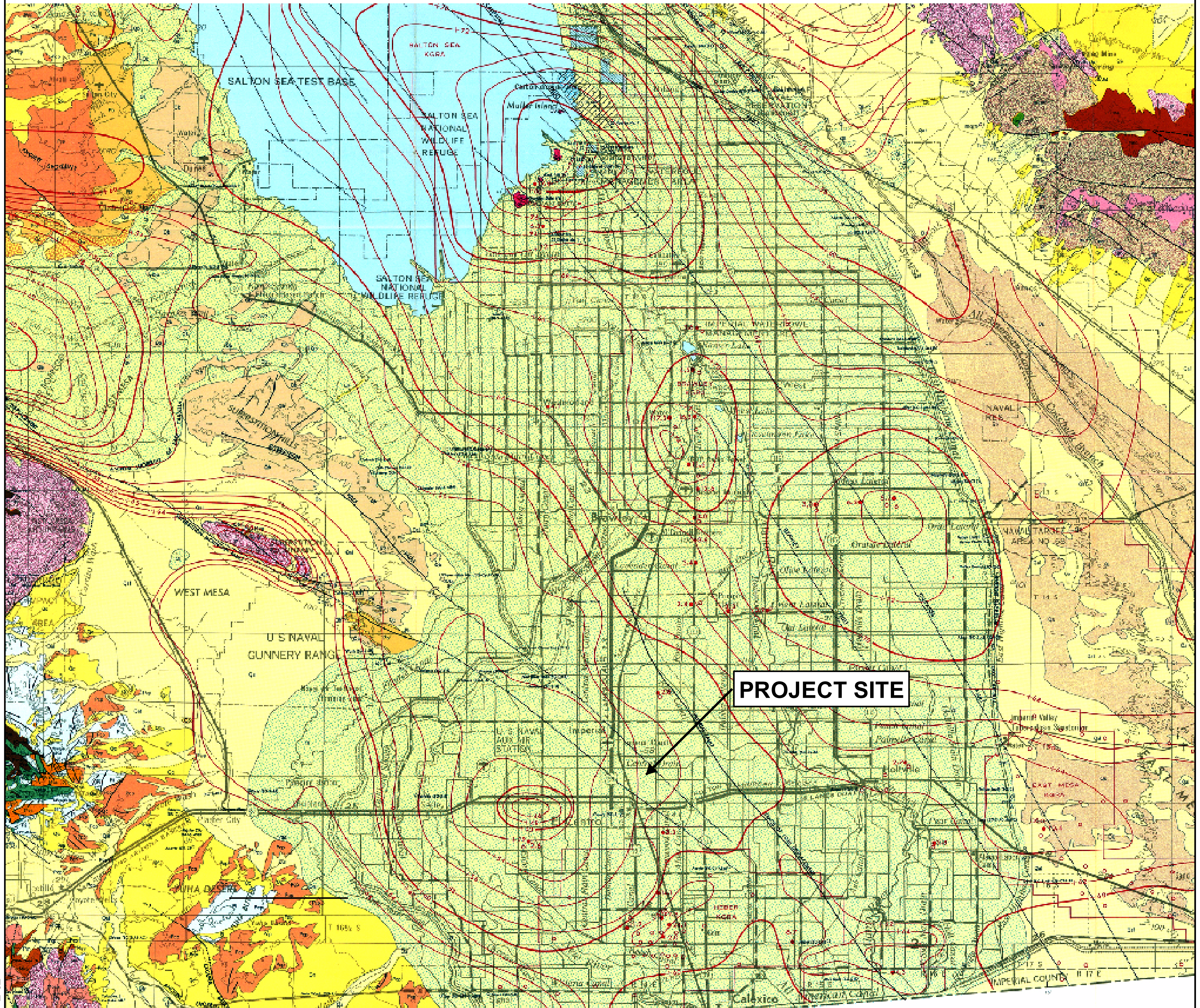

EXPLANATION

ROCKS OF COUNTY WIDE DISTRIBUTION

Qa — **Alluvium**
Unconsolidated clay, silt, sand, and gravel occurring primarily as valley fill and streamwash deposits.

Qc — **Older alluvium**
Partly dissected largely unconsolidated, poorly sorted silt, sand gravel of alluvial fans, desert pavement areas, margins of larger canyons, and terraces. Includes Chemehuevis Formation.

CENOZOIC ROCKS OF IMPERIAL VALLEY AND WESTERN IMPERIAL COUNTY

Ql — **Lake beds**
Sediments of ancient lake Cahuilla and playa lakes. Tan and gray fossiliferous clay, silt, sand and gravel in conjunction with Qal (shown Qal).

Qv — **Volcanic rocks**
Rhyolite, pumice and obsidian occurring as and adjacent to volcanic domes near the southeast shore of the Salton Sea.

CENOZOIC ROCKS OF THE CHOCOLATE MOUNTAINS AND EASTERN IMPERIAL COUNTY

Tv — **Volcanic rocks**
Tvi — intrusive
Tvp — pyroclastic
Tvr — rhyolitic
Tva — andesitic
Tvia — intrusive andesite
Tv — undifferentiated

gr — **Granitic rocks**
Largely Mesozoic in age.
gr1 - biotite granite
gr2 - leucogranite
gr3 - quartz diorite
gr4 - quartz monzonite

Chuckwalla Complex
Quartz diorite gneiss (mega), foliated hybrid granitic rocks, and granophyres, largely acidic to intermediate range in composition of Precambrian(?) age.

SYMBOLS

Contact
(dashed where approximately located; dotted where concealed; queried where inferred)

Fault
(dashed where approximately located; dotted where concealed; queried where inferred)

Thrust fault
(barb on upper plate)

CO_2 Field

Mill or abandoned mill

Steamwell

Mine or prospect

O 118
Temperature wells by U.S.B.R. and others Numbers (115) are U.S.B.R. designation.

+90
+88
Bouguer gravity contours*
(Contour interval 2 milligals)
Note: 1000 milligals have been added to all readings and the first digit is omitted; thus 84 is actually 984 - 1000 or -16 milligals. (Gravity by Shawn Biehler at Meiday and Rex, 1970)

● 11.9
Geothermal gradient in degrees Fahrenheit per 100 feet depth.*

—3—
Isothermal depth contours for a 300° C surface. (After Helgeson, 1968)

KGRA
KGRA = Known Geothermal Resources Area Designated by U.S.B.R.

Miles: 0 · 1.25 · 2.5 · 5.0

N

SOURCE: State of California
Division of Mines and Geology
(Geologic Map of California)

Geologic Map of Project Vicinity

El Centro Unit 3 Repower Project
Imperial Irrigation District

URS

FIGURE 6.5-3

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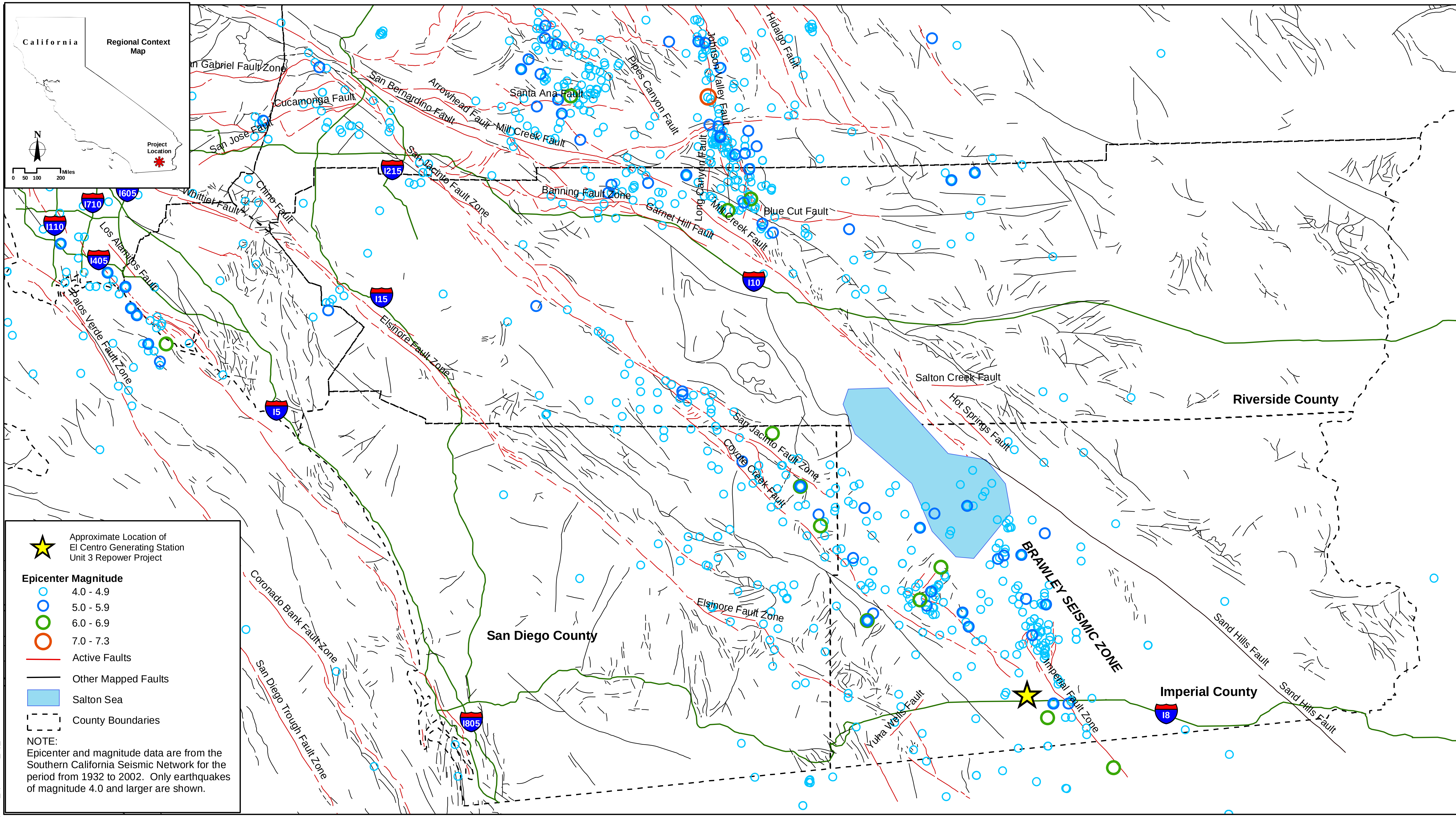

Regional Fault and Epicenter Map

El Centro Unit 3 Repower Project
Imperial Irrigation District

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FIGURE 6.5-4