# 5.5 Geologic Hazards and Resources

This section discusses the potential effects of the Palen Solar Power Project (PSPP or Project) on geologic resources and the potential geologic hazards that the Project may encounter. It begins with identification of applicable laws, ordinances, regulations, and standards (LORS), describes existing environmental conditions, assesses Project impacts, and identifies mitigation measures needed to avoid or reduce adverse impacts.

**Summary**

The Project will not have significant adverse impacts due to geologic hazards or nor will it have significant adverse impacts on geological resources. No major unique geologic or physical features have been identified in the Project area. No active fault zones are present within the Project boundaries or within a 2.5-mile radius of the site. The Project site is located in Seismic Zone 4, the zone with the highest seismicity. All Project structures will be designed to meet the strict seismic design standards established for Seismic Zone 4. Geotechnical investigations are being performed at present to provide additional data regarding site conditions to support the design of foundations of Project structures and other elements of site development, and additional investigations are expected in support of detailed design.

Evidence of ground subsidence (e.g., fractures possibly caused by historic groundwater extraction) has not been noted at the Project site. Given the high historic use in the Project vicinity (although not on the site) of local groundwater resources for agricultural development with no subsidence reported, it is not anticipated that the Project's limited pumping program will induce subsidence below the site.

## 5.5.1 LORS Compliance

This section addresses the LORS applicable to geologic hazards and resources that are relevant to the Project. Table 5.5-1 summarizes these LORS.

**Table 5.5-1 Summary of Applicable Geological Hazards and Resources LORS**

| LORS | Applicability | Where Discussed in AFC |
|---|---|---|
| **Federal:** | | |
| Uniform Building Code (UBC) | The UBC specifies acceptable design criteria for structures and excavations with respect to seismic design and load bearing capacity. | Section 5.5.2 |
| **State:** | | |
| California Building Code (CBC) | Specifies acceptable design criteria for structures and excavations with respect to seismic design and load bearing capacity. | Section 5.5.2 |
| Alquist-Priolo (AP) Earthquake Fault Zoning Act | Identifies areas subject to surface rupture from active faults. | Sections 5.5.2 and 5.5.3 |

**Table 5.5-1 Summary of Applicable Geological Hazards and Resources LORS**

| LORS | Applicability | Where Discussed in AFC |
|---|---|---|
| The Seismic Hazards Mapping Act: Title 14 California Code of Regulations Division 2, Chapter 8, Subchapter 1, Article 10 | Identifies non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides. | Sections 5.5.2 and 5.5.3 |
| **Local:** | | |
| Riverside County Implementation of the AP Earthquake Fault Zoning Act (Ordinance 547) | Geologic report required for permitted projects within designated zones. | Sections 5.5.2 and 5.5.3 |
| Riverside County Grading Code | Riverside County requires a grading permit when at least 50 cubic yards of earth is cut, filled, or imported on a site. | Section 5.5.1 |
| Riverside County Flood Hazard Zone Ordinance (Ordinance 458.13) | Riverside County requires a development permit prior to any construction or other development within any area of special flood hazards and requires that flood capacity of any altered watercourse be maintained. | Section 5.5.1 |

### 5.5.1.1 Federal LORS

The UBC specifies acceptable design criteria for structures with respect to seismic design and load-bearing capacity. The State has adopted these provisions in the CBC, discussed below.

### 5.5.1.2 State LORS

The Project is subject to the applicable sections of the CBC. The Riverside County Building Department is responsible for implementing the CBC for the Project.

**AP Earthquake Fault Zoning Act**

The AP Earthquake Fault Zoning Act was enacted by the State of California in 1972 to mitigate the hazard of surface faulting to structures planned for human occupancy and other critical structures. This law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. The State has established regulatory zones (known as Earthquake Fault Zones and often referred to as “AP zones”) around the surface traces of active faults and has issued “Earthquake Fault Zone Maps” to be used by government agencies in planning and reviewing new construction. In addition to residential projects, structures planned for human occupancy that are associated with industrial and commercial projects are of concern.

**Seismic Hazards Mapping Act**

The purpose of the Seismic Hazards Mapping Act is to protect public safety from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the AP Earthquake Fault Zoning Act, which addresses only surface fault-rupture hazards.

### 5.5.1.3 Local LORS

The Project is subject to the Riverside County's Department of Building and Safety requirements for building, grading, and flood development permits. The flood development permit is for development in areas within special flood hazards.

If a watercourse is to be altered or relocated, adjacent communities and the California Department of Water Resources must be notified prior to such alteration or relocation of a watercourse, and evidence of such notification must be submitted to the Federal Insurance Administration and Federal Emergency Management Agency. The Riverside County Flood Hazard Zone Ordinance also requires that the flood carrying capacity of the altered or relocated portion of said watercourse be maintained.

### 5.5.1.4 Involved Agencies

The agency and person(s) to contact for grading, building, National Pollutant Discharge Elimination System (NPDES), and floodplain development permits are identified in Table 5.5-2.

**Table 5.5-2 Agencies and Agency Contacts**

| Agency Contact | Phone/E-mail | Permit/Issue |
|---|---|---|
| John Carmona<br>Water Resources Control Engineer<br>Colorado River Basin Regional Water Quality Control Basin<br>Palm Desert Office<br>73-720 Fred Waring Dr., Suite 100<br>Palm Desert, CA 92260 | (760) 340-4521<br>JCarmona@waterboards.ca.gov | Waste Discharge Requirements, NPDES and Storm Water Permits,<br>Clean Water Act 401 |
| Scott Arnold<br>Riverside County Planning Department<br>4080 Lemon Street<br>Riverside, CA 92502-1629 | (951) 955-1852<br>sarnold@rctlma.org | Large scale (non-residential) grading permits, flood hazard areas permit |

### 5.5.1.5 Required Permits and Permit Schedule

Building and grading permits are required by the Riverside County Engineering and Survey Services Department, Building Inspections Division. Applications are required at least six weeks prior to construction. Table 5.5-3 discusses such permits.

**Table 5.5-3 Permits Required and Permit Schedule**

| Permit/Approval | Schedule |
|---|---|
| Building Permit | Application must be submitted six weeks prior to the start of construction. |
| Grading Permit | Application must be submitted six weeks prior to the start of construction. |
| Floodplain Development Permit | Application must be submitted six weeks prior to the start of construction. |

## 5.5.2 Affected Environment

This section discusses the existing geologic environment of the Project site. Underlying geologic structures, seismicity, and geologic hazards are discussed.

### 5.5.2.1 Geological Setting

The Project site is located in the northwestern Colorado Desert, which is part of the greater Colorado Desert Geomorphic Province. The Colorado Desert Province is characterized by isolated mountain ranges separated by broad alluvium-filled basins of Cenozoic sedimentary and volcanic materials overlying older rocks. Much of the Colorado Desert lies at low elevations, with some areas below sea level. The Colorado Desert province includes the Salton Sea, the Imperial Valley in the south, and the Coachella Valley in the north.

The Project is located in the alluvial-filled basin of the Chuckwalla Valley. The geology of this area is shown on Figure 5.5-1, Regional Geological Map. Regionally, this valley formed as a structural depression or a pull-apart basin. The basin is bound by the Eagle Mountains to the northwest, the Coxcomb, Palen, and McCoy Mountains to the north, and the Chuckwalla, Little Chuckwalla, and Mule Mountains to the south. Locally, the Project site is located southwest of the Palen Mountain foothills and is underlain by Quaternary-age alluvium and dune sands.

Regionally, the ground surface in the Chuckwalla Valley slopes gently downward in a southeast direction at a gradient of less than one percent. Locally, topography at the Project site is relatively flat with gentle slopes to the northeast, towards Palen Mountain. Site grades typically range from less than two percent in the central portion of the site to essentially flat in the northeastern portion of the site within the playa or dry lake bed. Steeper grades are present at isolated sand dunes along the northern portion of the site (T05S R17E- Section 21). Toward the north and central portions of the site, the ground becomes hummocky as it transitions to the flat playa located along the northern portion of the site. Ground surface elevations at the plant site range from 680 feet above mean sea level (msl) in the southwest to 425 feet above msl in the northeast.

The Project site is underlain by recent alluvium comprised of sand, silt, and gravel. The playa material along the northern portion of the site has a high fines content and is not typical of the more prevalent flat and mildly hummocky ground. Directly north and east of the site are sand dunes that appear to trend in a northwest to southeast direction. The dunes in the extreme northeast corner of Section 27 of T05S-R17E appear to be actively migrating, (from south to north) based on the lack of vegetation and active dirt devil observed during the field visit.

Surface water in the Chuckwalla Valley drains to the southeast and towards depressions formed by dry lakes. Palen Dry Lake is the largest playa in the valley, followed by Ford Dry Lake, which is almost as large. At the Project site, surface drainage is by sheetflow runoff toward the northeast. The Project site is bisected by several small drainages. These drainages carry runoff to the northeast from the Chuckwalla Mountains.

There are no permanent bodies of water located on the Project site. Groundwater in the area of the site is contained within the Chuckwalla Valley Groundwater Basin. Groundwater levels at the site were recently measured by AECOM in April 2009 at 190 feet below ground surface. A more detailed discussion of groundwater conditions at the Project site is provided in Section 5.17, Water Resources.

### 5.5.2.2 Seismicity

The Project site is located in seismically active Southern California, a region that has experienced numerous earthquakes in the past. A review of the AP Earthquake Fault Maps and the Riverside County

AP Earthquake Hazard Zone Map indicate that there are no AP fault zones present within the Project boundaries. In addition, no active fault zones are present within one mile of the Project site; however, the site is approximately 2.5 miles southwest of an unnamed fault located at the southern end of the Palen Mountains. This fault has not been mapped by the United States Geological Survey as a Quaternary (sufficiently active) fault, and is not listed by the EQFAULT program as a fault potentially affecting the site.

Regardless of whether there are faults across the site, because the Project is located in a seismically active area, all Project structures must be designed to comply with the CBC and UBC Zone 4 requirements. The CBC and UBC are considered to be standard safeguards against major structural failures and loss of life. The goals of the Codes are to provide structures that will: 1) resist minor earthquakes without damage; 2) resist moderate earthquakes without structural damage but with some non-structural damage; and 3) resist major earthquakes without collapse but with some structural and non-structural damage. The CBC and UBC base seismic design on minimum lateral seismic forces ("ground shaking"). The CBC and UBC requirements operate on the principle that providing appropriate foundations, among other aspects, helps to protect buildings from failure during earthquakes.

Although the Project is in an area that does not include mapped AP zones, a geotechnical/geologic constraints evaluation is underway to identify and evaluate geologic and geotechnical constraints that could affect the Project, including an evaluation of whether fault rupture; moderate-to-severe seismic shaking; subsidence and ground failure related to groundwater withdrawal; local flooding; and/or expansive or collapsible alluvial soils exist within the Project site.

The results of this evaluation will be included in a Preliminary Geotechnical/Geologic Constraints Evaluation Report that will be Appendix B to the AFC an will be provided to the regulatory agencies and other stakeholders when the investigation is completed. A placeholder has been provided in the AFC Appendices binders to insert this report.

Site geotechnical work will include soil borings and test pits in the solar array fields, and borings in the area of the power blocks and other proposed project structures. Soil borings will be drilled to obtain samples of the site soils for laboratory testing and soil classification. The purpose of the test pits is to gain a better spatial assessment of the near-surface soil materials and to provide a better understanding of the general grading recommendation, such as stripping depths and effects of the existing moisture conditions on the general grading operations. The investigation will include excavation and logging of test pits which will be approximately five feet in length and approximately 10 feet deep.

### 5.5.2.3 Geologic Hazards

Seismic hazards related to ground shaking include ground rupture, slope stability, liquefaction, subsidence, tsunamis, and seiches. Due to the inland location of the Project site and the absence of nearby large bodies of water, hazards from tsunamis and seiches are not present.

**Seismic Ground Shaking**

The Project is located in a seismically active area and therefore will likely be subjected to ground shaking from movement along one or more of the sufficiently active or well-defined faults in the region. A “sufficiently active fault” (previously referred to as an “active fault”) is defined as a fault that has broken the surface in the past 11,000 years. A “well-defined fault” (previously referred to as “potentially active fault”) is defined as a fault whose trace is clearly detectable by a trained geologist as a physical feature at or just below the ground surface.

A search was conducted that identified a total of 26 sufficiently active faults and well-defined faults within a 100-mile radius of the Project site. Table 5.5-4 highlights the most proximal fault that has the potential to generate ground acceleration 0.1 gravity (g). The 0.1g value is an industry standard for significance in terms of foundational design, and this potential acceleration can be managed with proper foundational design and site geotechnical investigation. The southern segment of the San Andreas Fault is located approximately 37 miles to the southwest of the site and has the greatest ground acceleration potential. This segment, from the Cajon Pass to the Salton Sea, may be capable of generating a moment magnitude 7.9 earthquake, which would be considered the maximum credible event that could impact the Project. Studies suggest that the San Andreas fault has a slip rate of 20 to 35 millimeters (mm) per year with a recurrence interval for large earthquakes of 20 years to over 300 years. The San Andreas fault (southern segment) has an estimated slip rate of 24 mm per year. The maximum historical earthquake magnitude within a 62-mile radius was 7.9 from the Fort Tejon Earthquake on the Mojave Segment of the San Andreas fault and occurred on January 9, 1857.

The closest seismically active area to the site is the Brawley Seismic Zone. This fault zone is located approximately 36.9 miles to the southwest and has the potential to generate a moment magnitude of 6.4; however the possible maximum ground acceleration for this fault zone is 0.042g.

Based on available online Seismic Hazard Zone Maps by the California Geological Survey, the Project site is located in an area that has not been mapped for seismic hazards. Based on the California Geological Survey's, Probabilistic Seismic Hazards Mapping Ground Motion Page, there is a 10 percent probability of earthquake ground motion exceeding 0.29g at the Project site over a 50-year period.

**Table 5.5-4 Active and Potentially Active Fault with Peak Site Greater than or Equal to 0.1g**

| Fault Name | Approximate Distance from Site | | Peak Site Acceleration (g) |
|---|---|---|---|
| | Miles | Kilometers | |
| San Andreas (southern segment) | 37 | 59.5 | 0.1 |

## Ground Rupture

Although located in an acknowledged seismically active area, the Project site is not located on a fault trace as designated by mapping as part of the AP Earthquake Fault Zoning Act. Therefore, the Project is not subject to the AP Earthquake Fault Zoning Act and the risk of earthquake-induced ground rupture is considered to be low. Fissures caused by the lowering of groundwater tables and by hydrocollapse when groundwater tables have risen have been reported in Riverside County. In addition, fissures have occurred along active faults that bound the San Jacinto Valley and Elsinore Trough approximately 100 miles east of the site. Fissures associated with groundwater levels or faults have not been reported at the site. Site-specific soil properties that may contribute to fissuring will be investigated during the preliminary geotechnical investigation.

## Slope Stability

The Project area is not considered to be an area with the potential for permanent ground displacement due to earthquake-induced landslides because surface topography at and near the site is relatively flat. A review of aerial photographs did not identify any active or inactive landslides at the site or in the adjacent areas. The Palen Mountains are located approximately one mile east of the Site. These mountains have slopes with angles of 30 percent or greater and have a high potential for seismically induced rockfalls and landslides to occur. However, because the Project site is not directly located adjacent to these slopes, the potential for seismically induced rockfalls and landslides to affect the site is low.

## Erosion

Erosion is the displacement of solids (soil, mud, rock, and other particles) by wind, water, or ice and by downward or down-slope movement in response to gravity. Due to generally flat terrain, the Project site is not prone to significant mass wasting at present. Soil characteristics at the Project site are not known because this area has not been mapped by the United States Department of Agriculture, Natural Resource Conservation Service; however, the Riverside County General Plan has classified the soils at the site as having a moderate to high susceptibility to wind erosion hazards.

Soil erosion from wind and water during construction activities is a topic covered in Section 5.12, Soils. Soil loss at the Project site will be estimated as part of the ongoing geotechnical investigation and will be reported to the regulatory agencies and other stakeholders when the when the investigation is complete. The implementation of Best Management Practices (BMPs) is expected to reduce water and wind erosion of soils to less than significant levels. The proposed BMPs are identified and described in the DESCP in Appendix L.

## Liquefaction

Liquefaction is a soil condition in which seismically induced ground motion causes an increase in soil water pressure in saturated, loose, sandy soils, resulting in loss of soil shear strength. Liquefaction can lead to near-surface ground failure, which may result in loss of foundation support and/or differential ground settlement. Sandy deposits deeper than 50 feet below ground surface usually are not prone to causing surface damage. In addition, soils above the groundwater table (soils that are not saturated) will not liquefy. Based on the Riverside County General Plan, the majority (75 percent) of the Project is located in an area with deep groundwater that is susceptible to liquefaction. It should be noted that the liquefaction information provided in the general plan is not site specific and is provided on a regional scale. Groundwater at an onsite well was measured by AECOM in April 2009 at a depth of 180 feet below ground surface, and thus, liquefaction at the Project site is considered unlikely (See Section 5.17, Water Resources). It is possible that, given the aeolian (wind) and alluvial (streams and washes) deposition of the site soils, there may be loose deposits across portions of the Project that may be subject to partial collapse and settlement if they are subjected to long-term wetting. These conditions are being investigated during the preliminary geotechnical investigation.

## Subsidence

Subsidence due to groundwater withdrawal has been documented in three regions of Riverside County: the Elsinore Trough, including Temecula and Murrietta; the San Jacinto Valley from Hemet to Moreno Valley; and the southern Coachella Valley, all approximately 25 miles or more west of the Project site. No subsidence has been documented at the Project site, although the site is in an area considered to be susceptible to subsidence.

The Project is located within the Chuckwalla Valley Groundwater Basin. Groundwater development within the basin is sparse, with the exception of the Desert Center area. At least six known wells exist in the immediate vicinity of the Project site. These wells are used to support the agricultural developments west of the site and as the domestic well for the residence there. The majority of these wells were installed in the 1950s and 1960s and little groundwater information is available for these wells. Available information suggests a historic maximum pumping rate of 1,250 to 1,600 gallons per minute for two of the offsite wells (5S/17E-19Q1 and 5S/17E-29E1). Total consumptive use (historical and current) for these wells is not known. Regional subsidence attributed to historical groundwater withdrawal has not been reported in the area of the Project or in the vicinity. Historical water use for two agricultural developments in the valley reported groundwater use of 3,000 acre feet per year (afy) and 4,500 afy. It is important to note that the proposed groundwater pumping by the Project of 500 afy is significantly less than that required by historical agricultural developments; therefore, subsidence from groundwater withdrawal associated with the Project is considered to be less than significant.

Seismically induced settlement can occur in areas where earthquake shaking causes densification of relatively loose sediments. Settlement can cause damage to surface and near-surface structures. However, with implementation of planned mitigation measures, the potential for damage due to seismically induced settlement is considered to be low at the Project site. Additional geotechnical investigations will be completed to assess seismically induced settlement in the vicinity of the Project site as part of the detailed design process. Although the potential for damage due to seismically induced settlement is considered to be low, the results of the investigation will be used to support Project detailed design and construction.

**Collapsible Soil Conditions**

Alluvial soils in arid and semi-arid environments have the tendency to possess characteristics that make them prone to collapse with increase in moisture content and without increase in external loads. In Riverside County, collapsible soils occur predominantly at the bases of the mountains, where Holocene-aged alluvial sediments have been deposited during rapid runoff events. Additionally, some windblown sands may be vulnerable to collapse and hydro-consolidation. The Project is located in a geologic environment where the potential exists for collapsible soils. Site-specific soil properties that may contribute to collapsible soil conditions will be investigated during the preliminary geotechnical investigation. However, the potential for damage due to collapsible soils is considered to be very low provided that the mitigation measures for sub-grade improvements are implemented. Active mitigation measures will be implemented to minimize soil erosion and collapse including:

- Engineering berms and drainage to minimize wetting of these soils; and directing runoff away from the power block;
- Pre-watering the Project site to induce hydro-consolidation in advance of the grading program that will be part of Project construction; and
- Removing collapsible soils as part of the grading program.

**Expansive Soil**

Expansive soil consists of fine-grained clay which occurs naturally. It is generally found in areas that were historically a flood plain or lake area, but can occur in hillside areas also. Expansive soil is subject to swelling and shrinkage, varying in proportion to the amount of moisture present in the soil. As water is initially introduced into the soil (by rainfall or watering) expansion takes place. If dried out, the soil will contract, often leaving small fissures or cracks. Excessive drying and wetting of the soil can progressively deteriorate structures over the years by leading to differential settlement within buildings and other improvements.

One surface soil sample collected at the site consisted of poorly graded sand with silt. Although preliminary, this sample suggests that the expansion potential of the onsite soils may be low. Soils present in other areas of the Project may be expansive. One sample collected in the northeast portion of the Project, near Palen Dry Lake, shows that soils consist of lean clay with sand. The expansion potential near this part of the site may be a bit higher than the rest of the site. The ongoing preliminary geotechnical investigation will further evaluate and verify the expansion potential of the native soil deposits.

### 5.5.2.4 Geologic Resources

Recreational and unique geologic resources and features typically include rock or mineral collecting, surface hydrothermal features, or surface expression of geologic features unique enough to generate recreational interests of the general public (natural bridges, caves, waterfalls, etc.). Based on a search of State recreation-related websites, there are no known recreational or unique geologic resources associated with the Project site. California Division of Oil, Gas, and Geothermal Resources oil and gas maps were reviewed to check for oil or gas resources beneath the Project site or in the adjacent areas; however, there is no map coverage for the Project area.

## 5.5.3 Environmental Impacts

Environmental impacts associated with the construction and operations of the Project are discussed in the following sections.

### 5.5.3.1 Construction

Construction-related impacts to the geologic environment primarily are related to terrain modification (cuts, fills, and drainage diversion measures) and dust generation (excavation and grading). Dust generation and the potential for erosion-related impacts associated with construction are discussed further in Section 5.12, Soils. No major unique geologic or physical features have been identified at the Project site. Based on the preliminary grading plan (see Appendix L) for the Project site, construction will require cut and fill activities on the site, but import/export of earthen materials to and from the site will not be required. Therefore, potential construction-related impacts to the geologic environment would be confined to the Project site.

Evidence of ground subsidence as a result of past groundwater withdrawal has not been documented in the Project area. Historic pumping rates of between 3,000 afy and 4,500 afy for agricultural development have been reported for two of the crops grown in the valley. Proposed pumping rates in support of construction activities and grading are significantly lower than that used by agricultural developments. Groundwater modeling for the construction period of 39 months showed that under an average pumping rate of 600 gallons per minute (gpm), the drawdown in the area of the pumping well would be 25 feet, and the radius of influence to the 5-foot contour would be 3,800 feet. See section 5.17.3.1 and Figure 5.17-14 in this AFC. It is anticipated that the moderate level of drawdown during this short period of pumping will not induce subsidence. The ongoing preliminary geotechnical investigation will provide information on soil properties that may contribute to fractures and collapsible soil conditions (when wetted), as well as expansive soil conditions.

A potential geologic hazard exists during construction if soils are wetted. BMPs implemented during construction will reduce the potential for wetting of these soils, directing surface water to drainage channels and away from the expansive and collapsible soils. In addition, engineering measures such as wetting the soils in advance of grading to induce consolidation and removal of these soils and re-compaction may also be implemented.

The Project site is in the seismically active Southern California region; thus, the Project site is subject to ground shaking, and potentially subject to fault movement from earthquakes along faults in the region. The potential for earthquake-related impacts would begin during Project construction. However, seismic impacts would be of greater concern during long-term Project operation than during the limited duration of the Project construction phase. These impacts are discussed immediately below.

### 5.5.3.2 Operation

Regional and local geologic conditions will not be altered significantly by the long-term operation of the Project. No major unique geologic or physical features have been identified at the Project site. The Project area may be underlain by deposits of sand and gravel, and these resources could not be recovered and used during the active life of the Project. No other impacts to the geologic environment have been identified.

The Project area is subject to ground shaking from nearby and distant earthquakes. Ground acceleration up to 0.29g may be experienced at the Project site, which represents the potential for moderate to severe shaking. The Project site is located in Seismic Zone 4, the zone with the highest potential for seismic ground shaking. The southern segment of the San Andreas fault has been identified as having the greatest potential to affect the Project site; thus, impacts resulting from severe shaking at the Project site may be anticipated. Project structures will be designed to meet the seismic design standards appropriate for Seismic Zone 4. The Project's preliminary geotechnical investigation program will address site-specific soil conditions and the potential for significant seismicity. Due to the depth to groundwater (190 feet), liquefaction is not expected to occur.

Evidence of ground subsidence, such as fractures possibly caused by groundwater extraction, has not been noted at the Project site. The potential for local settlement due to groundwater withdrawal could be present at the Project site if the regional groundwater table were to be lowered significantly. As discussed in Section 5.17, Water Resources, groundwater pumping is expected to lower the water table below the Project site less than 1 foot after 30 years of operation. Given that historical groundwater use in the area has been higher as a result of agricultural developments and that no subsidence has been reported, it is not anticipated that the Project's limited pumping program will induce subsidence below the site.

In addition to the preliminary geotechnical investigation, the Project also will perform a more detailed study of the potential for subsidence-related ground failure in support of detailed design. The study may contain a review of previous groundwater records including drawdown rates, groundwater usage, and other groundwater and well records, as well as groundwater modeling to quantify the amount of anticipated future settlement.

Soils at the Project site may have a potential for collapse. Soil properties will be investigated during the preliminary geotechnical investigation to approximate the level of collapse potential. To ensure that collapse potential is minimized, all foundations for plant facilities will be designed in accordance with the recommendations of the preliminary and future geotechnical investigations. Recommendations may include over excavation and recompaction where necessary.

In summary, the only identified potential geologic hazards for the Project are ground shaking, although as noted above, the potential for soil collapse is being investigated as part of the ongoing geotechnical investigation. Additional geologic hazards, such as collapse, may be identified after the preliminary geotechnical investigation is completed. Construction of facilities in accordance with the mitigation measures identified below will ensure that earthquake-related impacts and impacts from potential soil collapse are minimized such that Project impacts are considered less than significant.

### 5.5.3.3 Cumulative Impacts

The Project will be designed and constructed to meet UBC/CBC requirements for industrial facilities located in Seismic Zone 4 and will adhere to sound professional practices and appropriate regulatory requirements related to geologic hazards (e.g., grading, slope stability). For these reasons, the Project is expected to have no significant impacts on geologic hazards or resources. Other projects in the same vicinity also would be expected to adhere to the appropriate professional standards and regulatory requirements. As such, the Project would not be expected to contribute to significant cumulative effects on geologic resources and hazards during construction or operation.

## 5.5.4 Mitigation Measures

Geologic impacts associated with the construction and operation of the Project are expected to be less than significant. Site-specific geotechnical, seismic, and collapsible soil conditions will be appropriately addressed during detailed design and during construction. The following mitigation measures are proposed to ensure that impacts are less than significant.

**GEOL–1** Power plant structures and equipment as well as offsite linear facilities (natural gas, pipeline; transmission line) will be designed in accordance with Seismic Zone 4 requirements.

**GEOL-2** Project foundations will be designed in accordance with recommendations (e.g., overexcavation and recompaction beneath project structures and paved areas) provided in the Preliminary Geotechnical/Geologic Constraints Evaluation Report and as amended and/or refined by future geotechnical investigations.

## 5.5.5 References

Blake, T.F., 2000. EQFAULT, A Computer Program for the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults, A User's Manual.

California Department of Conservation, Division of Mines and Geology, 2000. Digital Images of Official Maps of Alquist-Priolo Earthquake Fault Zones of California, Southern Region, DMG CD 200-004.

California Geological Survey, 2003. Seismic Shaking Hazards in California; accessed at http://www.consrv.ca.gov/cgs/rghm/pshamap/pshamain.html. Accessed May 6, 2009.

California Geological Survey, 2009. Seismic Hazard Zonation Program, accessed at www.conservation.ca.gov/cgs/shzp. Accessed May 6, 2009.

California State Parks, 2008. Accessed at http://www.parks.ca.gov. Accessed May 6, 2009.

CH2MHill, 2008. Reconnaissance-Level Geotechnical and Water Supply Assessment for Palen Solar Projects, Draft. October.

Division of Oil, Gas, and Geothermal Resources, 2009. Oil and Gas Maps, District 1 Wildcat Map. http://www.conservation.ca.gov/dog/maps/Pages/index_map.aspx. Accessed on May 6.

Department of Water Resources, 1963. Data on Water Wells and Springs in the Chuckwalla Valley Area, Riverside County, California, Bulletin 91-7. May.

Division of Mines and Geology (DMG), 1967, Charles W. Jennings, Geologic Map of California, Salton Sea Sheet, Scale 1:250,000.

DMG 1994. Charles W. Jennings and George J. Saucedo, Fault Activity Map of California and Adjacent Areas, With Locations and Ages of Recent Volcanic Eruptions, Scale 1:750,000.

Reames, Allen, 1997. Historic Farming and Groundwater Use, Chuckwalla Valley, 1980 to 1997, Presentation to the Riverside County Planning Commission. February 5.

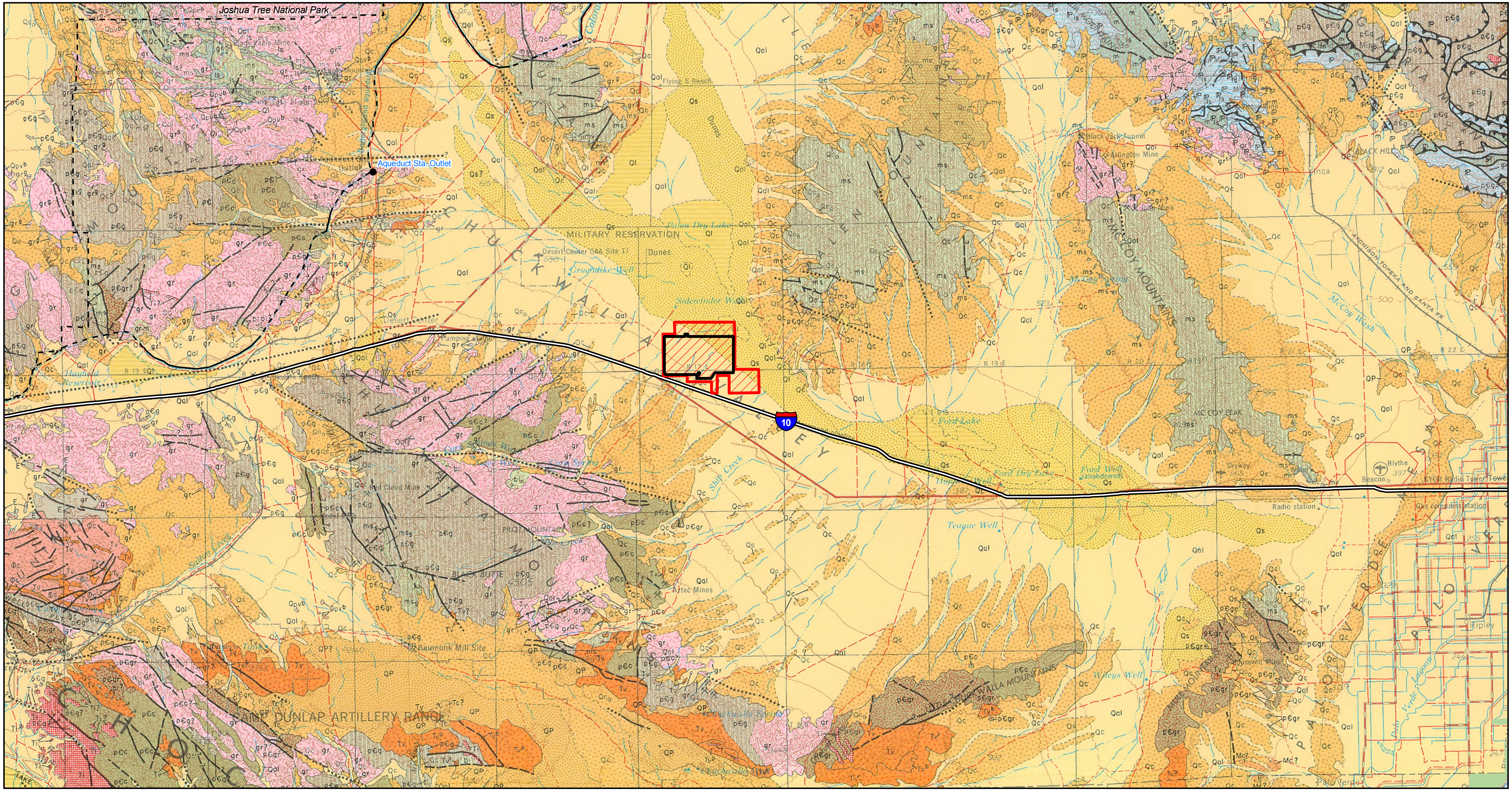
Riverside County Integrated Project, 2000. General Plan, Final Program Environmental Impact Report, Volume 1, Riverside County, California.

United States Geological Survey (USGS), 2009. Quaternary Faults and Folds Database, http://gldims.cr.usgs.gov/. Accessed on May 6.

USGS, 1983. Sidewinder Well Quadrangle, California – Riverside County, 7.5 Minute Series, 1:24,000.

USGS, 1969. Salton Sea, California; Arizona, 1:250,000.

Southern California Earthquake Center, 2009. Faults of Southern California, Southern Region, San Andreas Fault Zone, assessed at http://www.data.scec.org/fault_index/sanandre.html. Accessed on May 5.




Map Location


Legend

- Project Right-of-Way
- Facility Footprint
- Colorado River Aqueduct
- Colorado River Aqueduct (Dash showing underground interval)
- Freeway

See Figure 5.5-1b for Geologic Legend

Sources:
Division of Mines and Geology, Geologic Map of California,
Salton Sea Sheet, Scale 1:250,000, 1967

N W E S

0 4 8 Miles

**Palen Solar Power Project**

**Figure 5.5-1a**
**Regional Geologic Map**

Solar Millennium

AECOM

Project: 12944-001
Date: August 2009

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# EXPLANATION

## SEDIMENTARY AND METASEDIMENTARY ROCKS / IGNEOUS AND META-IGNEOUS ROCKS

### CENOZOIC

**QUATERNARY**

*Recent*
- Qs — Dune sand
- Qal — Alluvium
- Qsc — Stream channel deposits (GREAT VALLEY)
- Qf — Fan deposits (GREAT VALLEY)
- Qb — Basin deposits (GREAT VALLEY)
- Qrv — Recent volcanic: Qrv^r —rhyolite; Qrv^a —andesite; Qrv^b —basalt; Qrv^p —pyroclastic rocks
- Qst — Salt deposits
- Ql — Quaternary lake deposits
- Qg — Glacial deposits

*Pleistocene*
- Qt — Quaternary nonmarine terrace deposits
- Qm — Pleistocene marine and marine terrace deposits
- Qpv — Pleistocene volcanic: Qpv^r —rhyolite; Qpv^a —andesite; Qpv^b —basalt; Qpv^p —pyroclastic rocks
- Qc — Pleistocene nonmarine
- QP — Plio-Pleistocene nonmarine
- Quaternary and/or Pliocene cinder cones

**TERTIARY**

*Pliocene*
- Pc — Undivided Pliocene nonmarine
- Puc — Upper Pliocene nonmarine
- Pu — Upper Pliocene marine
- Pv — Pliocene volcanic: Pv^r —rhyolite; Pv^a —andesite; Pv^b —basalt; Pv^p —pyroclastic rocks
- Pmlc — Middle and/or lower Pliocene nonmarine
- Pml — Middle and/or lower Pliocene marine

*Miocene*
- Mc — Undivided Miocene nonmarine
- Muc — Upper Miocene nonmarine
- Mu — Upper Miocene marine
- Mv — Miocene volcanic: Mv^r —rhyolite; Mv^a —andesite; Mv^b —basalt; Mv^p —pyroclastic rocks
- Mmc — Middle Miocene nonmarine
- Mm — Middle Miocene marine
- Ml — Lower Miocene marine

*Oligocene*
- Φc — Oligocene nonmarine
- Φv — Oligocene volcanic: Φv^r —rhyolite; Φv^a —andesite; Φv^b —basalt; Φv^p —pyroclastic rocks
- Φ — Oligocene marine

*Eocene*
- Ec — Eocene nonmarine
- Ev — Eocene volcanic: Ev^r —rhyolite; Ev^a —andesite; Ev^b —basalt; Ev^p —pyroclastic rocks
- E — Eocene marine

*Paleocene*
- Epc — Paleocene nonmarine
- Ep — Paleocene marine

*Undivided*
- QTc — Cenozoic nonmarine
- QTv — Cenozoic volcanic: QTv^r —rhyolite; QTv^a —andesite; QTv^b —basalt; QTv^p —pyroclastic rocks
- Tc — Tertiary nonmarine
- Tgr — Tertiary granitic rocks
- Tl — Tertiary lake deposits
- Ti — Tertiary intrusive (hypabyssal) rocks: Ti^r —rhyolite; Ti^a —andesite; Ti^b —basalt
- Tm — Tertiary marine
- Tv — Tertiary volcanic: Tv^r —rhyolite; Tv^a —andesite; Tv^b —basalt; Tv^p —pyroclastic rocks

### MESOZOIC

**CRETACEOUS**
- K — Undivided Cretaceous marine
- Ku — Upper Cretaceous marine
- Kl — Lower Cretaceous marine
- KJf — Franciscan Formation
- KJfv — Franciscan volcanic and metavolcanic rocks
- gr — Mesozoic granitic rocks: gr^g —granite and adamellite; gr^g —granodiorite; gr^t —tonalite and diorite
- bi — Mesozoic basic intrusive rocks
- ub — Mesozoic ultrabasic intrusive rocks

**JURASSIC**
- Jk — Knoxville Formation
- Ju — Upper Jurassic marine
- Jml — Middle and/or Lower Jurassic marine
- JTrv — Jura-Trias metavolcanic rocks

**TRIASSIC**
- Tr — Triassic marine

**UNDIVIDED**
- m — Pre-Cretaceous metamorphic rocks (ls = limestone or dolomite)
- mv — Pre-Cretaceous metavolcanic rocks
- ms — Pre-Cretaceous metasedimentary rocks
- gr-m — Pre-Cenozoic granitic and metamorphic rocks
- P — Paleozoic marine (ls = limestone or dolomite)
- Pv — Paleozoic metavolcanic rocks

### PALEOZOIC

**PERMIAN**
- P — Permian marine
- Pv — Permian metavolcanic rocks

**CARBONIFEROUS**
- C — Undivided Carboniferous marine
- Cv — Carboniferous metavolcanic rocks
- CP — Pennsylvanian marine
- CM — Mississippian marine

**DEVONIAN**
- D — Devonian marine
- Dv — Devonian metavolcanic rocks
- Dv? — Devonian and pre-Devonian? metavolcanic rocks

**SILURIAN**
- S — Silurian marine
- pSs — Pre-Silurian metasedimentary rocks
- pS — Pre-Silurian metamorphic rocks
- pSv — Pre-Silurian metavolcanic rocks

**ORDOVICIAN**
- O — Ordovician marine

**CAMBRIAN**
- Є — Cambrian marine
- Є? — Cambrian – Precambrian marine

### PRECAMBRIAN
- pЄc — Precambrian igneous and metamorphic rock complex
- pЄ — Undivided Precambrian metamorphic rocks; pЄg = gneiss, pЄs = schist
- pЄgr — Undivided Precambrian granitic rocks
- lpЄ — Later Precambrian sedimentary and metamorphic rocks
- pЄan — Precambrian anorthosite
- epЄ — Earlier Precambrian metamorphic rocks

*HEAVY BORDER ON BOXES INDICATES UNITS THAT APPEAR ON THIS SHEET*

- Contact — *Dashed where approximately located, gradational or inferred*
- Fault — *Dashed where approximately located; dotted where concealed*
- Thrust fault — *Barbs on upper plate; dashed where approximately located, dotted where concealed*
- ● GEOTHERMAL WELLS
- + MUD VOLCANOES

## Map Location


## Legend

Sources:
Division of Mines and Geology, Geologic Map of California, Salton Sea Sheet, Scale 1:250,000, 1967

**Palen Solar Power Project**

**Figure 5.5-1b**
**Regional Geologic Map Legend**

Solar Millennium

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Project: 12944-001
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