4.6 Geology and Soils

The purpose of this Section is to identify existing topography, geology, soils, and seismicity within the Project area, analyze potential impacts to those conditions associated with the development of the proposed Project, and identify mitigation measures that would avoid or reduce the significance of any identified impacts. The primary information sources include Project-specific investigations, available resources from the USGS and the California Geological Survey (CGS), as well as other sources cited in the References Section. Thresholds of significance for the impact analysis are derived from Appendix G of the 2011 *CEQA Guidelines*.

In addition to the *CEQA Guidelines*, the operation of the Project will be managed under a GMMMP which incorporates additional safeguards and action criteria when adverse conditions occur attributable to the Project.

4.6.1 Environmental Setting

A number of field investigations have been performed over the years to describe the geologic setting of the general area of the proposed Project site. Until recently, geologic mapping conducted by the California Division of Mines and Geology (CDMG) published in 1964 had served as the basis for understanding local geologic conditions in the Fenner Gap. Prior to the CDMG investigation, detailed geologic mapping of the Project area had not been published. New geologic mapping of the southeastern portion of the Marble Mountains, the Fenner Gap, and the northwestern portion of the Ship Mountains was conducted for this CEQA investigation by Dr. Miles Kenney, Kenney GeoScience report, and is included within Appendix H of the Draft EIR. The Kenney GeoScience study consolidated the previous geologic and geophysical studies, and then updated and augmented the consolidated geologic information with a 21-day field investigation of the geology of the Fenner Gap area and discussions with previous investigators.[1] This detailed mapping was conducted to allow interpretation of the geologic structure in the Fenner Gap in order to determine potential groundwater flow paths. The Kenney GeoScience report formed the basis for construction of the groundwater flow model and impacts analysis developed by GEOSCIENCE Support Services, Inc., (Geoscience) and is also included within Appendix H of the Draft EIR) for the Project.[2] The environmental setting information below largely draws from the geologic setting information provided in both the Kenney GeoScience study and Geoscience's modeling and impact analysis.

Regional Physiographic and Geologic Setting

Regionally, the Project is located within the Eastern Mojave Desert portion of San Bernardino County, California, which is a part of the Mojave Desert Geomorphic Province, also cited as part of the Basin and Range Geomorphic Province.[3, 4] The Province is characterized by a series of

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1 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California,* August 2011.

2 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011.

3 Norris, Robert M. and Robert W. Webb, *Geology of California*, Second Edition, 1990, pages 220- 225.

4 California Geological Survey, *California Geomorphic Provinces, Note 36*, 2002, page 3.

structural and topographic basins bounded by relatively linear mountain ranges. The alternating mountain and valley topography primarily (**Figure 4.6-1**) resulted from extensional (pulling apart) tectonics that occurred during the Miocene (5 to 23 million years ago).[5] Most valleys within the region are truly basins in that sediments eroding from the local mountain ranges deposit locally as alluvial fan sediment aprons (bajadas) draped on the mountains and extend out into the immediate valley. This also means that streams remain trapped within the basins and do not flow outside of the basins to the Pacific Ocean or Gulf of California (Sea of Cortez) or the Colorado River. In addition, groundwater remains trapped in alluvial valley sediments and upper bedrock units within the basins and also does not flow to the Colorado River. In other words, all flow within basin drainages remains within the hydraulically-closed basins, eventually flowing to playas at the lowest elevations, creating dry lakes where flows gather, become saline, and evaporate.

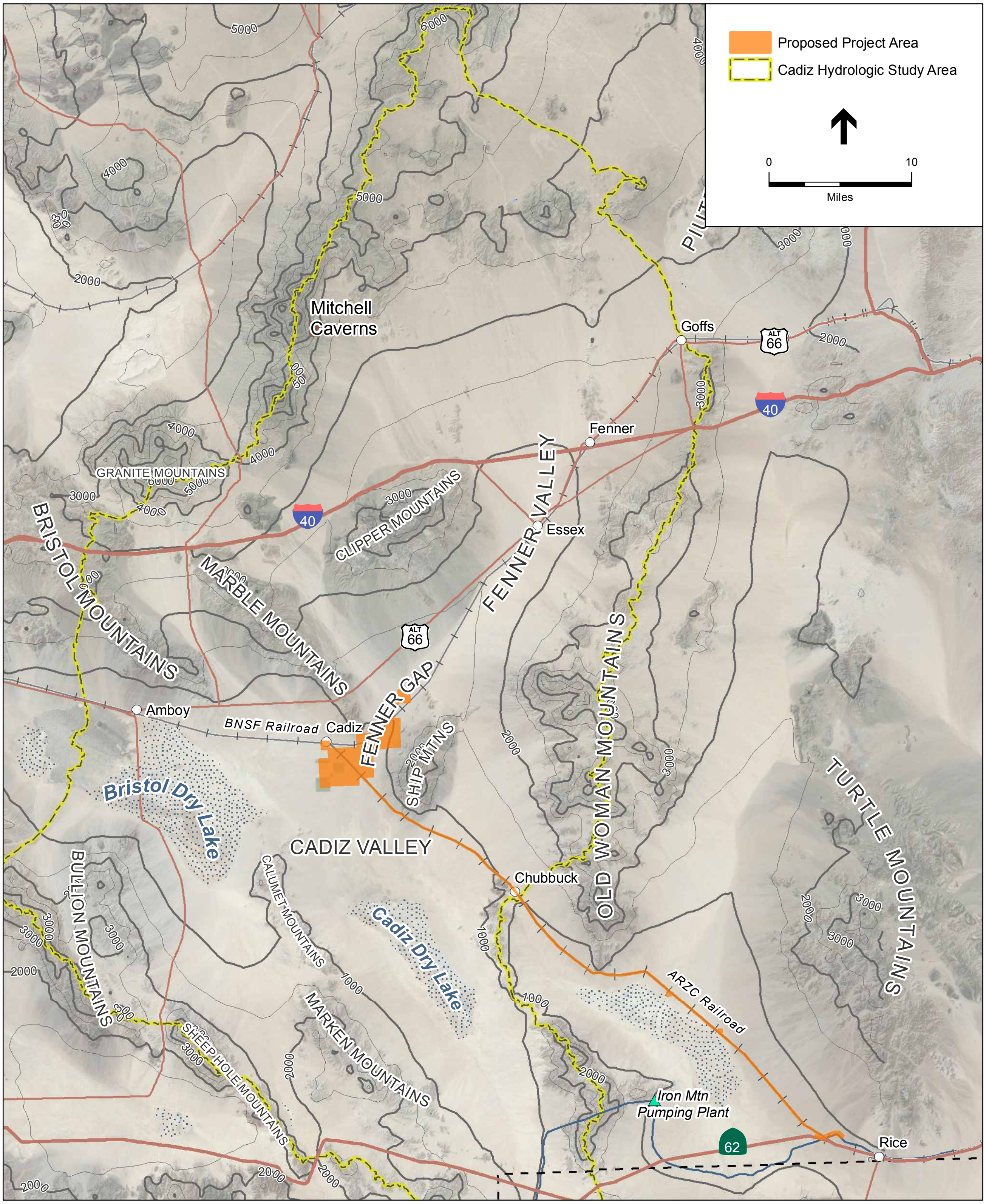
Topography and Geomorphology

The Project site is located at the confluence of the Fenner and Orange Blossom Wash Watersheds, as shown on Figure 4.9-1. This area is within a drainage basin consisting of the Watersheds, as discussed in Section 4.9, Hydrology and Water Quality. These combined Watersheds are considered one hydraulically-closed drainage system because all surface water and groundwater drain to Bristol and Cadiz Dry Lakes at the interior of the overall drainage basin. This drainage basin system is separated from surrounding drainage basins by topographic divides, generally mountain ranges.

The Fenner Watershed is located in the northern portion of the Project area. The New York Mountains, located at the northernmost end of the Project area at the head of the Fenner Valley and Fenner Watershed, are the highest mountains in the Project area, rising to an elevation of approximately 7,532 feet National Geodetic Vertical Datum of 1988 (NGVD).[6] The mountains bounding the east and west sides of the Fenner Valley range in height from 4,165 to 7,178 feet NGVD.[7] Generally, the Fenner Valley slopes south to southwest toward the Fenner Gap at an elevation of about 900 feet NGVD. The Fenner Gap occurs at the southern end of the Watershed between the Marble and Ship Mountains at 3,842 and 3,239 feet NGVD, respectively. At this location, surface water drainage and groundwater flow from the Fenner Watershed enter the Bristol and Cadiz Watersheds to the south. This area comprises the Fenner Watershed and encompasses approximately 1,090 square miles.

The Project wellfield and spreading basin facilities will be located within the Fenner Gap area on Cadiz Inc. owned property, as shown on Figure 3-14. As stated above, the axis of the Fenner Gap is located at an elevation of approximately 900 feet NGVD and is the location of constant groundwater and intermittent surface water outflow from the Fenner Valley to the Bristol and Cadiz Dry Lakes. The ground surface within the Fenner Gap trends gently toward the south at a slope of less than 50 feet per mile to the Cadiz and Bristol Dry Lakes. With minor local

5 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 3.
6 CH2M Hill, *Cadiz Groundwater Conservation and Storage Project*, July 2010, page 2-1.
7 CH2M Hill, *Cadiz Groundwater Conservation and Storage Project*, July 2010, page 2-2.



SOURCE: Bing Maps, 2011; ESRI, 2010
Cadiz Inc., 2011; CH2MHill, 2010; and ESA, 2011

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-1
Topography

exceptions, the slope of the ground surface ranges from approximately one to six percent (approximately 50 to 300 feet per mile).

Elevations across the Fenner Gap from northwest to southeast vary from about 1,600 feet NGVD in the southern Marble Mountains to about 930 feet NGVD at the base of the Marble Mountains to about 900 feet in the gap axis to about 1,100 feet NGVD at the base of the Ship Mountains to about 3,200 feet NGVD along the crest of the Ship Mountains.[8] Bajadas that range in age from late Pleistocene to present surround the deeply incised Marble and Ship Mountains. Numerous alluvial fan surfaces near the mountain fronts are latest Pleistocene in age (less than 25,000 years old). The fan surfaces do not exhibit any identified fault scarps or lineaments suggesting that faulting has not occurred locally since their deposition.[9] In addition, no lineaments associated with the now inactive normal faults that were active during the Miocene extensional tectonic phase of deformation were identified.

Relatively large bedrock inselbergs[10] exist along the northern flanks of the Ship Mountains (see **Figure 4.6-2**). The inselbergs provide critical information regarding the subsurface structure and lithology in the area.[11] The existence of inselbergs along mountain ranges is typical of Basin and Range extensional tectonic regions where they represent elevated bedrock highlands associated with normal faulting that subsequently received alluvial sediments around them once normal faulting ceased. The presence of the alluvial sediments provides strong evidence that normal faulting is no longer active in the Project area.

The Bristol and Cadiz Watersheds in the southern portion of the Project area form a broad depression that is referred to as the Bristol Trough (also referred to as the Barstow-Bristol or Bristol-Danby Trough).[12,13,14] This depression is thought to be six to ten million years old[15] and to have been formed as a result of regional movement along faults. The Bristol and Cadiz Watersheds are surrounded by the Bristol, Iron, Bullion, Sheep Hole, Calumet, and Coxcomb Mountains, ranging in elevations from 1,751 to 4,685 feet NGVD. The surface water drainage and groundwater flow from the Four Watersheds drain into the Bristol and Cadiz Dry Lakes with surface elevations of approximately 595 and 545 feet NGVD, respectively. The Bristol and Cadiz Dry Lakes are separated by a low topographic and surface drainage divide. The Cadiz Watershed encompasses approximately 590 square miles. The Bristol Watershed encompasses

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8 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 2.

9 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 2.

10 Isolated bedrock exposures surrounded by young alluvium.

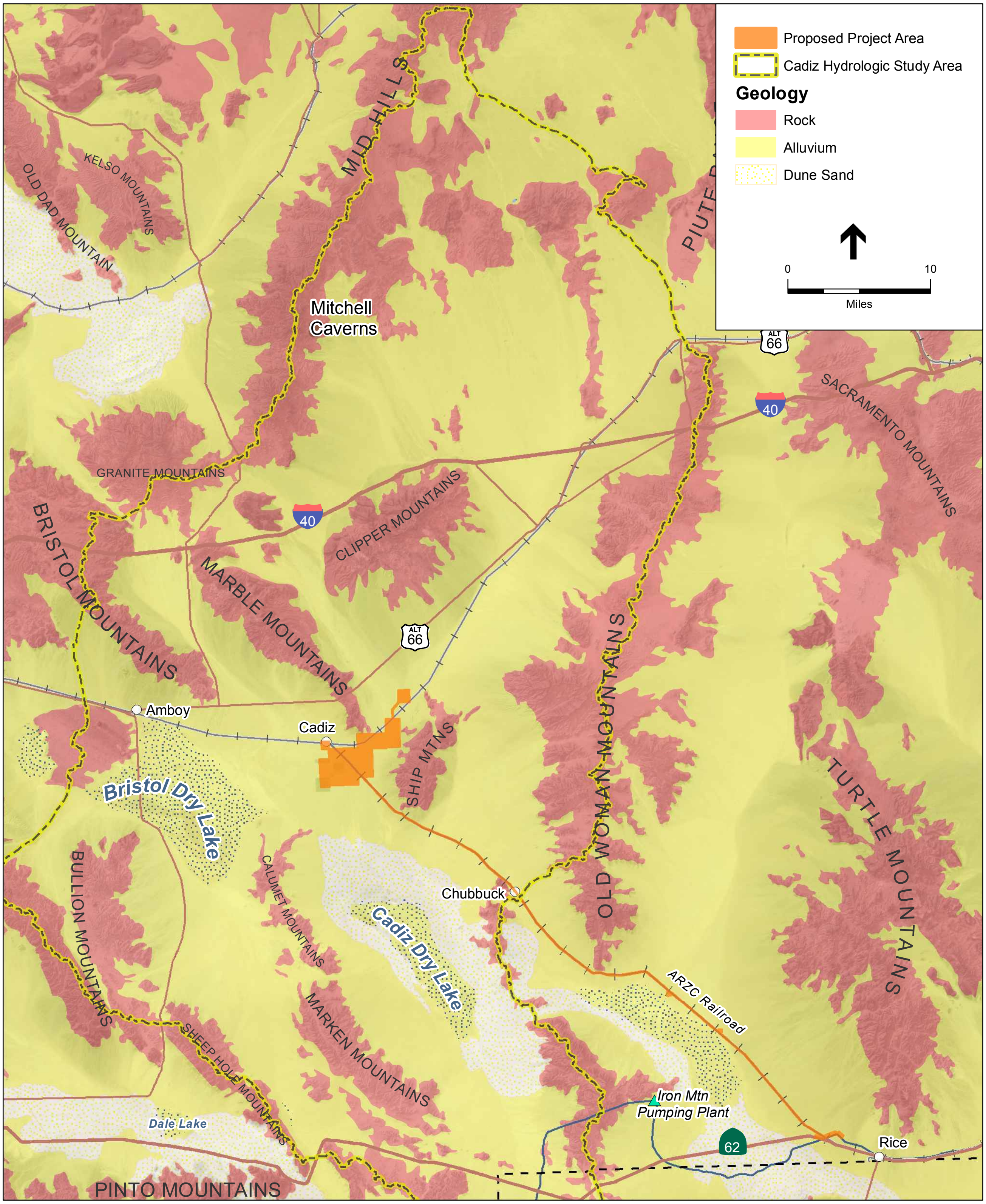
11 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 2.

12 Thompson, D.G., *The Mojave Desert Region, California: A Geographic, Geologic, and Hydrologic Reconnaissance,* U.S. Geological Survey Water Supply Paper 578, 1929 page 652.

13 Bassett, A.M. and D.H. Kupfer, *A Geologic Reconnaissance in the Southeastern Mojave Desert, California*, California Division of Mines and Geology Special Report 83, 1964, page 41.

14 Jachens, R.C., and Howard, K.A, “Bristol Lake Basin – A Deep Sedimentary Basin Along the Bristol-Danby Trough, Mojave Desert” In *Old Routes to the Colorado,* San Bernardino County Museums Special Publication 92-2, Redlands, CA, 2002, pages 57-59.

15 Rosen, M.R., *Sedimentologic, Geochemical and Hydrologic Evolution of Intracontinental, Closed-Basin Playa (Bristol Dry Lake, CA): Model for Playa Development and Implications for Paleoclimate,* 1989, page 23.



SOURCE: Bing Maps, 2011; ESRI, 2010
Cadiz Inc., 2011; CH2MHill, 2010; and ESA, 2011

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-2
Simplified Geology

approximately 640 square miles, which is considered to include the 160 square mile Orange Blossom Wash Watershed, discussed below.

The Orange Blossom Wash Watershed is located along the western portion of the Project area between the Marble and Bristol Mountains and below the Granite Mountains. It begins at the Granite Mountains, which are located along the western border of the Project area and rise to 6,786 feet NGVD. The Orange Blossom Wash Watershed comprises approximately 160 square miles and drains to the southeast into the Bristol Watershed, which is to the south and southwest.

Geologic Units

The Kenney GeoScience study provides a complete description of the geologic units present within the Project area including numerous subdivisions of the units, along with a detailed geologic map and eight detailed geologic cross sections.[16] Figure 4.6-2 provides a simplified geologic map of the larger study area showing the distribution of bedrock and alluvial deposits. The bedrock includes igneous, metamorphic, and consolidated sedimentary rocks. The alluvial and playa deposits are unconsolidated sediments deposited by streams, wind, or dry lakes. In general, bedrock forms the perimeter of the Four Watersheds.

Using all of the available geologic information, including the results of aquifer testing conducted by Geoscience and the recent mapping and interpretations in the Kenney GeoScience study, Geoscience grouped the geologic formations found in the Project area into the four broad categories listed below[17] with a focus on the generally differing hydraulic properties (i.e., the characteristics of groundwater movement through geologic materials).

- Holocene Playa Deposits
- Pleistocene to Holocene Alluvium
- Tertiary volcanic and fanglomerate units
- Archean to Jurrassic granitic and metamorphic rock units

A brief description of the grouped geologic units in the overall Project area is presented below, mostly drawing from the Kenney GeoScience study but also from others studies as cited. The units are presented from youngest to oldest.

Playa Deposits

The playa sediments underlying the Bristol and Cadiz Dry Lakes consist of brine-saturated clay, silt, fine-grained sand, and evaporite deposits. The clastic sediments were deposited when stream flow and sheet flow from the surrounding alluvial fans spread onto the playas during major storm

[16] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011.

[17] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, pages 6-7.

events.[18] The evaporite deposits formed from evaporation of both surface water and groundwater that seeped into the playa sediments from the adjacent alluvial fans.

The Dry Lake surfaces are devoid of vegetation due to the saline conditions and are usually dry. However, runoff from winter storms and late summer thunderstorms can result in occasional standing water.[19, 20, 21, 22, 23] The playas are made up of a variety of surface types, varying from the interior of the playas, where the Dry Lakes are located, towards the outer perimeter, to the edge where vegetation begins.[24] The sediments in the innermost area are generally composed of clay and silt with smaller amounts of sand. Because the playas have been closed drainages for thousands of years, these playas have acquired economically valuable deposits of evaporite salt minerals that are currently being produced (see Section 4.11, Mineral Resources). The salts bind the sediments of the playa surface in the innermost areas into a relatively hard, porous crust that is devoid of vegetation.[25] Czarnecki [26] proposed that the puffy surfaces are formed from surficial capillary water movement causing salts to precipitate and clays to swell on the surface, resulting in a network of polygons and hummocky relief. With the accumulation of salts in the central playa area over the past several thousand years, the annual rainfall and associated surface water runon from the surrounding areas appears to be sufficient to maintain the salt crust surface, as discussed in Section 4.9, Hydrology and Water Quality.

Cadiz Dry Lake is locally bordered by active dunes formed by fine to medium-grained windblown sand.[27] These Holocene[28] deposits overlie older playa deposits of differentiated Quaternary age.[29] In addition, Amboy Crater, located near the western margin of Bristol Dry Lake, is a basaltic cinder cone and lava field that is believed to be as young as 6,000 years.[30, 31]

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18 Gale, H.S., *Geology of the Saline Deposits, Bristol Dry Lake, San Bernardino County, California,* California Division of Mines and Geology Special Report 13, pages 4-5, 1951.
19 Bassett, A.M., Kupfer, D.H. and F.C. Barstow, *Core Logs from Bristol, Cadiz and Danby Dry Lakes, San Bernardino County, California,* U.S. Geological Survey Bulletin, 1045-D, 1959, pages 97-138.
20 Koehler, J.H, *Groundwater in the Northeast Part of Twentynine Palms Marine Corps Base, Baghdad Area, California: USGS Water Resources Investigations Report 83-4053*, 1983, page 2.
21 County of San Bernardino, *Draft Environmental Impact Report for the Proposed Cadiz Valley Agricultural Development*, 1993, page 4-5.
22 Cadiz Inc., *Communication with ESA*, December 9, 2010.
23 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Storage and Dry-Year Supply Program, Environmental Planning Technical Report, Groundwater Resources, Volume 2, Report No. 1163*, November 1999, page 29.
24 CH2M Hill, *Cadiz Groundwater Conservation and Storage Project,* July 2010, page 2-2.
25 HydroBio, *Fugitive Dust and Effects from Changing Water Table at Bristol Playa, San Bernardino County, California*, January 2011, page 9.
26 Czarnecki, J.B., *Geohydrology and Evapotranspiration at Franklin Lake Playa, Inyo County, California*: USGS Water Supply Paper 2377, 1997, page 5.
27 HydroBio, *Fugitive Dust and Effects from Changing Water Table at Bristol Playa, San Bernardino County, California*, January 2011, page 13.
28 Within the last 11,000 years.
29 Rosen, M.R., *Sedimentologic, Geochemical and Hydrologic Evolution of Intracontinental, Closed-Basin Playa (Bristol Dry Lake, CA): Model for Playa Development and Implications for Paleoclimate*, 1989, page 10.
30 Parker, R.B., *Recent Volcanism at Amboy Crater San Bernardino County,* California Division of Mines and Geology Special Report 76, *1963,* page 22.
31 Hazlett, R.W., "Some Thoughts on the Development of Amboy Crater" In *Old Routes to the Colorado, San Bernardino County Museum Association Special Publication 92-2,* page 71.

Alluvium

Sediments eroding from the bedrock are deposited as alluvium on the flanks of the hills and mountains, and over time, have largely filled the valleys (basins) between the mountain ranges.[32] Geophysical evidence indicates that the depth of alluvium locally exceeds 3,500 feet bgs in the area between Bristol Dry Lake and the Fenner Gap in the vicinity of the irrigation wellfield.[33] Based on recent drilling, the depth of alluvial sediments in the Fenner Gap is known to reach 1,500 feet.[34] Groundwater in the Bristol, Cadiz, and Fenner Watershed area is stored within these alluvial sediments. In addition, Geoscience reports that drilling conducted by CH2M Hill has revealed that permeable bedrock lying beneath the alluvium also contains an appreciable amount of groundwater within fractures and secondary porosity features.[35]

The alluvial sediments are primarily composed of layers of gravel, sand, silt, and clay in varying proportions.[36] The grain size of the alluvium is generally coarse on the upper parts of the alluvial slopes with more fine-grained deposits down slope. However, significant layers of coarse-grained material (including cobbles and boulders) have been noted in the Fenner Gap and as far down slope as Bristol Dry Lake. Most of the exposed alluvial sediments were deposited from 11,000 years ago to the present. However, deposits older than 11,000 years have been noted in some areas.

Volcanics and Fanglomerates

Tertiary volcanic rocks are found primarily on the northeast side of the Marble Mountains, the north side of the Ship Mountains, and in the Clipper Mountains. The volcanic rocks consist of tuffs, ashes, basalt, and pyroclastic deposits deposited about 14 to 19 million years ago.[37]

Tertiary fanglomerates[38] are exposed in the northeastern Ship Mountains.[39] The fanglomerate unit may be at least 1,000 feet thick and consists of sediments deposited into the basins prior to and during local Miocene extension. The basal members of the fanglomerate contain exotic and well-rounded clasts (conglomerates), very well sorted sedimentary members, and few volcanic deposits or clasts. The Fanglomerate unit was penetrated by a number of the borings within

[32] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, pages 21-22.

[33] Maas, J., *Depth to Basement Calculated from Gravity Data*, Proprietary report to Cadiz Land Company, Inc., In CH2M Hill, *Cadiz Groundwater Conservation and Storage Project*, July 2010, page 19.

[34] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1*, September 2011, page 19.

[35] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1*, September 2011, pages 25-26.

[36] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, pages 21-22.

[37] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 20.

[38] Fanglomerates are a series of conglomerates accumulated into an alluvial fan, in rapidly eroding (e.g. desert) environments. A conglomerate is a rock consisting of individual clasts within a finer-grained matrix that have become cemented together.

[39] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 19.

Fenner Valley during the Geoscience and CH2M Hill investigations and was found to consist of consolidated sediments of sand, gravel, and cobbles.[40]

Igneous, Metamorphic and Consolidated Sedimentary Bedrock

The bedrock exposed in the mountain ranges surrounding these regional watersheds consists of Archaen (up to 1.4 billion years old), and in some areas, Mesozoic (167 to 151 million years old) granitic and metamorphic rocks.[41] Paleozoic (570 to 240 million years old) meta-sedimentary rocks consisting of quartzite, shale, and the carbonates limestone and dolomite are present in the Marble Mountains and on the northwestern and northern flanks of the Ship Mountains, located on either side of the Fenner Gap. This bedrock also contains an appreciable amount of groundwater within fractures and secondary porosity features.

Geologic Structure

The following section provides a brief overview of the structure of the overall area and the Project area. For a complete description of the geologic history and structure in the study area, please refer to the Kenney GeoScience study.

Overview of Geologic History and Structure

The geologic structure in the Project area, as well as the Mojave Desert and Basin and Range Geomorphic Provinces in general, is the result of two main geologic events. Initially, Paleozoic sediments were deposited on Archaen cratonal crust during a relatively quiet geologic time period. During the Jurrassic, intrusive rocks were emplaced at depth resulting in folding and metamorphism of some of the older rocks into which they intruded. As an example within the Project area, Paleozoic Rocks in the Marble Mountains are unmetamorphosed but are moderately folded and faulted. Recent geologic mapping indicates that only a few granitic sills are present in the southern Marble Mountains area. In this area, the Paleozoic rocks are uplifted, metamorphosed, eroded away, and folded by the Jurassic igneous intrusions.

The second and most dominating event is the Miocene crustal extension (5 to 23 million years ago). The Miocene crustal extension occurred when detachment faults developed as a basal slip surface to accommodate the movement of the upper portions of the crust with respect to the lower portions.[42] An imbricated series of listric faults[43] developed above the detachment faults as the area was pulled apart. Highland and adjacent lowland areas (i.e., horsts and grabens[44]) formed from the movement of the listric faults.

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40 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, pages 20-21.

41 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, pages 16-19.

42 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, pages 24-25.

43 Listric faults are curved fault planes with the dip of the fault plane becoming shallower with increased depth.

44 Horsts and grabens are raised or lowered fault blocks, respectively, bounded by normal faults, typically caused by crustal extension.

The development of high-angle normal faults[45] occurred subsequent to the extension, and in places extends through and offsets the detachment faulting. The results of these processes, are highly faulted, tilted, and rotated blocks of Paleozoic sediments and Mesozoic granitic rocks. Movement along faults created highland areas (mountains) from which sediments were eroded, and basins (valleys) into which sediments were deposited, forming the fanglomerate and alluvium units described previously. Volcanic rocks, which are typically associated with the Miocene extensional period, were deposited following the deposition of the fanglomerate units. From the Miocene period of extension and continuing to the present, the basin areas were filled with sediments which continued to erode from the adjacent highland areas creating thick sequences of basin fill.

Geologic Structure in the Fenner Gap

In general, the geologic structure in the Fenner Gap is characterized by highly faulted and folded bedrock overlain by Tertiary fanglomerates and Pleistocene to Holocene alluvial units. **Figures 4.6-3a** and **4.6-3b** present a portion of the Kenney GeoScience geologic map[46] that focuses on the Fenner Gap. The geologic map shows numerous faults, identified by the dashed red lines; the down-dropped sides of the faults are indicated with the attached red ball. The geologic cross sections show even more detail about the development of the geologic structure in the Fenner Gap area by identifying the dominance of normal faults as well as the Jurassic intrusives.[47] In general, the southern portion of the Fenner Gap is underlain primarily by faulted Archaen and Jurassic intrusive rock on the western side of the Gap and by faulted Paleozoic limestones on the eastern side of the Gap. Due to faulting, an increase in Paleozoic limestone units are interpreted to occur beneath the Fenner Gap further up the valley. Paleozoic units (i.e., limestones and quartzites) are faulted, tilted, and folded. An antiform and synform is shown to be present near the center of the Fenner Gap as a means of explaining the distribution and bedding dip angles of the Paleozoic units. Both the normal faults and the detachment fault are shown to have a zone of fractures on the hanging wall of the faults (above the fault planes) which are approximately 150 to 400 feet thick. In the study area, the existence and zone of faulting is based on the geologic exposures of some of these faults. With respect to the movement of groundwater through the Fenner Gap, the existence of extensive faulting, tilting, and folding of both Paleozoic and Jurassic bedrock units, along with accompanying joint and fracture systems, provide extensive secondary groundwater flow paths within the bedrock.

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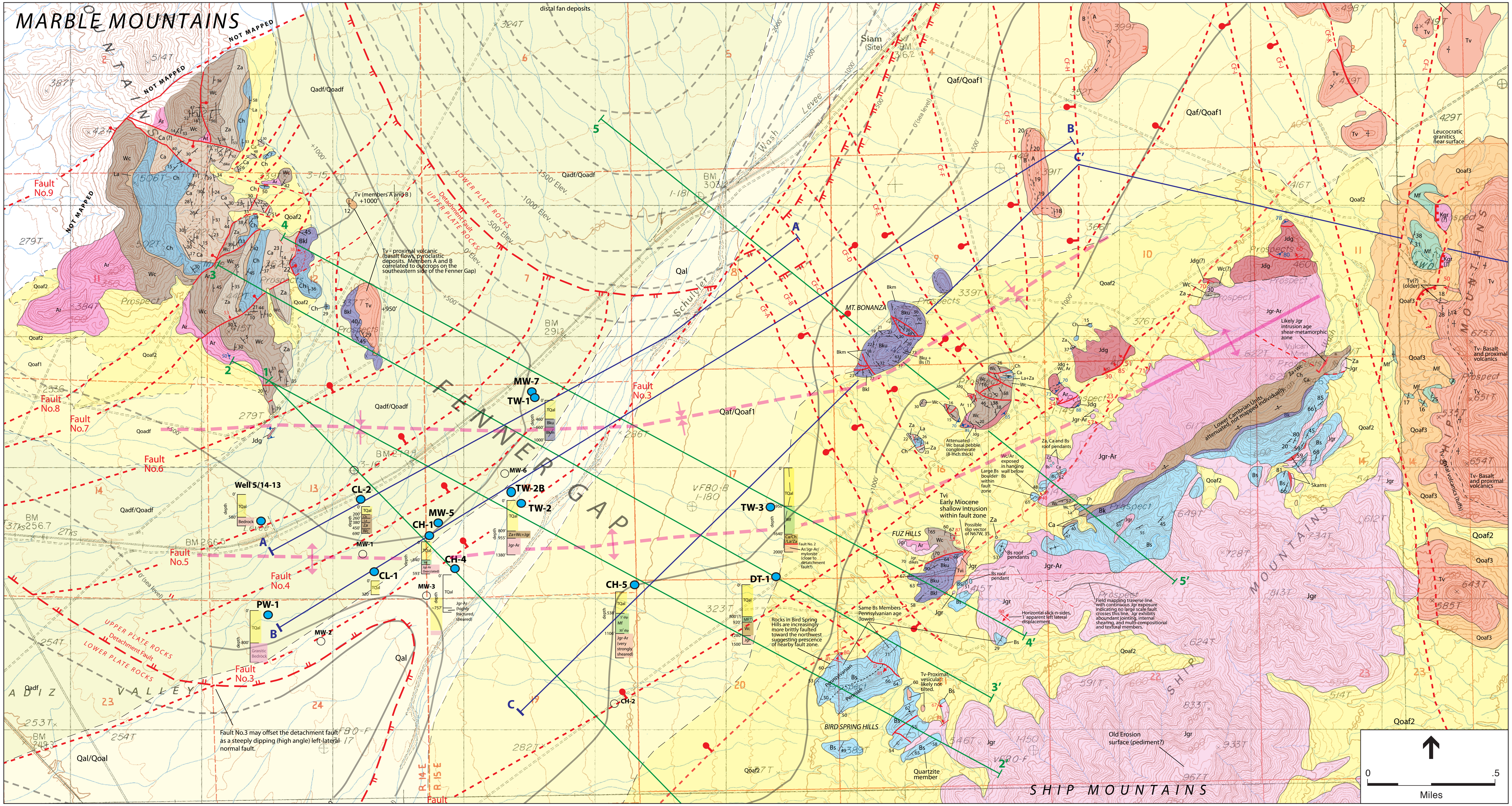
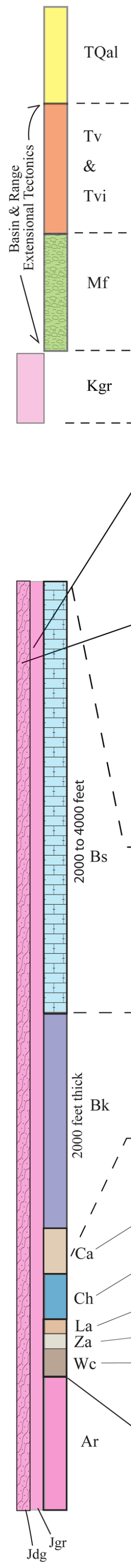
[45] Normal faults occur with extension; reverse faults occur with crustal shortening.
[46] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, Plate 2.
[47] Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, Plates 3, 4.



SOURCE: Kenney GeoScience, 2011.

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-3a
Geology of Fenner Gap Area



TQal - TERTIARY TO QUATERNARY ALLUVIUM (Neogene deposits)
Primarily composed of silty sand and gravels deposited by fluvial processes post early Miocene Basin and Range extension. By definition within this report, TQal exhibits horizontal to nearly horizontal bedding (2-3 degree dips typical of alluvial fans), a paucity of fractures or joints and thus is relatively undeformed suggesting it post dates Miocene extensional tectonics. However at depth, unit TQal could and likely is comformable with underlying unit Mf in some places. The unit exhibits fine beds of sility fine to medium sand, some thin silt beds, and occassional carbonate zones that likely represent paleosols or conglomerate layers with post depositional groundwater flow. Conglomerate members contain local clasts (volcanics, carbonates, igneous plutonic). This unit has been subdivided into various alluvial units based on relative age and depositional environment (Qal, Qadf, Qoaf1, Qoaf2 and Qoaf3). Unit Qal represents valley axis sediments from distal sources. There is a general coarsening from unit Qal to unit Qoaf3 primarily associated with sediment transport distances.

Uncomformity in most exposed localities

Tv and Tvi- TERTIARY VOLCANICS - PEACH SPRINGS TUFF AND BASALT FLOWS (EARLY MIOCENE ~17 MY)
Andesitic or dacitic tuffs including crystal-vitric, crystal-lithic, and vitri-lithic types. Tv and Tvi represent volcanic and hypabyssal (cooled and crystalized-emplaced near the surface) rocks. Colors range from dark gray to white and dark to light reddish brown. Partly massive and well bedded. Andesitic and basaltic flows comprise 1/4 of section. Limestone cobbles occur in lowestmember derived from local basement exposures in Fenner Valley & Wild Horse. Likely 1100 to 1200 feet thick locally and exhibit primarily distal tuffs and pyroclastic flows in the lower members which transition up section into primarily more proximal rhyolite tuffs and basalt flows. Unit Tv is mapped separate from unit Mf (below) however, interbedding of Tv and Mf particularly in the upper members of unit Mf is possible as both are associated with stages of Miocene extensional tectonics. Type section for intrusive unit Tvi occurs along Fault No. 1 in the Fuz Hills. Crude correlated stratigraphy of Tv exposures includes layers A (vesicular ash tuff 20 feet thick)/B (salmon colored tuff with blue iridesence sanidine 10 feet thick)/C (vesicular basalt 75 to 100' thick).

Mf - MIOCENE FANGLOMERATES
This unit represents a coarsening upward sequence of sediments composed of well bedded silty fine to medium sands (base of unit), to well bedded gravely sands with exotic well rounded clasts, to cobble conglomerate with rounded exotic and subangular to angular local clasts, to conglomerate-breccia composed of local mylonitic or other local subangular to angular clasts (upper members). The unit generally dips between 10 to 30 degrees to the east, is fractured, very dense, and well cemented. Mf is interpreted to represent deposition and deformation associated with local Basin and Range extensional tectonics during the early Miocene; however, basal members exposted in the northeastern Ship Mountains exhibit fluvial deposits with exotic clasts indicating possible deposition prior to local early Miocene extenstion. No purely volcanic layers were identified in unit Mf however volcanic clasts were identified at the base of unit Mf in some cores.

Kgr - CRETACEOUS LEUCOCRATIC GRANITE
Leucocratic granite (Late Cretaceous ?). Fine to coarse grained 2-mica granite. Zones of weak mylonitic texture where in close proximity to detachment fault to non foliated. Unit only identified in hanging wall rocks where detachment fault is exposed on the surface in the northeastern Ship Mountains. Unit may correlate to leucocratic 2-mica granites in the Old Woman Mountains described by Howard, 2002 and Howard et al, 1989 (units Kl and Kmg), and Karlstrom et al., 1993.

JURASSIC IGNEOUS AND METAMORPHIC SUITE (U-Pb ~167 Ma)

Jurassic Igneous

Jgr - Jurassic Granitics
Medium to fine grained biotite quartz syenite, syenogranite, quartz monzonite, and fine grained hypabyssal equivalents. The unit exhibits a paucity of quartz and salmon color orthoclase feldspar is common. The unit is typically not ductilly foliated but does exhibit considerable jointing and fracturing throughout suggesting some stress at upper crustal levels. Penetrative epidote secondary mineralization is very common. Relatively small to very large roof pendants of older bedrock units and sills are common. This intrusive suite likely correlates well in terms of general age, time transgressive composition variations from mafic to more felsic, occurence of aplite dikes and emplacement at relatively shallow crustal depths as described by Fox and Miller, 1990 evaluating similar rocks in the southern Bristol, southern Providence Mountains and Colton Hills. This unit intruded and deformed all relatively older units which has led to a change in structure across the Fenner Gap between the relatively unintruded Marble Mountains and strong intrusions within the Ship Mountains. The contact between these two structural terrains occurs within Fenner Gap. Aplite dikes are also common within this unit.

Jdg - Jurassic Dioritic Gneiss
This unit represents dioritic intrusives with zones of a banded gneiss with minor zones exhibiting weak mylonitic fabric. The unit is primarily dioritic but contains felsic zones. Intercalated zones of lower Cambrian units, particularly Wood Canyon and possibly Zabriskie Quartzite occur within the unit indicating that Jdg is not pre-Cambrian in age. Foliation of the unit likely occured during emplacement into Archean igneous and metamorphic suite and lower Cambrian stratigraphic units described below. Foliation is nearly vertical and strikes generally east-west. Fine grained aplite dikes and aphanitic rhyolitic injections parallel to the gneiss foliation occur. This newly discovered unit which was mapped as Pre-Cambrian by earlier studies is conidered here to represent part of the Jurrassic igneous suite of rocks associated with early stages of emplacment of unit Jgr. Secondary epidote is common but cannot rule out magmatic crystallization. Aphanitic dikes parallel to foliation are consistent with upper crustal emplacement similar to unit Jgr. Based on currentmapping data, unit Jdg may have been emplaced as a tabular body trending approximately east west through the Fenner Gap, then later intrusions associated with unit Jgr primarily occured south of the Jdg tabular body with unit Jdg representing the northern boundary of unit Jgr. Within this model considerable shearing occured within unit Jdg as magma associated with uint Jgr was emplaced causing vertical uplift and formation of an antiformal structure to pre-existing rocks. May correlate with unit Jqd of Howard et al., 1989 identified in the northern Kilbeck Hills.

Jgr-Ar - Jurrasic Granitics - Archean Complex
This unit represent regions where Jurrassic plutonism (primarily Jgr) intruded into pre-existing Archean Igneous and Metamorphic Complex (Ar) and Paleozoic rocks (Wc, Za, La, Ch, Ca, Bk, Bs).

Note: The Jurrassic Igneous and Metamorphic Suite is considered part of the Eastern Plutonic Belt by Powell, 1993.

Bs - PENNSYLVANIAN TO PERMIAN BIRDSPRING AND OTHER LIMESTONE FORMATIONS (LATE PALEOZOIC)
Regionally can be 4000 feet thick. Permian basal member 20 feet thick contains small black chert pebbles within sandy limestone (LS) interbeds with cross beds. About 75 feet above is a massive 70 foot light gray LS. As a unit the lower 750 feet of beds consists of dark and light gray LS in beds up to 10 feet thick. Platy to shaly, in partly sandy, fossiliferous, chert rich zones separate some of the massive beds. The upper 1380 feet of section is medium to light gray, sparingly fossiliferous LS in beds up to 5 feet thick. Minor chert and sandstone occur. Includes rocks of Wolfcamp and Leonard age. Bird Spring Fm. exists in upper Pennsylvanian to lower Permian section. Regionally, an additional ~1600 feet of LS units (Monte Cristo & Sultan Fm) exist from Devonian to Mississippian. Miller et. al (1982) indicate that metamorphosed Bird Spring containing early Pennsylvanian conodonts also occurs in the Marble Mtns and an unmetamorphosed section ~ 2500 feet thick (750 meters) crops out in the Ship Mountains. Monte Cristo Formation occurs in some places at the base of the Bird Spring Formation - vitreous, nearly pure, typically massive marble which may occur within the northern Ship Mountains. Marbles (metamorphosed) associated with the Sultan Limestone may also occur locally in the Ship Mountains although this has not be verified. The Bird Spring Formation in the northern Ship Mountains is attenuated due to emplacement of unit Jgr.

Uncomformity

Bk - MIDDLE CAMBRIAN BONANZA KING DOLOMITE (EARLY PALEOZOIC)

Bku: UPPER MEMBER: Light creamy gray dolomite, 200 - 250 feet thick:

Bkm: MIDDLE MEMBER - SILVER KING DOLOMITE: Very dark smoky gray to nearly black dolomite, 200 to 250 feet thick.

Bkl: LOWER MEMBER Dark smoky gray dolomite and partially dolomitized LS, locally cherty and sandy. Intraformational pebble and cobble conglomerates occur. 1500 - 1800 feet thick. Individual beds 3 to 6 feet thick.

Uncomformity

LOWER CAMBRIAN SEDIMENTARY SUITE

Lower Cambrian Sedimentary Section (total thickness is ~1,100 feet)

Ca - LOWER CAMBRIAN CADIZ FORMATION (EARLY PALEOZOIC)
Buff and gray muddy limestone, purplish and reddish platy shale, greenish gray platy shale and platy to massive quartzite. Unit is ~375 feet thick. (114 meters). Coarse grained marls exhibit distinctive herringbone structures.

Ch - LOWER CAMBRIAN CHAMBLESS LIMESTONE (EARLY PALEOZOIC)
Massive weathering, light to primarily dark gray limestone in beds 1 to 10 feet thick. Algal nodules and distinctive red blotches of unkown cause occur throughout the unit. Locally a 10 to 15 foot zone of platy fossiliferous limestone occurs a little above the middle. 85 to 155 feet thick (26 to 47 meters). Locally may be as thick as 200 feet.

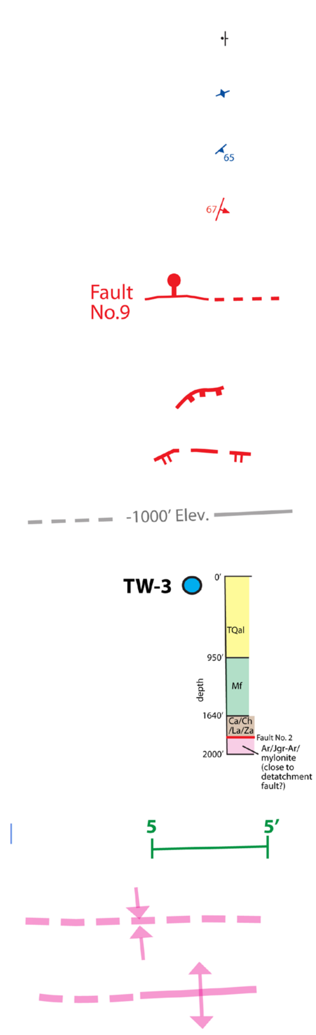
La - LOWER CAMBRIAN LATHAM SHALE (EARLY PALEOZOIC) - Correlates with Bright Angel Shale. Fossiliferous greenish gray platy shale which weathers to platy and paperthin fragments. Thin buff weathering sandy limestone layers are present. Famous Trilobite fossil beds. ~ 82 feet thick (25 meters). Also referred to as the Carrara Formation.

Za - LOWER CAMBRIAN ZABRISKIE QUARTZITE (PALEOZOIC) -Correlates with Tapeats Sandstone. Massive brownish weathering white to grayish white quartzite with beds 2 - 6 feet thick. Unit is 50 to 75 feet thick.

Wc - LOWER CAMBRIAN WOODCANYON FORMATION (PALEOZOIC)
Unit described by Hazard, 1954) as Fine grained dark greenish gray shaly to platy quartzite; fine grained reddish brown weathering white quartzite in beds 6-inches to 2 feet thick that can be friable with crossbedding and pebble lenses (thick unit); fine grained dark greenish gray platy quartzite; light gray to reddish brown weathering limestone, locally dolomitized; fine grained greenish black shaly quartzite with local pebble lenses occur a few feet above the base. Unit is 300 to 425 feet thick. Unit is dominantly quartzite.
UPPER MEMBER: Alternating siltstone, quartzite and carbonate (Fedo and Cooper, 1990)
MIDDLE MEMBER: Dark colored cross stratified quartzite
LOWER MEMBER: Alternating siltstone, quartzite and carbonate.

~~~~~~~~~~~~~ *Erosion Surface (correlates with the Great Unconformity in the Grand Canyon)*

Ar - ARCHEAN IGNEOUS AND METAMORPHIC COMPLEX
This unit consists of granite, gneiss, and schist. Granite portions range from leucocratic to pale orange. Relatively large pheonocrysts of plagioclase distinguish this unit from Jgr. 1.4 to 1.5 B.y. in the Marble Mountains (Silver and McKinney 1963; Lanphere, 1964).



Generalized strike and dip estimated from far field or Google Earth

Strike of vertically dipping foliation which primarily occurs in unit Jdg

Strike and dip of foliation which primarily occurs in unit Jdg

Stike and dip of fault plane most of which are associated with Miocene extensional tectonics

Approximate location of fault. Ball indicates down dip direction; solid line where fault is exposed at the surface; dashed lines where concealed by younger typically non-offset deposits (primarily unit TQal). The subsurface locations of Faults No. 1 through 9 are shown at evaluated depths of unfaulted deposits and thus are shown at the upper most exposure of the fault beneath unfaulted TQal deposits.

Detachment fault where exposed either at the surface or near the surface beneath alluvim, tick marks on down dip side.

Detachment fault where postulated to exist at depth and is exposed at the base of unfaulted unit TQal .

Approximate depth in elevation of basement rock below neogene sediments estimated from gravity data (CH2M Hill), boring data, and cross sections.

Approximate location of exploratory boring (well). Generalized stratigraphic section of the boring is provided with depths below the surface.

Approximate location of cross sections 1, 2, 3 4 5, A, B and C.

Approximate location of synform and antiform structure produced during emplacement of Jurassic intrustions (units Jdg and Jgr). The synform resulted from shearing along the contact with unit Jdg during emplacement and the antiform associated with relatively large volumes of Jgr intrusion. The folding involves all units older than mid-Mesozoic. Pink line is solid where fold is exposed on the surface and dashed where concealed by unfolded Tertiary sediments.

SOURCE: Kenney GeoScience, 2011.

Figure 4.6-3b
Map Key - Geology of Fenner Gap Area
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Regional Faults and Seismicity

The Project area is located at the eastern margin of the Eastern California Shear Zone, a broad seismically-active region dominated by northwest trending right-lateral strike-slip faulting.[48] Eleven named fault zones showing evidence of Quaternary movement[49] have been identified in and adjacent to Bristol, Cadiz, and Fenner Valleys and are illustrated on the generalized fault map on **Figure 4.6-4.**[50] Superposed on this map are recorded earthquake epicenters recorded by the USGS between 1900 and March 12, 1997.[51]

Cadiz Valley is underlain by two major northwest trending inactive faults, inferred on the basis of gravity and magnetic data.[52] These fault zones have strike lengths of at least 25 miles and may merge to the north and northwest with extensions of the Bristol-Granite Mountains and South Bristol Mountains fault zones.[53,54] Right-lateral slip of as much as 16 miles along the Cadiz Valley fault zone has been postulated on the basis of the correlation of a distinctive Precambrian gneiss unit across the zone.[55] Slickenside surfaces, produced by fault movement, and steeply dipping sediments recovered from cored drill holes beneath Cadiz Dry Lake, suggest that the fault zone displaces sediments of Pleistocene but not Holocene age.[56,57]

48 Dokka, R.K, and C.J. Travis, *Late Cenozoic Strike Slip Faulting in the Mojave Desert, California*, Tectonics, Vol. 9, 1990, page 336.

49 Potentially active faults are defined as having activity during Quaternary time or within the last 1.6 million years.

50 Howard, K. A. and D.M. Miller, "Late Cenozoic Faulting at Boundary between Mojave and Sonoran Blocks: Bristol Lake, CA", In S.M. Richard, ed., Deformation Associated with the Neocene Eastern California Shear Zone, Southwestern Arizona and Southeastern California: Redlands, CA., San Bernardino Museum Special Publications 92-1, 1992, page 39.

51 Advanced Geologic Exploration, *Map of Recorded Earthquake Epicenters in Proximity to Bristol Dry Lake, San Bernardino County, CA*, Report to Cadiz, 1997, page 2.

52 Simpson, R.W., R.C. Bracken and D.J. Stierman, *Aeromagnetic, Bouguer Gravity, and Interpretation Maps, Sheep Hole-Cadiz Wildness Study Area, California*: USGS MF 1615-B, 4 sheets, scale 1:62,500 (ID163), 1984.

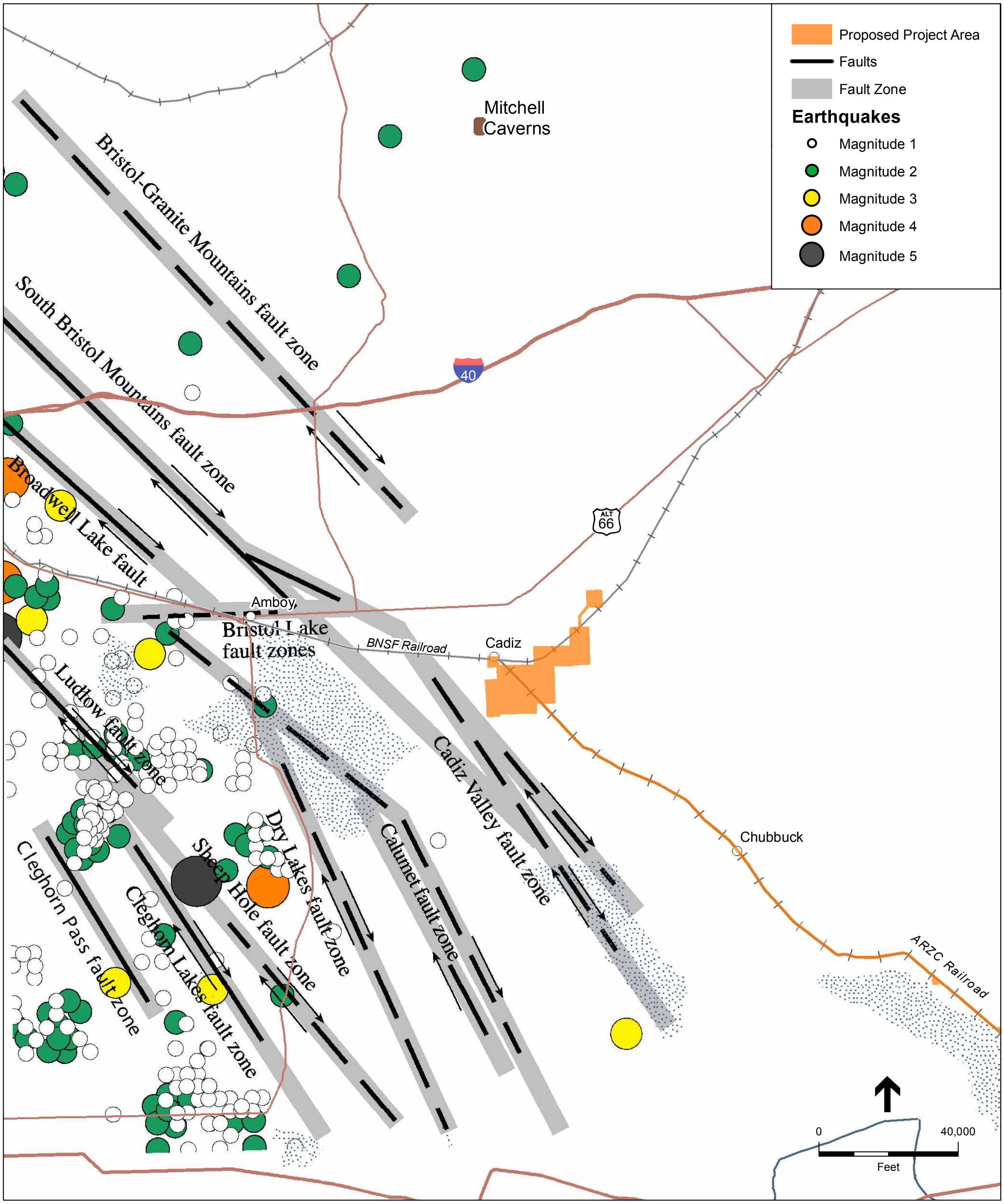
53 Howard, K. A. and D.M. Miller, "Late Cenozoic Faulting at Boundary between Mojave and Sonoran Blocks: Bristol Lake, CA", In S.M. Richard, ed., Deformation Associated with the Neocene Eastern California Shear Zone, Southwestern Arizona and Southeastern California: Redlands, CA., San Bernardino Museum Special Publications 92-1, 1992, page 42.

54 Lease, Richard Oliver, Nadine McQuarrie, Michael Oskin, and Andrew Leier, *Quantifying Dextral Shear on the Bristol-Granite Mountains Fault Zone: Successful Geologic Prediction from Kinematic Compatibility of the Eastern California Shear Zone*, Journal of Geology, Vol. 117, 2009, Figure 10.

55 Howard, K. A. and D.M. Miller, "Late Cenozoic Faulting at Boundary between Mojave and Sonoran Blocks: Bristol Lake, CA", In S.M. Richard, ed., Deformation Associated with the Neocene Eastern California Shear Zone, Southwestern Arizona and Southeastern California: Redlands, CA., San Bernardino Museum Special Publications 92-1, 1992, page 42.

56 Bassett, A.M., Kupfer, D.H. and F.C. Barstow, *Core Logs from Bristol, Cadiz and Danby Dry Lakes, San Bernardino County, California,* U.S. Geological Survey Bulletin, 1045-D, 1959, page 106.

57 Active faults are those defined as having activity during Holocene time or within the last 11,000 years.



SOURCE: Metropolitan, 2001; AGE,1997; ESRI, 2010; Cadiz Inc., 2011; CH2MHill, 2010; and ESA, 2011

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-4
Quaternary Fault Zones and Earthquake Epicenters

Bristol Dry Lake is bordered by possible extensions of the Cadiz Valley and South Bristol Mountains fault zones to the east, and by probable extensions of the Broadwell Lake and Dry Lake fault zones to the west.[58] Geophysical data indicate this structural depression may exceed 6,000 feet in depth.[59,60] Drill cores recovered from depths of over 1,000 feet beneath Bristol Dry Lake suggest that subsidence of this basin began by Pliocene time and continues to the present,[61] and therefore it may be tectonically active.

Figures 4.6-3a and 4.6-3b present the Kenney GeoScience geologic map of the Fenner Gap area showing the system of northeast-trending, northwest-dipping normal faults, some of which are exposed in outcrops of the bedrock that flank the Fenner Gap. The presence of these northeast-trending faults beneath the alluvial deposits that underlay the Fenner Gap were mapped using the gravity and magnetic surveys as well as a seismic reflection survey that was conducted across the Fenner Gap by NORCAL Geophysical Consultants.[62]

Very few earthquake epicenters have been recorded in the immediate region within and surrounding the Project area. One relatively minor earthquake of magnitude 3.0 was recorded approximately 20 miles west of the water conveyance system.[63] Although a relatively large amount of seismic events have been recorded in the western portion of the area shown in Figure 4.6-4, none of the faults in this area are presently classified as active or Holocene. The Kenney GeoScience study concluded that since the end of the Miocene extension 10 million years ago, the area has been relatively tectonically stable allowing for the deposition of the subsequent Tertiary and Holocene deposits.[64] The Kenney GeoScience study furthered noted that the alluvial fans in the Fenner Gap area do not show any fault scarps or lineaments, suggesting that faulting has not occurred since their deposition.[65]

The principal seismic hazard in the Project area is the potential for ground shaking associated with large earthquakes on distant faults. Of these, the most important is the San Andreas Fault Zone, an active fault of regional significance located 65 miles southwest of the Project area. The

58 Howard, K. A. and D.M. Miller, “Late Cenozoic Faulting at Boundary between Mojave and Sonoran Blocks: Bristol Lake, CA”, In S.M. Richard, ed., Deformation Associated with the Neocene Eastern California Shear Zone, Southwestern Arizona and Southeastern California: Redlands, CA., San Bernardino Museum Special Publications 92-1, 1992, pages 39, 42.

59 Advanced Geologic Exploration, 1997. *Map of Recorded Earthquake Epicenters in Proximity to Bristol Dry Lake, San Bernardino County, CA*. Report to Cadiz, page 2.

60 Maas, J., *Depth to Basement Calculated from Gravity Data*, Proprietary Report Prepared for Cadiz Land Company, Inc, 1994, In CH2M Hill, *Cadiz Groundwater Conservation and Storage Project*, July 2010.

61 Rosen, M.R., *Sedimentologic, Geochemical and Hydrologic Evolution of an Intracontinental,Closed-Basin Playa (Bristol Dry Lake, CA): A Model for Playa Development and Its Implications for Paleoclimate*, Ph.D. Dissertation: Austin, University of Texas, 1989, pages 145-149.

62 NORCAL Geophysical Consultants, Inc., *Seismic Reflection Survey Cadiz Valley, Cadiz, California*, Proprietary Report to Cadiz, 1997, page 16.

63 Advanced Geologic Exploration, *Map of Recorded Earthquake Epicenters in Proximity to Bristol Dry Lake, San Bernardino County, CA*. Report to Cadiz, 1997, page 2.

64 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 15.

65 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011, page 2.

Ludlow fault zone is located approximately 25 miles west of the Project area.[66] The Ludlow fault zone has displaced alluvium as young as late Pleistocene but not Holocene. As shown in Figure 4.6-4, the Ludlow, Sheephole and Cleghorn Lakes and Cleghorn Pass fault zones appear to be associated with a relatively high amount of micro-seismic activity, however, none of these fault zones are classified as active, and none trend toward the Project area.

In addition to the San Andreas Fault Zone, other regional fault zones that have been active in Holocene time include the Bullion and Mesquite Lake fault zones. These faults are located 35 and 40 miles west of the Project area, respectively. The maximum probable earthquake magnitudes on these faults are estimated to be similar to those on the San Andreas Fault Zone (Magnitude 7.1).[67] However, the recurrence interval of large earthquakes in the Eastern California Shear Zone is considered to be in the order of thousands of years.[68, 69] Therefore, the potential for a seismic event along these faults during the design life of the Project is considered to be very low.

The Hector Mine Earthquake

The magnitude 7.1 Hector Mine earthquake of October 16, 1999 occurred on the Lavic Lake fault, a northwest-southeast trending zone located approximately 13 miles west of the Ludlow fault zone.[70] The epicenter of the Hector Mine earthquake was located approximately 45 miles west of the Project area, and the closest surface rupture was located approximately 35 miles southwest of the Project area. Although the Project area is preliminarily estimated by the USGS to have been within the zone of 10 percent g (gravity) peak acceleration, no damage of any kind was observed to any existing facilities in the Project area. These facilities include at least seven irrigation wells (several of which were operating at the time of the earthquake), production well PW-1, and the pilot spreading basin (one cell of which was in operation). This earthquake is considered one of the four largest to have occurred in Southern California this century.

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66 Howard, K. A. and D.M. Miller, “Late Cenozoic Faulting at Boundary between Mojave and Sonoran Blocks: Bristol Lake, CA”, In S.M. Richard, ed., Deformation Associated with the Neocene Eastern California Shear Zone, Southwestern Arizona and Southeastern California: Redlands, CA., San Bernardino Museum Special Publications 92-1, 1992, pages 37-47.

67 Petersen, Mark D., William A. Bryant, Chris H. Cramer, Tianqing Cao, and Michael Reichle, *Probabilistic Seismic Hazard Assessment for the State of California,* California Department of Conservation, Division of Mines and Geology, Open-File Report 96-08, and U.S. U.S. Geological Survey Open-File Report 96-706, 1996.

68 Robert J. Mellors, Lydie Sichoix, and David T. Sandwell, *Lack of Precursory Slip to the Hector Mine Earthquake as Constrained by INSAR*, Bulletin Seismological Society of America, Vol.92(4), 2002, page 1443.

69 Price, Evelyn J. and Roland Bürgmann, *Interactions between the Landers and Hector Mine, California, Earthquakes from Space Geodesy, Boundary Element Modeling, and Time-Dependent Friction*, Bulletin of the Seismological Society of America, V. 92, No. 4, May 2002, page 1450-1451.

70 U.S. Geological Survey, *Special Report: The Hector Mine Earthquake, 10/16/1999*, http://pasadena.wr.usgs.gov/hector/report.html, accessed April 2010.

Soil Resources

Areas of low topographic relief consist of the Carrizo-Rositas-Gunsight soil series and are typically described as light colored, red, desert alluvial, sandy soils.[71] The majority of the Project footprint, including the proposed pipeline to the CRA, consists of the Carrizo-Rositas-Gunsight soil units. The Carrizo soils include floodplains, alluvial fans, and associated formations formed in mixed alluvium, with slopes ranging from 0 to 15 percent. Typical profiles range from extremely gravelly sand to very gravelly coarse sand, with low shrink-swell capacity, rapid to very rapid drainage, and negligible to low runoff potential. The Rositas soils consist of sand sheets to dunes formed of eolian material, with slopes ranging up to 30 percent in dune areas. Typical profiles include sand depths of about 60 inches, with less than 15 percent coarse to very coarse sand. These soils have rapid permeability, low shrink-swell capacity, and negligible to low runoff potential. Areas along the mountain slopes adjacent to the proposed water conveyance facilities consist of the Gunsight-Rillito-Chuckwalla soil series and are typically described as consisting of alluvium, colluvium, and residuum from granite, gneiss, quartzite, and limestone formations. The Gunsight and Rillito soils consist of mixed alluvium with mostly moderate slopes, though up to 60 percent slope in isolated areas; gravelly sandy loam to extremely gravelly sandy loam; somewhat excessively drained, with low shrink-swell capacity; and runoff potential from very low to high.

Other associations that could be intersected in proportionally small amounts include Tecopa Rock Outcrop-Lithic Torriorthents. The Tecopa formation comprises very shallow soils of recently weathered material on low hills and low mountain slopes with 15 to 75 percent slope, as well as rock outcrops and torriorthents, along the northwestern edge of the proposed wellfield area and the southern tip of the Old Woman Mountains along the proposed pipeline route. The Rillito-Gunsight association (mixed alluvium with mostly moderate slopes but isolated areas up to 60 percent slope, gravelly sandy loam to extremely gravelly sandy loam, somewhat excessively drained, and runoff potential from very low to high) is present along the proposed pipeline route to the southeast of the wellfield area and where the pipeline approaches the Old Woman Mountains.

All of the soils associations identified within the footprint of the Project contain very low to negligible amounts of clay material. Consequently, they all have a low potential for shrink-swell capacity. All of the soil units have moderate to high corrosion potential, meaning they could corrode uncoated steel due to their relatively high salt content. The corrosion potential for concrete is cited as low to moderate.

[71] Metropolitan Water District of Southern California and Bureau of Land Management, *Cadiz Groundwater Storage and Dry-Year Supply Program Final Environmental Impact Report and Final Environmental Impact Statement, Volume I*, September 2001, pages 5-34, 5-35.

Geologic and Seismic Hazards

Given the characteristics of the Project area as described above and in the Project Description, the Project area is potentially subject to a range of geologic and seismic hazards, such as slope failure, unstable soils, and seismic-related ground shaking and failure. Potential geologic and seismic hazards that could occur in the Project area are described below.

Geologic Hazards

Mass Wasting and Slope Failure

Slope failures (commonly referred to as landslides) include many phenomena that involve the downslope displacement and movement of material either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Slope failures are categorized as falls, topples, spreads, slides, or flows. Falls are masses of soil or rock that dislodge from steep slopes and free-fall, bounce, or roll downslope. Topples move by the forward pivoting of a mass around an axis below the displaced mass. Lateral spreads, described in more detail below, are commonly induced by liquefaction of material in an earthquake and move by horizontal extension and shear or tensile fractures. Slides displace masses of material along one or more discrete planes. In rotational sliding, the slide plane is curved and the mass rotates backwards around an axis parallel to the slope; in translational sliding, the failure surface is more or less planar and the mass moves parallel to the ground surface. Flows mobilize as a deforming, viscous mass without a discrete failure plane.[72] Slope stability can depend on a number of complex variables, including the geology, structure, and amount of groundwater, as well as external processes such as climate, topography, slope geometry, and human activity. The factors that contribute to slope movements include those that decrease the resistance in the slope materials and those that increase the stresses on the slope. Facility infrastructure located near and at the foot of mountainous or hilly areas could be subject to damage from slope failure.

Unsuitable Soils

The distribution of soil units is highly variable within the Project area. The NRCS has published individual soil surveys for all counties in California. Information contained in these soil surveys is typically used to help evaluate whether a particular soil type is suited for a specific use and what type of soil management might be required. A general discussion of potentially unsuitable soil conditions including corrosive, expansive, and erodible soils is provided below.

Corrosive Soils

Corrosivity of soils is commonly related to several key parameters: soil resistivity, the presence of chlorides and sulfates; oxygen content; and pH. Typically, the most corrosive soils are those with the lowest pH and highest concentration of chlorides and sulfates. Wet/dry conditions can result in a concentration of chlorides and sulfates as well as movement in the soil that tends to break down protective corrosion films and coatings on the surface of building materials. High-sulfate soils are also corrosive to concrete and may prevent complete curing, reducing its strength

72 California Geological Survey, *Landslides,*http://www.consrv.ca.gov/cgs/geologic_hazards/landslides/Pages/Index.aspx, accessed May 2010.

considerably. Low pH and/or low-resistivity soils can corrode buried or partially buried metal structures.

Subsidence and Expansive Soils

Land subsidence is the loss of surface elevation due to removal of subsurface support. Subsidence has many causes, including seismically-induced stresses and the extraction of mineral, liquid, and/or gas deposits. Although mineral and gas extraction can and do result in subsidence, it is more common for subsidence to occur as a result of groundwater extraction in excess of groundwater recharge. For example, in areas of the San Joaquin Valley of California, the extensive pumping of groundwater for use in crop production has resulted in much of the valley floor subsiding over several generations.

Expansive soils have a significant amount of clay particles that can give up water (shrink) or take on water (swell). The change in volume exerts stress on buildings and other loads placed on these soils. The occurrence of these soils often is associated with geologic units having marginal stability. Expansive soils can be dispersed widely and found in hillside areas as well as low-lying areas in alluvial basins. Although the soils in the Project area are predominantly composed of sand and gravel grain sizes, some clay has been noted in boring logs. As a result, soils testing to identify expansive characteristics and appropriate remediation procedures are routinely required by current grading and building codes.

Erodible Soils

Erosion is the detachment and movement of soil materials through natural processes or human activities. In general, rates of erosion can vary depending on the soil resource’s capacity to drain water, slope angle and length, extent of groundcover, and human influence. Areas with increased susceptibility to soil erosion would depend on the sediment or rock type, its porosity and permeability, the slope or grade of the land, the amount of existing ground cover from vegetation, amount of existing soil disturbance, and land use type. Due to the sandy or loamy nature of the soil and the sparse vegetation in most of the Project area, the soil can be susceptible to wind erosion.[73, 74]

Seismic Hazards

Seismic hazards are generally classified in two categories: primary seismic hazards (surface fault rupture and ground shaking) and secondary seismic hazards (liquefaction and other types of seismically induced ground failure, along with seismically induced landslides).

Surface Fault Rupture

Although future earthquakes could occur anywhere along the length of an active fault, only regional strike-slip earthquakes of magnitude 6.0 or greater are likely to be associated with

73 Metropolitan Water District of Southern California and Bureau of Land Management, *Cadiz Groundwater Storage and Dry-Year Supply Program Final Environmental Impact Report and Final Environmental Impact Statement, Volume I*, September 2001, page 5-35.

74 HydroBio, *Fugitive Dust and Effects from Changing Water Table at Bristol Playa, San Bernardino County, California*, January 2011, page 5.

surface fault rupture and offset.[75] It is also important to note that earthquake activity and fault rupture due to unmapped subsurface fault traces are a possibility that is not predictable.

As discussed above, no known active faults have been identified within the Project area. Consequently, the Project area does not have any active faults that could cause surface fault rupture as classified by the Alquist-Priolo Earthquake Fault Zoning Act.[76] This classification does not mean that the Project area could not be subject to surface fault rupture, only that there are no known active faults that could cause rupture.

Earthquake Ground shaking

An earthquake is classified by the amount of energy released, which traditionally has been quantified using the Richter scale. Seismologists now use a moment magnitude (Mw) scale because it provides a more accurate measurement of the size of major and great earthquakes. For earthquakes of less than 7.0, the moment and Richter magnitude scales are nearly identical. For earthquake magnitudes greater than 7.0, readings on the moment magnitude scale are slightly greater than a corresponding Richter magnitude.[77]

The intensity of earthquake-induced ground motions can be described using peak ground accelerations (PGAs), represented as a fraction of the acceleration of gravity (g).[78] The CGS provides data and maps to estimate PGAs in California. Taking into consideration the uncertainties regarding the size and location of earthquakes and the resulting ground motions that can affect a particular site, the map depicts PGAs with a 10 percent probability of being exceeded in 50 years, which equals an annual probability of 1 in 475 of being exceeded in any given year.[79] Shaking intensity for the proposed Project area is considered low, with estimated PGAs of 0.132g for firm rock, 0.144g for soft rock, and 0.187g for alluvium.[80] It is important to note that these estimates of PGAs are used primarily for formulating building codes and for designing buildings and are not intended for site-specific hazard analysis. It would be necessary to conduct a site-specific evaluation to estimate peak ground accelerations only at a level suitable for Project design; this Project does not propose any occupied structures.

Another commonly used measure of earthquake intensity is the Modified Mercalli Intensity Scale (MMI), which is a subjective measure of the strength of an earthquake at a particular place as determined by its effects on people, structures, and earth materials. **Table 4.6-1** presents the Modified Mercalli Scale for Earthquake Intensity, along with approximate earthquake magnitudes

75 California Geological Survey, *Probabilistic Seismic Hazard Assessment for the State of California*, from CDMG Open File-Report 96-08, http://www.consrv.ca.gov/CGS/rghm/psha/ofr9608/, accessed April 2010.

76 California Geological Survey, *Alquist-Priolo Earthquake Fault Zones*, http://www.consrv.ca.gov/cgs/rghm/ap/Pages/index.aspx., accessed May 2010.

77 Petersen, Mark D., William A. Bryant, Chris H. Cramer, Tianqing Cao, and Michael Reichle, *Probabilistic Seismic Hazard Assessment for the State of California*. California Department of Conservation, Division of Mines and Geology, Open-File Report 96-08, and U.S. U.S. Geological Survey Open-File Report 96-706, 1996.

78 Acceleration of gravity (g) = 980 centimeters per second squared. 1.0 g of acceleration is a rate of increase in speed equivalent to a car traveling 328 feet from rest in 4.5 seconds.

79 California Geological Survey, *Probabilistic Seismic Hazards Mapping Ground Motion*, http://redirect.conservation.ca.gov/cgs/rghm/ pshamap/pshamain.html, accessed April 2010.

80 California Geological Survey, *Probabilistic Seismic Hazards Mapping Ground Motion*, http://redirect.conservation.ca.gov/cgs/rghm/ pshamap/pshamain.html, accessed April 2010.

TABLE 4.6-1
MODIFIED MERCALLI INTENSITY SCALE FOR EARTHQUAKE INTENSITY

Intensity Value	Intensity Description	Approximate Earthquake Magnitude (Richter)	Average Peak Acceleration
I	Not felt except by a very few persons under especially favorable circumstances.	1.0–3.0	<0.015 g
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	3.0–3.9	
III	Felt noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly, vibration similar to a passing truck. Duration estimated.		
IV	During the day felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	4.0–4.9	0.015–0.03 g
V	Felt by nearly everyone, many awakened. Some dishes and windows broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles may be noticed. Pendulum clocks may stop.		0.03–0.08 g
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; and fallen plaster or damaged chimneys. Damage slight.	5.0–5.9	0.08–0.15 g
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.		0.15–0.25 g
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.	6.0–6.9	0.25–0.45 g
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.		0.45–0.60 g
X	Some well-built wooden structures destroyed; most masonry and frame structures with foundations destroyed; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.	7.0 and higher	0.60–0.80 g
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.		0.80–0.90 g
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.		>0.90 g

SOURCE: California Geological Survey, *Background Information on the Shake Maps*,http://quake.usgs.gov/research/strongmotion/effects/shake/about.html, accessed April 2010.

and average peak accelerations associated with each intensity value.[81] According to Map Sheet 49, published by the CGS, the Project area has not experienced damaging shaking of earthquakes of MMI VII or greater since data has been recorded between 1800 and 1999.[82]

Liquefaction

Liquefaction is a phenomenon in which saturated granular sediments temporarily lose their shear strength during periods of earthquake-induced, strong ground shaking. The susceptibility of soils to liquefaction is a function of the depth, density, and water content of the granular sediments and the magnitude of earthquakes. Saturated, unconsolidated silts, sands, silty sands, and gravels within 50 feet of the ground surface are most susceptible to liquefaction. Liquefaction-related phenomena include vertical settlement from densification, lateral spreading, ground oscillation, flow failures, loss of bearing strength, subsidence, and buoyancy effects.[83] Holocene-age alluvial sediments are especially prone to liquefaction. Older alluvial sediments deposited during the Pleistocene epoch are generally not liquefiable because they are more consolidated. Artificial fills are also highly prone to liquefaction.

Earthquake-Induced Settlement

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid rearrangement, compaction, and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments). Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Areas are susceptible to differential settlement if underlain by compressible sediments, such as poorly engineered artificial fill.

Seismic Slope Instability/Ground Cracking

Earthquake motions can also induce substantial stresses in slopes, causing earthquake-induced landslides or ground cracking when the slope fails. Earthquake-induced landslides can occur in areas with steep slopes that are susceptible to strong ground motion during an earthquake.

4.6.2 Regulatory Framework

Federal

Earthquake Hazards Reduction Act

The Earthquake Hazards Reduction Act was enacted in 1997 to “reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards and reduction program.” To accomplish this, the act established the National Earthquake Hazards Reduction Program (NEHRP). This program was significantly amended in November 1990 by the National Earthquake Hazards Reduction

[81] California Geological Survey, *Background Information on the Shake Maps,* http://quake.usgs.gov/research/strongmotion/effects/shake/about.html, accessed April 2010.
[82] California Geological Survey, *Regional Geologic Mapping Program, Epicenters of and Areas Damaged by M>5California Earthquakes, 1800-1999, Map Sheet 49, 2000.*
[83] U.S. Geological Survey, *Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility, Nine-County San Francisco Bay Region, California: A Digital Database,* USGS Open File Report 00-444, 2000, page 1.

Program Act (NEHRPA), which refined the description of agency responsibilities, program goals, and objectives.

NEHRP's mission includes improved understanding, characterization, and prediction of hazards and vulnerabilities; improvement of building codes and land use practices; risk reduction through post earthquake investigations and education; development and improvement of design and construction techniques; improvement of mitigation capacity; and accelerated application of research results. The NEHRPA designates the Federal Emergency Management Agency (FEMA) as the lead agency of the program and assigns it several planning, coordinating, and reporting responsibilities.

Federal Railroad Administration - Track Safety Standards

The Federal Railroad Administration (FRA) provides track safety standards in 49 CFR Chapter 5, Section 213. These standards developed a system of classification for track quality. The class of a section of track determines the maximum possible running speed limits for freight and passenger trains. The BNSF rail line is a Class 5 line. The ARZC rail line is a Class 4 line. **Table 4.6-2** below summarizes the maximum speeds allowed on these rail lines.

TABLE 4.6-2
MAXIMUM RAIL LINE SPEEDS

Track Type	Rail Line	Freight Train	Passenger Train
Class 4	ARZC	60 mph (97 km/h)	80 mph (129 km/h)
Class 5	BNSF	80 mph (129 km/h)	90 mph (145 km/h)

SOURCE: ESA, 2011.

Table 4.6-3 below from 49 CFR 213 summarizes various tolerance limits for changes to the track surface.

Track surface is the evenness or uniformity of track in short distances measured along the tread of the rails. Under load, the track structure gradually deteriorates due to dynamic and mechanical wear effects of passing trains. Improper drainage, unstable roadbed, inadequate tamping, and deferred maintenance can create surface irregularities. Track surface irregularities can lead to serious consequences, if ignored.

Allowable deviations in track surface include runoff at the end of a raise, deviation from uniform profile, deviation from zero cross level at any point on tangent or reverse cross level elevation on curves, and the difference in cross level between any two points less than 62 feet apart, are specified in the track surface table, Table 4.6-3.

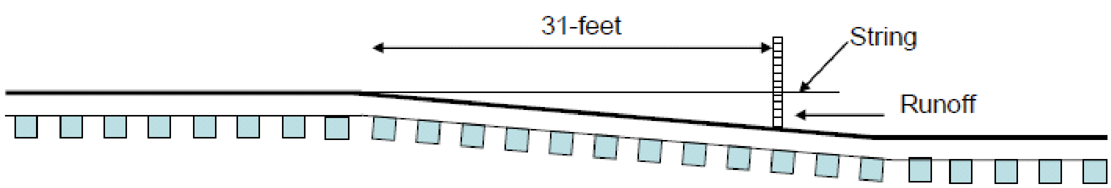
TABLE 4.6-3
TOLERANCE LIMITS

Track Surface	Class of Track 4	Class of Track 5
The runoff in any 31 feet of rail at the end of a raise may not be more than	1½"	1"
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	2"	1¼"
The deviation from zero cross level at any point on tangent or reverse cross level elevation on curves may not be more than	1¼"	1"
The difference in cross level between any two points less than 62 feet apart may not be more than	1¾"	1½"
Where determined by engineering decision prior to the promulgation of this rule, due to physical restrictions on spiral length and operating practices and experience, the variation in cross level on spirals per 31 feet may not be more than	1"	¾"

SOURCE: ESA, 2011.

The Tolerance Limits refer to the runoff (ramp) in any 31 foot segment at the end of a raise where the track is elevated as a result of automatic or manual surfacing or bridge work. Conditions created by track degradation (e.g., settlement or frost heaves) are to be addressed using the uniform profile parameter, under this section. Trains encountering a ramp (up or down) will experience a vertical pitch or bounce if the change in elevation occurs in too short a distance. As in the more general profile parameter, damage to car components, undesirable brake applications or derailments may occur; especially when the vehicle experiences a lateral force such as a buff force.

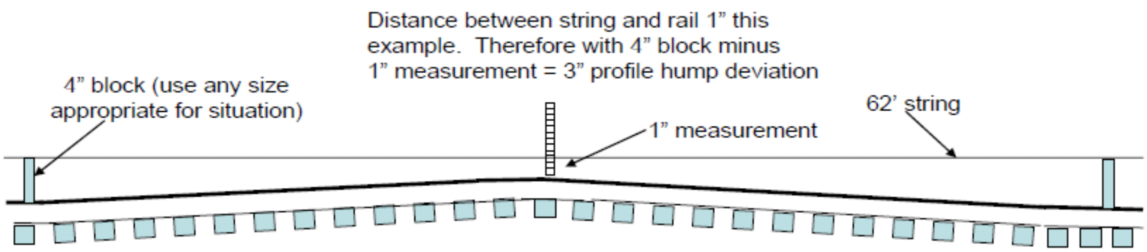
The schematic below illustrates the measurement of the runoff of raised track.

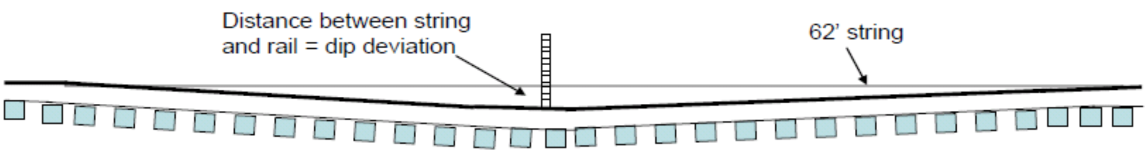


The second parameter (profile), relates to the elevation of either rail along the track. When trains encounter short dips or humps in the track, it can result in vertical separation of couplers and broken springs, bolsters, and truck frames. Dips can result from mud spots or develop at the ends of fixed structures (e.g., bridges, highway rail grade, and track crossings). Profile is determined by placing the mid-point of a 62-foot chord at the point of maximum measurement, irrespective of vertical curves. Profile may also be a track “hump” cause by a frost heave or other occurrence.

The schematic on the following page illustrates the measurement of profile conditions.

As summarized in Table 4.6-3 above, the maximum allowable deviation of the track surface is on the order of 1 to 2 inches over a 62-foot length of track.





State

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act[84] was passed in 1972 to mitigate the hazard of surface faulting to structures for human occupancy. In accordance with this Act, the California State Geologist (State Geologist) established regulatory zones, called earthquake fault zones, around the surface traces of active faults and has published maps showing these zones. Within these zones, buildings for human occupancy cannot be constructed across the surface trace of active faults. Each earthquake fault zone extends approximately 200 to 500 feet on either side of the mapped fault trace because many active faults are complex and consist of more than one branch that may experience ground surface rupture. This Act does not apply to the proposed Project because no active faults cross the Project area.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. Before a development permit is granted for a site within a seismic hazard zone, a geotechnical investigation of the site has to be conducted and appropriate mitigation measures incorporated into the Project design. To date, the State Geologist has not prepared a map for the area in which the Project is located.

84 California Geological Survey, *Alquist-Priolo Earthquake Fault Zones*,http://www.consrv.ca.gov/cgs/rghm/ap/Pages/index.aspx, accessed May 2010.

California Building Code

The California Building Code (CBC) has been codified in the California Code of Regulations (CCR) as Title 24, Part 2. Title 24 is administered by the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under State law, all building standards must be centralized in Title 24 or they are not enforceable. The purpose of the CBC is to establish minimum standards to safeguard the public health, safety and general welfare through structural strength, means of egress, and general stability by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of all building and structures within its jurisdiction. The CBC is based on the International Building Code (IBC; previously known as the Uniform Building Code) published by the International Code Conference. In addition, the CBC contains necessary California amendments, which are based on the American Society of Civil Engineers (ASCE) Minimum Design Standards 7-05. ASCE 7-05 provides requirements for general structural design and includes means for determining earthquake loads as well as other loads (flood, snow, wind, etc.) for inclusion into building codes. The provisions of the CBC apply to the construction, alteration, movement, replacement, and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures throughout California.

The earthquake design requirements take into account the occupancy category of the structure, site class, soil classifications, and various seismic coefficients, which are used to determine a Seismic Design Category (SDC) for a project. The SDC is a classification system that combines the occupancy categories with the level of expected ground motions at the site and ranges from SDC A (very small seismic vulnerability) to SDC E/F (very high seismic vulnerability and near a major fault). Design specifications are then determined according to the SDC. All constructed elements of the Project are subject to the CBC.

Local

San Bernardino County Land Use Regulations and Ordinances

The San Bernardino County General Plan Safety Element and building, grading, and erosion control ordinances are intended to ensure safe building construction and control erosion and sedimentation caused by construction activities. Specifically, Public Resources Code Section 2699 directs cities and counties to "take into account the information provided in available seismic hazard maps" when it adopts or revises the safety element of the general plan and any land-use planning or permitting ordinances.[85] A building permit typically requires that new construction be inspected during and after completion to ensure compliance with national, regional, and local building codes. A grading permit is typically required prior to initiating the construction phase of a project. As part of the permit, applicants usually must submit a grading and erosion control plan, vicinity and site maps, and other supplemental information. Standard conditions in the grading permit include a description of Best Management Practices (BMP) similar to those contained in a Stormwater Pollution Prevention Program (SWPPP). The BMPs typically included in a SWPPP are discussed in further detail in Section 4.9, Hydrology and Water Quality. The constructed

[85] California Geographical Survey, *Guidelines for Evaluating and Mitigating Seismic Hazards in Californi*a, Special Publication 117A, 2008.

elements of the Project are subject to the County regulations and ordinances described in this section.

4.6.3 Impact and Mitigation Analysis

Significance Criteria

Based on the *CEQA Guidelines*, Appendix G, a project may be deemed to have a significant effect on the environment with respect to geology and soils if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publication 42):
  - Strong seismic ground shaking;
  - Seismic-related ground failure, including liquefaction; or
  - Landslides;
- Result in substantial soil erosion or the loss of topsoil;
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse;
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property; or
- Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

Methodology

Site-specific and regional reports and maps were reviewed to evaluate the potential impacts of the Project relative to Geology and Soils. Geologic data from regional and local investigations were evaluated, including site-specific hydrogeologic data collected from 12 wells drilled in the Fenner Gap area. The Conservation and Recovery and Imported Water Storage Components are evaluated separately below.

Recent geologic mapping of the southeastern portion of the Marble Mountains, the Fenner Gap area, and the northwestern portion of the Ship Mountains was conducted for this investigation by Dr. Miles Kenney. The Kenney GeoScience report consolidated numerous previous geologic and geophysical studies and then updated and augmented the consolidated geologic information with a 21-day field investigation of the geology of the Fenner Gap area and discussions with previous investigators.[86] This detailed mapping was conducted to allow interpretation of the geologic structure in the Fenner Gap in order to determine potential groundwater flow paths and rates. The Kenney GeoScience report formed the basis for construction of the groundwater flow model developed by Geoscience in their report describing the geology and hydrology of the Project area.[87]

Using the available geologic and hydrologic information, including the recent geologic mapping, Geoscience prepared a three-dimensional, density-dependant groundwater flow and transport model to simulate the aquifer system in the Project area, including Fenner Valley, Fenner Gap, and the Cadiz Valley area that includes most of the Bristol Playa and the northern portion of the Cadiz Playa (Appendix H).[88] The groundwater model was used to simulate the potential response of the aquifer system to variations in recharge using two variations of the wellfield configuration and three variations of potential annual recharge volumes over a period of 50 years of groundwater production at 50,000 AFY, followed by 50 years of recovery (no groundwater production). The output of the simulations are the modeled drawdown of groundwater levels, the potential movement of the freshwater-saline water interface, and the amount of potential subsidence (groundwater drawdown and freshwater/saline water interface migration are addressed in Section 4.9, Hydrology).

The modeled scenarios vary by recharge amounts. The Project scenario assumes an annual recharge of approximately 32,000 AFY in the Fenner Watershed and Orange Blossom Wash, based on CH2M Hill's updated evaluation of recharge.[89] This recharge volume estimate is derived from the USGS INFIL3.0 Model, is based on long-term precipitation records, and represents the long-term average recharge within the Fenner Watershed that ultimately migrates to the Bristol and Cadiz Dry Lakes, becomes saline, and evaporates. Because a few earlier evaluations of available recharge predicted a lower potential range for recharge, two sensitivity scenarios also were applied to model conservative, worst-case aquifer responses where the average annual recharge over a 100-year time period is reduced to 16,000 and 5,000 AFY, respectively.[90] As discussed in Section 4.9, Hydrology, the modeling did not include recharge that occurs west, south, and east of the Bristol and Cadiz Dry Lakes. Consequently, the groundwater model provides the most conservative aquifer responses because the inclusion of recharge from other watersheds would reduce the predicted groundwater level drawdown and thus the potential for subsidence. The modeling also considered two different production well configurations: Well Configuration A would use 5 existing Cadiz agricultural wells, 2 new high

86 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California*, August 2011.
87 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1*, September 2011.
88 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, pages 27-48.
89 CH2M Hill, *Cadiz Groundwater Conservation and Storage Project*, July 2010, page 4-8.
90 GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, page 35.

capacity wells, and 15 new lower-capacity wells; Configuration B would use 5 existing Cadiz agricultural wells and 29 new lower-capacity wells.[91]

Using the results from the predictive aquifer model discussed above, Geoscience evaluated the model-predicted subsidence results for the three scenarios. The potential land subsidence results for the three scenarios are illustrated on **Figures 4.6-5, 4.6-6,** and **4.6-7.**[92]

The groundwater model simulated the elastic (recoverable) compaction and expansion and inelastic (permanent) compaction of compressible fine-grained beds (interbeds) within the aquifers. The deformation of interbeds is caused by changes in effective stress as a result of groundwater level changes. If the stress is less than the preconsolidation stress of the sediments, the deformation is elastic (i.e., recoverable). If the stress is greater than the preconsolidation stress, the deformation is inelastic (i.e., permanent). If necessary, this model will be updated and refined during Project operations through active management of groundwater extraction based on data obtained from the monitoring features.

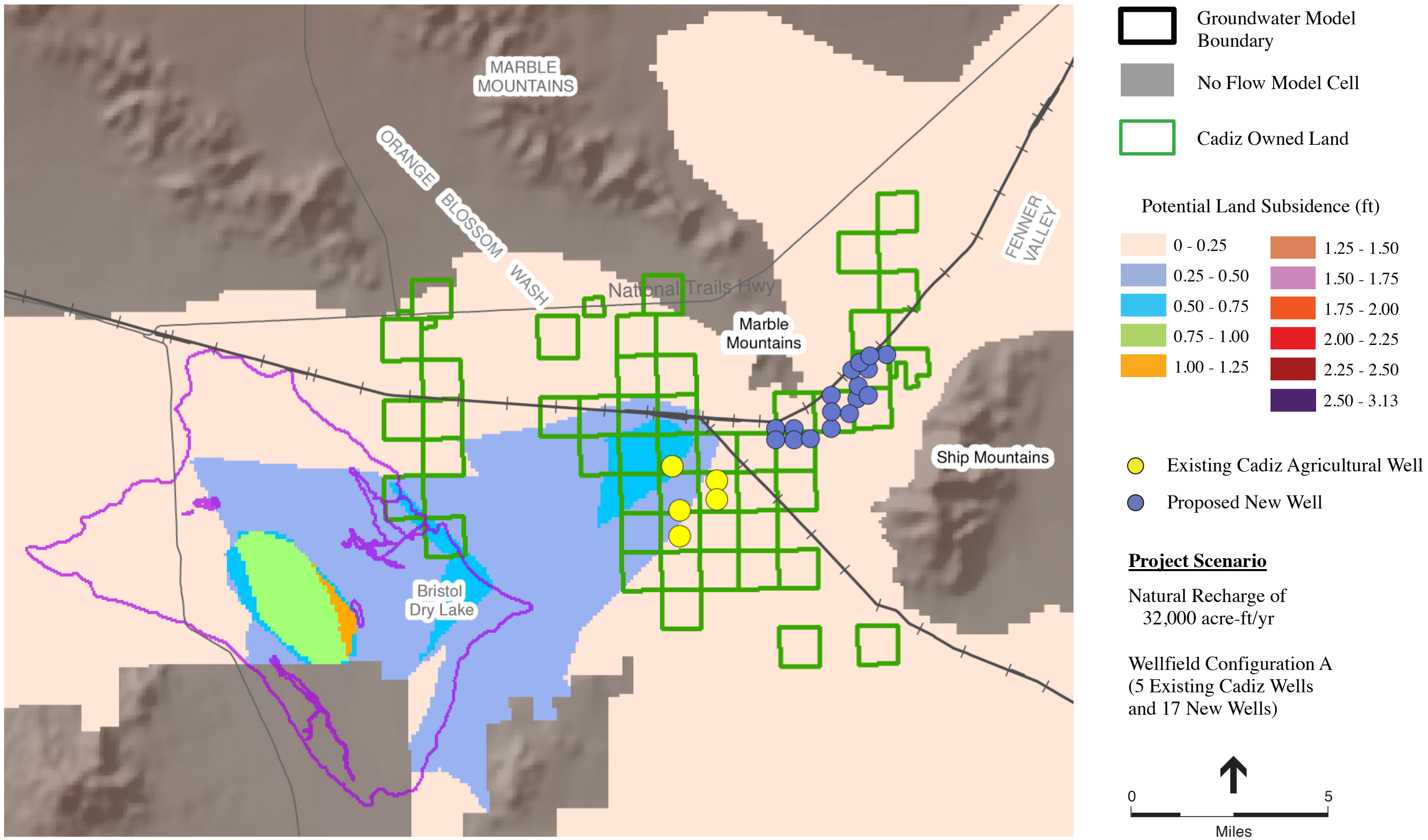
In general, the potential for land subsidence corresponds to the magnitude of groundwater level decline and the thickness of the clay layers in the aquifer. Based on the results of the Geoscience groundwater model, any predicted subsidence would occur gradually and be dispersed laterally over a large area from the Fenner Gap to the Bristol and Cadiz Dry Lakes.

Groundwater Management, Monitoring, and Mitigation Plan

The GMMMP prepared for the Project to provide for the adaptive management of the basin includes measures to monitor Project operations and potential effects on critical resources, and, as necessary, to implement corrective actions to insure protection of such resources (Appendix H).[93] These measures are referred to as Project Design Features (PDF) in this EIR and they are numbered according to the GMMMP Section in which they are described (i.e., Project Design Feature 6.3 – Land Subsidence is Section 6.3 of the GMMMP). These Project Design Features from the GMMMP include a monitoring element, action criteria, and corrective measures to address a potential issue if the action criteria are triggered. The action criteria are set below the trigger or threshold for impact significance as established in accordance with CEQA for each impact area, thus insuring adequate time to implement the corrective actions and avoid significant impact. The monitoring and response measure from the GMMMP for subsidence is listed below.

- GMMMP Project Design Feature 6.3 – Land Subsidence

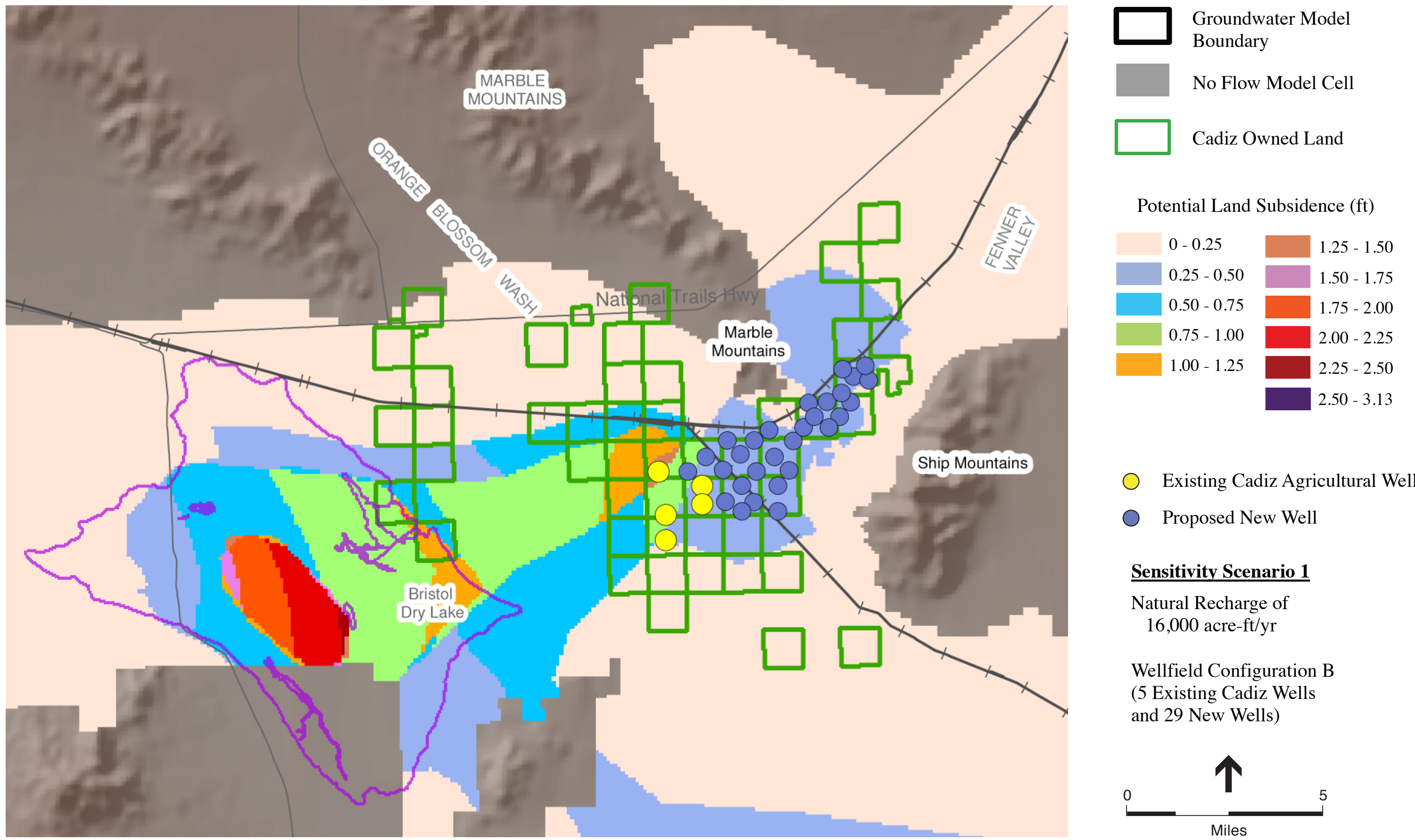
[91] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, page 47.
[92] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, pages 54-55, Figures 77-79.
[93] CH2M Hill, *Groundwater Management, Monitoring, and Mitigation Plan*, November 2011.



SOURCE: GeoScience, 2011.

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-5
Model-Predicted Land Subsidence - Project Scenario
(Assumes 32,000 AFY Recharge)

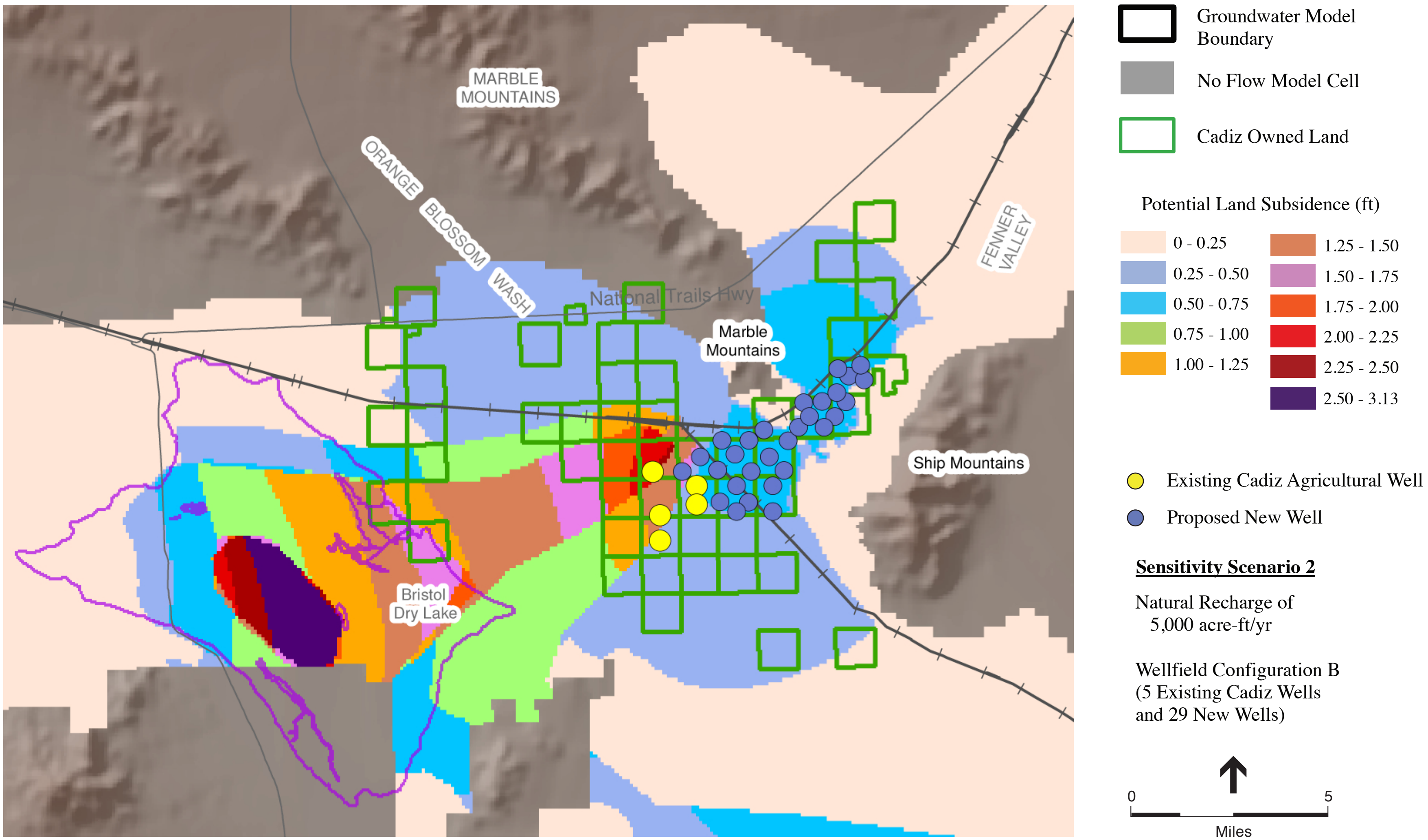


SOURCE: GeoScience, 2011.

Cadiz Valley Water Conservation, Recovery, and Storage Project

Figure 4.6-6

Model-Predicted Land Subsidence - Sensitivity Scenario 1 (Assumes 16,000 AFY Recharge)



SOURCE: GeoScience, 2011.

Figure 4.6-7
Model-Predicted Land Subsidence - Sensitivity Scenario 2
(Assumes 5,000 AFY Recharge)

Groundwater Conservation and Recovery Component

Seismic Impacts from Surface Fault Rupture, Ground Shaking, Landslides, or Liquefaction

Significance Threshold

Would the proposed Project expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publication 42);
- Strong seismic ground shaking;
- Seismic-related ground failure, including liquefaction; or
- Landslides.

Impact Analysis

The Project site is not located along the trace of an active or potentially active fault or fault system. A review of Alquist-Priolo maps provided by the CGS indicates no faulting zones in or adjacent to the Project area, with the nearest mapped active faults being located approximately 45 miles west of the Project site. Additionally, the Kenney GeoScience study, which included both the review of previous studies and a detailed on-site field investigation, indicated that no recent fault movement has been documented in the footprint of any of the Project facilities because the area has been relatively tectonically stable since Miocene time and no deformation or displacement of recent sediments are known within the Project area.[94]

Major seismic activity along the nearby and active San Andreas or Garlock fault systems, or other associated faults, could affect the Project site through strong seismic ground shaking. Strong seismic ground shaking could potentially cause structural damage to the proposed wellfield, water conveyance facilities, or associated infrastructure, possibly resulting in damage to facilities and interruption of service.

In the event that shallow groundwater is present, strong ground shaking could enable liquefaction of sediments. Liquefaction in such areas could cause differential settlement or other damage to pipelines, wells, and other proposed facilities. However, as discussed in Section 4.9, Hydrology and Water Quality, the depth to water along the water conveyance pipeline is generally over 100 feet below ground surface. Therefore, water-saturated soils are not anticipated along the pipeline alignment and liquefaction-prone conditions are not present.

Most of the Project facilities would be located upon relatively flat topography. As shown in Figure 4.6-1, portions of the water pipeline alignment are located along areas adjacent to

94 Kenney GeoScience, *Geologic Structural Evaluation of the Fenner Gap Region Located Between the Southern Marble Mountains and Ship Mountains, San Bernardino County, California,* August 2011, pages 2, 15, and 26.

mountains and hills with higher topographic relief. A review of geologic maps of the area did not reveal any existing landslides within or adjacent to the Project site, and the soils associations identified for sloped areas are not anticipated to have a high propensity for landslides. In addition, the water conveyance pipeline and wellfield manifold system piping would be placed below ground, thus protecting these facilities from potential landslides.

The Project facilities would be designed to withstand strong ground shaking, because the facility design would be required to comply with the CBC to minimize the potential effects of liquefaction, ground shaking, landslides, and other seismic activity within the Project area. This would include installing shut-off valves and blow-off valves in the pipeline to minimize water releases in the event of a pipe break. Well pads and interconnections would be installed on flat terrain with no liquefaction hazards. Due to the remote location, no people would be exposed to increased risk from installation of the facilities. Therefore, impacts related to surface rupture, seismic ground shaking, liquefaction, or seismically induced landslides are considered less than significant.

Mitigation Measures

None required.

Significance Conclusion

Less than significant.

Soil Erosion and Loss of Topsoil

Significance Threshold

Would the proposed Project result in substantial soil erosion or the loss of topsoil?

Impact Analysis

During the construction phase of the proposed Project, the use of heavy machinery for grading, trenching, well drilling, facilities installation, and other proposed activities would disturb surface topsoil layers. Existing desert vegetation in those locations would be removed from the facilities' installation sites, which would also disturb surficial sediments. These factors could expose construction areas to erosive forces including wind and storm-water runoff. Increases in erosion could result in changes to nearby topography, drainage patterns, and vegetation patterns in affected areas.

The Project wells and pipeline would not be subject to the NPDES Construction General Permit for Discharges of Stormwater since there are no Waters of the U.S. affected by the wells or pipeline. Nevertheless, the FVMWC would implement Mitigation Measure **HYDRO-1** to ensure that construction-related Best Management Practices (BMPs) are implemented to prevent soil erosion during construction, as well as to control hazardous materials used during construction from adversely affecting the environment.

Upon completion of pipeline construction activities, a surface restoration crew would follow the appurtenance installation crew to perform re-vegetation and erosion control. (See Section 4.4 Biological Resources regarding restoration efforts.) Excavated topsoil would be returned to the trenches and compacted. Washes and training dikes that are impacted by construction would be returned to their pre-construction condition in coordination with ARZC.

With implementation of Mitigation Measures **HYDRO-1** and **BIO-6**, impacts from potential erosion from construction activities would be less than significant.

Mitigation Measures

Implement **HYDRO-1** and **BIO-6**.

Significance Conclusion

Less than significant with mitigation.

Geologically Unstable Area

Significance Threshold

Would the proposed project be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?

Impact Analysis

As discussed above, the Project would not be located in areas subject to unstable soils or landslides, including seismically-induced landslides or liquefaction. The proposed Project would involve the installation of a production wellfield, water conveyance pipeline, natural gas supply line, and various appurtenances. These facilities would be installed primarily along areas with low topographic relief having sandy to rocky unconsolidated structure or along areas with exposed or very shallow bedrock. Installation of the proposed facilities would not interfere with the underlying structure of these formations and therefore would not increase formation instability or result in a subsequent increase in landslides, lateral spreading, collapse, or other surficial hazards.

The Project operations would result in the long-term extraction of groundwater, which would lead to a reduction in groundwater levels in the vicinity of the proposed Project. The long-term extraction of groundwater as part of Project operations could result in some land subsidence or settlement. Using the groundwater flow and transport model discussed above, Geoscience modeled the potential subsidence that could occur as the result of groundwater extraction.

Figures 4.6-5, 4.6-6, and 4.6-7 present the model-predicted amount of subsidence based on 50,000 AFY of groundwater extraction for 50 years using three aquifer recharge scenarios. The Project Scenario assumes the recharge to the Fenner and Orange Blossom Wash Watersheds would be 32,000 AFY and is based on CH2M Hill's evaluation of 60 years of precipitation records (see Section 4.9, Hydrology and Water Quality). To assess worst-case climate scenarios, Geoscience also ran the predictive model using 16,000 AFY and 5,000 AFY referred to as Sensitivity Scenarios 1 and 2, respectively. **Table 4.6-4** on the following page summarizes the potential model-predicted subsidence under the three recharge scenarios at five different locations.[95]

The model-predicted degree of potential land subsidence would not significantly impact the alluvial aquifer's storage capacity because consolidation of the aquifer will occur in clay and silt intervals, which do not contribute to the useable storage capacity. Subsidence at, or below, the range projected in Table 4.6-4 is therefore not considered to be a significant environmental impact to the aquifer.

The BNSF and ARZC rail lines, improved roads, and natural gas and crude oil pipelines cross parts of the Project area and are the only existing linear structures that could be affected by subsidence. The proposed Project infrastructure would also be within the area that could be affected by subsidence.

TABLE 4.6-4
SUMMARY OF MODEL-PREDICTED SUBSIDENCE AMOUNTS

		Maximum Potential Subsidence (feet)		
Location	**Time**	**Project Scenario (32,000 AFY Natural recharge)**	**Sensitivity Scenario 1 (16,000 AFY Natural Recharge)**	**Sensitivity Scenario 2 (5,000 AFY Natural Recharge)**
Center of Wellfield	End of 50 Years	0.2	0.4	0.7
	End of 100 Years	0.2	0.4	0.7
Existing Cadiz Wells	End of 50 Years	0.6	1.0	1.5
	End of 100 Years	0.6	1.0	1.5
Edge of Bristol Dry Lake	End of 50 Years	0.5	1.0	1.4
	End of 100 Years	0.5	1.0	1.7
Center of Bristol Dry Lake	End of 50 Years	0.9	1.7	1.2
	End of 100 Years	0.9	2.1	2.7
Edge of Cadiz Dry Lake	End of 50 Years	0.1	0.4	0.5
	End of 100 Years	0.1	0.4	0.6

SOURCE: GEOSCIENCE Support Services, Inc., Cadiz Groundwater Modeling and Impact Analysis, September 1, 2011, pages 54-55.

The area with the greatest potential for subsidence would be in the western part of the Project wellfield in the vicinity of the Cadiz agricultural operations and under Bristol and Cadiz Dry Lakes. Under the Project Scenario, the maximum potential subsidence ranges from 0.1 foot at the edge of Cadiz Dry Lake to 0.9 feet in the center of Bristol Dry Lake. Under Sensitivity Scenario 1, the maximum potential subsidence ranges from 0.4 foot at the edge of Cadiz Dry Lake to 2.1 feet in the center of Bristol Dry Lake. Under the Sensitivity Scenario 2, the maximum potential

[95] GEOSCIENCE Support Services, Inc., *Cadiz Groundwater Modeling and Impact Analysis, Volume 1,* September 2011, pages 54-55.

subsidence ranges from 0.6 foot at the edge of Cadiz Dry Lake to 2.7 feet in the center of Bristol Dry Lake.

The maximum railroad subsidence tolerance levels are 2 inches or less over a 62-foot rail chord length, which equates to a ratio of 0.002688 (2 inches divided by 62 feet). The maximum model-predicted subsidence ratio would occur under the worst-case Sensitivity Scenario 2 with subsidence up to 1.7 feet under the center of Bristol Dry Lake. Measured across the entire area of subsidence, this would equate to 1.7 feet of subsidence across the distance of about 12 miles from Bristol Dry Lake to the center of the wellfield which equates to a ratio of 0.00002683, two orders of magnitude below the maximum tolerance level for railroad lines. Furthermore, the rail lines are not located in the center of Bristol Dry Lake, where the maximum potential subsidence would be expected. Therefore, the maximum model-predicted subsidence would not exceed railroad tolerance levels and is considered a less than significant impact.

Although the maximum potential model-predicted subsidence would be considered a less than significant impact, Cadiz monitors subsidence at the Project area as part of its agricultural development monitoring program. The results of its current subsidence monitoring program are described in annual monitoring reports for the agricultural operations, which are submitted to San Bernardino County.[96] No subsidence has been observed in the area as a result of Cadiz' use of groundwater for irrigation since its agricultural operation began in 1993.

Even though the model-predicted subsidence would not exceed railroad tolerance levels and the degree of potential land subsidence would not significantly impact the alluvial aquifer's useable storage capacity, the GMMMP nonetheless includes project design features to verify model-predicted effects and confirm protection of critical resources. The project design feature relative to subsidence is GMMMP Project Design Feature 6.3 – Land Subsidence.[97] The Action Criteria and Corrective measures are summarized in **Table 4.6-5**.

TABLE 4.6-5
GMMMP PROJECT DESIGN FEATURE 6.3 – LAND SUBSIDENCE

Action Criteria	Corrective Measures
For land subsidence effects, the action criteria shall be: 1. Land subsidence and subsidence rate that are greater than projected by the groundwater flow simulation model for an equivalent elapsed time;, 2. A change in the ground surface elevation of more than 0.5 feet within the Project area; or 3. Land subsidence of more than one inch vertically over 62 feet horizontally within the vicinity of railroad tracks.	Corrective measures that would be implemented would be modification of Project operations to arrest subsidence that would include one or more of the following actions: • Reduction in pumping from Project wells; • Revision of pumping locations within the Project wellfield; • Stoppage of groundwater extraction for a duration necessary to correct the predicted impact; or • Repair of any structures damaged as a result of subsidence attributable to Project operations.

SOURCE: CH2M Hill, Groundwater Management, Monitoring, and Mitigation Plan, November 2011, pages 83-84.

96 Cadiz Inc., *13th Annual Groundwater Monitoring Report, January – December 2010, Cadiz Valley Agricultural Development*, June 2011.
97 CH2M Hill, *Groundwater Management, Monitoring, and Mitigation Plan*, November 2011, pages 83-84.

Chapter 5 of the GMMMP describes Monitoring Features 5 and 6 to be used to monitor for subsidence.[98] A network of approximately 20 land survey benchmarks and three extensometers would be installed in the area of the highest probability of subsidence to monitor changes in land surface elevation should they occur.

Implementation of the project design features in Chapter 6.3 of the GMMMP would reduce the potential impacts to infrastructure to less than significant. Therefore, for purposes of this CEQA analysis of the Project, the project design features in Chapter 6.3 of the GMMMP are incorporated into this EIR as Mitigation Measure **GEO-1**. Implementation of Mitigation Measure **GEO-1** would ensure that the potential impacts from subsidence are mitigated to less than significant.

Mitigation Measures

GEO-1: The project design features in Chapter 6.3 of the GMMMP shall be implemented to address the potential impact for land subsidence. If land subsidence is observed at rates that are greater than projected by the groundwater flow simulation model for an equivalent elapsed time, or if a change in the ground surface elevation of more than 0.5 feet within the Project area occurs, or if subsidence of more than one inch vertically over 62 feet horizontally within the vicinity of railroad tracks occurs, the following shall occur:

- Implement the corrective measures that involve modification of Project operations to actively arrest subsidence through one or more of the following:
  - Reduction in pumping from Project wells;
  - Revision of pumping locations within the Project wellfield;
  - Stoppage of groundwater extraction for a duration necessary to correct the predicted impact; or
  - Repair of any structures damaged as a result of subsidence attributable to Project operations.

Significance Conclusion

Less than significant with mitigation

Expansive or Corrosive Soils

Significance Threshold

Would the proposed Project be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?

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98 CH2M Hill, *Groundwater Management, Monitoring, and Mitigation Plan*, November 2011, page 73.

Impact Analysis

The geologic and soils maps have not identified expansive soils within the area of the proposed Project. Expansive soils generally occur in regions with moderate to high clay content. Mapped soil associations within the Project area contain very low to negligible amounts of clay material. Therefore, the issue of expansive soils would have no impact and no mitigation is required.

The Project site is located in areas where the soils are known to have lower pH levels and higher salt contents. The corrosive effects of such soil conditions could reduce the integrity of steel or concrete materials. Failure of the water pipeline would result in damage to the conveyance facilities and the erosion of soil at the break location. A sudden failure of the water or natural gas pipe integrity could cause the release of water or natural gas at pressures that could cause injury to nearby workers.

This impact is considered less than significant because, in compliance with relevant state and local requirements, the facility design of the water pipelines, natural gas supply lines, and associated subsurface infrastructure would be required to meet the minimum standards of the CBC, as required for areas with potential corrosive soils. Buried metal pipes typically have cathodic protection installed that reduces corrosive effects. Compliance with the CBC would ensure that the proposed facilities would be constructed to minimize the potential effects of corrosion. Therefore, impacts related to corrosion are considered less than significant.

Mitigation Measures

None required.

Significance Conclusion

Less than significant.

Soil Suitability for Septic System

Significance Threshold

Would the proposed Project have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of waste water?

Impact Analysis

The development of the proposed Project would not include the addition or removal of septic tanks or alternative wastewater disposal systems. Current worker accommodations in the vicinity are designed to accommodate septic demands for periodic work forces. Therefore, the issue of support for septic or alternate wastewater disposal systems would have no impact and no mitigation is required.

Mitigation Measures

None required.

Significance Conclusion

No impact.

Imported Water Storage Component

This component is analyzed on a programmatic basis.

Seismic Impacts from Surface Fault Rupture, Ground Shaking, Landslides, or Liquefaction

Significance Threshold

Would the proposed Project expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the state geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publication 42);
- Strong seismic groundshaking;
- Seismic-related ground failure, including liquefaction; or
- Landslides.

Impact Analysis

Similar to the Groundwater Conservation and Recovery Component, the Project area is not within an Alquist-Priolo Earthquake Zone and is not subject to surface rupture or seismically-induced landslides. The spreading basins, pump station, existing natural gas pipeline, and expanded wellfield would be subject to strong ground shaking resulting from nearby seismic activities. The spreading basins would be filled with water periodically. Side-slope failure could result in the release of water into the Schuyler Wash that could significantly impact down-stream infrastructure. Compliance with the existing standards would reduce the potential impact to less than significant. Mitigation Measure **GEO-2** would ensure that spreading basin berms are designed to minimize the potential for catastrophic failure during strong ground shaking events.

Mitigation Measures

> **GEO-2: Imported Water Storage Component.** The spreading basin berms shall be designed so that soil composition, side slopes, and freeboard requirements are approved by a qualified geotechnical engineer.

Significance Conclusion

Less than significant with mitigation.

Soil Erosion and Loss of Topsoil

Significance Threshold

Would the proposed Project result in substantial soil erosion or the loss of topsoil?

Impact Analysis

The expanded wellfield, pump station, and spreading basins would increase the potential for soil erosion during construction similar to the Groundwater Conservation and Recovery Component. In addition, construction activities for air relief valves and the pump stations needed to convert the existing natural gas pipeline would increase the potential for soil erosion during construction. However, the Imported Water Storage Component would not construct facilities within existing drainages. Compliance with construction BMPs to minimize erosion during construction, as included in Mitigation Measures **HYDRO-1** and **HYDRO-4**, would ensure that impacts were less than significant.

Mitigation Measures

Implement **HYDRO-1** and **HYDRO-4**.

Significance Conclusion

Less than significant with mitigation.

Geologically Unstable Area

Significance Threshold

Would the proposed Project be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?

Impact Analysis

As described above, the expanded wellfield, pump station, spreading basins, and appurtenances needed to convert the natural gas pipeline would not be subject to unstable soils. The spreading basins and pump station would not be located within the wellfield drawdown area. Therefore, they would not be subject to subsidence. The impact would be less than significant.

Mitigation Measures

None required

Significance Conclusion

Less than significant.

Expansive or Corrosive Soils

Significance Threshold

Would the proposed Project be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?

Impact Analysis

As with the Groundwater Conservation and Recovery Component, geologic and soils maps have not identified expansive soils within the area of the proposed Project. Expansive soils generally occur in regions with moderate to high clay content. As discussed previously, mapped soil associations within the Project area contain very low to negligible amounts of clay material. Therefore, expansive soils would have no impact and no mitigation is required.

The Project site is located in areas where the soils are known to have lower pH levels and higher salt contents. The corrosive effects of such soil conditions could reduce the integrity of steel or concrete materials. This impact is considered less than significant because, in compliance with relevant state and local requirements, the facility design would be required to meet the minimum standards of the CBC, as required for areas with potential corrosive soils. Compliance with the CBC would ensure that the proposed facilities would be constructed to minimize the potential effects of corrosion. Therefore, impacts related to corrosion are considered less than significant.

Mitigation Measures

None required.

Significance Conclusion

Less than significant.

Soil Suitability for Septic System

Significance Threshold

Would the proposed Project have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?

Impact Analysis

The development of the proposed Project would not include the addition, removal, or use of septic tanks or alternative wastewater disposal systems. Therefore, there would be no impact related to the issue of support for septic or alternative wastewater disposal systems and no mitigation is required.

Mitigation Measures

None required.

Significance Conclusion

No impact.

Mitigation Measure Summary Table

Table 4.6-6 on the following page presents the impacts and mitigation summary for Geology and Soils.

TABLE 4.6-6
IMPACTS AND MITIGATION SUMMARY

Proposed Project Impact	Mitigation Measure	Significance Conclusion
Groundwater Conservation and Recovery Component		
Seismic Impacts from Surface Fault Rupture, Ground Shaking, Landslides, or Liquefaction	None required	Less than significant
Soil Erosion and Loss of Topsoil	**HYDRO-1** and **BIO-6**	Less than significant with mitigation
Geologically Unstable Area	**GEO-1**	Less than significant with mitigation
Expansive or Corrosive Soils	None required	Less than significant
Soil Suitability for Septic System	None required	No impact
Imported Water Storage Component		
Seismic Impacts from Surface Fault Rupture, Ground Shaking, Landslides, or Liquefaction	**GEO-2**	Less than significant with mitigation
Soil Erosion and Loss of Topsoil	**HYDRO-1** and **HYDRO-4**	Less than significant with mitigation
Geologically Unstable Area	None required	Less than significant
Expansive or Corrosive Soils	None required	Less than significant
Soil Suitability for Septic System	None required	No impact