5.4 TOPOGRAPHY, GEOLOGY, SEISMICITY AND SOILS

5.4.1 AFFECTED ENVIRONMENT

Project Area Topography

The topography of the Cadiz Project area is characterized by generally northwest to north-trending mountain ranges separated by broad intervening valleys with interior drainage. The elevations of the floors of Bristol Valley (Bristol Dry Lake), Cadiz Valley (Cadiz Dry Lake) and Ward Valley (Danby Dry Lake), are all at elevations between 500 and 600 feet above mean sea level. The highest elevation in the Iron Mountains, located at the southern end of the Project area, is 3,296 feet. The Kilbeck Hills, a northerly extension of the Iron Mountains, crest at approximately 1,684 feet. The maximum elevation in the Old Woman Mountains, located north of Danby Dry Lake and east of the Kilbeck Hills, is 5,326 feet. The maximum elevation in the Ship Mountains, located north of Cadiz Valley, is 3,239 feet. The Marble Mountains, located northwest of the Ship Mountains, reach an elevation of 3,842 feet. The topographic and geologic setting of the Cadiz Project area is shown in Figure 5.4-1.

The project spreading basins will be located in Fenner Gap, which is located between the Marble and Ship mountains. Fenner Gap is the site of both surface drainage and groundwater outflow from the Fenner Valley. Fenner Valley, which forms the principal watershed for the project area, is a broad southwest-trending valley that drains an area of approximately 1,100 square miles.

The project water conveyance alignments will originate either at the Iron Mountain Pumping Plant on the eastern flank of the Iron Mountains (Eastern and Eastern/Canal Alternatives), or at the western terminus of the Iron Mountain Tunnel (Western and Combination Alternatives). The pumping plant and tunnel are parts of Metropolitan's Colorado River Aqueduct. All alternatives would traverse gently sloping ground along the flanks of the Iron Mountains and Kilbeck Hills. Ground surface elevations along these alternatives range from approximately 900 to 1,000 feet. With minor local exceptions, the slope of the ground surface ranges from approximately one to six percent, (approximately 50 to 300 feet per mile).

Extending northwest from the north end of the Kilbeck Hills, a single water conveyance facility common to all project alternatives will extend along the northeast margin of Cadiz Valley, adjacent to the ARZC line and to Cadiz-Rice Road. Near the north end of Cadiz Valley, the water conveyance facility will turn north toward the project spreading basin site in Fenner Gap. Ground surface elevations along this reach of the alignment range from about 750 to 1,000 feet, with the surface sloping gently southwest toward Cadiz Valley at a slope of approximately one percent (50 feet per mile).

The project wellfield will be centered on the project spreading basin complex. Ground surface elevations in this area range from about 750 to 1,000 feet.

The ground surface in the vicinity of the project wellfield and project spreading basin site slopes gently toward the west and southwest at a slope of less than 50 feet per mile.

Project Area Geology

Figure 5.4-1 shows the water conveyance alignments for the Cadiz Project alternatives on a regional geologic base map prepared by the California Division of Mines and Geology (Bishop 1963), supplemented with additional data compiled by Howard and others (1989). The geology summarized in Figure 5.4-1 is consistent with larger-scale (more detailed) geologic mapping available from a wide variety of sources, as referenced below.

The following discussion is intended to provide a general overview of regional stratigraphy and structure pertinent to the surface and groundwater hydrology of the Cadiz Project area and to the alternative alignments of the proposed conveyance facilities. A more detailed discussion of groundwater resources for the Cadiz Project area is provided in Section 5.5 (Water Resources).

The crystalline basement rocks exposed in the mountain ranges of the project area consist primarily of Precambrian granitic and metamorphic rocks, which are locally overlain by a sequence of Paleozoic sedimentary rocks. The Paleozoic rocks consist of sandstones, shales, slates, limestones and dolomites which are depositional equivalents of sediments exposed on the Colorado Plateau, 100 miles to the east. These Paleozoic sediments and the underlying basement rocks have been faulted and folded by numerous periods of regional tectonism. The crystalline basement rocks are generally impermeable and, even where deeply weathered, typically yield only minor quantities of water to wells (Freiwald 1984). Some of the Paleozoic sedimentary section, particularly limestones and dolomites that are fractured or contain solution cavities, may yield large quantities of water to wells although these formations have not been explored extensively (Metropolitan 1999b).

The basement complex and the overlying Paleozoic section were locally metamorphosed and intruded by granitic plutons during Mesozoic time. In the Old Woman Mountains, the Precambrian and Paleozoic section was also intensely deformed by ductile thrusting which accompanied the Mesozoic plutonism (Karlstrom and others 1993). Throughout the project area, the crystalline basement rocks form the boundaries of the groundwater aquifer system.

In the Fenner Valley, the Paleozoic section is unconformably overlain by clastic sediments and interbedded volcanic rocks of mid- to late-Tertiary age. The Tertiary volcanic rocks consist of lava flows of basaltic to andesitic composition, and pyroclastic tuffs of rhyolitic to dacitic composition. Dikes of similar composition are exposed in the Marble and Ship mountains. The Tertiary sediments consist of conglomerate, fanglomerate, sandstone, siltstone, water-laid tuff, and lake sediments, which form a composite section more than 7,000 feet thick (Dibblee 1980). The Tertiary sediments and interlayered volcanic rocks are gently dipping, due to extensional normal faulting of late-Tertiary age.

The Quaternary and late-Tertiary alluvial fill in the basins is largely derived from the Precambrian basement rocks, Paleozoic sediments and Tertiary volcanic rocks. Geophysical evidence indicates that this alluvial fill locally exceeds 3,500 feet in thickness beneath a portion of the project area (Maas 1994). These alluvial sediments form the principal aquifers in the project area.

The playa sediments underlying Bristol, Cadiz and Danby dry lakes consist of brine-saturated clay, silt, fined-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 events (Gale 1951). The evaporite deposits formed from evaporation of both surface water and groundwater, which seeps into the playa sediments from the adjacent alluvial fans (Rosen 1989).

Bristol, Cadiz and Danby dry lakes have static groundwater levels at or near the playa surfaces (Moyle 1967; Rosen 1989). Sodium chloride and/or calcium chloride are currently being recovered from trenches and brine wells on all three of these playas. Thompson (1929), Gale (1951), Bassett and others (1959), Handford (1982) and Rosen (1989) concur that the principal recharge to the playas occurs as diffuse seepage of groundwater onto the playas from the adjacent alluvial fans.

Cadiz and Bristol dry lakes are locally bordered by active dunes formed by fine to medium-grained windblown sand. These Holocene deposits overlie older playa deposits of undifferentiated Quaternary age (Moyle 1967).

Amboy Crater, located near the western margin of Bristol Dry Lake, is a basaltic cinder cone and lava field believed to be as young as 6,000 years (Parker 1963; Hazlett 1992).

As shown on Figure 5.4-1, the alternative water conveyance alignments extend, with minor exceptions, across broad areas that are mapped as alluvium (Qal) and dune sand (Qs). The lakebed sediments (Ql), which are confined to the lower portions of the valleys, are not crossed by the water conveyance facilities.

It is estimated that groundwater levels along the water conveyance alignments vary from a few tens of feet to several hundred feet below the ground surface. As a result, groundwater is not anticipated to occur within construction excavations for the Cadiz Project.

Project Area Soils

According to *Soils of the Western United States* (Soil Conservation Service of the United States Department of Agriculture (USDA 1964), the region of the alternative water conveyance facilities includes two soil types. Areas of low topographic relief are mapped as light colored, red, desert alluvial, sandy soils. The mountain slopes consist of alluvium, colluvium and residuum from granite, gneiss, quartzite and limestone formations.

A soil study performed on part of the Cadiz Project site (Western Ag Lab 1986) found the soils to be primarily loamy sands and sandy loams. Sandy soils were encountered at a few locations; no clay soils are known in the Cadiz Project area. The soils are alkaline, with pH between 8 and 9. Caliche, defined as soils with natural cementation, usually by calcium carbonate, occurs locally in the Cadiz Project area.

The USDA Natural Resources Conservation Service (formerly the Soil Conservation Service) classifies soils into four hydrologic groups based on infiltration rates obtained for bare soil after prolonged wetting. Their distribution in the Cadiz Project area is shown on mapping by the BLM (1982). Those four soil groups are described as follows:

<u>Group A Soils</u>

Group A soils have a low runoff potential and high infiltration rate. These soils generally consist of deep, well-drained sands and gravels. USDA soil textures normally included in this group are sand, loamy sand and sandy loam. Soils in this group have an infiltration rate of more than 0.3 inch per hour. In the vicinity of the Cadiz Project area, most of the areas underlain by undifferentiated alluvium and dune sand are mapped as Group A soils. The soils underlying the project spreading basins are also classified as Group A soils, as are most of the areas traversed by the alternative water conveyance facilities.

Group B Soils

Group B soils have a moderate runoff rate and moderate infiltration rate. These soils generally consist of moderately deep to deep, moderately well- to well-drained sandy loams with moderately fine to moderately coarse texture. These soils have an infiltration rate between 0.15 and 0.3 inch per hour. Group B soils are rare in the vicinity of the Cadiz Project area, and are not present in the areas of the water conveyance facilities or the project spreading basins.

Group C Soils

Group C soils have a moderate runoff rate and slow infiltration rate. These soils generally consist of silty loam with a layer that impedes the downward flow of water or has a moderately fine to fine texture. The soils have an infiltration rate of 0.05 to 0.15 inch per hour. Group C soils in the Cadiz Project area occur in the lower part of the alluvial valleys, i.e., in the playa deposits of Bristol, Danby and Cadiz dry lakes.

Group D Soils

Group D soils have a high runoff potential and very slow infiltration. These soils consist of clay with high swell potential, soils with a permanent high water table, soils with a clay pan or clay layer near the surface or shallow soils above nearly impervious material such as bedrock. Soil textures in this group include clay loam, silt loam, sandy clay, silty clay and clay. The soils have a very low infiltration rate, at 0.05 inch per hour. Group D soils in the Cadiz Project area are present in the areas mapped as bedrock, i.e., the Kilbeck Hills, and the Marble, Ship and Iron mountains.

Erosion and Sensitivity to Disturbance

Due to the sandy or loamy nature of the soil and the sparse vegetation in most of the Cadiz Project area, the soil is highly susceptible to wind erosion, particularly on the west side of the Iron Mountains. Signs of wind erosion, such as loss of soil around the bases of rooted bushes and the buildup of windblown soil along obstructions, are common.

According to mapping by the BLM (1982), the sensitivities of soils in the area to disturbance can be classified as high, medium or low, corresponding generally to mountainous areas with shallow bedrock, alluvium on the flanks of the mountain ranges, and playa/lakebed deposits, respectively. As shown on Figure 5.4-2, the water conveyance alignments primarily cross soils classified as having medium sensitivity to disturbance, with local areas of low sensitivity. The alternative water conveyance alignments also cross the edges of areas of high sensitivity soils along the flanks of the Iron Mountains and Kilbeck Hills.

Project Area Faults and Seismicity

Regional Structural Setting

The Cadiz 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 (Dokka & Travis 1990). Roughly a dozen fault zones showing evidence of Quaternary movement (during the last 1.6 million years) have been identified in and adjacent to Bristol, Cadiz and Fenner valleys (Howard & Miller 1992). Figure 5.4-3 shows the generalized locations of these Quaternary fault zones.

Cadiz Valley is underlain by two major northwest trending faults, inferred on the basis of gravity and magnetic data (Simpson & others 1984). 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 (Howard & Miller 1992).

Right-lateral slip along the Cadiz Valley fault zone of as much as 16 miles has been postulated on the basis of correlation of a distinctive Precambrian gneiss unit across the zone (Howard & Miller 1992). 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 age (Bassett & others 1959).

Bristol Dry Lake is bordered by probable 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 (Howard & Miller 1992). Geophysical data indicate this structural depression may exceed 6,000 feet in depth (Simpson & others 1984; Maas 1994). 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 (Rosen 1989), and therefore may be tectonically active.

Fenner Gap appears to be a structural half-graben, formed by a system of northeast trending, northwest dipping normal faults, some of which are exposed in outcrops of the bedrock that flank the gap as shown in Figure 5.4-4. The presence of these northeast trending faults beneath the alluvial deposits that underlay the gap can be inferred from gravity and magnetic surveys and a seismic reflection survey conducted across the gap by NORCAL Geophysical Consultants, Inc. (1997).

Classifications of Fault Activity

Under the terms of the California Public Resources Code, an “active” fault is defined as one that has “had surface displacement within Holocene time (about the last 11,000 years).” A “potentially active” fault has been defined as one that shows evidence of surface displacement during Quaternary time (about the last 1.6 million years). These definitions are illustrated in Figure 5.4-5. The California Public Resources Code does not provide criteria for definition of “inactive” faults (Hart 1994).

These fault definitions have been augmented with the new classifications of “sufficiently active” and “well-defined” faults. These two new terms constitute the present criteria used by the State Geologist in determining whether a given fault should be zoned under the Alquist-Priolo Act (Hart 1994). For the purpose of this discussion, the older classifications of “active” and “potentially active” have been used. No “active,” “sufficiently active” or “well defined” faults have been identified in proximity to the Cadiz Project area.

Faults in the Project Area

The locations of the Cadiz Project water conveyance alignments with respect to regional geology were shown earlier on Figure 5.4-1. The locations of these alignments with respect to known Quaternary fault zones were shown earlier on Figure 5.4-3. The east and west flanks of the Iron Mountains are believed to be bounded by faults, but these faults are not known to displace Quaternary alluvium and they are, therefore, not considered to be either “active” or “potentially active.” Two faults have been mapped as crossing the water conveyance alignments, as shown on Figure 5.4-1. One is a thrust fault, known as the Scanlon thrust fault, which underlies the Eastern, Combination and Eastern/Canal alternatives near Chubbuck Station. The other is an unnamed west-trending fault that crosses the Western Alternative south of the Kilbeck Hills.

As mapped by Howard & others (1989) the Scanlon thrust fault juxtaposes Permian to Mississippian rocks (about 240 to 360 million years old) against Cambrian rocks (about 500 to 570 million years old). The Scanlon thrust fault is offset by younger northwest-trending faults, indicating that its movement predates normal faulting, typical of the project area, that occurred during mid- to late-Tertiary time. Consequently, the Scanlon thrust fault is not considered to be "active" or "potentially active."

The unnamed west-trending fault that crosses the Western Alternative south of the Kilbeck Hills is not exposed at the ground surface. This fault does not displace Quaternary alluvium and, therefore, is not considered to be either "active" or "potentially active."

Other unmapped faults may be present beneath the alluvium in the project area, but no surface expression of such faults is known. Faults that displace Quaternary alluvium are typically expressed by linear topographic escarpments or displaced drainage courses. However, such expressions are rapidly eroded and are, therefore, transient in nature. Therefore, older faults are difficult to trace across alluvial areas due to the lack of surface expression. Such faults are typically inferred on the basis of regional geologic mapping, drilling or geophysical surveys.

The system of normal faults which formed the half-graben of Fenner Gap displace and tilt volcanic rocks of mid- to late-Tertiary age, as shown in Figure 5.4-4. However, these faults do not displace Quaternary sediments and are, therefore, not considered to be either "active" or "potentially active."

Very few earthquake epicenters have been recorded in the immediate region surrounding the Cadiz Project area. Figure 5.4-6 is a generalized map of fault zones near the project area that are inferred to have had movement during Quaternary time (within the past 1.6 million years). Superposed on this map are recorded earthquake epicenters recorded by the USGS (Advanced Geologic Exploration 1997). One minor earthquake of magnitude 3 has been recorded approximately six miles west of the Western Alternative. Although a relatively large amount of micro-seismic activity has been recorded in the western portion of the area shown on Figure 5.4-6, none of the faults in this area is presently classified as "active."

Areas underlain by known, active faults are subject to special building restrictions under the Alquist-Priolo Earthquake Fault Hazards Zoning Act. The California Division of Mines and Geology (CDMG) is charged with the publication of maps, based on USGS 7.5-minute topographic quadrangle maps, showing known earthquake hazards. No official maps of earthquake fault zones have been published for any part of the Cadiz Project area. The nearest such maps that have been published are for parts of the Twentynine Palms area, approximately 40 miles southwest of the Cadiz Project site.

Future seismic activity in the Cadiz Project area is not expected to have any impacts on the boundaries between individual groundwater basins or to create channels for movement of groundwater between basins.

<u>Regional Seismicity</u>

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 Cadiz Project area, well outside the area earlier shown on Figures 5.4-3 and 5.4-6. The timing of future large earthquakes on the San Andreas fault zone, which could cause strong ground shaking at the site, is unknown. However, considering that the average return interval for large to great (Magnitude 7 or greater) earthquakes on the south-central portion of the San Andreas fault zone is on the order of 140 years, and that the most recent such earthquake in this area occurred in 1837, the potential for strong, long duration ground shaking during the 50-year term of the Cadiz Project is evaluated as high.

The nearest other significant fault is the Ludlow fault zone, located 25 miles west of the Cadiz Project area (Howard & Miller 1992). The Ludlow fault zone is a major northwest trending structure, having a mapped length of over 50 miles. A portion of this strike length is shown on Figures 5.4-3 and 5.4-6. It is reported to have undergone a cumulative right lateral slip of over four miles. The Ludlow fault zone has displaced alluvium as young as late Pleistocene. In accordance with the definitions of the California Public Resources Code, this fault zone is considered to be "potentially active." As shown in Figure 5.4-6, the Ludlow, Sheephole, 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 is classified as "active," and none trends toward the Cadiz Project area.

In addition to the San Andreas fault zone, other regional fault zones that have been active in Holocene time (last 11,000 years) include the Bullion and Mesquite Lake fault zones. These faults are located 35 and 40 miles west of the Cadiz Project area respectively, west of the area shown on Figures 5.4-3 and 5.4-6. The maximum probable earthquake magnitudes on these faults are estimated to be similar to those on the San Andreas fault zone (Magnitude 7.1), but the return interval for earthquakes on these faults is far greater, on the order of 5,000 years (Peterson and others, 1996). Therefore, the potential for a seismic event along these faults during the design life of the Cadiz 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. The Hector Mine earthquake is reported to have triggered movement on the Bullion fault zone, which may be a southeastern extension of the Lavic Lake fault. Total surface rupture has been mapped for approximately 25 miles. Offset is estimated to be as much as 15 feet of right-lateral strike slip. This earthquake is considered to be one of the four largest to have occurred in Southern California this century.

The epicenter of the Hector Mine earthquake was located approximately 45 miles west of the Cadiz Project area, and the closest surface rupture was located approximately 35 miles southwest of the Cadiz Project area. Although the Cadiz Project is preliminarily estimated by the USGS to have been within the zone of 10% g (gravity) peak acceleration, no damage of any kind has been observed to any existing facilities in the area. These facilities include 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).

Site of Project Spreading Basins

Topography

The proposed location for the project spreading basins is in Fenner Gap, located between the Marble and Ship mountains, as shown earlier in Figure 5.4-1. The site is located on alluvial fan deposits having a gentle slope toward the southwest of approximately one percent (50 feet/mile). Specific attention was given in the selection of this site to avoidance of major active washes which flow into and through Fenner Gap. Accordingly, the site will require relatively little protection from potential erosion during major storm events.

Geology and Soils

As described in greater detail later in Section 5.5 (Water Resources), the Quaternary alluvium at the project spreading basin site was investigated by drilling seven shallow bore holes, eleven observation wells and a full-scale production well to test for the possible occurrence of continuous clay layers at depth. No clay layers were found as a result of this drilling. Such clay layers could impede the effectiveness of spreading imported Colorado River water at this site. The site was further tested by construction and operation of the pilot spreading basin, described later in Section 5.5 (Water Resources). The alluvium at the project spreading basin site is locally underlain at depth by carbonate, quartzite and shale formations of Paleozoic age and granitic rock of Precambrian age. According to mapping performed by the BLM (1982), the sensitivity of the soil to disturbance at the proposed site for the spreading basins is classified as moderate.

Faults and Seismicity

As described above, Fenner Gap appears to be a structural half-graben, formed by a system of northeast trending, northwest dipping normal faults as shown earlier on Figure 5.4-4. The Paleozoic strata are steeply rotated between the faults, and dip at angles which range from approximately 25 to more than 80 degrees. These faults also displace and tilt volcanic rocks of mid- to late-Tertiary age to angles of approximately 25 degrees, indicating that some of the fault movement occurred after deposition of these volcanic rocks. However, none of these faults is known to displace Quaternary sediments, and accordingly, they are not considered to be either “active” or “potentially active.”

Site of Project Wellfield

Topography

The project wellfield is located in Fenner Gap, between the Marble and Ship mountains, and on the broad alluvial fan down-gradient from the gap. The wellfield development area was shown earlier in Figure 5.4-1. This terrain is located on alluvial fan deposits having very gentle topography and a slope toward the southwest, which ranges between one and two percent (50 to 100 feet/mile). Specific well sites were selected to avoid major active washes, which flow through the area. Accordingly, the specific well sites will require relatively little protection from potential erosion during major storm events.

Geology and Soils

The project wellfield will be located entirely on Quaternary alluvium, which has been tested by numerous bore holes, observation wells and by the long term pumping history of the seven irrigation wells operated by Cadiz Inc. The hydrological characteristics of the wellfield site are described in detail in Section 5.5 (Water Resources). The alluvium at the site is locally underlain at depth by carbonates, quartzite and shale of Paleozoic age and granitic rock of Precambrian age. Based on available geophysical data (including both gravity and seismic reflection surveys), the depth to bedrock underlying individual well sites ranges from approximately 800 feet to more than 3,000 feet.

According to mapping by the BLM (1982), the sensitivity of the soil to disturbance at the proposed site for the project wellfield is classified as moderate.

Faults and Seismicity

As described above, Fenner Gap appears to be a structural half-graben, formed by a system of northeast trending, northwest dipping normal faults as shown earlier in Figure 5.4-4. The Paleozoic strata are steeply rotated between the faults, and dip at angles which range from approximately 25 to more than 80 degrees. The faults also displace and tilt volcanic rocks of mid- to late-Tertiary age to angles of approximately 25 degrees, indicating that some of the fault movement occurred after deposition of these volcanic rocks. However, none of these faults is known to displace Quaternary sediments, and accordingly, they are not considered to be either “active” or “potentially active.”

Water Conveyance Facility Alignments

Eastern and Eastern/Canal Alternatives

Topography. The alignment of the Eastern and Eastern/Canal Alternatives originates at the Iron Mountain Pumping Plant and proceeds northeasterly around the southeast edge of the Iron Mountains. The alignment then proceeds northwest along the eastern flanks of the Iron Mountains and Kilbeck Hills (the western margin of the Danby Dry Lake depression) to Chubbuck Station on the ARZC line. From this point, the alignment proceeds northwesterly to a point west of the Ship Mountains, and then north to Fenner Gap and the project spreading basins. This last segment of the water conveyance alignment is common to all alternatives.

Geology and Soils. The alignment of the Eastern and Eastern/Canal Alternatives traverses two geologic units: alluvium and dune sand. Dune sand is present near the south end of the alignment (where it curves northwesterly around the southeast portion of the Iron Mountains), approximately six miles northwest of this point (where the conveyance facilities come within one mile of the northwestern end of Danby Dry Lake), and three miles north of that point (where the alignment passes the east flank of the Kilbeck Hills). In all, approximately six miles of the 35-mile length of the Eastern Alternative traverses dune sand; the remainder is undifferentiated alluvium.

The Eastern and Eastern/Canal Alternatives originate in an area of high sensitivity to soil disturbance at the Iron Mountain Pumping Plant. From where the water conveyance facilities alignment turn from northeast to north in the area northeast of the Iron Mountain Pumping Plant, the balance of the alignment traverses soils of moderate sensitivity to disturbance.

Faults and Seismicity. The southern segment of the alignment for the Eastern and Eastern/Canal Alternatives parallels and is approximately one-half mile east of a fault located on the east side of the Iron Mountains as shown earlier on Figure 5.4-1. This fault, referred to as the Iron Mountains fault by Howard & Miller (1992), is reported to be of probable Pliocene age. Accordingly, it is not classified as either “active” or “potentially active.” Farther north, the Eastern Alternative crosses a projection of the Scanlon thrust fault, which is also not considered to be “active” or “potentially active.”

In the vicinity of Fenner Gap, the Eastern and Eastern/Canal Alternatives (along with the other alternative alignments) cross possible projections of the normal faults that formed the half-graben structure of Fenner Gap. However, as previously discussed, these faults are not known to displace Quaternary alluvium and are, accordingly, not considered to be either “active” or “potentially active.” Since the Eastern and Eastern/Canal alternatives generally parallel the overall northwest-southeast trend of the regional topography, it is considered unlikely that they cross any other significant fault zones.

Western Alternative

Topography. The alignment of the Western Alternative originates at the west end of the Iron Mountain Tunnel and proceeds north-northwesterly along the west side of the Iron Mountains and Kilbeck Hills, gradually curving northeasterly to a point at the north end of the Kilbeck Hills, where it turns northwest along the ARZC line. From this point northward, the Western Alternative follows the alignment common to all four alternatives.

Geology and Soils. The Western Alternative traverses two geologic units: alluvium and dune sand. The alignment traverses dune sand from a point approximately two miles north of the Iron Mountain Tunnel to a point west of the central part of the Kilbeck Hills. In all, approximately 12 miles of the 35-mile length of the Western Alternative traverse dune sand; the remainder is undifferentiated alluvium.

The Western Alternative originates in an area of medium sensitivity to soil disturbance, and traverses areas of medium sensitivity to disturbance throughout its length, except west of the Kilbeck Hills where it traverses an area of low sensitivity for approximately four miles.

Faults and Seismicity. The southern reach of the Western Alternative parallels and is approximately one to two miles west of an unnamed north-trending fault that runs through the western flank of the Iron Mountains. The alignment also crosses an unnamed west-trending fault at the southern end of the Kilbeck Hills as shown earlier on Figure 5.4-1. Neither of these faults is mapped as displacing Quaternary alluvium and, accordingly, they are not considered to be either “active” or “potentially active.”

As described above, in the vicinity of Fenner Gap the common segment of all four alternatives crosses possible projections of the normal fault system that formed the half-graben structure of Fenner Gap. However, these faults are not known to displace Quaternary alluvium and are, accordingly, not considered to be either “active” or “potentially active.” Since the Western Alternative generally parallels the overall northwest-southeast trend of the regional topography, it is considered unlikely that it crosses any other significant fault zones.

Combination Alternative

Topography. The alignment of the Combination Alternative originates at the west end of the Iron Mountain Tunnel and proceeds north-northwesterly along the west side of the Iron Mountains, following the same alignment as the Western Alternative. However, south of the Kilbeck Hills, the Combination Alternative turns northeasterly through the gap between the Iron Mountains and Kilbeck Hills. It then proceeds northward along the alignment of the Eastern and Eastern/Canal Alternatives to a point along the ARZC line. From this point, the alignment follows the Eastern and Eastern/Canal Alternatives route northwesterly along the railroad line to a point west of the Ship Mountains, and then north to Fenner Gap and the project spreading basin area.

Geology and Soils. The alignment of the Combination Alternative traverses two geologic units: alluvium and dune sand. The water conveyance facility alignment traverses dune sand from a point approximately two miles north of the Iron Mountain Tunnel to a point east of the central part of the Kilbeck Hills. In all, approximately 12 miles of the 35-mile length of the Combination Alternative are within undifferentiated alluvium. The Combination Alternative traverses areas of medium soil sensitivity to disturbance throughout its length.

Faults and Seismicity. The southern segment of the Combination Alternative (also common to the Western Alternative) parallels and is approximately one to two miles west of an unnamed north-trending fault that runs through the western flank of the Iron Mountains. The alignment also crosses the unnamed west-trending fault at the southern end of the Kilbeck Hills. Neither of these faults is mapped as displacing Quaternary alluvium and, accordingly, they are not considered to be either active or potentially active.

As described above, in the vicinity of Fenner Gap the common segment of all four alternatives crosses possible projections of the normal fault system that formed the half-graben structure of Fenner Gap. These faults are not known to displace Quaternary alluvium and are, accordingly, not considered to be either "active" or "potentially active." Since the Combination Alternative generally parallels the overall northwest-southeast trend of the regional topography, it is considered unlikely that it crosses any other significant fault zones.

5.4.2 CEQA THRESHOLDS OF SIGNIFICANCE

The proposed Cadiz Project facilities may be affected by the existing soil and geologic conditions along the proposed water conveyance alignments. For example, seismic shaking due to an earthquake on a nearby fault could cause structural damage to the water conveyance facilities, resulting in flooding and consequent erosion. The Cadiz Project may have the potential to affect the soil and other geologic formations within portions of the project area. Examples of such potential impacts include soil erosion, land subsidence and changes in groundwater levels. These potential impacts are discussed in detail later in Section 5.5 (Water Resources).

Guidance for preparing the information contained in this section is provided by the California Division of Mines and Geology Note 46 (CDMG, 1975). This report, *Guidelines for Geologic/Seismic Considerations in Environmental Impact Reports*, provides a checklist of potential geologic problems that should be discussed in an EIR. According to Note 46, a project is considered to have a significant adverse impact if it would:

(a) Result in or expose people or structures to any of the following:

- **Earthquake Damage**. Fault movement, liquefaction, land-slides, differential compaction/ seismic settlement, ground shaking, tsunami, seiche, seismically induced flooding;
- **Loss of Mineral Resources**. Loss of access, deposits covered by changed land use, zoning restrictions. These potential impacts are discussed later in Section 5.9 (Energy and Mineral Resources);
- **Waste Disposal Problems**. Change in groundwater levels (addressed in Section 5.5), disposal of excavated material, percolation of waste material;
- **Slope and/or Foundation Instability**. Landslides and mudflows, unstable cut and fill slopes, collapsible and expansive soil, trench wall stability;
- **Erosion, Sedimentation, Flooding**. Erosion of graded areas, alteration of runoff, unprotected drainage ways, increased impervious surfaces;
- **Land Subsidence**. Due to extraction of groundwater, gas, oil, geothermal energy; hydro-compaction; and peat oxidation; and
- **Volcanic Hazards**. Lava flows, ash falls.

In addition, for purposes of CEQA an impact of the Cadiz Project related to topography and landform was determined to be significant if it would:

(a) Remove or substantially alter a special or unique topographic feature on the site;
(b) Result in substantial landform alteration (cuts or fills more of 50 feet or more); and
(c) Conflict with Elements of the County General Plan and supporting documentation, specifically regarding special and unique topographic features.

For a further discussion of CEQA thresholds of significance, see Section 5.20.

5.4.3 METHODOLOGY

This analysis of potential impacts of the Cadiz Project related to topography, geology, seismicity and soils is based on a review of published and other available reports concerning the geology, soils, groundwater and seismicity of the Cadiz Project area. These reports are cited in the text and are listed in Section 15.0 (References).

5.4.4 IMPACTS

The design and construction of the Cadiz Project will conform to standard engineering and construction procedures (i.e. standard design requirements of Metropolitan and requirements of the Uniform Building Code).

Of the potential geologic impacts outlined above, the following do not apply to the Cadiz Project area and are not considered further in this document.

Landslides

The project wellfield and project spreading basins are located on gently sloping terrain. The four alternative water conveyance alignments also traverse areas of gently sloping topography. Cadiz Project construction will not involve significant alteration of land surface gradients. Therefore, construction of the Cadiz Project facilities is unlikely to result in conditions that could trigger landslides. Although steeper slopes are present in mountainous areas, topographically higher than the alignments, the mountains consist largely of crystalline rocks that are not typically prone to landsliding. Further, no landslides have been documented in the mountains adjoining the Cadiz Project area. Strong ground shaking from earthquakes on nearby faults could cause rock instabilities (i.e. rock falls, rock toppling) in the mountainous areas. However, because the pipelines will be buried and the Cadiz Project facilities will be sufficiently distant from the mountainous areas, they are not considered to be at risk.

Sand Flow

The project spreading basins could conceivably interrupt the movement of windblown sand and affect the formation of sand dunes such as those found adjacent to Cadiz and Danby dry lakes. However, the prevailing winds in the Cadiz Project area are westerly, and the project spreading basins are located approximately six miles north of the sand dunes, at the northern and eastern margins of Cadiz Dry Lake. Consequently, the potential for impact to any sand dunes in or adjacent to the Cadiz Project area is very remote.

Tsunami/Seiche

Since the Cadiz Project area is located far from any oceans or permanent lakes, there is no potential for tsunamis or seiches in the Cadiz Project area.

Percolation of Waste Material

Since excavation for the Cadiz Project facilities will occur in natural soils only, and since the excavated material will be backfilled into the trenches or spread along the pipeline reaches and revegetated after construction, there is no potential for percolation of any environmentally harmful material from the excavated soils. Water that may be generated from possible dewatering operations would be disposed of by percolation and/or evaporation. Such water could also be used for moisture-conditioning of soils to be placed as trench backfill. In any event, water disposal, if needed, would be performed according to construction dewatering regulatory and permit requirements. As a result, any potential impact associated with disposal of waste water during construction is not considered significant.

Increased Impervious Surfaces

No construction of impervious surfaces of substantial size is proposed under the Cadiz Project alternatives. Only the small pump stations, small well sites and electrical substations involve impermeable surface coverage. Therefore, the impervious surfaces that will be constructed will be insufficient in size to significantly impact percolation of surface waters into the subsurface.

Volcanic Hazards

Amboy Crater, located 17 miles west of Fenner Gap, is a volcanic cinder cone that has been dated as less than 10,000 years old. No historic volcanic activity is known in the eastern Mojave Desert, and the likelihood of a volcanic eruption during the operational life of the Cadiz Project is very low. In the event that an eruption at, for example, Amboy Crater resulted in an ash fall at the Cadiz Project site, ash deposited in the project spreading basins will be removed through normal basin maintenance and the buried pipelines will be unaffected.

The following discussion analyzes the potential geologic impacts that could occur from implementation of the Cadiz Project. This discussion is organized by Cadiz Project alternative alignment, with each type of impact addressed for each alternative.

Eastern and Eastern/Canal Alternatives

<u>Topography</u>

The project spreading basins will be constructed along the natural surface gradient with the excavated soil used to construct the berms. No importation of soil or deep excavation of native material is expected. Therefore, no significant impacts to topography would occur under these alternatives.

Long-term effects on topography would occur if the project wellfield or water conveyance facilities entailed excavation in areas of bedrock outcrops. However, construction of the Eastern or Eastern/ Canal Alternatives would not be expected to involve such excavation. Wellfield construction requires minor surface modification and no significant impacts to topography would occur.

<u>Faults and Seismicity</u>

The possibility exists that the project spreading basins could be damaged in the event of a major earthquake on a nearby fault. Liquefaction, differential settlement and hydrocompaction are associated risks. However, any such damage would depend to a large degree on the magnitude of the event and the distance of the earthquake epicenter from the Cadiz Project area. No known active or potentially active faults underlie the Cadiz Project site. Rupture of the project spreading basins during a seismic event could result in surface spillage of water, with the potential for localized flooding and erosion. This potential impact could occur only during spreading operations. Water would typically be only one to two feet deep and inflow to the basins would be shut off after a large magnitude event. As a result, impacts would be less than significant.

The project wellfield and wellfield manifold pipeline could be damaged in the event of a major earthquake. If this should occur during wellfield operations, the wellfield operations would be shutdown for repairs. No significant impacts would occur.

The possibility also exists that the water conveyance facilities could be damaged in the event of a major earthquake. Liquefaction, differential settlement and ground movement are the anticipated risks, and pipelines are potentially susceptible to damage. Pipeline rupture during a seismic event could result in underground and surface spillage of water, with the potential for localized flooding, soil saturation and mudflows, depending on where a rupture occurred and the characteristics of the local geological formations. This potential could occur only during the spreading and withdrawal operations. Such operations would be suspended and facilities inspected after a large magnitude event. The pipeline will be designed to avoid and minimize the potential for these impacts. Therefore, no significant impacts would occur.

Liquefaction

Standards for the evaluation of hazards associated with seismically-induced soil liquefaction are provided by the CDMG (Special Publication 117, 1997). The soils in the Cadiz Project area, including sand and silt, include types potentially susceptible to liquefaction. However, indicators of a low potential for liquefaction include the presence of bedrock near the surface and the occurrence of groundwater at a depth greater than 50 feet which is generally the case throughout the Cadiz Project area. Liquefaction could occur in the vicinity of the project spreading basins in the event that groundwater mounding were to rise to within approximately 50 feet of the ground surface. This potential impact will be reduced to a less than significant level with implementation of mitigation measure G-2. Liquefaction is addressed in further detail later in Section 5.5 (Water Resources) and in the Management Plan.

Local areas of shallow groundwater may exist where the alignment of the water conveyance facilities for the Eastern and Eastern/Canal alternatives pass in close proximity to Danby Dry Lake. This is the only segment of the water conveyance facilities alignment that has a significant risk of liquefaction. Mitigation will reduce this risk to a level of insignificance.

Soils

Project Spreading Basins. No expansive soils have been observed in proximity to the project spreading basin. However, the alluvial soils at this site are considered potentially susceptible to hydrocompaction. For this reason during construction of the pilot spreading basins, survey benchmarks were installed to identify and monitor any hydrocompaction that might occur as a result of the pilot test. To date, no hydrocompaction has been detected. Any hydrocompaction that may occur during operation of the project spreading basins would be reduced to a level of insignificance by the appropriate design and construction of the spreading basins.

Project Wellfield. Soil impacts for the project wellfield and manifold pipeline would be short term in nature, as the material excavated for the cut-and-cover trench would be suitable for backfilling the manifold trench, and would be replaced to cover the pipeline while maintaining the soil profiles. Short duration effects to disturbed soils are predicted and are described below. Excess materials from well drilling would be disposed of around each well.

Based on all available geological data, expansive soils are considered unlikely to be present in the vicinity of the project wellfield and manifold pipeline. However, some soils in proximity to the wellfield and manifold may have a reasonably high potential of being susceptible to hydrocompaction if saturated by water. The risk that the wellfield or manifold pipeline could introduce water into this soil and trigger hydrocompaction is evaluated as low, and impacts would be less than significant.

Water Conveyance Facilities. Soil impacts for the water conveyance facilities for the Eastern and Eastern/ Canal alternatives would be short term in nature, as the material excavated for the cut-and-cover trench would be suitable for backfilling the trench, and would be replaced to cover the pipeline while maintaining the soil profiles. Short duration effects to disturbed soils are predicted as described below.

Along the water conveyance facility, approximately 181,000 cubic yards of excavated material would be spread over the permanent right-of-way, to a depth of approximately four inches along the alignment. No soil disposal sites are anticipated for the other Cadiz Project facilities.

Since the water conveyance facilities for the Eastern and Eastern/Canal Alternatives cross two areas where rock could be encountered (i.e., areas are northeast of the Iron Mountain Pumping Plant and north of the Kilbeck Hills near Chubbuck Station), some ripping or blasting could be required.

Based on published and other available geologic and soil mapping, expansive soils are considered unlikely to be present along the water conveyance alignments. However, project area soils have a reasonably high potential of being susceptible to hydrocompaction when saturated with water. Design phase investigations will identify whether or not there is a potential for hydrocompaction along the Eastern and Eastern/Canal alternatives and will identify appropriate design features to address this issue, if needed. In the case of the Eastern Alternative, because the water will be conveyed via pipeline, as opposed to conveyance by a canal, the potential for the project pipeline to introduce water into the soil and trigger hydrocompaction is considered to be very low. For the Eastern/Canal Alternative, the potential for leakage into the underlying soil and the resulting risk of hydrocompaction is considered greater. Appropriate design and construction measures would be necessary, as required by mitigation measure G-3, described later in this section. Therefore, impacts would be less than significant.

<u>Slope Stability</u>

Project Spreading Basins. The project spreading basins would be constructed with berms formed from material excavated from the adjacent basins. This is expected to result in balanced cut-and-fill over the entire spreading basin facility. This design objective has been tested in the pilot spreading basin test with excellent results. Although precautions would be required to minimize and mitigate erosion of the berms due to wave action in the basins during spreading operations, no permanent instabilities are anticipated due to the low angles of the slopes and the compaction of the berms during construction. Commonly accepted construction practices would mitigate the potential for impacts due to berm stability to a level of less than significant.

No permanent cut or fill slopes are planned for the project wellfield or pipeline conveyance facilities.

The Eastern/Canal Alternative would involve construction of a permanent excavation along the canal segment of the alignment. In this case, specific design studies and commonly accepted construction practices would mitigate the potential for stability impacts related to the canal excavation to a level of less than significant.

Erosion

Project Spreading Basins. Special attention would be given during design and construction of the project spreading basin to mitigate any increased risk of soil erosion. No significant impacts would occur.

Project Wellfield. Grading for construction of the project wellfield and manifold pipeline would be limited to the conveyance facility and adjacent access roads. After the manifold pipelines were installed, the trench would be backfilled with compacted fill, and excess soil from the pipeline trench would be placed as a thin compacted fill along the alignment. As a result, the disturbed soils would be left in a compacted, recontoured state, and would not be substantially more susceptible to erosion than existing native soils. Therefore, no significant impact would occur.

Water Conveyance Facilities. Grading for the water conveyance facilities for the Eastern and Eastern/Canal Alternatives would be limited to the pipe and canal excavation and an adjacent access road. After the pipe is installed, the trench would be backfilled with compacted fill, and excess soil from the pipeline trench would be moisture conditioned, as appropriate, and placed as a thin compacted fill along the alignment. As a result, the disturbed soils would be left in a compacted, recontoured state, and would not be substantially more susceptible to erosion than existing native soils. Therefore, no significant impact would occur.

Drainage and Flooding

Project Spreading Basins. The project spreading basins have been specifically located to avoid all major natural drainages into and through Fenner Gap. Additional precautions would be taken during final design and construction to provide protection of the spreading basins from storm flow on minor drainages in the area. Accordingly, no significant erosion would result from construction or operation of the project spreading basins.

Periodic flash flooding occurs in desert regions as the result of heavy rainfall in upland areas. Because the project spreading basin facilities have been located outside of major drainages, any periodic flash flooding in the project area would not result in significant impact.

Project Wellfield. Grading for the project wellfield and manifold pipeline would not create new drainages. However, there is potential for erosion at locations where the manifold pipelines cross ephemeral streams, and erosion protection at such crossings may be required. Design studies will be performed to evaluate the potential need for erosion control.

Because the individual well sites would be above ground level and the manifold pipelines would have adequate burial, periodic flash flooding in the Cadiz Project area would not have a significant impact on these facilities.

Water Conveyance Facilities. Grading for the water conveyance facilities would not create new drainages. However, there is potential for erosion at locations where the water conveyance facility crosses ephemeral arroyos. Based on the depth of pipeline burial, erosion protection along existing arroyos may be required for the Eastern Alternative. Detailed design studies would be prepared in conjunction with final project design to evaluate the potential need for erosion protection of water conveyance facilities where the Eastern and Eastern/Canal alternatives cross arroyos**.**

Because the water conveyance facility would have adequate burial, periodic flash flooding in the Cadiz Project area would not create a potential impact. Design studies will be needed to evaluate the use of alternative structures where the Eastern and Eastern/Canal alternatives cross arroyos**.**

Sedimentation

Project Spreading Basins. The rate of natural sedimentation in proximity to the project spreading basins is very slow and it is not expected to be substantially changed by construction or operation of the project spreading basin facilities. Although the project spreading basins would collect windblown dust and other debris over time, these materials would be removed during routine maintenance and deposited at an appropriate landfill or at Cadiz agricultural holdings. Therefore, the potential for accumulation of sedimentation would not result in a significant impact under these alternatives.

Project Wellfield. The rate of sedimentation in the vicinity of the project wellfield and manifold pipeline is estimated to be slow and would not be substantially changed by Cadiz Project construction or operation. Therefore, no significant impact would occur.

Water Conveyance Facilities. The rate of sedimentation along the water conveyance facility is estimated to be slow and it is not anticipated to be substantially changed by Cadiz Project construction. Therefore, the potential for accumulation of sedimentation over the pipeline would not be an impact to the Cadiz Project.

Subsidence

Project Spreading Basins. Ground surface subsidence may occur as the result of the extraction of groundwater and is a potential concern in the project area, if thick lenses of clay are dewatered. Due to the planned extraction of groundwater during project withdrawal operations, subsidence does pose a potential concern for parts of the project area in the immediate vicinity of the project wellfield. Because no susceptible clay lenses would be dewatered during construction or operation of the project spreading basins, subsidence would not be expected to occur as a result of spreading operations. This topic is addressed in greater detail later in Section 5.5 (Water Resources) and in the Management Plan.

Project Wellfield. Ground surface subsidence as the result of extraction of groundwater is a potential concern within portions of the project wellfield, if thick lenses of clay are dewatered. Due to the planned extraction of groundwater during project withdrawal operations, subsidence does pose a potential concern in the project area. This risk is greatest in the western parts of the wellfield, were relatively fine-grained sediments occur at depth below the water table. This topic is addressed in greater detail in Section 5.5 (Water Resources), and in the Management Plan.

Water Conveyance Facilities. Soil subsidence as the result of large-scale withdrawal of groundwater is a potential concern in desert areas, if thick lenses of clay are dewatered. Large-scale extraction of groundwater is not expected as part of the water conveyance facility construction and, accordingly, no risk of subsidence would occur under these alternatives.

Western Alternative

Topography

Project Spreading Basins and Project Wellfield. Similar to the Eastern and Eastern/Canal Alternatives, the impacts of the project spreading basins and project wellfield under the Western Alternative on topography would not be significant.

Water Conveyance Facilities. Long term effects on topography would occur if the Cadiz project entailed excavation in areas of bedrock outcrops. However, the Western Alternative alignment for the water conveyance facility is not anticipated to involve such excavation. Therefore, no significant impacts to topography are anticipated.

Faults and Seismicity

The possibility exists that the project spreading basins, project wellfield and/or the water conveyance facility could be damaged in the event of a major earthquake. However, the Western Alternative does not have any geological characteristics that differ substantially from the Eastern Alternative as discussed earlier in Section 5.4.4. Accordingly, no differences in relative risk would occur.

Liquefaction

Project Spreading Basins and Project Wellfield. The project spreading basins and project wellfield, similar to the Eastern and Eastern/Canal Alternatives, are potentially susceptible to liquefaction. This potential impact will be reduced to a less than significant level with implementation of mitigation measure G-2. Liquefaction is discussed in more detail in Section 5.5 (Water Resources) and is addressed in the Management Plan.

Water Conveyance Facilities. Unlike the Eastern Alternative discussed earlier, the water conveyance facilities for the Western Alternative do not cross any geological terrain underlain by shallow groundwater. Therefore, the risk of liquefaction in the event of a major seismic event is not considered significant for the Western Alternative.

Soils

Project Spreading Basins and Project Wellfield. The soils impacts for the project spreading basins and project wellfield are the same for the Western Alternative as for the Eastern and Eastern/ Canal alternatives.

Water Conveyance Facilities. Soil impacts for the water conveyance facilities in the Western Alternative would be short-term, as the material excavated for the cut-and-cover trench would be suitable for backfilling the trench, and would be replaced to cover the pipeline while maintaining the soil profiles. Short-duration effects to disturbed soils are predicted. Except for a higher incidence of dune sand along the alignment of the Western Alternative, the Western Alternative does not differ substantially in any geological characteristics from the Eastern Alternative discussed earlier.

Since the Western Alternative water conveyance facility does not cross any bedrock outcrops, no blasting is anticipated at this time. However, the conveyance facility does cross one area, on the west side of the Kilbeck Hills, where harder than normal materials may be encountered. It is anticipated that standard excavation equipment would be able to excavate the trench in this area. However, some ripping and blasting may possibly be required.

<u>Expansive and Compressible Soils</u>

Project Spreading Basins and Project Wellfield. The project spreading basins and project wellfield for the Western Alternative are the same as for the Eastern and Eastern/Canal alternatives. Therefore, their potential impacts to and from expansive and compressible soils would be the same.

Water Conveyance Facilities. Based on published geologic and soil mapping, expansive soils are considered unlikely to be present along the water conveyance facility for the Western Alternative. The Western Alternative does not have any geological or soils characteristics that differ substantially from the Eastern Alternative discussed above.

<u>Slopes and Trench Wall Stability</u>

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and project wellfield on slopes would be the same for the Western Alternative as described earlier for the Eastern and Eastern/Canal alternatives.

Water Conveyance Facilities. No permanent cut slopes are planned for the water conveyance facilities, and fills placed to dispose of excess trench excavation materials would be thin, resulting in gentle slopes. Therefore, no potential slope stability hazards are anticipated for permanent slopes under the Western Alternative. Design studies would be needed to evaluate appropriate construction techniques within the dune sand portions of the alignment, as required by mitigation measure G-3 described later in this section.

<u>Erosion</u>

Project Spreading Basins and Project Wellfield. Erosion impacts for the project spreading basins and project wellfield under the Western Alternative would be the same as for the Eastern and Eastern/Canal alternatives.

Water Conveyance Facilities. Grading for the Western Alternative water conveyance facility would be limited to the pipeline trench and the adjacent access road. After the pipeline is installed, the trench would be backfilled with compacted fill, and excess soil from the pipeline trench would be moisture conditioned, as appropriate, and placed as a thin compacted fill along the alignment. As a result, the disturbed soils would be left in a compacted, recontoured state, and would not be substantially more susceptible to erosion than existing native soils.

<u>Drainage and Flooding</u>

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and project wellfield on drainage and flooding would be the same as for the Eastern and Eastern/Canal alternatives.

Water Conveyance Facilities. Grading for the water conveyance facility would not create new drainages. However, there is potential for erosion at locations where the pipeline alignment crosses ephemeral arroyos. Based on the depth of pipeline burial, erosion protection along existing arroyos may be required. Design studies will be needed to evaluate the potential need for erosion control where the conveyance facility crosses arroyos.

Periodic flash flooding occurs in desert regions as the result of heavy rainfall in upland areas. Because the pipeline would have adequate burial, periodic flash flooding in the Cadiz Project area would not create a potential impact under the Western Alternative.

Sedimentation

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and the project wellfield on sedimentation would be the same as for the Eastern and Eastern/Canal alternatives.

Water Conveyance Facilities. The rate of sedimentation along the water conveyance facility route is estimated to be slow, and is not anticipated to be significantly changed by Cadiz Project construction. Therefore, the potential for accumulation of sediment over the pipeline would not be an impact to the Western Alternative.

Subsidence

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and project wellfield on subsidence would be the same as for the Eastern and Eastern/Canal alternatives. As with these other alternatives, due to the planned extraction of groundwater during Cadiz Project operations, subsidence does pose a potential concern for parts of the Cadiz Project area underlying and surrounding the project wellfield. This topic is addressed in Section 5.5 (Water Resources) and in the Management Plan.

Water Conveyance Facilities. As described earlier for the Eastern Alternative, no risk of subsidence would occur as a result of the water conveyance facility construction.

Combination Alternative

Topography

Project Spreading Basins and Project Wellfield. The impacts of the project spreading basins and the project wellfield for the Combination Alternative would be the same as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. Long-term effects on topography would occur if the water conveyance facilities entailed excavation in areas of bedrock outcrops. However, the Combination Alternative would not be expected to involve such excavation. Therefore, no significant impacts to topography would occur under the Combination Alternative.

Faults and Seismicity

The possibility exists that the project spreading basins, project wellfield and/or the water conveyance facility could be damaged in the event of a major earthquake. However, the Combination Alternative does not have any geological characteristics that differ substantially from the other alternatives discussed above. Accordingly, no differences in relative risk are anticipated.

Liquefaction

Project Spreading Basins and Project Wellfield. Similar to the other three Alternatives discussed above, the project spreading basins and project wellfield would be potentially susceptible to liquefaction. This potential impact will be reduced to a less than significant level with implementation of mitigation measure G-2. Liquefaction is discussed in more detail in Section 5.5 (Water Resources) and in the Management Plan.

Water Conveyance Facilities. Unlike the Eastern Alternative discussed above, the water conveyance facility for the Combination Alternative would not cross any geological terrain underlain by shallow groundwater. Accordingly, the risk of liquefaction in the event of a major seismic event is not considered significant under the Combination Alternative.

<u>Soils</u>

Project Spreading Basins and Project Wellfield. The soils impacts for the project spreading basins and project wellfield would be the same for the Combination Alternative as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. Soil impacts for the water conveyance facility for the Combination Alternative would be short term, as the material excavated for the water conveyance facility would be suitable for backfilling the trench, and would be replaced to cover the pipeline while maintaining the soil profiles. Short-duration effects to disturbed soils are predicted. The Combination Alternative does not differ substantially in any geological characteristics from the three alternatives discussed above.

<u>Expansive and Compressible Soils</u>

Project Spreading Basins and Project Wellfield. The project spreading basins and project wellfield for the Combination Alternative would have the same impacts related to expansive and compressible soils as the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. Based on published geologic and soils mapping, expansive soils are considered unlikely to be present along the water conveyance facility for the Combination Alternative. This Alternative does not have any geological characteristics that differ substantially from the Alternatives discussed above.

<u>Slope Stability</u>

Project Spreading Basins and Project Wellfield. The impacts of the project spreading basins and project wellfield on slopes would be the same as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. No permanent cut slopes are planned for the water conveyance facility and fills placed to dispose of excess trench excavation materials would be thin, resulting in gentle slopes. Therefore, no potential slope stability hazards would occur for permanent slopes under the Combination Alternative.

<u>Erosion</u>

Project Spreading Basins and Project Wellfield. The impacts of the project spreading basins and project wellfield on erosion under the Combination Alternative would be the same as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. Grading for the Combination Alternative water conveyance facility would be limited to the pipeline trench and to an adjacent access road. After the pipeline was installed, the trench would be backfilled with compacted fill, and excess soil from the pipeline trench would be moisture conditioned, as appropriate, and placed as a thin compacted fill along the conveyance facility. As a result, the disturbed soils would be left in a compacted, recontoured state and would not be substantially more susceptible to erosion than existing native soils. Therefore, no significant impact would occur.

Drainage and Flooding

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and project wellfield on drainage and flooding would be the same for the Combination Alternative as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. Grading for Combination Alternative water conveyance facility construction would not create new drainages. However, there is potential for erosion at locations where the water conveyance facility crosses ephemeral arroyos. Based on the depth of pipeline burial, erosion protection along existing arroyos may be required. Design studies would be needed to evaluate the potential need for erosion protection where the water conveyance facility crosses arroyos.

Periodic flash flooding occurs in desert regions as the result of heavy rainfall in upland areas. Because the water conveyance facility would have adequate burial, periodic flash flooding in the Cadiz Project area would not create a significant impact under the Combination Alternative.

Sedimentation

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and the project wellfield on sedimentation would be the same as for the Eastern, Eastern/Canal and Western alternatives.

Water Conveyance Facilities. The rate of sedimentation along the water conveyance facility route is estimated to be slow and would not be significantly changed by project construction. Therefore, the potential for accumulation of sediment over the conveyance facility would not be an impact to the Combination Alternative.

Subsidence

Project Spreading Basins and Project Wellfield. The impact of the project spreading basins and project wellfield on subsidence will be the same as for the Eastern, Eastern/Canal and Western alternatives. As with those alternatives, due to the planned extraction of groundwater during Cadiz Project operations, subsidence does pose a potential concern for portions of the Cadiz Project area underlying and surrounding the project wellfield. Subsidence is addressed in Section 5.5 (Water Resources) and in the Management Plan.

Water Conveyance Facilities. As described earlier for the Eastern and Eastern/Canal alternatives, no risk of subsidence would occur as a result of the water conveyance facility construction on the Combination Alternative.

No Project

Under the No Project Alternative, the land would be left in its natural state and no modifications would be made. The site would, therefore, continue to be subject to natural, baseline processes of erosion, flooding, drainage, liquefaction and other impacts discussed above.

5.4.5 MITIGATION MEASURES

G-1 *Seismicity*. Final Cadiz Project design will incorporate appropriate facilities and operational procedures to minimize potential impacts due to seismic events and water discharge due to earthquake-related damage. Design measures will include ensuring that all the structures associated with the Cadiz Project, including the water conveyance facility and wellfield manifold, be designed and constructed in compliance with current engineering practices including the Uniform Building Code and all applicable seismic engineering guidelines.

G-2 *Liquefaction*. Detailed final design studies will be prepared to document the actual soil conditions and groundwater depths along the water conveyance facility and wellfield manifold so that the liquefaction potential, if any, is documented and assure the final design is appropriate.

G-3 *Slope and Foundation Instability*. Commonly accepted design and construction practices, in accordance with applicable building codes and regulations, will be implemented to reduce potential impacts to non-significant levels. For example, where groundwater may be locally encountered along the pipeline alignment, commonly accepted construction dewatering methods (i.e. sumps, well points, shallow pumping wells) may be employed to temporarily lower water levels for ease of construction.

G-4 *Erosion, Sedimentation and Flooding*. Commonly accepted design and construction practices, in accordance with applicable building codes and regulations, will be implemented to reduce potential impacts to non-significant levels. For example, the conveyance pipeline and wellfield manifold pipelines would be buried at a depth sufficient to protect them from minor erosion that may occur. Also, backfill in the pipeline trench would be compacted and recontoured to mitigate the potential for increased rates of erosion along the pipeline easement.

5.4.6 LEVEL OF SIGNIFICANCE AFTER MITIGATION

Seismicity. Appropriate design measures will minimize the potential impact to the Cadiz Project facilities from seismic events. Such impacts cannot be completely eliminated but they will be reduced to below a level of significance.

Liquefaction. Available information indicates that the potential for soil liquefaction along the alternative conveyance alignments is limited to a specific reach adjacent to Danby Dry Lake. Appropriate design measures will reduce this potential impact to below a level of significance.

Slope and Foundation Instability. Appropriate design and construction measures will reduce the potential impacts associated with instability to below a level of significance.

Erosion, Sedimentation and Flooding. Appropriate design and construction measures will decrease the potential impacts associated with these concerns to below a level of significance.