5.5 WATER RESOURCES

5.5.1 AFFECTED ENVIRONMENT

The project spreading basins and wellfield will be located entirely on Cadiz Inc. land, which includes more than 27,000 acres in the Cadiz and Fenner valleys as shown in Figure 5.5-1.

Approximately 1,600 acres of this land have been developed for vineyards, citrus orchards, and various types of row crops. Seven groundwater production wells were installed between 1984 and 1994 to provide irrigation for the agricultural operation using water-conserving drip and micro-spray techniques. Current groundwater use for irrigation averages between approximately 5,000 and 6,000 acre-feet/year. A more comprehensive description of the agricultural operation is provided in Section 5.1.

In 1993, San Bernardino County certified a Final Environmental Impact Report (FEIR) and granted various land use approvals for expansion of agricultural operations on the property up to 9,600 acres (URS Consultants, Inc. 1993b). As a component of this approval, the County identified specific groundwater monitoring activities to be undertaken by Cadiz. To comply with these monitoring requirements, the Cadiz Valley Agricultural Development Ground Water Monitoring Plan (GWMP) was developed in cooperation with San Bernardino County to monitor all potential environmental impacts that could result from the agricultural operations.

Physiography and Topography

The regional watersheds tributary to the Cadiz Project area are defined by a series of mountain ranges and topographic divides that surround Fenner Valley, Orange Blossom Wash, and the Bristol and Cadiz dry lake depressions as shown on Figure 5.5-2.

The Fenner Valley watershed, which contributes the principal source of groundwater recharge to the project area, includes all of Fenner Valley and a portion of Lanfair Valley. The boundaries of this watershed are defined by the Marble and Providence mountains to the west, the New York and Providence mountains to the north, the Piute Range to the northeast, and the Old Woman and Ship mountains to the east. The Clipper Mountains, which reach elevations above 4,600 feet, occur entirely within the Fenner Valley watershed. Elevations within the watershed range from a high of more than 7,500 feet in the New York Mountains to a low of approximately 900 feet in Fenner Gap. Fenner Gap, which forms the surface and groundwater drainage outlet of the Fenner Valley watershed, is located between the Marble and Ship mountains.

The Bristol and Cadiz dry lake depressions are bounded to the southwest by the Bullion, Sheephole, Calumet, and Coxcomb mountains, and to the northeast by the Bristol, Marble, Ship, Old Woman, and Iron mountains. The Bristol and Cadiz depressions are separated by a low surface drainage divide, located on the alluvial fan that formed downstream from Fenner Gap. Bristol and Cadiz dry lakes are located at the low points (elevations of 595 feet and 545 feet, respectively) on either side of this divide.

The eastern Mojave Desert is characterized by a desert climate with low annual precipitation, low humidity and relatively high temperatures. Winters are mild and summers are hot, with a relatively large range in daily temperatures. Temperature and precipitation vary greatly with altitude, with lower temperatures and higher quantities of precipitation in the higher elevations.

Weather Patterns

The seasonal weather patterns of the eastern Mojave Desert region are primarily controlled by semi-permanent high and low pressure systems located over North America and the Pacific Ocean (Houghton & others 1975). During the summer months, a semi-permanent high-pressure cell (the Pacific High), centered over the north Pacific about 1,600 miles west of the California coast, typically diverts low-pressure, moisture-carrying weather systems north of California. The Pacific High contracts and moves southward during the winter months, allowing storms to cross California. Another semi-permanent high-pressure cell (the Great Basin High) is centered over southern Idaho during the winter months and deflects cold Canadian low-pressure weather cells to the east of the project area (Houghton & others 1975). During the summer months, a seasonal low-pressure weather cell (the California Low) often develops over the vicinity of the project area as a result of intense surface heating (Houghton & others 1975).

Two weather stations have provided long-term data in the vicinity of the project area. The Amboy weather station is located on the northern margin of Bristol Dry Lake at an elevation of 625 feet. The Mitchell Caverns weather station is located on the flank of the Providence Mountains, northwest of Clipper Valley, at an elevation of 4,330 feet. Additional short-term data is available from a weather station located in the Fenner Gap portion of the project area. The Management Plan includes provisions for installation of an additional weather station within the higher elevations of the Fenner Valley watershed to provide additional precipitation data for refinement of rainfall and runoff models. Additionally, three meteorological towers will be installed in the region to collect data on wind direction, speed, and frequency as discussed in the Management Plan volume of this Final EIR/EIS.

Temperature

Air temperature in the eastern Mojave Desert region follows a general pattern of high summer and low winter readings. Daily patterns are also typical, with temperatures dropping to an early morning low and climbing to a mid-afternoon high before falling again to the next morning's low temperature (US Ecology 1989). During the winter, the Great Basin High generally protects the region from cold Canadian airflows, typically keeping temperatures above freezing at the lower elevations.

The average winter temperature for the project area is between 50 and 55 degrees Fahrenheit (F), with the average daily maximum near 65 degrees F and the average daily minimum near 40 degrees F (US Ecology 1989). The highest temperatures occur during the summer months, when the average daily temperature is more than 85 degrees F. Average daily maximum temperatures in the summer months are typically around 100 degrees F, although temperatures in excess of 120 degrees F are not unusual. Average daily minimum temperatures during the summer months are around 70 degrees F (US Ecology 1989). The daily temperature range (daily maximum minus daily minimum) is generally 20 to 30 degrees F. This range is greater during the summer months than during the winter months (Thompson 1929).

The average, maximum, and minimum monthly temperatures for the Amboy and Mitchell Caverns weather stations are shown in Table 5.5-1. The Mitchell Caverns weather station, located at an elevation of 4,330 feet, has an average annual temperature of approximately 63 degrees F. The floor of Fenner Valley, which ranges from approximately 1,000 to 3,500 feet, is generally a few degrees warmer than Mitchell Caverns. The average temperature at Amboy is higher than that of Fenner Valley due to its lower elevation (625 feet).

TABLE 5.5-1
TEMPERATURE DATA

Station	Yearly Average	Maximum Monthly Average	Minimum Monthly Average
Amboy	71.8°F	94.4°F (July)	50.7°F (January)
Mitchell Caverns	62.6°F	82.1°F (July)	46.3°F (January)

Source: San Bernardino County Flood Control District – Hydrology Department

Precipitation

Most of the precipitation (both rainfall and snowfall) in the eastern Mojave Desert occurs during the months of November through March (Thompson 1929, U.S. Ecology 1989). However, the frequency and intensity of rainfall from year to year is unpredictable.

Winter rainfall occurs in events lasting several hours to a day or more. These winter events are typically the result of frontal weather conditions, and rainfall during such events is generally steady. It is not unusual for snow to accumulate at elevations above 5,000 feet in the Fenner and Orange Blossom Wash watersheds. On average, 20 to 30 frontal systems move through the region each winter (Houghton & others 1975; California Air Resources Board (CARB) 1975). However, most of these systems are relatively weak by the time they reach the vicinity of the project area (CARB 1975).

The amount of precipitation in the Bristol, Cadiz, Fenner and Orange Blossom Wash watersheds varies with differences in elevation as shown in Figures 5.5-3, 5.5-4, and 5.5-5. Numerous measurements and estimates have been made. Average annual precipitation from measured data is 3.6 inches on Cadiz and Bristol dry lakes (elevations of 545 to 595 feet), 10.4 inches at the Mitchell Caverns weather station (elevation 4,330), approximately 9 inches at the University of California desert research station in the Granite Mountains (elevation 4,200) (UC Riverside), and is estimated to be approximately 12 inches in the upper elevations of the New York Mountains (NPS Mojave National Preserve Water Resources Scoping Report, 1999). Most of the project area receives only four to six inches of average annual rainfall (Freiwald 1984; Bedinger et al. 1989).

Early summer and late fall are typically periods of little rainfall. Mid- to late- summer rainfall is characterized by localized thunderstorms, induced by the California Low (US Ecology 1989). In general, summer thunderstorms deliver rain in intense bursts of short duration. These thunderstorms frequently result in flow on the major washes and occasionally result in flash flooding on the valley floors.

Relationship of Precipitation to Elevation

Questions have been raised regarding the relationship of average annual precipitation to elevation within the watersheds tributary to the project area. This relationship is important since estimates of average annual precipitation (both rain and snowfall) are employed in a variety of models used for estimating groundwater recharge. Such models include the "watershed" model employed by Metropolitan (1999b) for estimating groundwater recharge to the project area; the Maxey-Eakin model (1949) developed for use in Nevada; the Crippen model (1965) developed for use in the southern California coastal ranges; and various other "rule-of-thumb" methods that assume recharge to groundwater of specified percentages of average annual precipitation within a watershed.

The Management Plan calls for installation of a new weather station in the higher elevations of the Fenner Valley watershed. Over time, precipitation data from this station will provide important site-specific information regarding the relationship of average annual precipitation to elevation for the regional watersheds tributary to the project area. Further analysis of the regional precipitation data will be considered during the siting of the new weather station called for under the Management Plan.

Evaporation Rates

Relatively high temperatures, low humidity, and frequent strong winds result in a relatively high rate of evaporation in the vicinity of the project area (CDWR 1979). Surface water evaporation, as measured using an evaporation pan, is highest in the valleys and lowest in the higher elevations.

Measured monthly evaporation rates, using an evaporation pan located at the pilot spreading basin in Fenner Gap, are illustrated in Figure 5.5-6. The measured evaporation rates in Fenner Gap are slightly lower than reported at the Amboy weather station. Amboy evaporation rates range from approximately five inches per month in December and January to more than 22 inches per month in July, with an average annual pan evaporation of 158 inches.

Humidity

The average annual daily relative humidity in the project area is less than 30 percent. Relative humidity is minimal and is often recorded at below 10 percent during the hottest part of the day. Relative humidity occurs at its maximum in the early morning hours, when it ranges from 30 to 50 percent (CARB 1975). The higher early morning relative humidity readings are largely due to the range in daily temperatures (Thompson 1929). No data are available as to the effects, if any, the Cadiz Inc. agricultural operations have had on microclimate humidity.

Wind Speed

The average annual low-altitude wind speed in the Mojave Desert region is approximately eight miles per hour (mph) (US Ecology 1989), with the highest wind speeds recorded during the summer months (CARB 1975). The prevailing wind direction is from the west. During the spring, the wind is generally from the southwest; during the summer, from the south-southwest; during the fall, from the west; and during the winter, from the northwest (CARB 1984). Wind data measured in the project area at Fenner Gap between March and June 1999 indicate steady velocities (not including gusts) of up to 30 mph as shown on Figure 5.5-7.

Longer-term wind speed data, measured at the northern margin of Bristol Dry Lake, is presented in Figure 5.5-8 (Jacobs Engineering Group Inc. 1992). This wind rose shows that winds having velocities greater than 21 miles per hour typically blow from the west and northwest. These high-velocity winds may be the most significant determinant in causing mobilization of fine-grained dust and silt from Bristol and Cadiz dry lakes. Three meteorological towers (10-meters tall) will be installed in the region to collect data on wind frequency, direction and speed as discussed in the Management Plan volume of this Final EIR/EIS.

Surface Water

The boundaries of the regional watersheds depicted in Figure 5.5-2 have been determined from topographic maps, satellite imagery, and field reconnaissance, and are in accordance with previous investigations of the area (Thompson 1929; Freiwald 1984). These regional watersheds form a closed drainage system with no surface outflow (Thompson 1929; Bedinger & others 1989). Instead, all surface water in the vicinity of the project area drains to Bristol and Cadiz dry lakes. The only outlets for surface water are direct evaporation of precipitation, transpiration by vegetation, and evaporation from the lake surfaces (Shafer 1964).

In general, the amount of surface water flow is dictated by the intensity and duration of precipitation, topography, rock type, soil, and vegetation cover. A portion of the precipitation falling in any watershed area is intercepted by vegetation and evaporated.

Another portion of the precipitation wets and adheres to the soil before returning to the atmosphere through evaporation. In general, if precipitation exceeds infiltration capacity, overland flow occurs.

There are no measured perennial streams in the Bristol, Cadiz, Fenner, or Orange Blossom Wash watersheds. There are springs and associated intermittent streams distributed throughout these watersheds. Ephemeral runoff within the Bristol depression, including runoff from Orange Blossom Wash, flows into Bristol Dry Lake. Schulyler Wash, the principal drainage in the Fenner Valley watershed, flows through Fenner Gap to Cadiz Dry Lake. See Figure 5.5-9 for locations of known surface water resources in these watersheds.

The lake surfaces are normally dry, but runoff from major winter storms and late summer thunderstorms can result in occasional standing water (Bassett & others 1959; Koehler 1983; URS Consultants 1993a, b).

Groundwater

Regional Overview

The primary sources of replenishment to the groundwater system in the project area include direct infiltration of precipitation (both rainfall and snowfall) in fractured bedrock exposed in mountainous terrain and infiltration of ephemeral stream flow in sandy-bottomed washes, particularly in the higher elevations of the watershed. The source of much of the groundwater recharge within the regional watershed occurs in the higher elevations (Metropolitan 1999b).

Although some groundwater is tapped by vegetation near the range fronts, the remainder moves slowly downgradient through Fenner Valley and Orange Blossom Wash into the Bristol and Cadiz depressions, where it eventually discharges to Bristol and Cadiz dry lakes. Evaporation of groundwater and surface water from the dry lakes over the past several million years has resulted in thick deposits of salt (primarily calcium chloride and sodium chloride) and brine-saturated sediments (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 source of groundwater recharge to the playas occurs as diffuse seepage of groundwater into the playa sediments from the adjacent alluvial fans.

The mountain ranges that define the boundaries of the regional watersheds are composed predominantly of granitic and metamorphic basement rock, as described above. This relatively impermeable basement complex forms the margins and bottoms of the aquifer systems (Freiwald 1984). More permeable carbonate bedrock of Paleozoic age occurs locally within the boundaries of these watersheds (as in Fenner Gap).

Principal Aquifer Systems

The maximum thickness of sediments is unknown, but may be greater than 6,000 feet in the vicinity of Bristol Dry Lake (Maas 1994). Based on available geologic, hydrologic, and geophysical data, the principal formations in the project area that can store and transmit groundwater ("aquifers") have been divided into three general units: an upper alluvial aquifer; a lower alluvial aquifer; and a bedrock aquifer. Figure 5.5-10 presents a generalized cross-section of this aquifer system from Fenner Valley (to the northeast) across Bristol Dry Lake (to the southwest).

The upper aquifer consists of Quaternary and late-Tertiary alluvial sediments, including stream-deposited sand and gravel with lesser amounts of silt (Moyle 1967; Metropolitan 1999b). The thickness of the upper alluvial sediments is approximately 100 to 800 feet (Metropolitan 1999b) as shown in Figure 5.5-10. The lower alluvial aquifer consists of older sediments, including interbedded sand, gravel, silt, and clay of mid- to late-Tertiary age. Where these materials extend below the water table, they yield water freely to wells but are generally less permeable than the upper aquifer sediments (Moyle 1967; Metropolitan 1999b). Production well PW-1, located in Fenner Gap, draws water primarily from the upper and lower aquifers and yields 3,000 gallons per minute with less than 20 feet of drawdown (Metropolitan 1999b). The Cadiz Inc. agricultural wells draw water from the alluvial aquifers and typically yield 1,000 to more than 2,000 gallons per minute.

Based on findings from recent drilling in Fenner Gap, carbonate bedrock of Paleozoic age, located beneath the alluvial aquifers, contains groundwater and is considered a third aquifer unit (Metropolitan 1999b). Groundwater movement and storage in this carbonate bedrock aquifer primarily occurs in secondary porosity features (i.e. joints, faults, and dissolution cavities that have developed over time). The full extent, potential yield, and storage capacity of this carbonate aquifer have not been quantified at this time. The characteristics of the carbonate rock aquifer will be further evaluated as part the Management Plan. However, production wells in the project wellfield will not be drilled into the carbonate bedrock.

As noted above, granite and metamorphic basement rock form the subsurface margins of the aquifer system in the project area. This basement rock is generally impermeable and typically yields only minor quantities of water to wells (Freiwald 1984).

Groundwater Flow

In general, groundwater within the watersheds tributary to the project area flows in the same direction as the slope of the land surface (Metropolitan 1999b). In the Fenner Valley, groundwater generally flows southward and discharges through Fenner Gap toward Bristol and Cadiz dry lakes.

In Orange Blossom Wash, located between the Marble and Bristol mountains, groundwater flows generally southward from the Granite Mountains into Bristol Dry Lake.

Figure 5.5-11 presents a generalized contour map of groundwater elevations and horizontal flow directions in the vicinity of the project area, including the proposed sites for the project spreading basins and wellfield facilities in Fenner Gap. The contours in this figure are based on water levels measured in more than 80 wells. In some cases, published water level elevations have been adjusted to reflect more accurate reference elevations, obtained from updated topographic maps of the area. The velocity of groundwater flow in the upper aquifer is generally higher than that of the lower aquifer because the upper aquifer sediments are more permeable. Specific groundwater flow rates in the lower alluvial aquifer and the carbonate bedrock aquifer have not yet been quantified in the project area. As outlined in the Management Plan, flow meter surveys will be conducted in applicable observation and production wells to obtain direct measurements of flow velocities within specific aquifer zones. These data will be used to determine which sediments yield water to the production wells as described in the Management Plan.

Faults as Possible Barriers to Groundwater Flow

Questions have been raised as to whether subsurface faults may locally act as barriers to groundwater flow in the project area. Although no static groundwater level discontinuities (which could indicate such fault barriers) have been recognized in or adjacent to the project area, such fault barriers, if present, could behave as leaky dams, "ponding" groundwater on the up-gradient side of the faults. It has been suggested that such a stair-step pattern of the water table could lead to misinterpretation of the hydraulic gradient and consequent overestimation of groundwater flow velocities. During the pre-operational phase of the project, aquifer testing of both production wells and observation wells combined with measured changes in land surface elevation data will provide additional site-specific information regarding potential fault barriers within the project area. These data will be used to further define the geohydrologic system used in the Management Plan models.

Age of Groundwater

Questions have been raised regarding the age of groundwater based on isotopic analyses of groundwater sampled from wells in the Fenner Gap portion of the project area. As part of the Management Plan, additional isotopic sampling and analysis will be conducted on production wells and observation wells during the pre-operational phase of the project to refine estimates of the age of groundwater.

Groundwater Recharge to the Project Area

Mechanisms of Groundwater Recharge. Groundwater recharge occurs by several different mechanisms within the watersheds tributary to the project area. The principal mechanisms of groundwater recharge are summarized below.

Infiltration into Bedrock. Infiltration of runoff generated by rain fall and snow melt into the bedrock exposed in the mountainous portions of the regional watershed is a significant source of groundwater recharge. A substantial portion of this infiltration may occur directly into the fractured granitic, metamorphic, carbonate, and volcanic bedrock that is exposed in the mountainous areas of the watersheds. Additional study of the characteristics of bedrock infiltration will be conducted under the Management Plan to gain insight into this mechanism of groundwater recharge.

Infiltration into Sandy Washes. Another source of groundwater recharge within the watersheds tributary to the project area is infiltration of runoff into sandy-bottomed washes. Such runoff frequently occurs during major rainstorm events and as a result of melting of winter snowfall in the higher elevations of the watersheds. In addition, major precipitation events of short duration and high intensity frequently result in runoff and sheet flooding, during which surface flow is directed from valley floors onto nearby sandy-bottomed washes.

Questions have been raised regarding the duration of such runoff events, with the suggestion that stream flow occurs only during short periods of time, lasting no more than a few hours to a few days. For example, it has been stated that such short periods of runoff limit the depth to which water can infiltrate, leaving it susceptible to evaporation from the ground surface and transpiration by plants. The quantity of this recharge is unknown.

In order to further evaluate this recharge process, the Management Plan calls for installation of a stream gage (together with both rain and snow gages) at a site in the New York or Providence mountains[1]. Sampling and analysis of soil samples collected during drilling of observation and production wells, as proposed in the Management Plan, will provide further insight into mechanisms of groundwater recharge in valley floor environments. In addition, future watershed modeling will include streamflow routing in order to refine estimates of surface flow duration and rates of infiltration in sandy-bottom washes.

<u>Infiltration into Valley Floors</u>

Direct infiltration of precipitation within vegetated portions of the alluvial terrain on the valley floors is not believed to be a significant mechanism of groundwater recharge. Much of the precipitation within such terrain is evaporated directly from the soil surface or transpired by the desert scrub vegetation, which is highly adapted to capture shallow soil moisture. Surface water that infiltrates into such soil is unlikely to penetrate to depths beyond which it is subject to evapotranspiration. The accumulation of water-soluble salts in the upper portions of the alluvium in such terrain is evidence of this process.

Estimates of Recharge. A variety of methods have been used to estimate groundwater recharge to the project area. These methods range from simple estimates involving recharge as a percentage of average annual precipitation, to complex relationships between daily precipitation, evapotranspiration, soil moisture, and surface water runoff. Alternative methods for estimating average annual recharge to the project area were suggested by the NPS and San Bernardino County in comment letters submitted in response to the Draft EIR/EIS. As noted in Section 1, Metropolitan believes that the natural recharge is higher than is stated in these letters.

Given the limited availability of site-specific data and limitations in technology, and the dispute among experts as to the current estimates of natural recharge to the project area, the Management Plan outlines specific provisions designed to ensure that project operations will not result in any adverse impacts to critical resources in the vicinity of the project area, regardless of the amount of natural groundwater recharge.

[1] The installation of the stream flow and precipitation stations would be contingent upon permission from the National Park Service.

Natural Groundwater Discharge

The primary natural outlet, or discharge, of groundwater from the Bristol, Cadiz, Fenner, and Orange Blossom Wash watersheds is evaporation from Bristol and Cadiz dry lakes. Transpiration by vegetation is not a significant source of groundwater discharge, since no native phreatophyte[2] vegetation occurs in the vicinity of the project area.

Groundwater may discharge locally to springs that have been observed and sampled within several different bedrock units exposed within the watersheds tributary to the project area. Bedrock hosts for these springs include granitic rock in the Granite and Old Woman mountains, shallow intrusive rock in the Providence Mountains, and volcanic sediments in the Clipper Mountains. Many of these springs occur along joints, fractures, and fault zones in the host rock and at the interface of the fractured bedrock and the alluvial fill. Depth of infiltration and residence time for groundwater within fractured bedrock units may be highly variable. Additional study of springs located within the watershed will be conducted, as outlined in the Management Plan, to gain insight into this mechanism of groundwater recharge.

Groundwater Use

The total amount of groundwater pumped in and surrounding the project area has been minimal until the last decade. The primary groundwater uses in the region are the Cadiz Inc. agricultural operations, the Burlington Northern Santa Fe Railroad (BNSF), the various salt-mining companies operating on Bristol and Cadiz dry lakes, and the few residents in and around the communities of Chambless and Essex.

Between 1901 and 1947, approximately 2,365 acre-feet of groundwater, or an average of 50 acre-feet per year, was produced from Fenner Valley (Shafer 1964). Between 1948 and 1962, Shafer (1964) estimates that approximately four acre-feet per year were pumped from Fenner Valley. The sharp drop in production was attributed to a switch from steam- to diesel-powered engines on the railroad. Freiwald (1984) estimates that between 1954 and 1981, groundwater pumping in Fenner Valley remained constant at approximately seven to eight acre-feet/year. Using Freiwald's (1984) pumping rate estimate for 1954 through 1981, and assuming that this rate continued through 1998, the total volume of groundwater estimated to have been pumped from this valley since 1901 ranges from approximately 2,700 to 2,750 acre-feet.

Shafer (1964) reports that approximately 14,300 acre-feet of fresh water were pumped from the Bristol and Cadiz valleys from 1910 (when the first fresh water well was drilled) to 1964, or an average pumping rate of approximately 265 acre-feet per year. Assuming these historical pumping rates continued from 1964 through 1998 (not including the Cadiz Inc. agricultural operations), a total of approximately 9,000 additional acre-feet was pumped from these valleys during this time period. In addition, from 1983 through 1998, the Cadiz Inc. agricultural operations produced approximately 61,740 acre-feet of groundwater from its wellfield. Yearly groundwater production for the Cadiz Inc. agricultural operations has averaged 5,000-6,000 acre-feet per year from 1986 through 1998. Accordingly, the total amount of groundwater pumped from the Bristol and Cadiz valleys from 1910 through 1998 is approximately 85,000 acre-feet.

Calcium chloride and sodium chloride are produced by mining operations on both Bristol and Cadiz dry lakes. The highly saline brine is pumped from brine wells and from trenches for concentration

[2] Types of vegetation that draw water from the saturated zone.

in evaporation ponds. These mining operations are conducted on patented lands and on unpatented claims on Federal land administered by the BLM. The amount of brine produced is proprietary information, and precise estimates are unavailable. The Management Plan provides for a comprehensive program of monitoring designed to ensure that project operations will not adversely impact these brine resources.

Groundwater Quality

With the exception of the areas underlying and immediately adjacent to Bristol and Cadiz dry lakes, the quality of the groundwater in the Fenner Gap portion of the project area is relatively good, with TDS concentrations averaging approximately 300 milligrams per liter (mg/L), as shown in Figure 5.5-12. The TDS concentration in Fenner Valley groundwater is typically in the range of 300 to 400 mg/L. On Bristol and Cadiz dry lakes, surface water and shallow groundwater evaporation has concentrated dissolved salts, resulting in TDS concentrations as high as 298,000 mg/L (Schafer, 1964). The location of the interface between the low-TDS "fresh" groundwater and high-TDS "saline" groundwater underlying the dry lakes has been mapped on the basis of data from observation wells in the area (Shafer 1964; Rosen 1989).

The State of California guideline for drinking water is a maximum TDS of 1,000 mg/L. However, all groundwater having a TDS below 3,000 mg/L is considered by the State to be a potential domestic or municipal source of water supply.

Springs and Phreatophyte Vegetation

No springs or native phreatophyte vegetation are in the project area. The closest springs to the project area are located in the Granite, Clipper and Old Woman mountains, more than 10 miles from the proposed spreading basins and wellfield. Because springs located within the Mojave National Preserve, within designated BLM wilderness areas, and within other BLM-managed areas within the affected watersheds are considered critical resources (see Section 2 of the Management Plan volume), the Management Plan outlines a comprehensive program for monitoring and is designed to prevent any adverse impacts to such springs as a result of project operations. Figure 5.5-13 shows the location of the Mojave National Preserve and nearby communities in relation to the project area and the regional watersheds of the eastern Mojave Desert.

Dust Mobilization from Bristol and Cadiz Dry Lakebeds

Questions have also been raised about the potential for the Cadiz Project to indirectly increase the amount of dust mobilized from the surface of Bristol and Cadiz dry lakebeds resulting from project operations. It is currently believed that the groundwater (brine water) beneath the lakebeds is sufficiently near the ground surface to moisten the surface soils through the capillary rise of moisture off of the water table. It is believed this process reduces the amount of dust generated on the dry lakes because the surface moisture holds the soil together. Because the brine beneath the lakebeds is believed to be hydraulically connected to the freshwater aquifer outside the dry lakes, excessive lowering of the groundwater surface at the margins of the dry lakes could lower brine levels beneath the lakebeds to the point that the capillary rise does not reach the ground surface. If this were to happen, the surface soils could dry out, resulting in an increased potential for dust mobilization during wind storms. A regional study (Reheis and Kihl 1995) of dust deposition in southern Nevada.

and southeastern California found that climatic factors that affect dust interact with each other as well as source type, source lithology, geographic area and human disturbance. The study also found that the rate of dust accumulation mostly reflects changes in annual precipitation rather than temperature, and that playa and alluvial sources respond differently to annual changes in precipitation.

The US Environmental Protection Agency (USEPA) designated a major portion of the San Bernardino County area of the Southeast Desert Air Basin as a moderate nonattainment area for the PM_{10} National Ambient Air Quality Standards. The designation was based on a number of violations which occurred in the populated areas of the Mojave Desert Air Quality Management District (MDAQMD) during the period 1989-1991. However, although PM_{10} concentrations have not been monitored in the sparsely populated eastern portion of San Bernardino County, the USEPA has included the eastern portion in the PM_{10} nonattainment area. In consideration of the locations of the observed violations and the sources of PM_{10}, the MDAQMD prepared and submitted to USEPA a PM_{10} attainment plan that identifies a smaller nonattainment area surrounding the heavily populated cities and towns in the MDAQMD. This region includes the Victor Valley, Morongo Basin, Barstow, and Lucerne Valley, and is referred to as the Mojave Desert Planning Area. The MDAQMD has also requested that the eastern portion of San Bernardino County be redesignated as unclassifiable for PM_{10}. The USEPA has not approved this plan and has specified changes that must be made by MDAQMD in order to consider the redesignation.

The Management Plan includes specific provisions designed to prevent the mobilization of dust as a result of project operations. Due to the possible relationship of groundwater levels beneath the dry lakes to dust mobilization at the dry lake surfaces, a key monitoring feature will be monitoring well clusters at the margins of Bristol and Cadiz dry lakes which will provide early warning monitoring of groundwater level changes resulting from project operations. The Management Plan also includes provisions for the monitoring of lakebed surface soil moisture and direct measurement of airborne dust. Additionally, to determine where any project-mobilized lakebed dust could be transported, regional meteorological towers will be installed to better determine the speed and direction of winds in the region.

5.5.2 CEQA THRESHOLDS OF SIGNIFICANCE

For purposes of CEQA, the significance thresholds listed below have been used to evaluate the Cadiz Project with respect to effects that are related to water resources. It is noted that the Management Plan has been incorporated into the project and potential effects are reviewed in light of implementation of the Management Plan.

The Management Plan, presented as Volume IV of this Final EIR/EIS, identifies critical resources, potential adverse impacts of the Cadiz Project on the critical resources and action criteria which, if reached, may indicate that an adverse impact may occur as a result of the project. Because the Management Plan has been developed to predict and avoid significant adverse effects, the potential adverse impacts and the action criteria have been set conservatively and would be triggered well in advance of the occurrence of a significant adverse effect as identified by the CEQA significance thresholds listed below.

A project is normally considered to have a significant adverse impact on surface water or groundwater flow, groundwater supply, groundwater levels, groundwater quality, or air quality if it results in:

- The violation of any drinking water quality standards or waste discharge requirements, including those in the California Regional Water Quality Control Board's Colorado River Basin Region.
- Substantial depletion of groundwater supplies or substantial interference with groundwater recharge, such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table to the extent that existing nearby well production would not support existing land uses or planned uses for which permits have been granted.
- Substantial fluctuations in brine levels on Bristol or Cadiz dry lakes resulting in significantly reduced production at the salt-mining operations on the dry lakes.
- Substantial alteration of the existing drainage pattern of a site or area, including the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site.
- Substantial increase of the rate or amount of surface runoff in a manner which would result in flooding on- or off-site.
- Creation or contribution of runoff water that would exceed the capacity of existing or planned stormwater drainage systems or providing substantial additional sources of polluted runoff.
- Structures placed within a 100-year flood hazard area which would impede or redirect flood flows.
- Exposure of people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a project facility, such as a spreading basin or pipeline.
- Substantial increases in ground instability in the project area, including subsidence, hydrocompaction, or increased risk of liquefaction.
- Substantially increased mobilization of dust from Bristol or Cadiz dry lakes during periods of high wind.
- Drawdown of groundwater within the boundary of the Mojave National Preserve or BLM-managed lands within the affected watersheds that results in substantial adverse impacts to springs.
- Inundation by a seiche, tsunami or mudflow.

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

5.5.3 METHODOLOGY

Preliminary studies by Metropolitan and Cadiz Inc. were conducted to assess the feasibility of storing large quantities of Colorado River water beneath the Fenner Gap portion of the Cadiz Project area. These studies involved collecting extensive geologic, hydrologic and water quality data in the Cadiz Project area, not only to evaluate the feasibility of the Cadiz Project but also to evaluate the potential impacts that a large-scale storage program would have on existing environmental resources in the region. Potential geological/hydrological impacts evaluated include:

1. Ground structure instability, including possible land subsidence from lowering of groundwater levels, settlement from hydro-compaction and increased risk of liquefaction.
2. Water quality impacts from mixing Colorado River water with indigenous groundwater underlying the project spreading basins and project wellfield.
3. Water quantity impacts from storing and extracting Colorado River water and indigenous groundwater which might affect nearby wells and nearby salt mining operations.
4. Changes to the microclimate of Fenner Gap.

The studies used to evaluate these potential impacts included:

Collection of background data regarding the geology and hydrogeology of the groundwater aquifer system underlying the Cadiz Project area.

2. Collection of field data on the soil/rock types, groundwater levels, aquifer characteristics and water quality in the Cadiz Project area.
3. Construction and operation of an infiltration test using two 2.5-acre pilot spreading basins located within the area of the Cadiz Project spreading basins.
4. Development of water quality mixing models (both computer and laboratory) to assess the effects of mixing Colorado River water with indigenous groundwater.

Collection of Field Data

The field studies provide valuable information that continues to be used in the analyses presented in this Final EIR/EIS. Seven shallow boreholes were drilled in the Fenner Gap portion of the project area to assess soil types and variations in subsurface stratigraphy. Eleven groundwater monitoring wells were drilled and installed in the Fenner Gap portion of the project area to monitor water levels and facilitate collection of water quality data. Monitoring wells were installed in and adjacent to the pilot spreading basins and soil moisture sensors were installed to monitor vertical movement of infiltrating water through the unsaturated zone beneath the pilot test basins. A production well was drilled in the Fenner Gap to serve as a source of water for the pilot spreading basin test as well as a test of the well design for the project wellfield.

Pilot Spreading Basins

The pilot spreading basin test was performed to determine the feasibility of storing Colorado River water in, and later retrieving it from, the aquifer system underlying the Fenner Gap portion of the project area. The pilot test program was also designed to assess the types and extent of environmental impacts that could potentially result from implementation of the Cadiz Project. The pilot spreading basin consists of two 2.5 acre cells. The pilot basin is operated by pumping water from a production well via a temporary pipeline into one of the cells. Spreading tests were performed to evaluate the infiltration rate of percolating water to determine the dimensions of the resulting mound of elevated groundwater that forms as a result of surface spreading, and to monitor any changes to water quality during the spreading test. A weather station and an evaporation pan located at the pilot spreading basin collected data on wind speed and direction, precipitation, air temperature, relative humidity and evaporation rates.

Groundwater Flow Model

A groundwater flow model for the project spreading basin complex and wellfield was prepared for the Draft EIR/EIS using the USGS's MODFLOW model (McDonald & others 1988). Because of technical disagreement regarding the flow model, it was not used in the revised impact analyses presented in the Supplement to the Draft EIR/EIS and in this Final EIR/EIS.

Water Quality Mixing Model

The water quality mixing model used laboratory tests and a physical scale model of the affected portion of the aquifer to evaluate the chemical effects of mixing Colorado River water with indigenous groundwater underlying the Fenner Gap part of the project area. The laboratory model takes into account various environmental factors, including soil chemistry, indigenous water temperature, and potential biological impacts. The results of the physical model were further tested using a computer model to simulate the mixing of waters of different composition (Parkhurst & others 1980).

Operational Scenarios

Six operational scenarios were presented in the Draft EIR/EIS to assess potential impacts of the Cadiz Project. Because of technical disagreement regarding the groundwater flow modeling used in the Draft EIR/EIS, the six operational scenarios presented in the Draft EIR/EIS are no longer being utilized to evaluate potential impacts of the proposed project. The Management Plan, presented as Volume IV of this Final EIR/EIS, has replaced the use of the operational scenarios and has been incorporated into the proposed action. The Management Plan will require measurement of physical parameters at key locations throughout the potentially affected region for early detection of changes to groundwater levels, groundwater quality, and air quality related to mobilization of dust from the dry lakebeds. Data obtained from physical monitoring facilities will be used to calibrate models that will be used to predict behavior of the affected aquifers and surface water features. Early modifications to project operations dictated by the Management Plan will avoid impacts that could be caused by the project. Impacts are evaluated in the following section assuming implementation of the Management Plan.

5.5.4 IMPACTS

The Management Plan will provide guidelines for assessment and management of Cadiz Project operations. All project operations will comply with the provisions and requirements of the Management Plan for the purposes of avoiding or minimizing adverse impacts that could potentially result from the project. The "project area" under the provisions of the Management Plan refers to the area encompassing the proposed recharge and extraction facilities and existing Cadiz agricultural wellfield. During storage operations, the surface of the water table underlying the project spreading basins will rise (mound) in response to the infiltration of the imported Colorado River water. During extraction operations, a depression will form in the water table underlying the project wellfield. During storage operations, Colorado River water, which is of a different quality than local groundwater, will blend with indigenous groundwater. Project operations could result in potential impacts to the following critical resources identified in the Management Plan:

- Springs Within Affected Watersheds Including Springs of the Mojave National Preserve and BLM-Managed Lands.
- Aquifer System.
- Brine Resources of Bristol and Cadiz Dry Lakes.
- Air Quality in the Mojave Desert Region.

The potential impacts include:

- Spring flow due to fluctuation of groundwater levels
- Aquifer system
  - Groundwater quality and recharge capacity due to project operations
  - Neighboring wells due to groundwater level fluctuations
  - Ground structure (land subsidence, increased risk of liquefaction, and settlement from hydrocompaction)

  - Induced flow of lower quality water from Bristol and Cadiz dry lakes
  - Long-term drawdown of groundwater
- Brine resources of Bristol and Cadiz dry lakes
  - Dilution of brine
  - Migration of stored Colorado River constituents
  - Raising or lowering the depth to brine
- Air quality related to mobilization and transport of lakebed dust in the Mojave Desert Region.
- Water quality in the CRA due to introduction of indigenous groundwater
- Fenner Gap microclimate modifications
- Desert environment due to implementation of the Management Plan.

Eastern Alternative

Potential Impacts to Spring Flow Due to Fluctuation of Groundwater Levels

The closest boundaries of the Mojave National Preserve are located approximately 15 miles north of, and upgradient from, the proposed project spreading basins and wellfield. There is continuity between the aquifer systems underlying the project area and some parts of the Mojave National Preserve. Because groundwater levels underlying the Mojave National Preserve are considered a Critical Resource, the Management Plan includes specific provisions to prevent any adverse impacts to groundwater levels or springs located within the Mojave National Preserve, or to springs located within BLM-managed lands.

No springs are known to exist in the project area. The closest spring (Bonanza Spring located on BLM-managed land) is located in the Clipper Mountains approximately 12 miles north of the proposed spreading basins and wellfield. Other springs in the region are located in the Granite and Old Woman mountains. These springs range in distance from 15 to 20 miles from and are up-gradient of the project area. Springs located within the Mojave National Preserve, federally designated Wilderness Areas, and Bonanza Spring are identified in the Management Plan as critical resources. A comprehensive program for monitoring and preventing any adverse impact to such springs has been prepared.

An inventory of springs within the Fenner and Orange Blossom Wash watersheds will be prepared as part of the Management Plan. During the pre-operational phase of the project, approximately eight springs will be selected as long-term monitoring sites. These sites will be monitored to further evaluate the recharge characteristics affecting the springs and determine whether fluctuations of spring flow are caused by project operations or natural variation.

S-Series observation wells will be located between the project area and springs and will serve as an "early warning system" by providing outpost monitoring of potential water level changes as a result of project operations. If water level changes in excess of one foot occur at these S-Series observation wells, these changes would be evaluated in accordance with the provisions of the Management Plan. Corrective measures (Management Plan Section 7) that would be implemented, as appropriate, would entail modification of project operations to prevent adverse impacts. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Accordingly, the potential impacts to springs as a result of project operations are determined to be less than significant.

Potential Impacts to Aquifer System

Potential Impacts to Groundwater Quality or the Recharge Capability of the Project Spreading Facilities due to Introduction of Colorado River Water. Potential changes in groundwater quality or the recharge capability of the project spreading facilities would occur as a result of introducing Colorado River water into the groundwater basin underlying the project area. These changes would include: 1) transport of salts from the unsaturated zone into the indigenous groundwater, 2) introduction of undesirable constituents, such as TDS and perchlorate, from Colorado River water; and, 3) precipitation of minerals (primarily calcium carbonate) within the sediments that make up the aquifer system.

Based on results obtained during operation of the pilot spreading basin and groundwater analyses from the nearby observation wells, the initial infiltration of Colorado River water during project spreading operations is expected to dissolve salts in the upper parts of the unsaturated zone and carry them downward to the water table (Metropolitan 1999b). Although this process would create some initially high TDS concentrations in groundwater immediately below and adjacent to the spreading basins, over time the effect would be transitory because the dissolved salts would be pumped out or assimilated into the groundwater within the project area and would not impact wells outside the project area. Accordingly, such impacts are less than significant.

The introduction of Colorado River water (approximately 600 mg/L TDS) into indigenous groundwater in the project area (approximately 300 mg/L TDS), will result in an increase in groundwater TDS concentrations. It is anticipated that this effect will be limited to the area of groundwater mounding caused by the project spreading operations. Any introduced Colorado River water would most likely be removed by the project wellfield during extraction operations. To recover stored Colorado River water from the basin, selected production wells will be screened in the more permeable upper alluvial sediment (current unsaturated zone). This design feature will allow for extraction of stored water that contains greater concentrations of TDS than the indigenous groundwater. Any remaining increase in TDS concentrations within the project area groundwater would be small and would not affect compliance with State and federal drinking water standards or other beneficial groundwater uses (municipal, industrial and agricultural) in or adjacent to the project area. Further, to ensure that neighboring wells will not be significantly impacted, the Management Plan (Section 7) prescribes specific provisions including curtailment of delivery of Colorado River water to the spreading basins.

In addition, perchlorate has been identified as the only other undesirable constituent in Colorado River water and will impact the water quality of the indigenous groundwater in the Cadiz Project area. Recent testing has detected this constituent in Colorado River water at concentrations ranging from non-detectable to as high as 9 micrograms/liter (µg/L). The current provisional State of California Department of Health Services action level for perchlorate is 18 µg/L.

Any increased perchlorate concentrations that may occur in the project area would be in compliance with drinking water standards. However, the Management Plan provides (Section 7) for specific corrective actions should perchlorate concentrations affect any neighboring wells. Such corrective actions include improving impacted wells, blending impacted well water with other local sources, modifying project operations, or constructing replacement wells. It is anticipated that most of this perchlorate would be pumped back to the CRA during extraction operations. As a result, it is not expected that an increase in perchlorate concentrations within the project area groundwater will adversely affect beneficial groundwater uses (municipal, industrial and agricultural) in or adjacent to the project area. Accordingly, these adverse impacts will be less than significant.

Potential changes in groundwater quality may occur in the event that operation of the project wellfield induced migration of water from the deeper aquifer zones underlying the project area. However, as this deeper aquifer is not characterized, information regarding water quality from the deeper zones is not available. Deep exploratory drilling and water quality sampling conducted in development of the project wellfield will provide site-specific information regarding water quality variation with depth in the project area. This information will be used to site and design production wells in order to avoid or minimize potential water quality impacts. Based on the more than 16 years of pumping history of the Cadiz agricultural wells, no significant changes in water quality have been observed. Accordingly, potential adverse impacts to groundwater basin water quality due to migration of water from the deeper aquifer zones are anticipated to be less than significant.

During spreading operations, the mixing of Colorado River water and indigenous groundwater could potentially result in the precipitation of minerals (primarily calcium carbonate) within the sediments that make up the aquifer system in the vicinity of the spreading basins. Such precipitation could, by decreasing the porosity of the aquifer, reduce the recharge capability of the project spreading facilities. The results of extensive laboratory testing and computer modeling indicate that significant precipitation of minerals under the geochemical conditions modeled will not occur (Metropolitan 1999b). As a result, it is concluded that this effect is highly unlikely, and if it were to occur, it would be limited in its areal extent. Accordingly, the potential impacts are less than significant.

Potential Impacts to Neighboring Wells Due to Groundwater Level Fluctuations. The communities nearest the project area are Chambless (six miles), Amboy (15 miles), Essex (20 miles) and the cities of Twentynine Palms (40 miles) and Needles (60 miles). The locations of these communities in relation to the project area are shown on Figure 5.5-13.

The community of Chambless, located approximately six miles from Fenner Gap, is underlain by groundwater that is in hydraulic continuity with that of the project area. As a result, there is potential for project groundwater operations to impact wells in the Chambless area. To ensure that there will be no significant adverse impacts to wells located in the community of Chambless, the Management Plan includes specific provisions (Sections 6 and 7) to monitor wells in the area and to modify project operations if necessary. As a result, adverse impacts to wells in the community of Chambless will be less than significant.

The community of Amboy, which is located north of Bristol Dry Lake, is separated from the project area by brine-saturated sediments and salt deposits underlying Bristol Dry Lake. Consequently, there is no potential for continuity of potable groundwater in the project area with groundwater beneath this community.

The community of Essex is located in Fenner Valley, approximately 20 miles up-gradient from the project spreading basins and wellfield. Although there is continuity between the aquifer systems underlying the project area and Essex, all the wells in the Essex area are located beyond and up-gradient of what is anticipated to be the maximum area of influence of project operations. To ensure that there will be no significant adverse impacts to wells located in the community of Essex, the Management Plan includes specific provisions (Sections 6 and 7) to monitor wells in the area, and to modify project operations if necessary.

The project area is separated from groundwater in the Twentynine Palms area by at least 30 miles. Nearly eight miles of this distance is occupied by the brine-saturated sediments and salt deposits of Bristol Dry Lake, which reach depths of more than 6,000 feet. Furthermore, the project area is separated from Twentynine Palms by crystalline basement rock exposed in the Bullion Mountains. The Bullion Mountains exceed 4,000 feet in elevation and are located on the southwest side of Bristol Dry Lake, creating a barrier to the transmission of groundwater. Accordingly, there is no potential for groundwater continuity or flow between the project area and Twentynine Palms, thus there will be no impacts due to project operations.

Groundwater in the vicinity of Needles and the Colorado River is separated from the project area by 60 miles, including intervening mountain ranges of crystalline basement rock, which reach elevations in excess of 5,000 feet. Similar to the case of groundwater in the Twentynine Palms area, there is no potential for groundwater continuity or flow between the project area and either the town of Needles or the Colorado River. Consequently, there will be no impact due to project operations.

Within the project area, the greatest potential for impact due to groundwater mounding and depression is in the vicinity of the project spreading basins and wellfield. As specified in the Management Plan (Section 6), static groundwater levels will be monitored regularly beginning in the pre-operational phase (the period from the publication of the Records of Decision and Notice of Determination until the completion of facilities necessary to store water; approximately 15 to 24 months), throughout the operational phase and through the post-operational phase (10 years following the cessation of project operations, or a time period as otherwise determined by the BLM). Groundwater levels will be monitored continuously using downhole pressure transducers in designated wells described in the Management Plan.

The project observation well network may be supplemented with a network of microgravity stations located in the immediate project vicinity. The microgravity stations will measure changes in the depth to groundwater by identifying subsurface density differences between saturated and unsaturated soils. This supplemental microgravity data could be used in conjunction with water levels measured in observation wells.

If neighboring landowners submit written complaints regarding decreased groundwater production yield, degraded water quality, or increased pumping costs, and it is determined that these effects are attributable to the project, these changes will be evaluated in accordance with the provisions of the Management Plan.

To ensure that there will be no significant adverse impacts to long-term groundwater levels due to project operations, corrective measures would be implemented. Corrective measures include the following: deepen or otherwise improve the efficiency of the impacted well(s); blend impacted well water with another local source; construct replacement wells; or modify project operations until adverse impacts were no longer present at the impacted well(s). Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Implementation of the Closure Plan will be designed to ensure that static groundwater levels will not be depressed by more than 100 feet at the end of the project operational phase. In addition the overall purpose of the Closure Plan is to (1) ensure that no residual effects of project operations will result in adverse impacts to critical resources in or adjacent to the project area and (2) protect groundwater quantity and quality for future beneficial uses in and adjacent to the project area. These limitations together with all other provisions of the

Management Plan will protect groundwater resources within the project area. Accordingly, adverse impacts to groundwater levels as a result of project operations will be less than significant.

Potential for Land Subsidence

The area with the greatest potential for subsidence is in the western part of the project wellfield in the vicinity of the Cadiz Inc. agricultural operations. This area contains the highest proportion of fine-grained sediments observed in the subsurface, below the water table. Railroad lines owned and operated by BNSF and Arizona California Railroad (ARZC), and natural gas and crude oil pipelines operated by El Paso Natural Gas Co., All American Pipeline L.P. and Questar cross part of this area.

The Management Plan provides that during the pre-operational phase approximately 20 survey benchmarks will be installed at appropriate locations within the area of the project wellfield. Benchmark surveys will be conducted on an annual basis during all phases of the project. In addition to the benchmark surveys, InSAR data may be obtained for the project area, if appropriate. The InSAR data would be used to monitor relative changes of land surface elevation that could be related to aquifer system deformation in the project area and would complement the land survey data to establish changes in land surface elevations.

In addition, an extensometer well may be constructed within the area of the highest probability of subsidence pending results of the annual benchmark surveys and evaluation of InSAR data. The extensometer would be constructed to measure non-recoverable compaction of fine-grained materials interbedded within the alluvial aquifer systems.

If this field monitoring determines that project operations caused a surface elevation change of 0.5 feet within the project area, all relevant information would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented as appropriate include modification to project operations. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Accordingly, the potential impact of subsidence as a result of project operations is determined to be less than significant.

Potential for Liquefaction

Liquefaction is the transformation of water-saturated granular material (usually sand or sand/silt mixtures) from a solid state to a liquid state as a result of increased pore water pressure during intense ground shaking, as from a major earthquake. When undergoing liquefaction, surface soils can be transformed into a state that will no longer support structures. Liquefaction is generally considered a risk where fine-grained sediments are saturated by groundwater to within 50 feet of the ground surface. The most shallow groundwater levels anticipated during the project storage operations will be approximately 80 feet below ground surface. As outlined in Section 6 of the Management Plan, groundwater levels will be continuously monitored in the vicinity of the project spreading basins during spreading operations, and shallow groundwater levels will be avoided by modification of project operations. Should groundwater levels attributable to project operations be measured within 50 feet of the ground surface outside a radius of 500 feet of the boundary of the project spreading basins, these groundwater level changes will be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modifications to project operations. These modifications would include halting of any ongoing spreading operations or pumping of groundwater to reduce groundwater levels to below the action criterion level. Accordingly, an increase in the risk of liquefaction will be less than significant.

Potential for Hydrocompaction

Hydrocompaction refers to the settlement of sediments as a result of the saturation, displacement, and consolidation of the mineral grains within the sediments. Hydrocompaction generally affects the upper 20 feet of sediments and does not usually exceed 12 inches in total vertical settlement. The part of the project area that could be affected by settlement due to hydrocompaction is limited to the area to be occupied by the project spreading basins. It is not anticipated that project operations will result in hydrocompaction impacts to railroad tracks, pipelines, local residences, agricultural operations or any other entity.

Annual benchmark surveys will be used to identify and quantify potential hydrocompaction in the immediate vicinity of the project spreading basins. If it were determined through monitoring that project operations resulted in a change of surface elevation of 3 feet in the immediate vicinity of the project spreading basins, all relevant information will be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, are described in the Management Plan (Section 6). These corrective measures include repair of damage to spreading basins and related appurtenances and repair or replacement of any other facilities in the immediate vicinity of the spreading basins damaged by hydrocompaction attributable to project operations. Accordingly, potential hydrocompaction impacts will be less than significant.

Potential for Induced Flow of Lower Quality Water from Bristol and Cadiz Dry Lakes

Migration of lower-quality groundwater into the project area from the dry lakes is not likely to result from project extraction operations. With the exception of saline groundwater beneath and adjacent to the dry lakes, water quality is relatively consistent throughout the region as shown in Figure 5.5-12. Groundwater TDS concentrations in the vicinity of the dry lakes are higher than those found in the Fenner Gap. However, the influence of the project wellfield in the vicinity of the dry lakes will be slight, and accordingly, the migration of the saline interface into the project area would be minimal.

The location of the saline groundwater interface (defined by the 1,000 mg/L TDS concentration line) was determined using recent groundwater data from wells in the vicinity of the project area. Regular monitoring of potential movements of this saline groundwater interface will be undertaken as part of the Management Plan. Monitoring will be accomplished with a network of cluster wells established between the project wellfield and the margins of Bristol and Cadiz dry lakes. Should project operations cause the TDS concentrations to change in excess of 25 percent of background concentrations in these cluster wells, these changes will be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. As a result, potential adverse impacts to users of the fresh water aquifer in the vicinity of the project area and to the salt mining operations due to movement of the saline groundwater interface will be less than significant.

Potential for Long-Term Drawdown of Groundwater

The amount of groundwater in storage underlying the Bristol, Fenner and Cadiz valleys is estimated to be 16.9 MAF (CDWR 1975). The aquifer system underlying these valleys encompasses an area of approximately 1,860 square miles (CDWR 1975). The depth to groundwater in these groundwater basins is estimated to range from less than 10 feet to over 400 feet below ground surface. The depth to groundwater in the Fenner Gap area is about 274 feet below ground surface (Metropolitan 1999b).

During the operational phase, groundwater levels will rise in the area surrounding the spreading basins in response to storage of Colorado River water, and fall in the area surrounding the project wellfield in response to extraction of stored Colorado River water and indigenous groundwater. The localized area with the greatest potential for long-term drawdown of groundwater levels directly underlies the project wellfield. To a lesser extent, drawdown of groundwater will occur in the area immediately surrounding the project wellfield.

As specified in the Management Plan (Section 6), static groundwater levels will be monitored regularly beginning in the pre-operational phase, throughout the operational phase and through the post-operational phase. Groundwater levels will be monitored continuously using downhole pressure transducers in designated wells described in the Management Plan. The project observation well network could be supplemented with a network of microgravity stations located in the immediate project area. Supplemental data gathered with the microgravity stations could be used in addition to water levels measured in observation wells.

To prevent significant adverse impacts to long-term groundwater levels throughout the aquifer system due to project operations, corrective measures would be implemented as required in the Management Plan (Section 7). Corrective measures entail modification of project operations such as reduced groundwater extraction. Implementation of the Closure Plan will require that pre-operational average static groundwater levels will not be depressed by more than an average of 100 feet in the area underlying the project wellfield at the conclusion of the operational phase, or lead to projections of adversely impacting critical resources in the post-operational phase. The Closure Plan will be implemented during the operational phase and will remain in effect through out the entire post-operational phase, which will be a minimum of 10 years, and will continue as long as deemed necessary to prevent potential adverse impacts. All provisions of the Management Plan will remain in effect and run concurrently with the term of the post-operational phase. In addition, all water use associated with the Cadiz Valley Agricultural Development will be conducted without adverse impacts to critical resources in accordance with the Management Plan including the provisions of the Closure Plan.

As a result of the above provisions the potential adverse impacts due to the potential for long-term drawdown of groundwater will be less than significant.

Potential Impacts to Bristol and Cadiz Dry Lakes

Potential Impacts To Brine Resources At Bristol And Cadiz Dry Lakes. The potential impacts related to the brine resources of Bristol and Cadiz dry lakes can be divided into three areas: 1) dilution of brine resources, 2) migration of stored Colorado River water constituents. These potential impacts are discussed below, and 3) raising or lowering the depth to brine.

Potential Dilution of Brine and Effects on Salt Mining Operations. During storage of Colorado River water, the lateral extent of mounding is not expected to reach either Bristol Dry Lake or Cadiz

Dry Lake. However, if Colorado River water were to reach these dry lakes, it would migrate upward to the dry lake surface and evaporate. The evaporation potential of the dry lakes is adequate to accommodate any such increased recharge. Therefore, dilution of brines would not occur, and the salt mining operations would not be affected, and this impact will be less than significant.

Potential migration of stored Colorado River water during long storage periods will be managed by using the project wellfield for periodic pumping and re-spreading of the extracted groundwater to avoid loss of stored Colorado River water. This project operational criterion will minimize migration of stored water toward Bristol or Cadiz dry lakes.

In addition, TDS levels will be regularly measured at the cluster wells between the project wellfield and the margins of the dry lakes. If TDS levels changed in excess of 25 percent of background levels, or water or brine levels changed by one foot in the cluster wells at the margins of the dry lakes, these changes will be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. Accordingly, the potential adverse impacts to the salt mining operations will be less than significant.

Potential Migration of Stored Water Constituents into the Brine Resources. No Colorado River water is anticipated to migrate to Bristol or Cadiz dry lakes during the term of the Cadiz Project. However, should any Colorado River water migrate to the dry lakes and evaporate, it would contribute sodium and calcium to these dry lakes for the production of calcium chloride and sodium chloride because Colorado River water contains more sodium and calcium than the indigenous groundwater. The availability of chloride in the brine underlying the dry lakes could facilitate production of these compounds and be beneficial to salt mining operations on the Bristol and Cadiz dry lakes. Accordingly, adverse impacts will be less than significant.

Any Colorado River water that migrates to the dry lakes would also contribute a small amount of perchlorate to Bristol and Cadiz dry lakes. As stated above, perchlorate has been detected as a constituent in Colorado River water at concentrations ranging from non-detectable to as high a 9 μg/L. The current provisional State of California Department of Health Services action level for perchlorate is 18 μg/L. Perchlorate is a salt and would become a very small component of the TDS constituents comprising the brines at Bristol and Cadiz dry lakes. It is anticipated that most of the Colorado River water introduced into the groundwater basin will be extracted by the Cadiz Project wellfield. As a result, adverse impacts will be less than significant.

Potential Raising or Lowering of the Depth to Brine. Cadiz Project storage and extraction operations have the potential to raise or lower groundwater levels beyond their natural fluctuations near the margins of Bristol and Cadiz dry lakes, potentially affecting the depth to brine levels under the dry lakebeds. During extended storage periods, potential migration of stored Colorado River water will be managed by using the project wellfield for periodic pumping of the extracted groundwater to prevent brine levels from rising beyond their natural fluctuations. Conversely, during extraction operations, pumping operations will be adjusted to prevent brine levels from lowering beyond natural fluctuations.

In addition, if brine levels changed by one foot in the cluster wells at the margins of the dry lakes, these changes will be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient at the margins of Bristol and Cadiz dry lakes. Accordingly, the potential adverse impacts to brine levels will be less than significant.

Potential Impacts to Air Quality Due to Dust Mobilization at Bristol and Cadiz Dry Lakes

It is currently believed that the groundwater (brine) beneath the lakebeds is sufficiently near the ground surface to moisten the surface soils through the capillary rise of moisture off of the water table. It is also believed that brine beneath the lakebeds is hydraulically connected to the freshwater aquifer outside the dry lakes. If so, excessive lowering of the groundwater surface beneath the dry lakes could lower brine levels to a level where capillary rise is reduced. Potential for increased mobilization of dry lake dust due to project operations would occur if: 1) the surface soils on Bristol and Cadiz dry lakes were to dry out; and 2) the drying out of surface soils, (attributable to project operations) would result in an increased potential for wind-blown dry lake dust.

To ensure that project operations will not result in water level changes beneath Bristol and Cadiz dry lakes that would cause an increase in dust mobilization, the Management Plan requires monitoring and analysis of potential changes to air quality (airborne dust), groundwater levels beneath the dry lakes, soil moisture and evapotranspiration (ET) at the dry lake surfaces, and wind speed and direction at the dry lakes and in the region. Correlation of groundwater level information, soil moisture, ET, airborne particulate measurements, and wind speed will allow judgements to be made as to whether the Cadiz Project was contributing to any increase in the frequency or severity of dust storms on the dry lakes. Because the Management Plan will use a conservative action criterion for groundwater levels beneath the dry lakes, any adverse changes would be detected early, and modifications to the project operations identified through the Management Plan decision-making process would be implemented to promptly reverse any condition before it would become a significant effect.

Further, monitoring of regional wind speed and direction as specified in the Management Plan will provide information necessary to determine where potential dust emissions from Bristol or Cadiz dry lakebeds could be transported.

Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Accordingly, the potential adverse impacts to air quality due to the mobilization of dust from Bristol and Cadiz dry lakes will be less than significant.

Potential Impacts to Water Quality in the Colorado River Aqueduct due to Introduction of Indigenous Groundwater

Potential changes to water quality in the CRA resulting from introduction of indigenous groundwater from the project area include: (1) reduction of TDS levels; (2) reduction of perchlorate concentration; (3) increase in bromide concentration; (4) increase in arsenic concentration; (5) increase in hexavalent chromium concentration; and (6) increase in nitrate concentration. Introduction of indigenous groundwater can provide water supply reliability and water quality benefits with regards to certain constituents. Although introduction of indigenous groundwater into the CRA would raise concentrations of some undesirable constituents, these constituent levels in the CRA will not appreciably increase and will not affect the ability to meet standards for drinking water established by the California Department of Health Services. Accordingly, adverse impacts to water quality in the CRA will be less than significant.

Potential Impacts to Fenner Gap Microclimate

Average annual evaporation pan measurements in the Amboy area, located approximately 15 miles west of the Cadiz Project area, average 158 inches per year. Actual evaporation rates from a larger surface water body, such as the project spreading basins, will be approximately 70 percent of the pan evaporation rate (Chow 1964).

Because the elevation of Fenner Gap is approximately 300 feet higher than that of Amboy, the annual evaporation is expected to be slightly lower. This has been verified with an evaporation pan located immediately adjacent to the pilot spreading basins in Fenner Gap. However, the record for this installation is relatively short-term, and the Amboy pan data have been employed here as a conservative estimate (Figure 5.5-6).

Based on the corrected surface water evaporation values obtained from the Amboy evaporation pan, the amount of water expected to evaporate from the project spreading basins ranges from approximately 600 to 1,000 acre-feet per year over the 50-year term of the project. Evaporation will occur only during spreading operations. The maximum projected evaporation estimate is approximately three percent of the total volume of Colorado River water to be stored in the project area. For comparison, Lake Havasu, located on the Colorado River east of the project area, loses approximately 133,000 acre-feet of water each year to evaporation (CDWR, 1979). This corresponds to a loss of approximately 22 percent of its total storage capacity every year.

The effect of evaporation from the project spreading basins on the microclimate of Fenner Gap is expected to be minimal. It is anticipated that the majority of spreading will occur during the first 15 years out of the 50-year term of the operational phase. In addition, minor spreading may be conducted during the storage periods to maintain the project wellfield and meet the Management Plan objectives. As a result, the amount of time that water will be susceptible to evaporation will be minor in comparison to the life of the project. Therefore, the existing natural long-term climatic conditions in Fenner Gap will not be significantly affected by the project.

Potential Impacts to the Desert Environment due to Implementation of the Management Plan

The Management Plan would require the installation, inspection and maintenance of monitoring facilities to provide for collection of data. These facilities are detailed in Table 1 and Figures 4 and 5 of the Management Plan volume of this Final EIR/EIS which include more specific information such as frequency of monitoring and conceptual location. Monitoring facilities generally include observation wells throughout the aquifer system, climatological monitoring instruments including weather stations, meteorological towers, stream gaging stations and evapotranspiration stations, survey benchmarks and other minor features that could gather data if additional monitoring is provided as a result of the Management Plan.

The technical team assembled to develop the Management Plan has specified the general location of the monitoring facilities proposed in the Management Plan. As the Management Plan is implemented, the technical team will define specific locations for all monitoring facilities. This Final EIR/EIS provides a qualitative discussion of the types of impacts that could occur as a result of implementation of the Management Plan. Such impacts are related to the drilling of new monitoring wells at specific locations, utilization of existing wells for monitoring purposes, placement of other types of monitoring equipment within the potentially affected region, and visiting these facilities in order to collect data and to provide for maintenance of them.

Monitoring facilities will be sited to avoid or minimize the potential environmental impacts discussed below.

The monitoring program could adversely affect biological resources, cultural and paleontological resources, and aesthetic, wilderness and recreational values. Potential direct effects will be caused by construction of facilities, modification of existing facilities, inspection of facilities to collect data, and provision of maintenance. Indirect effects will be caused by increased public use of remote areas of the desert through new or improved access.

Wildlife habitat will be affected and lost to construction of facilities. As discussed in Section 5.8, the predominant habitat type in the eastern Mojave Desert is creosote scrub, and it is most likely that this habitat type will be affected. Additionally, the threatened desert tortoise could be affected by such habitat losses and by inspection and maintenance of monitoring facilities. The installation of any new, above-grade power distribution facilities and meterological towers could indirectly affect the tortoise by providing perching and nesting opportunities for predatory ravens.

Cultural resources, such as historic and pre-historic remnants of past human use, and paleontological resources (fossil localities) could be affected directly if they were not avoided by ground disturbance necessary for construction or modification of facilities, or indirectly if improved or new access increases the potential for disturbance.

Any new access or power distribution facilities will have long-term effects on aesthetic values in the desert, particularly if they occur in previously undisturbed portions of the desert. The monitoring facilities are quite small and will not be noticeable from a distance. Visual impacts to the landscape associated with construction will be somewhat larger, but will blend back into the desert landscape over time. Wilderness and recreational values could be adversely affected by such aesthetic impacts if they occurred in proximity to wilderness areas or other areas used for recreational purposes.

Monitoring features described in the Management Plan will be installed within the general areas shown in Figure 4 of the Management Plan. Within these areas, specific locations will be selected that pose the least likelihood of creating adverse impacts. BLM or NPS, as appropriate, will review and consider for approval the location of individual monitoring features prior to installation. Pre-construction surveys required for installation of various elements of the Cadiz Project, such as the conveyance facilities, project wellfield, and spreading basins will also be conducted prior to installation of the monitoring features. These surveys will ensure that the appropriate mitigation measures for biological, cultural, and paleontological resources are implemented during construction in specific areas. Installation activities and periodic access to monitoring features located within the Mojave National Preserve will be approved by NPS prior to installation. No monitoring features will be located within designated wilderness areas. Periodic access to monitoring features required for long-term monitoring activities will be subject to all applicable mitigation measures identified in the Final EIR/EIS, including training of personnel for minimizing impacts to biological resources.

Each of the potential impacts described above is similar to impacts associated with the construction and operation of project facilities as identified throughout the Final EIR/EIS. As such, implementation of the Management Plan would be subject to the same mitigation measures as construction and operational activities associated with other elements of the Cadiz Project. Adherence to the mitigation measures identified in this Final EIR/EIS will minimize potential impacts associated with installation of Management Plan facilities. As a result, potential impacts have been determined to be less than significant. No additional mitigation measures are required.

Western Alternative

Construction and operation of the Western Alternative would result in the same impacts to water resources as would occur under the Eastern Alternative.

Combination Alternative

Construction and operation of the Combination Alternative would result in the same impacts to water resources as would occur under the Eastern Alternative.

Eastern/Canal Alternative

Construction and operation of the Eastern/Canal Alternative would result in the same impacts to water resources as would occur under the Eastern Alternative.

No Project Alternative

The No Project Alternative would have no impact on water resources within the project areas because the Cadiz Project would not be constructed, operated, or maintained.

However, as discussed in Section 4.8.3, the No Project Alternative could result in potential overdraft of groundwater basins and depletion of groundwater storage within Metropolitan's service area. In some basins, a prolonged decrease in groundwater elevations could cause a consolidation of water-bearing formations such that the storage capacity of the basins is reduced and/or the recharge capacity of the basin is permanently degraded by slower percolation rates. A related impact would be the potential for land subsidence.

5.5.5 MITIGATION MEASURES

The Management Plan, identified as mitigation measure WR-1 of the Draft EIR/EIS, has been fully incorporated as part of the Cadiz Project. The Management Plan establishes a comprehensive network of monitoring and data collection facilities combined with procedures for comprehensive review of all actions and decisions.

One of the key objectives of the Management Plan is to provide "early warning" of potential adverse impacts to critical resources that could result from Cadiz Project operations. With such early warning, adverse impacts will be prevented by implementation of suitable mitigation measures or corrective actions. With implementation of the Management Plan, unacceptable adverse impacts to critical resources will be avoided regardless of the amount of natural recharge to the project area. The Management Plan will be implemented as described in the Management Plan volume of this Final EIR/EIS.

5.5.6 LEVEL OF SIGNIFICANCE AFTER MITIGATION

Potential impacts to water resources include adverse changes to the quality and quantity of surface water and groundwater.

Surface water quality could be affected primarily during construction of the Cadiz Project facilities, including the wellfield, spreading basins, and water conveyance facilities. The Cadiz Project could introduce sediment and contaminants into surface waters. However, due to the general lack of surface water in the project area, the ability to control erosion and sedimentation, existing regulation of the use of potential contaminants (fuel, oil, etc.), the ability to clean up accidental spills, and with the short construction activities, the risk of potential adverse impacts is not considered significant.

Potential water quantity impacts include adverse changes in the location of surface water flow. Such impacts could be created by construction of Cadiz Project facilities and continue through the term of the Cadiz Project. The project will create small impermeable areas associated with the well heads and pumping plants. The spreading basins and water conveyance facilities will be earthen and will not change surface water characteristics appreciably.

The project spreading basins (all alternatives) and the canal segment of the Eastern/Canal Alternative will require diversion of surface flows. Diverted flows will maintain existing volumes and return water to their existing paths downstream of Cadiz Project facilities. Consequently, the Cadiz Project is not anticipated to have a significant adverse impact on surface water quantity and will have only minor impacts due to the relocation of surface flow.

Groundwater quantity impacts will include potential reduction in flow and groundwater elevation changes. As discussed earlier, groundwater elevation can be managed through the Cadiz Project operation. As required under the Management Plan, groundwater elevations will be monitored and the Cadiz Project operations adjusted to avoid significant adverse impacts.

Potential groundwater quality impacts include the potential introduction of undesirable constituents from Colorado River water into the groundwater aquifer system and the potential introduction of undesirable constituents from the indigenous groundwater into the Colorado River Aqueduct. As discussed above, Cadiz Project operations will transfer undesirable constituents. However, this transfer will not cause exceedance of any drinking water standards. Therefore, these impacts are less than significant.