Beneath the East Brawley K.G.R.A., the shallow water temperature has been reported as 90 degrees Fahrenheit (°F) (USBR, 1992). A log for a well in the East Brawley K.G.R.A. indicated that temperature ranged from 170 °F at 1,000 feet below ground surface (bgs) to 288 °F at 2,000 feet bgs. The temperature above 1,000 feet bgs was not recorded due to the sensitivity of the temperature probe but is likely cooler at shallower depths.

A temperature of 170°F was assumed for the entire East Mesa aquifer due to the similar aquifer depth and proximity to wells in the East Brawley K.G.R.A.

Groundwater temperature for the Heber K.G.R.A. was estimated using a temperature log from the HGU well 109. The temperature at 250 feet bgs was 178 °F, which is the depth of the shallow aquifer; and 308 °F at 1,500 feet bgs for the intermediate aquifer. Heber K.G.R.A. has the highest temperatures in the region for the shallow and intermediate aquifers.

Groundwater temperature for the Salton Sea K.G.R.A. was estimated using a log from the Megamax 4 well. At 300 feet bgs, at the base of the shallow aquifer, the temperature was recorded as 94 °F. The intermediate aquifer, with a depth of about 1,500 feet bgs, has a temperature recorded of 145 °F.

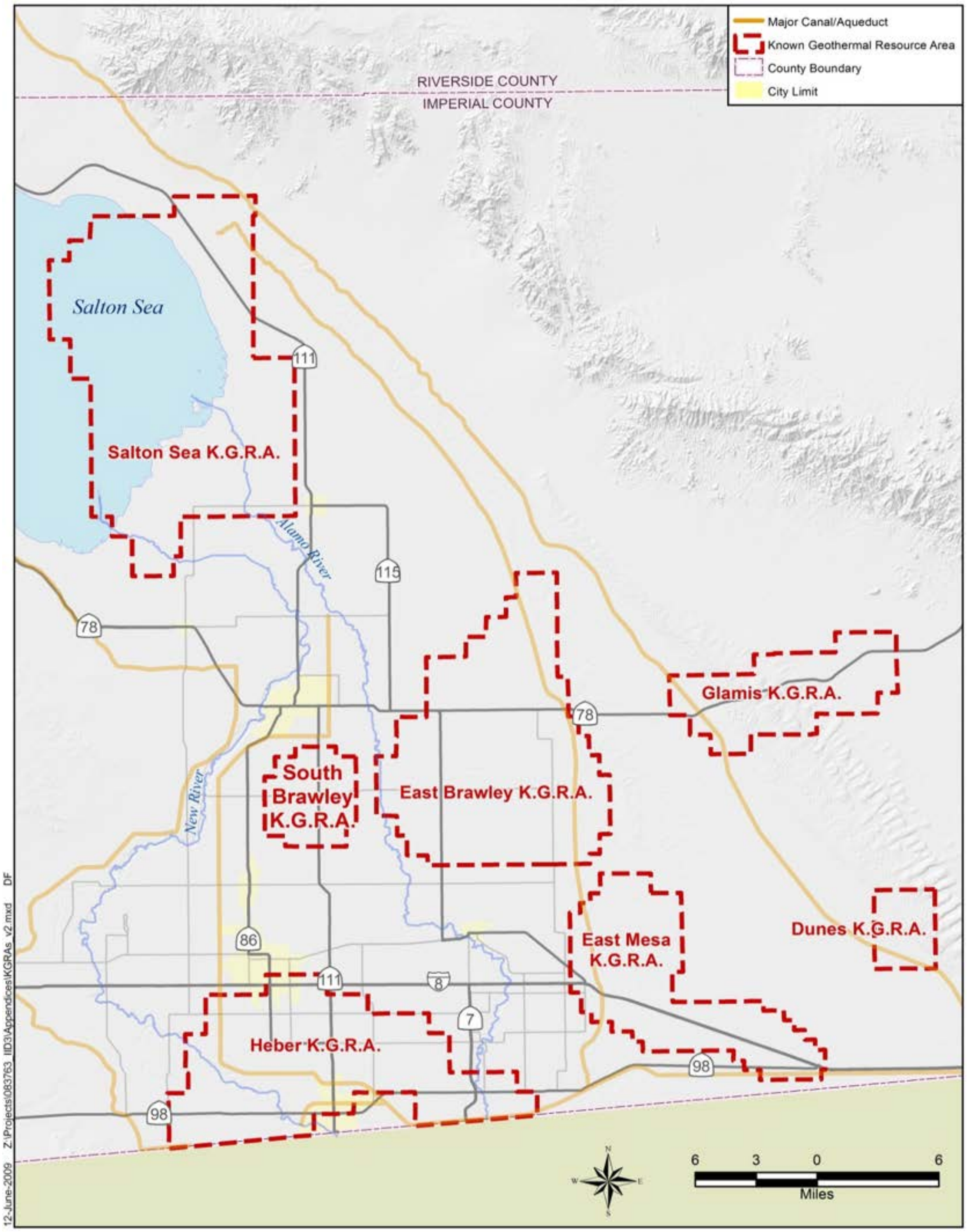


Figure B-12.Known Geothermal Resource Areas

B.9 AQUIFER HYDRAULIC CHARACTERISTICS

Aquifer hydraulic characteristics are present in terms of hydraulic conductivity, transmissivity and specific yield or storativity. The hydraulic conductivity is the rate at which water can move through a permeable medium and the units of Length/Time. Transmissivity is the ability of an aquifer to transmit water. The capacity of aquifer to transmit groundwater under pressure, expressed as a quantity of water, at the prevailing temperature, transmitted horizontally in a given period of time through a vertical strip of a given width of the fully saturated thickness of the aquifer, under a hydraulic gradient of one with unit of Length squared/Time or by multiplying these values by 7.48 to obtain units of gallons per day per foot. The transmissivity is equal to the hydraulic conductivity times the thickness of the aquifer. Porosity is the voids or open spaces in sediments that can be filled with water, frequently expressed ratio of the volume of open space to the total sediment volume, and is expressed as a percentage.

Storativity is the volume of water released from storage in an aquifer in a vertical column of one foot-square when the water surface in a confined aquifer (potentiometric surface) declines 1 foot. In an unconfined aquifer the storativity is approximately equal to specific yield.

Another common term used during evaluations of wells is specific capacity, which simply divides the gallons per minute (gpm) divided by the drawdown (static water level – pumping water level). Specific capacity units are gpm/foot (gpm/ft). The higher the number the better the well and indicates the sediments are more highly transmissive. The values range from less than 1 to 150 gpm/ft.

Several sources of data exist that provide information on the hydraulic parameters of aquifers in the Imperial IRWMP area. Areal distribution of aquifer transmissivity values derived from pumping tests, which typically provide high quality data, is shown on Figure B-12 (Tetra Tech, 1999). Unfortunately the data was not organized by aquifer. The highest aquifer transmisivities are found in the East and West Mesas, and the lowest are within the Imperial Valley.

Transmissivity values varied from 200 square feet/day in the Imperial Valley, to 100,000 square feet/day in East Mesa.

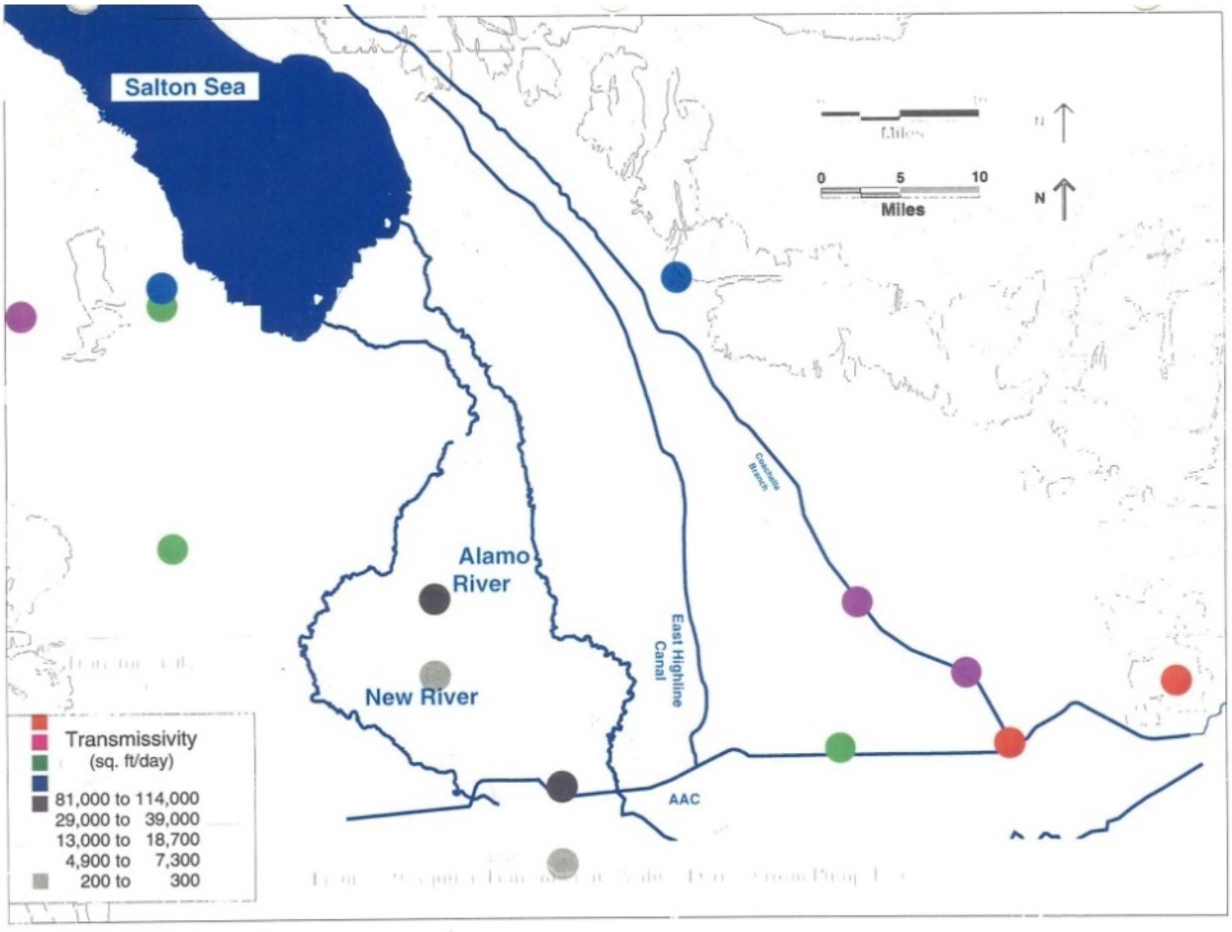


Figure B-14.Areal Distribution of Aquifer Transmissivities

Hydraulic conductivity values for the shallow and deeper aquifers were initially estimated using transmissivity data from the Imperial County Groundwater Model report (Montgomery Watson, 1995). Aquifer hydraulic conductivity values varied from a low value of 0.5 foot per day in the central irrigated area of the Basin where the previously described low conductivity lake bed sediments dominate, to a high value of 80 feet per day in East Mesa, where sediments are highly transmissive sands and gravels. Values for the Sand Hills, east of East Mesa, are 50 feet per day. Areas lacking data are assumed to have a hydraulic conductivity value of 30 feet per day for locations east of the pre-historic Lake Cahuilla shoreline (see Figure B-4) and 0.5 feet per day for locations west of the pre-historic Lake Cahuilla shoreline. Thus, based on the data presented; on average, new wells in the East Mesa would be expected to have higher yields than those in the West Mesa. Montgomery Watson (1995) presents a summary of hydraulic characteristics in various areas of the Imperial Valley. This is reproduced on Table B-2 below:

Table B-2. Summary of Hydraulic Characteristics

Area	Transmissivity (gpd/ft)	Transmissivity (sq ft/day)	Hydraulic Conductivity (ft/day)	Specific Yield
Imperial Valley	1,700 - 2,200	227 - 294	0.67 - 0.94	
East Mesa	140,000 - 50,000	18,717 - 113,636	32 - 1,337	
Sand Hills	62,000 - 590,000	8,289 - 78,887	9.7 - 401	
Ocotillo-Coyote Wells Groundwater Basin	10,000 - 82,000	1,336 - 10,963		0.04 - 0.15

Source: Montgomery Watson (1995)

Beyond those data cited above, Crandall (1983) provides data on estimated specific yield for the East Mesa aquifer. The range of values reported by Crandall varied from about 4 percent near the East Highline Canal, to 25 percent which occurs in areas along the Coachella Canal and AAC. The average specific yield for the East Mesa area was listed as 21 percent. Consistent with the geologic model described previously, specific yields decrease closer to the valley floor in proximity to the pre-historic Cahuilla Lake bed deposits. Higher values found elsewhere in the area are associated with coarser grained deposits of wind-blown origin.

Well logs obtained from the CDWR were used to evaluate depth specific aquifer characteristics. Aquifer characteristics were estimated from pumping test information contained on some of the logs; however, because the results are based on a single well the quality of the estimate is moderate. Table B-3 shows the aquifer characteristics by aquifer and generalized areas. The results show that East Brawley K.G.R.A. and East Mesa K.G.R.A. intermediate aquifers have the highest transmissivity and hydraulic conductivities. The aquifers in these locations will be able to supply greater quantities of water more sustainably than the Salton Sea or Heber K.G.R.A.s.

Table B-3. Aquifer Hydraulic Parameters

K.G.R.A.	Depth (feet)	Transmissivity (gpd/ft)	Hydraulic Conductivity (ft/day)	Storativity	TDS (mg/L)	Water Temprature (F)
Shallow Aquifer						
East Brawley [4]	80-300	10,000	13	0.01	1576 [7]	90
Heber [4]	80-300	10,000	13	0.01	3603 [7]	178
Salton Sea [4]	80-300	10,000	13	0.01	1500 [8]	94
Intermediate Aquifer						
East Brawley [6]	200-900 [2]	250,000	71	0.0001	1886 [7]	170-288 [11]
Heber [3,5]	300-1500	120,000	25	0.0001	1478 [9]	308
Salton Sea [3]	300-1500	60,000	25	0.0001	3200 [10]	94-145
East Mesa [1]	200-900 [2]	250,000	47	0.0001	1584 [7]	170

Notes:

LeRoy Crandall and Associates [1]
Assumed aquifer thickness form Cross -Sections A and B [2]
Hydraulic Conductivity assumed 25 ft/day and Transmissivity was backsolved [3]
Transmissivity Estimated from CDWR Paper 486-K [4]
Aquifer thickness averaged from CDWR well logs and CDWR Paper 486-K [5]
East side of Calipatria Fault and assumed sediments similar to that of East Mesa [6]
TDS is average for the well field area [7]
TDS only one measruement available in the area [8]
TDS Value is average from available vaues along Alamo River and East of Heber [9]
TDS Value from Niel at NCRS for Alamo River Flows [10]
From 1000 to 2000 feet depth [11]

Other data available for wells in the East Mesa include well yields and specific capacities. Reported well yields varied from 80 to 3,000 gpm, depending on depth and location. In general, yields in excess of 900 gpm were associated with depths of 200 feet or more. Specific capacity data reported for seven wells in the East Mesa, varied from 0.8 to 85 gpm/ft. The well with the highest specific capacity was located at the junction of the AAC and Coachella Canal. Specific capacities were highest to the east, and diminished to the west. Higher specific capacities were associated with wells deeper than 200 feet (Crandall, 1983).

Consistent with the overall geologic model for the Imperial IRWMP area, the highest transmissivities are associated with the East and West Mesas where aquifer formations are generally more homogenous and include a much higher proportion of coarse sands and gravels then the Imperial Valley floor, allowing groundwater to move at higher rates.

B.10 GROUNDWATER LEVELS AND MOVEMENT

The direction of groundwater movement is controlled primarily by contours of groundwater level elevation; the rate of groundwater movement is proportional to the gradient or slope of the groundwater table. Groundwater levels and flow have changed with lining of the canals; therefore, two temporal sets of water level data are presented: one for 1960 representing conditions with recharge from the canals and one for 1993 after the southerly portions of the Coachella Canal was lined. Lining of portions of the AAC, generally about six miles east of the East Highline Canal to about five miles east of the Coachella Canal was not started until 2006 so neither set of maps reflect the reduction of seepage from the AAC. A portion of the AAC still contributes recharge to East Mesa. Additional details groundwater contour maps are also provided for both the East and West Mesas.

B.10.1 Imperial IRWMP Area Historic Groundwater Levels (1960 Data)

Published water level contours are available for 1965 for Imperial IRWMP area (Loeltz et al., 1975) and 1960 for the East Mesa (USBR, 1994). A composite water level contour map of the area based on the 1960 and 1965 data is presented on Figure B-13. The dashed water level contours east of the Salton Sea area reflect limited data for this area.

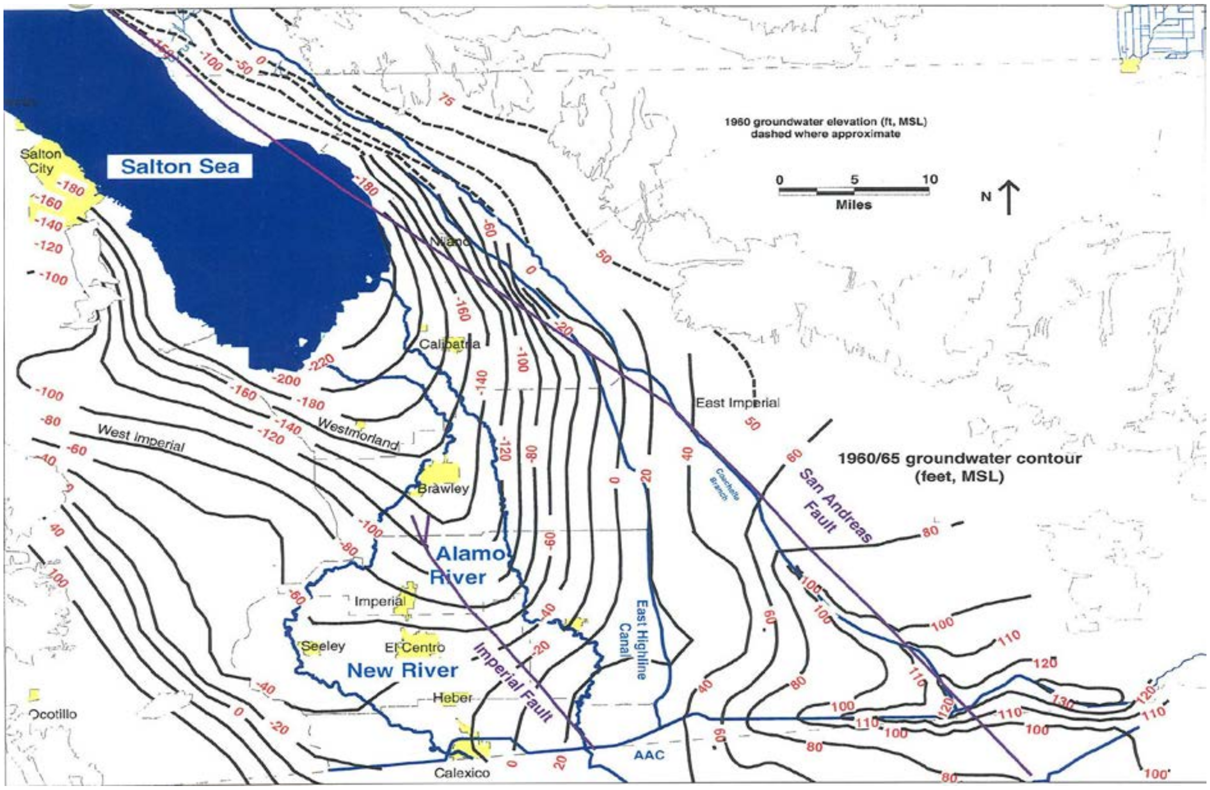


Figure B-15.Groundwater Contour Map, 1960/65 Data

The groundwater contours show a broad groundwater mound in the East Mesa area, from east of the San Andreas Fault and continuing to the East Highline Canal. This mound is associated with seepage recharge from unlined portions of the AAC beginning with its construction in the 1940s. The groundwater mound also extends northwest along the unlined Coachella Canal due to seepage recharge. Between the canals, the direction of movement is west-northwestward; but south of the AAC, the flow direction is into Mexico. East of the Coachella Canal, the flow direction is northward for the first 20 miles, but further north, gradually swings to the west. East of the San Andreas Fault zone, groundwater reportedly flows north and east toward the Colorado River.

Groundwater moves from the recharge areas east and west of Imperial Valley, toward the axis of the valley, and converges upon the New and Alamo Rivers respectively, which discharge to the Salton Sea. The overall direction of flow of groundwater in the area based on the 1960 data is presented on Figure B-14. Historically, artesian groundwater conditions have been quite common between the East Highline Canal and the Alamo River, but artesian conditions do not extend west of the Alamo River. This suggests that the Alamo River may be a more significant source of discharge from the upper aquifer than the New River in the central valley area.

As illustrated in Figure B-14, flow directions are westward along the AAC between the Coachella Canal and the Alamo River, then northwest to north between the Alamo and New River. Flow direction below the AAC is to the south into Mexico east of the Coachella Canal, but then turns southwest between the Coachella Canal and the East Highline Canal. Apparent flow direction is to the northwest in western Imperial Valley near the West Mesa and to the southwest east of the Salton Sea, as flow from both these areas converges towards the Salton Sea. Flow direction in East Mesa is west to northwest, although it was also locally influenced by the presence of the groundwater mound under the former unlined Coachella Canal. Groundwater flow east of the San Andreas Fault system is to the north.

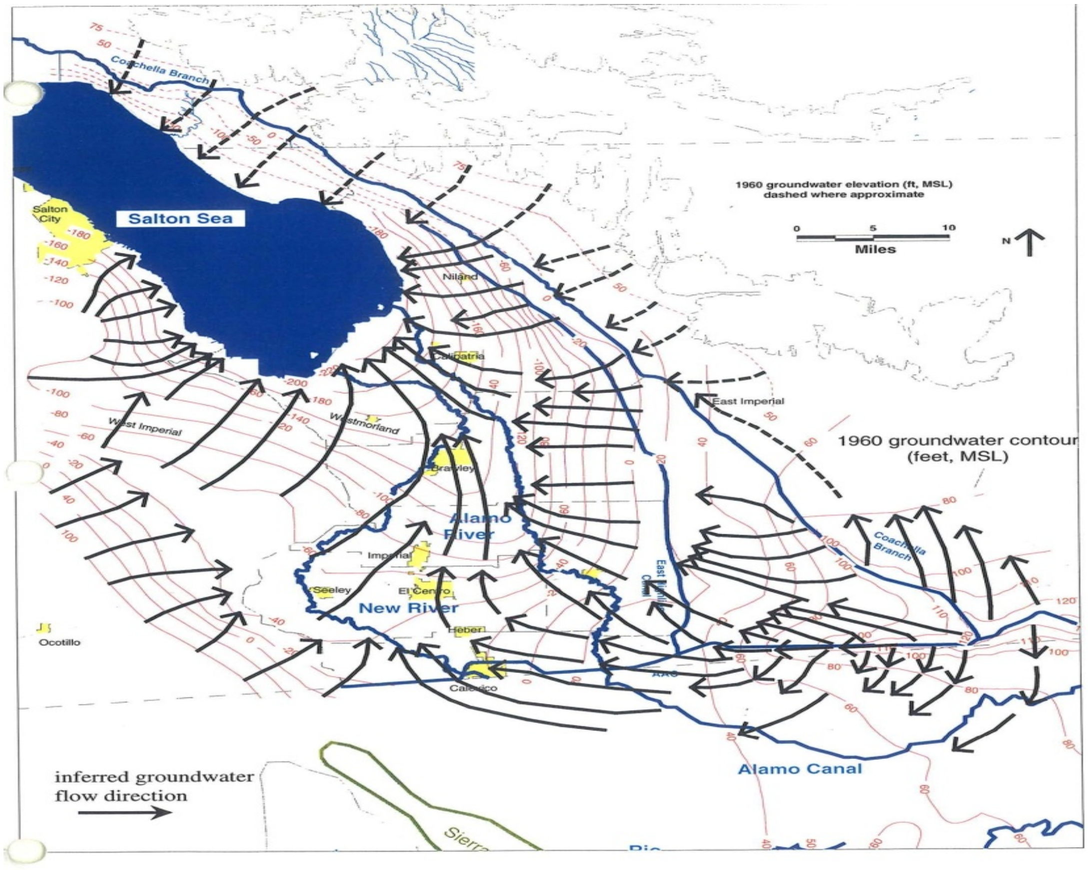


Figure B-16.Regional Groundwater Flow Map, 1960

Groundwater levels adjacent to the canal in the East Mesa area have varied significantly over time, primarily in response to seepage of imported Colorado River water. These canals have had the most significant impact on water levels in the study area. In the irrigated Imperial Valley groundwater levels have remained essentially the same for many decades, due to the existence of the tile drain network and the New and Alamo Rivers, which act as regional drains and control groundwater levels.

Many East Mesa wells have seasonal trends in the water levels, with highest water levels in March and the lowest water levels in September. The seasonal trends appear strongest near the AAC below Drop 1, although they can also be observed in East Mesa. These seasonal trends are thought to be associated with variations in canal leakage prior to lining of the canal.

B.10.2 Imperial IRWMP Area Recent Groundwater Levels (1993 Data)

Groundwater levels for the Imperial IRWMP area, based on 1993 data, are shown on Figure B-15. The 1993 time period represents the most recent period with comprehensive data of the entire area, including the Mexicali Valley, and it also is a time period that should accurately represent present day water levels in the East Mesa and Imperial Valley (Tetra Tech, 1999). The decline in the water table in East Mesa, due to the lining of the first 49 miles of the Coachella Canal, began in 1980 and stabilized in the early 1990s. A similar affect should be expected in the southern margin of East Mesa upon completion of the lining for the AAC in 2010.

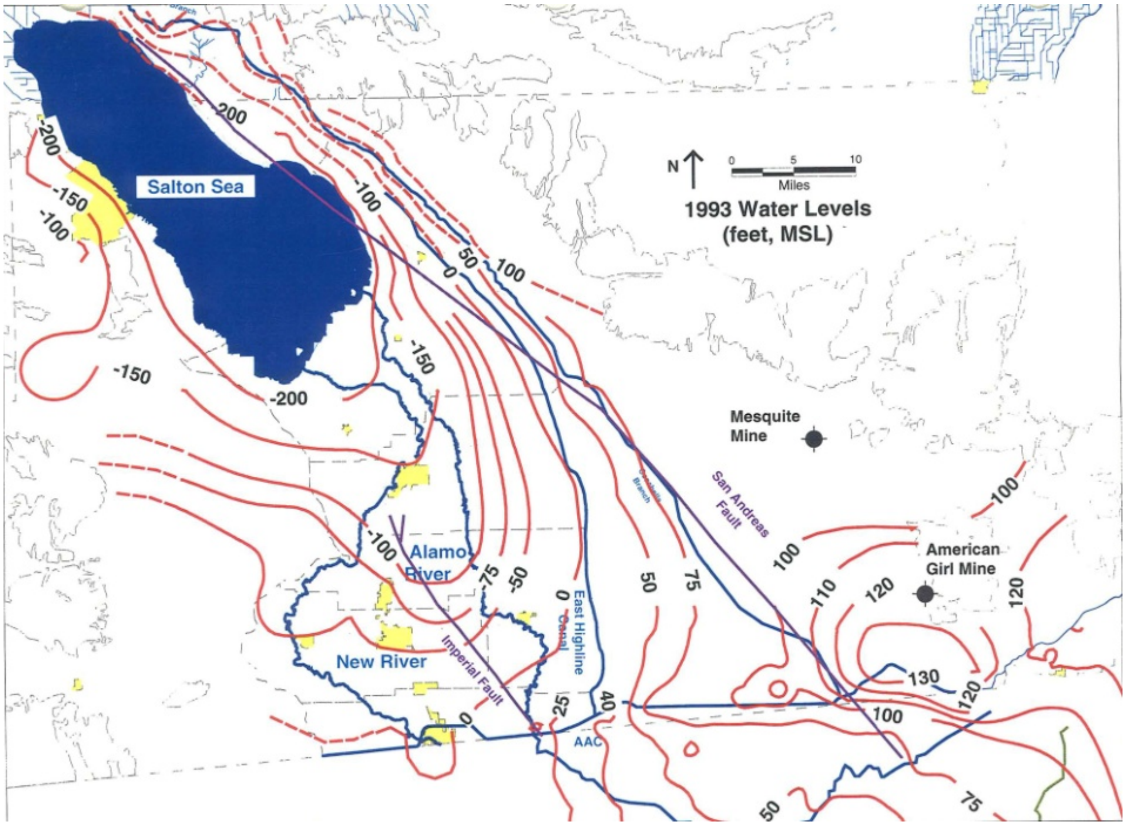


Figure B-17.Groundwater Contour Map, 1993 Data

As can be seen on Figure B-15, groundwater contours are generally unchanged from the 1960s data in the Imperial Valley, the area east of the Salton Sea, Mexicali Valley, and the East Mesa area adjacent to the AAC. However, the water table declined significantly along the first 49 miles of the Coachella Canal due to its 1979 lining. This has resulted in a more northerly flow direction into East Mesa near Drop 1 of the AAC. In general, the water levels along the AAC are similar to the 1960 conditions because AAC seepage was not controlled by water level elevations near Drop 1 on the AAC. It is expected further decreases in groundwater levels will occur after the completion of addition lining of the ACC in 2010.

B.10.3 West Mesa

Groundwater levels beneath West Mesa, as show on Figure B-14, show the groundwater flow direction beneath West Mesa is from the southwest to the northeast toward the Salton Sea.

Groundwater levels in the Ocotillo-Coyote Wells Groundwater Basin west of the West Mesa area are measured by the USGS. The most recent (1995) water level elevation data are shown on the groundwater contour map in Figure B-16. This map shows the groundwater slopes (and therefore moves) southwesterly through the Ocotillo-Coyote Wells Groundwater Basin, from areas of recharge in the Coyote and Jacumba Mountains, to areas of discharge in Mexico and across the Elsinore/Laguna Salada Faults. The data also reveal the difference in groundwater elevations from one side to the other of the Elsinore/Laguna Salada Faults, reflect the fact that these faults are an impediment to the movement of groundwater into West Mesa.

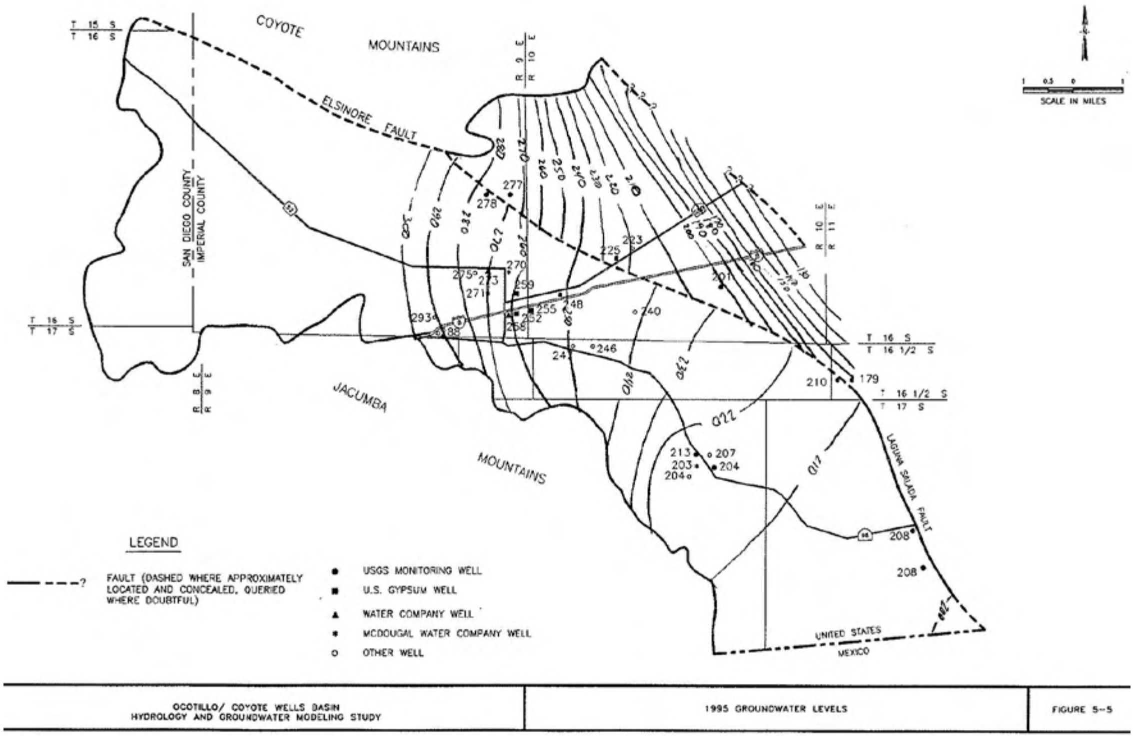


Figure B-18.West Mesa Groundwater Contour Map, 1995 Data

B.10.4 East Mesa

As previously described, the East Mesa includes the roughly triangular area southwest of the San Andreas Fault, north of the Mexican border, and east of the East Highline canal (shoreline of ancient Lake Cahuilla) as shown on Figure B-4. Recharge to the East Mesa is almost entirely a result of historic seepage from unlined portions of the AAC and Coachella Canal. The movement of groundwater in areas of the East Mesa is, therefore, reflective of these sources of recharge. Little data are available on the existence and continuity of clayey lake beds and aquitards in the East Mesa; and, as described previously, groundwater occurs under unconfined conditions in most areas. Figure B-17 presents a groundwater contour map of the East Mesa based on 1982 data, shortly after the lining of the Coachella Canal in 1979 but before ACC lining project in 2006 (USBR, 1988). As shown in Figure B-17 groundwater in the southern part of East Mesa, near the ACC, generally flows north-northwesterly. In the more northern portions of East Mesa flows are in a more westerly direction toward the East Highline Canal and the Imperial Valley.

As previously mentioned, several significant faults in the area alter and restrict the flow of groundwater flow from east to west, into the Imperial Valley. These are, from west to east, the Brawley, Calipatria, San Andreas (main branch), and Algodones/Sand Hills Faults. Crandall (1983) reports that water levels are offset across both the Brawley and Calipatria faults, indicating they may be partial barriers to the flow of groundwater from East Mesa into the Imperial Valley. To the east, the Sand Hills (also known as the Algodones Dunes) lie between the San Andreas and Algodones Faults. This area may provide a favorable structural zone in which groundwater recharge and recovery activities can be considered.

B.11 GROUNDWATER VELOCITY

Data was reviewed that presents approximate groundwater flow rates, based on the slope of the water table, the aquifer hydraulic conductivity, and the aquifer effective porosity. Groundwater velocity in the permeable East Mesa sands and gravels is estimated to be 450 feet per year using a gradient of 0.001 foot per foot (ft/ft), a hydraulic conductivity of 250 feet per day and an effective porosity of 20 percent. In contrast, groundwater velocity in the semi-permeable pre-historic Lake Cahuilla sediments beneath the Imperial Valley is estimated to be only 10 feet per year using a gradient of 0.004 ft/ft, a hydraulic conductivity of 0.5 foot per day, and an effective porosity of 8 percent. In addition to the major differences in groundwater flow rates between the East Mesa and the Imperial Valley, smaller groundwater flow rate variations occur due to variability in the gradient and hydraulic conductivity within each area (Bureau of Reclamation, 1987; Tetra Tech, 1999; Crandall, 1983).

B.12 RECOVERY AND ARTIFICIAL RECHARGE POTENTIAL

The potential for artificial recharge and recovery varies greatly between the Imperial Valley, West and East Mesas due to the permeability of the sediments and the ability to convey water to the recharge areas. A discussion for each area is provided below.

B.12.1 Imperial Valley

The Imperial Valley has limited potential for conjunctive use or banking opportunities. The Imperial Valley is underlain by at least two regional aquifers. The upper aquifer is about 200 feet thick and may contain about 0.8 million AF poor quality of water (see Figure B-8). The aquifers for the most part are relatively thin sand beds. Groundwater levels are near ground surface (10 to 15 bgs) indicating the aquifer is full. Recovery of water could be by wells or drains, but they are hampered low transmissive sediments, poor and highly variable quality water as shown on B-8, and other impacts such as land subsidence.

Since irrigation began in the valley, recharge to the aquifer is from percolation of applied water not captured by the drain system; therefore, no recharge facilities would need to be constructed.

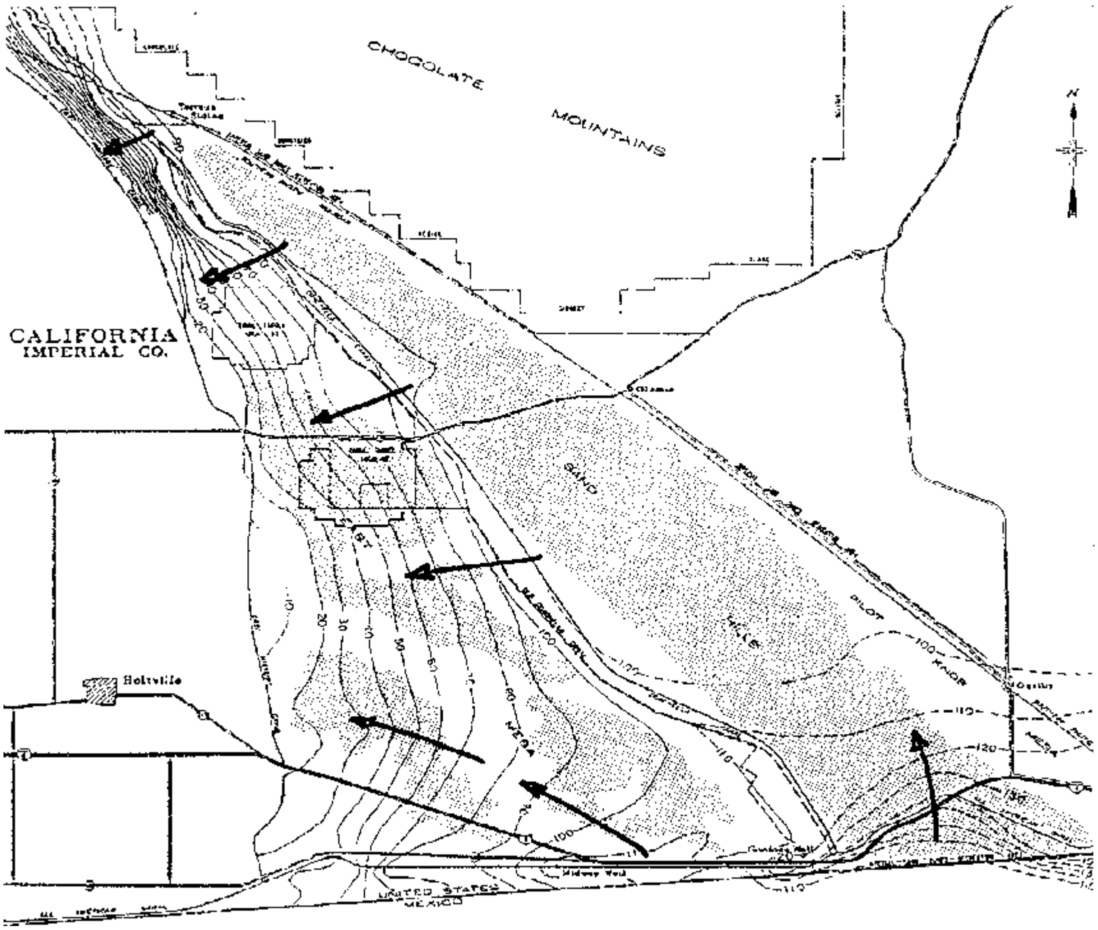


Figure B-19.East Mesa Groundwater Contour Map, 1982 Data

The intermediate aquifer, beneath the Imperial Valley is about 600 feet thick and may contain about 24 million AF of water. There are relatively thick sand beds which could be favorable for developing high capacity wells. The salinity of the groundwater ranges from about 700 to 3,330 mg/L, which makes treatment of the water feasible. The full extent of the aquifer is unknown and its hydraulic interconnection to the upper aquifer is poorly understood. Geologic information is insufficient to ascertain the source area for recharge to the intermediate aquifer. It could be from the overlying upper aquifer to the south in Mexico, or to from the East Mesa area west of the San Andreas Fault. If recharge to the intermediate aquifer comes from the East Mesa area and the water can cross the Calipatria Fault, which is at least a partial barrier to groundwater flow, then it is possible that an artificial recharge project through unlined portions of the old Coachella Canal could be an effective conjunctive use project for the intermediate aquifer. Because of its large storage and areal extent, relatively consistent water quality, and apparent ability to convey water to high capacity wells, the intermediate aquifer could possibly be a conjunctive use target. However, with the high degree of uncertainty in the recharge, this aquifer should not be considered for a conjunctive use project.

B.12.2 West Mesa

Constraints to groundwater banking activities in the West Mesa include the potential conflicts with the U.S. Gypsum operation, sole source aquifer designation for Ocotillo-Coyote Wells Groundwater Basin and maintaining the recharged water for use by IID. However, recharge water in the West Mesa is a possibility. The mountain front areas along the west side of mesa include portions of several small groundwater basins identified by CDWR. Most of the basins in this area include a small number of highly productive wells, reflective of the more permeable aquifers that underlie this area. Aquifer materials and hydraulic characteristics are highly favorable for recharge of water to the subsurface, and subsequent recovery. Water quality is generally good, and might not require treatment prior to use. Areas that warrant further investigation are near the Carrizo Wash or Palm Canyon.

B.12.3 East Mesa

The East Mesa area is the most favorable for an aquifer storage and recovery operation. The concept of storing and recovering Colorado River water during IID underruns in the East Mesa and has been the subject of investigation by both IID and the USBR since the mid-1980s.

In 1989, a recharge study using a portion of the old unlined Coachella Canal just south of the Glamis K.G.R.A and west of the San Andreas Fault, diverted an average of 80 cfs (17,000 AF) of water into the canal for 3.5 months proving the sediments are favorable for a recharge facility (USBR, 1992). The recharged water raised the water table by about 15 feet near the canal, but only raised the piezometric head in the semi-confined intermediate aquifer by about 3 feet. USBR postulated the piezometric head in the intermediate aquifer was raised due to the overburden of the recharged mound of water in the shallow aquifer applying great pressure to the intermediate aquifer. Most likely the confining layer separating the two aquifers is not a significant barrier to groundwater flow and that by pumping from the intermediate aquifer could induce recharged water to enter the intermediate aquifer where the aquifers have a higher transmissive capacity and potential for developing high yielding wells. Additional testing is needed.

The upper and intermediate aquifers beneath East Mesa are highly permeable. Groundwater in storage beneath the East Mesa west of the San Andreas fault in just the upper aquifer is estimated to be about 1.5 million AF. The aquifers are generally full and may need to be pumped to create storage for recharged water. The aquifers are favorable for development of high capacity wells, and water is generally of good quality, with TDS ranging from 500 to 1,000 mg/L, (see Figure B-8 and Figure B-10).

B.13 CONJUNCTIVE USE FACILITY CONCEPTUAL DESIGNS

This section presents conceptual designs for using groundwater as the source of supply and groundwater recharge facilities.

New water supply will be needed to support future development of geothermal plants in each of the K.G.R.A.s and other Municipal, Commercial and Industrial (MCI) development. The water could also be used by agriculture to augment supplies when a potential annual overrun is projected.

Development of groundwater supply wells and well fields, was evaluated as a source to supply water to each of the K.G.R.A.s. Imperial Valley groundwater quality is generally of moderate to poor quality in the aquifers and would require treatment. The shallow aquifer has the most variable concentrations ranging from 800 to over 10,000 mg/L. The intermediate aquifer has the most consistent salt concentrations ranging from about 800 to 2,220 mg/L. Generally better quality water is present beneath East Mesa due to historic recharge from the unlined canals. Desalination plants would be required and the brine associated with the treatment will require disposal.

Extraction of groundwater in the desert environment would eventually deplete the resource if the aquifers were not recharged. Selection of the well pumping capacity and the well field locations were based on the ability to recharge the aquifers either from deep percolation of agricultural applied water or by replenishing the water through groundwater recharge. Conceptual well fields were not located between closely spaced parallel faults due to their potential to be barriers to groundwater flow, limited storage capacity, and the potential lack of recharge that could lead to subsidence and ground fissuring. The well locations were further constrained by geologic hazards and other design constraints.

B.14 GEOLOGIC HAZARDS AND DESIGN CONSTRAINTS

The Imperial region lies in one of the most seismically active areas in the United States. Several geologic hazards face the region including earthquakes, liquefaction, sieches, flooding due to breaching of canals, and subsidence.

B.14.1 Earthquakes

Near the K.G.R.A.s, major active and potentially active faults trend in a northwestern direction. Figure B-18 shows the location of these faults. The San Andreas and the Imperial faults are active. The Brawly and Calipatria Faults are classified as potentially active according to the California Geological Survey. Near the active and potentially active faults the potential for surface displacement and cracking is high.

The potential for shaking is high near the K.G.R.A.s. Facilities should be designed to within the appropriate level of shaking and to the extent possible be set back as far as possible from the faults. Where distribution pipelines cross faults they will be subject to shearing.

B.15 LIQUEFACTION

Liquefaction may occur during an earthquake where saturated soils are shaken and the geologic media become buoyant in the groundwater and structures can sink or sag due to the decrease in the soil's structural integrity. Potential for liquefaction is low beneath East Mesa, but increases to the west where the potential is moderate to high, due to irrigation that may cause perched water above the pre-historic Lake Cahuilla clayey lakebed deposits.

Groundwater pumping could locally decrease the potential for liquefaction by lowering groundwater levels.

B.16 SIECHES

When an earthquake occurs in a location near a large body of water a sieche can occur. A sieche is a large wave in an inland body of water that can cause flooding and damage nearby structures. A strong earthquake could create a sieche from either the Salton Sea or in the canals. Although sieches have not been reported, the potential is moderate to high.

B.17 FLOODING

Imperial Valley and even East Mesa are at risk for flooding were canals to be sheared and offset due to fault activity. A significant surface rupture of one or multiple canals could flood portions of the Imperial Valley. Potential for flooding is moderate to high. Facilities located down gradient of the major canals should be designed to withstand flooding though elevation of structures or inclusion of diversion measures to redirect water away from the facilities.

B.18 SUBSIDENCE

Two inches of naturally occurring subsidence annually are centered at the middle of the Salton Sea. The two inches of subsidence decreases radially outward from the Salton Sea. Near the Mexican border the natural subsidence is essentially zero (Imperial County, 2006).

Imperial Valley has a dense irrigation network of canals and laterals that supply water throughout the valley. This network relies on canal grades to gravity feed the water throughout the system. Subsidence can cause the ground surface to sink or sag damaging or changing the grade on infrastructure.

Subsidence may also be induced by removing more water from the aquifer than can be replaced naturally or by injection. Imperial Valley's geothermal wells remove steam and water from below the deep aquifer. In some cases water is injected back into the zones where water was removed and aid to mitigate potential subsidence. Subsidence has been detected in the Salton Sea K.G.R.A.

Potential for subsidence as a result of groundwater pumping is high in the Imperial Valley and low to moderate in the East Mesa area. Geotechnical investigations will be required for foundation designs to withstand settlement due to subsidence and how potential subsidence would affect existing infrastructure, canals, drains, and bridges. Pipelines should be constructed with flexible materials or incorporate expansion joints.

B.19 CORROSIVE SOILS

Data was gathered on 28 soil types that are common in the Imperial Valley and East Mesa showed that some soil types can be corrosive to steel and concrete. The risk of corrosion to both concrete and steel were reported as either low, moderate, or high (NRCS *http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx*). Of the 28 soils from the soil survey all 28 had a high rating for being corrosive to steel. Of the 28 soil types, 13 were considered low, 13 were considered moderate, 1 was considered high, and 1 was not rated for corrosiveness to concrete.

To withstand the corrosive soils, pipelines should be constructed with polyvinylchloride or high density polyethylene. Depending on the location, special mixtures of concrete may be required for foundations.

B.20 COLORADO RIVER EFFECTS

The Colorado River is located about 50 miles to the east of the Imperial IRWMP area. An accounting surface method was developed in the 1990s by the U.S. Geologic Survey, in corporation with the Bureau of Reclamation to identify wells outside of the flood plain of the lower Colorado River that yield water that will be replaced by water from the river. This method was needed to identify which wells require an entitlement for diversion of water from the Colorado River and need to be included in accounting for consumptive use of Colorado River water as outlined in the Consolidated Decree of the

United States Supreme Court in Arizona v. California. The method is based on the concept of a river aquifer and an accounting surface within the river aquifer. The study area includes the valley adjacent to the lower Colorado River and parts of some adjacent valleys in Arizona, California, Nevada, and Utah and extends from the east end of Lake Mead south to the southerly international boundary with Mexico. Contours for the original accounting surface were hand drawn based on the shape of the aquifer, water-surface elevations in the Colorado River and drainage ditches, and hydrologic judgment.

This method for determining well impacts to the Colorado River was published in the Federal Register for the Department of the Interior on July 16, 2008, but was not formalized. It indicated that if static water levels in wells are equal to or the elevation of water in the Colorado River it is assumed that water from the wells is coming from Colorado River. The elevations of the river were projected into areas surrounding the river to create the accounting surface. The accounting surface extended into portions of East Mesa (Scientific Investigations Report 2008-5113, USGS 2008).

In 2008, the USGS published another method for assessing whether wells deplete groundwater that would otherwise recharge the Colorado River aquifers. They developed a superposition model that simulates the percentage of water depleted from the river (Scientific Investigations Report 2008-5189, USGS 2008). The assumption is that when a well is initially pumped, virtually all the water comes from groundwater storage; but over time, as the cone of depression grows, the percentage of water from the river or other recharge sources increases. The southeastern portion of the East Mesa has been designated as having a potential to deplete water in the Colorado River as shown on Figure B-18 as the Depletion Model Area. The Dunes K.G.R.A. is adjacent to and overlaps the proposed depletion area.

B.21 ENDANGERED SPECIES

Endangered and threatened species are present in the Region. The endangered species habitat areas were mapped to the extent possible to highlight areas that were excluded as desalination plant and well field locations. These locations are illustrated on Figure B-18. Most of the Glamis and Dunes K.G.R.A.s are occupied by endangered species.

B.22 SEEPAGE RECOVERY SYSTEM

IID has installed a Seepage Recovery (SR) system to collect seepage from the East Highline Canal and the ACC as part of the system efficiency conversation. Water collected by the SR system interceptors is protected. About 13,000 AFY has been recovered from the East Highline Canal SR system and about 25,000 AFY has been recovered from the ACC SR system. Well fields for the desalination plants should be designed to minimize drawdown along the SR system so they will not collect water that would have been otherwise collected through SR system.

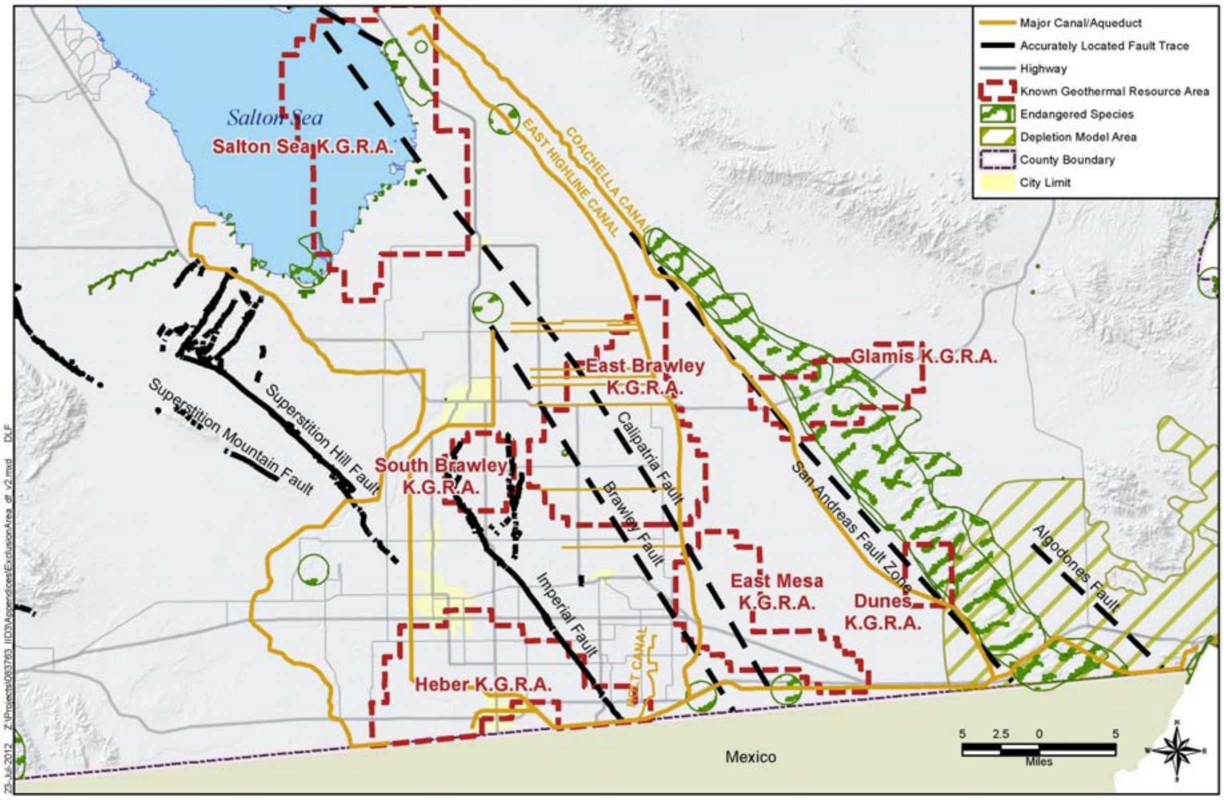


Figure B-20.Exclusion Zones

B.23 WELL FIELD CONCEPTUAL DESIGNS

Preliminary designs for well fields were developed to supply 5,000 AFY, 25,000 AFY, and 50,000 AFY of groundwater to the East Brawley, East Mesa, Heber, and Salton Sea K.G.R.A.s. Attachment A contains conceptual sketches of the well fields along with the raw and finished water distribution systems. Because the water will need to be treated, the amount of groundwater pumped had to be increased as the treatment plants will operate with 75 percent efficiency. Using the 75 percent efficiency, the wells will need to produce 6,600 AFY, 33,300 AFY, and 66,600 AFY.

Aquifer characteristics listed in Table B-3 for each K.G.R.A. were used to determine the potential well pumping rate over the 30 year life of the project. A Theis analysis of the potential well fields was conducted assuming the wells are arranged in a grid shape. Spacing between wells was initially estimated to limit well interference to about 10 feet. Analysis predicted the average drawdown expected due to pumping of the well field. These estimations were used to determine if the drawdown would exceed the thickness of the aquifers or in the case of the intermediate aquifer to maintain groundwater levels above the confining bed. The number of wells and their pumping rates were then adjusted to select the optimum number of wells. The number of wells and their production rates for each proposed well field by K.G.R.A. are summarized in Table B-4.

Table B-4. Wells Required for Each Well Field Based on K.G.R.A.s

K.G.R.A.	Plant Capacity (AFY)	Aquifer	Well Depth (feet)	Tranmissivity (gpd/ft)	Hydraulic Conductivity (ft/day)	75% Efficency Water Needed (AFY)	GPM per Year	Pumping Rate (gpm)	Number of Wells
East Brawley	**5,000**	Shallow	80-300	10,000	13	6,667	4,133	100	41
	25,000	Shallow	80-300	10,000	13	33,333	20,665	100	207
	50,000	Shallow	80-300	10,000	13	66,667	41,331	100	413
	5,000	Intermediate	200-900	250,000	71	6,667	4,133	2000	2
	25,000	Intermediate	200-900	250,000	71	33,333	20,665	2000	11
	50,000	Intermediate	200-900	250,000	71	66,667	41,331	2000	21
Heber	**5,000**	Shallow	80-300	10,000	13	6,667	4,133	100	41
	25,000	Shallow	80-300	10,000	13	33,333	20,665	100	207
	50,000	Shallow	80-300	10,000	13	66,667	41,331	100	413
	5,000	Intermediate	300-1500	120,000	25	6,667	4,133	350	12
	25,000	Intermediate	300-1500	120,000	25	33,333	20,665	350	59
	50,000	Intermediate	300-1500	120,000	25	66,667	41,331	350	118
Salton Sea	**5,000**	Shallow	80-300	10,000	13	6,667	4,133	200	21
	25,000	Shallow	80-300	10,000	13	33,333	20,665	200	103
	50,000	Shallow	80-300	10,000	13	66,667	41,331	200	207
	5,000	Intermediate	300-1500	60,000	25	6,667	4,133	350	12
	25,000	Intermediate	300-1500	60,000	25	33,333	20,665	350	59
	50,000	Intermediate	300-1500	60,000	25	66,667	41,331	350	118
East Mesa	**5,000**	Intermediate	200-900	250,000	47	6,667	4,133	2000	2
	25,000	Intermediate	200-900	250,000	47	33,333	20,665	2000	10
	50,000	Intermediate	200-900	250,000	47	66,667	41,331	2000	21

Note: Pumping Rate assumes pumping 365 per year for 24 hours/day

The aquifers beneath the K.G.R.A.s have varying salt concentrations and groundwater temperatures. Table B-3 summarizes aquifer quality and temperatures associated by aquifer and each K.G.R.A.

The aquifers likely have a broad regional extent and may extend to the valley edges. However, groundwater flow may be blocked by faults, which would limit recharge. The Calipatria and Brawley Faults are considered at least partial barriers to flow on the east side of the Imperial Valley. Well fields for the East Brawley, East Mesa, and Salton Sea K.G.R.A.s were positioned east of these faults so that water recharged near the Coachella Canal would reach the well fields.

The Dunes and Glamis K.G.R.A.s were not evaluated, because most of their areas are occupied by endangered species and their proximity to the proposed Colorado River depletion surface.

B.24 SOUTH BRAWLEY WELL FIELD

Developing groundwater as a source of supply for the South Brawley K.G.R.A. (including the Keystone development area) was considered and then abandoned due to the area being located between two branches of the Imperial Fault. Where faults are closely spaced, they may create small compartments that have limited recharge and can be easily dewatered, which could result in subsidence and ground fissuring. Therefore, a well field within the K.G.R.A. was not planned. Groundwater supply to this area could be from a well field in the East Brawley K.G.R.A., as described below. Water could be conveyed west to the South Brawley K.G.R.A. and the Keystone development area using either pipelines or existing IID canal infrastructure; however, not in high periods of agricultural demands. Attachment A, Figures A-1 through A-6, contains conceptual well field layouts for feasible alternatives in the South Brawley/Keystone areas.

B.25 EAST BRAWLEY WELL FIELD

Conceptual well field designs were developed to supply water to the East Brawley K.G.R.A. These designs would also apply to serve the South Brawley K.G.R.A., but the water would have to be conveyed to that demand area. Well field designs were prepared to produce 5,000

AFY, 25,000 AFY, and 50,000 AFY after treatment as shown in Figures A-7 through A-10. The well fields were located east of the Calipatria Fault to receive recharge from percolation basins potentially located in the old unlined Coachella Canal, on private land not managed by Bureau of Land Management (BLM). The K.G.R.A. generally overlies lakebed deposits which pinches out to the east where the recharge facilities are planned. Therefore recharge facilities located in the old unlined Coachella Canal could replenish water in either the shallow or intermediate aquifers.

Both the shallow and intermediate aquifers were evaluated for development of the well field. The characteristics for each aquifer are presented in Table B-3. The intermediate aquifer is more favorable for development, because it is thicker and has a corresponding higher capacity to transmit water than the shallow aquifer. Flow rates from each well were selected to prevent dewatering of the aquifer. Estimated pumping rates per well for the shallow aquifer is 100 gpm and 2,000 gpm for the intermediate aquifer.

Table B-4 lists the number of wells required to provide 5,000 AFY, 25,000 AFY, and 50,000 AFY. Development of the shallow aquifer is not feasible because between 40 and 400 wells would have to be constructed in comparison to the intermediate aquifer which will only require construction of 2 to 21 wells. Attachment A, Figures A-7 and A-8, contains conceptual well field layouts for feasible alternatives in the East Brawley K.G.R.A.

Two pumping wells could be constructed to supply 5,000 AFY of water from the intermediate aquifer. The pumping would reduce the water surface elevation by about 35 feet over the 30 year project lifespan.

Ten wells would be required to produce 25,000 AFY from the intermediate aquifer. The water surface would be lowered by an average of 92 feet over the 30-year project lifespan.

Twenty-one wells would be needed to produce 50,000 AFY. The average groundwater surface would decline by about 172 feet in the center of the well field over the 30-year life of the project. The drawdown would diminish away from the well field.

Conjunctively managing the groundwater levels through recharge would reduce the drawdown of the aquifer. Management of the groundwater could lower the groundwater surface in the shallow aquifer, depending upon the interconnectedness of the shallow aquifer to the intermediate aquifer. The insert on Figure A-8 shows where potential recharge facilities on the old unlined Coachella Canal could be located to conjunctively manage surface water and groundwater and create a water bank. Groundwater levels could be lowered below the root zone which could benefit local agricultural users and would reduce the potential for liquefaction. Management of recharge and pumping would be required to reduce the potential for subsidence associated with pumping.

B.26 EAST MESA WELL FIELD

Due to the land limitations and the lack of demand in the area, a 5,000 AFY plant is recommended for this area. Well fields were designed for the East Mesa K.G.R.A. for both the shallow and intermediate aquifers. Most of the East Mesa K.G.R.A. is BLM-managed land. The small portion of the K.G.R.A. that does not belong to BLM is between the Calipatria and Brawley Faults and was not considered because they are partial barriers to groundwater flow and could limit recharge of the aquifers. The 5,000 AFY well field could be positioned on existing geothermal plant leases whereas the 25,000 AFY and 50,000 AFY well fields would need to be on land acquired from BLM, which could require lengthy negotiations.

Aquifer characteristics for the East Mesa well field are assumed to be similar to the East Brawley well field; therefore, the number of wells is similar. Based on the analysis for the East Brawley K.G.R.A., the shallow aquifer was not considered for development. Table B-4 provides information for the number of wells needed, their depths and their production capacities. For the 5,000 AFY well field only two wells would be needed. Locally the wells would lower the water surface by about 35 feet over the 30-year project lifespan. If the well field is to produce 25,000 AFY, 10 pumping wells would need to be constructed. The water surface locally would be lowered an average of 92 feet over the 30-year project lifespan. For a 50,000 AFY well field, 21 wells would be needed. The average groundwater surface would decline by about 172 feet in the center of the well field over the 30-year life of the project. The drawdown would diminish away from the well field. Attachment A, Figures A- 11 to A-13, contains conceptual well field layouts for feasible alternatives in the East Mesa K.G.R.A.

Pumping effects could be offset by recharge in the unlined old Coachella Canal recharging potentially both the shallow and intermediate aquifers. Management of the recharge and pumping would be needed to reduce the potential for subsidence associated pumping.

B.27 SALTON SEA WELL FIELD

The well field designs were prepared to produce after treatment, 5,000 AFY, 25,000 AFY, and 50,000 AFY from the shallow and intermediate aquifers. Well fields were located east of the Calipatria Fault to be able to receive recharge from percolation basins potentially located in the unlined old Coachella Canal. It is estimated that the shallow aquifer is from 80 feet bgs to 300 feet bgs with about 100 feet of the sediments consisting of sandy sediments. Although the intermediate aquifer is located between 300 and 1,500 feet, it only likely contains about 300 feet of sandy sediments which can readily convey water to a well. Because of the thinner sequence of coarse grained sediments, the transmissivity is lower than in the East Brawley K.G.R.A.

Well field designs showed the number of wells required would range from 12 to over 200 wells. Table B-4 (page 40) lists the number of wells by aquifer and production capacity. Well fields for producing about 5,000 AFY could be developed by using either the shallow or intermediate aquifers. Production of 25,000 AFY and 50,000 AFY from wells is not reasonable.

The shallow aquifer could produce 5,000 AFY with 21 wells pumping at a rate of 200 gpm each. Over the 30-year project lifespan it is estimated that there will be about an average of 190 feet of drawdown which will not be below the base of the aquifer.

The intermediate aquifer could also be utilized to produce 5,000 AFY with 12 wells pumping at about 350 gpm. Over the 30-year project lifespan it is estimated that there will be about an average of 83 feet of drawdown.

Pumping of the shallow aquifer has the additional benefit to agriculture and communities by locally lowering groundwater levels below the root zone and by reducing the potential for liquefaction. Although a greater number of wells would be required than if pumping from the intermediate aquifer, wells constructed into the shallow aquifer would be less costly to construct. Construction of a well field in the shallow aquifer is a preferred option for this K.G.R.A. Attachment A, Figure A-16, contains a conceptual well field layout for a 5,000 AFY facility in the Salton Sea – K.G.R.A.

Pumping effects could be offset by recharge in the unlined portions of the old Coachella Canal recharging potentially both the shallow and intermediate aquifers. Management of the recharge and pumping would be needed to reduce the potential for subsidence associated pumping.

B.28 HEBER WELL FIELD

A 5,000 AFY, 25,000 AFY, and 50,000 AFY well field was evaluated for the Heber K.G.R.A. The evaluation considered extraction of water from both the shallow and intermediate aquifers. The ability of the aquifers to transmit water is lower in this area and therefore a larger number of wells were required. Table B-4 lists the aquifer characteristics and the number of wells required. The number of wells ranged from 12 to over 400. Only the 5,000 AFY well field was reasonable, requiring 12 wells to produce from the intermediate aquifer. Wells have been estimated to produce 350 gpm each and the aquifer has about 650 feet of saturated sediments. Pumping of the wells would locally lower the piezometric surface head in the semi-confined aquifer by about 44 feet over the 30-year project lifespan. Attachment A, Figure A-17, contains a conceptual well field layout for the 5,000 AFY facility in the Heber K.G.R.A.

Recharge to the intermediate aquifer in this area could occur from percolation of water applied for agriculture which has migrated through the shallow aquifer and the weakly confining clay bed. No dedicated recharge facilities are planned. Additional testing will be needed to confirm source of water is either vertically from the shallow aquifer or from Mexico. Pumping would need to be designed to limit pumping affects to groundwater in Mexico.

B.29 CONCEPTUAL GROUNDWATER STORAGE BANKING FACILITIES FOR WELL FIELDS

Groundwater recharge facilities constructed within the unlined old Coachella Canal can be used for conjunctive use and to mitigate pumping effects for the East Brawley, East Mesa, and Salton Sea K.G.R.A.s. The groundwater gradient is to the west and would provide recharge to replenish water extracted by the well fields constructed east of the Calipatria Fault. Groundwater banking within the East Mesa will provide a method of storing water during under run years when excess water would be available. Historically, under run volumes for IID have ranged from 15,000 acre-feet to over 250,000 acre-feet and could be placed into storage.

A 15-mile long section of the old unlined Coachella Canal west of the San Andreas Fault and south of the Glamis K.G.R.A. was abandoned when the lined canal was constructed. The unlined Coachella Canal has the ability to recharge about 10,000 AFY per mile of unlined canal (USBR, 1992). If all of the unlined portions were used, about 150,000 AFY could be recharged.

Conceptually the old unlined canal will need to be modified to serve as a recharge facility. A turnout would have to be constructed to divert water from the lined Coachella Canal into the unlined canal. Under run water could be allowed to flow into the unlined canal saturating whatever length of the unlined canal until the ideal volume of water percolates. This approach limits the potential environmental impacts. However, along portions of the unlined canal layer of clay, 1 to 1.5 feet thick, was installed into the canal to reduce percolation losses. Removal of the clay layer would increase percolation rates. The sediments could be used to create intermediate berms in the canal confine the recharge water to highly permeable soil sections and reduce evaporation. Spillways could be constructed in the intermediate berms to allow excess water to spill into the adjacent basin, depending upon the amount of water available. This will allow for a compartmentalized series of recharge basins for greater infiltration and less evaporation. To keep the recharge near the well fields, modifying any favorable two-mile long section of the old unlined Coachella Canal could provide capacity to percolate 20,000 AFY to 40,000 AFY.

Constraints to the recharge facilities include ownership and management of the canal area by the BLM, existence of sensitive habitats, and ability to obtain easements and rights-of- way. A land exchange could overcome some of the potential constraints. The possibility for the land exchanges should be researched to determine the feasibility of such exchanges.

B.30 RIVER AND TILE DRAIN SOURCE WATER CONCEPTUAL DESIGN

Water in the Alamo and New Rivers contain tailwater from the irrigated areas within the Imperial Valley and some of the water in the rivers could be reused. About 2.6 MAFY quantity of water is applied to irrigate agriculture and for MCI use within the Imperial Valley. About 30 percent of the water delivered for irrigation is percolated through the soil and captured by tile drains or becomes tailwater that is conveyed by a vast drainage system to the Alamo and New Rivers, which convey the water to the Salton Sea. In 2011, the tilewater and tailwater amounted to 830 AF. The irrigated areas could possibly be considered a recharge area. As such, no recharge facilities would have to be constructed. Because the water gravity drains to the rivers no wells would be required. After 2017, the tailwater can be considered a water supply source to the desalination plants. However, possible environmental complications need to be considered.

Water can be retrieved from large drains or the water could be pumped from the Alamo River to be used as source water for the desalination plants. The quantity of water available from these sources to use for desalination is greater than the amount needed to supply 50,000 AFY of new water. Refer to Appendix G for the analysis of available water from the Alamo River and the various drains. This concept could be used as a source of supply to the South Brawley and Salton Sea K.G.R.A.s as shown on Figures A-4 and A-14, contained in Attachment A.

B.31 CONCEPTUAL BRINE DISPOSAL

The desalination process produces brine that will need to be disposed. It has been assumed that 25 percent of the raw water delivered to the treatment plant will become brine. The brine could be disposed of by either injecting it through wells into deeper aquifers, which begin about 1,500 feet below ground surface, or it can be pumped into evaporation ponds at the ground surface.

There are two choices for the use of injection wells. Either new injection wells will be constructed for the disposal or, if possible, existing injection wells that are operated by the local geothermal power plants may be utilized.

Should new injection wells be elected to be constructed for brine disposal their number, injection rates, and depths will have to be confirmed. Assuming the injection wells can dispose of about 2,000 gpm the number of injection wells ranges from one to five depending on the size of the well field.

B.32 CAPITAL PROJECT ALTERNATIVES

Seventeen desalination (desal) alternatives were developed to compare the combination of different source water, distribution system, and recharge elements. Table B-5 summarizes the alternatives, their components, and whether they are feasible or not. Each alternative is summarized below by their K.G.R.A. locations. The costs to develop and operate each alternative were developed and are reported in Appendix N and summarized in Table 12-5. Figure B-11 shows the general locations of each K.G.R.A..

Table B-5. Drawdown and Feasibility of Alternatives

K.G.R.A.	Alternative Designation	Plant Capacity (AFY)	Aquifer	Pumping Rate (gpm)	Number of Wells	30-Year Drawdown (ft)	Banking (Y/N)	Recommended (Y/N)
South Brawley	1	**50,000**	Intermediate	2000	21	172	N	N
	2	**50,000**	Intermediate	2000	21	172	Y	Y
	3	**50,000**	Intermediate	2000	21	172	Y	Y
	4	**50,000**	N/A	N/A	0	N/A	N	Y
	5	**25,000**	Intermediate	2000	11	92	Y	N
	6	**25,000**	Intermediate	2000	11	92	N	N
East Brawley	7	**25,000**	Intermediate	2000	11	92	N	Y
	8	**25,000**	Intermediate	2000	11	92	Y	Y
	9	**25,000**	Intermediate	2000	11	92	Y	Y
	10	**5,000**	Intermediate	2000	2	35	Y	Y
East Mesa	11	**25,000**	Intermediate	2000	10	92	N	Y
	12	**25,000**	Intermediate	2000	10	92	Y	Y
	13	**5,000**	Intermediate	2000	2	35	N	Y
Salton Sea	14	**50,000**	N/A	N/A	0	N/A	N	Y
	15	**50,000**	N/A	N/A	0	N/A	N	Y
	16	**5,000**	Shallow	200	21	190	N	Y
Heber	17	**5,000**	Intermediate	350	12	44	N	Y

Note: Pumping Rate assumes pumping 365 per year for 24 hours/day
N/A = Not applicable

B.33 SOUTH BRAWLEY K.G.R.A – KEYSTONE AREA

Desal Alternative 1: 50,000 AFY Keystone Desalination with Well Field. This alternative is represented in Figure A-1 and was created to test the feasibility of pumping 50,000 AFY of groundwater for the desalination plant without the mitigation effects of groundwater recharge. The new water from this alternative would be used to for IID irrigation purposes.

Desal Alternative 2: 50,000 AFY Keystone Desalination with Well Field and Groundwater Recharge. This alternative builds on Desal Alternative 1 and is represented in Figure A-2. It

highlights the use of groundwater to supply the desalination plant and use recharge in an unlined portion of the Coachella Canal to mitigate for groundwater pumping. The location of the planned recharge facilities is located in the inset on Figure A-2.

Desal Alternative 3: 50,000 AFY Keystone Desalination with Well Field, Groundwater Recharge and MCI Distribution. This alternative is the same as Desal Alternative 2 and adds the conveyance of new water to be used for MCI purposes. Figure A-3 represents this alternative.

Desal Alternative 4: 50,000 AFY Keystone Desalination with water from the Alamo River water. The use of surface water does not require a dedicated groundwater recharge facility and will not have the additional annual operations and maintenance costs of a well field. A pump lift station would be required to take water from the river and take it into the treatment plant. Figure A-4 represents this alternative.

Desal Alternative 5: 25,000 AFY Keystone Desalination with Well Field, Groundwater Recharge and Evaporation Ponds. This alternative was created to test the feasibility of using evaporation ponds to dispose of the brine stream. Figure A-5 shows a potential location of the evaporation ponds and the disposal and land costs have been estimated.

Desal Alternative 6: 25,000 AFY Keystone Desalination with Well Field. This alternative was developed to determine if pumping 25,000 AFY would have a low enough groundwater impact to supply the desalination plant without using groundwater recharge in the unlined Coachella Canal and is represented by Figure A-6.

B.34 EAST BRAWLEY K.G.R.A.

Desal Alternative 7: 25,000 AFY East Brawley Desalination with Well Field. This alternative is represented in Figure A-7 and was created to test the feasibility of pumping 25,000 AFY of groundwater for the desalination plant without the mitigation effects of groundwater recharge. The new water from this alternative would be used for IID irrigation purposes.

Desal Alternative 8: 25,000 AFY East Brawley Desalination with Well Field and Groundwater Recharge. This alternative builds on Desal Alternative 7 and is represented in Figure A-8. It highlights the use of groundwater to supply the desalination plant and use recharge in a portion of the old unlined Coachella Canal to mitigate for groundwater pumping. The location of the planned recharge facilities is located in the inset on Figure A-8.

Desal Alternative 9: 25,000 AFY East Brawley Desalination with Well Field and Groundwater Recharge and MCI Distribution. This alternative is the same as Desal Alternative 8 and adds the conveyance of new water to be used for MCI purposes. Figure A-9 represents this alternative.

Desal Alternative 10: 5,000 AFY East Brawley Desalination with Well Field. This alternative represented in Figure A-10 uses groundwater for the desalination plant without the use of recharge. The new water from this alternative would be used for IID irrigation purposes.

B.35 EAST MESA K.G.R.A.

Desal Alternative 11: 25,000 AFY East Mesa Desalination with Well Field and Industrial Distribution system to the nearby K.G.R.A.. This alternative was developed to determine if pumping 25,000 AFY would have a low enough impact to supply the desalination plant with groundwater without using groundwater recharge in the unlined Coachella Canal and is represented by Figure A-11. The new water from this alternative would be used for IID irrigation purposes and industrial distribution.

Desal Alternative 12: 25,000 AFY East Mesa Desalination with Well Field and Groundwater Recharge and Industrial Distribution. This alternative builds on Desal Alternative 11 and is represented in Figure A-12. It highlights the use of groundwater to supply the desalination plant and use recharge an unlined portion of the Coachella Canal to mitigate for groundwater pumping. The location of the planned recharge facilities is located in the inset on Figure A-12. The new water from this alternative would be used for IID irrigation purposes and industrial distribution.

Desal Alternative 13: 5,000 AFY East Mesa Desalination with Well Field and Industrial Distribution. This alternative represented in Figure A-13 uses groundwater for the desalination plant without the use of recharge. The new water from this alternative would be used by local geothermal plants.

B.36 SOUTH SALTON SEA K.G.R.A.

Desal Alternative 14: 50,000 AFY South Salton Sea Desalination with Alamo River water. Using the river as the source water is a way to recover the tilewater and tailwater. This alternative does not impact groundwater through pumping the aquifers. The alternative is presented in Figure A-14. The new water from this alternative would be used by local geothermal plants.

Desal Alternative 15: 50,000 AFY South Salton Sea Desalination with Alamo River Water and MCI Distribution system pipeline. This alternative uses the same concept as Desal Alternative 14 with the addition of conveyance of new water to water treatment plants for municipal users and to the geothermal plants. This alternative is represented in Figure A-15.

B.37 SOUTH SALTON SEA K.G.R.A. – EAST

Desal Alternative 16: 5,000 AFY South Salton Sea – East Desalination with Well Field. This alternative represented in Figure A-16 uses groundwater for the desalination plant without the use of recharge. The new water from this alternative would be used by local geothermal plants.

B.38 HEBER K.G.R.A.

Desal Alternative 17: 5,000 AFY Heber Desalination with Well Field with M & I Distribution. This alternative represented in Figure A-17 uses groundwater for the desalination plant without the use of recharge. The new water from this alternative would be used for irrigation purposes and new MCI purposes.

B.39 RECOMMENDATIONS

Limited data was available and was interpolated to prepare the conceptual well fields, recharge facilities and brine disposal injection wells. Validation of the assumptions is needed before proceeding to preliminary designs. We recommend the following initial activities:

1. Discuss use of the old unlined canal as a recharge facility with the landowner.
2. Acquire additional information is needed to verify the assumptions and interpretations of the well production capacities, salt concentrations, and temperature of the water in the aquifers used in the analysis.
3. Drill a large diameter pilot production well into the intermediate aquifer in the East Brawley K.G.R.A. to confirm its production capacity and to allow use of existing monitoring wells during production testing to confirm the interconnectedness of the intermediate aquifer to the sediments beneath the unlined canal.
4. Install one nested piezometer on the west side of the Calipatria Fault to assess the effect of the fault during pumping.
5. Excavate several potholes within the unlined canal to resolve whether there is a clay liner and whether its removal could enhance the percolation rates.
6. Drill additional test wells in the other K.G.R.A.s to confirm the production capacity of the wells along with the temperature and salinity with depth.
7. Enter into preliminary discussions with geothermal power plant operators as to whether they would be willing to accept and dispose of the brine water.

Upon completion of this work, refine the previously developed Imperial County Groundwater Model to more accurately predict the effects of the well field pumping in conjunction with recharge in the unlined canal.

B.40 REFERENCES CITED

Bookman-Edmonston Engineering (B-E/GEI), Inc., 1996, Ocotillo/Coyote Wells Basin Hydrology and Groundwater Modeling Study, prepared for U.S. Gypsum Co., March 14, 1996.

Bookman-Edmonston Engineering (B-E/GEI), Inc., 2004, Ocotillo/Coyote Wells Hydrology and Groundwater Modeling Study, prepared for U.S. Gypsum Co., Unpublished Work © January 16, 2004.

California Department of Water Resources, 1975, California's Ground Water, Bulletin 118, Department of Water Resources, Sacramento, California.

California Department of Water Resources, 1979, Ground Water Basins in California, Bulletin 118-80, Report to The Legislature in Response to Water Code Section 12924, Department of Water Resources, Sacramento, California.

Colorado River Basin Salinity Control Forum, 2008, Water Quality Standards for Salinity Colorado River System 2008 Review, July 2008.

Durbin, Tim, and Imhoff, Ed, Hydrologic Consultants, Inc., Preliminary Analysis of the Hydrologic Potential for a Ground-water Alternative, Oral Presentation, August 20, 1993.

Dutcher, L.C., Hardt, W.F. and Moyle, W.R. Jr., Preliminary Appraisal of Ground Water in Storage With Reference to Geothermal Resources in the Imperial Valley Area, California, Geological Survey Circular 649. Washington 1972.

Hardt, William F. and French, James J., 1976, Selected Data on Water Wells, Geothermal Wells, and Oil Tests in Imperial Valley, CA. USGS, Open-File Report. Menlo Park, CA, July 1976.

Imperial County General Plan, Prepared by: Planning/Building Department. “Seismic and Public Safety Element”, 2006.

Imperial Irrigation District, Water Conservation Plan, 2007.

Imperial Irrigation District. 2012. Systems Conservation Program Description. http://www.iid.com/index.aspx?page=205

Irwin, George A., 1971. Water-Quality Data for Selected Sites Tributary to the Salton Sea, California August 1969 - June 1970, U.S. Department of the Interior Geological Survey Water Resources Division OFR, prepared in association with the IID. Menlo Park, California.
January 12, 1971.

Leroy Crandall and Associates, 1983, Phase 1 Hydrogeologic Investigation Feasibility of Recovering Ground Water in the East Mesa Area, Imperial County, CA. Prepared for Six Agency Committee, November 30, 1983.

Loeltz, O.J., et. al., 1975, Geohydrologic Reconnaissance of the Imperial Valley, CA, U.S. Geological Survey Professional Paper 486-K. United States Government Printing Office, Washington.

Montgomery Watson, 1995, Imperial County Groundwater Study, Final Report. December, 1995.

Norris, R.M., Webb, R.W., 1976, Geology of California, John Wiley & Sons, New York.

Tetra Tech, Inc., 1999, Final Report, A Study on Seepage and Subsurface Inflows to Salton Sea and Adjacent Wetlands, report prepared for Salton Sea Authority July 9, 1999.

U.S. Department of the Interior Bureau of Reclamation and Coury and Associates, Inc., 1979, Geothermal Resource Investigations East Mesa Test Site, Concluding Report, Part I Executive Summary, and Part II Technical Summary, September 1979.

U.S. Department of the Interior Bureau of Reclamation, 1988, Colorado River Water Underground Storage and Recovery Study, Imperial County, California, prepared for the Colorado River Board of California, June 1979.

U.S. Department of the Interior Bureau of Reclamation, 1989, East Highline Canal Seepage and System Improvement Study, Imperial Irrigation District, CA, Special Technical Report, August 1989, Lower Colorado Region, Boulder City, Nevada.

U.S. Department of the Interior Bureau of Reclamation, 1992, Colorado River Recharge Study, Imperial County, California, Report on Findings of Recharge Demonstration Performed Under Study Agreement No. 7-AG-30-05470, Lower Colorado Region, Boulder City, Nevada, July 1992.

U.S. Department of the Interior Bureau of Reclamation and Lower Colorado Region, 1994, Final Environmental Impact Statement/Final Environmental Impact Report, Imperial County, CA, March 1994.

U.S. Department of the Interior Bureau of Reclamation and Lower Colorado Region, 1994, Geohydrology Appendix for Final Environmental Impact Statement/Final Environmental Impact Report, Imperial County, CA, March 1994.

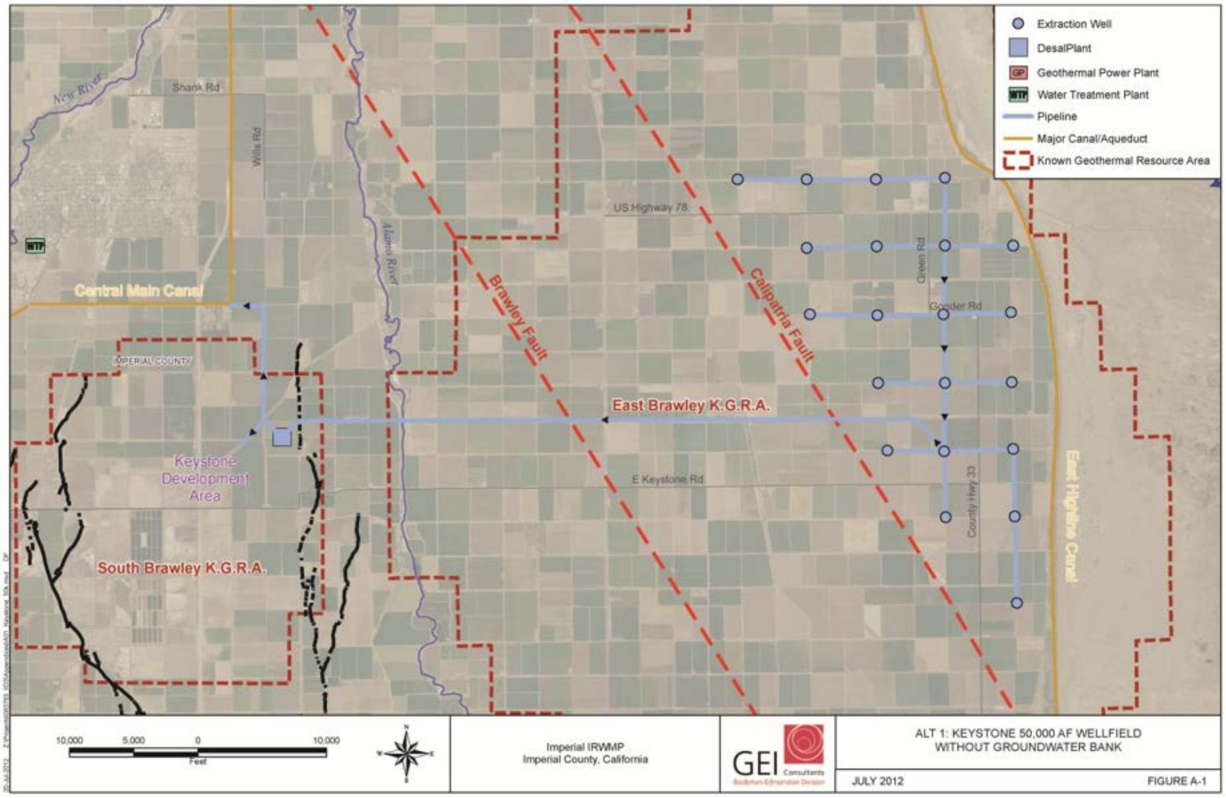
U.S. Department of the Interior, U.S. Geological Survey (2008), Update of the Accounting Surface Along the Lower Colorado River, USGS Scientific Investigations Report 2008-5113

U.S. Environmental Protection Agency, 61 FR 47752, September 10, 1996; or see ftp://ftp.co.imperial.ca.us/icpds/eir/usg/final/17revisions-sect3.pdf

Zimmerman, R.P., 1981, Soil Survey of Imperial County, California, Imperial Valley Area, U.S. Department of Agriculture Soil Conservation Service.

Attachment A

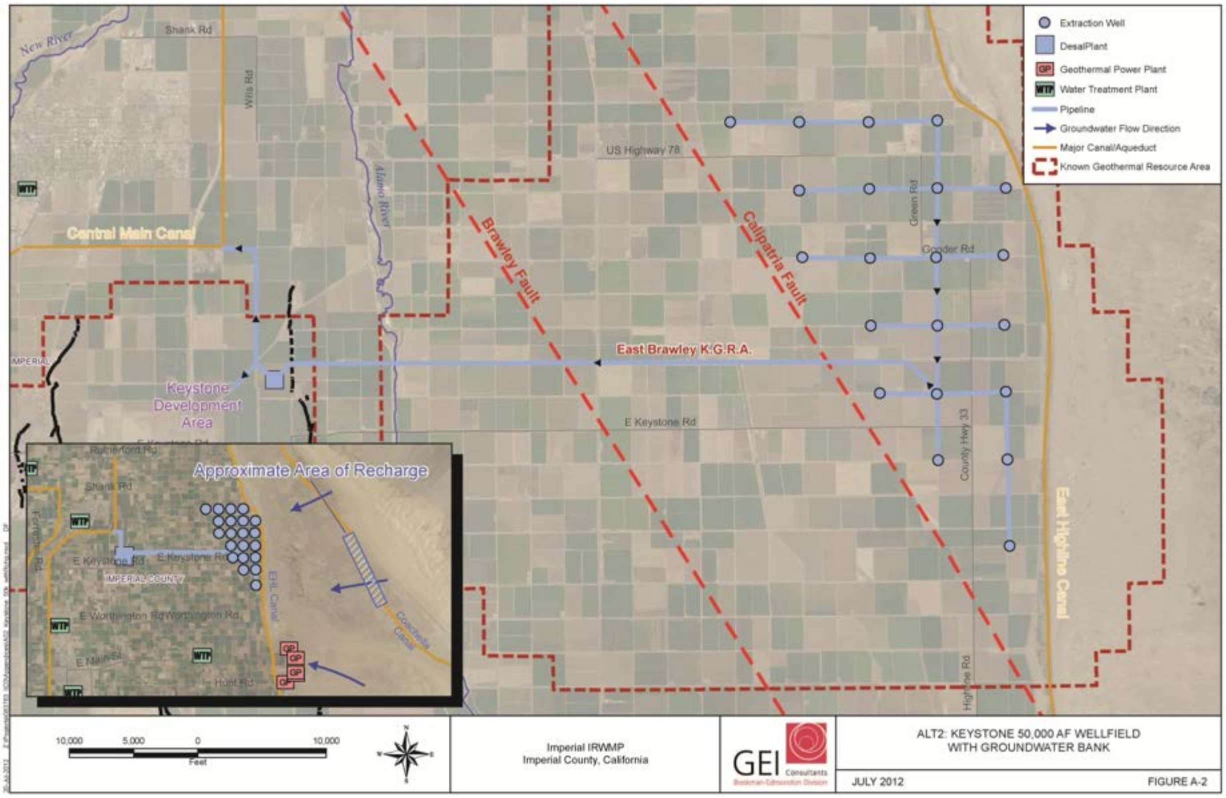
(intentionally blank page)



ALT 1: KEYSTONE 50,000 AF WELLFIELD
WITHOUT GROUNDWATER BANK

JULY 2012

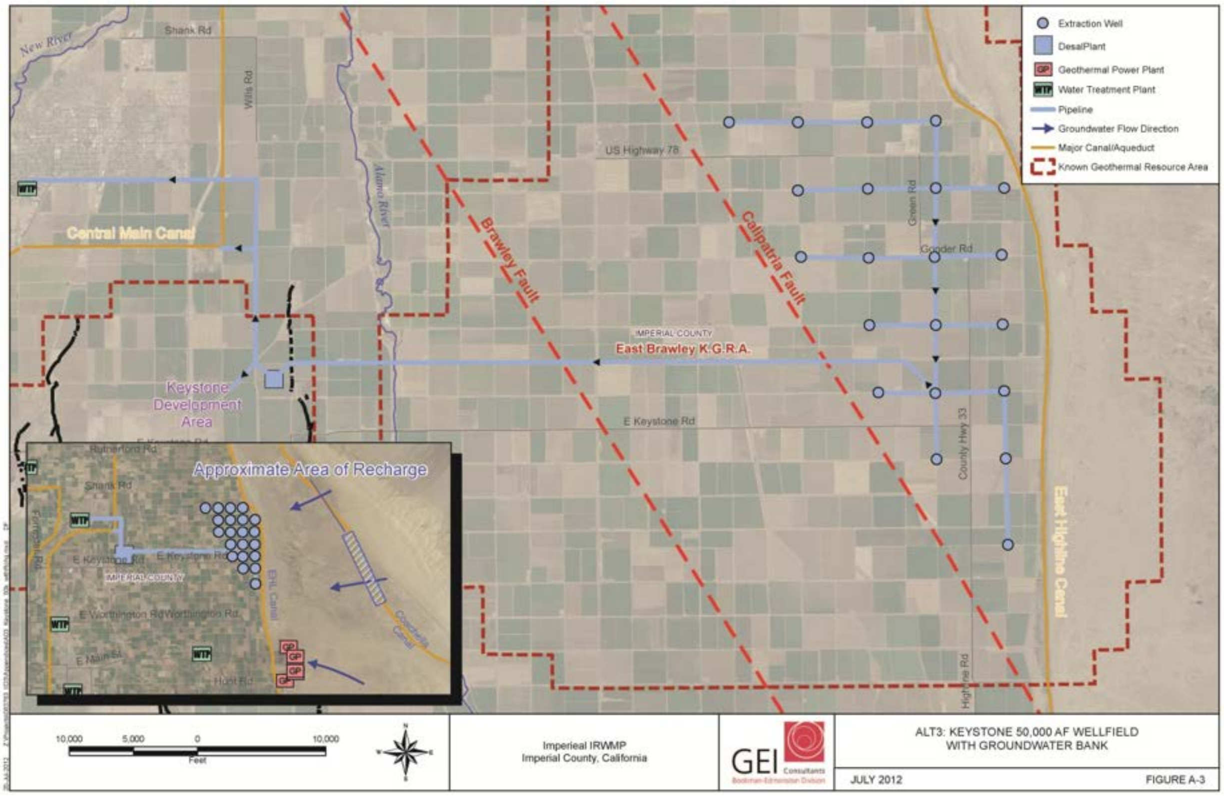
FIGURE A-1



ALT2: KEYSTONE 50,000 AF WELLFIELD
WITH GROUNDWATER BANK

JULY 2012

FIGURE A-2

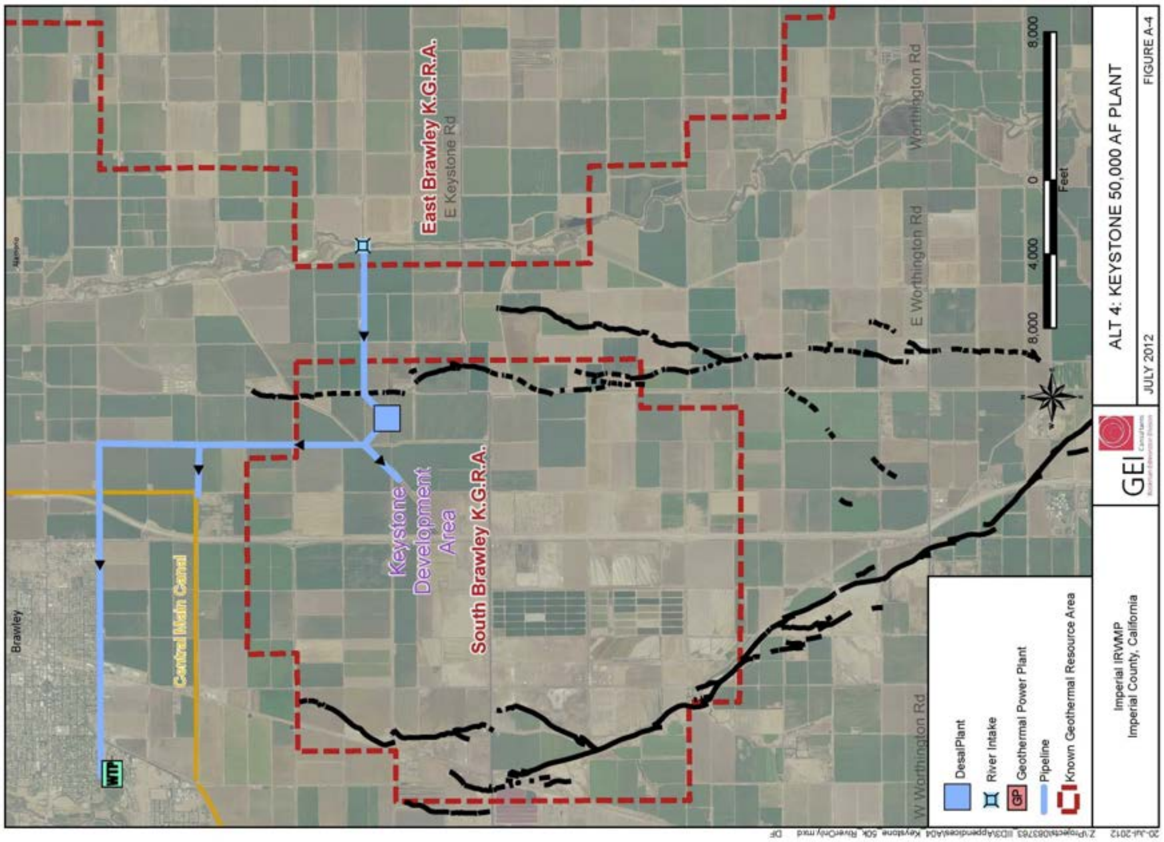


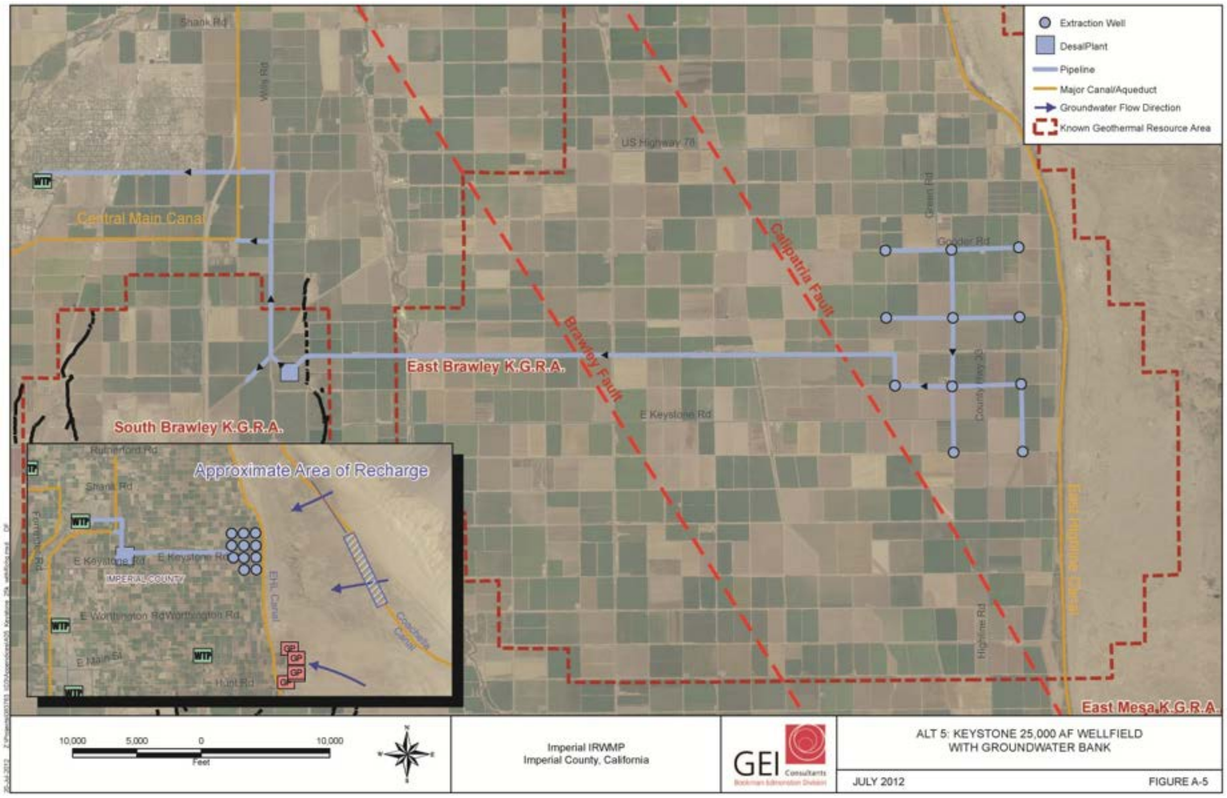
ALT3: KEYSTONE 50,000 AF WELLFIELD WITH GROUNDWATER BANK

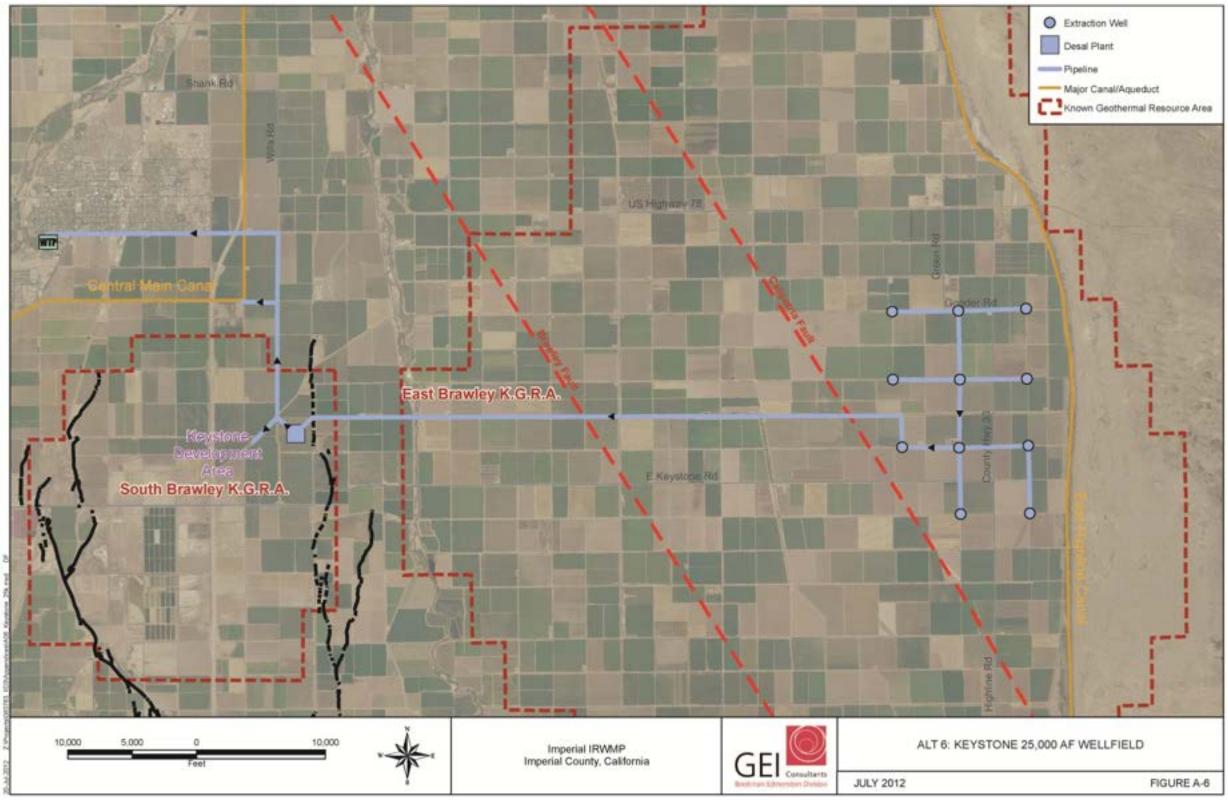
JULY 2012

FIGURE A-3

Imperieal IRWMP
Imperial County, California


East Brawley K.G.R.A.
E Keystone Rd
Worthington Rd
E Worthington Rd
W Worthington Rd
Keystone Development Area
South Brawley K.G.R.A.
Central Main Canal
Brawley
WTP
8,000
4,000
0
8,000
Feet
DesalPlant
River Intake
GP Geothermal Power Plant
Pipeline
Known Geothermal Resource Area
Imperial IRWMP
Imperial County, California
GEI Consultants
ALT 4: KEYSTONE 50,000 AF PLANT
JULY 2012
FIGURE A-4
20-Jul-2012 Z:\Projects\083763_IID3\Appendices\A04_Keystone_50k_RiverOnly.mxd DF

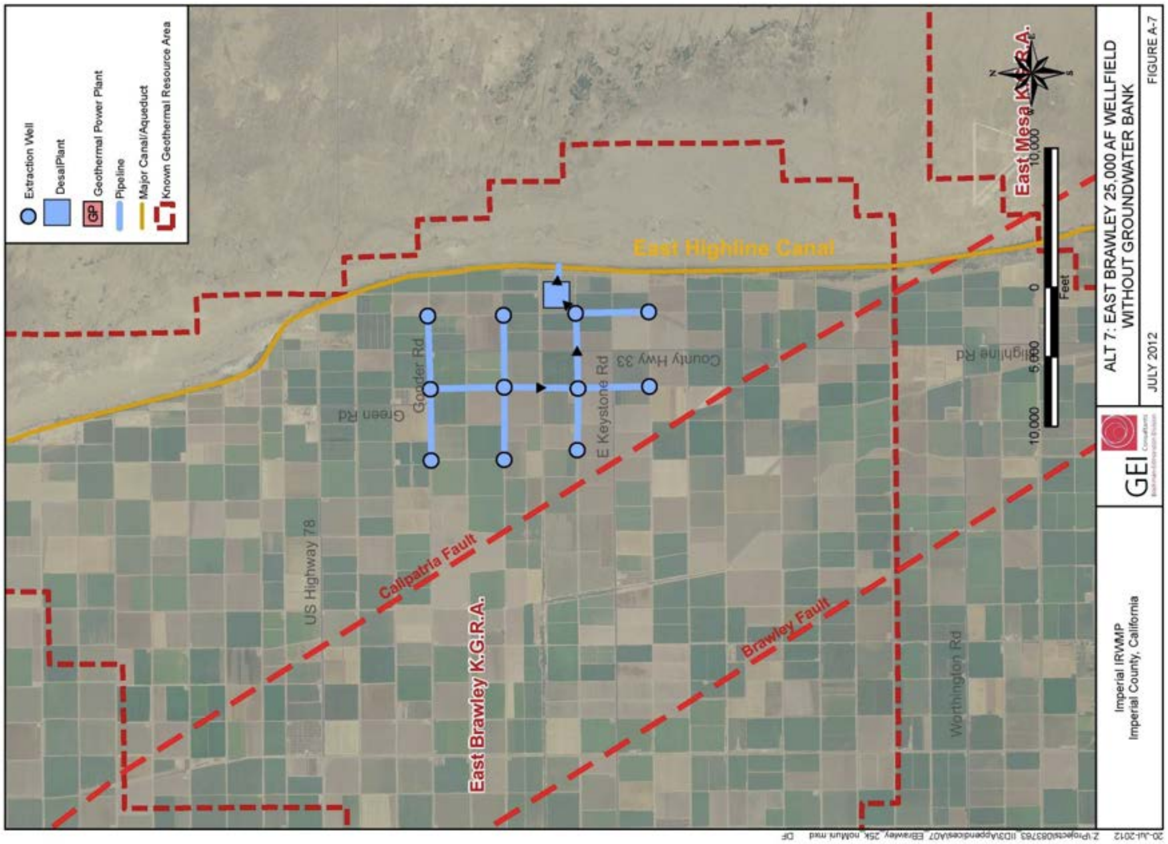

Extraction Well
DesalPlant
Pipeline
Major Canal/Aqueduct
Groundwater Flow Direction
Known Geothermal Resource Area
Shank Rd
Wills Rd
US Highway 78
WTP
Central Main Canal
Gonder Rd
Green Rd
Calipatria Fault
Brawley Fault
East Brawley K.G.R.A.
E Keystone Rd
County Hwy 30
South Brawley K.G.R.A.
Approximate Area of Recharge
Rutherford Rd
E Keystone Rd
IMPERIAL COUNTY
E Worthington Rd
Worthington Rd
E Main St
Hunt Rd
EHL Canal
Coachella Canal
GP
Highline Rd
East Mesa K.G.R.A.
10,000
5,000
0
10,000
Feet
Imperial IRWMP
Imperial County, California
GEI Consultants
ALT 5: KEYSTONE 25,000 AF WELLFIELD WITH GROUNDWATER BANK
JULY 2012
FIGURE A-5

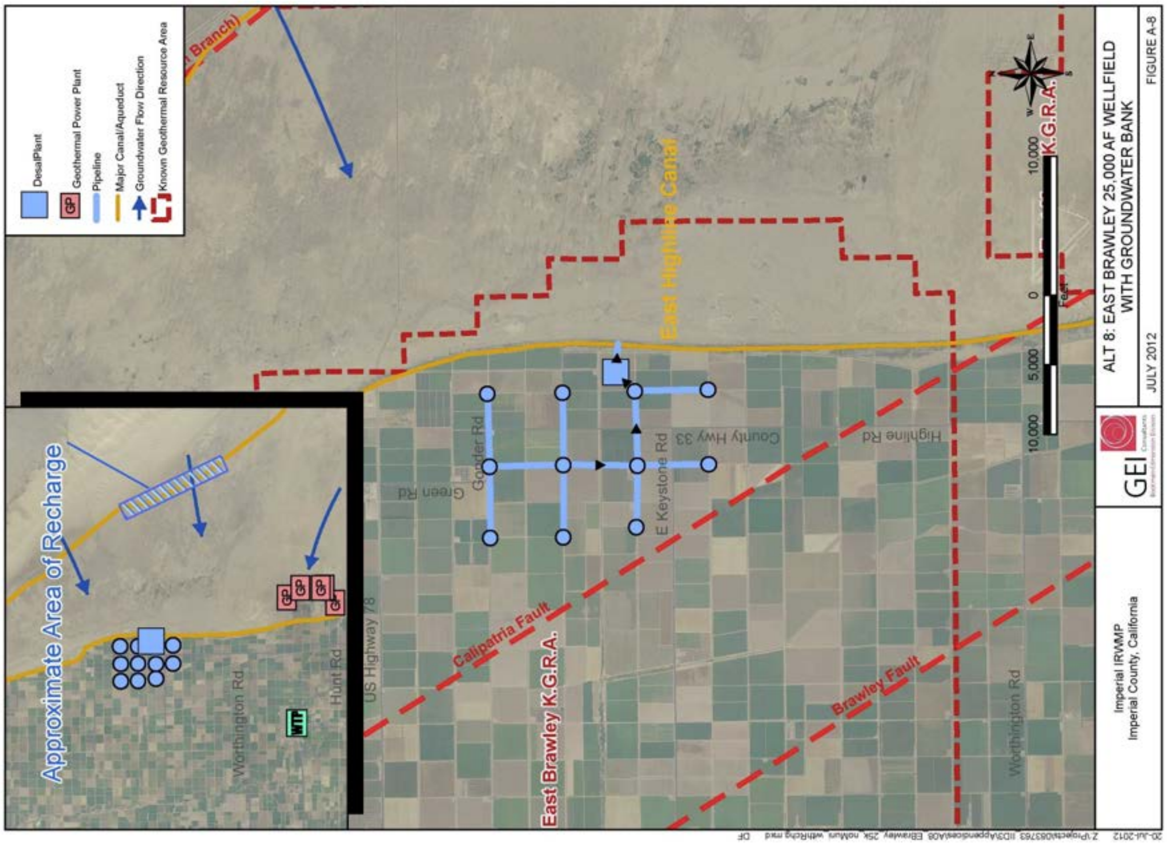


ALT 6: KEYSTONE 25,000 AF WELLFIELD

JULY 2012

FIGURE A-6


Extraction Well
Desal Plant
GP Geothermal Power Plant
Pipeline
Major Canal/Aqueduct
Known Geothermal Resource Area
East Highline Canal
East Mesa K.G.R.A.
N
E
S
W
10,000
5,000
0
10,000
Feet
Highline Rd
County Hwy 33
Green Rd
Gonder Rd
E Keystone Rd
US Highway 78
Calipatria Fault
East Brawley K.G.R.A.
Brawley Fault
Worthington Rd
ALT 7: EAST BRAWLEY 25,000 AF WELLFIELD WITHOUT GROUNDWATER BANK
FIGURE A-7
JULY 2012
GEI Consultants
Imperial IRWMP
Imperial County, California
Z:\Projects\083763_IID3\Appendices\A07_EBrawley_25k_noMuni.mxd DF
20-Jul-2012

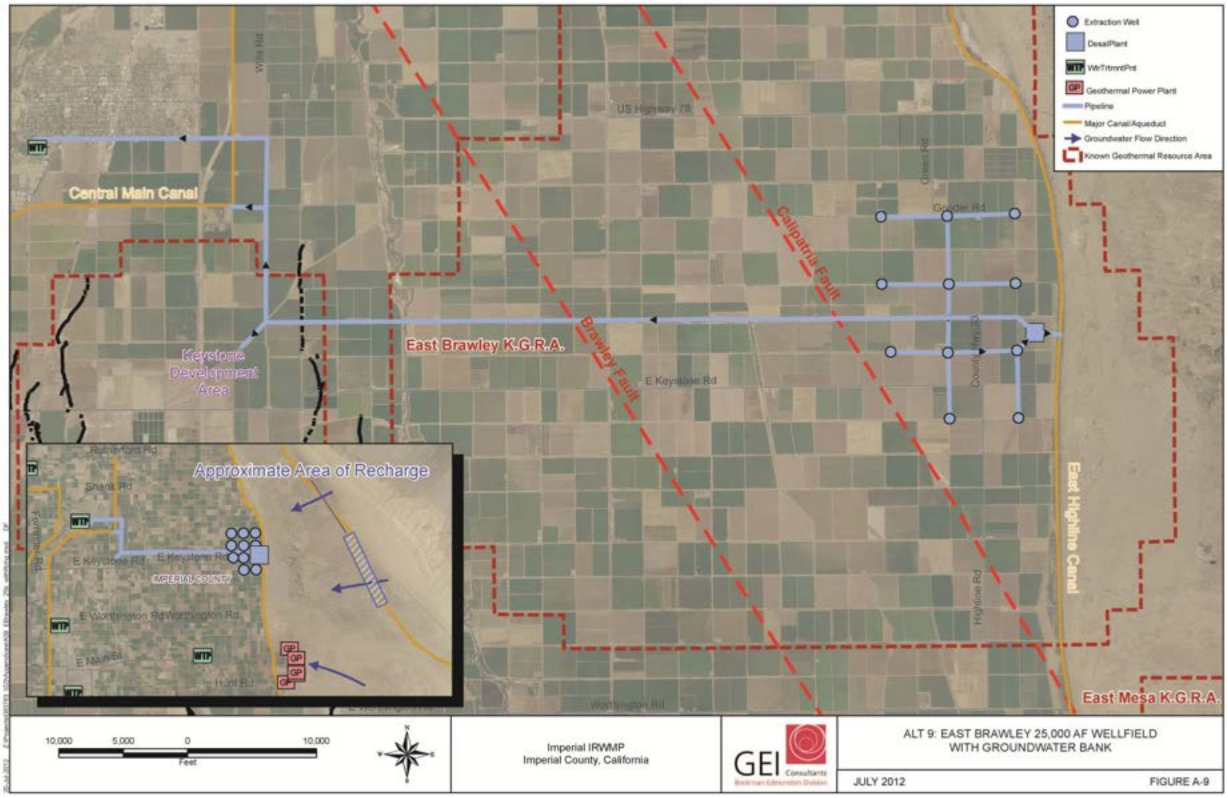


ALT 8: EAST BRAWLEY 25,000 AF WELLFIELD WITH GROUNDWATER BANK

Imperial IRWMP
Imperial County, California

JULY 2012

FIGURE A-8

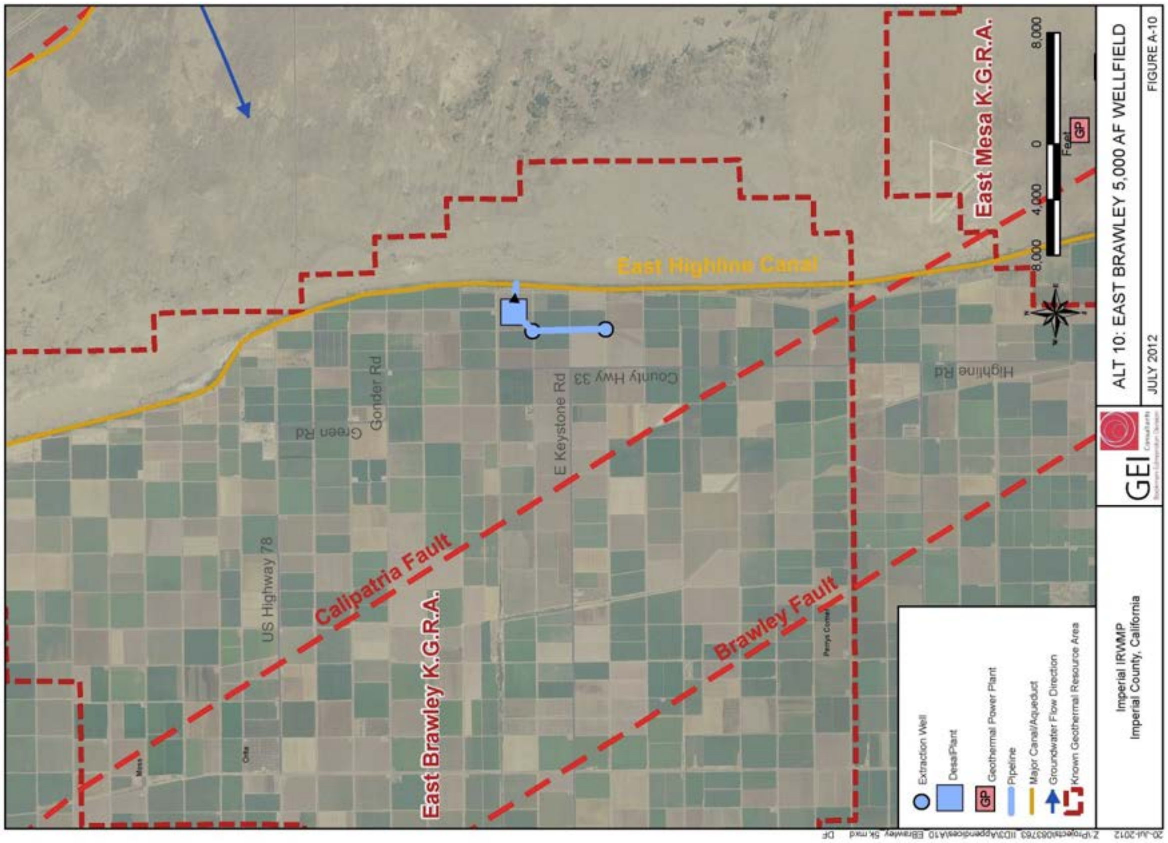


Imperial IRWMP
Imperial County, California

ALT 9: EAST BRAWLEY 25,000 AF WELLFIELD WITH GROUNDWATER BANK

JULY 2012

FIGURE A-9

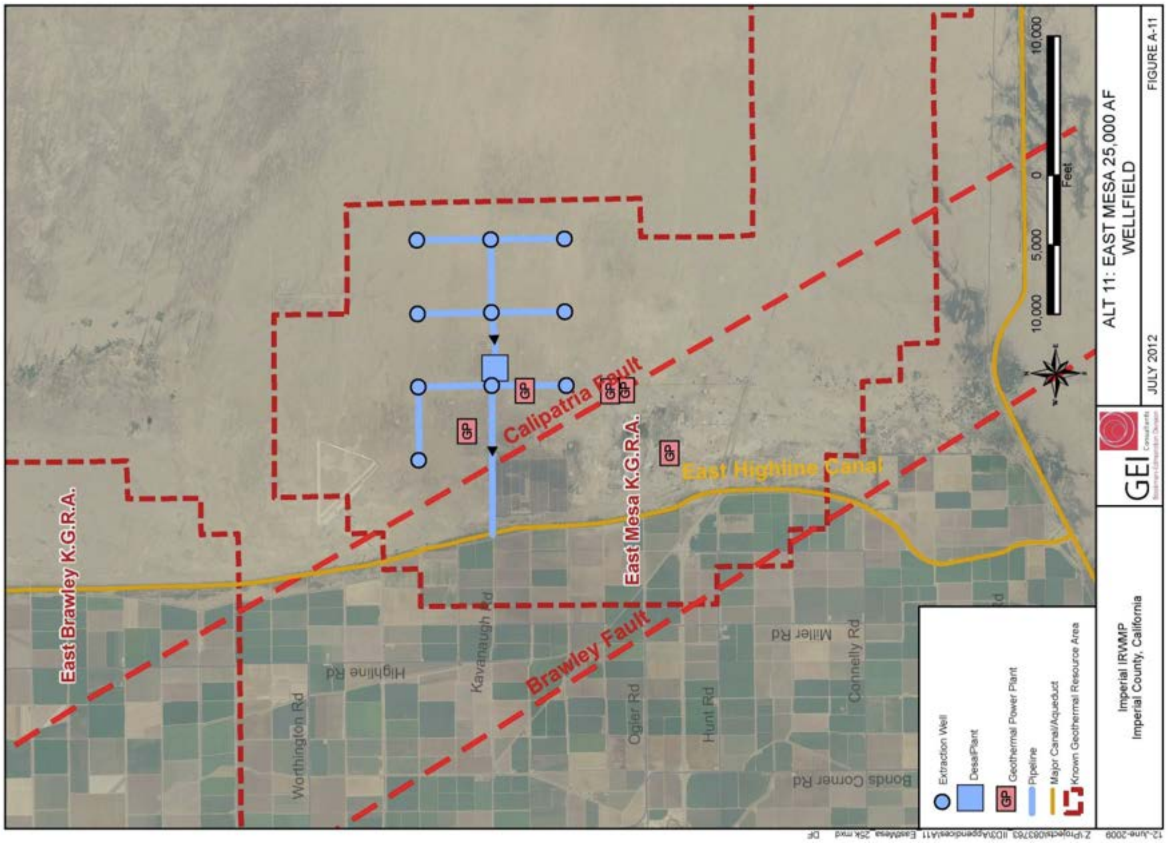


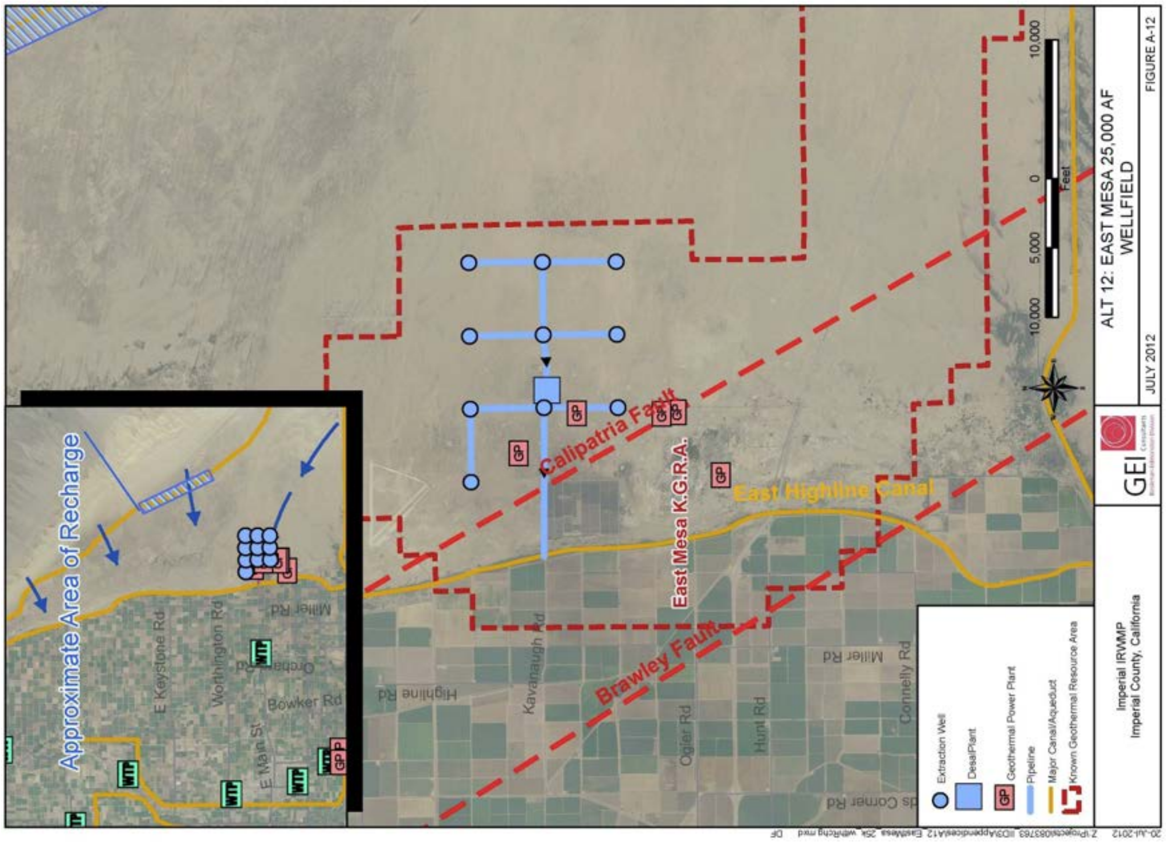
ALT 10: EAST BRAWLEY 5,000 AF WELLFIELD

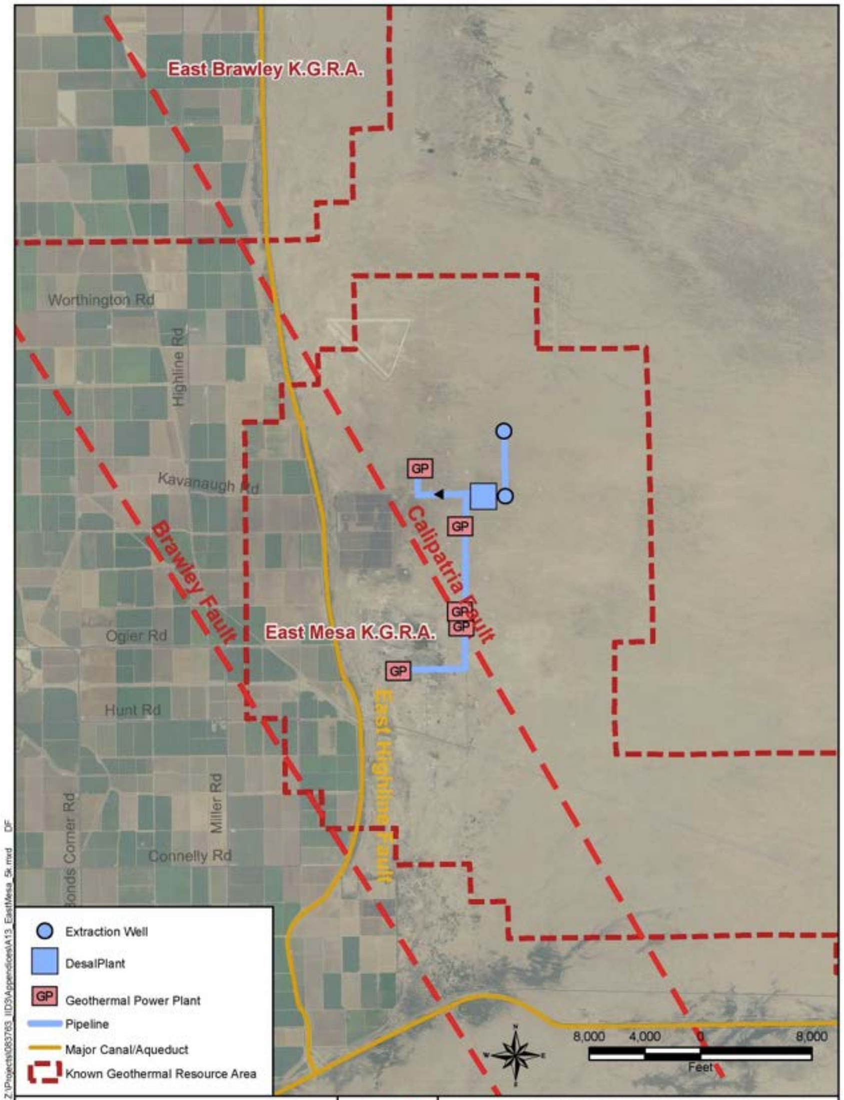
JULY 2012

FIGURE A-10

Imperial IRWMP
Imperial County, California


ALT 11: EAST MESA 25,000 AF
WELLFIELD
JULY 2012
FIGURE A-11
Imperial IRWMP
Imperial County, California
GEI Consultants
10,000
5,000
0
10,000
Feet
Extraction Well
Desal/Plant
GP Geothermal Power Plant
Pipeline
Major Canal/Aqueduct
Known Geothermal Resource Area
East Brawley K.G.R.A.
East Mesa K.G.R.A.
Calipatria Fault
Brawley Fault
East Highline Canal
Worthington Rd
Highline Rd
Kavanaugh Rd
Ogier Rd
Hunt Rd
Miller Rd
Connelly Rd
Bonds Corner Rd
12-June-2009


ALT 12: EAST MESA 25,000 AF WELLFIELD
FIGURE A-12
JULY 2012
GEI Consultants
Imperial IRWMP
Imperial County, California
Extraction Well
Desal/Plant
Geothermal Power Plant
Pipeline
Major Canal/Aqueduct
Known Geothermal Resource Area
10,000
5,000
0
10,000
Feet
Calipatria Fault
Brawley Fault
East Mesa K.G.R.A.
East Highline Canal
GP
Miller Rd
Highline Rd
Kavanaugh Rd
Ogier Rd
Hunt Rd
Donnelly Rd
ds Corner Rd
Approximate Area of Recharge
E Keystone Rd
Worthington Rd
Orchard Rd
Bowker Rd
E Main St
WTP
20-Jul-2012 Z:\Projects\083763_IID3\Appendices\A12_EastMesa_25k_wellfield.mxd DF



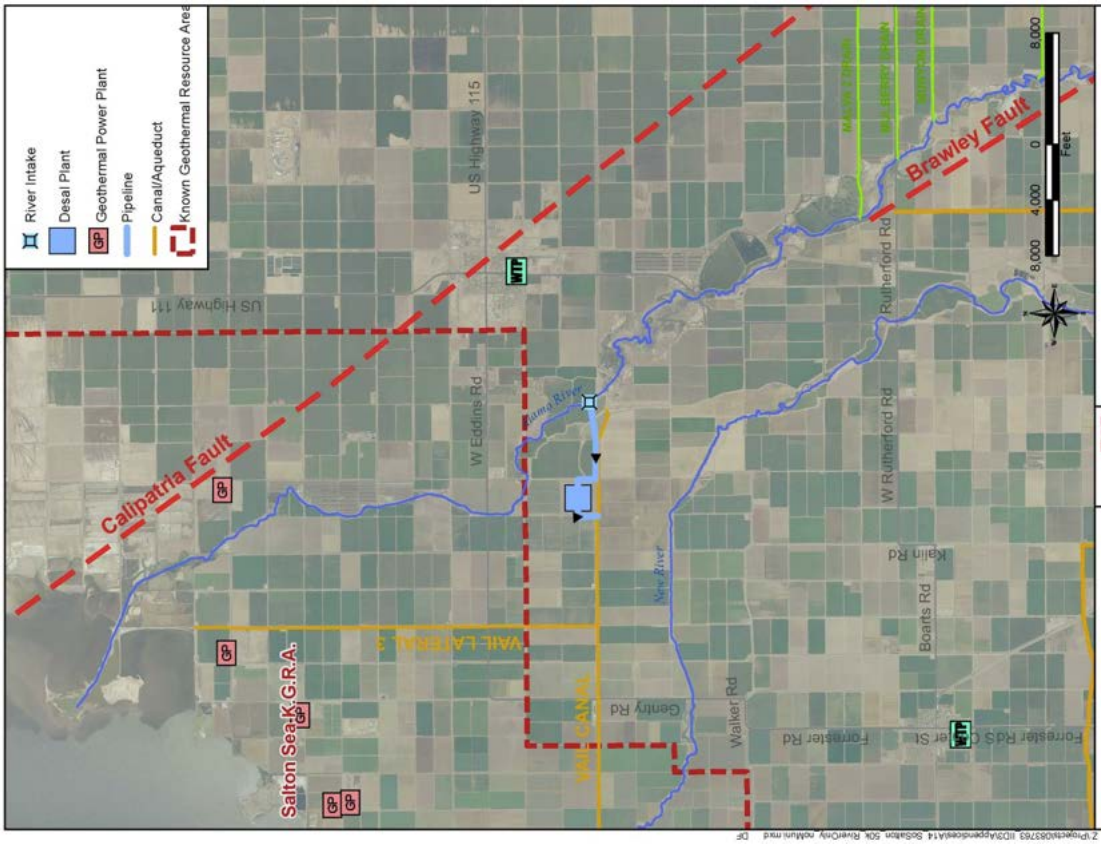
Imperial IRWMP
Imperial County, California

GEI Consultants

ALT 13: EAST MESA 5,000 AF WELLFIELD

JULY 2012

FIGURE A-13



ALT 14: SOUTH SALTON SEA 50,000 AF PLANT

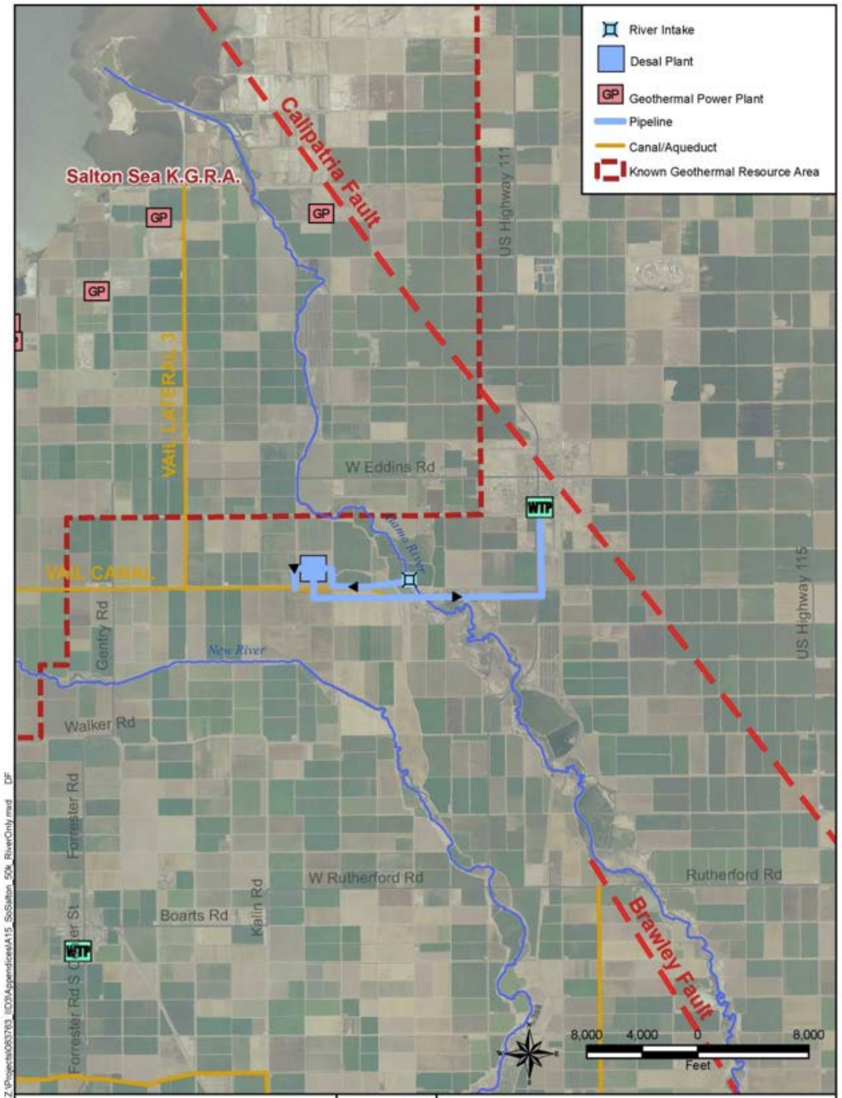
JULY 2012

FIGURE A-14

GEI Consultants

Imperial IRWMP
Imperial County, California

22-Jul-2012 Z:\Projects\083763 IID3\Appendices\A14_SoSalton_50k_RiverOnly_noMuni.mxd DF



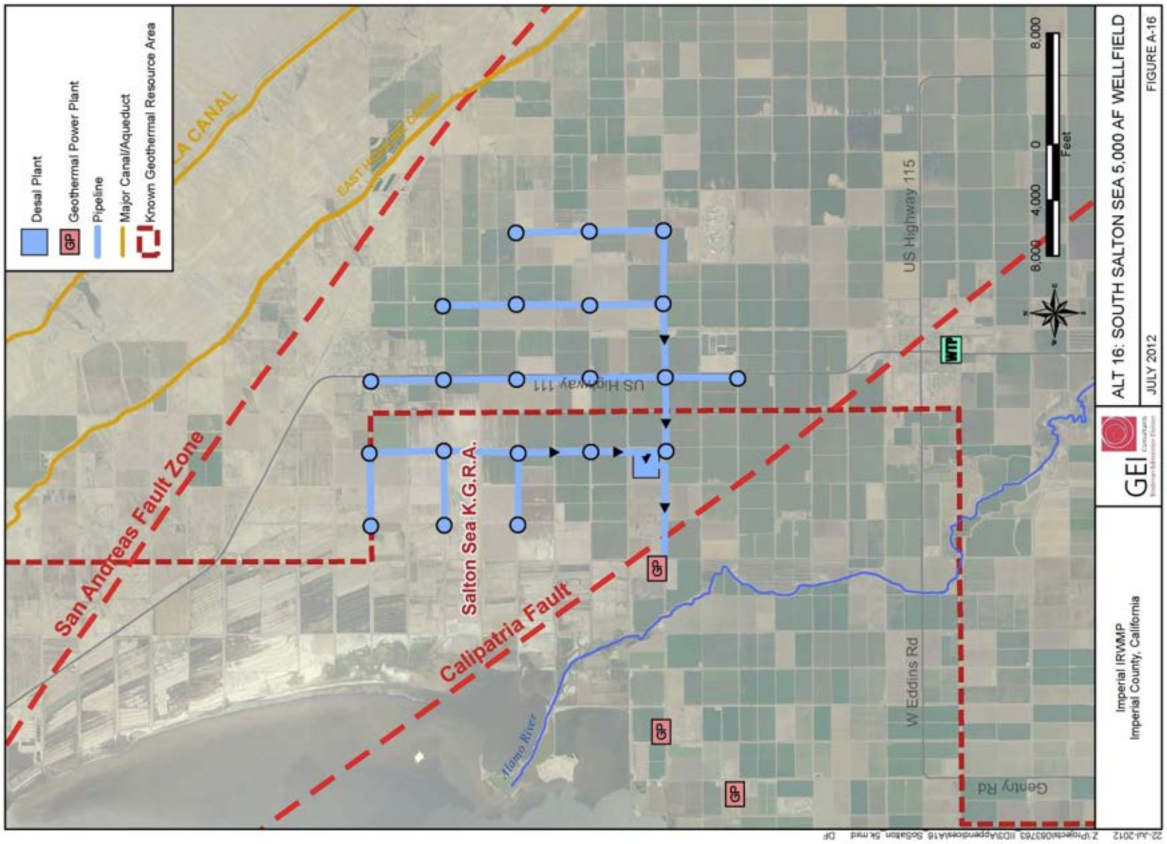
Imperial IRWMP
Imperial County, California

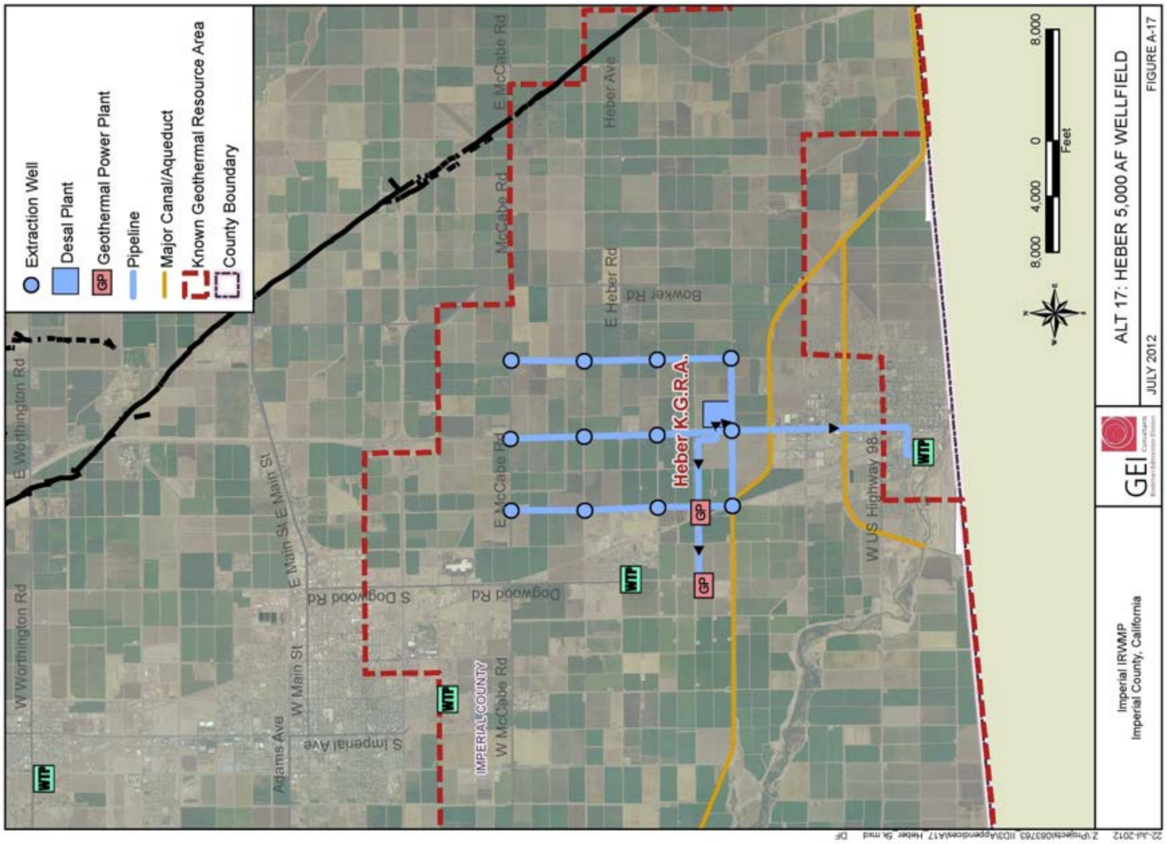
GEI Consultants

ALT 15: SOUTH SALTON SEA 50,000 AF PLANT

JULY 2012

FIGURE A-15


Desal Plant
GP Geothermal Power Plant
Pipeline
Major Canal/Aqueduct
Known Geothermal Resource Area
A CANAL
EAST HIGHLINE CANAL
San Andreas Fault Zone
Salton Sea K.G.R.A.
Calipatria Fault
US Highway 111
US Highway 115
W Eddins Rd
Gentry Rd
Alamo River
GP
GP
GP
WTP
8,000
4,000
0
8,000
Feet
N
ALT 16: SOUTH SALTON SEA 5,000 AF WELLFIELD
JULY 2012
FIGURE A-16
GEI Consultants
Imperial IRWMP
Imperial County, California
22-Jul-2012
Z:\Projects\083763_IID3\Appendices\A16_SoSalton_5k.mxd
DF



ALT 17: HEBER 5,000 AF WELLFIELD

JULY 2012

FIGURE A-17

Imperial IRWMP
Imperial County, California

22-Jul-2012 Z:\Projects\083763_IID3\Appendices\A17_Heber_5k.mxd DF

IMPERIAL
IRWMP
INTEGRATED REGIONAL
WATER MANAGEMENT PLAN

GEI Consultants