Mojave Water Agency

Technical Study to Evaluate a

Potential Long-Term Water Management Program Between Mojave Water Agency and Metropolitan Water District

December 2005

Bookman-Edmonston
A Division of GEI Consultants
in association with
SAIC Science Applications International Corporation
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Geotechnical
Environmental and
Water Resources
Engineering

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Mr. Norman T. Caouette
Assistant General Manager
Mojave Water Agency
22450 Headquarters Drive
Apple Valley, CA 92307-4304

Subject: Technical Study to Evaluate a Potential Long-Term Water Management Program Between the Mojave Water Agency and Metropolitan Water Storage District

Dear Mr. Caouette:

Bookman-Edmonston a division of GEI Consultants in association with Science Applications International Corporation is pleased to submit our report entitled "Technical Study to Evaluate a Potential Long-Term Water Management Program Between the Mojave Water Agency and Metropolitan Water Storage District."

We are prepared to present the findings of this report to the local community or other parties. We are also available to provide any further technical support, including evaluation of additional scenarios or response to comments. It has been our privilege to provide this service to Mojave Water Agency and to Metropolitan Water District.

Sincerely,

Richard A. Rhone, P.E.
Managing Executive Engineer

Enclosures

cc: Robert Beeby, SAIC

www.geiconsultants.com
GEI Consultants, Inc.
225 West Broadway, Suite 400, Glendale, California 91204-1331
818.244.0117 fax: 818.242.0480

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Date: December 2005
Project No: 042810

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Introduction

The MWA is a regional water management entity created by special act of the California legislature. It is one of the 29 contractors with the California Department of Water Resources (DWR) and has a contract for up to 75,800 acre-feet of water from the State Water Project (Table A entitlement). The MWA encompasses over 4,900 square miles within the High Desert Region of San Bernardino County in southern California and contains several distinct groundwater basins and subareas. Plate1 illustrates the MWA area. Two of those basins, Mojave Area Basin including its five subareas, and the Warren Valley Basin which is a subarea of the Morongo Basin/Johnson Valley Basin, have been adjudicated because of the long-term overdraft of groundwater for agricultural, municipal, and industrial water supplies. The region has historically imported a negligible amount of SWP water and has been dependent upon its groundwater supply, the region has experienced cumulative groundwater overdraft since the early 1950s.

Groundwater has been the primary source of water for the MWA. Consequently, MWA programs have focused on ways to increase the availability and reliability of the local water supply through the continued review and improvement of its management of groundwater resources. MWA recognizes that years of cumulative overdraft have increased the available groundwater storage. This presents an opportunity for enhanced conjunctive management of groundwater and surface water resources, both local and imported. MWA has been examining the potential to increase the availability of dry-year (drought) water supplies and overall supply reliability through regional conjunctive use efforts. In recognition of the groundwater storage opportunity within MWA, Metropolitan and MWA desire to review the potential to enter into a long-term water management program. Metropolitan needs local water storage and MWA has that storage available within the groundwater basin. The location of MWA near the terminus of the East Branch of the State Water Project provides an opportunity to not only serve Metropolitan with water near the point of its demand but also to reduce peaks on the East Branch. The "predelivery" of water for storage in the Mojave Basin increases water in storage, locally decreases pumping lifts, and allows for additional water distribution throughout the MWA.

Bookman-Edmonston, a division of GEI Consultants (B-E/GEI), in association with Science Application International Corporation (SAIC), herein known as "the Team" was hired by the Mojave Water Agency (MWA) to conduct a technical study which would evaluate the potential for a long-term water management program between the MWA and Metropolitan Water District of Southern California (Metropolitan).

In 2004, B-E/GEI conducted a demand study of the East Branch Contractors to assess their demands over the next 20 years. The study found that demands are approaching the capacity of the East Branch. Accordingly, the deliveries are expected to change from a "time of use" conveyance to a "supply-driven" conveyance. The change will create a run-of-the-river operation of the East Branch. Large storage capability in short periods of time is presumed to favor the supply-driven conveyance.

The study performed by the Team and reported in this document describes the process taken to determine the initial range of water storage and return program alternatives, how they were analyzed, and screened by performing engineering and hydrogeologic, and economic analysis to provide a list of the most promising alternatives that could address the needs of both Agencies.

Organization of Report

An Executive Summary follows the introduction. The Study was structured with the development and delivery of Technical Memoranda (TM's). Each TM was delivered to MWA and Metropolitan. This report is a summary of the TM's. The TM's prepared are as follows:

- TM 01 – Initial Alternatives and Screening Matrix (summarized in Section 1.0)
- TM 02 – Preliminary Engineering and Hydrogeology for *Put* Alternatives (summarized in Section 2.0)
- TM 03 - Metropolitan Water Storage Assessment (summarized in Section 3.0)
- TM 05 – Preliminary Engineering for *Take* Alternatives (summarized in Section 4.0)
- TM 06 – Local Water Use 10% Design Arrangements (summarized in Section 5.0)
- TM 07 – Facilities Cost Estimate (summarized in Section 7.0)
- TM 09 – Institutional Screening of Alternatives (summarized in Section 6.0)

The analysis originally intended for TM 04 was incorporated into other memoranda. The analysis intended as part of TM 08 was incorporated into the environmental documentation.

Executive Summary

This report presents the results and the recommendations of the technical study undertaken by the Team to define a potential long-term water management program between Mojave Water Agency (MWA) and Metropolitan Water Storage District of Southern California (Metropolitan). The Water Management Program is designed to store Metropolitan's surface water within the Mojave River Basin (Basin). The study focused on the *put* and *take* mechanisms and groundwater storage capabilities within the Basin. A water management program between MWA and Metropolitan could give Metropolitan more operational flexibility by enabling it to store water it normally would have lost, and allow Metropolitan to have supplemental water during a dry year. MWA's local purveyors would also benefit from higher groundwater levels and lower pumping lifts.

Program Alternatives

Early in the process, MWA and Metropolitan agreed upon screening criteria and assumptions for the *put* and *take* alternatives of the potential MWA/Metropolitan Water Management Program (MWA/Metropolitan Program). The areas within the Basin that have the physical, geographical, and environmental characteristics most suited to implement a long-term MWA/Metropolitan Program were identified, as well as the volumes of water that can reasonably be stored and extracted from these areas. The areas near the East Branch of the State Water Project (East Branch) and nearby existing facilities were identified as being favorable locations for the *put* and *take* alternatives. After meeting with staff from MWA, Metropolitan, and the environmental consultant, the Team identified an initial range of conditions, including storage and return volumes, which were used to screen the alternatives. The alternatives were sized to *put* up to one-third of the program's capacity in storage in a nine-month period and to *take* up to one-fifth of the storage in ten months. MWA will return Metropolitan's stored water by either a direct return to the East Branch by physical means, with entitlement exchange, or a combination of the two methods.

After the preliminary engineering and cost screening of the *put* and *take* alternatives, seven *put*, and five *take* alternatives were identified, evaluated and sized for the composition of the MWA/Metropolitan Program. One of the *put* alternatives (new engineered spreading grounds with extraction wells) is located in the Oeste subarea, near Sheep Creek just north of the East Branch. The other six *put* alternatives are located in the Alto subarea, either through the construction of new spreading facilities or the use of existing facilities such as the Rock Springs turnout, or a combination of both. The MWA also decided on the range of State Water Project (SWP) allocation entitlement it believes could be used in the MWA/Metropolitan Program as entitlement exchange (3,000 to 38,000 acre-feet per year).

The evaluation, sizing, and screening process resulted in three potential MWA/Metropolitan Programs (Program) of storage capacities: 225,000, 300,000, and 450,000 acre-feet. Each Program is composed of several *put* and *take* alternatives of various sizes that include existing and new facilities, and 20,500 acre-feet per year of entitlement exchange.

The Programs and their respective alternatives are shown on Tables E-1 to E-3. The Tables show the *put* and *take* volumes for each alternative, as well as the area required for new spreading grounds. Plate 7 illustrates the locations of these alternatives.

All alternatives with direct return to the East Branch will have to meet the Department of Water Resources (DWR) water quality guidelines.

The Recommended MWA/Metropolitan Program

Both MWA and Metropolitan would benefit more from a Program that offers several recharge facilities near the East Branch and within the area's growing communities. The recommended MWA/Metropolitan Program is one that offers operational flexibility, such as the 450,000 and 300,000 acre-foot storage Programs described on Tables E-1, and E-2. These Programs have more recharge facilities at close proximity to the East Branch, making it easier to return water to Metropolitan.

Approximately 80 percent of the 225,000 acre-foot storage Program's recharge operations are on the Mojave River. Metropolitan will most likely be putting water into storage during wet years. If Metropolitan decides to store water right after a big storm, it may be difficult to do so if the River is flowing full. The other 20 percent of the 225,000 acre-foot storage Program's recharge operations utilize the existing spreading grounds located in Hodge, Lenwood, Daggett, Yucca Valley, and Newberry Springs. These existing spreading grounds are located more than 30 miles from the East Branch, which leaves entitlement exchange as the only method of returning stored water from these locations to Metropolitan. Furthermore, the amounts available for exchange is limited by the SWP allocations for that year, making the 225,000 acre-foot storage Program even more dependant on the Mojave River spreading operations.

The 450,000 and 300,000 acre-foot storage Programs have greater flexibility because of the size of the facilities that put water into storage and the size of facilities that return water to the East Branch. These are important Program attributes that will enable Metropolitan the ability to respond to changes in both the availability of surplus water for recharge and the need to return water to the East Branch.

Table E-1
Facility Composition for a 450,000 Acre-Foot
MWA/Metropolitan Water Management Program
with 20,500 Acre-Feet of the Return Capacity as Entitlement Exchange

Facility Description	***Put* Capacity 9 Months (acre-feet/year)**	**Area Required[1] (acres)**	***Take* Capacity 10 Months (acre-feet/year)**
P3A/P7-Mojave River Pipeline or Oeste recharge basins	50,000	545	-
T1/T4 - Mojave River Pipeline or Oeste wells fields[2]	-	-	25,400
Cedar Springs Dam & Rock Springs Turnout, unnamed wash[3]	61,000	-	-
T3 – Upper Mojave River Well Field[3] and Water Supply Pipeline w/ south of Rock Springs Spreading Grounds	-	100	39,300
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia Detention Basin, land-locked lands	39,000	435	-
T0 - Cedar Avenue and land-locked lands	-	-	4,800
Entitlement Exchange	-	-	20,500
Totals	150,000	1,080	90,000

[1]Spreading grounds.
[2]Well capacities of 2 cfs each.
[3]May require some costs for easement on the unnamed wash.
[4]Well capacity of 3 cfs each.

Table E-2
Facility Composition for a 300,000-Acre-Foot
MWA/Metropolitan Water Management Program
with 20,500 Acre-Feet of the Return Capacity as Entitlement Exchange

Facility Description	***Put* Capacity 9 Months (acre-feet/year)**	**Area Required[1] (acres)**	***Take* Capacity 10 Months (acre-feet/year)**
Cedar Springs Dam & Rock Springs Turnout, unnamed wash[2]	61,000	-	-
T3 – Upper Mojave River Well Field[3] and Water Supply Pipeline w/ south of Rock Springs Spreading Grounds	-	100	39,500
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia Detention Basin, land-locked lands	39,000	435	-
Entitlement Exchange	-	-	20,500
Totals	100,000	535	60,000

[1]Spreading grounds.
[2]May require some costs for easement on the unnamed wash.
[3]Well capacity of 3 cfs each.

Table E-3
Facility Composition for a 225,000 Acre-Foot
MWA/Metropolitan Water Management Program
with 20,500 Acre-Feet of the Return Capacity as Entitlement Exchange

Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)
Cedar Springs Dam & Rock Springs Turnout, unnamed wash[3]	61,000	-	-
T3 – Upper Mojave River Well Field[2] and Water Supply Pipeline w/ south of Rock Springs Spreading Grounds	-	100	24,500
Existing Spreading Grounds- Hodge, Lenwood, Daggett, Yucca Valley, Newberry Springs	14,000	-	-
Entitlement Exchange	-	-	20,500
Totals	75,000	100	45,000

[1]Spreading grounds.
[2]Well capacity of 3 cfs each
[3]May require some costs for easement on the unnamed wash.

Another water management opportunity that is discussed briefly within this report and that requires further consideration is a program referred to as "mutual exchange." A "mutual exchange" program would allow MWA to get water placed into storage that it currently cannot afford to purchase itself and the local purveyors could then benefit from higher groundwater levels and lower pumping lifts. Metropolitan would benefit from an operational point of view; it can store water that it would have otherwise lost due to a lack of storage facilities, and it would also have supplemental water during a dry year. There are, however, some limitations with a "mutual exchange" program. MWA's participation in this mutual exchange program will be especially beneficial before MWA can afford to purchase its own entitlement. It may also aid in other situations such as when more water is available than MWA's contract aqueduct capacity.

Cost Sharing Opportunities

Each MWA/Metropolitan Program contains at least one alternative that could be considered a conjunctive use project that can serve local water districts. The largest is the Upper Mojave River Well Field and Water Supply Pipeline (Alternative T3). This alternative was developed as part of the MWA/Metropolitan Program however; there is significant interest in this alternative from the local water districts. The alternative has been designed with facilities that allow for deliveries to local water districts when Metropolitan is not taking water from storage. The water districts with connections on the Upper Mojave River Water Supply Pipeline would be expected to contribute a percentage of the cost associated with this alternative. Other alternatives with conjunctive use features that may offer some cost sharing opportunities are the proposed storm detention basins/spreading grounds. These alternatives can benefit the local communities and still be an integral part of the MWA/Metropolitan Program.

Program Cost Summary

The estimated capital cost and equivalent annual cost per acre-foot of both Programs are shown in Table E-4. The equivalent annual cost was evaluated using a present-worth calculation over 30 years, 5 percent interest, and 5 percent debt service.

Table E-4
Summary of Cost

Program Storage Capacity (AF)	P*ut* Capacity (acre-feet/yr)	*Take* Capacity (acre-feet/yr)	Capital Cost (2005$)	Annual Cost (2005$/AF)
450,000	150,000	90,000	$186,208,000	$410
300,000	100,000	60,000	$130,041,000	$360
225,000	75,000	45,000	$77,195,000	$260

Not included in these costs estimate are any wheeling charges, or the cost of water from MWD.

Assumes 20,500 acre-feet per year of entitlement exchange is used in conjunction with direct returns to MWD.

The equivalent annual cost includes the capital and operation and maintenance cost, which is predominately energy for pumping (assumed to be $ 0.12/kWh and a pump efficiency of 0.8).

1.0 Existing Water Management Program and Initial Screening of Alternatives

Mojave Water Agency's existing water management program and facilities are discussed in this section, along with an initial description of the MWA/Metropolitan water management program including an initial screening of alternatives. The criteria to be used for the evaluation and screening is also included. This information was previously presented in Section 4.1 of TM 01.0., which includes additional detailed information. The reader, on occasion will be referred to TM 010.

1.1 Current MWA Operations

1.1.1 Current Water Management Principles

Four water management principles were developed as part of the MWA Regional Water Management Plan (RWMP) Update, 2004. These principles help to guide the implementation of the plan, while ensuring that local concerns and potential impacts were fully addressed prior to constructing specific projects:

1 All actions should be supportive of the plan's goals and objectives.

2 Technical studies should receive input by the Technical Advisory Committee[1] or appropriate subcommittee.

3 Proposed projects will be implementable, in that they will have broad stakeholder acceptance and will be legally and financially feasible.

4 No project will result in significant redirected impacts to MWA stakeholders.

1.1.2 Land Use and Water Requirements

The MWA consists of two distinct hydrologic planning areas: the Mojave Basin Area and the Morongo Basin/Johnson Valley Area. The Mojave Basin Area is divided into five subareas: the Alto, Baja, Centro, Este and Oeste. The Morongo Basin/Johnson Valley Area is divided into four: Johnson Valley, Means/Ames Valley, Copper Mountain Valley and Warren Valley Basins. These are shown on Plate 1.

Agricultural uses have been declining in all the Mojave Basin Area subareas since about 1990, while urban consumptive uses have been increasing or remaining fairly constant. The Alto and Oeste subareas experienced an increase in municipal consumptive use between 1995 and 2001. In the Centro subarea, the total consumptive use has declined during the same period. The industrial consumptive use in Baja subarea has increased due mostly to an increase in water use

[1] The TAC is an organization made up of water purveyors, farmers, property owners and other stakeholder groups in the High Desert.

by power generating facilities in the area. The urban consumptive use in the Este subarea has remained relatively constant during these years.

In the Morongo Basin/Johnson Valley area the majority of the consumptive use was for municipal use in 2001, with the remainder being used for a golf course in the Warren Valley. Agricultural, industrial, or recreational lake uses are minimal.

1.2 Water Supplies

1.2.1 Surface Water

MWA's surface water supply originates as natural runoff from the Mojave River and other tributaries and streams or is supplemental water imported from the SWP. The Rules and Regulations of Mojave Basin Area Watermaster (Revised December 1996) defines "supplemental water" as water imported to the Basin Area from outside the Basin Area. This definition will be used to describe water supplies imported from the SWP.

The SWP was constructed through the area in the 1970s. MWA's Table A entitlement is 75,800 acre-feet. MWA has an internal allocation of SWP water for a maximum of 7,257 acre-feet to Improvement District M (IDM) located in the Morongo Basin/Johnson Valley Area. This internal allocation is limited to the same percentage of total entitlement that MWA is approved to receive from the SWP. MWA has an existing agreement to exchange up to 2,250 acre-feet per year to the Antelope Valley-East Kern Water Agency (AVEK). The water is transported by AVEK to a power plant located near Kramer Junction within the MWA. The variability of the SWP deliveries is expected to increase in the future as Contractors request larger amounts of their entitlement.

<u>The Mojave Basin Area.</u> The Mojave River is the main natural surface water drainage feature within the MWA service area. The drainage area of the Mojave River is 3,800 square miles. The Mojave River is fed by rainfall and melting snow pack from the San Gabriel and San Bernardino Mountains. The river is formed by the convergence of the West Fork and Deep Creek at a place called "The Forks." From The Forks, the river runs north and then east for about 100 miles, where it flows through Afton Canyon and terminates at Soda and East Cronese Lakes. The Mojave River only flows continuously along a short section downstream of The Forks; in the vicinity of Upper and Lower Narrows; at Afton Canyon; and in the section immediately downstream of the Victor Valley Wastewater Reclamation Authority's (VVRWA) treatment plant. During the winter after large rainstorms, the Mojave River can flow along most of its reaches.

Five stream gage locations on the Mojave River have been used to monitor surface flow. Records for some sites extend as far back as 1900. Consistent records are available from 1931 when the U. S. Geological Survey (USGS) established gaging stations on the Mojave River. The stream gages are maintained and operated by the USGS under a cooperative program with MWA.

The flow at The Forks is the primary water supply to the main stem of the Mojave River; consequently, the combined data from the Deep Creek and West Fork gages represent the total flow at the headwaters of the Mojave River. The average annual discharge at The Forks is

71,300 acre-feet for the period 1931 through 2001 (RWMP Update 2002). The Mojave River Dam (also known as the Forks Dam) is an ungated flood control dam that attenuates peak flows below The Forks. Surface flows are augmented about 22 miles downstream of The Forks by discharges from the VVWRA treatment plant. This discharge was 9,006 acre-feet in water year 2000.

The Alto subarea has the largest surface water supply due to its proximity to the headwaters of the Mojave River. The Centro and Baja subareas are dependent upon infrequent, very large storms for groundwater recharge. The Este and Oeste subareas have the least surface water supply, most of which originates from ungauged streams.

The Afton gage is about six miles downstream (east) of the eastern boundary of the Baja subarea and approximately 100 miles from The Forks. Thus, it serves as a measure of the surface water exiting the Mojave Basin Area. During 80 percent of the recorded years, discharge at the Afton gage averaged less than 1,000 acre-feet. Almost all of the water entering the basin infiltrates within the basin except during big storms which result in big losses.

Morongo Basin/Johnson Valley Area. The Morongo Basin/Johnson Valley Area has only small ephemeral streams that include the Pipes Wash and Yucca Wash. They collect runoff from the surrounding mountains (the Little San Bernardino and San Bernardino Mountains) during storms. This mountain stream runoff either percolates into the streambed, or, during large storms, flows to dry lakebeds where it evaporates. The future water supply of the Morongo Basin/Johnson Valley Area will greatly depend on MWA's ability to provide supplemental SWP water through the Morongo Basin Pipeline.

1.3 Groundwater

The principal water supply to the MWA service area is groundwater. Groundwater occurs in two large groundwater basins; the Mojave River Groundwater Basin (MRB) and the Morongo Groundwater Basin (MB).

Mojave River Groundwater Basin. The MRB occupies approximately 1,400 square miles. The MRB has been divided into five subareas, based on their relative elevation and location with respect to the Mojave River. These include: Alto (Victorville/Apple Valley area), Este (Lucerne Valley), Oeste (El Mirage/Pinon Hills area), Centro (Barstow, Harper Lake/Kramer Junction area) and Baja (Daggett/Newberry Springs area). The Transition Zone, a part of the Alto subarea, is a designated reach of the Mojave River watershed between the Lower Narrows and the Helendale fault. The Transition Zone, per the MRB adjudication, is a "water bridge" between the Alto and Centro subareas.

Groundwater flow within the MRB varies by subarea. In the Alto subarea groundwater flow is to the north–northeast. In the Este subarea, groundwater flow east of the Helendale fault is radial to the northeast toward Lucerne Dry Lake, an evaporite lakebed, in the Lucerne Valley. West of the Helendale Fault groundwater flow is westward and northwestward into the Alto subarea. In the Oeste subarea, groundwater flow is toward the north-northeast. In the Transition Zone, groundwater flow is northward toward the Centro subarea. Groundwater flow in the Centro subarea varies from northward toward Harper Dry Lake, an evaporite lakebed west of Iron Mountain, to northeast and east along the Mojave River toward Barstow east of

Iron Mountain. In the Baja subarea, groundwater flow is typically eastward toward Newberry Springs and Afton Canyon with localized northerly flows toward Coyote Dry Lake, an evaporite lakebed.

The estimated usable storage capacity of the MRB is nearly five million acre-feet (B-E, 1994). However, there is subsurface flow between the various basin subareas (e.g., Alto subarea into Transition Zone and Centro subarea). Groundwater recharge principally occurs via infiltration of streamflow in the Mojave River and to a much lesser extent from infiltration of storm runoff from the mountains and manmade discharges from irrigation, the VVWRA treatment plant, fish hatcheries and deliveries of imported SWP water. Over 90 percent of the MRB groundwater recharge originates in the San Gabriel and San Bernardino mountains.

Morongo Groundwater Basin. The Morongo Groundwater Basin (MB) occupies about 1,000 square miles. The MB contains several major subareas: Copper Mountain, Johnson Valley, Means/Ames Valley and Warren Valley. About 60 percent of the MB is located within the southeastern portion of the MWA service area. Groundwater recharge into the MB is derived from precipitation runoff in the San Bernardino Mountains which border the basin on the west and south. Groundwater flow is away from the mountain front toward the east-northeast. Localized groundwater flow conditions occur in the developed portions of Yucca Valley and in the vicinity of a nearby artificial recharge site.

Groundwater is withdrawn from the MB principally by pumping from wells, evaporation through the soil, evapotranspiration and seepage to dry lakebeds where it evaporates.

1.4 Geology

The MWA service area is located within the Mojave Desert Geomorphic Province of California. The Mojave Desert in the MWA service area is comprised of generally northwest-southeast trending mountain ranges and hills with intervening valleys. Numerous northwest-southeast trending faults border and/or transect the mountain ranges and extend into the intermountain valleys. The mountain ranges and hills are underlain by a variety of rock types including pre-Cambrian through Mesozoic metamorphic and igneous rocks (e.g., metasedimentary and metavolcanic rocks, gneiss, schist and granitic rocks) and Tertiary sedimentary and volcanic rocks. The intermountain lowlands including the Mojave River area are largely underlain by mostly Quaternary and some Tertiary sedimentary deposits, chiefly alluvial debris eroded from adjoining mountain and highland areas and transported onto the valley floor. The alluvial deposits along the Mojave River and most of the ephemeral drainage channels are predominantly unconsolidated or poorly consolidated. The alluvial fan deposits that underlie the vast majority of the lowland areas, with the exception of the aforementioned drainages, are commonly more consolidated and cemented particularly at depth due to overburden pressures and the accumulation of salts in these deposits. The alluvial deposits underlying the Mojave River and other ephemeral drainage channels are principally composed of sand and gravel with lesser amounts of fine-grained silt and/or clay. The alluvial fan deposits are more heterogeneous and consist of individual layers and mixtures of sand, gravel, silt and clay. In addition, various salts such as calcium sulfate as anhydrite or gypsum and calcium carbonate as caliche have accumulated and /or precipitated in certain horizons within these deposits and locally cemented the alluvial materials.

Numerous faults have influenced the trend of mountain ranges and valleys therein. The most prominent are the Helendale, Lockhart and Camp Rock faults (also called the Waterman Fault). These faults, as well as many others have been the locus of pre-historic and historic earthquakes and underscore the seismic potential of this portion of the Mojave Desert.

1.5 Hydrogeology

The principal water-bearing geologic materials in the MWA service area are the alluvial sediments comprising the drainage channel deposits or floodplain deposits of the Mojave River and the alluvial fan deposits. The floodplain deposits are largely localized to drainages and have limited areal and vertical extent. However, because these deposits underlie active drainages they are permeable, have relatively high infiltration characteristics and can readily transmit water in the subsurface. The alluvial fan deposits are considerably thicker and are also permeable where composed of sand and gravel and minimally cemented. However, where these coarser grained materials are mixed with silts and clay and/or partially cemented, the permeability and infiltration characteristics are lower and they do not transmit water as readily in the subsurface. In many portions of the MWA service area, the alluvial fan deposits are intermixed with and/or separated by accumulations of fine-grained clay deposits that represent former lakebeds. These former lakebeds or lacustrine deposits, where present, further lower the overall permeability of the alluvial fan deposits and may act as impediments to the recharge of surface water to underlying aquifers. Significant buried lacustrine deposits have been identified in Lucerne Valley in the Este subarea, north of Newberry Springs in the Baja subarea and near Oro Grande Wash in the Alto subarea.

Groundwater occurring in the floodplain alluvial deposits is known as the Floodplain aquifer (also known as the Mojave River aquifer in the Mojave River drainage) and the Regional aquifer in the alluvial fan deposits. Groundwater present in the Floodplain aquifer is largely unconfined or is a water table aquifer. Groundwater occurring in the Regional aquifer is more complex and may be unconfined, semi-confined or confined depending on the nature and extent of the alluvial and lacustrine deposits that comprise the aquifer.

1.6 Groundwater Quality

Groundwater quality within the MWA service area varies considerably. In the Floodplain aquifer where groundwater recharge readily occurs, groundwater quality can vary depending on the type and quantity of water recharged. During seasonal storms, runoff from the San Bernardino and San Gabriel mountains percolates into the Floodplain aquifer and the upstream portions of the Regional aquifer adjacent to the mountain fronts and replenishes the aquifers with water that is relatively low in dissolved salts. Recharge into the Regional aquifer from the Floodplain aquifer also replenishes the Regional aquifer with higher quality groundwater. Farther downstream where the influence of municipal and industrial practices are more common, discharges from wastewater treatment plants such as VVWRA and the City of Barstow impact the quality of groundwater in those reaches of the Floodplain and Regional aquifers. Groundwater occurring in the vicinity of dry lakebeds (e.g., Harper, Lucerne) commonly contains more dissolved salts (i.e., are more saline) than elsewhere because the dry lakebeds are the locus of the accumulation of water that evaporates leaving the salt residue behind. As a result, the salts produced dissolve when wet and increase the salinity of the groundwater.

Other more localized sources of poor quality groundwater may be the result of the leaching of specific metals in the sediments comprising the aquifer. For example, groundwater recharged by Sheep Creek which drains a portion of the San Gabriel Mountains near the border of Oeste and Alto subareas contains elevated concentrations of chromium 6. The source of the chromium 6 is from the leaching of certain eroded geologic materials in the watershed that now comprise a portion of the Regional aquifer in this area. Similarly, throughout portions of the Alto and Centro subareas, and perhaps elsewhere, elevated concentrations of arsenic have been encountered in the Regional aquifer. The exact source of the arsenic is not presently known but might be related to the leaching of certain volcanic sediments beneath the groundwater surface.

1.7 Existing Facilities

1.7.1 State Water Project

The East Branch enters the western boundary of the MWA service area at 263rd Street East about 0.5 miles south of State Route 138 (milepost [MP] 377.81). The East Branch extends generally easterly to southeasterly through the MWA service area and leaves the southern MWA service area boundary at State Route 138 near Cedar Springs Dam (MP 405.6). The locations of turnouts along the portion of the East Branch that passes through the MWA service area is presented in Table 1-1.

Table 1-1.

Turnout Locations off the East Branch within the MWA Boundaries

Milepost*	Identifier*	Design Flow*
MP 383.95	Sheep Creek Turnout	30 cubic feet per second (cfs)
MP 389.20	Mojave River Pipeline Turnout	94 cfs (1 barrel @ 24", 1 @ 42")
MP 393.22	Highway 395 Turnout	50 cfs
MP 401.10	Morongo Basin Pipeline Turnout	60 cfs (1 barrel @ 24", 2 @ 30")
MP 402.96	Four turnouts	
	- MWA Hesperia	110 cfs (48" barrel)
	- MWA Hesperia	25 cfs
	- DWA Hesperia	109 cfs (60" barrel)
	- CVWD Hesperia	66 cfs

* Information from strip maps and from "Data Handbook, State Water Project", 2003.
DWA = Desert Water Authority, CVWD = Coachella Valley Water District

1.7.2 MWA Facilities

MWA owns and operates two pipelines that are supplied from the East Branch: the Mojave River Pipeline and the Morongo Basin Pipeline.

Mojave River Pipeline. The Mojave River Pipeline stretches about 74.9 miles from the East Branch, initially paralleling the Mojave River, and ending near Newberry Springs. Plate 1 illustrates the route of the pipeline and identifies other infrastructure on or near the pipeline.

The first 60.7 miles of the pipeline is constructed of welded steel pipe, having diameter ranging from 48 to 35 inches. Reach 4A, the last 14.2 miles is 24-inch diameter PVC pipe. The entire conveyance is a falling grade (i.e., gravity flow) pipeline. The pipeline delivers surface water to areas with depleted groundwater conditions.

Three pressure-reducing facilities (Cassia, Helendale, and Lenwood) constructed along the pipeline reduce the internal pressure thus allowing reductions in the pipewall thickness of the steel pipe. The pressure-reducing facilities decrease the downstream pipeline pressure to near-atmospheric (a standpipe 10 feet above ground is located at each facility). The facilities consist of a subterranean valve vault that houses a single pressure-reducing valve. A second valve for each facility will be installed in the future.

Three turnouts along the pipeline direct water to the Hodge, Lenwood, and Daggett groundwater spreading areas. The Hodge and Daggett spreading grounds are within the Mojave River, and the Lenwood spreading grounds are within constructed spreading ponds alongside the river. A fourth spreading facility is planned near Newberry Springs. A turnout to the High Desert Power Plant (HDPP) is located near the intersection of Helendale Road and Colusa Road.

MWA provided the team with a condensed plan and profile drawings for the entire pipeline. Obviously, the pipeline can be used to deliver water for future groundwater spreading alternatives; however, the question is, can the pipeline be used to convey water pumped back to the SWP. This is addressed in Section 4.0.

Morongo Basin Pipeline. The Morongo Basin Pipeline stretches about 82 miles from the East Branch easterly along the southern boundary of the MWA service area and terminates near Yucca Valley, California. Plate1 illustrates the route of the pipeline and identifies other infrastructure on, or near, the pipeline.

The first 7 miles is 54-inch diameter concrete cylinder pipe. A turnout at the end of this reach of pipe delivers water to the Mojave River for spreading at the Rock Springs Turnout. The remaining 75 miles of pipeline is 30-inch diameter welded-steel pipe until it reaches the reservoir in Landers where it reduces to 24-inch until reaching Yucca Valley (HDWD spreading basins). Two booster pump stations (Lucerne Valley and Johnson Valley) lift the water to a regulating reservoir in Landers. The pipeline delivers surface water to areas with depleted groundwater supplies. Water is also recharged with spreading grounds near Yucca Valley.

MWA provided the team with a condensed plan and profile drawings for the entire pipeline. The pipeline can be used to deliver water for future groundwater spreading alternatives; however, as with the Mojave River Pipeline, can the pipeline be used to convey water pumped back to the SWP. This will also be addressed in Section 4.0 of this report.

1.7.3 Local Water Purveyors

Local agency infrastructure, including wells and pipelines, may be useful for conveying direct returns to the SWP for Metropolitan in *take* years or direct deliveries to MWA for recharge or agricultural use in *put* years. If the region and/or individual cities construct a water treatment plant in the future, then surface water could be delivered, treated, and distributed within the purveyors' existing pipelines in lieu of pumping groundwater (i.e., in-lieu recharge in a *put* year). Presently, however, the best use of the local purveyors' infrastructure would be for the extraction of water and direct return to the SWP in a *take* year. Production wells are located throughout the MWA service area in the following subareas:

- Alto
- Oeste
- Este
- Alto Transition Zone
- Centro
- Baja

Most production wells are within a few miles of the Mojave River, but some wells in Lucerne Valley are located over 20 miles from the river. The highest demand areas, based on high production well capacities, are within the Alto subarea (cities of Victorville, Apple Valley, and Hesperia), Centro subarea (city of Barstow), and Baja subarea. The Alto subarea is closest to the SWP, while the Centro and Baja subareas are farther away.

Population growth within the Alto subarea is predicted to be very significant over the next 25 years; hence, water demands will also increase significantly. Section 5.0 reviews the groundwater production by water purveyors, evaluates their infrastructure and its compatibility with either *put* or *take* scenarios, and provides recommendations for possible conjunctive use projects that benefit local purveyors, and that would compliment the MWA/Metropolitan Water Management Program.

1.7.4 Demonstration Banking Report

In 2003, MWA entered into an agreement for a water banking demonstration project with Metropolitan. Under this program, MWA would take delivery of up to 75,000 acre-feet of Metropolitan's SWP entitlement water in 2003 or 2004. Metropolitan may take up to five years to ask for the return of previously delivered water through an exchange of MWA allocated Table A entitlement from the SWP. Approximately 25,000 acre-feet of Metropolitan's water was delivered to MWA under this program. Deliveries were made from Silverwood Lake through Cedar Springs Dam and MWA turnout facilities at Rock Springs, Hodge, Lenwood, and Daggett. The demonstration project also involved construction of small sand levees in the normally dry Mojave River channel near Hesperia to manage water released from Silverwood Lake and the Rock Springs Outlet. MWA processed a mitigated negative declaration and secured a U.S. Army Corps of Engineers Section 404 permit for the demonstration project only.

Arroyo Toad

Releases from the pipeline turnouts were essentially problem-free; however, the release from Cedar Springs Dam was controlled by mitigation measures to protect the habitat of the arroyo toad (Bufo californicus), a federally listed species. The mitigation measures include:

- A maximum release of 500 cfs from Cedar Springs Dam
- An incremental ramp-up of 50 cfs per 24 hours
- Releases limited from September 15 to February 15

The toad is found in the West Fork of the Mojave River, between Cedar Springs Dam and the Mojave River Dam. Releases from Cedar Springs for groundwater spreading must be monitored to ensure that they do not negatively affect the toad or its habitat.

1.8 MWA/Metropolitan Water Management Program

The development of this Water Management Program study included the preparation of seven individual technical memoranda.

The Water Management Program will plan for delivery of water by Metropolitan to MWA before the stored water is returned to Metropolitan. Figure 1-1 is a conceptual representation of supplemental water from the SWP being stored into MWA's area, either by direct spreading or in-lieu recharge. Figure 1-2 presents a conceptual representation of Metropolitan's water being returned to them. MWA will return Metropolitan's water by one or combination of the following methods; entitlement exchange, mutual exchange, or a direct return to the East Branch (less aquifer losses).

1.8.1 Storage of Supplemental Water

The Mojave Basin Area Adjudication does allow storage programs. A project that operates within the constraints of the judgment must be developed.

The recharge of water in the Mojave River is relatively simple. There are however, regulatory constraints regarding permitting that will need to be addressed. Additionally, water quality will also need to be reviewed.

Flexibility is very important in developing a water management program. Changes can occur and programs may be operated differently than originally planned. The MWA – Metropolitan partnership and the implementation of a comprehensive water management program will give both agencies the necessary flexibility in the future.

1.8.2 Recovery of Stored Water

Stored water can be recovered by entitlement exchange, direct return, or mutual exchange.

Under an entitlement exchange, during a call for delivery of the supplemental water back to Metropolitan, MWA would not take delivery of all of its SWP supply. MWA would allow a portion of its SWP supply to be delivered to Metropolitan as an exchange for the supplemental water that MWD delivered to MWA. Since Metropolitan had already delivered water to MWA the pumpers within the MWA service area are left whole, the net balance is zero. Water levels in the area will likely be at higher levels than they would have been without the MWA/Metropolitan Water Management Program (Program).

A challenge with an entitlement exchange is that during a dry year, the contractor's entitlement supply may be 50-percent or less. This reduces the amount of water that can be exchanged in that particular year.

An entitlement exchange on the East Branch could cause the shifting of groundwater from one subarea to another, for example, if predelivered water is stored in one subarea (e.g., Alto) and during the exchange period, water is needed in another subarea (e.g., Centro). Moving water from the place stored to the place of demand has a cost that must be evaluated, and it may also have a higher cost because it may require pumping the water twice.

The groundwater basins need to be managed so that local water users are not negatively impacted. Consideration needs to be given to water users who may require direct deliveries. One means of protecting the ability to make these deliveries is to reserve the first entitlement delivery to MWA.

Direct return is return of stored water by pumping groundwater back to the East Branch. When water is to be returned to the East Branch, there are physical requirements that must be met. It is necessary to have facilities with return flow capability. The Mojave River and Morongo Basin Pipelines were not designed with the capability to handle the pressures created by returning water; however, this is discussed further in Section 4.0.

Mutual exchange programs involve traditional water storage combined with on-going exchange programs. Mutual exchange programs allows for management of supplies on a flexible basis, including short-term storage and exchange of supplies among multiple agencies, depending on water availability and availability of storage within each agency's service area. The result is that at any given time one agency will owe the other agency water. MWD may take and store water for MWA; MWA may take and store water for MWD. The storage balance at any given time will depend on the net of the storage and exchanged actions.

1.9 Screening Matrix

Various alternatives for the Program were assessed and evaluated to determine their feasibility as measured in numerous categories. These categories, also known as "screens" in a screening matrix, provided the basis for determining which alternatives were carried forward to implementation. These screens included:

- Engineering
- Hydrogeology
- Economics (capital, operation and maintenance costs)
- Water quality
- Environmental
- Institutional (adjudication, legal)
- Regulatory
- Other Considerations

1.10 Criteria and Assumptions

The criteria and assumptions developed by all stakeholders associated with the Program are shown in Tables 1-2 and 1-3. These tables should be considered dynamic and subject to change as the Program progresses from conceptualization through implementation.

Table 1-2.
Criteria for the Water Management Program between Mojave Water Agency and Metropolitan Water District of Southern California

Item	Assumption
Groundwater Operations Criteria	Groundwater levels with a storage program cannot be less than groundwater levels without a storage program
Aquifer losses	10-percent (to be verified)
Water spreading timetable ➢ At Rock Springs Turnout ➢ Between Cedar Springs and Forks Dam ➢ Any other location	 Six to nine months over the following months: September through November December through February (weather permitting) March through May September 15 to February 15 Six to nine months over the following months: September through May
Metropolitan's *take* of stored water	Depends on capacity of the East Branch. Cost screening (see tables below) assume for a direct return to the SWP, that water would be returned over six, nine, or ten months. Limited by previously stored water less allowance for losses.
MWA's SWP priority MWA's operation	MWA will retain the first 12,000 acre-feet of their SWP Table A Allocation The Program cannot affect MWA's operation without MWA's approval
Adjudication	The Program must assess the MWA Adjudication
Local area hydrology for purposes of estimating *put* and *take* (using SWRCB D-1485 nomenclature)	1 wet year 2 above normal year 3 normal years 3 dry years 1 critical year

Table 1-3.
Metropolitan's Groundwater Storage Assumptions

Item	Assumption
Ratio of stored water volume to maximum annual return water volume	5 to 1 (e.g., for 100,000 AF stored, annual maximum return capacity equals 20,000 AF)[2]
Total stored water volume	250,000 acre-feet minimum
Range of Maximum *put* per year (*put* water may be dependent on SWP Allocations, East Branch hydraulic capacity, Article 21 water, etc.)	25,000- to 150,000-AF/year
Maximum annual *take* capacity	15,000- to 90,000 acre-feet/year

[2] A 3 to 1 ratio is evaluated in Section 5.

1.11 Alternatives

This section of the report discusses opportunities for conjunctive use projects that could be integrated into the Program as part of the water transfer and storage alternatives (*put* alternatives) and the water recovery alternatives (*take* alternatives).

1.11.1 Multipurpose Opportunity Alternatives

Some potential conjunctive use projects can benefit both the Water Management Program and a second (and sometimes third) party. The following discussion identifies the conjunctive use projects that were considered in combination with other alternatives identified later in this section.

Hesperia Master Plan of Drainage[3] The San Bernardino County Flood Control District's (SBCFCD) 1996 drainage master plan studied two alternatives for mitigating the runoff south of the East Branch. One alternative, the Recommended Alternative, proposed to a collection trench parallel to the East Branch that would direct the flow to a large detention basin near an overchute, where flows could be directed over the aqueduct. The proposed capacity of the detention basin is 920 acre-feet. The second alternative, the South Community Alternative Plan, would have a 260 acre-feet detention basin, and runoff would continue to enter the East Branch.

Proposed Detention Basin Location Along SWP in Hesperia

A second detention basin (720 acre-feet) is also planned along Ranchero Road in Antelope Wash near the golf course. The City and the SBCFCD need to address the runoff issue south of the East Branch. Mitigation of the runoff might be possible with a dual project combining spreading grounds and detention basins.

East Branch near Check No. 66. The Mojave Siphon Power Plant, a three-unit hydroelectric project, is limited to only two-unit operation. If there is a power failure while all three units are operating, a large negative wave would propagate upstream within pool 65 (upstream of Check No. 66). This restriction is imposed only because of a hydraulic condition that can easily be solved. A dual purpose project is envisioned whereby a side-channel spillway just upstream of Check No. 66 would be notched into the left embankment of the canal and armored to protect the canal's earthwork. With the spillway, the negative wave would "peel off" the canal and flow easterly towards the Mojave River in a dry wash. This unnamed wash is located within the proposed Rancho Las Flores Development. The Team reviewed the land use schematic amendment to the Rancho Las Flores specific plan (Figure 1-3) to understand

[3] *Hesperia Master Plan of Drainage for Antelope Valley Wash and Adjacent Areas That are Tributary to the Mojave River*, San Bernardino County Flood Control District, May 1996.

how the unnamed wash would be hydraulically altered. The plan called for the wash to remain natural and for a small reservoir located very close to the SWP within this wash. This reservoir, if planned and designed cooperatively with the developer, city of Hesperia, the DWR, and MWA, could accommodate the release of spill flows from the East Branch.

A second component of this project would be to use the unnamed wash to convey recharge water from the East Branch to the Mojave River. An aqueduct turnout located very near Check No. 66 could release flows into this wash. An advantage of making releases at this location rather than from Cedar Springs Dam is that these releases would likely not affect the habitat for the arroyo toad.

1.11.2 Water Transfer and Storage Alternatives

This element of the Program is the predelivery of Metropolitan's water from the SWP to storage within the MWA's service area. The transfer of water from the SWP into the MWA area can be accomplished in various ways, as presented in Table 1-4.

Table 1-4
Options for Transferring Water Into Storage

Use of Existing Facilities	Use of New Facilities
▪ P1- Surface storage behind The Mojave River Dam	▪ P4- In-lieu delivery of potable water through a new regional/local water treatment plant(s)
▪ P2- Releases from Cedar Springs Dam into the Mojave River aquifer	▪ P5- In-lieu delivery of surface water to agricultural users
▪ P4- Releases from the Morongo Basin Pipeline into the Mojave River aquifer and/or the Yucca Valley area.	▪ P7/P8- New spreading grounds within the regional aquifer (Oeste and Alto subareas) along the SWP and using either new East Branch turnouts or existing MWA pipelines
▪ P3- Releases from the Mojave River Pipeline into the Mojave River aquifer.	▪ P8- New spreading grounds within Alto subarea at the Oro Grande Wash and the Antelope Valley Wash
▪ P6-Transfer of water to the Mojave River aquifer through the unnamed wash just upstream of Check No. 66 through existing turnouts	▪ P8/P4- New spreading grounds within the Oeste subarea at Sheep Creek
	▪ P6- Transfer of water to the Mojave River aquifer through the unnamed wash just upstream of Check No. 66 through new turnout in conjunction with side channel spillway
	▪ P4- New spreading within the Lucerne Valley

Supplemental water (i.e., water imported to the MWA area) that Metropolitan puts in the MWA aquifers will be termed "regulated water" within this study. Regulated water is water owned by Metropolitan, stored within MWA's area, and is available for return to Metropolitan, less aquifer losses. Table 1-2 presented an assumption of anticipated aquifer losses. These losses are further evaluated in subsequent technical memoranda.

The Team conducted an initial siting evaluation of new spreading grounds along a one-mile swath paralleling the East Branch and along the Mojave River Pipeline down to the Cassia Pressure Reducing Facility. Costs were developed to guide the Team's understanding of how costs for direct return to the East Branch vary with distance from the aqueduct. A comparative cost analyses was done to illustrate the variation in cost as the direct return infrastructure moves farther away from the SWP. Plate 2 presents a comparative cost “contour map” illustrating the variation in cost as the direct return infrastructure moves farther away from the SWP. Cost components included capital cost for wells, manifold, pump stations, and pipelines, and well and pump station electrical operation costs. Where the return infrastructure is located farther north, the topography has gradient falling away from the SWP; thus return water needs to be pumped uphill to the aqueduct. Wells located farther north of the aqueduct have less pump-lift because the depth to groundwater becomes shallower the farther north from the SWP the wells are located. Infrastructure located south of the SWP will have greater well pump lift because the depth to groundwater is greater but will require an energy dissipation structure to break the head of the water entering the aqueduct.

1.11.3 Recovery Operations

This element of the Program is the return of regulated water to Metropolitan. This process is often referred to as the *tak*e operation, because water is taken from storage and conveyed to Metropolitan.

Return of regulated water to Metropolitan would be at Metropolitan’s request and during “off-peak” periods for local agencies involved. Recovery can be accomplished by two basic mechanisms as shown in Table 1-5. A third recovery mechanism, referred to as “mutual exchange”, will be addressed in Section 8.0 of this report.

The groundwater operation criteria establishes that returning water to Metropolitan will not cause groundwater levels with the Program to be lower than they would be without the Program. Metropolitan also will not export local water; instead only exporting the water they placed in storage less any losses.

Table 1-5
Options for Recovery and Return of Water from Storage

Direct Return	Entitlement Exchange
• Use of local purveyors wells, manifold together and water conveyed to the SWP • New well field(s) near the area(s) of spreading, extracting the water, manifold together, and conveyed to the SWP	• MWA’s entitlement, less minimum withholding, is exchanged with Metropolitan’s regulated water in the storage account. This return mechanism is especially useful for water stored in subareas far from the SWP, e.g., Baja, Centro, Este, and Yucca Valley.

Entitlement exchange as a return element is limited in the quantity of return depending on the allocations on the SWP. Figure 1-4 is the annual exceedance probability curve for MWA’s SWP Table A allocations. The exchange opportunity presumes that 12,000 acre-feet would be reserved for use within MWA and not available for exchange. The exceedance probability function is derived from the DWR’s draft delivery reliability report.[4]

1.12 Conclusion and Recommendations

A preliminary PASS or FAIL screening of the alternatives identified in this section was conducted to document the elimination of alternatives that had an obvious fatal flaw. Each

[4] *The State Water Project Delivery Reliability Report, DRAFT*, California Department of Water Resources, August 2002.

alternative was screened against the eight screens presented in the subsection Screening Matrix. Most alternatives received a passing evaluation. Some alternatives had obvious failing conditions. Tables 1-6 and 1-7 present the *put* (storage) and *take* (return) alternatives, respectively, that passed the initial screening. Table 1-8 presents the alternatives that failed, and a discussion of the attribute(s) that was judged to cause the failing ranking.

The alternatives, which received a passing evaluation, were carried forward for further technical evaluation, institutional evaluation, and further screening in Sections 2.0 and 5.0.

Table 1-6
***Put* Alternatives that Passed the Initial Screening**

Alternative Description
Surface storage behind The Mojave River Dam
Releases from Cedar Spring Dam for Mojave River spreading in Alto subarea
Releases from Mojave River Pipeline for spreading in: - Alto (new turnout(s) for spreading grounds) - Transition Zone - Centro - Baja
Releases from Morongo Basin Pipeline for spreading in: - Antelope Wash (Alto) - Mojave River (Alto) via Rock Springs Turnout - Lucerne Valley (Este subarea) - Morongo Basin/Johnson Valley - Yucca Valley
Regional or City Water Treatment Plant(s) for in-lieu recharge
In-Lieu recharge within: - Johnson Valley - Este (Lucerne Valley) - Alto - Baja - Centro - Transition Zone
Oeste spreading along and from East Branch
Oeste spreading in Sheep Creek from East Branch
Alto spreading along and from the East Branch
Alto spreading in Oro Grande Wash from East Branch
Convey water to upper Mojave River in unnamed wash near Check 66 for spreading

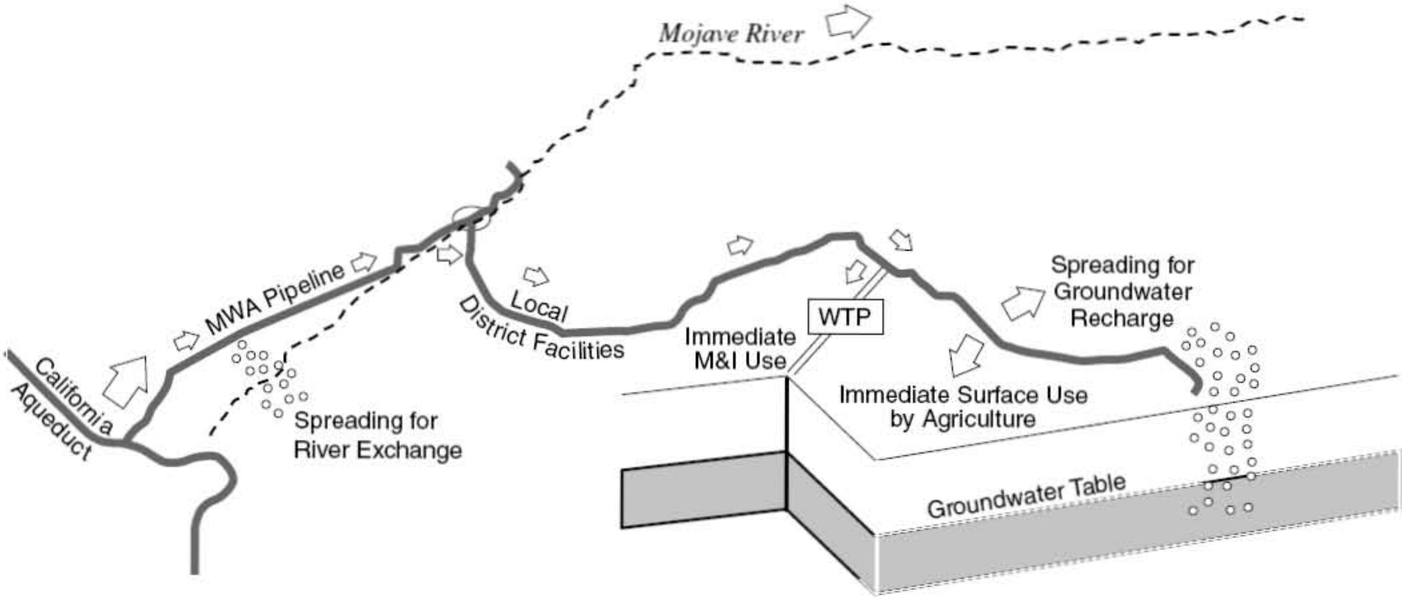
Table 1-7
***Take* Alternatives that Passed the Initial Screening**

Alternative Descriptions
Direct Return through Mojave River Pipeline from Alto subarea
Direct Return through Morongo Basin Pipeline from Alto subarea
Direct Return from the Floodplain Aquifer (in combination with local direct return projects in Alto subarea along the East Branch)
Return through Entitlement Exchange for Spreading in Baja
Return through Entitlement Exchange for Spreading in Centro
Return through Entitlement Exchange for Spreading in Centro
Return through Entitlement Exchange for Spreading in Este (Lucerne Valley)
Return through Entitlement Exchange for Spreading in Johnson Valley
Return through Entitlement Exchange Spreading in Yucca Valley
Return through Entitlement Exchange for Spreading in Joshua Basin

Table 1-8
Alternatives that Failed the Initial Screening

***Put* or *Take* Alternative**	**Alternative Description**	**Reason for FAIL Ranking**
Put	In-lieu recharge in Yucca valley	Economically infeasible because of low water demands.
Put	Spreading near Check 66	Infeasible based on review of geologic cross-section provided by MWA which showed rock to the ground surface
Put	Injection wells	Both economically infeasible and infeasible due to water quality issues with the Regional Water Quality Control Board. Use of injection wells is judged to require the water be pre-treated to, at a minimum, meet potable standards before injection.
Take	Pumped return in the Mojave River Pipeline from Baja, Centro, and the Transition Zone	Economically infeasible due to the distance and cost to pump water back to the East Branch.
Take	Pumped return in the Morongo Basin Pipeline from Yucca Valley, Johnson Valley, Joshua Basin and Este	Economically infeasible due to the distance and cost to pump water back to the East Branch.

“Put Year”



WTP = Water Treatment Plant

Figure 1-1. Conceptual Representation of Metropolitan’s Water Transferred Into Storage Within MWA.

“Take Year”
Direct Return

“Take Year”
Entitlement Exchange

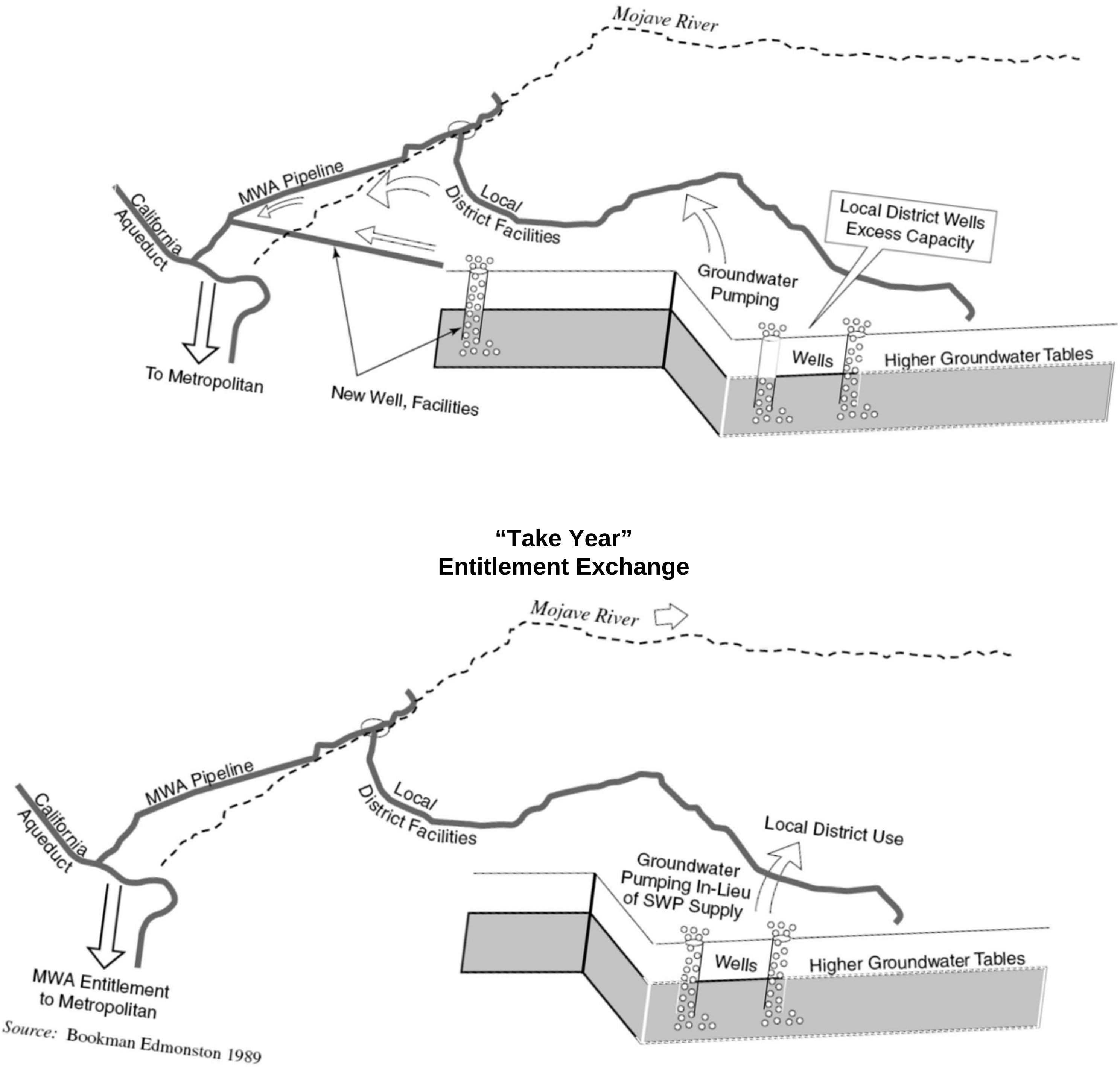


Figure 1-2. Conceptual Representation of Metropolitan’s Water Transferred from MWA Back to Metropolitan.

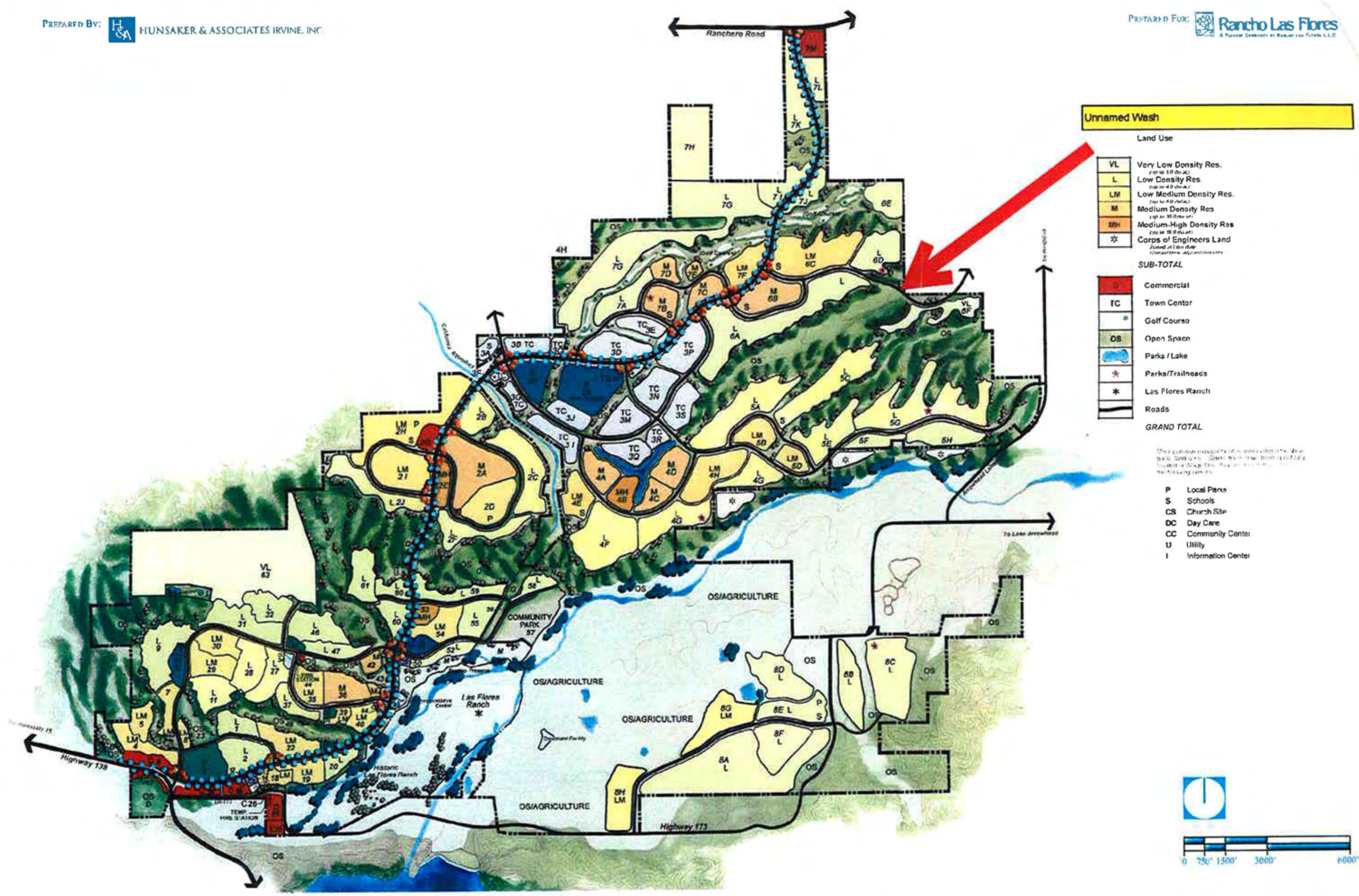


Figure 1-3 Land Use Schematic for the Rancho Las Flores Development

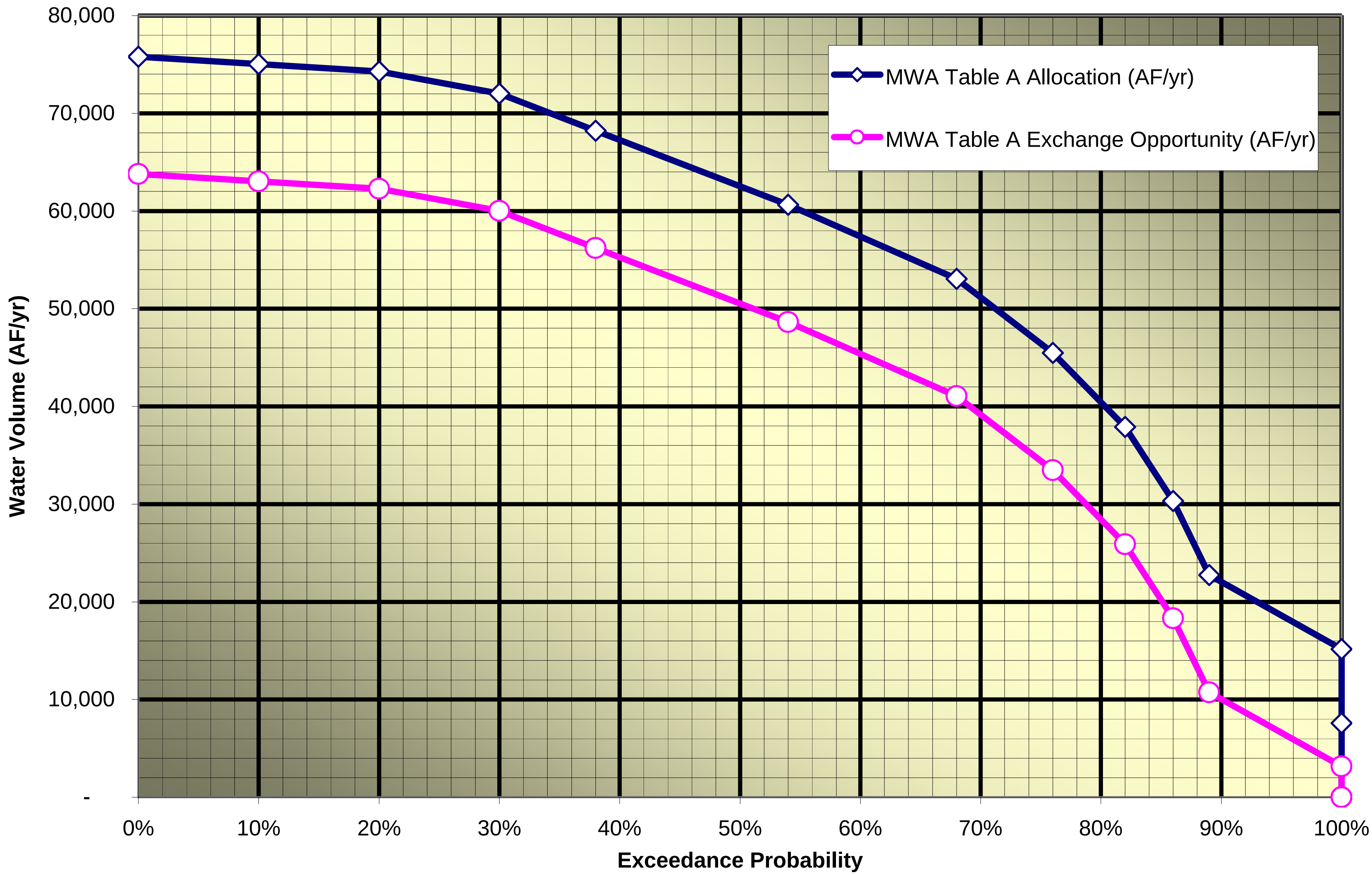


FIGURE 1-4 ANNUAL EXCEEDANCE PROBABILITY CURVE FOR MWA's SWP DELIVERIES

2.0 Preliminary Engineering and Hydrogeology Review for *Put* Alternatives

This section provides additional insight into the storage or *put* alternatives identified in Section 1.0. It also eliminates those that have fatal flaws and conducts engineering and hydrogeology reviews of the remaining alternatives. Environmental and other considerations were identified if they significantly contributed to the assessment of an alternative's viability.

The MWA provided B-E/GEI with an extensive database that included historical literature, oil and gas logs, water well driller reports, boring logs, Mojave River stream gage data, aerial photographs, well hydrographs, and groundwater quality data. Additional data included California Department of Health Services (DHS) well groundwater quality data and MODFLOW model simulation results obtained from an in-house B-E/GEI study conducted explicitly for this report.

The following activities were performed in association with this section.

- A complete review of the data provided by the MWA and of B-E/GEI reports and files
- Selective review of DHS well groundwater quality data for wells in the Oeste and Lucerne Valley areas
- A MODFLOW model simulation of several recharge scenarios on the Mojave River from The Forks to the Narrows
- Preliminary sizing and cost estimates for the *put* alternatives
- Additional screening of alternatives

2.1 Summary of *Put* Alternatives

After the drought in the 1980s, Metropolitan recognized the importance of adding local storage resources to its overall water supply portfolio. Metropolitan began adding local storage programs to its portfolio in 1993. Metropolitan has increased local storage by more than ten times as shown n Figure 2-1. Metropolitan continues to review and expand upon the local storage component.

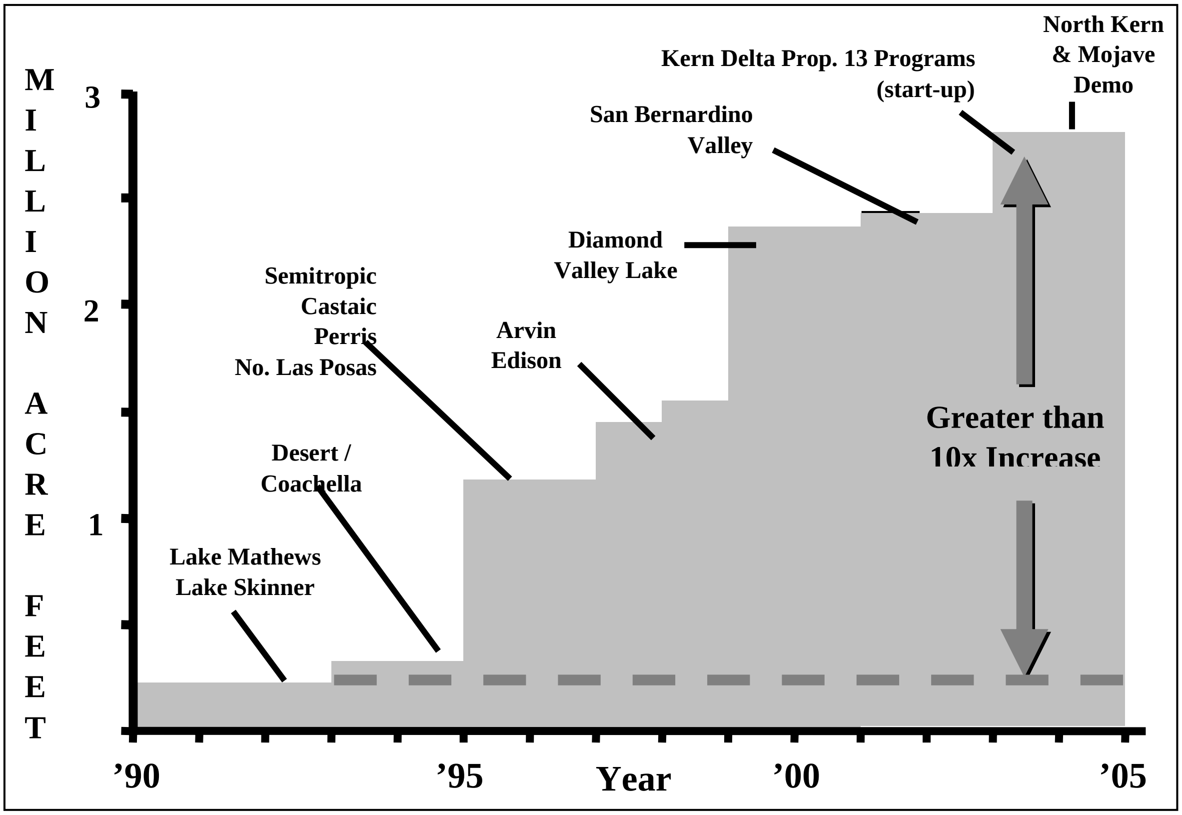


Figure 2-1
Metropolitan's Storage Programs 1990 to 2005

Another philosophical change is occurring within southern California regarding the use of the East Branch. As part of an ongoing investigation for the enlargement of the East Branch of the SWP, B-E/GEI (2004) conducted a demand study of the East Branch Contractors to assess their demands on the East Branch to 2025. An important finding from the study was that demands are shifting to be supply-driven, meaning that when "wet year" water is available, the East Branch Contractors will endeavor to import that surplus water and store it for future dry year use. Supply-driven demands for the East Branch affect this Water Management Program insofar as the *put* objectives should satisfy the need to put into storage as much water as possible in the shortest time possible. Table 1-3 identified a range of annual *put* volumes between 25,000 and 150,000 acre-feet/year. This section evaluates putting those volumes into storage over nine months. Table 2-1 presents the flows required to put those various volumes in storage over three to nine months. These are the flows evaluated in this section.

Table 2-1
Average Flow for Range of Annual *Put* Volumes and *Put* Durations

Annual *Put* Volume (acre-feet/year)	*Put* Duration and Required Flow (cfs) 3 months	4 months	5 months	6 months	9 months
25,000	140	105	84	70	47
50,000	280	210	168	140	93
75,000	420	315	252	210	140
100,000	560	420	336	280	187
150,000	840	630	504	420	280

MWA has infrastructure to deliver and store water within the groundwater basin; however, this infrastructure is limited compared to the flows identified in Table 2-1. New infrastructure in the form of larger SWP turnouts, larger pipelines, new spreading grounds, new pump stations, and other new hydraulic structures are identified and evaluated within this section. Use of the existing infrastructure is often evaluated in combination with the new hydraulic structures.

Table 2-2 lists the *put* alternatives from Section 1.0 and identifies those that are further evaluated in this section. Some alternatives were not evaluated further because storing large volumes in a short period of time would not be possible with those particular alternatives. For example, storing water in the Centro or Baja subareas is currently available to MWA because there is infrastructure to transport and spread the water. Enlargement of this infrastructure to spread even more water in a short period of time is, by observation, very costly. Finding large areas near the East Branch to store large volumes of water was judged to have the best chance for producing a viable project.

Table 2-2
Summary of Potential *Put* Alternatives

Alt ID	Description	Evaluated in Section 2.0
P1	Surface storage behind the Mojave River Dam (the Forks Dam)	No[3]
P2	Releases from Cedar Spring Dam for Mojave River spreading in Alto subarea	Yes
P3	Releases from Mojave River Pipeline for spreading in:	
P3A	Alto (new turnout(s) for spreading grounds)	Yes
P3B	Transition Zone	No[1]
P3C	Centro	No[1]
P3D	Baja	No[1]
P4	Releases from Morongo Basin Pipeline for spreading in:	
P4A	Alto subarea (Apple Valley area)	Yes
P4B	Mojave River (Alto) via Rock Springs Turnout	Yes
P4C	Lucerne Valley (Este subarea)	No[1]
P4D	Morongo Basin/Johnson Valley	No[1]
P4E	Yucca Valley/Warren Valley	No[1]
P5	Regional or city water treatment plant(s) for in-lieu recharge	Yes
P6	In-lieu agricultural recharge within:	

Table 2-2
Summary of Potential *Put* Alternatives

Alt ID	Description	Evaluated in Section 2.0
P6A	Johnson Valley	No[2]
P6B	Este (Lucerne Valley)	No[2]
P6C	Alto	No[2]
P6D	Baja	No[2]
P6E	Centro	No[2]
P6F	Transition Zone	No[2]
P6G	Oeste	No[2]
P6H	Means	No[2]
P6I	Ames	No[2]
P7	Oeste spreading within Sheep Creek and along the East Branch	Yes
P8	Alto spreading along the East Branch and in Oro Grande and Antelope Valley Washes	Yes
P9	Convey water to upper Mojave River in unnamed wash near Check 66	Yes

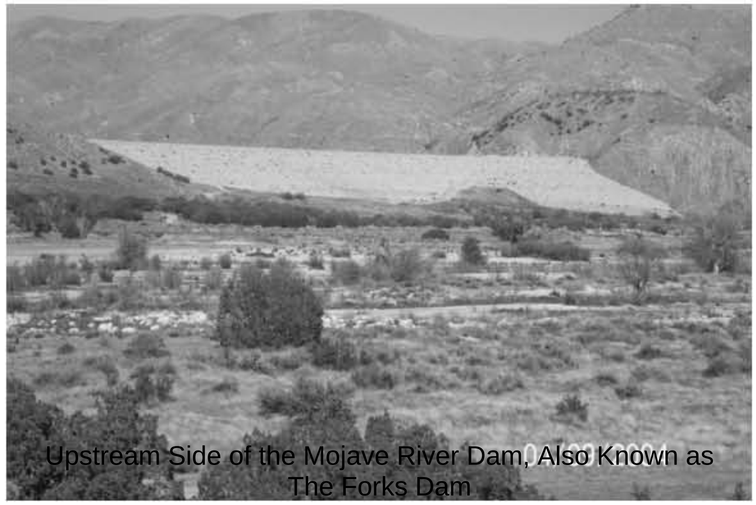
[1]Alternative judged too costly to provide large-volume groundwater storage as compared with alternatives that are closer to the East Branch. Those alternatives with infrastructure associated within them are still viable options for use in combination with infrastructure used to put larger volumes into storage.
[2]Agriculture quantity within MWA is small and diversified among many subareas. Agriculture also is declining within the MWA, and all agriculture is far from the East Branch. Building new infrastructure for in-lieu recharge of agricultural lands under these circumstances is judged infeasible.
[3]The probability that this alternative would negatively impact the arroyo toad's habitat made this alternative infeasible.

Presented in the following section are engineering and hydrogeology reviews of the *put* alternatives identified in Table 2-2. Where possible, the specific elements of the alternatives were grouped together, based on similar engineering or hydrological appraisals.

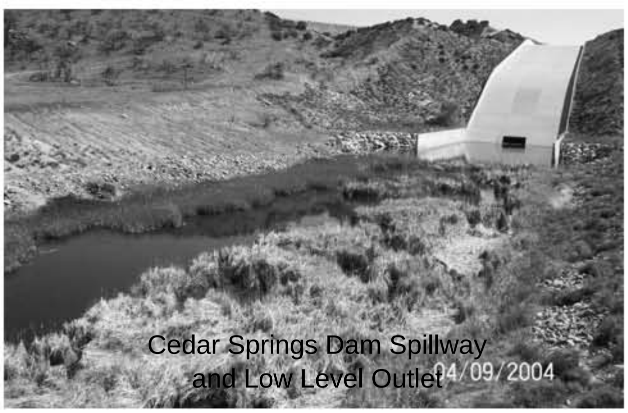
2.2 Description of *Put* Alternatives

Aerial photographs taken in April 2004 were reviewed to identify unimproved properties that could be used for spreading facilities. Plate 3 shows the locations of the *put* alternatives evaluated in this section. The features of these *put* alternatives are presented in the following subsections. Some of these descriptions also include environmental or other conditions that may significantly affect the viability of the alternative. Hydrogeologic considerations are also presented in this section.

2.2.1 Alternative P1 – Mojave River Dam Storage


Upstream Side of the Mojave River Dam, Also Known as The Forks Dam

Using the Mojave River Dam to store water was determined to be too problematic. The main reason why this alternative has been eliminated as a possible alternative is because it would most likely affect the arroyo toad's habitat, a federally listed species. Another reason why this alternative was not given further consideration is because the annual evaporation within this region is relatively high (seven feet per year), resulting in a significant loss of water to any surface storage alternative. A more detailed summary of the engineering data and results of the analyses conducted by the U.S Corps of Engineers on the Mojave River Dam can be found in Technical Memorandum No. 02.



Cedar Springs Dam Spillway and Low Level Outlet

2.2.2 Alternative P2 – Mojave River via Cedar Springs Dam

The demonstration storage project by MWA and Metropolitan confirmed that water released from Cedar Springs Dam can be percolated into storage within the Alto subarea by spreading within the Mojave River. Storage within the Floodplain aquifer would be located downstream of the Mojave River Dam (the Forks Dam); therefore, releases from Cedar Springs Dam have to flow past the Mojave River Dam. Located 14 miles downstream of the Mojave River Dam is a geologic feature known as the Upper Narrows. The Upper Narrows is a barrier within the Floodplain Aquifer, acting as an underground "dam" and allowing water to be stored upstream. Excess water behind the Upper Narrows flows up and over the barrier, becoming surface flow to downstream areas. Releases into the river are limited in capacity and timing as described in Table 1-2.

The estimated storage potential between the Mojave River Dam and the Upper Narrows is about 61,000 acre-feet. This volume assumes a dry zone of 20 feet within the upper portion of the aquifer to reduce the risk of liquefaction and water use by phreatophytes. The storage potential within this reach is a function of the regional hydrology. The volume estimate was based on a review of water levels within the Floodplain aquifer between the Mojave River Dam and the Upper Narrows.

During years of surplus on the SWP, water could be released from Cedar Springs Dam and percolated into the Floodplain aquifer. The water migrates rapidly to the north because the aquifer has a high transmissivity. Wells along the river, which are predominately for municipal and industrial use, can extract the water. A large capacity backbone pipeline leading west and/or east from the river out into the populated areas would "artificially increase the transmissivity" from the Floodplain aquifer to the Regional aquifer. During dry periods, the water extraction will lower the Floodplain aquifer level, creating a storage opportunity for the next time the SWP has surplus water.

Environmental Considerations

The area between the Mojave River Dam and Cedar Springs Dam provides habitat for the arroyo toad, a federally listed species. The habitat is reported to extend about two miles upstream of the Mojave River Dam, up both forks of the streambed. This area is occasionally flooded for short durations during large runoff events; however, releases from Cedar Springs Dam would be regulated to prevent the flooding of the toad's habitat.

Other Considerations

This alternative may require some levees in the River and potentially land purchases.

2.2.3 Alternative P3A – Alto Subarea via Mojave River Pipeline and East Branch

The Mojave River Pipeline starts within the western Alto subarea and extends northerly through the Transition Zone into the Centro and Baja subareas. This pipeline near the East Branch is 48 inches in diameter and is designed to convey 94 cubic feet per second (cfs) by gravity in a northerly direction. The hydraulic pressure along the pipeline is controlled by pressure reducing facilities that reduce the pressure with sleeve valves. The Cassia Pressure Reducing Facility, the first of three along the pipeline, is located 5.4 miles north of the East Branch.

Surplus water can be delivered to the Regional aquifer and the Floodplain aquifer through the Mojave River Pipeline for direct recharge in either new or existing spreading grounds. Table 2-2 identified various alternatives associated with putting water into storage along the Mojave River Pipeline. The first of the existing spreading grounds is nearly 20 miles to the north of the East Branch, making the return of stored water through an entitlement exchange the only practical method for taking water out of storage. Constructing new spreading grounds parallel to the pipeline and closer to the East Branch is costly but offers the advantage of proximity when considering a direct return of Metropolitan's stored water.

An area approximately within one mile of the pipeline and as far north as the Cassia Pressure Reducing Facility was selected for this initial review of possible spreading ground sites. Aerial photographs identified approximately 5,900 acres of unimproved property along the Mojave River Pipeline where new spreading facilities could be constructed, see Plate 3.

At its design capacity of 94 cfs, the maximum monthly spreading capacity through the pipeline is 5,600 acre-feet per month. The velocity of 94 cfs in a 48-inch-diameter pipeline is 7.5 feet per second (fps). If the maximum velocity of the pipeline were allowed to reach 10 fps, then the flow capacity would be 126 cfs, which equates to 7,500 acre-feet per month. Storage volumes greater than 7,500 acre-feet per month will require one or more new turnouts to supplement the current turnout capacity.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Coordination with users of the pipeline must be incorporated into the operation of the pipeline.

2.2.4 Alternative P4A and P4B – Alto Subarea via Morongo Basin Pipeline

The Morongo Basin Pipeline, which passes through the Alto and Este subareas and into the Morongo Basin-Johnson Valley area. This pipeline is 54 inches in diameter from the East Branch to the Rock Springs Turnout and 30 inches in diameter thereafter.

The 54-inch portion of the pipeline is designed as a gravity pipeline with a 110-cfs capacity. The capacity of the pipeline beyond Rock Springs Turnout is 30 cfs; hence, the capacity of the Rock Springs facility is 80 cfs.

Table 2-2 identified various alternatives associated with putting water into storage along the Morongo Basin Pipeline. Surplus water can be delivered to the Regional aquifer in the Alto area near the community of Apple Valley (Alternative P4A) or to the Floodplain aquifer (Alternative P4B) via the Rock Springs facility. The spreading grounds in the Yucca Valley (Alternative P4E) area are more than 70 miles from the East Branch, making the return of stored water through an entitlement exchange the only practical method. Construction of new spreading grounds parallel to the pipeline and closer to the aqueduct would be costly, but offers the advantage of proximity when considering the direct return of Metropolitan's stored water.

Areas within Apple Valley and within one to two miles of the pipeline were selected for the initial review of possible spreading ground sites. Aerial photographs were also reviewed and approximately 1,750 acres were to identified as unimproved property along the Morongo Basin Pipeline where new spreading facilities could be constructed, see Plate 3.

Presently spreading between Rock Springs Turnout and the Upper Narrows with releases from the Morongo Basin Pipeline recharges the Floodplain aquifer. The storage that might be available for this project within this stretch of the river is estimated to be 30,000 acre-feet.

At its design capacity of 110 cfs, the maximum monthly spreading capacity through the pipeline is 6,500 acre-feet, or 4,800 acre-feet per month at Rock Springs and 1,700 acre-feet per month further downstream. If the maximum velocity of the pipeline were 10 fps, then the flow capacity would equal 50 cfs beyond the Rock Springs Turnout, which equates to 3,000 acre-feet per month that could be delivered to the spreading grounds. Storage volumes greater than 3,000 acre-feet per month beyond Rock Springs Turnout along the Morongo Basin Pipeline will require one or more new turnouts and likely a parallel pipeline to supplement the current turnout and pipeline capacity. Alternatively, flow could be released into the Mojave River from either Cedar Springs Dam (Alternative P2) or from the East Branch through the unnamed wash (Alternative P9), collected from the river, and pumped into a shorter pipeline that would parallel the Morongo Basin Pipeline along Tussing Ranch

Road. A comparative cost analysis concluded that a new parallel pipeline starting at the California Aqueduct and ending at the proposed spreading grounds in the Town of Apple Valley was less costly than a pump station and pipeline.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

There are no other considerations to report at this point in the study.

2.2.5 Alternative P5 – In-Lieu Recharge via Water Treatment Plant

Some production wells could be temporarily turned off, likely for months, while surface water is delivered to a water treatment plant, treated, and then used in a domestic water system. In lieu of pumping groundwater, the use of treated surface water would offset groundwater production; hence the groundwater would naturally recharge.

The high desert communities near the East Branch have collectively and individually evaluated new surface water treatment plant(s) as part of their future water supply portfolio. A review of planning documents for these communities and conversations with local purveyors (refer to Section 5.0) indicates that one or more treatment plants may be constructed within the region. A regional plant (Parsons 2001) was evaluated that could serve Victorville, Baldy Mesa, Adelanto, and County Service Areas. Recent conversations with some of these water purveyors indicate that a regional plant is less likely and individual purveyor plants may be more likely. The capacity range of the proposed plants is 20 to 30 million gallons per day (mgd). As these plants would have an interruptible supply of surface water; it is important that the purveyors maintain their current wells and continue to invest in new wells to meet demand. Assuming that the plants are sized to augment groundwater pumping and that some wells will be used to meet peak flows, the surface water delivery volume from the plants may range from 22,000 to 33,000 acre-feet per year.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Surface water treatment plants would reduce MWA's flexibility and the quantity of entitlement water available for exchange with Metropolitan. To maximize the exchange potential, it would be beneficial if MWA's Table A entitlement were increased by a quantity equal to or greater than the plant capacity, while still maintaining the infrastructure and institutional ability to care treatment plant operation to facilitate entitlement exchange.

2.2.6 Alternative P7 – Oeste Spreading Along East Branch

An initial review of possible spreading ground sites within the Sheep Creek area along the East Branch was conducted using the aerial photographs. Properties within one or two miles of the aqueduct were examined and approximately 5,400 acres were identified as possible locations for spreading facilities. The aerial photographs helped locate any obstructions such as structures or roads along the one to two miles of land along the aqueduct. United States of the Interior Geological Survey (USGS) maps were also used to evaluate and identify which properties were best suited for spreading grounds.

Surplus water can be delivered to the Regional aquifer via new spreading grounds located along the East Branch and within the Sheep Creek area in the Oeste subarea. Stored water could then be returned to Metropolitan via direct return and/or entitlement exchange.

Storing large volumes of water in a short period will require one or more new turnouts. The 30-cfs turnout at MP 383.95 (See Table 1-1) is too small for spreading large water volumes, and is located about three miles downstream of the areas being considered for spreading grounds.

Storing large volumes of water in a short period of time would require one or more new turnouts. The 30-cfs turnout at MP 383.95 (see Table 1-1) is too small to provide short-term spreading of large water volumes and is located about three miles downstream of the areas being considered as possible spreading grounds.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Groundwater quality in the Oeste subarea near El Mirage has been noted. Conversations with County Service Areas regarding the water quality in their wells in the Oeste subarea indicate that water quality is good. Further investigation is needed.

2.2.7 Alternative P8 – Alto Spreading Along East Branch and in Oro Grande and Antelope Valley Washes

Surplus water can be delivered to the Regional aquifer via new spreading grounds located along the East Branch in the Alto subarea. Both Oro Grande Wash and Antelope Valley Wash cross the East Branch and are candidates for spreading grounds. Stored water could be returned to Metropolitan via direct return and/or entitlement exchange.

The aerial photographs provided by MWA were examined and approximately 5,200 acres within the Alto subarea were identified as unimproved property along the East Branch.

A large portion of the unimproved property lies within the communities of Victorville and Hesperia. While there are large undeveloped areas near the East Branch within these communities, it is understood that plat maps for these lands have been filed with the cities and/or these areas are scheduled to become part of the cities' business development plan. Furthermore, these lands are very expensive to purchase, and when considering the tax benefit to the cities for lands on which business will be developed, they may not be available for spreading grounds. Eminent domain could be exercised to acquire this land; however, it was judged that these lands offer no benefit that is superior to land in other areas (e.g., the Oeste or western Alto subareas); therefore, only 493 acres of the 5,200 acres identified are being considered as possible spreading sites.

Three small areas of land within Hesperia may be available for spreading water. Two are scheduled to be stormwater detention ponds near Cedar Street and Ranchero Road. It is understood that sewer lines from the third parcel, which is adjacent to the East Branch, would have to cross north under the East Branch, making development of this land very problematic. This land may be available below market value and be suitable for spreading works. Plate 3 shows these three areas highlighted in red.

The Oro Grande Wash flows through the Victorville area and is not under the same urban development pressures as the Hesperia sites. Development within the wash is prohibited, leaving the opportunity for construction of spreading grounds. MWA conducted pilot spreading within this wash upstream of the East Branch and determined that spreading is possible. However, a low permeability subsurface layer was identified near the East Branch, and as a result, spreading within this specific region was judged unlikely. MWA is conducting additional studies within the wash including upstream from the aqueduct crossing. The location of the pilot project is presented in Plate 3 (shown in yellow).

Vacant land west and east of the East Branch's Antelope Wash Siphon could be used for spreading with gravity flow off the East Branch. There are 245 acres of vacant land.

In summary, this alternative has a number of small areas totaling 493 gross acres that could serve to recharge the Alto subarea:

- Stormwater detention pond near Cedar Street - 60 acres
- Stormwater detention pond near Ranchero Street (Antelope Wash) - 50 acres
- Land-locked land along East Branch - 49 acres
- Oro Grande Wash - 16 acres
- Antelope Wash - 318 acres

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

The multipurpose use of the detention basins is judged a beneficial use of the projects.

2.2.8 Alternative P9 – Upper Mojave River via East Branch through Unnamed Wash

Alternative P9 is similar to Alternative P2 except that water would be discharged into the upper Mojave River below the Mojave River Dam via an unnamed wash. Plate 3 locates the wash, which starts west of the East Branch, crosses the Aqueduct, continues easterly, crosses Lake Arrowhead Road, and terminates in the Mojave River below the dam. No spreading sites along the wash are available because the terrain is rocky. The rocky terrain should be conductive for conveying water from the aqueduct to the river.

A reconnaissance of the unnamed wash was conducted, using MWA's three-dimensional software. The only structures located within the wash were a wall and possibly a shed located near Lake Arrowhead Road.

A preliminary hydraulic analysis was conducted to determine water depths for flows up to 500 cfs. Water would be about one foot deep at the 500-cfs flow. Higher discharges were not evaluated but have been judged feasible.

The unnamed wash is located near four SWP turnouts (refer to Table 1-1). Two of the turnouts are for MWA, and the other two are for Coachella Valley Water District (CVWD) and Desert Water Agency (DWA). The combined capacity for MWA is 135 cfs. A new turnout would be required to increase the spreading capacity within the river.

Spreading water within the upper portion of the Mojave River has the same advantages previously described for Alternative P2. Using the unnamed wash to convey the water to the river has the following additional advantages over Alternative P2:

- The arroyo toad habitat upstream of the Mojave River Dam would not be impacted.

- The wash is located near Check 66 on the SWP. A side channel spillway could be constructed on the left side of the canal in the vicinity of the wash. The spillway could be used to direct negative surge waves caused by a rapid shutdown of the Mojave Siphon Hydroelectric Plant out of the canal and down to the wash. The spillway would be a DWR project, but combined with the unnamed wash and new turnout project, there may be cost savings to both DWR and MWA/Metropolitan.

- The area of the wash has also been proposed for an urban development known as the Rancho Las Flores Development. The developers are presently preparing an environmental impact study for the project. Their plans for the wash may be integrated into a dual project for conveying SWP flows to the river. MWA had a conversation with the developer regarding this concept.

Environmental Considerations

No environmental considerations have been identified at this point in the study.

Other Considerations

This alternative has potential to be a multipurpose project that benefits several end users. Water depth will be shallow but will flow for many weeks. This may entice the public to trespass and recreate in the flowing water which may be a safety concern.

2.3 Hydrogeology Review of *Put* Alternatives

This section describes findings of the hydrogeologic review of the alternatives. Alternatives were combined according to hydrogeologic similarities and are grouped as follows:

- Alternatives close to the East Branch (Alternatives P7 and P8). Spreading within Oro Grande Wash and Antelope Wash are part of Alternative P8.

- Alternatives along the Mojave River Pipeline (Alternative P3) and Morongo Basin (Alternative P4) Pipelines

- Mojave River recharge alternatives (Alternatives P1, P2 and P9)

These groups represent alternatives with similar hydrogeologic problems associated with recharge to either the Regional or Floodplain aquifers.

The Mojave River is the principal surface water recharge source to the Mojave River Basin. The relationship between the Mojave River and the Floodplain aquifer has been well documented by Izbicki, Martin, and Michel (1995), Lines (1996), Izbicki and Michel (2004), Stamos (2001), Stamos, Martin, and Predmore (2002) and others (2001). Because of the excellent hydrologic connection between the Mojave River and the Floodplain aquifer, potential artificial recharge directly to the Floodplain aquifer and indirectly to the Regional aquifer by the Mojave River has been proposed by Lines (1996) and Stamos, Martin, and Predmore (2002) and is one of the alternatives discussed below.

Artificial recharge directly to the Regional aquifer has also been suggested. Several specific areas were proposed by Bechtel (1993), Dodson (1997), Bookman-Edmonston (1999), and Izbicki, Radyk, and Michel (2000). In contrast to the Mojave River and the Floodplain aquifer, the Regional aquifer has not benefited from intense hydrological study. Studies by the California Department of Water Resources (1967), Catchings, Gandhok, and Goldman (2001), Goodrich (1978), Schaefer (1979), Huff, Clark, and Martin (2002), Mendez (1997), Christensen (1997), and Cox and Owen (2003) have provided some general background information on the Regional aquifer that suggests site selection will be critical to the success of the alternatives that would artificially recharge directly to the Regional aquifer. A review of aquifer recharge alternatives is presented below.

2.3.1 Alternatives P7 and P8 - Close to the East Branch

The operation of recharge sites near the East Branch would spread SWP water in engineered spreading grounds either above or below the East Branch and return stored water by groundwater pumping and conveyance directly to the aqueduct. All associated operations, such as spreading grounds, groundwater conveyance pipelines, wells, and any needed booster pumping stations, would be constructed for these alternatives. Alternatives or project areas could in theory be located anywhere along the East Branch from Antelope Wash to the western border of the MWA on the Los Angeles–Kern county line. Because SWP water would be stored in the Regional aquifer, potential hydrogeologic and groundwater quality problems associated with the Regional aquifer are primary considerations in the location of these alternatives.

Historical literature on the Regional aquifer generally consists of work by the U.S Geological Survey, thesis, and specific site reports performed by consulting companies. Izbicki, Radyk, and Michel (2000) published a site-specific investigation on water movement through the unsaturated zone underlying Oro Grande Wash, and Bookman-Edmonston (1999, 2001) produced site studies relating to SWP water injection into the Regional aquifer for the High Desert Power Project on the northern end of Oro Grande Wash near Adelanto. Bookman-Edmonston (2002) also examined the effects of SWP water injection on groundwater quality to the Regional aquifer in the vicinity of the High Desert Power Project. Ball and Izbicki (2004) studied the occurrence of hexavalent chromium in groundwater in the western Mojave Desert, and found concentrations up to 60 micrograms per liter (µg/L) in the Sheep Creek alluvial fan deposit in the Oeste area of the MWA. Christensen and Fields-Garland (2001) produced maps showing the concentrations of total dissolved solids, arsenic, boron, fluoride, and nitrite as nitrate for wells sampled in the Mojave Water Agency Management Area.

Data provided by the MWA and lithologic logs published by Huff, Clark, and Martin (2002) were used to construct a geologic cross section along the East Branch. The geologic cross section showed that recharge to the Regional aquifer could be affected by fine-grained material (such as clay or clayey silts and clayey fine-grained sands) that would prevent the downward movement of water or by the presence of material with high solute potentials as noted by Izbicki, Radyk, and Michel (2000) in the Oro Grande Wash. Izbicki, Radyk, and Michel (2000) conclude that groundwater away from Oro Grande Wash is controlled by high solute potentials produced by the accumulation of soluble salts in the subsurface and not by the influence of gravity. The unsaturated zone away from Oro Grande Wash has a low water content and most of the water movement is by water vapor. This led Izbicki, Radyk, and Michel (2000) to conclude that artificial recharge in washes where natural recharge occurs would present several advantages to artificial recharge at other locations where the unsaturated zone is drier and high chloride layers could degrade water quality. The soluble salt accumulation is not distinguishable in driller's logs and would require site-specific investigations to determine the potential effects to recharge water quality.

However, driller's logs do indicate the presence of clay and fine-grained materials along sections of the East Branch. These could present significant problems to Regional aquifer recharging. The geologic cross section did show that thick and locally extensive clay layers exist from approximately well 5N/6W-22R1 to 5N/7W-24D1. The clay occurs above the groundwater table and recharging would probably be affected. The low permeability of the clay layers can cause water to perch above the water table or could create excessive recharge times. MWA encountered a similar clay interval while drilling ADW-1, which is located about one mile north of the East Branch in Oro Grande Wash.

In addition to permeability problems associated with clay layers, potential groundwater quality problems could affect Regional aquifer recharge alternatives along the East Branch. As noted above, Ball and Izbicki (2004) found concentrations of hexavalent chromium in groundwater up to 60 µg/L in the Sheep Creek alluvial fan. Well water quality data from the DHS showed hexavalent chromium values up to 21 µg/L in 5N/7W-24D3 and 15 µg/L in well 5N/7W-30B1 in the same area. However, arsenic values were below detection and total dissolved solid values averaged about 332 milligrams per liter (mg/L) in well data.

In summary, artificial recharge alternatives directly recharging the Regional aquifer along the East Branch will need to determine local hydrogeologic conditions in order to eliminate the potential adverse effects associated with impermeability caused by clay layers and the potential poor groundwater quality problems of the Regional aquifer. Although excessive dry unsaturated zone and high chloride layers could present challenges, these challenges should not be the limiting factor to alternatives. The most likely areas for recharging alternatives of this type are between Antelope Wash and well 5N/6W-36R1, where driller's logs have not indicated clay material above the water table, and where the Regional aquifer water quality is expected to be good.

2.3.2 Antelope Wash

Direct recharge to Antelope Wash has been proposed as an alternative. For this alternative, SWP water would be spread in the Antelope Wash adjacent to the East Branch and recharge water would migrate southeasterly toward the Mojave River and the current Rock Springs Recharge Site. No information on the hydrogeology of Antelope Wash was found in the literature. No well logs were found for Antelope Wash to help determine aquifer thickness and to estimate the potential storage capacities of the alluvial aquifer. Slade and Associates (2004) constructed a geologic cross section (Z'-Z" on Plate 2B) that shows over 400 feet of sand and gravel beneath Antelope Wash in the City of Hesperia, suggesting that direct recharge to Antelope Wash would recharge the Regional aquifer and the Mojave River. Using typical specific capacity values for wells in the southern and western portions of the Hesperia area, Slade and Associates (2004) estimated transmissivity values from 100,000 to 140,000 gallons per day per foot and states that the semi-confined to confined aquifer system considered to be present in the Hesperia area should have storativity values on the order of 10^{-3} to 10^{-4}.

Additional field work will be required to determine the potential adverse hydrogeological effects to groundwater storage in Antelope Wash between the East Branch and the Rock Springs Recharge Site. Recharge alternatives will need to address the potential effects from rising groundwater and liquefaction susceptibility in addition to recharge consideration. However, given the 400 foot depth to groundwater and the large area available for recharge, additional study is probably not needed.

2.3.3 Alternatives P3 and P4 – Along the Mojave and Morongo Basin Pipelines

These alternatives would spread SWP water in engineered spreading grounds along either the Mojave River or the Morongo Basin Pipelines and return stored groundwater by pumping and conveyance directly to the East Branch or could include entitlement exchange scenarios. The alternatives could require that associated operations, such as spreading grounds, groundwater conveyance pipelines, wells, and perhaps booster pumping stations, be constructed for the project alternatives. Sites could be located anywhere along either the Mojave River or Morongo Pipelines and would store SWP water in the Regional aquifer. Again, potential hydrogeologic and groundwater quality problems associated with the Regional aquifer are the primary considerations in alternative locations.

The Mojave River Pipeline follows the Mojave River for much of its northern extension, but from the East Branch north to the City of Adelanto and the former George Air Force Base, the pipeline overlies the Regional aquifer west of the City of Victorville. Although the proximity of the Mojave River Pipeline to the Mojave River north of Adelanto does not preclude recharging directly to the Regional aquifer, the more practical scenario of directly recharging the Mojave River from the Mojave River Pipeline should be considered, and the subsequent return of water to the East Branch is more dependent on engineering considerations than hydrogeological. The Mojave River and Floodplain aquifer alternatives are discussed below. Thus, for this set of alternatives, the hydrogeological consideration of alternatives was limited to the Mojave River Pipeline south of Adelanto.

Bookman-Edmonston (1999, 2001, 2002) conducted a comprehensive study for the High Desert Power Project groundwater banking operation to determine the viability and effects of recharging the Regional aquifer from the Mojave River Pipeline. The High Desert Power Project utilizes aquifer storage and recovery (ASR) wells to accomplish the groundwater storage operation. However, the information obtained from this study suggests that direct recharge to the Regional aquifer along the Mojave River Pipeline is hydrogeologically practical south of the former George Air Force Base.

Cox and Owen (2003), Catchings, Gandhok, and Goldman (2001), and URS (2003) studied the stratigraphy in the area at the former George Air Force Base and at Adelanto. Based on these studies, recharging the Regional aquifer in this area would not be feasible due to a thick lacustrine clay unit. The northern extent of the clay interval encountered in ADW-1 is unknown and could be a potential problem for areas south of the High Desert Power Project.

Several studies were conducted to locate potential recharge sites along the Morongo Basin pipeline. Bechtel (1993), and Dodson and Associates (1997) conducted two such studies in Lucerne Valley. Bechtel (1993) studied potential recharge at two sites: the Lucerne Valley Sub-basin study area and the Fifteen Mile Sub-basin study area. These sub-basins were described by Schaefer (1979) and represent two of the three sub-basins in the Lucerne Valley: the Fifteen Mile Sub-basin, located west of the Helendale Fault; the Lucerne Lake Sub-basin, located east of the Lucerne Lake Fault; and the Rabbit Springs Sub-basin, located between the Helendale and Lucerne Lake faults. Schaefer (1979) discussed seven important conditions that must be satisfied for an area to be considered suitable for artificial recharge and recommended one area to be considered. The seven conditions are:

1. The infiltration rate of the spreading grounds must be high enough to accept the anticipated rate of recharge.

2. The storage capacity of the groundwater basin must be adequate to accommodate the anticipated volume of recharge.

3. The transmissivity of the water-bearing material must be sufficient to transmit the water at an acceptable rate away from the recharge site toward the area of extraction.

4. An adequate supply of water must be available for recharge, and it must be close enough to the area of need to meet economic criteria.

5. The spreading grounds should be up-gradient of the withdrawal areas or be so situated with respect to withdrawal areas that water moves as directly as possible from one area to the other.

6. Faults and other hydrogeologic barriers should not impede the movement of recharge water.

7. The recharge water must be geochemically compatible with that in the aquifer to minimize mineral precipitation and clogging of the aquifer with consequent reduction in rates of recharge.

Bechtel’s (1993) Lucerne Valley Sub-basin study area (Sections 15, 20 to 23, and the NW ¼ of 29, T4N, R1E, SBM) is generally the same site recommended by Schaefer (1979).

Bechtel’s (1993) Fifteen Mile Sub-basin study area is located about four miles west of the Helendale Fault in Sections 17 to 20, T4N, R1W, SBM and Sections 13 and 24, T4N, R2W, SBM. Dodson and Associates (1997) prepared an initial study on a smaller site located in the NE ¼ of the NE ¼ of Section 14, T4N, R1W, SBM.

Bechtel (1993) recommended six sites in the two study areas for further investigation. However, a review of their geologic cross-sections for this study suggests that both areas contain a significant amount of clay and fine-grained material and that recharge could be a problem in these areas. Additionally, a geologic cross-section constructed of the Lucerne Valley Sub-basin for this study by B-E/GEI also suggests that a significant amount of lacustrine clay probably exists at this site. A review of DHS groundwater quality data was inconclusive due to limited data.

Based on the information obtained in this task and discussed above, recharge alternatives should be located between ADW-1 and the Adelanto area on the Mojave River Pipeline and/or before the Fifteen Mile Sub-basin Study area of Bechtel (1993). Each project will need to address detailed site-specific hydrogeological conditions.

2.3.4 Alternatives P1, P2, and P9 – Mojave River Recharge Alternatives

The U.S. Geological Survey and others have made considerable efforts to understand the relationship between the Mojave River, the Floodplain aquifer, and the Regional aquifer. The references cited at the beginning of this discussion are some of the studies that have produced a better understanding of this relationship. This understanding can now be used to determine the benefits of different recharge alternatives.

Stamos, Martin, and Predmore (2002) have determined the effects of several artificial recharge alternatives on the Mojave River and at two sites along the East Branch (Manzanita and Oro Grande Washes) by using a numerical groundwater flow model of the Mojave River groundwater basin produced by Stamos, Martin, and others (2001). A similar numerical groundwater flow model was used to simulate the possibility of recharging the upper section of the Mojave River from The Forks to the Narrows. Details of this simulation are included in Appendix A entitled “Local Model Simulating River Recharge and Pumping Scenarios.” Lines (1996) included this area of the upper Mojave River as a favorable reach alternative.

With the exception of Alternative #3 of Stamos, Martin, and Predmore (2002), which models artificial recharge alternatives at Manzanita and Oro Grande Washes, no hydrogeological conditions were found that would adversely affect the recharge alternatives suggested in their study. As stated above and as indicated by Stamos, Martin, and Predmore (2002), additional infiltration and site characterization data are needed to determine if recharge alternatives at Manzanita and Oro Grande Washes are viable.

URS (2003) conducted a detailed hydrogeological study of the Mojave River Transition Zone for the MWA. According to URS (2003), clay and silt layers form a low permeability layer that corresponds with riparian vegetation between the Oro Grande and Bryman segments of the Mojave River in the Transition Zone. This low permeability layer would adversely affect recharge in this section of the Mojave River. Additionally, B-E/GEI used groundwater level data to calculate available recharge capacities for reaches of the Mojave River in the Alto subarea and determined that little recharge capacity is available.

2.4 Screening of *Put* Alternatives

Table 2-3 presents the results of a fatal flaw screening for the alternatives described above. Those alternatives receiving a "Pass" ranking are carried forward for cost estimating and future screening.

Table 2-3
Fatal Flaw Screening of *Put* Alternatives

	Alternative	**Pass-Fail**
P1	Mojave River Dam Storage	Fail
P2	Mojave River via Cedar Springs Dam	Pass
P3	Alto Subarea via Mojave River Pipeline and East Branch	Pass
P4	Alto Subarea via Morongo Basin Pipeline	Pass
P5	In-Lieu Recharge via Water Treatment Plan	Pass
P7	Oeste Spreading Along East Branch	Pass
P8	Alto Spreading Along East Branch and in Oro Grande and Antelope Valley Washes	Pass
P9	Convey Water to Upper Mojave River in Unnamed Wash near Check 66	Pass

Alternative P1 was given a "Fail" ranking for the following reasons:

- Long-term impoundment of water behind the dam would harm arroyo toad habitat.
- The San Bernardino Flood Control District is not interested in operating a dual-purpose project (i.e., flood control and water conservation). MWA is not currently staffed to take over the operation of the dam.
- Evaporation losses in the desert are very high.

2.5 Cost Assessment of *Put* Alternatives

Table 2-4 identifies the durations of spreading and volumes of annual storage that are evaluated within this section. Percolation within the Regional aquifer is slow and is estimated at 0.5 feet per day (see Table 1-6 in TM 01). Percolation within the Floodplain aquifer is much faster (estimated conservatively at 2 to 3 feet per day).

The storage capacity within the Regional aquifer for the alternatives identified in this section is judged to be in excess of the ultimate total storage volume. This volume, however, will be evaluated and addressed in more detail within Section 6.0. The net spreading areas needed for the durations and volumes being evaluated are also presented in Table 2-4.

Table 2-4
Net Spreading Area in Regional Aquifer for Various *Put* Volumes, Spreading Durations, and Assumed Percolation Rate of 0.5 Feet Per Day

Annual *Put* Volume	Net Spreading Area (acres)				
(acre-feet/year)	3 months	4 months	5 months	6 months	9 months
25,000	556	417	333	277	185
50,000	1,111	833	667	556	370
75,000	1,667	1,250	1,000	833	556
100,000	2,222	1,667	1,333	1,111	741
150,000	3,333	2,500	2,000	1,667	1,111

The ratio of net spreading acreage to gross spreading acreage is a function of the slope of the land, the width of the berms, and the design depth within the spreading basins. A standard B-E/GEI berm design was utilized to assess the layout of a typical spreading ground, see Figure 2-2. The slope of the land along the East Branch is similar from the Oeste subarea to the Alto subarea. The land slope is fairly steep and results in a low ratio of net-to-gross spreading acreage. The following parameters were used to develop a typical spreading ground:

- Typical water depth within spreading pond - 3 feet
- Typical height of spreading pond - 5 feet
- Top width of berm separating spreading ponds - 12 feet
- Side slope of berms - 2H:1V
- Berm spacing (transverse) were placed every 500 feet
- Berm spacing (longitudinal) at every 3-foot contour.

The ratio of net-to-gross spreading acreage was computed to be 68 percent. Based on this ratio and using the results presented in Table 2-4 the gross spreading acreage for the various annual *put* volumes is presented in Table 2-5.

Table 2-5
Gross Spreading Area in Regional Aquifer for Various Annual Volumes, Spreading Durations, Assumed Percolation Rate of 0.5 Feet Per Day, and an 68 Percent Net-to-Gross Ratio

Annual *Put* Volume	Gross Spreading Area (acres)				
(acre-feet/year)	3 months	4 months	5 months	6 months	9 months
25,000	817	613	490	408	272
50,000	1,634	1,225	980	817	545
75,000	2,451	1,838	1,471	1,225	817
100,000	3,268	2,451	1,961	1,634	1,089
150,000	4,902	3,676	2,941	2,451	1,634

The land in the Town of Apple Valley is flatter than all the other new spreading ground sites being evaluated in this study; therefore, with all other parameters the same, the ratio of net-to-gross spreading acreage is 88 percent. Based on this higher ratio, the gross spreading acreage for the various annual *put* alternatives are presented in Table 2-6. Table 2-6 applies only to sites being considered in the Town of Apple Valley.

Table 2-6
Gross Spreading Area in Regional Aquifer for Various Annual Volumes, Spreading Durations, Assumed Percolation Rate of 0.5 Feet Per Day, and an 88 Percent Net-to-Gross Ratio

Annual *Put* Volume	Gross Spreading Area (acres)				
(acre-feet/year)	3 months	4 months	5 months	6 months	9 months
25,000	631	473	379	316	210
50,000	1,263	947	758	631	421
75,000	1,894	1,420	1,136	947	631
100,000	2,525	1,894	1,515	1,263	842
150,000	3,788	2,841	2,273	1,894	1,263

These tables are used when evaluating those *put* alternatives located within the Regional aquifer. Some alternatives did not have enough gross acreage to spread the range of volumes of water within the time frames being evaluated.

The estimated cost of facilities for the alternatives that passed the fatal flaw screening is discussed in the following subsections. Tables 2-7 and 2-8 list the assumptions used for spreading ground cost estimates associated with both net-to-gross ratios.

Table 2-7
Cost Screening Assumptions Associated with Spreading Grounds with Net-to-Gross Ratio of 68 Percent

Description	Unit per Acre	Unit	Unit Cost
Berm construction	1,797	CY	$2.30
Chain link fence	35	LF	$7
Major hydraulic structure	0.29	Ea	$22,000
Minor hydraulic structure	0.22	Ea	$2,700
Distribution pipeline (24” ø RCP) [1]	40	LF	$84
Pumping cost[1]	---	Acre	$2,500

[1]For sites located south (uphill) of SWP.

Table 2-8
Cost Screening Assumptions Associated with Spreading Grounds with Net-to-Gross Ratio of 88 Percent

Description	Unit per Acre	Unit	Unit Cost
Berm construction	1,535	CY	$2.30
Chain link fence	35	LF	$7
Major hydraulic structure	0.06	Ea	$22,000
Minor hydraulic structure	0.06	Ea	$2,700
Distribution pipeline (24” ø RCP) [1]	40	LF	$84
Pumping cost[1]	---	Acre	$2,500
Conveyance pipeline (24” ø. RCP)	14	LF	$84

[1]For sites located south (uphill) of SWP.

The screening unit costs were calculated by analyzing two parcels of land that had a ground slope representative of the land being considered for spreading. The average slope on most of the properties being considered for spreading is approximately 2 percent; with the exception of the land in the town of Apple Valley (average slope was 0.5 percent). All the features needed to construct spreading grounds were laid out on these two representative parcels to establish a unit cost per acre. These costs were used to estimate the costs for all the *put* alternatives.

The alternative cost assessment estimates include infrastructure associated with putting water into storage, and the present value of identifiable operating costs (spreading grounds are assumed to be operated 10 times in 30 years). The costs do not include the cost of water nor the variable costs associated with pumping water from the SWP to the MWA.

2.5.1 Alternative P2 – Mojave River via Cedar Springs Dam

No new facilities are required for this alternative; therefore, the cost is presumed to be zero. Long-term operational costs were not assessed at this time because they are common among all alternatives.

2.5.2 Alternative P3A – Alto Subarea via Mojave River Pipeline and East Branch

The infrastructure needed to implement this alternative depends on the size of the Program. Table 2-9 shows the capital costs associated with the different annual *put* volumes and durations. Costs shown include land, the East Branch turnout (which would be located approximately 500 feet east of the Mojave River Pipeline), hydraulic structures, and earthwork.

Table 2-9
Capital Costs Associated with Alternative P3A Spreading Grounds for Various Annual Volumes and Spreading Durations

Annual *Put* Volume (acre-feet/year)	Cost (millions, 2004 dollars)				
	3 months	4 months	5 months	6 months	9 months
25,000	$36	$26	$21	$18	$12
50,000	72	54	43	36	23
75,000	107	81	65	54	36
100,000	142	107	86	72	48
150,000	212	160	128	107	72

A market study prepared for MWA on July 1, 2005 concluded that the land cost was twice the value that was assumed in Technical Memorandum No. 02 ($15,000 per acre rather than $7,500 per acre). The project costs shown in Table 2-9 have been adjusted accordingly.

After reviewing the hydraulic capacity of the Mojave River Pipeline, it was determined that constructing a turnout off the existing pipeline rather than off the East Branch would be less costly. Constructing a new turnout on the East Branch isn't completely avoidable. The turnout off the Mojave River Pipeline cannot be bigger than 126 cfs. For projects that require spreading flow rates greater than 126 cfs, a turnout off the East Branch can be constructed to make up the difference. Sufficient land is presumed available downhill from the East Branch; therefore, gravity flow will supply the spreading basins.

2.5.3 *Alternatives P4A and P4B – Alto Subarea via Morongo Basin Pipeline*

Spreading water via the Morongo Basin Pipeline to new spreading facilities in the Town of Apple Valley (Alternative P4A) would require building a new parallel pipeline approximately 63,000 feet in length; a new turnout off of the East Branch; a turnout off of the Morongo Basin Pipeline near the new spreading sites; land acquisition for the new spreading grounds at a cost of $30,000 per acre and a 74-foot wide right-of-way along the entire pipeline (108 acres); hydraulic control structures; and 24-inch diameter distribution pipelines. The diameter, size of the turnout, and amount of land required will vary with the size of the Program being considered. Table 2-10 shows the costs associated with Alternative P4A.

Table 2-10
Capital Costs Associated with Alternative P4A Spreading Grounds for Various Annual Volumes and Spreading Durations

Annual *Put* Volume (acre-feet/year)	**Costs (Millions – 2004 dollars)** 3 months	4 months	5 months	6 months	9 months
25,000	78	$62	$50	$41	$13
50,000	137	109	91	78	55
75,000	*	150	126	109	78
100,000	*	*	158	137	99
150,000	*	*	*	*	137

*Insufficient land available for this scenario.

Energy costs were not included in the calculations because both the Morongo Basin Pipeline and the new parallel pipeline are gravity flow pipelines. There is enough pressure in the pipelines to deliver the water from the East Branch to the furthest spreading grounds located south (uphill) of the pipelines.

There are no capital costs associated with direct recharge of the current spreading within the Floodplain aquifer via the Rock Springs Turnout (Alternative P4B). The volume of water that can be stored within the Aquifer is the only limiting factor, estimated to be approximately 35,000 acre-feet between Rock Springs Turnout and the Upper Narrows.

2.5.4 *Alternative P5 – In Lieu Recharge via Water Treatment Plant*

The estimated capital costs for a 20- or a 30-million-gallon-per-day (MGD) surface water treatment plant are $30 million, and $45 million, respectively. A unit cost of $1.50 per gallon per day was used to calculate the total construction costs (So 2001). The estimated construction cost for the joint water treatment facility includes site purchase, site development, hydraulic structures, mechanical equipment, electrical controls, instrumentation and piping. Other costs include the turnout structure at the East Branch and the approximate 17,400-foot-long transmission pipeline that will transport the SWP water to the water treatment plant in Victorville. A 20 MGD plant's flow capacity is approximately 31 cfs and would require a 24-inch diameter transmission pipeline (assuming a velocity of 10 fps). The 30 MGD plant's flow capacity is approximately 46.5 cfs and would require a 24-inch diameter line. A unit cost of $8 per diameter inch was used to assess the cost of the pipeline. The total cost, including contingency and engineering costs, for the water treatment plant were determined to be $36 million and $53 million, respectively.

2.5.5 Alternative P7 – Oeste Spreading Along the East Branch

Spreading along the East Branch in the Oeste Subarea will require land purchases, turnouts off of the aqueduct, and construction of engineered spreading grounds that include hydraulic control structures. If the storage scenario requires more than 3,910 acres (refer to Table 2-5), then spreading grounds south (uphill) of the East Branch are also needed, see Plate 3. Spreading 150,000 acre-feet in 3 months will require delivering water uphill, pumps and distribution pipelines will be necessary.

Table 2-11
Capital Costs Associated with Alternative P7 Spreading Grounds for Various Annual Volumes and Spreading Durations

Annual *Put* Volume (acre-feet/year)	Cost (million, 2004 dollars) 3 months	4 months	5 months	6 months	9 months
25,000	$30	$22	$18	$15	$10
50,000	60	45	36	30	20
75,000	89	67	54	45	30
100,000	117	89	71	60	41
150,000	194	134	107	89	60

A market study prepared for MWA on July 1, 2005 concluded that the land cost was higher than the value that was assumed in Technical Memorandum No. 02 ($10,000 per acre rather than $7,500 per acre). The project costs shown in Table 2-9 have been adjusted accordingly.

Pump station operation costs were calculated using an energy cost of 12 cents per kilowatt hour (kWh) and the additional assumption that the pump station would only be operated 10 times a year in a 30-year period. The distribution lines were assumed to be 24 inches in diameter. Table 2-11 show the costs associated with this alternative.

2.5.6 Alternative P8 – Alto Spreading Along East Branch and in Oro Grande and Antelope Valley Washes

Large volume spreading within the Alto subarea within the communities of Victorville and Hesperia was judged to be unlikely because of the urbanization. There are opportunities for small scale spreading adding up to about 493 gross acres as described earlier in this study.

The flood detention basin that is planned adjacent to Ranchero Road is estimated to cost $15 million; however, these costs might be shared by the San Bernardino Flood Control District, the City of Hesperia, and MWA if the facility could also be used for spreading water. The Antelope Wash spreading grounds (up to 318 acres) will cost approximately $16 million. Included in this cost is; a 24-inch conveyance pipeline approximately 8,000 feet in length, land, hydraulic structures, and one 55-cfs turnout structure off the East Branch near the Morongo Basin Pipeline. Both the 60-acre detention basin near Cedar Street and the land-locked lands located upstream of the East Branch will require turnout structures with flow capacities of 10 cfs. The 16-acre site on the Oro Grande Wash will require approximately 5,300 feet of pipe to transport the water from the East Branch to the spreading grounds, and a 5 cfs turnout structure. All three sites require distribution pipelines, and pump stations.

Table 2-12
Capital Costs Associated with Alternative P8 Spreading Grounds for Various Annual Volumes and Spreading Durations

Annual *Put* Volume (acre-feet/year)	Cost (million, 2004 dollars) 5 months	6 months	9 months
25,000	$46	$35	$16
31,800	*	44	17
45,000	*	*	45

* Insufficient land available for this scenario.

The combined costs for these three spreading ground sites are estimated at $14 million. The costs shown in Table 2-12 also include operating cost for those spreading grounds located upstream (uphill) of the East Branch. The operation or energy costs were calculated using a unit cost of 12 cents per kilowatt hour. The project is assumed to operate 10 times in 30 years.

2.5.7 Alternative P9 – Upper Mojave River via East Branch through Unnamed Wash

If more than 135 cfs is diverted through the unnamed wash and on to the Mojave River for spreading, an additional turnout off of the East Branch will be required. Because the wash is expected to run through the proposed Rancho Las Flores development, other improvements such as two road bridges and one pedestrian bridge across the wash will also be needed. If the development is constructed per the land use map submitted in the specific plan amendment, the first 5,800 feet of the wash will run adjacent to areas designated for town centers, a lake, and medium density housing. A 96-inch diameter pipeline will be used along this section of the wash. The rest of the wash (approximately 15,800 feet) will remain a natural channel. Preliminary hydraulic analyses of the wash determined that a 500 cfs flow down the unnamed wash was acceptable however, 3 drop structures are needed to control the water's velocity along the wash. The new 365 cfs turnout is estimated to cost approximately $1.3 million, which include the cost of the structure, slide gates, control building, metering vault, temporary cofferdam, electrical and controls installation. The cost of each road bridge is approximated at $1,350,000, and $50,000 for the pedestrian bridge. The total cost for this alternative is estimated at approximately $13.4 Million.

2.6 Ranking of Alternatives

Table 2-13 presents a qualitative ranking of the alternatives relative to the objectives of the study, which are to evaluate the engineering and hydrogeology of the alternatives, and to assess the costs of the alternatives. Costs include capital cost and pump operation costs, and do not include operation personnel, maintenance, or wheeling costs.

Table 2-14 shows the numeric ranking of four of the eight screening categories described in Section 1.0. All categories were ranked from plus 1 to plus 5, except for the category Environmental/Other Considerations. This category was ranked with a scale of negative 5 to positive 5 because the "other considerations" may be negative or positive.

Table 2-13
Qualitative Ranking of *Put* Alternatives

Aquifer Recharge Alternatives	Potential Annual *Put* (AF/yr)	Cost Range[2] ($$10^6$ - 2004$)	Cost Range[3] (2004$/AF)	Ability to Store Large Volumes in Short Duration	Proximity to Water Source	Operational Flexibility	Environ-mental/ Other Consider-ations
Alternative P2- Mojave River via Cedar Springs Dam	61,000[1]	0	0	Low-Medium	High	Low	Arroyo toad habitat
Alternative P3A- Alto Subarea via Mojave River Pipeline and East Branch	25,000- 150,000	12 - 212	480 - 1,410	High	Medium-High	High	
Alternative P4A- Alto Subarea via Morongo Basin Pipeline	25,000- 100,000	13 - 158	520 - 1,580	Medium-High	Medium	High	
Alternative P4B- Rock Springs	25,000 - 30,000[1]	0	0	Low-Medium	High	High	
Alternative P4- In-Lieu Recharge via Water Treatment Plant	22,000- 33,000	36 - 53	1,180 - 1,610	Low	High	Low-Medium	
Alternative P7- Oeste Spreading Along East Branch	25,000- 150,000	10 - 194	400 - 1,290	High	High	High	
Alternative P8- Alto Spreading Along East Branch and Oro Grande and Antelope Washes	25,000 - 45,000	16 - 46	640 - 1,000	Low	High	High	Could serve as a multi-purpose project.
Alternative P9- Upper Mojave River via East Branch through Unnamed Wash	61,000[1]	13.4	220	Low-Medium	High	High	Could serve as a multi-purpose project.

Notes
[1]The Floodplain aquifer storage volume is estimated at 61,000 acre-feet between the Mojave River Dam and the Upper Narrows, and 30,000 acre-feet between Antelope Wash and Upper Narrows.
[2]Costs do not include the cost of water nor variable costs associated with pumping water from SWP to MWA.
[3]Capital cost per acre-foot of capacity plus nine years of operating costs.

Table 2-14
Numeric Ranking of *Put* Alternatives

Aquifer Recharge Alternatives	Engine-ering[1]	Ability to Store Large Volumes in Short Duration	Economics[2]	Environ-mental/ Other Considerations	Total	Relative Rank
Alternative P2- Mojave River via Cedar Springs Dam	3	2	5	0	10	T5
Alternative P3A- Alto Subarea via Mojave River Pipeline and East Branch	4	5	2	0	11	T3
Alternative P4A- Alto Subarea via Morongo Basin Pipeline	4	4	1	0	9	7
Alternative P4B- Rock Springs	5	2	5	0	12	T1
Alternative P4- In-Lieu Recharge via Water Treatment Plant	3	NA	1	-2	2	8
Alternative P7- Oeste Spreading Along East Branch	5	5	2	0	12	T1
Alternative P8- Alto Spreading Along East Branch and Oro Grande and Antelope Washes	5	2	1	2	10	T5
Alternative P9- Upper Mojave River via East Branch through Unnamed Wash	5	2	5	-1[3]	11	T3

[1]Engineering evaluation of the proximity to water source and operational flexibility in Table 2-13.
[2]Economic evaluation of the cost per acre-foot in Table 2-13.
[3]Judged +1 for dual project and -2 for possible safety issues, for a final of -1.

2.7 Conclusions and Recommendations

Nine *put* alternatives were described, and eight alternatives passed the fatal flaw screening and were carried forward to the initial cost assessment phase of the study. The alternatives range from small (few tens-of-thousand acre-feet) to very large (hundreds-of-thousand acre-feet). The alternatives were evaluated separately to assess their individual characteristics; however, combination of alternatives will ultimately provide the water management strategies for both MWA and Metropolitan.

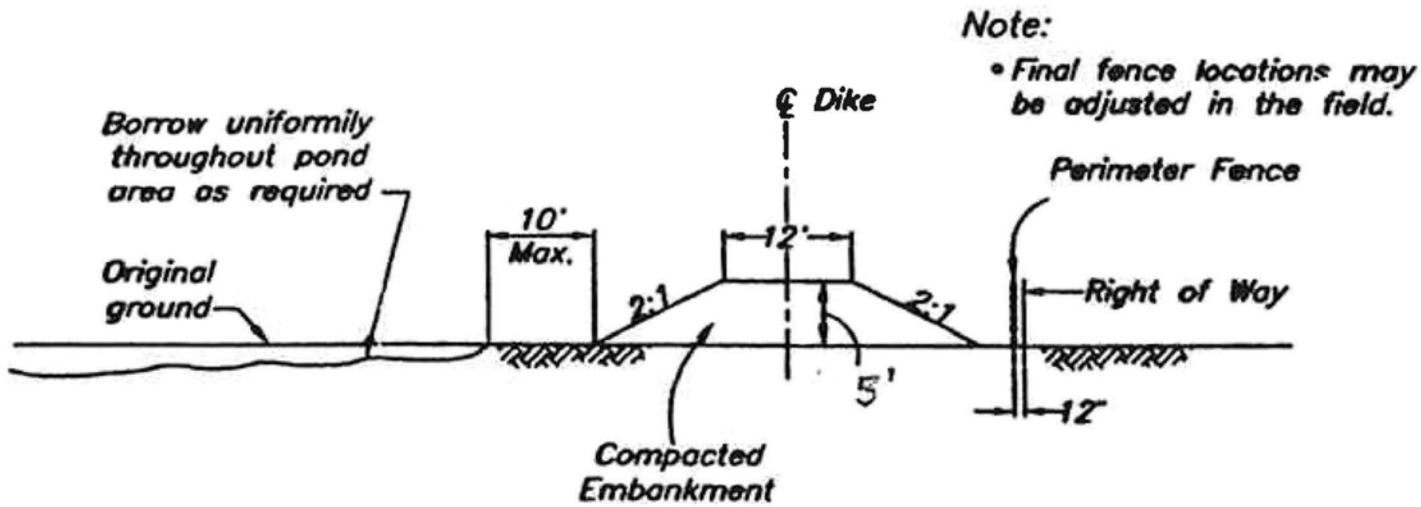
The ranking of *put* alternatives based on the merits of engineering, hydrogeology, economics, and environmental and other considerations, yield the following conclusions:

- Storing large amounts of water is most favorable along the East Branch in the Oeste subarea. The Alto subarea along the East Branch and the Mojave River Pipeline is judged nearly as favorable for large-scale storage programs.

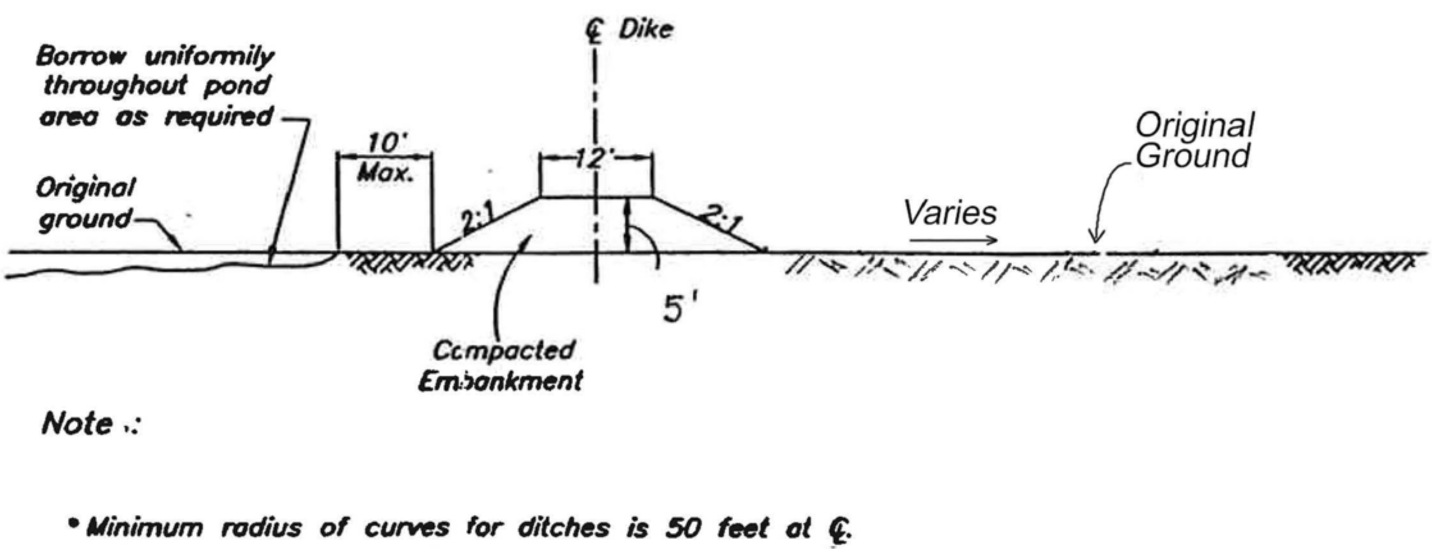
- Storing small amounts of water is most favorable in the Floodplain aquifer within the Mojave River using the Rock Springs Turnout on the Morongo Basin Pipeline. Using the unnamed wash to convey water to the River or releasing water from Cedar Springs Dam is judged nearly as favorable.

- Storage along the East Branch within Victorville, Hesperia, and Apple Valley is judged practical and might be best integrated in small part as an element of a more favorable alternative.

All of the eight alternatives were carried forward to the *take* evaluation within Section 4.0.



TYPICAL EXTERIOR BERM



TYPICAL INTERIOR BERM

Figure 2-2 Berm Cross Section (Typical)

3.0 Metropolitan Water Storage Assessment

Developing a Water Management Program that benefits both agencies and their water users requires a thorough understanding of Metropolitan's needs coupled with the water supply and storage conditions in the MWA area.

This section describes Metropolitan's water supply situation, its need for storage and dry year yield, and the surplus water available to Metropolitan in wet and normal years. Metropolitan's water needs are sometimes affected by water quality concerns and blending needs. Metropolitan has storage programs with other entities; their general arrangements will be discussed. Finally, there is discussion of the general range of quantities, capacities, and frequency of Metropolitan's storage needs as they may relate to MWA.

3.1 Activities Relating to Storage Options

In August 2004, the Team and staff from MWA and Metropolitan toured Metropolitan's current and proposed water storage projects in Kern County and inspected spreading grounds and facilities that pump water back to the SWP. This group met with staff and managers from three districts. Meetings were held with the Semitropic and Arvin-Edison Water Storage Districts, both of whom participate in storage projects with Metropolitan. A meeting was also held with North Kern Water Storage District, which is negotiating a storage agreement study with Metropolitan.

On December 20, 2004, Metropolitan and MWA staff and the Team met to discuss Metropolitan's water storage needs. The objective of this meeting was to better understand how groundwater storage within MWA could best be used to meet Metropolitan's storage needs.

Related work by the Team that provides added insight in developing the Water Management Program is a study being prepared on the capacity limitations of the East Branch. The study includes a determination of the demands on the East Branch from all contractors and a hydraulic capacity study. The study showed that in the future East Branch operations will be supply-driven and not demand-driven (in other words, when a supply is available, the contractors *take* the water and *put* it into storage). In wet years when the supply is high, East Branch capacity will be the restraint on deliveries.

Data referred to in this section on Metropolitan's water supply were obtained from two reports:

- Metropolitan's Water Supplies: A Blueprint for Water Reliability, March 25, 2003
- Metropolitan's Annual Operating Plan, May 2004

3.2 Metropolitan's Water Supply

Metropolitan is the primary supplier of imported water to the Coastal Plain of southern California for over 16 million people living in a 5,200 square mile area. Metropolitan obtains its supplies from the Colorado River and the SWP. These two projects have very different supply characteristics, which challenges Metropolitan to provide a reliable supply to its member agencies.

The Colorado River drains a seven state area of the southwestern United States. The water supply is extensively developed, with major dams on the river. The water rights were prioritized during the first half of the last century. California has the largest right on the river but the bulk of the first rights are held by agricultural interests. Metropolitan has junior rights on the river. For the last four decades, Metropolitan has used, in addition to its own rights, surplus water from the Colorado River. Metropolitan has used a full-flow Colorado River Aqueduct flow of about 1.2 million acre-feet per year. With increased water use by other states on the river and the drought of the last several years, Metropolitan's supply has been reduced to about 600,000 acre-feet per year. In 2004, Metropolitan was initially allocated 504,000 acre-feet. On November 1, 2004, Metropolitan was allocated about an additional 200,000 acre-feet, made available by the reduced use by the senior California right holders. This water had to be taken before January 1, 2005. This recent change in the Colorado River supply makes it even more important for Metropolitan to have storage readily available and a stored supply.

The SWP supplies water originating in northern California. Metropolitan has an annual entitlement of 2,011,500 acre-feet per year. Because the necessary water conservation facilities north of the Delta were never completed, the SWP can deliver full entitlements only in very wet years. Each year, the SWP sets the contractor's allocations as a percentage of their full entitlements. These allocation percentages are issued monthly from the first of the year and are generally finalized in April. These values are normally set low (25 percent) in December and increase as the water supply becomes better known. The allocation percentages for 1994 through 2005 are shown below in Table 3-1:

Table 3-1
State Water Project Allocation Percentages (1994-2005)

Month	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Dec	40	75	40	40	55	50	40	20	20	35	35	40
Jan	50	60			60			20	45	45	50	60
Feb	50			100	80	60	70					
Mar			100		100	100	100	30	60	50	65	
Apr	50	100					90			70		70
May	50							35	65	90	65	80
Jun												90
Jul								39	70			

Because planners do not know until well into the year how much water will be available, operations planning at Metropolitan and the other contractors is difficult.

A year like 2003 presents a special problem. Although the final allocation was 90 percent, this was not known until May. As such, many agencies were unable to take their entitlements because they had reduced their deliveries in the early months when they were still expecting a lower entitlement. Additionally, by pushing the deliveries to the end of the year there was insufficient capacity in some reaches of the Aqueduct, making the delivery of all water impossible. It also had the effect of adversely affecting the power purchases forcing the State to purchase more costly power causing an increase in the melded power cost charged to all State Water Contractors.

The challenge in setting annual allocations is caused, in large part, by the relatively small amount of storage on the SWP system. While the SWP has 1.67 million acre-feet of storage available, this quantity is much less than Metropolitan's allocation. Thus, each year's supply is dependent upon the annual precipitation and runoff. The SWP estimates that it can deliver, on the average, 3 million acre-feet to all of its contractors, and under its contract, Metropolitan may use 48 percent of this quantity or about 1.4 million acre-feet. In single dry years (like 1997), Metropolitan may receive as little 400,000 acre-feet and, in multiple dry years (like 1990–1992), receive 800,000 acre-feet per year.

An additional factor in water planning is the timing of deliveries to Metropolitan. While most of the SWP water may be scheduled as entitlement water, a significant amount of early year water may not be scheduled. This early year water is generally Article 21 water (i.e., water in the SWP system above the requested scheduled delivery of entitlement water). In most cases, it is runoff from precipitation that falls downstream of the reservoirs and would otherwise flow to the ocean. Also, to protect against a dry year, some contractors keep carryover water in San Luis Reservoir at the end of the Calendar year. If early precipitation occurs and the State can fill San Luis Reservoir then the carryover water is lost unless it can be moved from the Reservoir. These conditions show the value of having the capability to quickly store water in the January to mid-March period. This also represents a period of time when Aqueduct capacity is available.

The above description of Colorado River and SWP supplies illustrates Metropolitan's need for storage and dry year supplies, especially on the SWP system.

3.3 Metropolitan's Storage Programs

Metropolitan has initiated plans to deal with the water supply situation. It has the following programs available for State Water Project deliveries:

- San Luis Reservoir Carryover Storage
- Advance Delivery with Coachella Valley Water District and Desert Water Agency
- Semitropic Water Banking and Exchange Program
- Arvin-Edison Water Management Program
- San Bernardino Valley Municipal Water District Program

- Kern-Delta Water District Program
- Market Transfer Options

Currently under development are programs with other entities for additional transfers or storage, including:

- San Bernardino Conjunctive Use Program
- Westside San Joaquin Valley Transfers
- Eastside San Joaquin Valley Transfers

Metropolitan is also working with its own member agencies for conjunctive use storage. Three specific programs can be compared to the MWA Program.

3.3.1 Coachella Valley Water District and Desert Water Agency

Constructing facilities to deliver SWP water to the Coachella Valley would require a large expenditure of funds. Because the Colorado River Aqueduct passes through the Coachella Valley, a water exchange program was initiated with the delivery of SWP water under the terms of an agreement signed in 1967. Because of the substantial groundwater storage capacity available in the Coachella Valley, this exchange also allows the timing of water deliveries to be changed. Metropolitan delivers Colorado River Aqueduct water to the Whitewater River for spreading in the upper reaches of the Coachella Valley. Metropolitan then receives the Coachella Valley Water Agency’s and Desert Water Agency’s SWP entitlement water on an entitlement delivery schedule.

Under the Agreement, Metropolitan can place up to 600,000 acre-feet in its storage account. There are now about 140,000 acre-feet in the Advanced Delivery account. Metropolitan expects to obtain 61,200 acre-feet (the annual entitlement of the two desert contractors) in a wet year under this program. (These annual entitlements are being increased.) In an average year, the supply will be 46,100 acre-feet; in a single dry year (like 1977), the supply will be 12,300 acre-feet; and in a three-year dry period (like 1990–1992), the supply will average 24,600 acre-feet.

This arrangement works well because both areas benefit. The desert agencies did not spend money on the construction of an extension of the SWP to their service areas and Metropolitan gained water storage rights. The Coachella and Desert areas are currently investigating the construction of a pipeline from the Aqueduct to their service areas. This will reduce the storage value that Metropolitan obtains from the exchange.

3.3.2 Semitropic Water Storage District

Semitropic Water Storage District (Semitropic) is a large agricultural area located in northern Kern County east of the SWP. It obtains SWP water as a member agency of the Kern County Water Agency. Semitropic and Metropolitan signed a water banking and exchange agreement in 1994 that allows Metropolitan to pre-deliver water to Semitropic. Semitropic has essentially no spreading grounds because of the presence of confining layers which prevents the downward movement of water. Semitropic instead delivers water to its growers, who in turn do not pump from groundwater resulting in “in-lieu” recharge. Semitropic has contracts for a storage account in the groundwater bank of one million acre-feet and Metropolitan purchased 35 percent of that account, giving it a storage capacity of 350,000 acre-feet. Metropolitan has put nearly 400,000 acre-feet in that account and has withdrawn about 60,000 acre-feet.

Water is put in storage by scheduled deliveries to Semitropic, which delivers it on an irrigation schedule to the growers. Semitropic can, therefore, take large quantities in the summer and limited amounts or nothing in non-irrigation months. A 10 percent water loss rate is assigned to the water put in storage.

Two methods to return water to Metropolitan and the other storage contractors are available; (1) Water can be returned by an entitlement exchange whereby Semitropic leaves its entitlement water (except for the first 22,000 Acre Feet of entitlement water which Semitropic reserves for operation considerations) in the SWP for the banking partners use or (2) Semitropic can return up to 300 cubic feet per second (cfs) directly to the SWP during the five non-irrigation months. The return facilities include additional Semitropic-owned wells, leased growers wells, transmission facilities, a 78-inch diameter pipeline, and pumping plant. Returning water at a rate of 300 cfs for five months will result in a total return of 90,000 acre-feet each year. Because Metropolitan has a 35 percent share of the program, it is entitled to an annual return of only 31,500 acre-feet. In addition, to obtain more return water, Metropolitan may use the unused capacity of other partners; however, it cannot depend on this added supply as a firm supply. The system has operated at the rated capacity of 300 cfs in returning water to the Aqueduct. Studies have shown that it may be possible for Semitropic to return water in a critically dry year for almost 7 months increasing the return capacity.

Payment terms are relatively complicated. In a simplified version, Metropolitan pays $90 per acre-foot for each acre-foot delivered to Semitropic until it has delivered 350,000 acre-feet. At that point, it pays $50 per acre-foot for each additional acre-foot delivered. To withdraw water, Metropolitan pays $40 per acre-foot plus actual power costs, regardless of whether the water is delivered to the SWP or delivered to Metropolitan as entitlement water. When entitlement water is delivered to Metropolitan (in other words, Semitropic’s entitlement water is left in the SWP), Semitropic pumps a like amount of water for delivery to its growers. The power costs paid by Metropolitan for an entitlement delivery are lower because the water is not pumped to the SWP. The payments to Semitropic (except power) are escalated from 1995.

Semitropic has developed another banking project, the Stored Water Recovery Unit, which includes a large well field, a 120-inch diameter return pipeline, pumping plants, and regulating reservoirs. Its advantage is that it can return water to the SWP throughout the year and is not limited to the non-growing season. The well field water contains arsenic, however, which must be considered. Metropolitan has declined to participate in this program.

3.3.3 Arvin-Edison Water Storage District

Arvin-Edison Water Storage District (Arvin-Edison) is located in the southern end of the San Joaquin Valley generally east of Interstate 5. Arvin-Edison obtains a large supply of Class II water from the Friant-Kern Canal of the Central Valley Project. This supply varies from about 30,000 acre-feet per year to well over 300,000 acre-feet per year. Arvin-Edison operates a conjunctive use project that includes large spreading grounds for wet year storage and a large well field for dry year extraction. Over the years, it has expanded its flexibility and takes deliveries of SWP water through the Cross Valley Canal at a turnout near Bakersfield.

In 1997, Metropolitan entered into an agreement with Arvin-Edison that allows Metropolitan to store available water in Arvin-Edison's groundwater basin, either through direct spreading operations or through deliveries to Arvin-Edison's growers. This water can be delivered to Arvin-Edison through the Cross Valley Canal or through a direct pipeline connecting the SWP and Arvin-Edison's South Canal. This pipeline has a diameter of 78 inches and is 22,000 feet long. A pumping plant at the South Canal can pump 150 cfs of water to be returned to Metropolitan through the 78-inch pipeline back to the SWP. Water can also be returned to Metropolitan by exchanges that involve numerous other agencies with whom Arvin-Edison has exchange agreements and who use water from the Friant-Kern Canal.

Metropolitan can store up to 250,000 acre-feet in Arvin-Edison and has the option to increase this amount to 350,000 acre-feet. It has placed over 250,000 acre-feet in storage and water was returned in 2003 and 2004.

Metropolitan's payments to Arvin-Edison are defined in the agreement. These payment provisions are summarized below.

- Metropolitan paid $24 million to Arvin-Edison to construct 500 acres of spreading grounds, 15 wells, a pumping plant with a 150 cfs capacity, and a two-way pipeline from Arvin's distribution system to the SWP.
- For the first 277,778 acre-feet put into storage, Metropolitan pays $55 per acre-foot for water put in and $40 for water taken out.
- For over 277,778 acre-feet put into storage, Metropolitan pays $70 per acre-foot for water put in and $40 for water taken out.
- Metropolitan pays Arvin-Edison for the cost of water provided by Arvin-Edison.
- Metropolitan pays Arvin-Edison the power cost for water put in and taken out.
- Metropolitan pays an operation and maintenance fee of $6.63 per acre-foot for water put in and $8.63 per acre-foot for water taken out.

- Metropolitan pays $10.95 per acre-foot for any water transported through Arvin-Edison's system.

Except for the capital payment and the power costs, these charges are subject to escalation, based on the Consumer Price Index change after December 1995.

3.4 Metropolitan's Range of Storage Programs with Mojave Water Agency

Metropolitan needs additional storage and dry year yield. Although diversification is important, a program must be of sufficient size to warrant consideration. The programs now used by Metropolitan hover around a three-to-one up to a five-to-one ratio of storage-to-return capacities. Based on past performance, it appears that a program with 250,000 acre-feet of storage and 50,000 acre-feet of dry year yield would be about the correct size. Obviously, an objective of this water management program study is to develop a size for the water bank. The storage capacity should be not less than the return capacity. Capacity to store water in greater amounts is beneficial. Programs two-thirds of that mentioned may qualify as well as programs at twice the amount shown.

3.5 Program Flexibility

It cannot be emphasized enough that a flexible water management program is the most significant element in creating a program to quickly respond to changed hydrologic conditions. Flexibility in the size of the facilities that put water into storage and in the size of facilities that return water to the East Branch are important if Metropolitan is to respond to changes in both the availability of surplus water for recharge and the need to return water to the East Branch. Flexibility is a component of this study because it evaluates recharge facilities that can accommodate large volumes of water in a short time. Obviously, such facilities have a greater capital cost when compared to facilities that would accommodate a smaller volume of water over a longer time period; nonetheless, this Program study evaluates large-scale *put* alternatives that could accommodate a need to quickly put water into groundwater storage. As the operation of the East Branch changes to that of a supply-driven conveyance, the value of the MWA/Metropolitan Water Management Program will increase if it has the ability and flexibility to rapidly recharge large volumes.

Flexibility includes the ability to take water when it is available on short notice. This is particularly important in the early part of the year when not only rainfall below the level of the storage reservoirs occurs but also the potential for loss of carryover water in San Luis Reservoir is possible. Mojave offers a storage opportunity south of the San Joaquin Valley downstream of the major pumping plants and the Tehachapi Mountains. While the value of this storage is not quantified it certainly offers value in situations of earthquake or major power disruption.

3.6 Conclusion

This section's basic conclusion is that Metropolitan needs storage programs, both inside and outside its boundaries. Metropolitan would like a storage amount of three to five times the return capacity. The *put* capacity should be not less than the return capacity and preferably should be larger than the return capacity. The ideal program would have a return capacity of about 50,000 acre-feet per year, within an overall range of about 30,000 to about 100,000 acre-feet per year.

4.0 Preliminary Engineering for *Take* Alternatives

After the initial fatal flaw screening in Section 1.0, a list of possible *take* alternatives were identified as requiring further evaluation. The following section contains a hydraulic review of both the Morongo Basin and Mojave River Pipelines; evaluates the extent of their use as part of the return facilities; the size of the *take* facilities are established; and preliminary cost estimates are prepared.

In Section 1.0, aerial photographs taken in April 2004 were reviewed to identify unimproved property along the East Branch and within areas that could be used for new spreading facilities. These photographs were also used to determine the locations of the potential wells and pipelines needed to return Metropolitan's stored water. Depending on the volume of water stored by Metropolitan, the number of wells needed to return water at a 5:1 ratio, (e.g., for 150,000 acre-feet stored, the annual maximum return capacity would be 30,000 acre-feet) ranges from 13 to 126 wells. Metropolitan expressed an interest in a return ratio of 3:1. Table 4-1 presents the number of wells that would be required to return Metropolitan's stored water under a 3:1 ratio.

Table 4-1
Number of Wells for Various Storage Volumes with 3:1 Return Ratio

Total Stored Volume* (acre-feet)	Gross Return Volume (acre-feet per year)	Number of Wells Required Per Return Period** 6 Months	9 Months	10 Months
75,000	25,000	35	23	21
150,000	50,000	70	46	42
225,000	75,000	105	70	63
300,000	100,000	140	93	84
450,000	150,000	210	140	126

*Range of stored water taken from Section 2.0
**Capacity of wells is assumed to be 2 cfs

The number of wells needed to return water at a 3:1 ratio was judged excessive and infeasible, and this return ratio is not considered further. Therefore, only a 5:1 return ratio was evaluated.

The cost for a six-month return period was also judged infeasible due to the quantity of wells that are required; therefore, longer return periods of nine and 10 months were evaluated. The number of wells required for a return ratio of 5:1 over six, nine, and 10 months is presented in Table 4-2. A 10-month return period was judged to be the longest practical duration because anything longer would not allow planners at Metropolitan enough time to decide if water will be taken from the groundwater bank.

Table 4-2
Number of Wells for Various Storage Volumes with 5:1 Return Ratio

Total Stored Volume* (acre-feet)	Gross Return Volume (acre-feet per year)	Number of Wells Required Per Return Period**		
		6 Months	9 Months	10 Months
75,000	15,000	21	14	13
150,000	30,000	42	28	25
225,000	45,000	63	42	38
300,000	60,000	84	56	50
450,000	90,000	126	84	75

*Range of stored water taken from Section 2.0
**Capacity of wells is assumed to be 2 cfs

The *take* alternatives, identified in Table 1-7, can range in return water volumes, from a few thousand acre-feet to tens of thousands of acre-feet. MWA has the infrastructure to deliver and store water within the groundwater basin; however, the infrastructure is hydraulically limited compared to the range of return volumes being evaluated in Table 4-2. New infrastructure in the form of larger pipelines, well fields, new pump stations, and other new hydraulic structures are identified and evaluated within this section. Use of the existing infrastructure is often evaluated in combination with the new hydraulic structures. Table 4-3 identifies the *take* alternatives that are evaluated within this section.

Table 4-3
Summary of Potential *Take* Alternatives

Alt ID	Description
T0	Direct Return through Regional Sub-Projects from Alto subarea
T1	Direct Return through Mojave River Pipeline from Alto subarea
T2	Direct Return through Morongo Basin Pipeline from Alto subarea
T3	Direct Return from Floodplain Aquifer and Delivered Laterally to Cities (use River to treat water)
T4	Direct Return from Oeste subarea
T5	Entitlement Exchange Alternative

4.1 Effect of Entitlement Exchange on Return Scenarios

As previously described, a 3:1 return ratio is not judged economical; however, the infrastructure identified for a 5:1 return ratio, coupled with an entitlement exchange, could also be used with a 3:1 return ratio. Table 4-4 presents the range of entitlement exchange volumes necessary for the infrastructure identified for the 5:1 return ratio to function as a 3:1 return ratio project.

Table 4-4
Equivalent *Take* Projects when considering Entitlement Exchange

Total Stored Water	3:1 Ratio Volumes	5:1 Ratio Volumes	Entitlement Exchange Volume
75,000	25,000	15,000	10,000
150,000	50,000	30,000	20,000
225,000	75,000	45,000	30,000
300,000	100,000	60,000	40,000
450,000	150,000	90,000	60,000

The entitlement exchange component brings great value in combination with return "hardware" (i.e., wells, pipes, etc). Returning water to Metropolitan quickly is value added to the overall Program.

It was determined that incorporating an entitlement exchange element at this time of the analyses could unfairly sway the results of the individual alternatives therefore, all alternatives were analyzed without an entitlement exchange component. Entitlement exchange is addressed later in this report.

4.2 Description of *Take* Alternatives

Plate 4 illustrates the locations of the *take* alternative described within this section. Their general features are presented in the following subsections. Some of these descriptions also include environmental or other conditions that may significantly affect the viability of the alternative.

4.2.1 Alternative T0 – Direct Return Through Regional Sub-Projects from Alto Subarea

In general, most of the projects being considered are large enough in scale to return the whole 5:1 return required for a 450,000 acre-foot Program. However, "smaller"-scale programs were considered desirable because they afford more operational flexibility than the larger projects. Alternative T0 is composed of projects near or within the city of Hesperia. Each project consists of one or two wells, each with the capacity to return 1,190-1,785 acre-feet of water per year back to the East Branch. The wells would be located within or near the following recharge basins: Oro Grande Wash, Antelope Wash, the Hesperia storm detention basin (off Cedar Creek Road), and the "land locked" land mentioned in Section 2.0.

This alternative also includes the construction of a 14-inch diameter pipeline that would connect to four existing wells and one new well (to be drilled at the Ranchero Road detention basin). The water would be returned to Metropolitan through a connection to the Morongo Basin Pipeline. Their locations are shown in Plate 4.

The total return capacity for these five projects is approximately 15,000 acre-feet per year in 10 months. For the purpose of this initial analysis, Alternative T0 is combined with Alternative T3 however; it may be used in combination with any other *take* alternative.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Where possible the points of delivery will be designed so they are located at existing East Branch turnouts or at the new turnouts required for the *put* alternatives discussed in Section 2.0. Return deliveries through the Morongo Basin Pipeline will have to be coordinated with downstream users. The motors and pumps of the existing wells will require major modifications before they can be used to return water back to the SWP.

4.2.2 Alternative T1 – Direct Return through the Mojave River Pipeline from Alto Subarea

The Mojave River Pipeline, located within the western Alto subarea and extending northerly through the Transition Zone and into the Centro and Baja subareas, is described in Technical Memorandum No. 01. This 48-inch pipeline near the East Branch is designed to convey 94 cubic feet per second (cfs) by gravity in a northerly direction. Pressure-reducing stations along the pipeline control the hydraulic pressures with sleeve valves. The first of these stations, the Cassia Pressure Reducing Facility, is located 5.4 miles north of the East Branch.

Preliminary analysis indicate that the pipeline can be used to convey a portion of the water for direct return to the East Branch from the proposed spreading grounds located along the Mojave River Pipeline (spreading locations and sizes are discussed in Section 2.0). Constructing well fields parallel to the pipeline and closer to the East Branch offers the advantage of proximity for direct return.

At its design capacity of 94 cfs, the maximum monthly return capacity through the pipeline is approximately 5,600 acre-feet. The velocity of 94 cfs in a 48-inch diameter pipeline is approximately 7.5 feet per second (fps). If the maximum velocity of the pipeline were allowed to reach 10 fps, the flow capacity would equal 126 cfs, which equates to approximately 7,500 acre-feet per month that could be returned to Metropolitan. Returning volumes greater than 7,500 acre-feet per month will require one or more new pipelines to supplement the current flow capacity of the Mojave River Pipeline.

Based on the assumptions presented, about 75,000 acre-feet per year of Metropolitan’s stored water could be returned through the Mojave River Pipeline over a 10-month return period. Any remaining volume would be returned through new pipelines connected to the well field manifolds. A bypass and valve will need to be installed so deliveries can be made to downstream users during return periods.

Plate 4 is a general overview of the possible spreading areas and the wells required for up to a 450,000 acre-foot program with a 90,000 acre-foot per year return. Wells are spaced one-third of a mile apart, the well locations shown are conceptual, further technical studies are required before determining actual well sites. Smaller storage programs can be accommodated by reducing the size of the spreading grounds and the number of wells. Table 4-5 summarizes the infrastructure requirements (wells) for various storage volumes.

Table 4-5
Number of Wells for Various Storage Volumes with 5:1 Return Ratio over 10 Months

Program (Total Stored Volume* acre-feet)	Return Volume (acre-feet per year)	Number of Wells Required for a 10-Month Return Period	Mojave River Pipeline's Capacity Adequate to Return Volume (yes/no)
75,000	15,000	13	Yes
150,000	30,000	25	Yes
225,000	45,000	38	Yes
300,000	60,000	50	Yes
450,000	90,000	75	No

*Range of stored water taken from Section 2.0

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

The points of delivery will be located at existing East Branch turnouts or at the new turnouts required for the *put* alternatives that were proposed in Section 2.0.

4.2.3 Alternative T2 – Direct Return through the Morongo Basin Pipeline from Alto Subarea

The Morongo Basin Pipeline is used to convey water for several existing recharge sites. This study identified some unimproved properties within the Town of Apple Valley as possible locations for new recharge facilities. The *put* facilities discussed in Section 2.5.3 (Alternative P4A) included a new parallel pipeline for all water management programs greater than 75,000 acre-feet. Although the new pipeline adds a considerable amount of money to the capital costs, the operation cost are relatively low because the pipelines are gravity lines. During a direct return from these recharge basins, pumping plants would be required to lift the water up to the East Branch. Technical Memorandum No. 05.0 discusses the facilities required and energy costs associated with returning water from Apple Valley via the Morongo Basin Pipeline. This pipeline is 54 inches in diameter between the East Branch and the Rock Springs Turnout and 30 inches in diameter thereafter. The 54-inch portion of the pipeline is designed as a gravity pipeline with a 110-cfs capacity. The capacity of the pipeline beyond Rock Springs Turnout is 30 cfs. The capacity through the 30-inch diameter section can be increased to 50 cfs without overstressing the pipeline. At this higher capacity, the pipeline can return approximately 3,000 acre-feet per month or 30,000 acre-feet in the 10-month return period. During the evaluation of the various *put* alternatives discussed in Section 2.0, it was determined that an additional pipeline (parallel to the Morongo Basin Pipeline) would be needed for this alternative to be viable.

Alternative T2 would return Metropolitan's stored water through both the new pipeline and the Morongo Basin Pipeline. Pump stations with enough horse power to raise the return water from an elevation of 3,020 feet to an elevation of 3,467 feet at the East Branch would be required. The number of wells required and the diameter of the new pipeline will depend on the quantity of groundwater stored by Metropolitan. Plate 4 shows the two new pump stations and the wells required to return 60,000 acre-feet per year to the East Branch. It will be possible to make water deliveries to customers downstream of the spreading grounds during pump back.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

There are no other considerations to report at this point in the study.

4.2.4 Alternative T3 – Direct Return from the Floodplain Aquifer

Several isolated project sites are associated with Alternative T3. The largest project involves a pipeline that would collect water from new well field along the upper Mojave River area and several existing wells in the city of Hesperia. The other pipeline associated with this project is a 14-inch diameter pipeline that would connect four existing wells and one new well. The 14-inch diameter pipeline would return water to the East Branch via the Morongo Basin Pipeline and the other pipeline would deliver the water directly to the East Branch.

Plate 4 shows the proposed pipeline alignments and the potential well locations required to return approximately 60,000 acre-feet to Metropolitan. The well sites include Oro Grande Wash, the Hesperia storm water detention basin, the "land locked land," and the proposed recharge site located in the Antelope Wash.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Coordination with users of the Morongo Basin Pipeline and the existing wells must be incorporated into the operation of the pipeline. Because the new pipelines would traverse urbanized areas, alignments that least affect the communities should be chosen.

4.2.5 Alternative T4 – Direct Return from Oeste Subarea

Stored water pumped by new wells located along the East Branch and within the spreading facilities proposed in Section 2.0 can be returned to Metropolitan as a direct return from the Regional Aquifer.

As shown in Table 4-2, a 450,000 acre-foot program with a 5:1 return ratio would require 75 wells (at 2 cfs) to deliver 90,000 acre-feet to the East Branch over a 10-month period. Returning smaller volumes of water would require fewer wells. The point of delivery will be coordinated with the existing and proposed new turnout locations described in Section 2.0.

Environmental Considerations

There are no environmental considerations to report at this point in the study.

Other Considerations

Conversations with County Service Areas staff regarding the water quality in their Oeste subarea wells indicate that water quality is good. Further investigation is recommended.

4.2.6 *Alternative T5 – Entitlement Exchange Alternative*

Returning stored water to Metropolitan via an entitlement exchange means that MWA's state water entitlement would be delivered to Metropolitan. MWA's maximum annual Table A entitlement is 75,800 acre-feet. Each year [5] the Department of Water Resources (DWR) establishes an allocation of water, expressed as a percentage of the maximum annual entitlement. The first allocation is estimated in December and this allocation is adjusted throughout the winter and spring as the understanding of California's hydrology improves.

Figure 1-4 presents an annual exceedance probability curve of MWA's Table A amount based on DWR's reliability report[6]. The graph illustrates the statistical probability that an annual allocation will be equaled or exceeded in any year. A sampling of values taken from Figure 1-4 is presented in Table 4-6.

Table 4-6
Annual Exceedance Probability for MWA's SWP Deliveries

Probability of Exceedance	MWA Entitlement (acre-feet/year)	SWP Allocation	MWA Entitlement Less Reserve of 12,000 Acre-Feet per Year (acre-feet/year)
0%	75,800	100%	63,800
25%	73,000	96%	61,000
50%	61,000	80%	49,000
75%	46,000	61%	34,000
80%	40,000	53%	28,000
90%	22,000	29%	10,000
100% (high)	15,000	20%	3,000
100% (low)	0	0%	0

Source: Figure 1-4, Section 1.0

MWA's SWP priority capacity (Table 1-2) identified 12,000 acre-feet as the annual water reserve that MWA will retain from its SWP entitlement. The 12,000 acre-feet equates to about a 15 percent SWP allocation; therefore, the annual allocations on the SWP must exceed 15 percent before water is available for an entitlement exchange. Table 4-6 indicates that there is almost always enough water in the SWP to provide a minimum of 3,000 acre-feet for exchange. Metropolitan staff has stated they could be in a *take* mode when allocations are at 64 percent or less; therefore, the maximum volume available for entitlement exchange is approximately 38,000 acre-feet per year.

Through ongoing work with the State Water Project Contractors Authority, MWA has preliminarily reported[7] the projected annual demands on the East Branch to change over time as follows:

Year 2005 - 15,000 acre-feet

[5] Year used within this context is a water year, spanning from October 1 to September 30.
[6] *The State Water Project Delivery Reliability Report, DRAFT,* California Department of Water Resources, August 2002.
[7] "Technical Memorandum No. 001, Study of East Branch Demands 2004-2025", Bookman-Edmonston, a Division of GEI Consultants, Inc., May 28, 2004.

Year 2010 - 29,000 acre-feet

Year 2015 - 44,000 acre-feet

Year 2020 - 58,600 acre-feet

Year 2025 - 73,200 acre-feet

The rapidly rising demands in the region could affect the quantity of water available for an entitlement exchange however, if MWA stores MWD water in advance to meet MWA demands, MWA can operate on this water reducing demands on the SWP. Using an entitlement exchange as a return alternative provides more operational flexibility to MWA and offers significant cost savings. Around 2020, MWA will likely need to acquire additional Table A entitlement to meet demand. Some of this acquired entitlement could be earmarked for use in stored water returns, or the added entitlement could be purchased and stored for use by MWA or MWD or both, and provide more entitlement to exchange back to MWD when needed.

An option available to MWA to relinquish some of the 12,000 acre-foot reserve is to pre-deliver water to spreading grounds in the Yucca Valley area. A portion of this reserve is an annual delivery needed through the Morongo Basin Pipeline.

The Team recommends that MWA evaluate its entitlement to determine if water is available that could be used in an entitlement exchange. An option to consider is a stepped approach, whereby in the early years (e.g., 2005 to 2010), a minimum volume is established for possible return through an entitlement exchange, and in later years this volume would step downward until MWA acquires more Table A water. MWA could also meet Yucca Valley's demand or other demand (i.e., HDPP) if previously stored water can be purchased and placed into MWA pipelines and delivered to the customer thereby increasing the ability to return water to MWD via exchange.

4.2.6.1 Environmental Considerations

There are no environmental considerations to report at this point in the study.

4.2.6.2 Other Considerations

There are no other considerations to report at this point in the study.

4.3 Hydrogeology Review of *Take* Alternatives

The Theis solution was used to estimate the potential drawdown effects of the extraction wells in the well fields. A well spacing of one-third of a mile and a 2 cfs pumping rate for a 300 day period were used. Data from the 2001 U.S. Geological Survey groundwater model for the Qtu unit of the Regional Aquifer were used to estimate the transmissivity (2,500 ft^2/day) and storativity (0.05).

An additional drawdown of about 20 feet should be expected for each adjacent well in the well field. Although the Theis solution is used for a confined aquifer system, this drawdown value is a reasonable estimate of the interaction between the wells in the well field, and provides a level of assurance that the 100 feet drawdown assumed for well pump operation analysis likely is conservative.

4.4 Fatal Flaw Screening of *Take* Alternatives

All of the *take* alternatives passed a fatal flaw screening and will be carried forward for cost estimating and future screening.

4.5 Cost Assessment of *Take* Alternatives

Table 1-5 in Technical Memorandum No. 01 presents cost screening criteria for the *take* alternatives. The following additional parameters were used to assess the *take* alternatives.

5 Elevation of groundwater table – 2,800 feet

6 Cone of depression – 100 feet

7 Well spacing (each way) – every 1,760 feet (1/3 mile)

To reduce the costs associated with land purchases, most wells have been located within the spreading grounds. In some instances, the total area intended for spreading is insufficient to lay out the wells at the minimum distance of one-third of a mile.

The estimated cost of facilities for the alternatives that passed the fatal flaw screening is discussed in the following subsections.

4.5.1 Alternative T1 – Direct Return Through Mojave River Pipeline from Alto Subarea

Returning water to the East Branch via the Mojave River Pipeline at a 5:1 ratio will require a *puts* in storage varying number of wells, depending on the total quantity of water that Metropolitan banks (shown in Table 4-2). The costs for the expected range of stored projects are shown in Table 4-7.

Table 4-7
Capital Costs Associated with Alternative T1 for Various Volumes
10-Month Return Period

Total Stored Volume (acre-feet)	Return Volume (acre-feet per year)	Cost (millions, 2004 dollars)		
		Capital	Operation (annual)	Total cost for 30 Year Project (used 12 times)
75,000	15,000	$ 12.7	$2.8	$46
150,000	30,000	24.4	5.3	88
225,000	45,000	37.1	8.1	134
300,000	60,000	48.8	10.8	178
450,000	90,000	73.1	16.3	269

Energy costs were calculated using $0.12 per kilowatt hour.

These costs include well pumps with sufficient horsepower to pump the water from groundwater level to the elevation of the East Branch. A group of four wells would be manifolded together and connected to the Mojave River Pipeline. Delivering water downstream during a return period can be made possible by closing off the valve on the Mojave River Pipeline (located just downstream of the well fields) and installing a bypass line with a throttling valve. The water that is diverted downstream can be made up by entitlement exchange.

4.5.2 Alternative T2 – Direct Return Through Morongo Basin Pipeline

The infrastructure needed to implement Alternative T2 depends on the size of the Program. With the new parallel pipeline, this alternative could return up to 90,000 acre-feet in 10 months: however, the limiting factor is the area required to lay out 75 wells at a spacing of one-third of a mile. Regardless of the size of the Program, this alternative would require one or two pump stations. Any amount of water returned to Metropolitan will require new infrastructure to lift the water to the East Branch.

Table 4-8a
New Parallel Pipeline Infrastructure for Alternative T2

Annual Return at 5:1 Ratio (AF/yr)	Flow rate for Return (cfs)	Diameter** (inches)	Velocity of Return Water (fps)	Headloss (feet)	TDH (feet)	Pump Station Power (hp)
15,000*						
30,000*						
45,000	25	42	2.6	25	472	1688
60,000	50	48	4.0	52	498	3565
90,000	101	66	4.2	42	489	6992

*Using existing Morongo Basin Pipeline with new pump station.
**Diameters are sized for the *put* volumes, Section 2.0.

Table 4-8a shows the different size pipelines, flow capacities, and pump station horse power required for the various return scenarios. The new parallel pipeline is oversized, thus resulting in low velocities and minimal headloss. The new diameters were determined by the *put* requirements established in Technical Memorandum No. 02. The diameters shown are those required to deliver 75,000, 100,000, and 150,000 acre-feet of water with the existing Morongo Basin Pipeline and the new parallel pipeline to the spreading grounds in the town of Apple Valley. Plate 4 illustrates the 50 potential well locations for a total stored volume of 300,000 acre-feet. The surrounding area is highly urbanized, making the cost of an additional 25 wells (75 wells are required for a 450,000 acre-feet Program) infeasible.

Table 4-8b

Capital Costs Associated with Alternative T2 for Various Volumes

10-Month Return Period

Total Stored Volume (acre-feet)	Return Volume (acre-feet per year)	Cost (millions, 2004 dollars)		
		Capital	Operation (annual)	Total Cost for 30 Year Project (used 12 times)
75,000	15,000	$ 14.9	$2.7	$47
150,000	30,000	30.0	6.3	105
225,000	45,000	50.0	9.0	158
300,000	60,000	69.8	11.9	213
450,000	90,000	*	*	*

* Significant number of wells outside spreading grounds, judged infeasible.
Energy costs were calculated using $0.12 per kilowatt hour.

Table 4-8b shows the costs associated with the different stored volumes. These costs are high because the well field is located approximately 12 miles away from the East Branch and at a much lower elevation (a static lift of 450 feet). The energy required by the well fields to return the water from the originating groundwater elevation of 2,800 feet to the Morongo Basin Pipeline or to the proposed parallel pipeline at an elevation of 3,050 feet (including the two pump stations) for 10 months is shown on the fourth column. The operating costs are approximately 70 percent of the total project costs, assuming Metropolitan takes water 12 times in the 30 year life of the project.

4.5.3 Alternative T3 – Direct Return from Floodplain Aquifer (in combination with Alternative T0)

Alternative T0 will be used to supply the first 15,000 acre-feet of returned water in Alternative T3. A Program larger than 75,000 acre-feet per year will require the construction of a pipeline and up to 22 new wells. The 14-inch pipeline would be connected to four existing wells (part of Alternative T0). Alternative T3 has been combined with Alternative T0 in order to return up to 60,000 acre-feet in 10 months. The size of the proposed pipeline running transversely through the City of Hesperia (East-West Pipeline) will depend on the size of the Program. Table 4-9a shows the various sizes and capacities associated with the different return scenarios.

Table 4-9a
Preliminary East-West Pipeline Infrastructure for Alternative T3

Annual Return at 5:1 Ratio (AF/yr)	Flowrate for Return (cfs)	Diameter (inches)	Velocity of Return Water (fps)	Headloss (feet)	TDH (feet)	Pump Station Power (hp)
15,000	*	*	*	*	*	*
30,000*	25	33	4.5	80	630	2,400
45,000*	51	45	4.6	60	610	4,400
60,000*	74	54	4.5	50	600	5,600

*15,000 AF/yr is returned with infrastructure from Alternative T0 (various local projects)
Note: The facilities for this alternative were changed significantly in Section 7.0.

Table 4-9b shows the capital costs and the annual operation costs associated with this alternative. The pumping station on the East-West pipeline will raise the water to the East Branch (a static lift of about 535 feet).

Table 4-9b
Capital Costs Associated with Alternative T3 for Various Volumes
10-Month Return Period (also includes cost for T0)

Total Stored Volume (acre-feet)	Return Volume (acre-feet per year)	Capital (millions, 2004 dollars)		
		Capital	Operation (annual)	Total Cost for 30 Year Project (used 12 times)
75,000	15,000	$13	$1	$25
150,000	30,000	47	3	83
225,000	45,000	67	4	115
300,000	60,000	82	6	154
450,000	90,000	*	*	*

*Number of wells required judged infeasible
Energy costs were calculated using $0.12 per kilowatt hour

Thirty-eight wells are required for a 300,000 acre-foot bank. Fewer wells are needed than calculated in Table 4-1 because 22 of the 38 wells are in the Mojave River aquifer and 2 are in the Antelope Wash. These wells are assumed to be 3 cfs each rather than the 2 cfs used for the wells located outside these two areas. Depending on the number of return years during the life of the project (assumed to be 12 years in this analysis); energy costs will become a large percentage of the total project cost.

4.5.4 Alternative T4 - Direct Return from Oeste Subarea

Sufficient land is available to lay out all 75 wells required to return 90,000 acre-feet in 10 months within 1.5 miles of the East Branch. Plate 4 shows the potential well locations.

Table 4-10
Capital Costs Associated with Alternative T4 for Various Volumes
10-Month Return Period

Total Stored Volume (acre-feet)	Return Volume (acre-feet per year)	Cost (millions, 2004 dollars) Capital	Operation (annual)	Total Cost for 30 Year Project (used 12 times)
75,000	15,000	$15.8	$2.8	$49
150,000	30,000	30.3	5.3	94
225,000	45,000	46.1	8.1	143
300,000	60,000	61.8	10.7	190
450,000	90,000	97.5	16.2	292

Energy costs were calculated using $0.12 per kilowatt hour.

The costs shown in Table 4-10 include the capital costs for the wells, pipelines, and pumps needed to return one-fifth of the stored volume per year, as well as the annual operating costs. Each well would be equipped with a pump capable of returning the groundwater to the East Branch. The energy cost increases as the distance between the well and the aqueduct increases. The static lift of 770 feet is constant, but the head loss increases proportionately with the distance away from the East Branch. If Metropolitan requests the maximum annual return 12 times (four times every 10 years), the operating costs will amount to approximately 67 percent of the total project costs.

4.5.5 Alternative T5 – Entitlement Exchange Alternatives

There are no capital or electrical operation costs associated with this project.

4.6 Ranking of Alternatives

Table 4-11 presents a qualitative rating of these *take* alternatives relative.

Table 4-11
Qualitative Rating of *Take* Alternatives

Alter-native	Potential Range of Annual Return (acre-feet per year)	Capital Cost Range* (millions, 2004 dollars)	Annual Operation Cost Range* (millions, 2004 dollars)	Cost Range** (dollars per acre-foot of *Take*)	Ability to Return Large Volumes	Proximity to State Water Project	Oper-ational Flexibility	Environ-mental/ Other Consid-erations
T1	15,000-90,000	$13– 73	$3– 16	$302–273	High	Medium-High	High	None
T2	15,000-60,000	$15– 70	$3– 12	$315–330	Medium-High	Low-Medium	High	None
T3	15,000-60,000	$13– 82	$1– 6	$154–238	Medium-High	Low-Medium	Medium	Medium
T4	15,000-90,000	$16– 98	$3– 16	$321–298	High	High	High	None

T5	Varies; see Figure 1-7	$0	$0	$0	Low-Medium	High	High	None

*Cost range is screening-level costs for infrastructure and operation (electrical energy).
**Assumes 12 years of maximum return volume to MWD, groundwater bank is cycled 3 times during the 30 year period. *Take* is 12 times the maximum return volume minus the 10-percent aquifer loss.

Table 4-12 shows the numeric ranking of four of the seven screening categories listed in the screening matrix. All categories are ranked from +1 to +5, except for the category Environmental/Other Considerations. This category is ranked with a scale of negative -5 to positive +5 because the "other considerations" could be negative or positive.

Table 4-12
Numeric Ranking of *Take* Alternatives

Alternative	Engineering[1]	Hydrogeology[2]	Economics[3]	Environ-mental/ Other Considerations	Total	Relative Rank
T1	4	5	4		13	T1
T2	3	4	3		10	5
T3	2	4	4	3[4]	13	T1
T4	4	5	4		13	T1
T5	5	2	5		12	4

[1]Engineering evaluation of the proximity to the SWP and operational flexibility in Table 4-11.
[2]Hydrogeologic evaluation of the ability to return large volumes in Table 4-11.
[3]Economic evaluation of the cost per acre-foot in Table 4-11.
[4]Judge +3 for its integration of multipurpose facilities that benefit local cities.

4.7 Conclusions and Recommendations

All five of the *take* alternatives described passed the fatal flaw screening and were carried forward to the cost assessment phase of the study in Section 7.0. The alternatives range from small (few tens-of-thousand acre-feet) to relatively large (several tens-of-thousand acre-feet). The alternatives were evaluated separately to assess their individual characteristics; however, a combination of alternatives may ultimately provide the best match of water management strategies to both MWA's and Metropolitan's water portfolio. For example, Alternative T0 on its own may not have the same benefits or appeal as the other alternatives because it is limited to a 15,000 acre-feet per year return (equivalent to a 75,000 acre-foot bank), but it is a necessary component of Alternative T3.

The ranking of alternatives based on the merits of engineering, hydrogeology, economics, and environmental and other considerations, yielded the followings conclusions:

- A return project is most favorable along the East Branch in the Oeste subarea, or along the Mojave River Pipeline.

- Small return projects such as Alterative T0 are practical and bring local value when integrated with larger scale projects. They also increase the overall operational flexibility.

- Entitlement exchange can bring additional value to the *take* alternatives. It can reduce the overall *take* infrastructure cost as well as reduce energy cost if it is a fixed quantity within the Program. It can also allow construction to be phased. The value added is clear, but at the same time, an entitlement exchange can reduce MWA's operational flexibility. Local demands are rapidly increasing, which could reduce entitlement exchange volumes over time unless MWA stores sufficient volumes of Metropolitan water to meet the local groundwater demands.

5.0 Local Water Agency Participation

The purpose of this section is to determine which local agencies could participate in the MWA/Metropolitan Program, and present a review of their existing and potential facilities. Estimates are made for the potential quantities of water for local agency participation (*put* and *take* operations).

This section describes the following activities:

- Potential benefits for local agency participants
- Screening of local agencies that could be involved
- Existing facilities of these agencies that could be used in the Program
- Potential new facilities for these agencies that could be used in the Program
- Suggested monitoring options for use of the facilities

This following subsections focuses on reviewing *put* and *take* mechanisms as a means of storing imported water within the MWA boundary by local agencies.

The *put* of Metropolitan water will be by direct recharge or by in-lieu recharge. In-lieu recharge refers to when Metropolitan's supply is used directly by participating agencies and local wells are shut off during that time, resulting in a net input to groundwater storage.

The return of water to Metropolitan, or *take*, will be by one of three means:

1. "Entitlement exchange" in which, MWA would leave its State Water Project Entitlement water in the Aqueduct for delivery to Metropolitan in return for previously stored water.
2. "Direct return" in which MWA or a local agency would pump groundwater and convey it directly to the East Branch for delivery to Metropolitan.
3. "Mutual exchange" in which MWA or a local agency would deliver water from some other source to the East Branch for delivery to Metropolitan.

The MWA Formation Act, the Mojave River Judgment (Judgment), and the Regional Water Management Plan (RWMP) allow for a long-term water management program that includes storing water to be developed. Without the Judgment storing would not be possible – any stored water would be subject to being extracted by others. A project must be developed which operates within the constraints of the Judgment.

5.1 Potential Benefits for Participating Local Agencies

There are several potential benefits for local agencies that participate in the proposed Program. Local agencies' wells could be used during the Program in return for a cost-sharing benefit in *take* years. Local agencies could participate by accepting Metropolitan supply in *put* years as direct delivery to spreading areas, agricultural areas, or water treatment plants, reducing their use of groundwater (this equates to in-lieu recharge).

The *put* operation translates to higher groundwater levels in localized areas. For example, higher groundwater levels would occur when and where the *put* water is recharged to the groundwater aquifer, either directly or as *in-lieu* recharge.

In-lieu recharge means that the groundwater does not get pumped out as usual, but that the additional surface water supply is used instead, and therefore the groundwater levels stay at a higher level. In-lieu recharge may be a good option for agricultural users because no water treatment of SWP water for agriculture is required. Reduced energy requirements and costs associated with pumping are also benefits of such a program. With in-lieu recharge, pumps would be shut off so that pumping energy would be saved.

Local agencies' existing distribution facilities could also be used to convey water for groundwater storage. Excess capacity of pipelines, water treatment facilities, storage reservoirs, and current recharge facilities may be used more often and for multiple purposes. This would mean higher maintenance costs associated with running facilities for longer periods of time, however cost-sharing opportunities would also be available if several local agencies participated.

There is the potential that certain MWA/Metropolitan Program components could create need for new facilities to be used not only for the Program but also by the local agency. The program may delay or replace building a high cost well or storage facility by a local agency. These potentials need further investigation by the local agencies and are currently being discussed at inter-agency meetings.

5.2 Screening of Local Agencies

The entire MWA service area was considered for screening of local agencies. Local agency participation would have to be consistent with MWA's RWMP, specifically, any projects would need to:

- Be supportive of the RWMP goals and objectives,
- Receive input by the Technical Advisory Committee (TAC) or appropriate subcommittee,
- Have broad stakeholder acceptance and be institutionally and financially feasible,
- Have no significant redirected impacts to MWA stakeholders.

Specific criteria were established for screening of local agencies that could participate in the Program by shared use of their facilities. Based on costs of conveying water over distance, and involving the agencies with greater system capacities, three factors were used; proximity to the East Branch, existing production, and projected growth.

5.2.1 Proximity to the East Branch

The first screening criterion applied was the distance from the East Branch, since it has an essential role in the Water Management Program. The closer the local water agency is to the East Branch, the lower the costs for transferring water to and from the Aqueduct.

The Alto and Oeste subareas are the closest to the East Branch of all six MWA subareas (Plate 5). Therefore, the Alto and Oeste subareas were the subject of further screening with production well data derived from the MWA database. Although these two subareas contain a large number of water agencies, only County Service Area 70L, Baldy Mesa Water District, Victor Valley Water District, County Service Area 70J, and Hesperia Water District are closest to the East Branch (Plate 5). Sheep Creek Water Company and the City of Adelanto were not as close to the Aqueduct and so did not pass the screening at this time.

5.2.2 Existing Production Data

Data provided by MWA shows that recent (2002-3 water year) well production ranges from one acre-foot per year to 2,500 acre-feet per year. The average production from 1993 to 2003 was approximately 176,470 acre-feet per year for the entire MWA service area. Because this study was focused on districts near the East Branch, only high production wells in this vicinity were looked at in more detail.

The highest well production, is within Alto subarea (Victorville, Apple Valley, and Hesperia). This subarea contains 14 wells with recorded production rates over 1,000 acre-feet. Most of these are about 5 miles from the East Branch.

5.2.3 Projected Growth and Future Production

According to the Southern California Association of Governments (SCAG) data, the highest projected 2000 to 2030 population growth rate is up to 5,000 percent near Kramer Junction, and over 250 percent in the Victor Valley, Apple Valley, and Hesperia area.

For *take* operations in terms of production well locations, the Alto subarea appears to be the most ideal location for extraction. This area contains numerous water agency purveyors. High growth areas are Baldy Mesa Water District, County Service Area 70J, Hesperia Water District, and Victor Valley Water District. In addition to County Service Area 70L, all of these areas are identified as being close to the East Branch.

5.3 Selection of Local Water Agencies

The following water agencies were identified and contacted to discuss their interest in a potential MWA/Metropolitan Program:

1. Hesperia Water District,
2. Victor Valley Water District,
3. Baldy Mesa Water District,

4. San Bernardino County Special Districts 70J and 70L.

Though identified in section 5.2.1 as potential contacts, Sheep Creek Water Company and the City of Adelanto were not contacted because of low production and growth.

A phased approach was adopted to consider further development of the potential participation of the selected local agencies. The first phase was to meet with these districts, introduce the MWA/Metropolitan Program, and discuss their facilities and potential interest in such a program. This was accomplished and documented in the following subsections. Later phases of involvement by local agencies will depend on subsequent technical analysis, their continued interest, and the direction of the MWA/Metropolitan Program.

5.4 Existing and Potential Facilities of Interested Local Agencies

A description of the facilities of interested water agencies is given below. Information was derived from available documentation and from interviews with the agencies. As agencies continue to be interested and the potential Water Management Program moves forward, more collaboration will be needed.

Initial meetings with these agencies were held during November 3-4, 2004. It was stated to all parties in the meetings by MWA that this study was an initial analysis of the possibilities of engaging in a water management program that included groundwater storage with Metropolitan. Meeting details are provided in Attachment 1 of Technical Memorandum No. 06.0. At each meeting, an overview of the potential Water Management Program was given first, including a general description of possible *put* and *take* activities. This was followed by listing some potential benefits for local agencies and a preliminary discussion about how the individual water agency could be involved.

All four agencies were interested in some aspect of the potential Water Management Program or obtaining more information as it becomes available. Each agency provided data on their system and concepts for potential facilities. Some facilities could be conceptualized at a regional level, for example, a connection between Baldy Mesa Water District and the neighboring County Special Districts. The agency representatives all see the importance of considering common projects now, because of the rapid growth and opportunities for purchasing land for the required facilities becoming more limited and expensive.

The agencies' representatives interviewed expected that there would be cost-sharing benefits that were at least worth investigating. Use of a water treatment plant is a high priority for Baldy Mesa Water District and Victor Valley Water District and the agencies' representatives expected it to operate on an interruptible basis, when State Water Project supplies are available. Institutional issues about guaranteeing SWP supplies for financing the water treatment plants (WTPs) will need further investigation.

Water quality issues are a common concern of the agencies interviewed. The quality of return water accepted in the Aqueduct will need to be determined and agreed upon by the California Department of Water Resources (DWR) and Metropolitan.

5.4.1 Victor Valley Water District

Victor Valley Water District (VVWD) is located in the northern portion of the Alto subarea, and has the Mojave River Pipeline passing through its boundary, see Plate 5.

In the year 2000, the estimated population of VVWD was over 49,000 with 15,668 service connections. The average day demand was 695 gallons per day (gpd)/connection or 10.9 million gallons per day (MGD). The maximum day demand was 2,085 gpd/connection or 32.7 MGD. Under year 2000 conditions with 25 existing wells operating at full capacity there is an excess of 2.67 MGD of supply over maximum daily demand.

VVWD has over 300 miles of pipelines with two booster pumping stations and 19 storage facilities with a total capacity of 54 MG. There are also 25 wells with a total production capacity of 24,538 gallons per minute (GPM) or 35.3 MGD (Table 5-1). With a projected growth rate of 500 connections per year, by the year 2005 the existing wells will not be able to meet maximum daily demand.

Table 5-1
Victor Valley Water District Well Details

Well No.	Ground Elevation (ft)	Capacity (GPM)	Overall Efficiency (%)
2	2753	548	72.5
4	2875	424	62.7
5	2894	475	61.2
7	2940	231	37.2
9	2985	669	69.2
10	2947	536	64.2
15	2940	580	64.3
16	2880	995	70.8
18	2730	756	73.5
19	2710	513	52.4
20	3000	1,980	70.6
21	2860	411	62.9
22	3000	1,980	71.2
23	3060	1,066	69.7
24	3070	679	64.8
25	3080	1,072	NA
26	3110	1,123	71.7
27	2930	950	66.2
28	3105	873	70.3
29	3265	834	57.7
30	2940	960	67.5
31	3020	1,423	73.3
32	3040	809	63.8
33	2885	1,029	61.5
34	3110	1,072	65.9
35	---[1]	750	---[1]
36	2875	800	---[1]
37	2999	1,000	---[1]

[1]--- Data not available

Source: So and Associates 2000

Table 5-2 shows the relationship between the expected growth rate and percentage of total system capacity used during the Average Day flows.

Table 5-2.
VVWD Projected Average Day Water Requirements

Year	Total Connections	Average Day Requirements (MGD)	Total System Capacity (%)
Projected Growth at 500 Connections/Year			
2000	15,668	10.80	30.6%
2005	18,168	12.63	35.7%
2010	20,668	14.36	40.7%
2015	23,168	16.10	45.6%
2020	25,668	17.84	50.5%
Higher Growth Rate at 750 Connections/Year			
2000	15,668	10.80	30.6%
2005	19,418	13.50	38.2%
2010	23,168	16.10	45.6%
2015	26,918	18.71	52.9%
2020	30,668	21.31	60.3%

Source: So and Associates 2000

Table 5-3 describes the existing storage capacities per each pressure zone. Most of the facilities' capacity is within Pressure Zone 2.

5.4.1.1 Proposed Facilities

VVWD has a plan to increase well production with 10 new wells that are in design stage, and are expected to be completed within 18 months. This will accommodate the maximum day supply they need for most days, and allow their use of off-peak energy rates. VVWD is investigating the potential for groundwater recharge at a 64 acre parcel near the center of their district, and there is a demonstration spreading facility near Sycamore Drive. To increase flexibility of their operations and bring in a new water source, VVWD is considering a 20-30 MGD surface water treatment plant for an interruptible SWP supply. The proposed VVWD facilities are shown in Plate 6.

A draft memorandum regarding a concept for VVWD and BMWD joint percolation facilities at a northern Oro Grande Wash 64 acre site (VVWD 2004) states that VVWD has an interest in capacity of 13,000 AF/yr. The proposed concept includes a siphon turnout adjacent to the Oro Grande Wash and a water pipeline with several points of delivery. The siphon turnout capacity would be 41 MGD for BMWD and VVWD combined. The pipeline turnouts would include among others VVWD's 64 acre percolation property south of Yates Road and VVWD's 20 acre WTP at Amethyst and Sycamore.

MWA, BMWD, the City of Hesperia, the City of Victorville, and the County are currently engaged in conceptual level design of potential joint use facilities in the Oro Grande Wash area.

Table 5-3
Existing VVWD Storage Reservoirs

Pressure Zone	Reservoir Number	Elevation (ft) Base	Elevation (ft) High Water Level	Capacity (MG)
1	2	2,874	2,906	1.50
1	3	2,889	2,905	0.27
	4	2,874	2,906	1.5
	6	2,840	2,880	0.1
			Subtotal:	*3.37*
1A	9	2,915	2,939	0.5
			Subtotal:	*0.5*
2	5	3,049	3,081	2.0
	13	3,050	3,080	3.0
	15	3,050	3,081	5.0
	18	3,050	3,081	3.0
	19	3,050	3,081	5.0
	20	3,050	3,081	5.0
			Subtotal:	*23.0*
3	7	3,269	3,309	2.5
	8	3,269	3,309	2.5
	12	3,268	3,306	5.0
	14	3,268	3,307	5.0
			Subtotal:	*15.0*
4	10	3,150	3,189	2.5
	11	3,150	3,189	2.5
	16	3,150	3,189	2.5
	17	3,150	3,189	2.5
			Subtotal:	12.5
			Total Storage (MG):	**54.37**

Source: So and Associates 2000

5.4.2 Baldy Mesa Water District

Baldy Mesa Water District (BMWD) is adjacent to the East Branch in the Alto subarea and the Mojave River Pipeline cross its boundary. BMWD serves over 6,000 connections. It contains nine production wells that can pump a total of 34.1 AF/day. There are also seven reservoirs within the District.

By 2010 it is expected that there will be 7,000 connections in the District, with build out conditions likely to total 64,000 connections. Therefore a long term goal for Baldy Mesa Water District is to secure an alternative water source.

5.4.2.1 Proposed Facilities

BMWD is planning for a new 5,000 gpm ion-exchange Arsenic treatment plant for water from five of its wells. The Arsenic WTP will be located within a mile of the East Branch. The District also is constructing a 500-700 gpm well near the East Branch. These proposed facilities may be considered as a possible link for the MWA/Metropolitan *take* operations that would only require a pipeline connection to the East Branch.

BMWD considered participation in a 10 MGD regional water treatment plant (Parsons 2001). This WTP could serve Adelanto, County Services Districts, Hesperia, Sheep Creek Water Company, and Victor Valley. See Plate 6 for locations of the proposed BMWD facilities.

As stated for the VVWD in section 5.4.1, BMWD has a proposed project with VVWD for a 64 acre recharge facility in Oro Grande Wash (VVWD 2004). The BMWD capacity in this project is 10,000 acre-feet per year.

5.4.3 Hesperia Water District

The Hesperia Water District (Hesperia) is located to the west of the Mojave River. The East Branch and Morongo Pipeline cross its borders.

There were 20 wells producing 15,210 GPM (21.9 MGD) in water year 2003 and storage capabilities of over 40 MG. The average day demand was 10 MGD. Excess pumping capacity over the average daily demand based on current production was 6.5 MGD. Table 5-4 lists Hesperia's production wells including the available well production capacity in excess of current demand.

Hesperia has excellent groundwater quality and no reported constituents of concern. They have no need for a regional water treatment plant for their own supply.

5.4.3.1 Proposed Facilities

Hesperia and other water providers have had preliminary discussions regarding the potential for a regional pipeline from a well field near the Mojave River, to carry groundwater westward, with possible connections to BMWD and VVWD. This pipeline could be used in reverse to bring SWP supply from a treatment plant (VVWD or the Regional WTP) eastward to Hesperia.

Hesperia is proposing to expand groundwater recharge facilities and get a wide distribution of recharge sites within their boundary. They are working with San Bernardino County Flood Control District and Cal-Trans to make dual use of flood control detention basins. Sites include Ranchero Road and Cedar Avenue. Proposed facilities are shown in Plate 6.

Table 5-4
Hesperia Water District Production Well Details (Alto Sub Basin)
(GPM)

State Well No.	Maximum Production[1]	Production in WY 2003	Excess Well Production
03N04W02C01	1,938	1,911	27
04N04W08G02	1,725	1,725	0
04N04W08G03	0	0	0
04N04W08N01	1,236	0	1,236
04N04W15F01	839	703	136
04N04W24G01	0	0	0
04N04W24G02	0	0	0
04N04W24P02	2,740	1,710	1,030
04N04W26Q01	0	0	0
04N04W26Q02	2,951	2,385	566
04N04W28C01	1,453	1,107	346
04N04W28H01	0	0	0
04N04W29F02	1,611	1,564	47
04N04W29J01	1,245	299	946
04N04W32R02	2,359	2,359	0
04N04W36G03	0	0	0
04N04W36Q01	65	65	0
04N04W36Q02	103	66	37
04N04W36R01	525	388	137
04N05W13J01	930	930	0
Total (gpm)	**19,720**	**15,212**	**4,508**
Total (MGD)	**28.4**	**21.9**	**6.5**

[1] based on production data from water year 1994 through water year 2003
Source: MWA data

5.4.4 San Bernardino County Special District 70L and 70J

San Bernardino County Special Districts 70L and 70J (County Districts) are located to the south of the East Branch in the Alto subarea. Based on a 1991 report, demand in District 70L was met by groundwater production from eight wells grouped into three sites. The 1990 combined production capacity of these wells was 2,873 GPM (4.1 MGD). The estimated 1990 production was 1,937 GPM (2.7 MGD).

The distribution system for County Districts 70L and 70J is primarily comprised of 6- and 8-inch diameter distribution lines with limited 10-, 12-, and 16-inch diameter transmission lines. A few of the pipeline diameters are indicated as 24-inch in Zones 1 and 2 of County District 70 L.

One new well, Well 10 for County District 70L, is located just west of the County line and adjacent to the East Branch. In County District 70J there is a new 1,000 GPM well in Section 33 near Oro Grande Wash.

5.4.4.1 Proposed Facilities

There are proposed improvements to water transmission lines over the next five years. New wells are being drilled to help accommodate the recent increase in demand and to shift pumping to off-peak energy rates. An initial analysis by Parsons (2001) indicates limited capacity for moving additional water from Aquifer Storage and Recovery (ASR) wells to the East Branch and proposed a 4- to 10-MGD water treatment plant (WTP) near the East Branch. The ASR system that was studied could provide some capacity to move water to the East Branch; however, the area that was studied has been identified as having groundwater quality issues. The proposed WTP is located close to the East Branch. Delivery of *put* water could be made through this plant to Adelanto, VVWD, Hesperia, or the County Districts.

Additional capacity to transmit groundwater to the East Branch for *take* operations may be considered by using extraction wells instead of the ARS. New Well 14 is an example of this. It may be possible to use delivery of SWP water for recharge in winter months in exchange for SWP water delivered to the proposed WTP in the summer months.

5.5 Integration of Local Agency Information

The data from the interviews allowed the Team and MWA to develop an overview of what the districts were planning and how regional projects could be developed that would benefit the potential Water Management Program and multiple local agencies. Three of the districts are most interested in all *put* and *take* alternatives, while VVWD was more interested in entitlement exchange possibilities.

Potential planned facility demands for Baldy Mesa Water District, Victor Valley Water District, and San Bernardino County Special Districts are presented in Table 5-5. Excess well production expected in 2010 is indicated in Table 5-6.

Table 5-5
Summary of Demand Estimates
(Values in MGD)

Demand Type	Year	Hesperia	Baldy Mesa	County Districts	Victor Valley	Total
Maximum Capacity	Estimated for 2010; assumed available in 2004	28.5	11.1	8.3	40.0	87.9
Maximum Day	2000	28.5[2]	6.7	8.3	35.5	79.0
Typical Summer Day[1]	2000	21.4	5.0	6.2	26.6	59.2
Minimum Winter Day	2000	---[3]	1.7	1.7	7.1	10.5

[1]Typical Summer Day assumes 75 percent of Maximum Day Average demand
[2] estimated by capacity
[3] no data

In all cases demands are highest for VVWD. In most cases, the scenario requirement for 2010 is higher than for current or past demands.

Table 5-6
Estimated Excess Well Production for 2010
(MGD)

	Baldy Mesa		County Districts		Victor Valley		Total	
	Production							
Estimated Well Production Capacity	11.1		8.3		40.0		71.4	
	Demand							
Day Type	***Demand***	***Excess***	***Demand***	***Excess***	***Demand***	***Excess***	***Demand***	***Excess***
Maximum Day	11.1	0.0	10.9	(2.6)	60.0	(20.0)	98.0	(26.6)
Typical Summer Day	8.3	2.8	8.2	0.1	45.0	(5.0)	70.3	1.1
Minimum Day	1.7	9.4	1.7	6.6	7.1	32.9	13.3	58.1

Note: ( ) indicates a negative value

Tables 5-7a and 5-7b are summaries of the local facilities that incorporates the documentation review and the interviews.

Table 5-7a
Summary of Local Facilities for *Put* Operations

Existing Facilities	Proposed Facilities/Active Construction
Victor Valley Water District	
19 storage facilities (54 MG capacity)	20-30 MGD water treatment plant, or Regional WTP (10 MGD)
Pipelines with total length of 749,000 feet (including 5-24-inch diameter)	New turnout from East Branch, 30 MGD pipeline
Oro Grande Wash Demonstration Project (1-acre). A previous 2-acre demonstration site in Oro Grande Wash has been backfilled.	New 64-acre recharge facility.
Hesperia Water District	
N/A	New recharge sites at Cedar Street, and Ranchero Road. Potential regional project for discharge to recharge at the Unnamed Wash.
	Potential to use treated water from VVWD or a regional WTP via the regional pipeline
Baldy Mesa Water District	
7 reservoirs = 14 MG Storage	Regional water treatment plant (10 MGD)
San Bernardino County Special Districts	
N/A	Regional water treatment plant (10 MGD)

Table 5-7b
Summary of Local Facilities for *Take* Operations

Existing Facilities	Proposed Facilities/ Active Construction
Victor Valley Water District	
25 production wells	10 new wells
Pipelines with pressure reducing and booster pumping stations	N/A
Hesperia	
N/A	Regional Pipeline – with 5 new wells
	New wells near Morongo Pipeline
Baldy Mesa	
9 wells in production totaling 34.1 AF/day (26 MGD)	Arsenic Water Treatment Plant 5,000 gpm (7 MGD) capacity to treat 5 wells.
N/A	New well up to 700 gpm (1 MGD) near Aqueduct, and an Arsenic water treatment plant (not a regional WTP).
San Bernardino County Special Districts	
New well near County line.	Reverse flow pipelines for regional water treatment plant (10 MGD)

5.5.1 Potential Local Agency Involvement in MWA/Metropolitan Program

These four agencies could participate in the MWA/Metropolitan Program. Plate 6 shows the facilities that could be involved. Schematic diagrams showing how existing and potential local agency projects could be part of *put* or *take* operations are shown in Figure 5-1 and Figure 5-2.

To demonstrate the quantity of water that could be involved with the four local agencies participating in the Program, preliminary estimates of maximum capacity for *put* and *take* operations are summarized in Table 5-8. For this "order of magnitude" estimate, it was assumed *take* operations would only occur when local demands were low, at 20 percent of capacity, as in typical winter days in four local agencies studied. The remaining 80 percent of capacity in low demand days could be available for the MWA/Metropolitan Program or other programs.

Entitlement exchange using local facilities would be limited to the capacities of the *put* facilities listed in Table 5-8. The *take* from entitlement exchange would equal the *put* quantities, and timing would depend on availability of MWA's SWP supply.

5.6 Potential Mitigation Planning for Alternatives

In Section 1.0, alternatives that passed the initial screening were described as *put* or *take* alternatives. In discussions with the local water agencies, other alternatives were put forward as possibilities. This section includes a discussion of mitigation options that could be considered and the potential monitoring could help detect problems. Only the last two items of the following list of MWA/Metropolitan Program mitigation issues are discussed in this section:

- Environmental mitigations – for new facilities
- Financial mitigations – if water costs and pricing structure become un-workable for any parties.
- Accounting for water quantities – mitigation for delivery losses or stored water that is unrecoverable.
- Water quality mitigations- for the effect of *put* water on groundwater quality and for the quality of *take* water that is delivered to the East Branch.

The alternatives that involve the local agencies have monitoring requirements for flow measurements and water quality sampling. Some basin-wide groundwater monitoring needs to be considered to estimate losses from the water bank in the subareas. Groundwater modeling may be required to determine effects of the water storage.

Mitigation options and associated monitoring should be revisited if there is a problem with the use of a facility. It may be decided that the facility should no longer be used for *put* or *take* operations.

Table 5-9 compares *put* and *take* issues with potential monitoring needs.

5.7 Conclusion and Recommendations

Local Agencies could have an important role in the MWA/Metropolitan Program, in terms of quantities for water storage operations, and in terms of the practical aspects of facility ownership, and operating and maintaining the facilities. There are also potential cost sharing benefits of new facilities and benefits of regional planning that may occur.

Selection of projects that would have mutual benefits to the local agencies and the MWA/Metropolitan Program will be done in Section 7.0 of this report. For the selected projects, anticipated steps include:

1. Preparing maps showing existing and planned facilities, including wells, distribution lines, and storage with capacities.

2. Estimating how much of the existing or planned wells, distribution lines, and storage capacity would most likely be available to deliver water under the *put* or *take* operations. It is assumed this would involve using regional distribution lines and vary by seasons within the operating year.

3. Listing operational and institutional constraints concerning the facilities and well production, such as water quality or water level criteria that would not allow the use of excess capacity, or Watermaster guidelines.

4. Identifying methods of financing the surface water treatment plants, and what water supply reliability guarantees are needed.

Further meetings are recommended with the four selected agencies in the next phases of this project and before facility design stage so that they have the opportunity to consider sizing the projects for regional benefits and cost sharing potential.

MWA may consider discussions with the City of Adelanto if the regional WTP and/or other City water system connections with VVWD continue to develop. Also Sheep Creek Water Company could become part of discussions if the County Special Districts choose to participate in water storage activities.

Table 5-8A: Maximum "Take" Operations

	Capacity of Facilities			Competing Use (b)	Excess over Demand			
					Day	1 Month	2 Months	3 Months
"TAKE" (DIRECT RETURN) OPERATIONS	**cfs**	**MGD**	**AF/day**	**MGD**	**MGD**	**AF**	**AF**	**AF**
New S.B. County Service Area 70L Well 14 (d)	1.5	1.0	3.0	0.2	0.8	71	141	212
VVWD Aqueduct Diversion (c)	46.4	30.0	92.1	20.9	9.1	838	1,676	2,513
New BMWD Well (d)	1.5	1.0	3.0	0.2	0.8	71	141	212
BMWD Pipeline supplied by Arsenic WTP/ BMWD wellfield (e)	11.0	7.1	21.8	1.4	5.7	524	1,049	1,573
Morongo Pipeline (reverse flow) (f)	23.3	15.0	46.2	3.0	12.0	1,108	2,216	3,323
Total "Take"	**83.7**	**54.1**	**166.1**	**25.7**	**28.4**	**2,541**	**5,081**	**7,622**

Notes:

Take (Direct Return) Estimates:

Treatment facilities on pipeline assumed to limit flow during "Take" operations.

(a) Can only be used when no local runoff or MWA/ VVWD recharge.

(b) Competing Use assumes that local daily demand use 20% of capacity in winter or low demand days; the remaining 80% of capacity is considered excess over demand and can be used for other programs.

(c) Victor Valley aqueduct diversion pipeline can be supplied by either VVWD's new or existing wells and proposed regional distribution pipeline from the Mojave River. Capacity of pipe assumed to be limited to 30 MGD of WTP.

(d) Proposed BMWD well has a capacity of 500-700 GPM (1.5 cfs max). Also used 1.5 cfs for County well #14.

(e) BMWD Arsenic Treatment Facility has a proposed capacity of 5,000 GPM (11 cfs on BMWD pipeline).This pipeline assumed to be limited to 11 cfs.

Table 5-8B: Maximum "Put" Operations

"PUT" OPERATIONS	cfs	Capacity MGD	AF/day	Competing Use (a) MGD	Day MGD	Excess over Demand 1 Month AF	2 Months AF	3 Months AF
Regional WTP (b,c)	15.5	10.0	30.7	0.0	10.0	921	1,841	2,762
VVWD Aqueduct Diversion (b,f,g)	46.4	30.0	92.1	0.0	30.0	2,762	5,524	8,286
Proposed Oro Grande Recharge Site (1 acres, 1.5 ft/day percolation) (d,e)	0.8	0.5	1.5	0.0	0.5	45	90	135
Cedar Street Detention Basin (60 acres, 6"/day percolation) (h,i)	15.1	9.8	30.0	0.0	9.8	900	1,800	2,700
Ranchero Road Recharge Site (35 acres, 6"/day percolation) (h,j)	8.8	5.7	17.5	0.0	5.7	525	1,050	1,575
Morongo Pipeline/ Rock Springs and other Recharge Sites (k)	127.0	82.1	251.9	0.0	82.1	7,557	15,114	22,671
Diversion to Unnamed Wash (h,l)	500.0	323.2	991.8	0.0	323.2	29,753	59,505	89,258
Total "Put"	**713.6**	**461.2**	**1415.4**	**0.0**	**461.2**	**42,462**	**84,925**	**127,387**

Put Estimates:

(a) Assumed that Put Estimates are not limited by local agency demand but will serve as alternative supply when available for In-lieu recharge.

(b) Treatment facilities on pipeline assumed to limit flow to served pipeline during "Put" operations.

(c) In-lieu recharge to supply water to meet demand for VVWD, BMWD, County Special districts, and City of Adelanto.

(d) Can only be used when no local runoff or MWA/ VVWD recharge

(e) Oro Grande Wash recharge facilities are estimated at a capacity of 8,000 afy based on VVWD letter of 10/27/04 and 15,000 in letter of 1/14/05. Recharge in tests was 3.25 ft/day under aggressive pond cleaning and maintenance. Use roughly half of test result for this estimate (1.5 ft/day) for long-term average.

(f) VVWD proposed Water Treatment Plant has a proposed capacity of 20-30 MGD (46.4 cfs max) on VVWD Aqueduct Diversion pipeline.

(g) Victor Valley's aqueduct diversion pipeline can be used to supply either VVWD demand (In-lieu recharge) , Hesperia's demand (In-lieu recharge) via proposed regional distribution pipeline, or VVWD's 64-acre spreading ground.

(h) Can only be used when no local runoff or MWA/Hesperia recharge.

(i) Cedar Street net rechargeable area (60 acres) estimated from examination of aerial mapping (April 2004).

(j) Assumed 35 acres (70 percent) of total 50 acre area is used for perennial recharge when not utilized for flood control.

(k) Flow in Morongo Pipeline in "Put" operation is based on maximum flow of pipe at 8 ft/sec velocity. This can be utilized when not competing with other MWA arrangements with pipeline users.

(l) Recharge to the Unnamed Wash would be limited by the turnout capacity from the Aqueduct or flow limitations in the Wash. Maximum turnout flow of 500 cfs is assumed.

Table 5-9. *Put* and *Take* Alternatives and Future Associated Monitoring

Alternative	Monitoring
***Put* Options**	
Aqueduct deliveries to detention pond or recharge spreading grounds (along proposed or existing pipelines)	Provide flow meter to measure inflows to spreading facilities. Maintain monitoring wells near ponds and spreading grounds or if a new facility, install monitoring wells to check on groundwater movement away from the facility. Groundwater quality sampling in the area of influence of the site may be needed.
Aqueduct deliveries through WTP to be delivered to storage, spreading, use or for in-lieu recharge	The WTP will already have flow measurement and water quality testing planned as part of the facility. If water is transferred from the WTP to storage basins/spreading, the monitoring suggestions are the same for the *Put* option described above.
Aqueduct deliveries to washes leading to river recharge	Provide flow measurement at the Aqueduct turnout. Monitoring wells should be established/used to ensure water levels are as expected along the wash. Water quality sampling can be conducted at the wash entrance to the river.
***Take* Options**	
Deliveries to aqueduct from well sites along proposed or existing pipelines	Provide flow meter for deliveries to Aqueduct. Meters will be needed for accounting of local agency contributions to the regional pipelines. Water quality sampling should be done prior to release of water to the aqueduct.

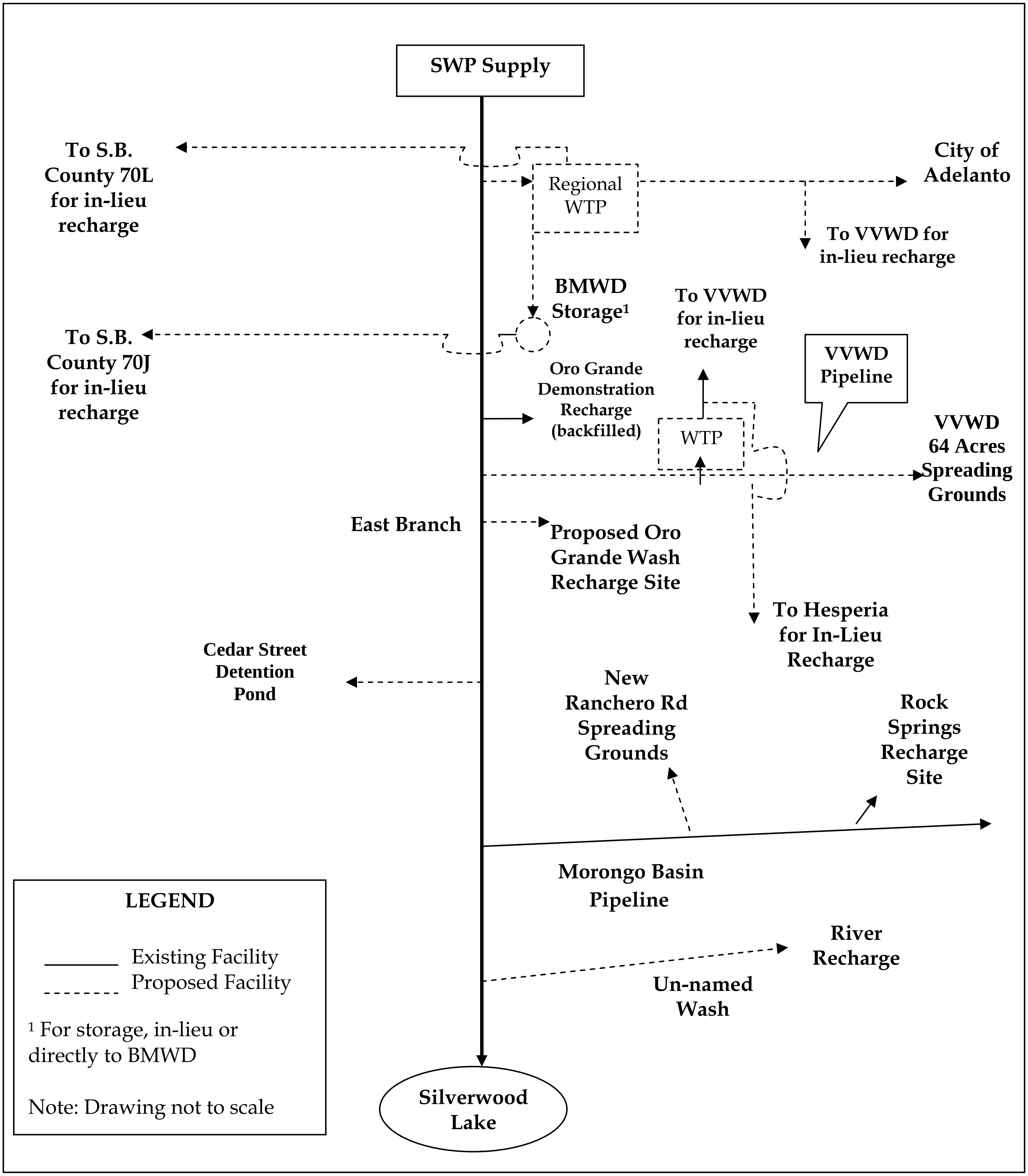


Figure 5-1. Schematic of Main Components of Potential Delivery of Metropolitan "Put" Water to MWA

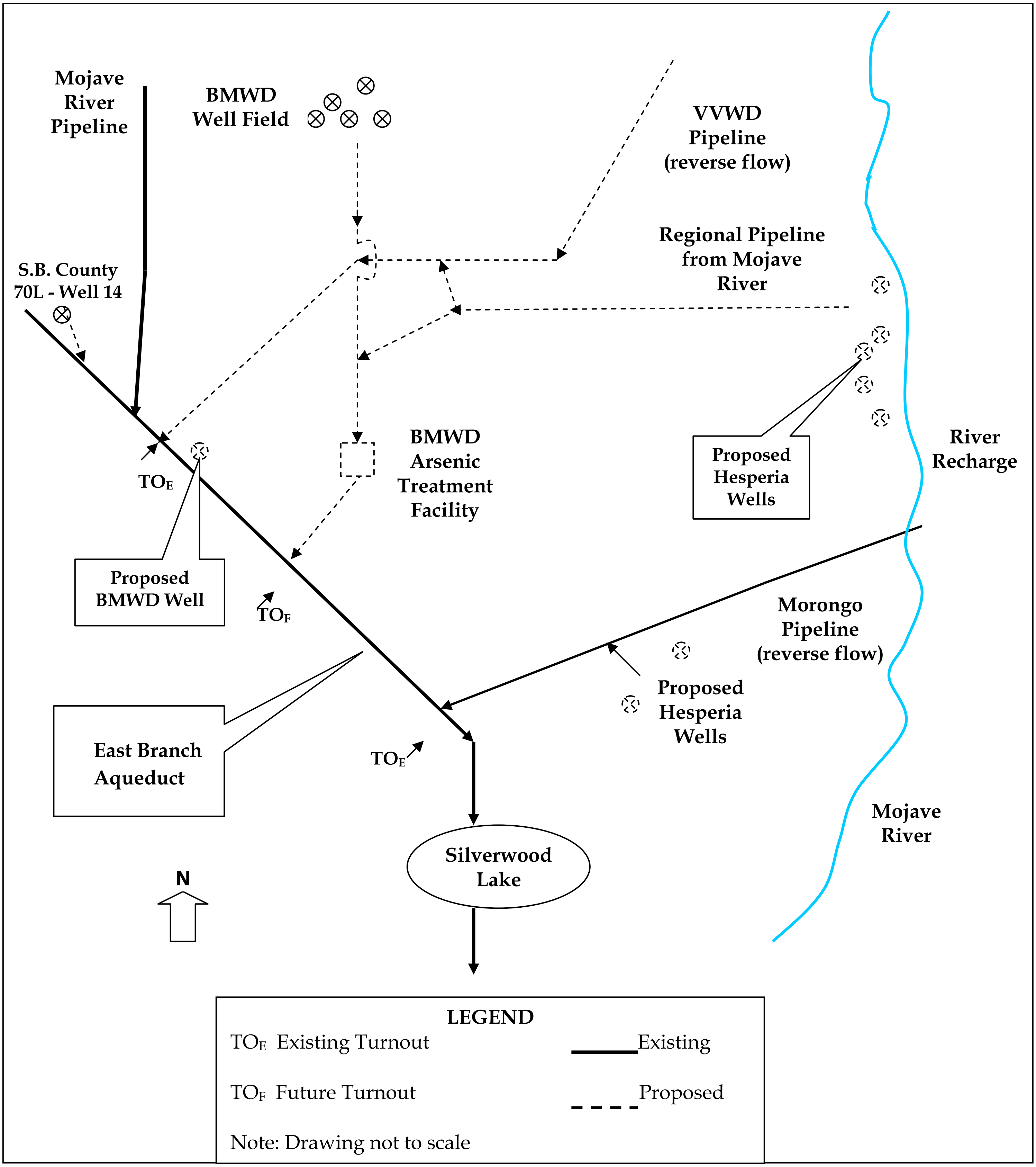


Figure 5-2. Schematic Components of a Potential "Take by Direct Return" Operation

6.0 Institutional Issues Screening of Alternatives

The purpose of this section is to review and screen the previously identified alternatives of the MWA/Metropolitan Program for consistency with, or conflicts with agreements between water agencies, the Mojave Basin Area Adjudication and the Warren Valley Basin Judgment. These issues are identified and their potential effect on the MWA/Metropolitan Program assessed. Closely related water quality effects on the local groundwater basins are being addressed in the environmental documents for this Program, so will not be described within this report.

There are several categories of documents that were reviewed to provide a comprehensive overview of the institutional issues for this section, as shown in Table 6-1.

Table 6-1
Issues – Groundwater Storage and Exchange Projects

Category	Specific Documents
Adjudicated Groundwater Basins	▪ Warren Valley Basin Judgment ▪ Mojave Basin Area Judgment
Conjunctive Use Agreement	▪ Warren Valley Basin Conjunctive Use Agreement
Agreements for use of DWR supply and facilities	▪ California DWR, Standard Contracts, Article 19 ▪ Point of Delivery Agreement
Other Agreements or Policy within Mojave Basin Area	▪ MWA Reserve Entitlement Policy ▪ MWA Storage agreements with Watermaster ▪ Storage agreement between Watermaster and VVWD ▪ City of Victorville Connection Agreement with MWA ▪ Morongo Basin Pipeline Agreement (includes MWA, High Desert WD, Bighorn-Desert View Water Agency, Joshua Basin Water District, and San Bernardino County Special Districts ▪ Antelope Valley East Kern Point of Delivery Agreement
Water Storage and Exchanges in other areas	▪ MWA and Solano County Water Agency ▪ Central Valley Examples - Arvin-Edison Water Storage District/ Metropolitan Water Storage and Exchange Program

6.1 Overview of Institutional Issues

6.1.1 Adjudicated Groundwater Basins

Warren Valley Basin

An adjudication of groundwater rights within the Warren Valley Basin was completed by stipulated judgment in 1977. At the time of the adjudication the basin was in overdraft and a physical solution was required by the appointed Watermaster to maintain groundwater supplies by obtaining supplemental (imported) water. Additionally, growth forecasts foresaw a need for supplemental water to meet the projected demands in the basin. The Watermaster is required to report to the court annually on conditions affecting groundwater use and disposal and implementation of a groundwater monitoring program for basin management.

The Warren Valley Basin area can accept imported water from MWA as part of the potential MWA/Metropolitan Program. The Warren Valley Basin already participates in programs to import supplemental water in the Warren Valley Basin judgment, and as described in later sections, the Warren Valley Basin Conjunctive Use agreement, and the Morongo Pipeline Agreement.

Mojave Basin Area

The Mojave Basin Area Adjudication (1996) establishes that the Basin is in a state of overdraft and, by subarea, provides a physical solution to maintain the groundwater supply. Judgment concepts are fixed and should not be affected by the Program, these include:

- Free Production Allowance
- Base Annual Production Right
- Base Flow at the Lower Narrows
- Production Safe Yield
- Recirculated Water
- Replacement Obligation
- Subarea Obligation

If the Program does involve extraction of previously stored groundwater by MWA for the benefit of MWD, it may be necessary for the Court to determine whether it is feasible and what are the proper accounting methods to be used. Exchange only programs would not have these constraints.

6.1.2 Conjunctive Use Agreement

Warren Valley Basin Conjunctive Use Agreement

The Mojave Water Agency has a conjunctive use agreement (Warren Valley Basin Conjunctive Use Agreement Between Mojave Water Agency, Hi-Desert Water District and Warren Valley Basin Watermaster, October 28, 2004) with the Hi-Desert Water District (HDWD) and Warren Valley Basin Watermaster (WVBW). The purpose of the agreement is "to more efficiently use the water supplies available to the MWA and the HDWD, and to make supplemental water supplies available to the WVBW in the event the Safe Yield of the Basin falls below the combined Adjudicated Water Rights in the Basin of the parties to the Judgment besides HDWD. State Water Project water delivered to the Basin pursuant to this Agreement shall be credited to a 'MWA Storage Water Account.' "

As also considered by the WVBW, deliveries, or lack of deliveries, to the Warren Valley Basin are constrained to prevent adverse effects that could occur to the groundwater basin, such as high groundwater levels causing liquefaction risk or structural problems, or low groundwater levels that cause subsidence or excessive pumping costs.

The conjunctive use agreement included consideration of the Morongo Basin Pipeline Agreement to convey MWA's SWP supplies, and the possibility of conveying and storing other SWP water, such as MWA/Metropolitan Program water, within the Warren Valley Basin. SWP water delivered to Warren Valley Basin would be credited to the MWA storage account.

This agreement does not limit the potential MWA/Metropolitan Program, except for the consideration of scheduling deliveries to allow for existing uses first.

6.1.3 Use of State Water Project Supplies and Facilities

Use of SWP supply in the Mojave Groundwater Basin

The recharge of imported waters into the MWA groundwater basins is part of the water supply program discussed in the Regional Plan (Bookman-Edmonston 1994, Schlumberger Water Services, adopted February 2005) and the Mojave Basin Area Judgment (1996). Implementation of the MWA/Metropolitan Program would necessitate monitoring, and mitigation, as necessary, to address negative effects of recharge and withdrawal. Should there be a pump-back component of MWA/Metropolitan water, monitoring and mitigation would be needed to assure that other users of imported water will not be adversely affected.

Returning Water to SWP Facilities

There are several issues that need to be addressed if there is delivery of previously stored water from local basins to the East Branch. These issues are dealt with in Article 19 of DWR standard water supply contracts, DWR "Interim Water Quality Criteria for Acceptance of Non-Project Water into the State Water Project (March 1, 2001), and the Implementation Procedures for the Review of Water Quality from Non-Project Water Introduced into the State Water Project (March 14, 2001). Based on the criteria in these references, the quality of the water pumped into the Aqueduct is compared to the ambient water quality of SWP water in the Aqueduct. The criteria reflect that the ambient quality can vary by season and by year. If the water is accepted, then monitoring is required to confirm that the water continues to meet the requirements.

Article 19 Water Quality Objectives are shown in Table 6-2 in terms of the maximum, average monthly, 10-year average maximum concentrations.

Table 6-2
State Contract Article 19 Water Quality Objectives

Constituent	Maximum Concentration (mg/L) Monthly Average	10 -Year Average	Maximum
Chloride	110	55	n/a[1]
Sodium	50	40	n/a
TDS	440	220	n/a
Total Hardness	180	110	n/a
Arsenic	n/a	n/a	0.05
Boron	0.6	n/a	n/a
Hexavalent Chromium	n/a	n/a	0.05
Copper	n/a	n/a	3.0
Iron & Manganese	n/a	n/a	0.3
Lead	n/a	n/a	0.1
Selenium	n/a	n/a	0.05
Zinc	n/a	n/a	15.0

[1] n/a = not a water quality objective under Article 19. (California DWR, 1962)

The 2001 DWR guidelines require meeting ambient water quality of the SWP supply, which can be more stringent than Article 19 Water Quality Objectives or Maximum Contamination Limits (MCL's). A long-term summary of the SWP water quality is attached as Exhibit A, in Technical Memorandum No. 09.

The constituents of concern in the groundwater that could be returned to the East Branch include the major ions, Nitrate, Arsenic and Chromium (total Chromium and hexavalent Chromium). Each alternative would have to consider water quality for any constituent that doesn't meet the DWR guidelines.

6.1.4 Other Agreements

Antelope Valley East Kern Delivery Agreement,

MWA has agreed to transfer to Antelope Valley East Kern (AVEK) a part of their SWP annual entitlement, up to 2,250 acre-feet. The AVEK transfer is part of the MWA 12,000 acre-foot reserve on entitlement. The water transferred is conveyed through the AVEK system to a water user within the MWA that otherwise could not receive delivery due to facility limitations. MWA and AVEK have a joint agreement with the DWR to implement the transfer.

MWA Entitlement Reserve

MWA has a policy to reserve up to 12,000 acre-feet of annual SWP entitlement for local needs. This is comprised of up to 2,250 acre-feet to Antelope Valley East Kern (AVEK), up to 7,257 acre-feet to the Morongo Basin Pipeline Participants, and about 2,500 acre-feet for miscellaneous uses. This entitlement reserve would not be available to the MWA/Metropolitan Program unless the Program results in the ability for MWA to pump previously stored water for re-distribution through MWA facilities to meet in-basin demand,

and/or sufficient water is stored under the Warren Valley Conjunctive Use Agreement to meet the delivery needs of Hi-Desert Water District. In that case, it would be only necessary to "reserve" up to 2,250 acre-feet for the AVEK entitlement transfer. Note that AVEK use has historically been less than 1,500 acre-feet per year.

If MWA can utilize previously stored MWD or other water to meet local needs, then MWA would have gained flexibility to make Table A available to exchange partners.

Solano County Water Agency Exchange Agreement

MWA has an exchange agreement with Solano County Water Agency (SCWA). SCWA is able to place a call on MWA approved Table A entitlement equivalent to ½ of the balance of SCWA entitlement previously delivered to MWA for storage, not to exceed 20,000 acre-feet. This agreement has a 10,000 acre-foot reserve for MWA. SCWA is required to notify MWA by April 5 of each year in which they will either deliver or take water. Return of stored water to SCWA occurs by entitlement exchange and would have precedence over entitlement exchange return to MWD.

MWA Storage Agreement with Watermaster

The MWA storage agreement is currently limited to 350,000 acre-feet total of MWA storage, spread over five subareas as follows:

Alto	150,000 AF
Centro	50,000 AF
Baja	100,000 AF
Este	25,000 AF
Oeste	25,000 AF

MWA had 95,000 acre-feet in designated storage as of March 2004. The storage agreement might need to be modified to increase the quantities that MWA can store to accommodate the volumes of water that might occur with the MWA/Metropolitan Program.

Morongo Pipeline Agreement

There is a 1991 agreement between MWA and Hi-Desert Water District, Bighorn-Desert View Water Agency, Joshua Basin Water District, and the County of San Bernardino office of Special Districts that identifies how the Morongo Basin Pipeline is financed and operated. This agreement provides that the participants can receive a defined portion of a maximum of 7,257 acre-feet per year when SWP allocations are at 100%, and proportionately less when allocations are reduced by DWR.

The water delivery requirements of this Agreement have the potential to reduce the amount of water available for exchange back to MWD during dry years, with the exceptions noted in the "MWA Entitlement Reserve" discussion.

High Desert Power Plant Delivery

The High Desert Power Plant (HDPP) currently uses State Water Project water for cooling. The City of Victorville purchases the water from the MWA under Ordinance 9 and conveys the water to the plant. Under Ordinance 9 and the HDPP California Energy Commission permit, the HDPP must be self-sufficient when there is a need to reduce SWP deliveries. HDPP has a storage program with Victor Valley Water District to provide previously stored SWP water from the local groundwater basin during periods when SWP water cannot be provided from the Aqueduct.

Agreements with Local Water Agencies

To date, there are no other agreements with local water agencies that would limit the MWA/Metropolitan Program. Agreements with local agencies may become needed if specific water storage alternatives are developed that use local agency facilities.

6.2 Issues with Existing Groundwater Banks

There are several successful long-term groundwater storage programs and water exchanges in California. The potential MWA/Metropolitan Program can take “lessons” from these other cases and identify items to include in a potential exchange agreement (Natural Heritage Institute, 2001). Principles for agreement were written for the Arvin-Edison/Metropolitan water bank project in neighboring Kern County (Bookman Edmonston 1989) that has become an example of a successful working water bank. The BE/SAIC Team experience, the important points from this agreement and the lessons learned would be useful to the MWA/Metropolitan Program:

Integrity of current water supplies

Importing water should not interfere with the maintenance of current water contracts and availability of water. This involves not only the amount of water, but the rate of delivery and associated costs. The agreement should also clarify that the reliability of the current supply of Metropolitan and Mojave water would be improved by the Program. DWR and contractors of the SWP supply would want to be informed about potential effects on the SWP.

Water use by existing Mojave Basin Area purveyors could also be made more efficient in terms of energy use and cost with the MWA/Metropolitan Program compared to without the Program. For example, after a *put* operation there will be a mound of groundwater, reducing pumping lifts until the time a *take* operation brings the water back to MWD. Basin conditions, such as groundwater levels and water quality, should not be worsened by the Program.

Point of Delivery Agreement

An agreement would be needed between the main parties (in this case DWR, MWA and Metropolitan) defining points of delivery, priorities with any other users, and limits to quantities. The Arvin-Edison/Metropolitan point of delivery agreements took seven years to complete and the program was initiated using annual letters of agreement. The Arvin-Edison/ Metropolitan Program (Arvin-Edison, 1997) involved Central Valley Project water supplies, which complicated the "Place of Use" issue, which is not the case with a MWA/Metropolitan Water Management Program.

Cost sharing terms

Cash flow terms should also be included in the agreement so that there is no adverse impact on cash flow for MWA. Cost allocation can be broken up into capital, start up costs and operating costs (*put* or *take* costs).

Use of facilities and exchange water.

An agreement between MWA and Metropolitan should contain some description of the uses of stored water and facilities needed. For example, existing facilities, such as spreading basins, extraction wells or conveyance canals, and new facilities, should be described to the extent possible in the agreement. Operation and maintenance costs, for use of existing or additional facilities, should also be described in the agreement.

The priority for use of any facility that may be constructed or used to implement a program should also be addressed, in terms of priority for facility use for an MWA/Metropolitan Program vs. priority of use by MWA or local agencies for local purposes. It should also be understood that MWA has the discretion to use exchange water in a convenient and cost effective way.

The exchange agreement should define the amount of water lost to the Program through evaporation, transportation, or aquifer losses that are mutually acceptable.

Water storage account.

The amount of water initially delivered from Metropolitan should be defined by MWA and Metropolitan. This would be the amount of *put* water accepted by MWA prior to the first *take*. Also a minimum balance in the water bank needs to be agreed upon.

The MWA/Metropolitan storage account will need to be analyzed and accounted for in each subarea.

Non-technical Contract Issues

When contract documents are written, non-technical issues that will likely need to be addressed include:

- *Liability*. Indemnification statements typically would also be included in any exchange agreement. This includes liabilities for MWA and Metropolitan.
- *Terms of contract and dispute resolution*. As in many contracts, an expiration date for the agreement should be included as well as termination issues addressed by all parties. Dispute resolution options may also be necessary.

6.3 Screening of Alternatives by Institutional Issues

Potentially acceptable *put* and *take* alternatives for a water bank exchange between MWA and Metropolitan were first screened using criteria developed in TM 02 and TM 05. In this memorandum the alternatives from these technical memoranda were compared to relevant institutional issues.

The results of comparing the MWA/Metropolitan alternatives to the institutional issues discussed herein showed no "fatal flaws" for alternatives previously developed in TM 02 and TM 05.

Alternatives can only be screened generally at this level of analysis. When they are physically defined in more detail, additional analyses and monitoring would be needed. Issues that would require more complex analysis and/or may limit a Program include the following:

- Recharge to store MWD entitlement in MWA groundwater basins should not require Court review to determine consistency with the Mojave Basin Area Judgment. Extraction of previously stored water by MWA for MWD's benefit may require Court review.

- In dry years, the MWA/Metropolitan Program would generally not use any of the 12,000 acre-feet of MWA entitlement "reserved" by MWA policy. The MWA entitlement reserve would normally be used to supply local uses and would not be left in the East Branch for delivery to MWD unless other arrangements to meet local supply needs have been made.

- The direct *take* alternatives need to be guided by DWR Article 19 water quality limits for returning water to the East Branch. These alternatives would need to consider whether water treatment might be necessary to meet the Article 19 objectives, and whether treatment requirements and the associated capacity limitations and cost would render an alternative non-viable.

- The *put* alternatives along the Morongo Basin Pipeline would need to consider the Morongo Basin Pipeline Agreement and ensure that MWA/Metropolitan deliveries do not interfere with Hi-Desert Water District responsibilities as Watermaster to satisfy the requirements of the Warren Valley Basin Judgment.

- Points of Delivery are understood to be turnouts from the East Branch or Silverwood Lake. Any alternatives will have to be able to *take* or *put* water at a turnout structure.

- Increased monitoring would be necessary to adequately account for the MWA/Metropolitan water.

7.0 Facilities Cost Estimate

The following section presents and evaluates the cost of the MWA/Metropolitan Programs that were formulated during a meeting with MWA, Metropolitan, and the MWA's environmental consultant, Jud Monroe. The Programs are evaluated as three possible storage volumes, maximum (450,000 acre-feet), moderate (300,000 acre-feet), and minimum (225,000 acre-feet) and their respective physical facilities. A combination of entitlement exchange and direct return facilities were evaluated to assess the overall costs. The Programs are sized to put up to one-third of the storage in one year and to take up to one-fifth of the maximum storage in one year.

7.1 Formulation of Possible MWA/Metropolitan Program Matrix

On March 10, 2005, B-E/GEI and staff from MWA, the environmental consultant, and Metropolitan (via conference call) discussed the alternatives presented in Sections 2.0 and 4.0 and formulated the Water Management Program matrix described in Table 7-1.

Table 7-1
Possible Water Management Program Matrix

Alternative Number	Type of Operation	Facilities
1A 1B	Traditional Water Storage* Water Storage with Exchange	Minimum Facilities Alternative --Existing facilities plus new wells. a. Mojave River Pipeline b. Morongo Basin Pipeline c. Mojave Basin recharge basins (Hodge, Lenwood, Daggett, Newberry Springs) d. Morongo Basin recharge basins (Yucca Valley) e. Mojave River mainstem f New extraction wells and conveyance pipelines in the Alto Area
2A 2B	Traditional Water Storage* Water Storage with Exchange	Small Projects Alternative -- Minimum Facilities Alternative plus: a. Oro Grande Wash recharge b. Antelope Wash recharge c. Cedar Avenue Flood Control Detention recharge d. Hesperia Detention Basin recharge e. Enhancement of recharge on Mojave River mainstem f. Land-locked lands along East Branch (Alto Subarea) g. New extraction wells and conveyance pipelines
3A 3B	Traditional Water Storage* Water Storage with Exchange	Large Projects Alternative -- Small Projects Facilities plus: a. Oeste Area recharge basins along the East Branch north of Phelan, and/or b. Alto Area recharge basins along the Mojave River Pipeline c. Enhanced delivery of SWP supplies via an unnamed wash discharging to the Mojave River about 1 mile downstream from Mojave Forks Dam d. New extraction wells and conveyance pipelines

* No entitlement exchange

The estimated storage volumes for Alternatives 1 and 2 in Table 7-1 are 225,000 and 300,000 acre-feet, respectively. A Program with a storage capacity of approximately 450,000 acre-feet will require the facilities listed under Alternative 3 in Table 7-1. The number of new extraction wells needed to return Metropolitan's water will depend on the amount returned as an entitlement exchange.

Each alternative's maximum *take* facilities (wells used to return Metropolitan's water) can be reduced if entitlement exchange is used as part of the return volume. Table 7-2 illustrates how entitlement exchange can greatly reduce the number of wells required to return water to Metropolitan. The values used to analyze the effects of entitlement exchange are the maximum, median, and minimum estimated volumes that MWA expects to have available for exchange under a 65, 43, and 20 percent SWP allocation (see Section 4.0, Table 4-6).

Table 7-2
Entitlement Exchange's Effect on the Number of Wells Required for Direct Return to Metropolitan

Program Size (acre-feet)	Annual Return (acre-feet)	Entitlement Exchange (acre-feet)	Direct Return with Entitlement Exchange (acre-feet)	No. of Wells Without Entitlement Exchange*	No. of Wells With Entitlement Exchange*
450,000	90,000	38,000	52,000	76	44
450,000	90,000	20,500	69,500	76	58
450,000	90,000	3,000	87,000	76	73
300,000	60,000	38,000	22,000	50	18
300,000	60,000	20,500	39,500	50	33
300,000	60,000	3,000	57,000	50	48
225,000	45,000	38,000	7,000	38	6
225,000	45,000	20,500	24,500	38	21
225,000	45,000	3,000	42,000	38	35

*Assumed well capacity of 2 cfs and a return period of 10 months. The actual number of wells would be less than the numbers shown because 22 of the wells will be located along the Mojave River and will have an estimated capacity of 3 cfs each.

If the maximum entitlement exchange (38,000 acre-feet per year) is used to analyze a 450,000 acre-foot project, the total number of wells is reduced by 32. Using the minimum exchange amount of 3,000 acre-feet per year reduces the number of wells by three.

Incorporating entitlement exchange into the return volumes will lower both the capital and operation costs. The MWA believes it will have at least 20,500 acre-feet available for exchange for the next 30 years.

7.1.1 Mutual Exchange Program

Another opportunity that requires further consideration is the program referred to as "mutual exchange." Depending on the amount of water that could be "mutually exchanged" between Metropolitan and MWA, in combination with the traditional entitlement exchange, very few to no new wells would be required to return water to Metropolitan.

Currently, Metropolitan generally has surplus water available for storage. The MWA, on the other hand, does not have funds available to import SWP water. As urban growth in MWA continues, and direct pumping by purveyors increases, the funds available to MWA will increase. As a result, the funds available to MWA for water purchases will also increase. In the intervening years, however, Metropolitan can deliver its surplus SWP water to MWA for storage at no cost to MWA. This water would be spread at existing recharge sites or in the Mojave River. During a dry year, Metropolitan buys some of MWA's SWP allocation and either delivers it to its member units or stores it in Diamond Valley Lake or some other reservoir. Because MWA is still unable to purchase its whole SWP entitlement, there is no negative impact to MWA. The amount of water Metropolitan has stored with MWA is the difference between the initial water put into storage and the amount MWA "mutually exchanged" with Metropolitan. In the end, both transactions are paid by Metropolitan.

The net result of the mutual exchange is that MWA gets water placed into storage that it currently cannot afford to purchase itself and the local purveyors benefit from higher groundwater levels and lower pumping lifts. Metropolitan benefits from an operational point of view; it stores water that it would have otherwise lost, and it also has supplemental water during a dry year. There are, however, some limitations with a "mutual exchange" program. MWA participation in this mutual exchange program will be beneficial only until it cannot afford to purchase its own entitlement. When it reaches that point, a more traditional storage program would make more sense.

7.2 Sizing the MWA/Metropolitan Program

Technical Memorandum No. 01.0 presented cost screening criteria and some hydrologic assumptions that were used to screen the various project alternatives. The cost analysis performed in Sections 2.0 and 4.0 helped establish the following project criteria:

- The projects are sized for the maximum *put* (one-third of the storage in one year) and the maximum *take* (one-fifth of the storage in one year)
- The *put* period is nine months.
- The *take* (return) period is ten months.
- The hydrology used to assess how often the bank will be in a *put* or *take* mode was derived by assuming that during a ten-year period, the local area will experience one wet year, two above-normal years, three normal years, three dry years, and one critical year. During the assumed 30-year life of this project. Water will be *put* during each wet and above-normal years and taken during each dry and critical year. That is, put in nine out of 30 years and taken in 12 out of 30 years.
- Well capacities along the Mojave River are estimated at 3 cfs (also two wells located in Antelope Wash).
- Wells located in the Regional aquifer are assumed to have capacities of 2 cfs each.
- All the recharge basins are designed with 12-foot wide roads, 2-to-1 side slopes, and 5-foot tall dikes (these parameters were used to calculate total gross area required to recharge the required volumes). Refer to Figure 2-2 for typical cross sections of the basins.

The earlier sections studied several potential projects with a wide range of *put* volumes and *take* capacities. Because it is still unclear what size project would best fit Metropolitan's future water storage goals, the three Programs were analyzed.

The recommended facilities required for a 450,000 acre-foot storage Program, shown in Table 7-3, is composed of some new recharge facilities, approximately 1,080 acres, approximately 58 new wells, and 4 existing wells.

Table 7-3
Facility Composition for a 450,000 Acre-Foot
MWA/Metropolitan Program with No Entitlement Exchange

Alternative -Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)	No. of Wells Required for Return
P3A/P7-Mojave River Pipeline or Oeste recharge basins	50,000	545	-	-
T1/T4 - Mojave River Pipeline or Oeste wells fields	-	-	30,000	25[2]
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	-
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds	-	100	44,000	25[4]
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia detention Basin, land-locked lands, and small pipeline.	39,000	435	-	-
T0 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia Detention Basin, land-locked lands, and 14-inch pipeline.	-	-	16,065	12[3]
Totals	150,000	1,080	90,065	62[3]

[1]New spreading grounds.
[2] Well capacities of 2 cfs each.
[3]Four of the twelve wells are existing wells. Two wells have flow capacities of 3 cfs, ten wells are 2 cfs each.
[4]Well capacities of 3 cfs each

Table 7-4
Facility Composition for a 300,000 Acre-Foot
MWA/Metropolitan Program with No Entitlement Exchange

Alternative-Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)	No. of Wells Required for Return
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds	-	100	44,000	25[3]
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia detention Basin, land-locked lands, and small pipeline.	39,000	435	-	-
T0 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia detention Basin, land-locked lands, and 14-inch pipeline	-	-	16,065	12[2]
Totals	100,000	525	60,065	37

[1]New spreading grounds.
[2]Four of the twelve wells are existing wells. Two wells have flow capacities of 3 cfs, ten wells are 2 cfs each.
[3]Well capacities of 3 cfs each

Table 7-4 lists the recommended facilities required for a 300,000 acre-foot storage Program without any entitlement exchange. It is composed of the same projects listed in Table 7-3 with the exception of the spreading grounds and wells fields in the Oeste or Mojave River Pipeline areas. The new recharge basin facilities total approximately 535 acres and would require an estimated 33 new wells and 4 existing wells.

The recommended facilities required for a 225,000 acre-foot storage Program without any entitlement exchange are listed in Table 7-5. It is composed of the same projects listed in Table 7-4 with the exception of the spreading grounds and wells fields located along the East Branch (from the Oro Grande Wash to the Antelope Wash). Added to this list of projects are the Hodge, Lenwood, Daggett, Newberry Springs, and Yucca Valley recharge basins, which will be used to recharge approximately 14,000 acre-feet per year.

Table 7-5
Facility Composition for a 225,000 Acre-Foot
MWA/Metropolitan Program with No Entitlement Exchange

Alternative-Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)	No. of Wells Required for Return
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project	-	100	45,000	25[2]
Existing Spreading Grounds—Hodge, Lenwood, Daggett, Yucca Valley, Newberry Springs	14,000	-	-	-
Totals	75,000	90	45,190	25

[1]New spreading grounds.
[2]Well capacities of 3 cfs each.

These recharge facilities were not used in the two other Programs because returning water directly to the East Branch from these locations was considered infeasible; however, a direct return from these locations is not necessary under this scenario because the Upper Mojave River Well Field and Water Supply Pipeline alternative can be sized to return the maximum return volume of 45,000 acre-feet per year.

7.2.1 Facility Composition with Entitlement Exchange

Up to now, all facilities, both *put* and *take*, have been sized and analyzed without taking any entitlement exchange into account. This was good to help screen potential projects, but the final project requires a more realistic and detailed cost analysis. The following projects were formulated with the assumption that for the next 30 years, MWA would have approximately 20,500 acre-feet per year of its entitlement available for exchange. The criteria used to size the projects in the previous section were carried over to this analysis. Tables 7-6, 7-7, and 7-8 are similar to the Tables 7-3, 7-4, and 7-5; however; the *take* facilities have been changed to reflect the new maximum capacities required for a direct return to the East Branch now that 20,500 acre-feet/year of an entitlement exchange will be returned with MWA's entitlement.

Table 7-6
Facility Composition for a 450,000 Acre-Foot MWA/Metropolitan Program with 20,500 acre-feet/year of the Return Capacity as Entitlement Exchange

Alternative-Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)	No. of Wells Required for Return
P3A/P7-Mojave River Pipeline or Oeste recharge basins	50,000	545	-	-
T1/T4 - Mojave River Pipeline or Oeste wells fields	-	-	25,400	23[2]
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	-
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds	-	100	39,300	22[3]
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia Detention Basin, land-locked lands	39,000	435	-	-
T0 - Cedar Avenue and land-locked lands	-	-	4,800	4[2]
Entitlement Exchange	-	-	20,500	
Totals	150,000	1,080	90,000	49

[1]New spreading grounds.
[2]Well capacities of 2 cfs each.
[3] Well capacity of 3 cfs each.

Table 7-7
Facility Composition for a 300,000 Acre-Foot MWA/Metropolitan Program with 20,500 acre-feet/year of the Return Capacity as Entitlement Exchange

Alternative-Facility Description	*Put* Capacity 9 Months (acre-feet/year)	Area Required[1] (acres)	*Take* Capacity 10 Months (acre-feet/year)	No. of Wells Required for Return
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	-
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds	-	100	39,500	22[2]
P8 - Antelope Wash, Oro Grande Wash, Cedar Avenue, Hesperia Detention Basin, land-locked lands	39,000	435	-	-
Entitlement Exchange	-	-	20,500	
Totals	100,000	535	60,000	22

[1]New spreading grounds.
[2]Well capacity of 3 cfs each.

Table 7-8
Facility Composition for a 225,000 Acre-Foot MWA/Metropolitan Program with 20,500 acre-feet/year of the Return Capacity as Entitlement Exchange

Alternative-Facility Description	***Put*** **Capacity 9 Months (acre-feet/year)**	**Area Required[1] (acres)**	***Take*** **Capacity 10 Months (acre-feet/year)**	**No. of Wells Required for Return**
Cedar Springs Dam & Rock Springs Turnout, unnamed wash	61,000	-	-	-
T3 – Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds	-	100	24,500	14[2]
Existing Spreading Grounds- Hodge, Lenwood, Daggett, Yucca Valley, Newberry Springs	14,000	-	-	-
Entitlement Exchange	-	-	20,500	
Totals	75,000	100	45,000	14

[1]Pipeline easement and spreading grounds.
[2]Well capacity of 3 cfs each.

The number of wells required for return is the only column affected by the use of entitlement exchange because all the *put* facilities are still necessary. With entitlement exchange, the number of wells is reduced by 13, 15, and 11 in the 450,000, 300,000, and 225,000 acre-foot Programs, respectively. The potential facilities are shown on Plate 7.

7.3 Program Facilities

In previous sections of this report several *take* and *put* alternatives were screened on various categories. This section will describe in detail the facilities that make up the potential Programs listed in Section 7.2.1.

P3A/T1-Mojave River Pipeline Spreading Grounds and Well Field

The spreading grounds located adjacent to the Mojave River Pipeline (545 acres), just north of the California Aqueduct, will consist of two turnouts off the Mojave River Pipeline, 30 cubic feet per second (cfs), and a 70 cfs turnout. Both turnouts will require energy dissipaters at the control structures. The 30 cfs turnout will serve the southernmost recharge basins, an area of approximately 160 acres.

The remaining 385 acres will be served by a similar 70 cfs turnout that discharges into a storm channel along the western boundary of the spreading grounds. The channel's width is estimated at 50 feet with 5-foot high dikes and 2-to-1 side slopes (a verification of the channel's capacity with area hydrologic data is required). Three hydraulic structures along the conveyance/storm channel will direct water into the recharge basins. A structure at the northernmost point of the channel will act as a check structure by retaining the water within the channel during recharge periods. Each structure will serve approximately 128 acres (gross area). A one-foot high concrete dike will be placed in the channel immediately downstream of these double barrel structures. The channel structures will convey the water one basin downstream, giving the flow approximately three feet of head when it is discharged into the basins. Using the channel to convey water to the downstream basins offers operational flexibility because water is discharged at three different locations, but its capacity must be given full consideration so that it is adequate to carry flood waters.

When water is being pumped out of storage for return to Metropolitan, a 48-inch butterfly valve will be closed just downstream of the spreading facilities. A 27-inch diameter bypass with throttling valve (20 cfs capacity) will be opened if water must be delivered to downstream customers, such as the High Desert Power Plant. The well fields will require three connections to the Mojave River Pipeline for a 15-inch, 24-inch, and 27-inch diameter laterals. The Mojave River Pipeline's designed capacity is 94 cfs at 7.5 feet per second (fps). The pipeline's velocity would have to be increased to 8 fps to supply the new spreading grounds with approximately 100 cfs, which is the capacity needed to spread 50,000 acre-feet in nine months. Building the spreading grounds as shown in Figure 7-1 will require closing off one farm road.

P7/T4-Oeste Spreading Grounds and Well Field
If the Oeste site is chosen over the Mojave River Pipeline site, a layout similar to the one used for the Mojave River Pipeline recharge site may be used. The Oeste site has a storm runoff channel that runs adjacent to the proposed recharge site and can be used to transfer water to the basins at multiple locations. But unlike the Mojave site, three other structures would need to be built: a turnout structure off the California Aqueduct, a culvert under Highway 18, and a conveyance pipeline to return the water from the well fields to the California Aqueduct. The same channel-sizing considerations must be made at this site. Some other concerns are the possible water quality issues in this area and the rugged topography that will require more earthwork. Figure 7-2 shows a conceptual layout of these facilities.

P8/T0-Multiple Alto Subarea Spreading Grounds and Wells
The *Oro Grande*, *Cedar Avenue*, and *Land Locked* recharge sites will either have a 5 cfs or 10 cfs turnout off the California Aqueduct. The turnout capacities for the *Antelope Wash* and the *Hesperia Detention Basin* are a combined 47 cfs (two turnouts) and 15 cfs, respectively. A training dike and flood channel will also be constructed along the Antelope Wash. The recharge basins will be separated with a 50-foot wide channel with 5-foot dikes, and require twelve culverts, sixty-one interbasin structures, approximately 6,000 feet of 30-inch diameter pipeline, and the closure of one dirt road (see Figure 7-3). The capacity of the channel must also be given full consideration to ensure it is adequate to carry flood waters.

All recharge facilities can have three types of interbasin control structures; a double barrel structure, a single barrel (24 inch diameter pipe) with a rectangular weir, and/or an 18-inch by 50-foot notch-weir (see Figure 7-4). The exact well locations have not been determined because further technical studies are required. The wells shown on the Figures are to help illustrate the project concept.

Unnamed Wash
The flow capacity through the unnamed wash was determined to be 500 cfs, the maximum release capacity from Lake Silverwood that the permitting agencies allowed during the Mojave River Pilot Recharge Program. Currently, MWA has two unused turnouts with a combined capacity of 135 cfs on the SWP (about 1,800 feet upstream of the unnamed wash).

A new 365 cfs turnout, combined with the existing turnouts, could direct 500 cfs down the unnamed wash. Because the wash is expected to run through the proposed Rancho Las Flores development, other improvements such as two road bridges and one walk bridge across the wash will also be needed. If the development is constructed per the land use map submitted in the specific plan amendment (see Figure 1-3), the first 5,800 feet of the wash will run adjacent to areas designated for town centers, a lake, and medium density housing. A 96-inch diameter pipeline will be used along this section of the wash. The rest of the wash (approximately 15,800 feet) will remain a natural channel. Preliminary hydraulic analyses of the wash indicate that drop structures will also be needed to control the water's velocity along the wash.

T3-Upper Mojave River Well Field and Water Supply Pipeline w/ south of Rock Springs Spreading Grounds

The Upper Mojave River Well Field and Water Supply Pipeline (UMRP) Project is a network of 22 new wells (3 cfs, with approximately 90 horsepower each, approximately 500 feet deep) with four lateral turnouts along its alignment, approximately 46,000 feet of pipeline, and three pump stations with storage tanks. The four turnout locations and the pipeline alignment were determined after several meetings with local agencies that have shown interest in participating in this project (California Service Area 64, City of Hesperia Water District, Victor Valley Water District, and Baldy Mesa Water District). A crossing of the railroad is required as well as a crossing of Interstate 15. It is assumed, based on prior experience, that in both cases sleeves will be required to be jacked or tunneled under and the carrier pipe placed inside the sleeve. Jacking pits will be required on each side of the roadway. A turnout structure at the California Aqueduct is also required.

The UMRP requires the spreading of water in the Mojave River. The water should be spread upstream of the well field a sufficient distance so that the wells are not under the direct influence of the spreading of surface water and so that sufficient storage space is available. Accordingly, two sites were selected for consideration of additional off-river spreading. On the west side of the Mojave River a site was investigated which is property formally used by the Lake Arrowhead Community Services District for disposal of effluent water by crop irrigation. The area is usable for groundwater recharge and as it is adjacent to the River, it can be incorporated into River spreading when desired. This site is referred to as the Hesperia Lake Site and is located about two miles south of Rock Springs.

An alternative site was selected on the East side of the Mojave River, about one mile upstream of Rock Springs. A site of 100 acres of flat vacant land adjacent to the river was selected for the analysis. For the East Side site, it was assumed that some water for spreading would also be turned out into the River at Rock Springs. These sites are shown on Figure 7-5. An outlet to the Mojave River will be constructed to allow for River spreading as well as an emergency spill to the River. It is expected that long term recharge rates of up to 0.5 feet per day will be achieved on the site but testing is required to confirm this.

The spreading grounds will potentially provide a water supply of up to 40,000 acre-feet per year over a nine-month period. This requires a pipeline with capacity of 74 cfs. As there is more than sufficient pressure in the Morongo Basin pipeline a velocity of up to 8 feet per second is used and a pipeline diameter of 42 inches was selected. The flow would be metered and a pressure reducing valve would be installed at the Morongo Basin Pipeline Turnout. Final sizing will be determined after percolation testing of the site and further consideration of the capacity of the Morongo Basin pipeline to Rock Springs.

Spreading water on the Mojave River will be more difficult to operate than the traditional spreading grounds. To insure proper operation five sets of dual monitoring wells are proposed to be constructed. These will be constructed well in advance of any other project facilities. At each site a shallow well will extend to near the bottom of the River Aquifer with the well screened in the bottom 20 feet. The deep wells will extend at least 500 feet with the bottom 40 feet screened. The wells will be equipped with 2-inch diameter PVC casing and will be capable of sampling water quality. At least two of the wells should be drilled to the full depth of the producing aquifer early in the design process to better assess the geologic conditions at the site.

7.4 Cost Evaluations

The following cost evaluations were performed on the projects described in Section 7.2.1. Table 7-9 lists the cost assumptions that were used to evaluate the project costs. Several cost assumptions have changed from the screening criteria listed in Table 1-5 in Technical Memorandum No. 01.0.

Table 7-9
Cost Assumptions

Item	Assumption
Well capacity:	
In the Regional aquifer	2 cfs per well
In Mojave River or Antelope Wash	3 cfs per well
Pump Efficiencies	
Well pump/motor	70 percent
Pump station pump/motor	80 percent
Pipe design velocity for pumped system	5 to 6 feet per second
Electrical cost to pump	$0.12 per kWh
Pipeline cost (design & construction)	$6.00 per foot per diameter-inch
Pipeline crossing river underground	$16.00 per foot per diameter-inch
Well cost (design & construction)	$750,000 per well
Land Cost (per acre)	Varies depending on location and property characteristics (cost used range from $10,000 to $20,000)
Shared capital project cost	50 percent of Upper Mojave River Well Field and Water Supply Pipeline Project
Pump Station Cost (assumes vertical turbine pumps in a wet well)	$1,000/horsepower
Contingency	30%
Engineering, Construction Management and Legal	25%

Tables 7-10 through 7-12 show the estimated capital costs for each Program. They show the total cost for wells, pumping plants, spreading facilities, pipelines, and appurtenances and the land cost for spreading grounds (see Appendix B for more detailed costs).

7.4.1 Annual Cost Evaluations

Tables 7-13 through 7-15 show a probable *put* and *take* scenario for each Program. Some of the costs for certain alternatives (the Upper Mojave River Well Field and Water Supply Pipeline) were reduced by a percentage of the total cost (in this case, 50 percent) because they are expected to be constructed jointly with the help of local agencies and possibly with some grants from the State of California. For cost comparisons, the equivalent annual costs in dollars per acre-foot of *take* were calculated in Tables 7-13 through 7-15 for the Programs using entitlement exchange. The Programs were evaluated using a present-worth calculation over 30 years, 5 percent interest, and 5 percent debt service.

The equivalent annual cost per acre-foot for the 450,000, 300,000, and 225,000 acre-foot Programs are $410, $360, and $260, respectively. Similar annual costs were calculated for the same projects only no entitlement exchange was used. The result was higher capital and operation costs. The cost comparisons are shown in Table 7-16.

Table 7-16
Comparison of Equivalent Annual Cost of Selected Programs with and Without Entitlement Exchange

Total Stored Volume (acre-feet)	Equivalent Annual Cost per Acre-Foot of *Take*	
	Without Entitlement Exchange	With Entitlement Exchange
225,000	$360	$260
300,000	$480	$360
450,000	$480	$410

In both cases, the 225,000 acre-foot Program resulted in the lowest cost per acre-foot. It is evident; however, that including entitlement exchange reduces each of the Program's equivalent annual cost.

The operation and maintenance unit costs used to evaluate the projects in Tables 7-13, 7-14, and 7-15 are shown in Table 7-17.

Table 7-17
Operation and Maintenance Unit Costs

Description	Unit	Unit Cost
Spreading Operations		
Maintenance	$/Acre-foot of capacity	$3
Put	$/Acre-foot of *put*	$3[2]
Take operation cost[1] for :		
T1 (Mojave River Pipeline)	$/Acre-foot	$178
T4 (Oeste)	$/Acre-foot	$178
T0 (Small new local projects)	$/Acre-foot	$187
T3 (Upper Mojave River Well Field and Water Supply Pipeline Project w/ south of Rock Springs Spreading Grounds)	$/Acre-foot	$154
Project capital cost subsidizing		
Upper Mojave River Well Field and Water Supply Pipeline Project (T3)	%	50%

[1]Includes power for pumping at $0.12 per kilowatt-hour.

Table 7-17
Operation and Maintenance Unit Costs

Description	Unit	Unit Cost

[2]Unit cost for *put* operations on the Mojave River is assumed to be $6.

The unit cost for the Upper Mojave River Well Field and Water Supply Pipeline Project is less for two reasons; (1) it is capable of returning more acre-feet per year because each well's capacity is 3 cfs rather than 2 cfs and (2) it uses a pumping plant, unlike the other projects that use only the individual well pumps to return stored water to the East Branch, and the motor efficiency for a well is assumed to be lower than that of a pumping plant (70 percent versus 80 percent). Costs that were not taken into account include the costs associated with moving the water from the Delta, over the Tehachapi Mountains, and to MWA's service area.

7.5 Project Flexibility

The 225,000 acre-foot Program is the most economical of the three Programs being considered, it is also the least flexible because it only has 100 acres of new storage. Since it is more likely that Metropolitan would choose to store surplus water after a wet year or shortly after a significant storm event, it may be difficult to store large quantities of water in the Mojave River aquifer; therefore, most of the recharge will have to *take* place at recharge facilities that are located at great distances from the East Branch.

Flexibility is a major asset in successful conjunctive use projects. The occurrence of surface water is uncertain and conditions of water supply, especially on the SWP system, can change rapidly. Experience shows that the ability to rapidly respond to surplus water conditions is extremely valuable.

The estimated storage capacity within the Mojave River aquifer between the Cedar Springs Dam and the Upper Narrows is 61,000 acre-feet. This storage capacity is small relative to the storage capacity available within the Regional Aquifer.

7.6 Conclusion

After reviewing the sections analysis, it is the Team's conclusion that Metropolitan and MWA should consider entering a water management program that offers operational flexibility, such as the 450,000 and 300,000 acre-foot Programs described in this section. Although it is more economical to build a 225,000 acre-foot Program, the flexibility that the two larger projects offer justifies the higher cost per acre-foot. Both MWA and Metropolitan would benefit more from a program that offers several recharge facilities near the East Branch and within the area's growing communities.

Table 7-10
Estimated Capital Cost for 450,000 Acre-Foot Storage Program

Spreading Facilities		
Spreading Grounds (interbasin structures, dike construction, culverts, and misc.)	$	11,456,000
Ranchero Detention Basin (60 acre)[1]	$	9,000,000
Turnout Structures		
Turnouts off the California Aqueduct (4 turnouts, 5 cfs, 15 cfs, 10 cfs, 66 cfs, and unnamed wash 365 cfs)	$	2,580,000
Turnouts off Morongo Pipeline (Antelope wash spreading -47 cfs, Ranchero Basin, and South of Rocks Springs -76 cfs)	$	310,000
Turnouts off Mojave River Pipeline (70 cfs, 30 cfs)	$	106,000
Distribution Hydraulic Structures		
Pipeline & appurtenances, hydraulic structures (includes turnout laterals to water agencies)	$	18,534,940
Unnamed wash pipeline, hydrualic structures, and bridges	$	6,872,800
Well Fields (total of 49 wells)		
Wells, pumps, motors, manifold pipelines, collection pipelines (500 hp, depth 500 ft - 750 ft)	$	43,663,300
5 Monitoring Wells	$	350,000
Pumping Stations		
Pump stations for spreading grounds located uphill of SWP in Alto subarea	$	600,000
Pump stations for Upper Mojave River Well Field and Pipeline project (TDH=650 ft., 6,100 hp)	$	6,100,000
Storage tanks (2 hr storage, 66 cfs, 4 MG)	$	4,050,000
Bare Construction Cost=	**$**	**103,623,000**
with 30% Contingency	$	134,710,000
with 25% Engineering & CM, Administration and Legal	$	168,388,000
Land Costs for Spreading Grounds (535 acres)	$	16,200,000
Acquisition Fee (10% of Land Cost)	$	1,620,000
Total Estimated Capital Cost=	**$**	**186,208,000**

[1]San Bernardino County Department of Public Works, Flood Control Planning Division's cost estimate.
Not included in these costs estimate are any wheeling charges, or the cost of water from MWD.
Assuming 20,500 acre-feet per year of entitlment exhange is used in conjunction with direct returns to MWD.

Table 7-11
Estimated Capital Cost for 300,000 Acre-Foot Banking Program

Spreading Facilities			
	Spreading Grounds (interbasin structures, dike construction, culverts, and misc.)	$	5,684,000
	Ranchero Detention Basin (60 acre)[1]	$	9,000,000
Turnout Structures			
	Turnouts off the California Aqueduct (4 turnouts, 5 cfs, 15 cfs, 10 cfs, 66 cfs, and unnamed wash 365 cfs)	$	2,580,000
	Turnouts off Morongo Pipeline (Antelope wash spreading -47 cfs, Ranchero Basin, and South of Rocks Springs -76 cfs)	$	310,000
Distribution Hydraulic Structures			
	Pipeline & appurtenances, hydraulic structures (includes turnout laterals to water agencies)	$	18,234,940
	Unnamed wash pipeline, hydrualic structures, and bridges	$	6,872,800
Well Fields (total of 22 wells)			
	Wells, pumps, motors, manifold pipelines, collection pipelines (each 90 hp, depth 500 ft)	$	20,810,000
	5 Monitoring Wells	$	350,000
Pumping Stations			
	Pump stations for spreading grounds located uphill of SWP in Alto subarea	$	600,000
	Pump stations for Upper Mojave River Well Field and Pipeline project (TDH=650 ft., 6,100 hp)	$	6,100,000
	Storage tanks (2 hr storage, 66 cfs, 4 MG)	$	4,050,000
	Bare Construction Cost=	**$**	**74,592,000**
with 30% Contingency		$	96,970,000
with 25% Engineering & CM, Administration and Legal		$	121,213,000
Land Costs for Spreading Grounds (535 acres)		$	8,025,000
Acquisition Fee (10% of Land Cost)		$	803,000
	Total Estimated Capital Cost=	**$**	**130,041,000**

[1]San Bernardino County Department of Public Works, Flood Control Planning Division's cost estimate.
Not included in these costs estimate are any wheeling charges, or the cost of water from MWD.
Assuming 20,500 acre-feet per year of entitlment exhange is used in conjunction with direct returns to MWD.

Table 7-12
Estimated Capital Cost for 225,000 Acre-Foot Banking Program

Spreading Facilities		
	New spreading south of Rocks Springs Turnout (connection to MBP, pipeline, structures, basins,)	$ 2,114,000
	Using existing facilities in Hodge, Lenwood, Daggett, Yucca Valley, and Newberry Springs	$ -
Turnout Structures		
	Turnouts off the California Aqueduct (Unnamed wash, turnout for Upper Mojave River water supply pipeline)	$ 2,020,000
Distribution Hydraulic Structures		
	Pipeline & appurtenances (includes turnout lateral lines to water agencies)	$ 14,406,440
	Unnamed wash pipeline, hydrualic structures, and bridges	$ 6,872,800
Well Fields (total of 14 wells)		
	Wells, pumps, motors, manifold pipelines (each 90 hp, depth 500 ft)	$ 13,390,000
	3 monitoring wells	$ 210,000
Pumping Stations		
	3 Pump station for Upper Mojave River Well Field and Water Supply Pipeline project (TDH=680 ft., 4,100 hp)	$ 4,100,000
	Storage tanks (42 cfs, 2 hr. storage, 3 MG)	$ 3,037,500
	Bare Construction Cost=	**$ 46,151,000**
with 30% Contingency		$ 59,996,000
with 25% Engineering & CM, Administration and Legal		$ 74,995,000
Land Costs for Spreading Grounds (100 acres @ $20,000 per acre)		$ 2,000,000
Acquisition Fee (10% of Land Cost)		$ 200,000
	Total Estimated Capital Cost=	**$ 77,195,000**

[1]San Bernardino County Department of Public Works, Flood Control Planning Division's cost estimate.
Not included in this cost estimate are any wheeling charges, or the cost of water from MWD.
Assuming 20,500 acre-feet per year of entitlment exhange is used in conjunction with direct returns to MWD.

Table 7-13. Estimated Annual Cost for a 450,000 Acre-Foot Program

ASSUMPTIONS: Maximum Entitlement Exchange of 20,500 for 30 years — **PW interest= 0.05**

Debt Service interest= 0.05

Total Bank Volume is 450,000 AF — **n= 30**

	Assessed Water Supply				Cost Data					Annual Cost			
	Put (AF)	90,000 AF "Take"			Operation (2005 $)			Capital (2005 $)		Debt Service ($)		$	
Year	(9 months)	Direct Take (10 months)	Entitlement Exchange	Storage (AF)	New Spreading Grounds Maintenance	Put	Take	Put	Take	Put	Take	Total Annual Cost	Present Worth
1	-	-	-	-	-	-	-	69,077,187	32,350,200	4,493,570	2,104,427	6,597,997	$ 6,597,997
2	150,000	-	-	135,000	267,000	886,000	-	-	44,975,000	4,493,570	5,074,824	10,721,394	$ 10,210,852
3		69,500	20,500	45,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 19,447,623
4	150,000	-	-	180,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 9,261,543
5	-	69,500	20,500	90,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 17,639,567
6	-	-	-	90,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 7,706,289
7	-	69,500	20,500	-	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 15,999,607
8	150,000	-	-	135,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 7,619,495
9	-	69,500	20,500	45,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 14,512,116
10	150,000	-	-	180,000	267,000	886,000		-	-	4,493,570	5,074,824	10,721,394	$ 6,911,106
11	-	69,500	20,500	90,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 13,162,917
12	150,000	-	-	225,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 6,268,577
13	150,000	-	-	360,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 5,970,073
14	-	69,500	20,500	270,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 11,370,622
15	-	69,500	20,500	180,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 10,829,164
16	-	-	-	180,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 4,730,993
17	-	-	-	180,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 4,505,707
18	-	69,500	20,500	90,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 9,354,639
19	-	-	-	90,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 4,086,809
20	150,000	-	-	225,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 4,242,820
21	-	69,500	20,500	135,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 8,080,889
22	150,000	-	-	270,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 3,848,363
23	-	-	-	270,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 3,362,228
24	150,000	-	-	405,000	267,000	886,000	-	-	-	4,493,570	5,074,824	10,721,394	$ 3,490,578
25	-	-	-	405,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 3,049,640
26	-	-	-	405,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 2,904,419
27	-	69,500	20,500	315,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 6,030,084
28	-	-	-	315,000	267,000	-	-	-	-	4,493,570	5,074,824	9,835,394	$ 2,634,394
29	-	69,500	20,500	225,000	267,000	-	11,605,610	-	-	4,493,570	5,074,824	21,441,004	$ 5,469,464
30	-	69,500	20,500	135,000	267,000	-	11,605,610			4,493,570	5,074,824	21,441,004	$ 5,209,013
		834,000	246,000	5,670,000	7,743,000	7,974,000	139,267,320	69,077,187	77,325,200	134,807,104	149,274,322	439,065,746	234,507,588
Totals=	**1,350,000**	**1,080,000**				**$ 7,974,000**	**$ 139,267,320**	**$ 69,077,187**	**$ 77,325,200**			**$ 439,065,746**	**$ 234,507,588**
													$ 410.00 ->PW per AF of Take

For the 150,000 AF of Put; 50,000 AF to MRP/Oeste, 61,000 AF in Mojave River, 39,000 AF in P8 spreading grounds.

On all Take years, the first 20.5k AF are entitlement exchange, 25.4k come from Oeste/MRP, the next 39.3k AF from T3, and 4,800 AF from T0.

Table 7-14. Estimatated Annual Cost for 300,000 Acre-Foot Program

ASSUMPTIONS: Maximum Entitlement Exchange of 20,500 for 30 years

PW interest= 0.05
Debt Service interest= 0.05
n= 30

Total Bank Volume is = 300,000 AF

	Assessed Water Supply				Cost Data					Annual Cost			
	Put (AF)	60,000 AF "Take"			Operation (2005 $)			Capital (2005 $)		Debt Service ($)		$	
Year	(9 months)	Direct Take (10 months)	Entitlement Exchange	Storage (AF)	New Spreading Grounds Maintenance	Put	Take	Put	Take	Put	Take	Total Annual Cost	Present Worth
1	-	-	-	-	-	-	-	50,135,381	-	3,261,378	-	3,261,378	$ 3,261,378
2	100,000	-	-	90,000	117,000	736,000	-	-	40,100,000	3,261,378	2,648,425	6,762,804	$ 6,440,765
3		39,500	20,500	30,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 10,941,872
4	100,000	-	-	120,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 5,841,964
5	-	39,500	20,500	60,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 9,924,600
6	-	-	-	60,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 4,722,158
7	-	39,500	20,500	-	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 9,001,905
8	100,000	-	-	90,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 4,806,198
9	-	39,500	20,500	30,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 8,164,993
10	100,000	-	-	120,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 4,359,364
11	-	39,500	20,500	60,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 7,405,890
12	100,000	-	-	150,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 3,954,071
13	100,000	-	-	240,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 3,765,782
14	-	39,500	20,500	180,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 6,397,486
15	-	39,500	20,500	120,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 6,092,844
16	-	-	-	120,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 2,898,996
17	-	-	-	120,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 2,760,948
18	-	39,500	20,500	60,000	117,000	-	6,036,610	-	-	3,261,378	2,648,425	12,063,414	$ 5,263,227
19	-	-	-	60,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 2,504,261
20	100,000	-	-	150,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 2,676,271
21	-	39,500	20,500	90,000	117,000	-	6,724,325	-	-	3,261,378	2,648,425	12,751,129	$ 4,805,766
22	100,000	-	-	180,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 2,427,457
23	-	-	-	180,000	117,000	-		-	-	3,261,378	2,648,425	6,026,804	$ 2,060,262
24	100,000	-	-	270,000	117,000	736,000	-	-	-	3,261,378	2,648,425	6,762,804	$ 2,201,775
25	-	-	-	270,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 1,868,718
26	-	-	-	270,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 1,779,732
27	-	39,500	20,500	210,000	117,000	-	6,724,325	-	-	3,261,378	2,648,425	12,751,129	$ 3,586,137
28	-	-	-	210,000	117,000	-	-	-	-	3,261,378	2,648,425	6,026,804	$ 1,614,269
29	-	39,500	20,500	150,000	117,000	-	6,724,325	-	-	3,261,378	2,648,425	12,751,129	$ 3,252,732
30	-	39,500	20,500	90,000	117,000	-	6,724,325			3,261,378	2,648,425	12,751,129	$ 3,097,840
		474,000	246,000	3,780,000	3,393,000	6,624,000	75,190,180	50,135,381	40,100,000	97,841,354	76,804,329	259,852,864	137,879,662
Totals=	**900,000**	**720,000**				**$ 6,624,000**	**$ 75,190,180**	**$ 50,135,381**	**$ 40,100,000**			**$ 259,852,864**	**$ 137,879,662**
													$ 360.00 ->PW per AF of Take

For the 100,000 AF of Put; 39k AF in P8 spreading grounds, 61k AF in Mojave River.
On all Take years, the first 20.5k AF from entitlement exchange, 39.5k AF come from T3, and 4,800 AF from T0.

Table 7-15. Estimated Annual Cost for 225,000 Acre-Foot Program

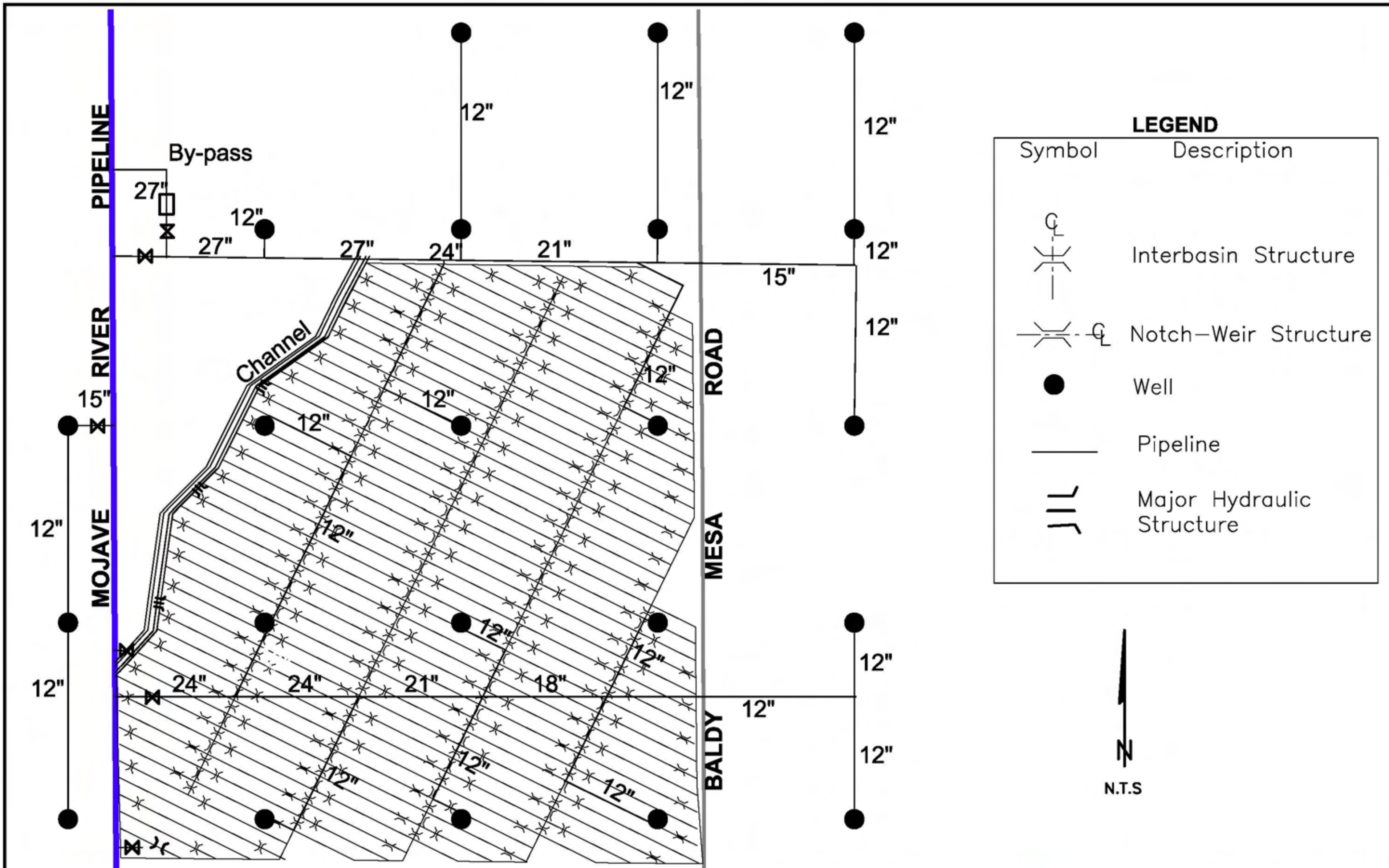
ASSUMPTIONS: Maximum Entitlement Exchange of 20,500 for 30 years

Total Bank Volume is 225,000 AF

PW interest= 0.05
Debt Service interest= 0.05
n= 30

	Assessed Water Supply									Annual Cost			
	Put (AF)	45,000 AF "Take"			Operation (2005 $)			Capital (2005 $)		Debt Service ($)		$	
Year	(9 months)	Direct Take (10 months)	Entitlement Exchange	Storage (AF)	Existing Spreading Grounds Maintenance	Put	Take	Put	Take	Put	Take	Total Annual Cost	Present Worth
1	-	-	-	-	-	-	-	13,400,000		871,689	-	871,689	$ 871,689
2	75,000	-	-	67,500	42,000	408,000	-	-	31,800,000	871,689	2,100,247	3,379,937	$ 3,218,987
3		24,500	20,500	22,500	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 6,323,752
4	75,000	-	-	90,000	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 2,919,716
5	-	24,500	20,500	45,000	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 5,735,829
6	-	-	-	45,000	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 2,328,590
7	-	24,500	20,500	-	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 5,202,566
8	75,000	-	-	67,500	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 2,402,058
9	-	24,500	20,500	22,500	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 4,718,881
10	75,000	-	-	90,000	42,000	408,000		-	-	871,689	2,100,247	3,379,937	$ 2,178,737
11	-	24,500	20,500	45,000	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 4,280,164
12	75,000	-	-	112,500	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 1,976,179
13	75,000	-	-	180,000	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 1,882,075
14	-	24,500	20,500	135,000	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 3,697,367
15	-	24,500	20,500	90,000	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 3,521,302
16	-	-	-	90,000	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 1,429,552
17	-	-	-	90,000	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 1,361,478
18	-	24,500	20,500	45,000	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 3,041,833
19	-	-	-	45,000	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 1,234,901
20	75,000	-	-	112,500	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 1,337,556
21	-	24,500	20,500	67,500	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 2,627,650
22	75,000	-	-	135,000	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 1,213,202
23	-	-	-	135,000	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 1,015,956
24	75,000	-	-	202,500	42,000	408,000	-	-	-	871,689	2,100,247	3,379,937	$ 1,100,410
25	-	-	-	202,500	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 921,502
26	-	-	-	202,500	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 877,621
27	-	24,500	20,500	157,500	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 1,960,793
28	-	-	-	157,500	42,000	-	-	-	-	871,689	2,100,247	2,971,937	$ 796,028
29	-	24,500	20,500	112,500	42,000	-	4,000,000	-	-	871,689	2,100,247	6,971,937	$ 1,778,497
30	-	24,500	20,500	67,500	42,000	-	4,000,000			871,689	2,100,247	6,971,937	$ 1,693,806
		294,000	246,000	2,835,000	1,218,000	3,672,000	48,000,000	13,400,000	31,800,000	26,150,677	60,907,174	138,729,851	73,648,680
Totals=	**675,000**	**540,000**				**$ 3,672,000**	**$ 48,000,000**	**$ 13,400,000**	**$ 31,800,000**			**$ 138,729,851**	**$ 73,648,680**
													$ 260.00 ->PW per AF of Take

For the 75,000 AF of Put; 61,000 AF in Mojave River, 14,000 AF in Existing spreading grounds.
On all Take years, first 20.5k AF entitlement exchange, and 24.5k AF from T3.



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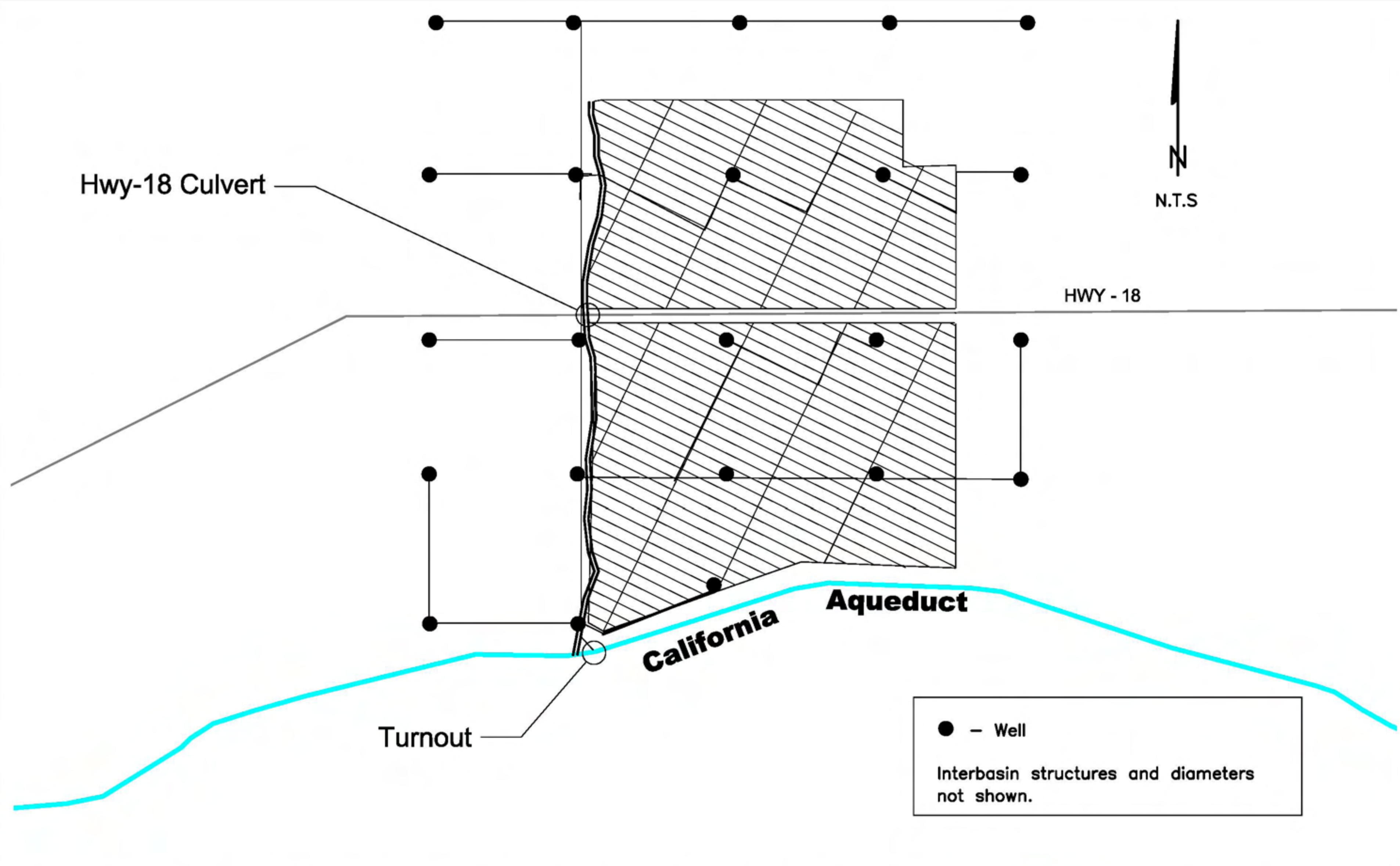
MOJAVE RIVER PIPELINE
Spreading Grounds Schematic

11/3/05	FIGURE 7–1



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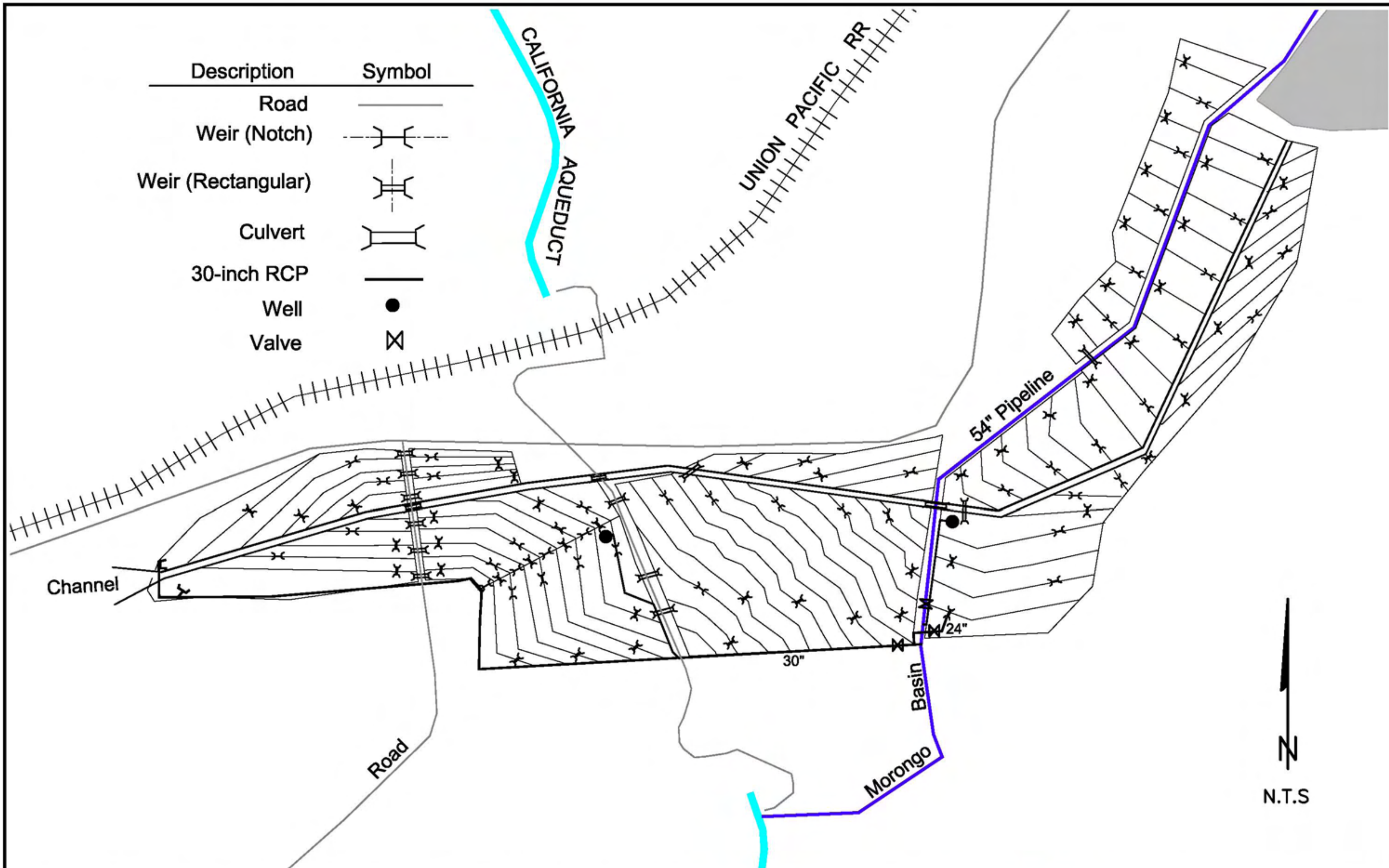
OESTE
Preliminary Spreading Grounds

11/3/05

FIGURE 7–2



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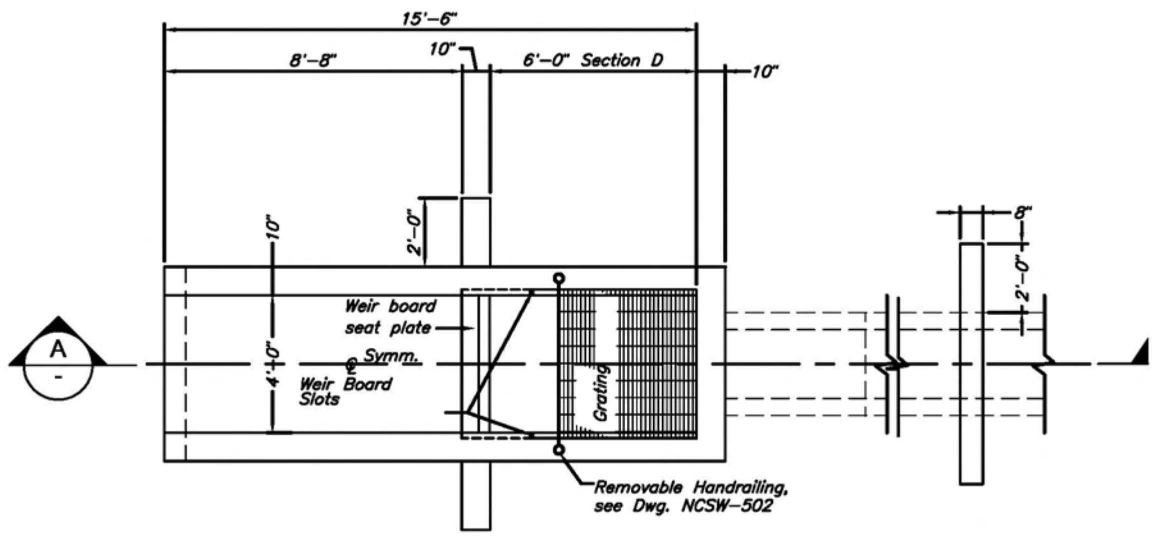
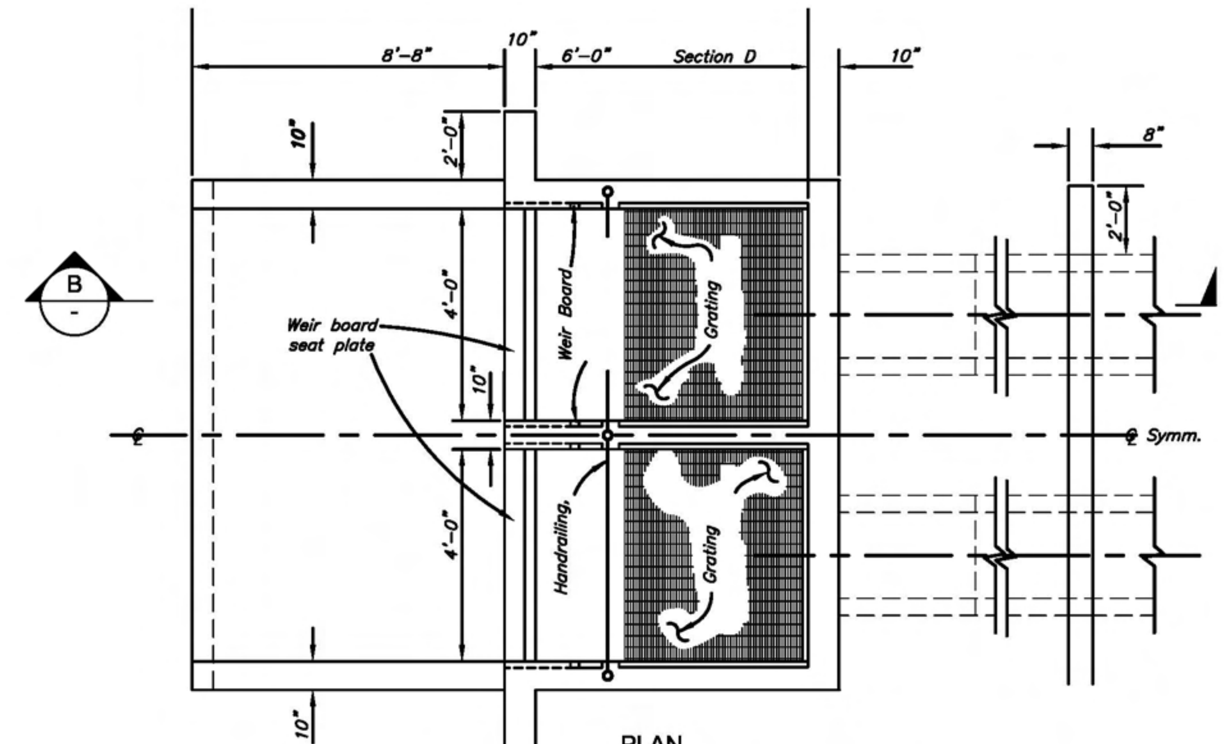
MOJAVE WATER AGENCY		11/3/05	FIGURE 7-3



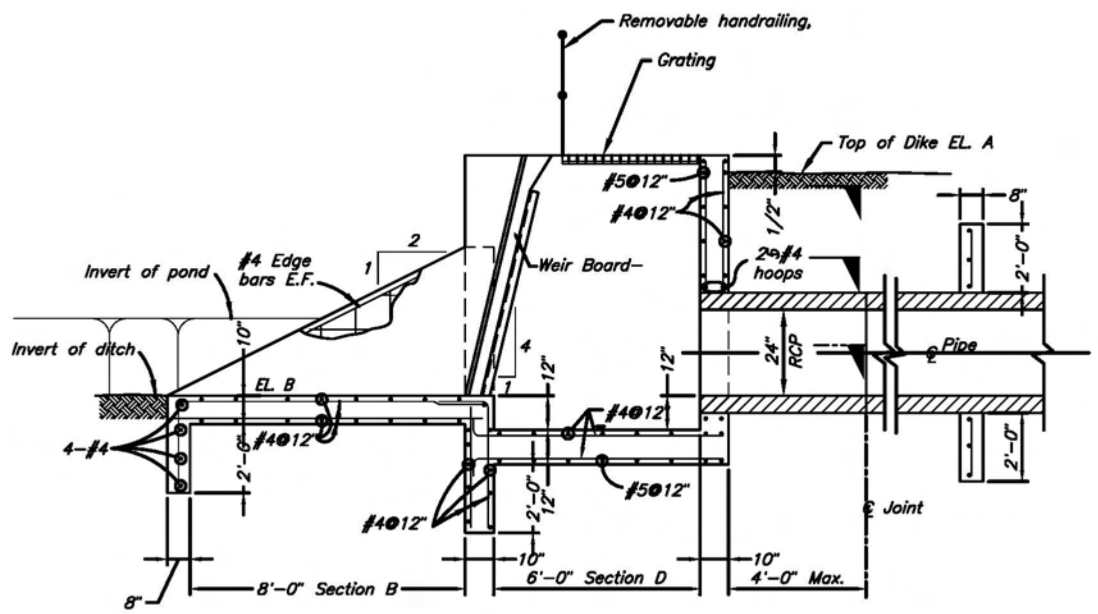
PLAN

INTERBASIN HYDRUALIC STRUCTURE

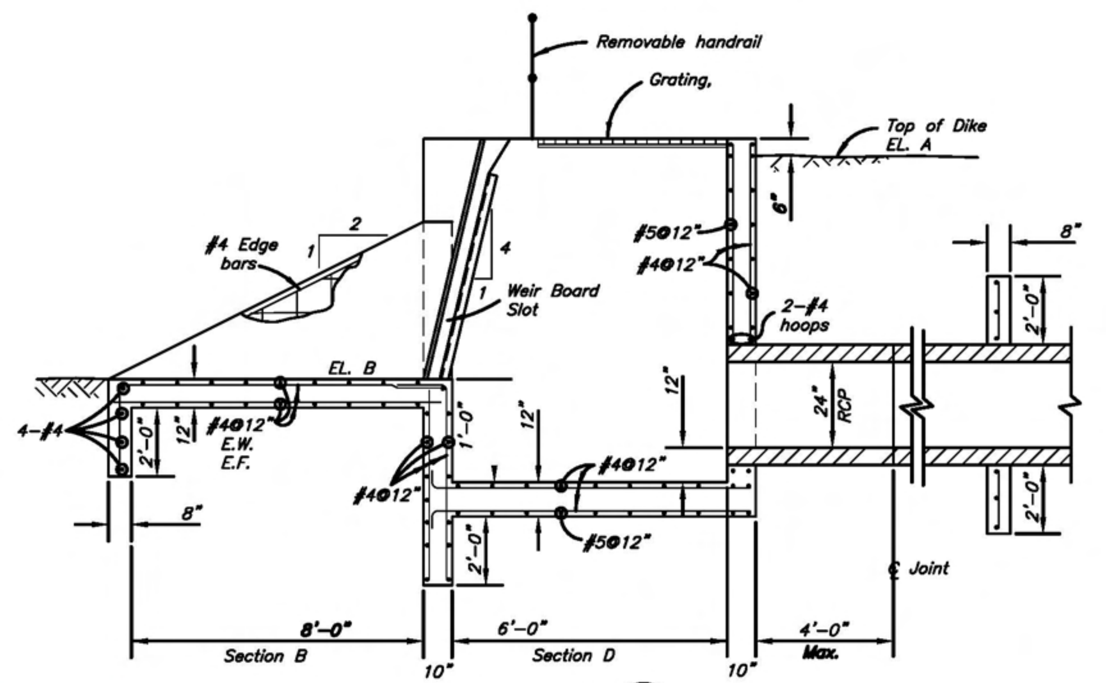


PLAN

HYDRUALIC STRUCTURE (DOUBLE BARREL)



SECTION A



SECTION B

Scale: N.T.S.

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Interbasin Structure and Hydraulic Structure

Plan and Section

Proj. No. 042810	11/3/05	FIGURE 7-4

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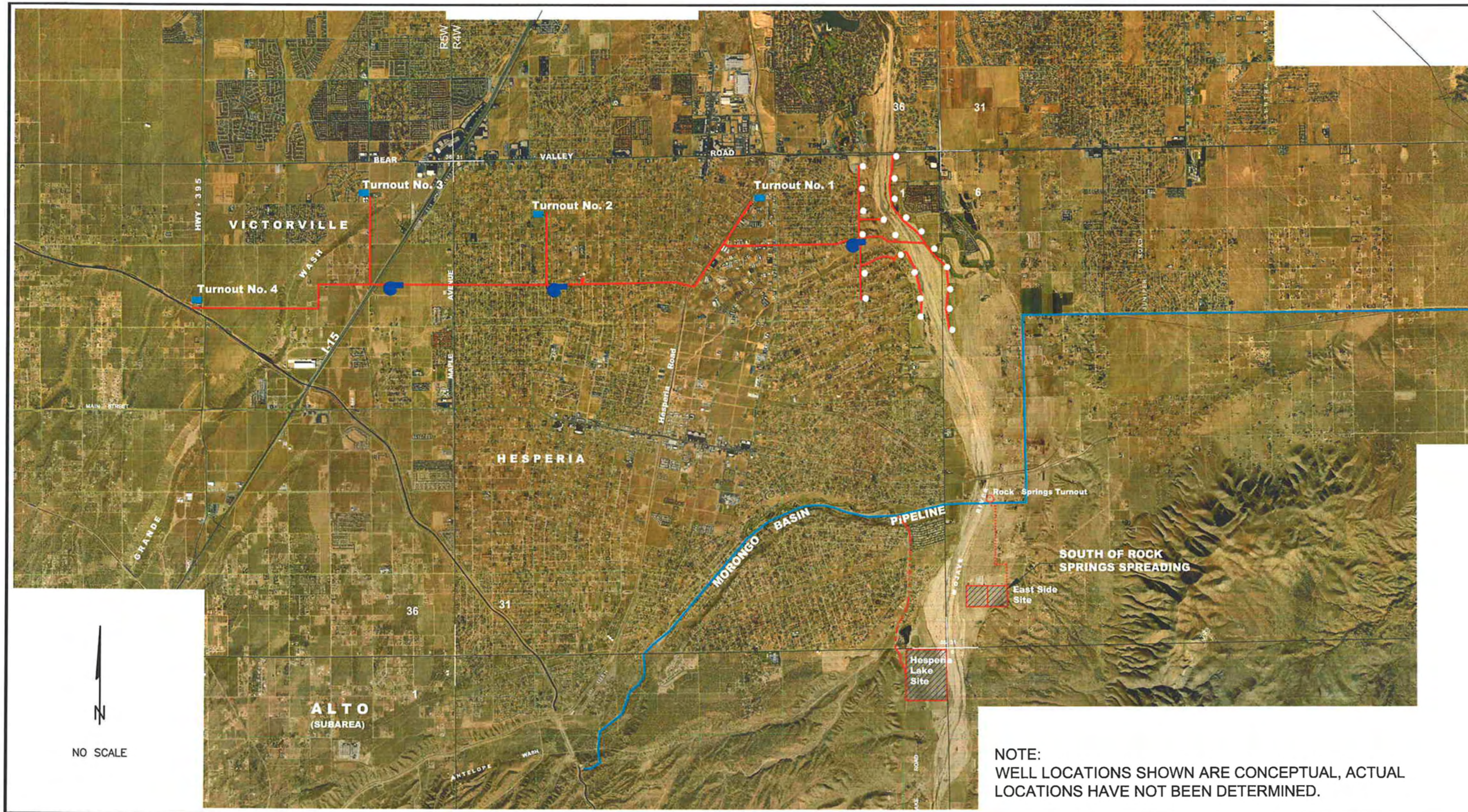

NOTE:
WELL LOCATIONS SHOWN ARE CONCEPTUAL, ACTUAL LOCATIONS HAVE NOT BEEN DETERMINED.

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UPPER MOJAVE RIVER WELL FIELD & SUPPLY PIPELINE

W/ SOUTH OF ROCK SPRINGS SPREADING

Proj. No. 042810	11/3/05	FIGURE 7-5

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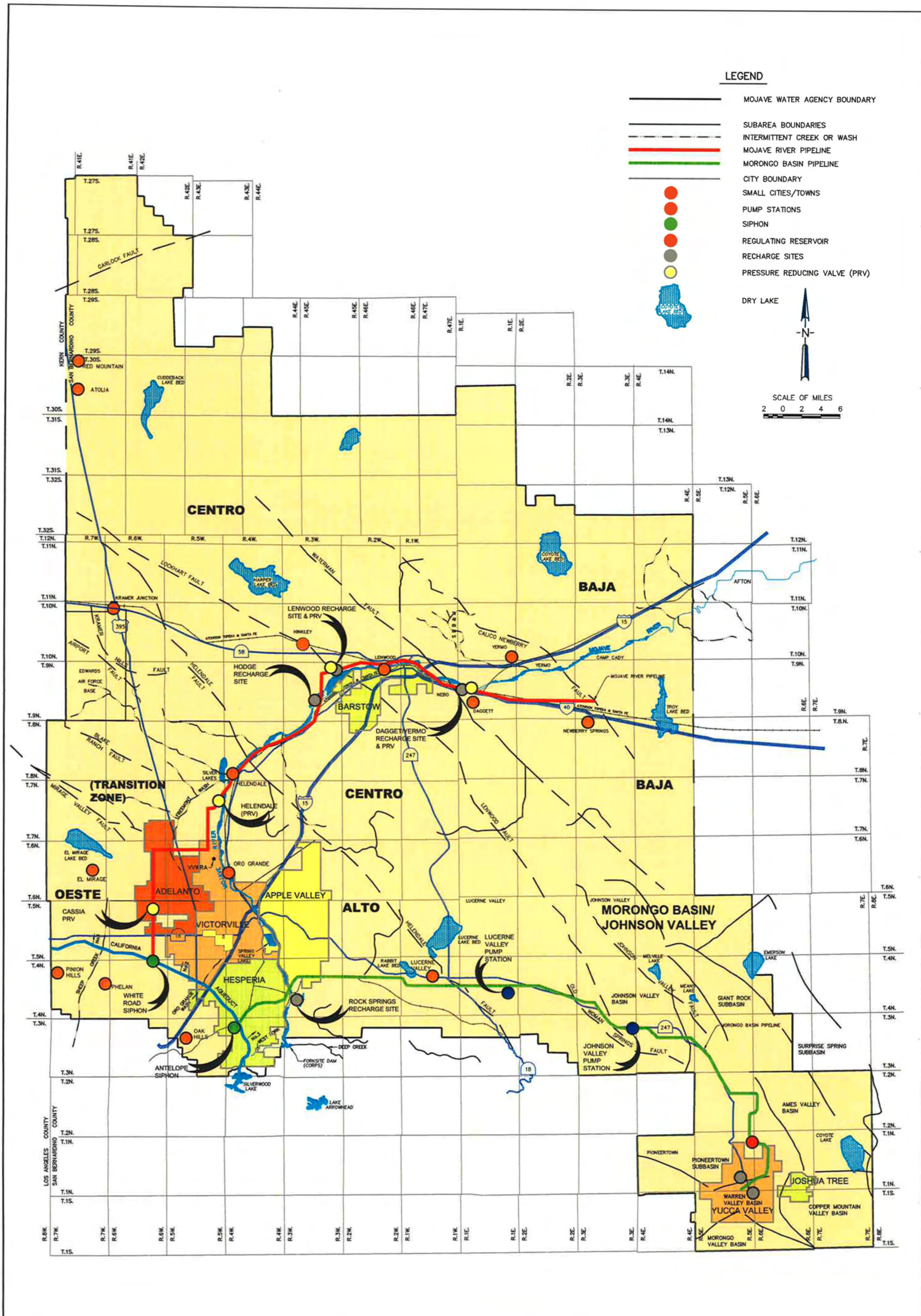

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BASE MAP

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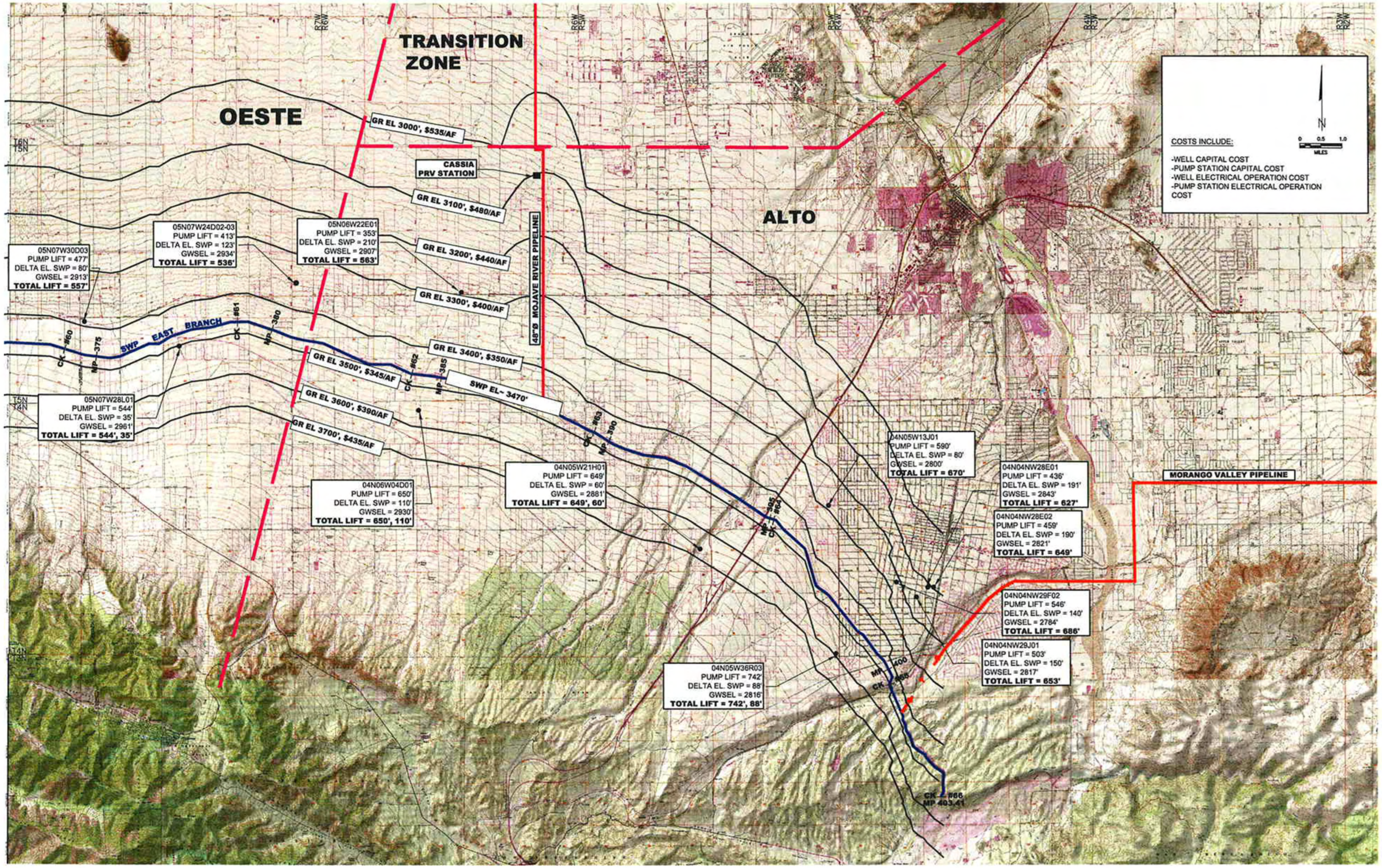

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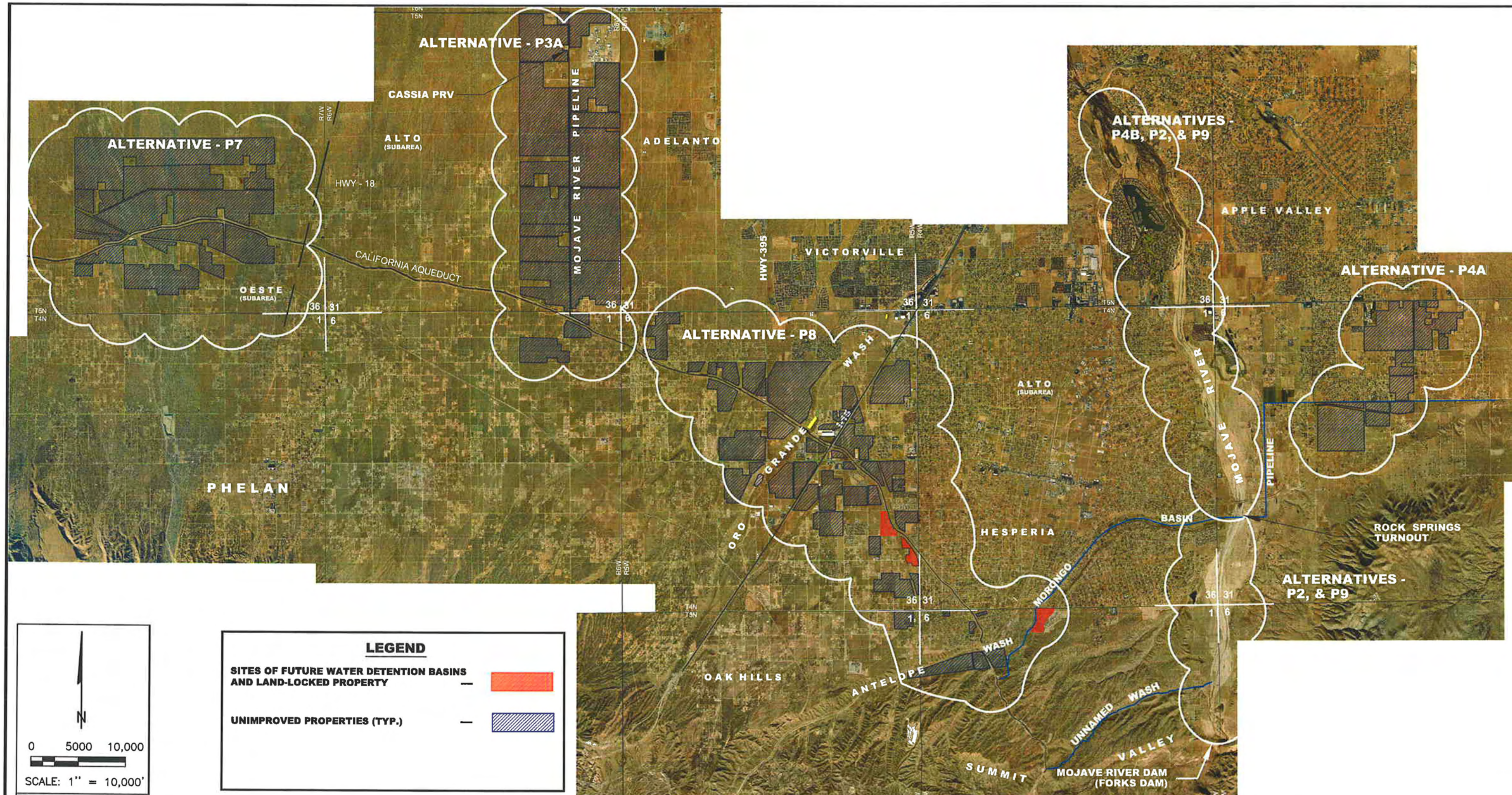
MOJAVE WATER AGENCY		Proj. No. 042810 · 10/14/05 · PLATE 2



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LOCATION OF PUT ALTERNATIVES

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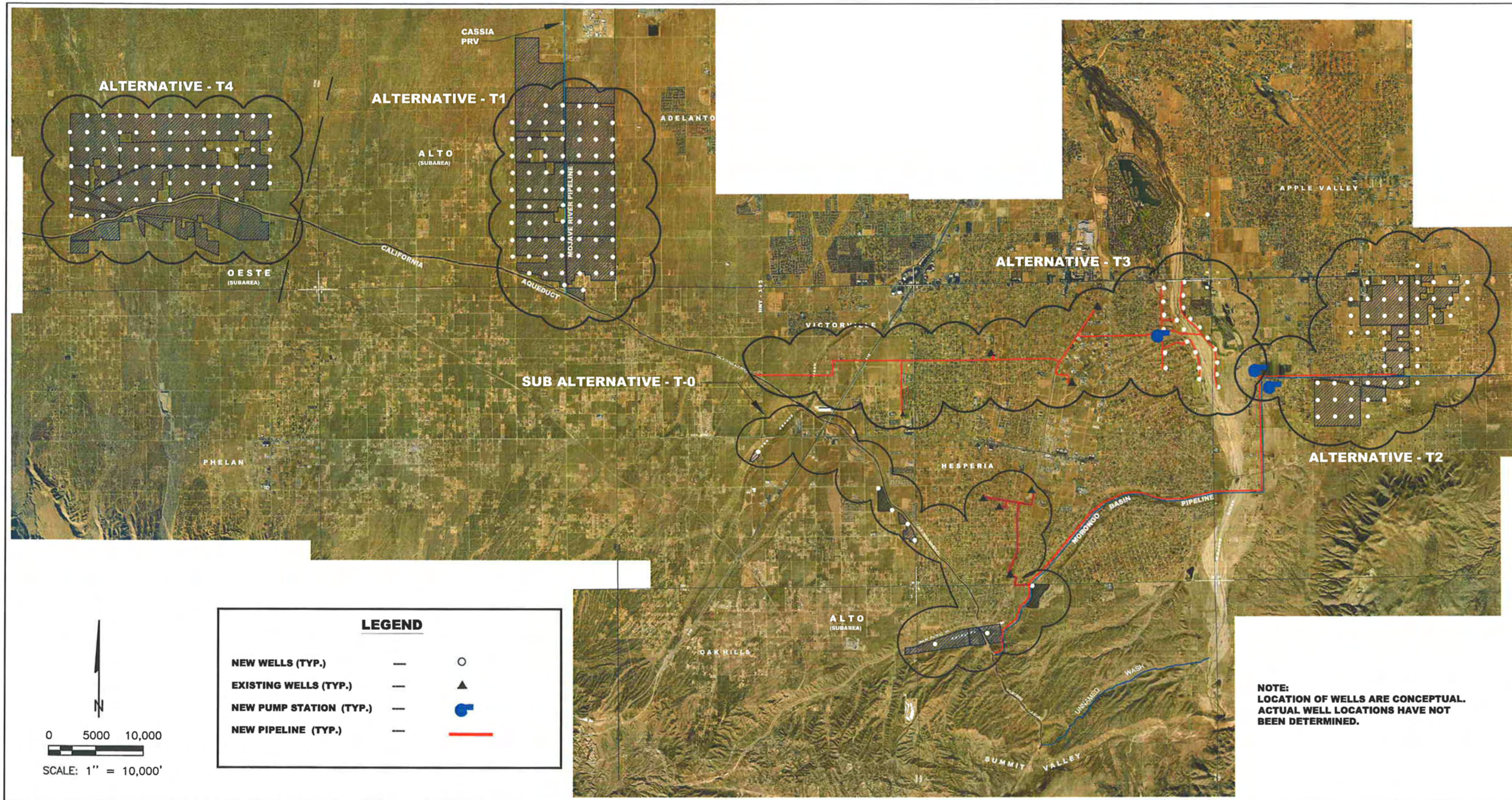

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LOCATION OF TAKE ALTERNATIVES

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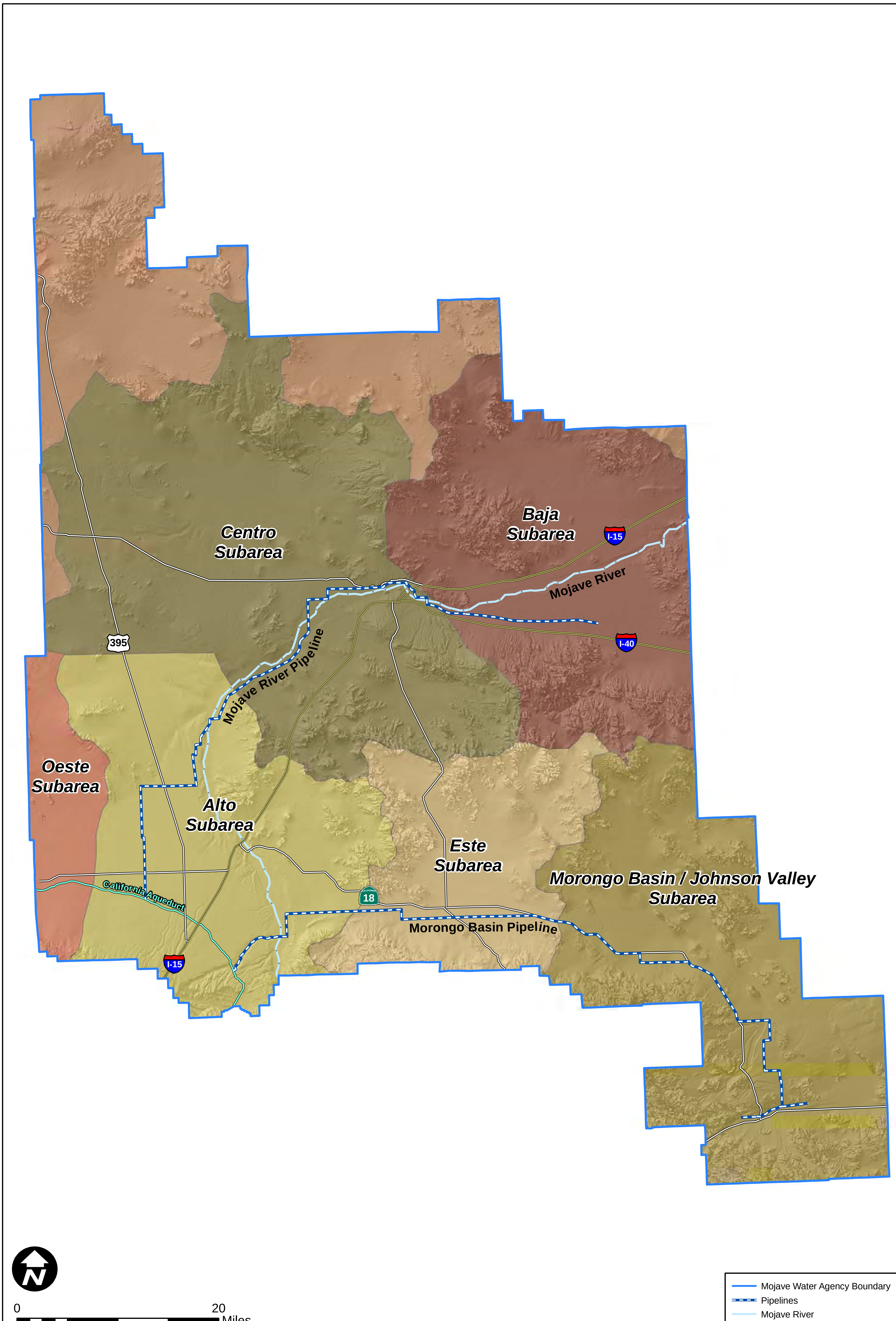


Subareas of Mojave Water Agency

PLATE - 5

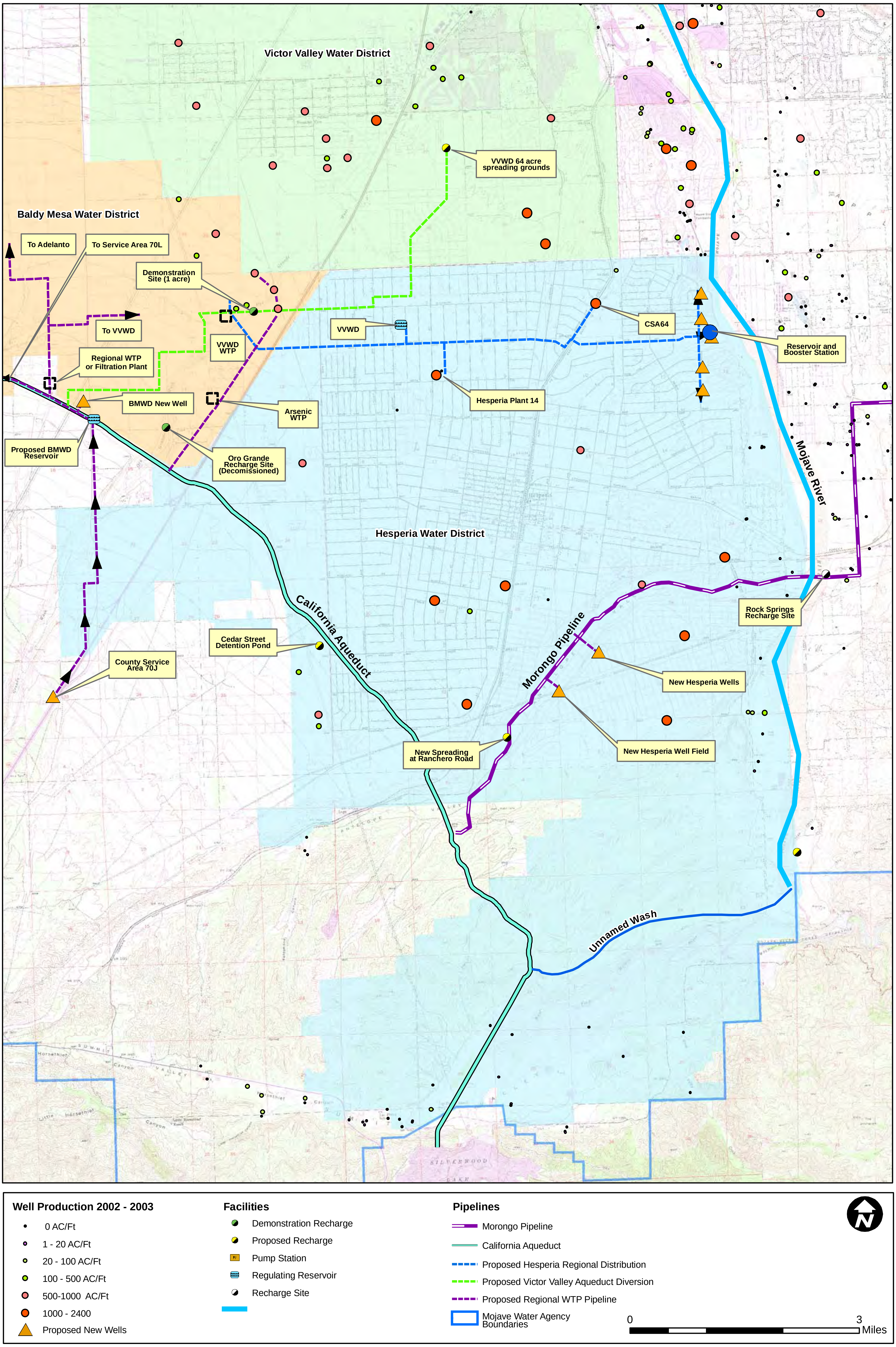
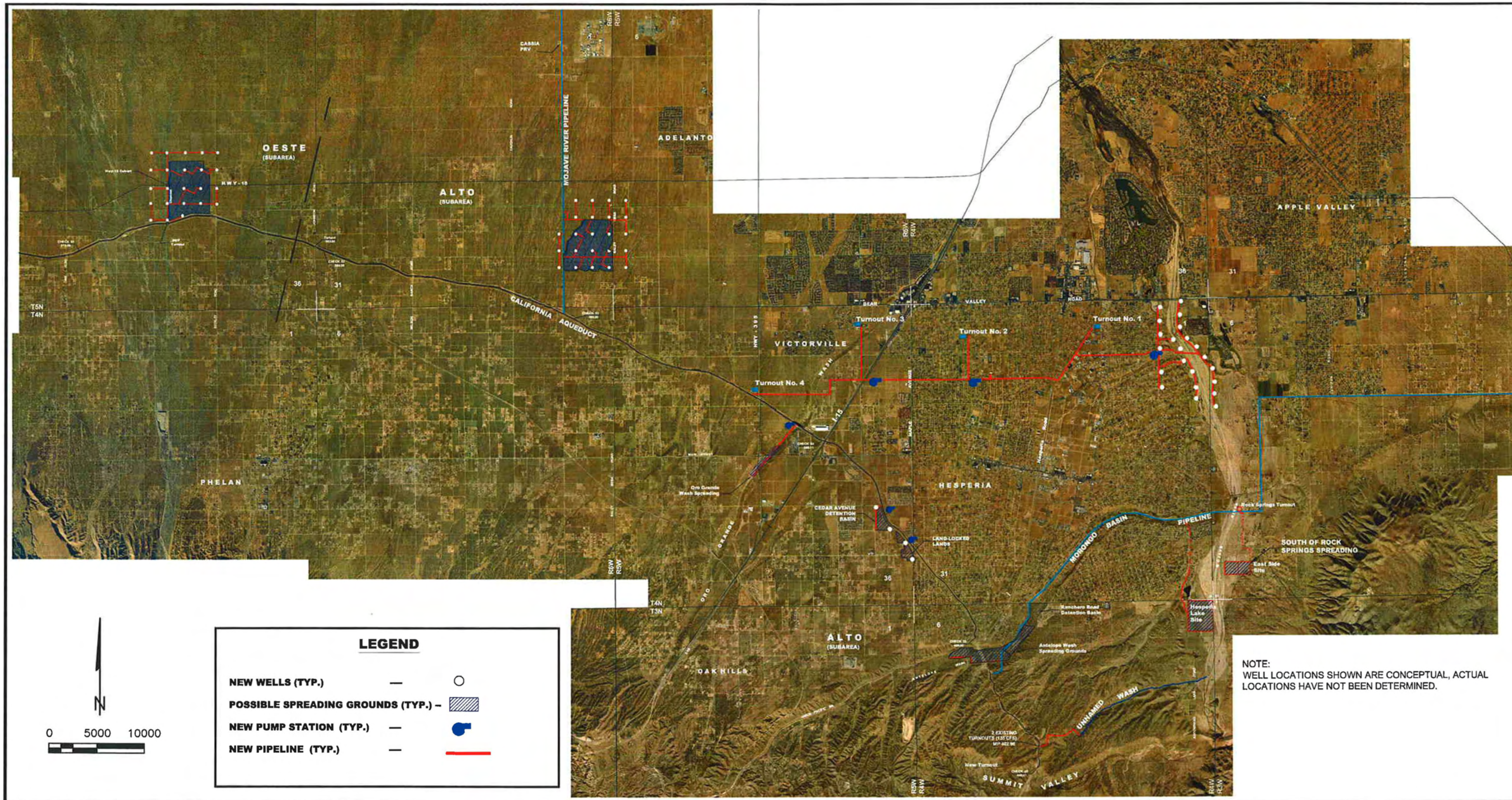


PLATE - 6

Local Agency Facilities that have Potential for the MWA/Metropolitan Program



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LOCATION OF POTENTIAL FACILITIES

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Appendix A

Local Model Simulating River Recharge and Pumping Scenarios

Local Model Simulating River Recharge And Pumping Scenarios

Mojave Water Agency
Long-Term Management Program
September 10,2004

Objective and Assumption

The objective of this model simulation is to test the possibility of the proposed banking program of using Mojave River as a recharge site. The developed model covers a local area from The forks to Narrows. The MODFLOW was used as a tool to develop this model. Most aquifer parameters were based on USGS Mojave River Basin Model (USGS Model). The proposed artificial recharge (put) from the Mojave River to groundwater and proposed extraction (take) were set up in this model. The natural recharges (natural river recharge, irrigation return flow, fish hatchery, and etc.) and discharge (existing pumpage, evapotranspiration, and etc.) were not included in this model setup. Therefore, the modeling results only show the changes of groundwater levels with this proposed banking program from the groundwater levels without this banking program.

Model Setup

- Model Area covers Mojave River from The Forks to Narrows as shown in Figure 1,
- Conceptual model is shown in Figure 2. A two-layer model was used to simulate the aquifer system as shown in Figure 2. Model layer 1 thickness is determined as 100 feet (river aquifer thickness), and regional aquifer thickness is 1300 feet. The width of river aquifer is set up as 7,000 feet,
- Model grid size is 500 ft by 500 ft as shown in Figure 3 (USGS model grid size is 2,000 ft by 2,000 ft). There are 68 cell in X direction and 160 cells in Y direction, therefore model area is about 6.4 mile by 15 mile,
- Northern and southern boundaries are set up as the constant heads shown in Figure 4, the values of constant head at northern boundary and southern boundary

are set up as 2670 ft and 2920 ft based on the predicted 1998 groundwater levels from USGS Model as shown in Figure 5,

- Mojave river width was set up as 2,000 ft (USGS Model), the elevation of river bed is 100 ft above the bottom elevation of river aquifer,
- Horizontal hydraulic conductivity of river aquifer is set up as 100 ft/day and regional aquifer is set up as 7 feet/day, the transimissivities calculated using these values are close to the USGS Model's transmissivities (transmissivity equals to horizontal hydraulic conductivity multiplied by aquifer thickness) shown in Figure 6 (layer 1) and Figure 7 (layer 2). These values of horizontal hydraulic conductivities were also recommended by Tom Regan,
- Layer 1 vertical hydraulic conductivity was set up as one-tenth of horizontal hydraulic conductivity based on USGS model data shown in Figure 9, and layer 2 vertical hydraulic conductivity was also set up as one-tenth of horizontal hydraulic conductivity based on USGS Model input (USGS Model report page 53),
- Layer 1 specific yield of 0.2 was used in the model (also recommended by Tom Regan). Specific yield of layer 1 in USGS model ranges from 0.12 to 0.39 in the model area as shown in Figure 8. Layer 2 specific storage value of 0.000001/ft (USGS Model report page 53) was used in the model,
- Initial groundwater elevations shown in Figure 10 were interpolated based on the elevations at the southern and northern boundaries,

River Recharge

- The artificial recharges from river to groundwater were over six months: March, April, May, September, October and November. In the recharge period, river water depth was set up as one feet.
- Riverbed conductance is equal to the product of the vertical hydraulic conductivity of the riverbed and riverbed area, divided by the vertical thickness of the riverbed. The average value of riverbed conductance in the model area is about 0.8 ft^2/s (69,120 ft^2/day) as indicated in USGS Model,

Pumping Scenarios

Scenario 1

- Pump wells in regional aquifer (layer 2) about 2 miles west of Mojave River were set up as shown in Figure 11. The space between wells is 500 feet. Each well pumps 40,000 ft3/day for all the simulation period (5 years) except the first two months. In order to eliminate the initial effects, the wells stat pumping from the third month of the entire simulation. As shown in Figure 11, there are 11 wells in one-mile distance; therefore, these 11 wells pump about 10 acre-foot per day (af/day).
- Simulated Groundwater elevations in layer 1 and layer 2 at a cross-section are shown in Figure 12 and 13, respectively. The location of this cross-section is shown in Figure 14.

Scenario 2

- Pump wells in regional aquifer (layer 2) about 1250 feet from the bank of Mojave River on each side were set up as shown in Figure 15, each well pumps 20,000 ft3/day for all the simulation period (5 years) except the first two months. In order to eliminate the initial effects, the wells stat pumping from the third month of simulation. As shown in Figure 15, there are 22 wells in one-mile distance; therefore, these 22 wells pump about 10 af/day.
- Simulated Groundwater elevations in layer 1 and layer 2 at a cross-section are shown in Figure 16 and 17, respectively. The location of this cross-section is shown in Figure 14.

Conclusion

- As the results of comparing scenarios 1 (Figures 12 and 13) with scenario 2 (Figures 16 and 17), the groundwater level in scenario 1 drops about 40 feet in 5 years and 5-year average groundwater level in scenario 2 does not drop. The reason that groundwater levels in layer 2 in scenario 1 drop 40 feet is that recharged water flows slowly in layer 2 due to the low transimissivity of layer 2. From this point of view, the scenario 2 is better one. As suggested by Dick Rhone, the water quality of scenario 2 is not a problem since water pumped from layer 2 (Although the proposed wells are very close to the River in the plan view). Table 1 (at the end of Figures) shows the average artificial recharges and extractions of scenario 2 in each month in this 5-year model simulation period. As shown in this Table, total artificial recharge is about 156,000 acre-foot per year. (af/yr) and total extraction is 134,740 af/yr. Part of the excess recharge water (artificial recharge less extraction) makes the groundwater level slightly high as shown in Figure 17 and part of it flows to down-gradient as groundwater underflow. The feasibility of construction of production wells along Mojave River in 1250 feet distance from the riverbank needed to be studied.

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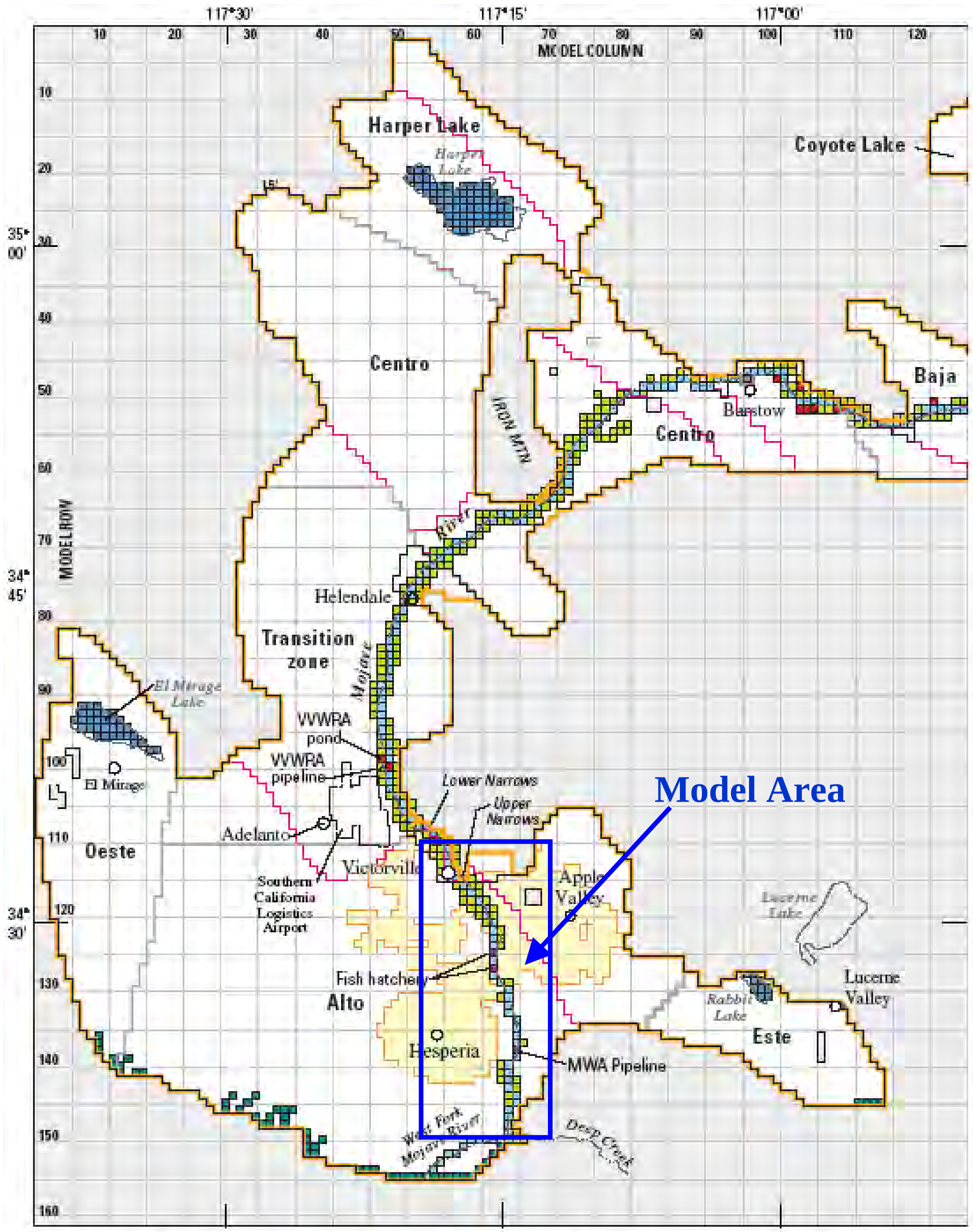

Figure 18. Location of model grid and model boundaries and location of horizontal-flow barrier, mountain-front recharge, drain, California. (VVWRA, Victor Valley Wastewater Reclamation Authority; MWA, Mojave Water Agency)

46 Simulation of Ground-Water Flow in the Mojave River Basin, California

Figure 1 Model Area

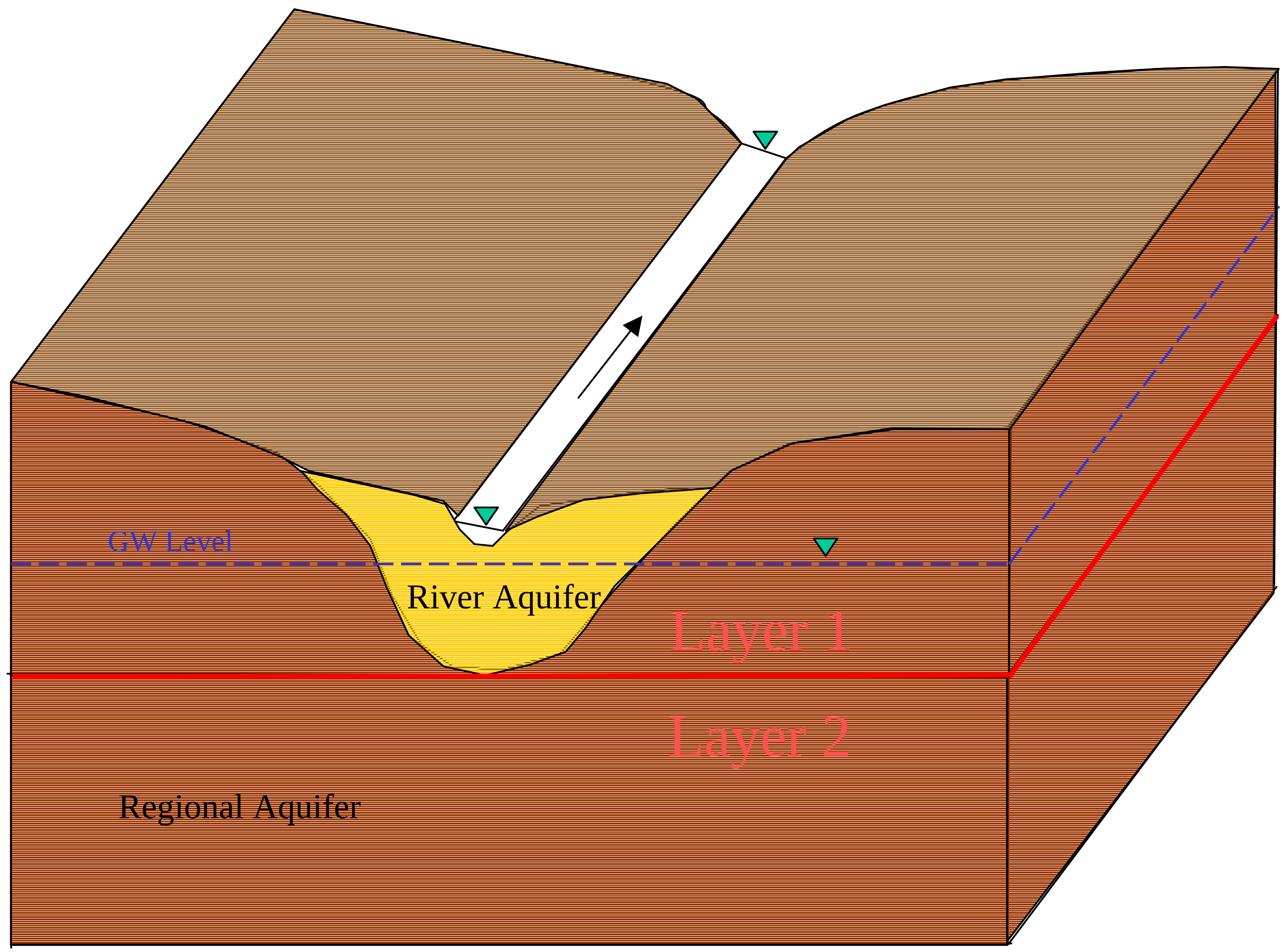

Figure 2 Conceptual Model

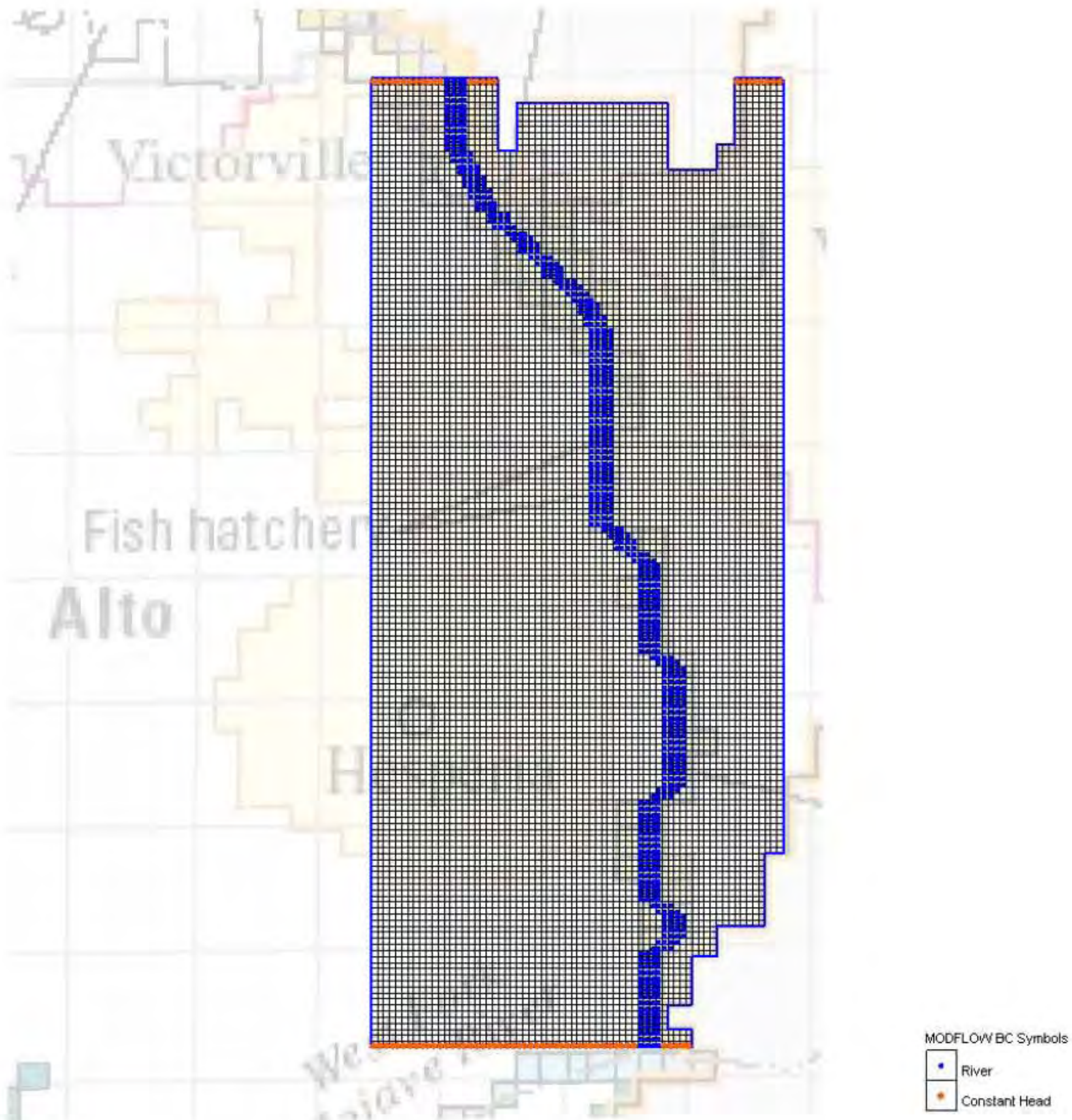

Figure 3 Model Grid

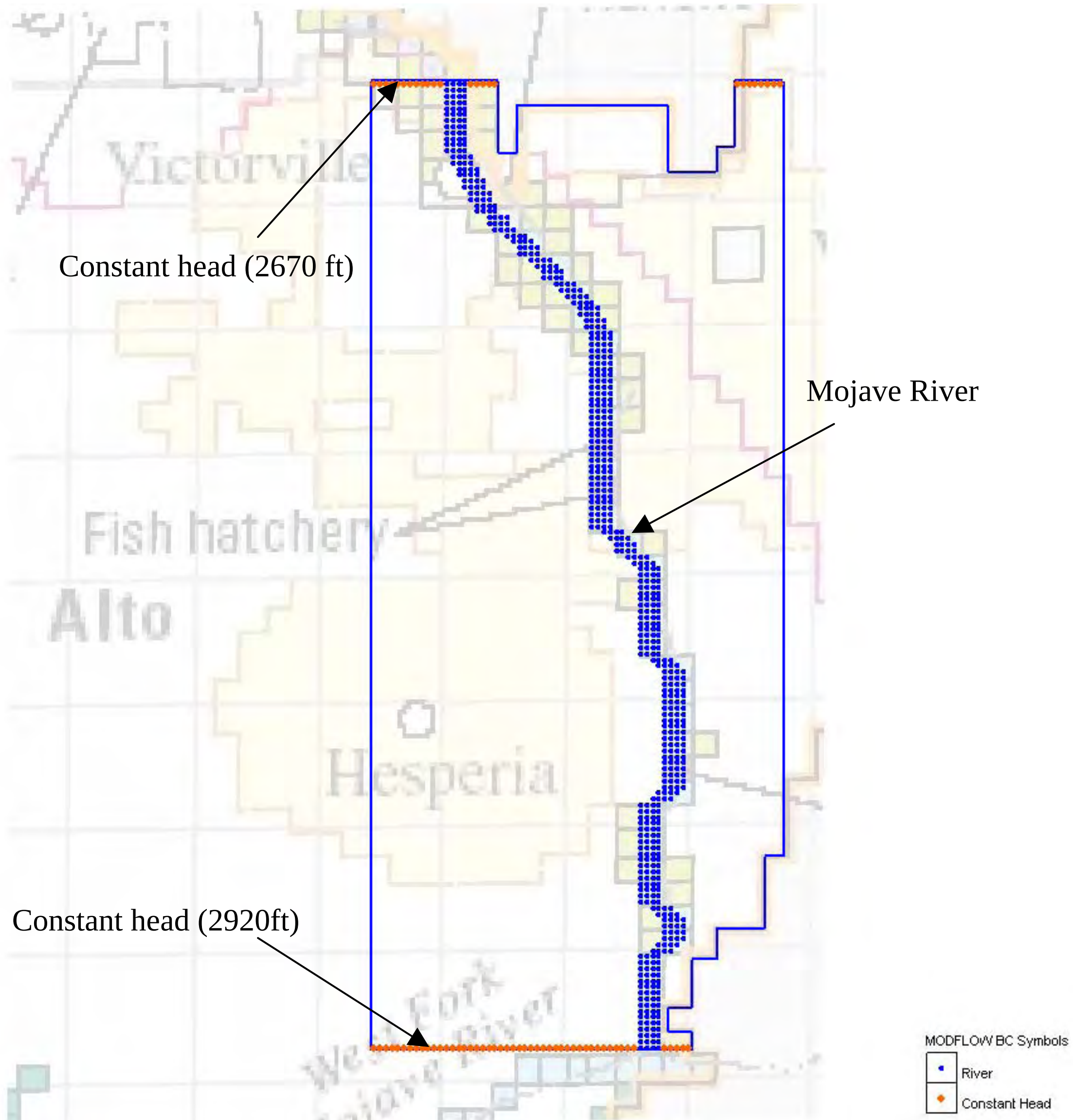

Figure 4 Boundary Conditions

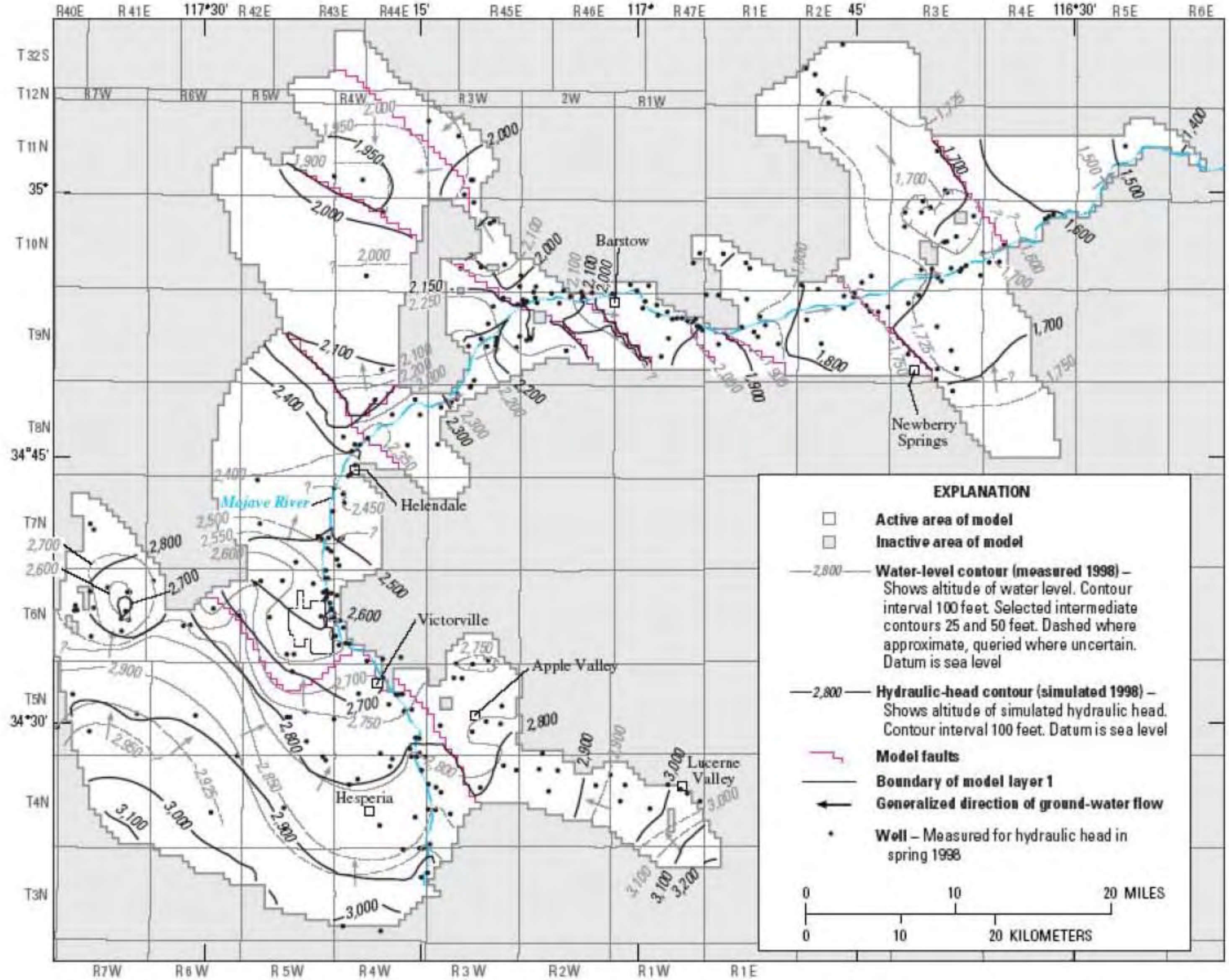

Figure 37. Measured water levels, spring 1998, and simulated hydraulic-head contours, 1998, for model layer 1 of the ground-water flow model of the Mojave River ground-water basin, southern California.

Figure 5 1998 Groundwater Levels (USGS Model)

50 Simulation of Ground-Water Flow in the Mojave River Basin, California

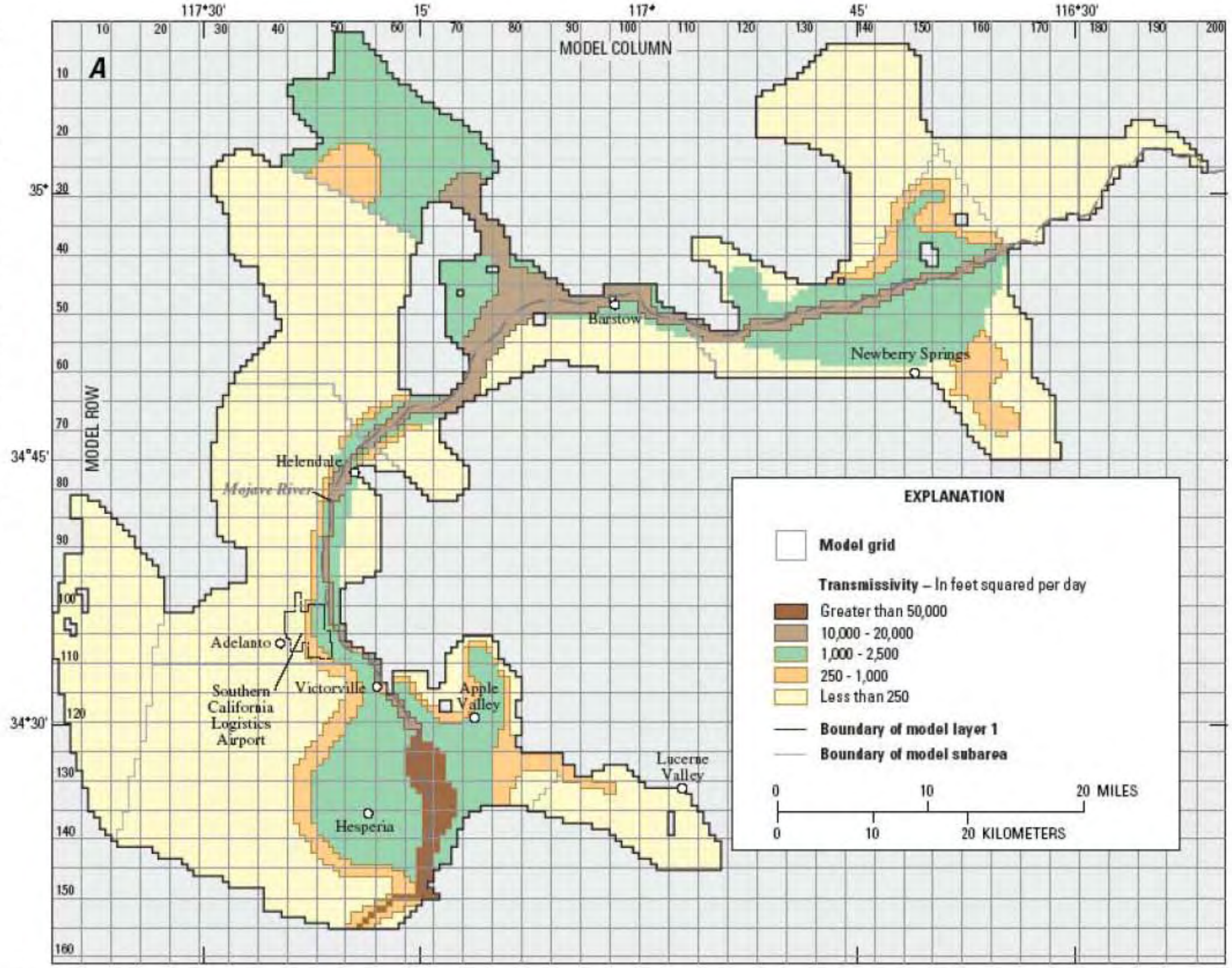

Figure 19. Areal distribution of transmissivity in the ground-water flow model of the Mojave River ground-water basin, southern California. ***A***, Model layer 1. ***B***, Model layer 2.

Figure 6 Layer 1 Transmissivity (USGS Model)

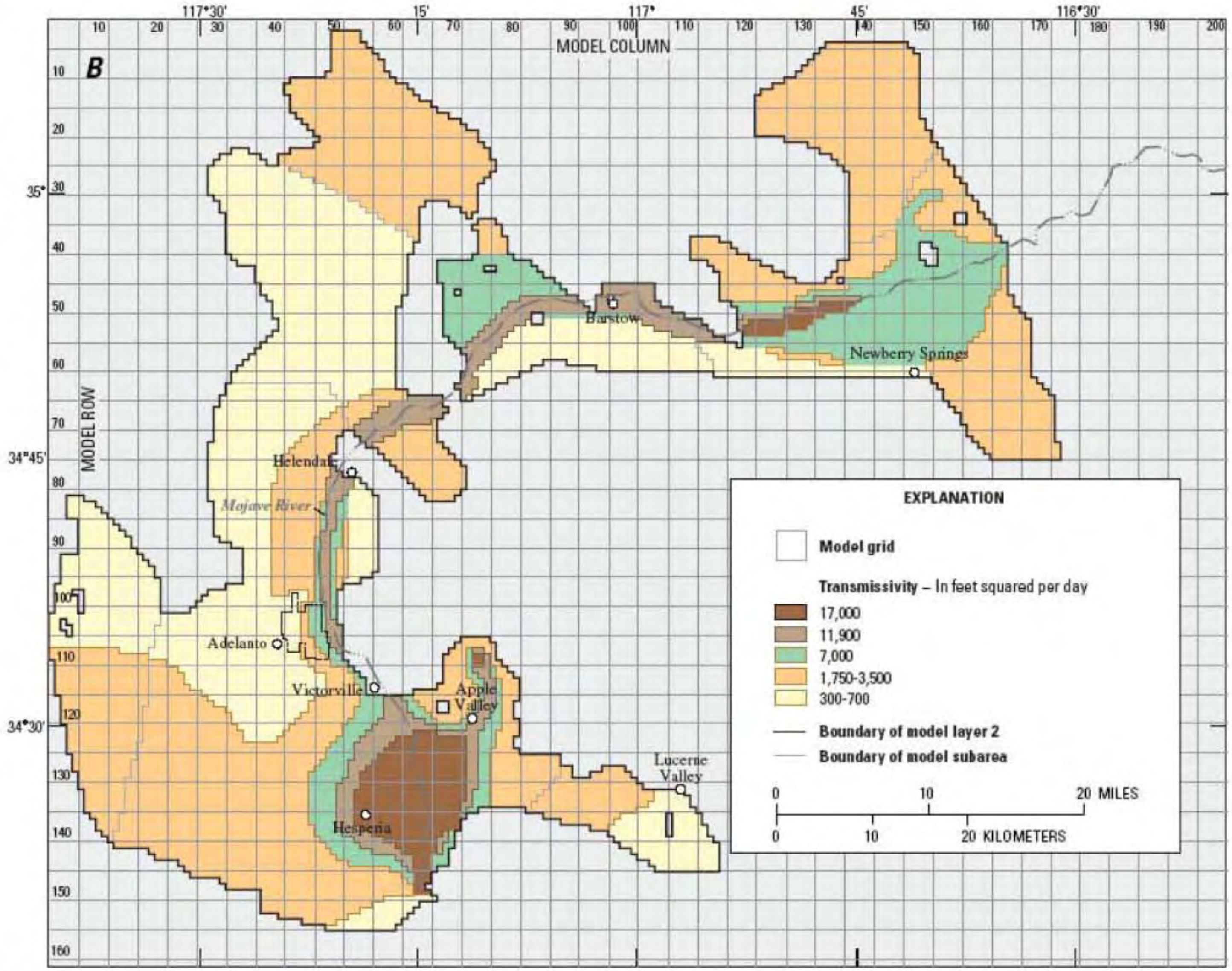

Figure 19.—Continued.

Figure 7 Layer 2 Transmissivity (USGS Model)

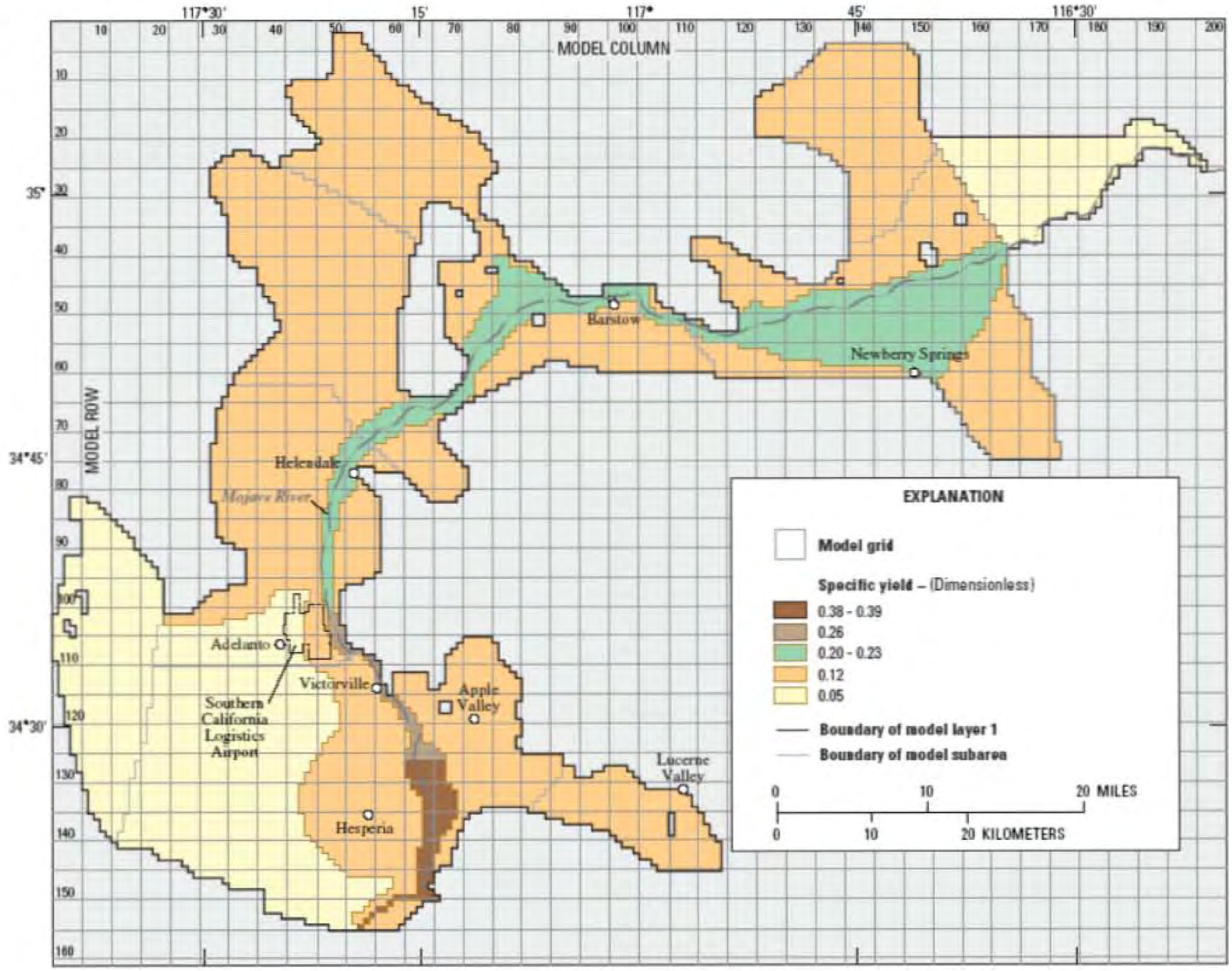

Figure 20. Areal distribution of specific yield for model layer 1 of the ground-water flow model of the Mojave River ground-water basin, southern California. See figure 18 for location of model subareas.

Figure 8 Layer 1 Specific Yield (USGS Model)

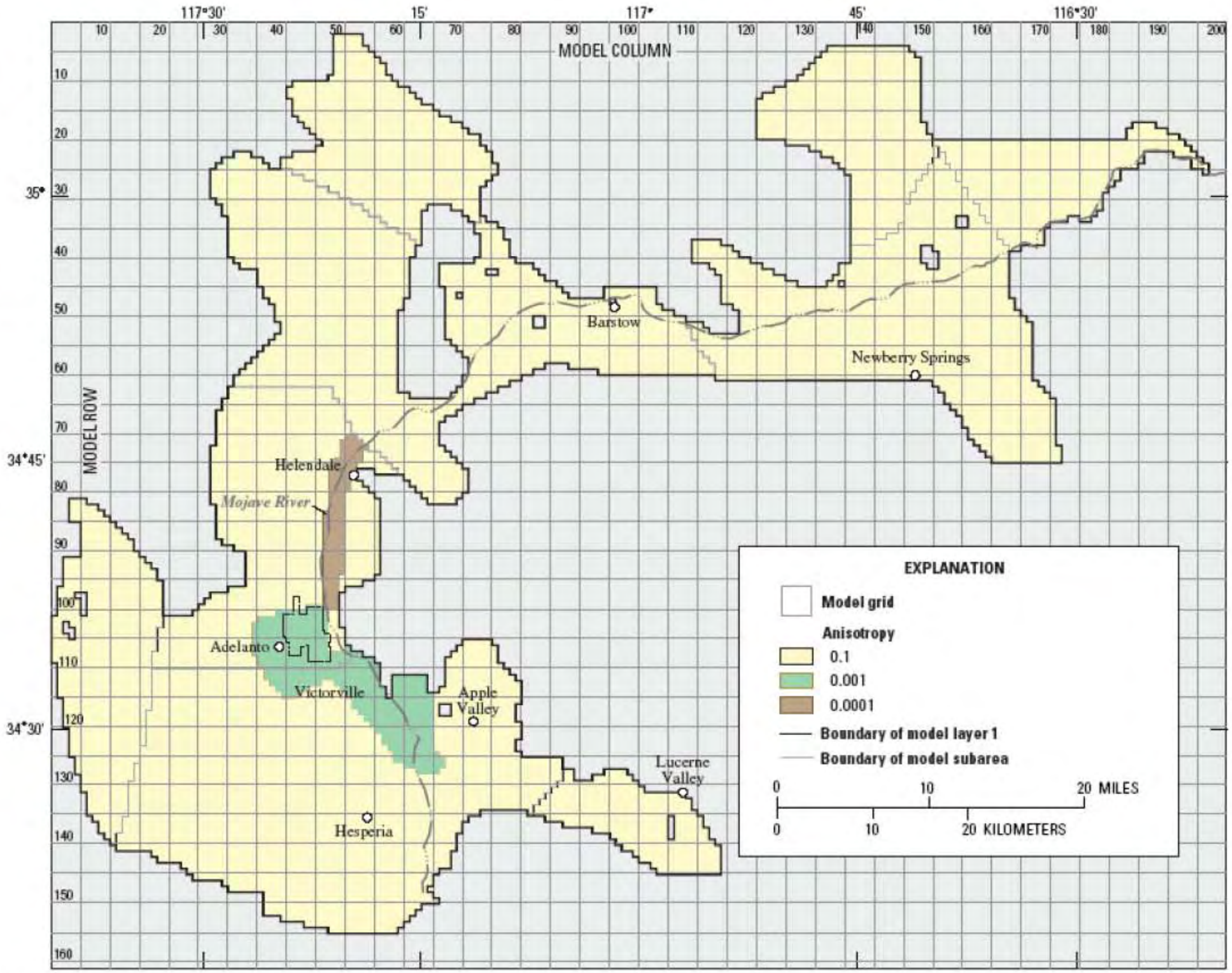

Figure 21. Areal distribution of anisotropy for model layer 1 of the ground-water flow model of the Mojave River ground-water basin, southern California.

Figure 9 Ratio of Vertical Hydraulic Conductivity and Horizontal Hydraulic Conductivity

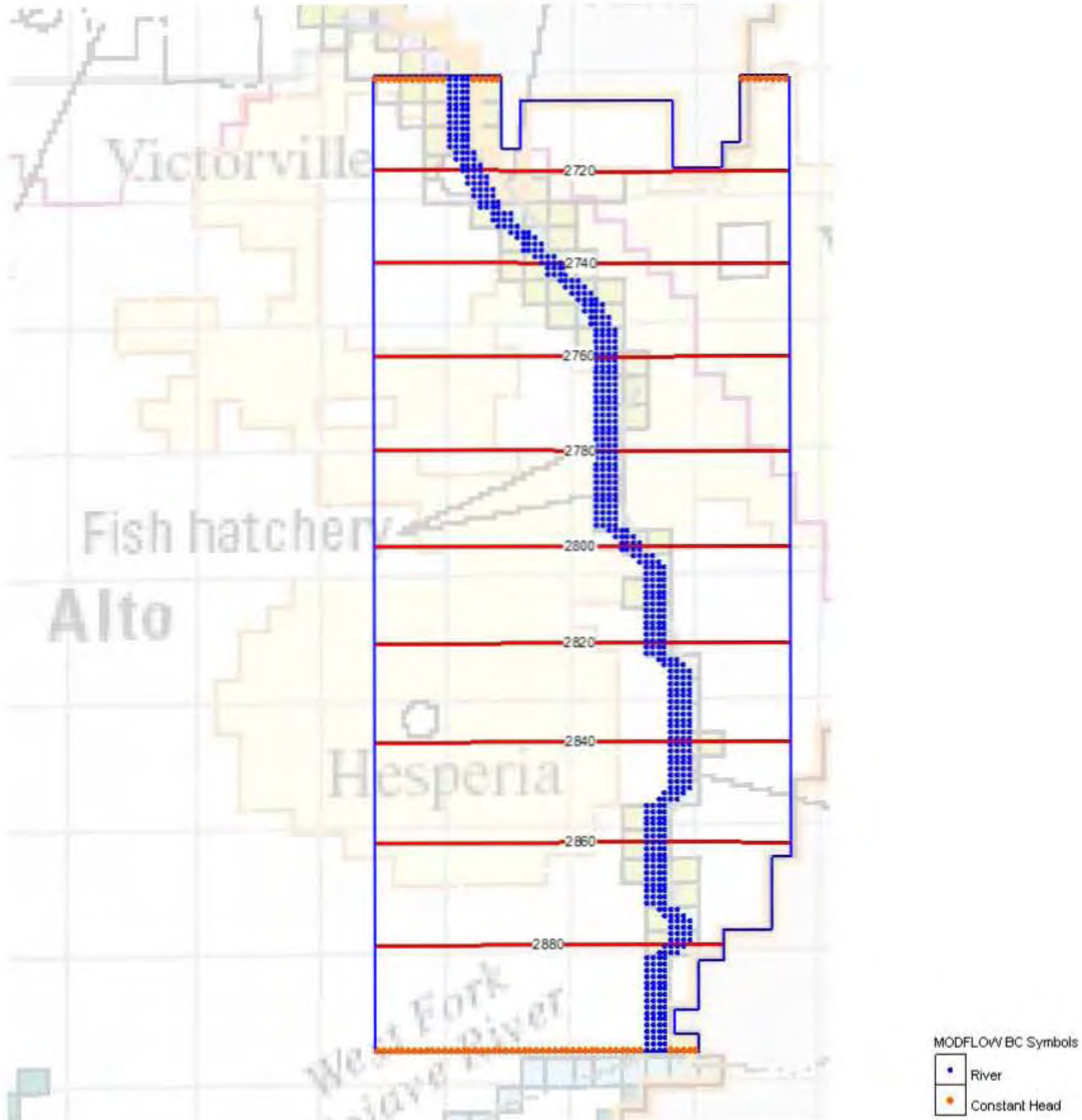

Figure 10 Initial Groundwater Level

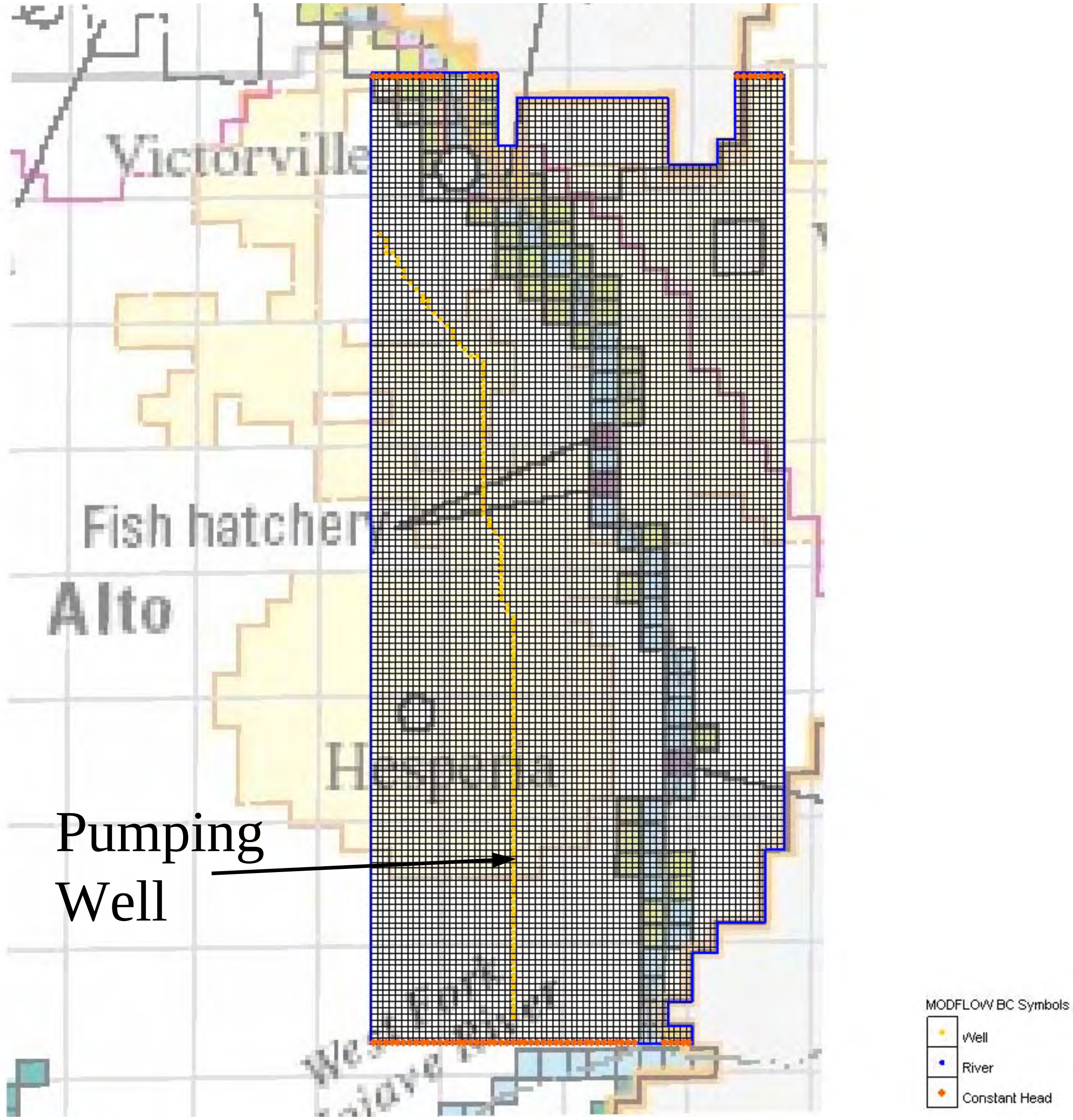

Figure 11 Pumping Well Location in Layer 2 (Scenario 1)

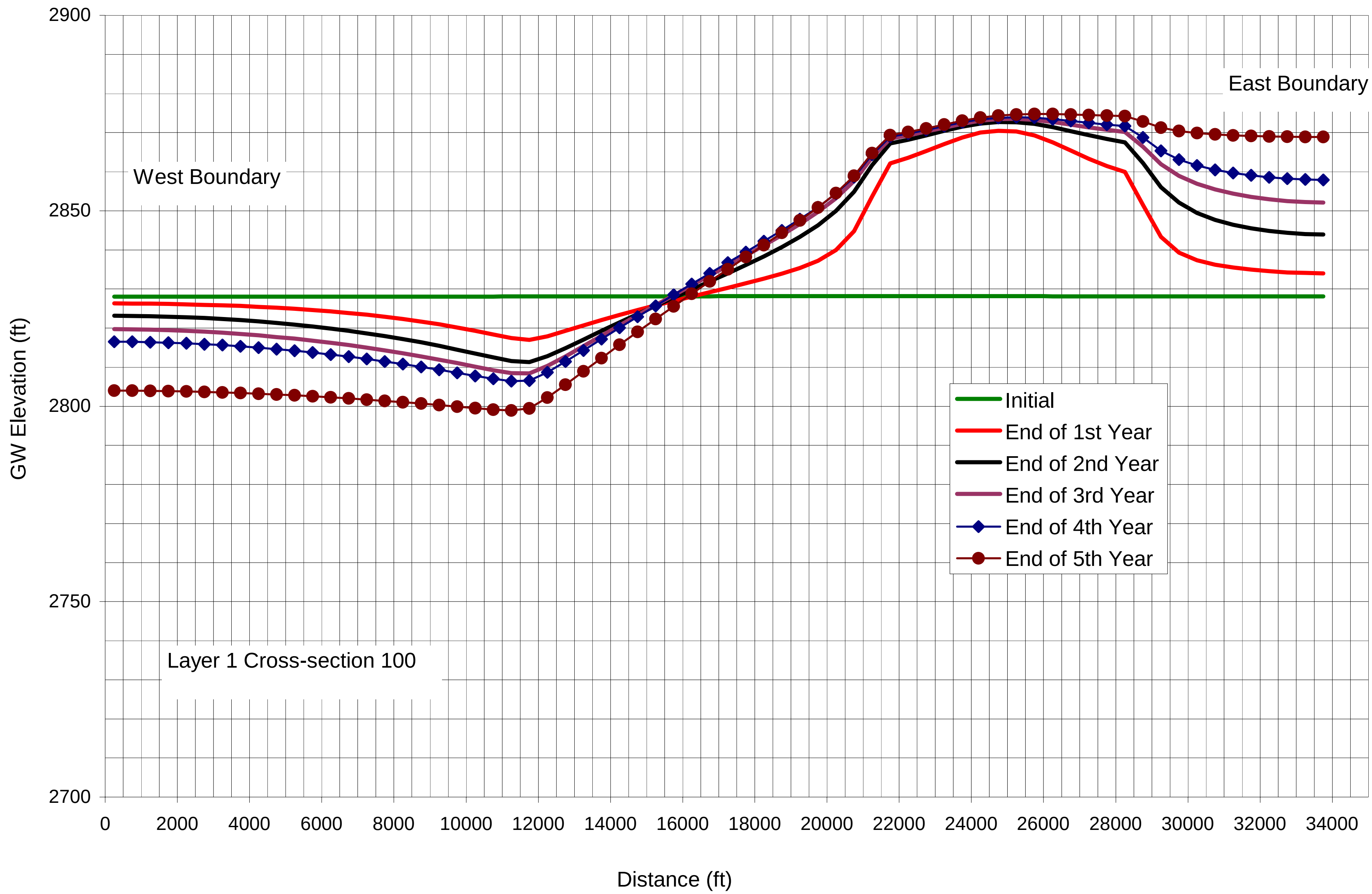

Figure 12 Layer 1 Groundwater Elevation (Pumping Scenario 1)

(Cross-section Location Shown in Figure 14)

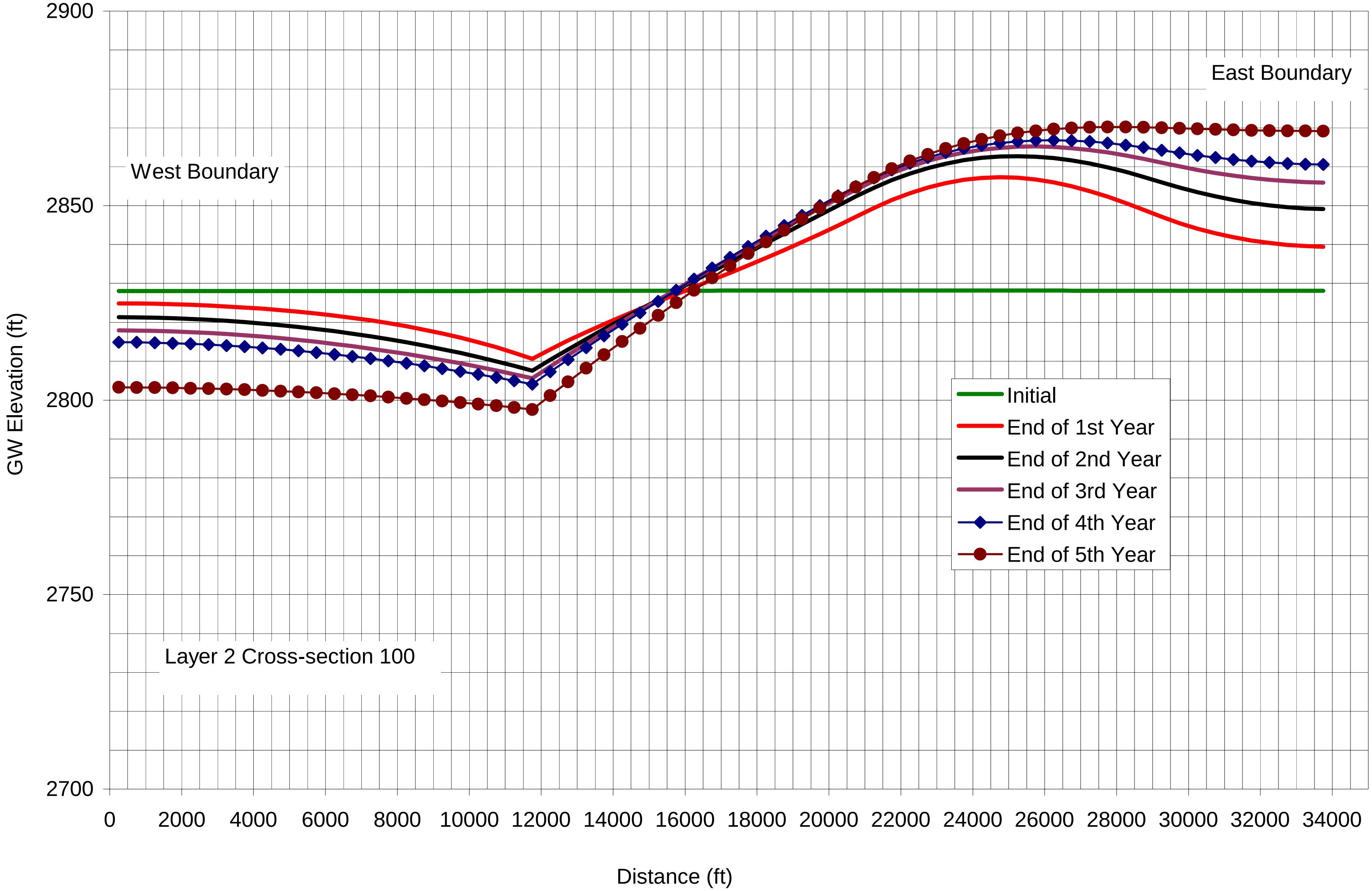

Figure 13 Layer 2 Groundwater Elevation (Pumping Scenario 1)

(Cross-section Location Shown in Figure 14)

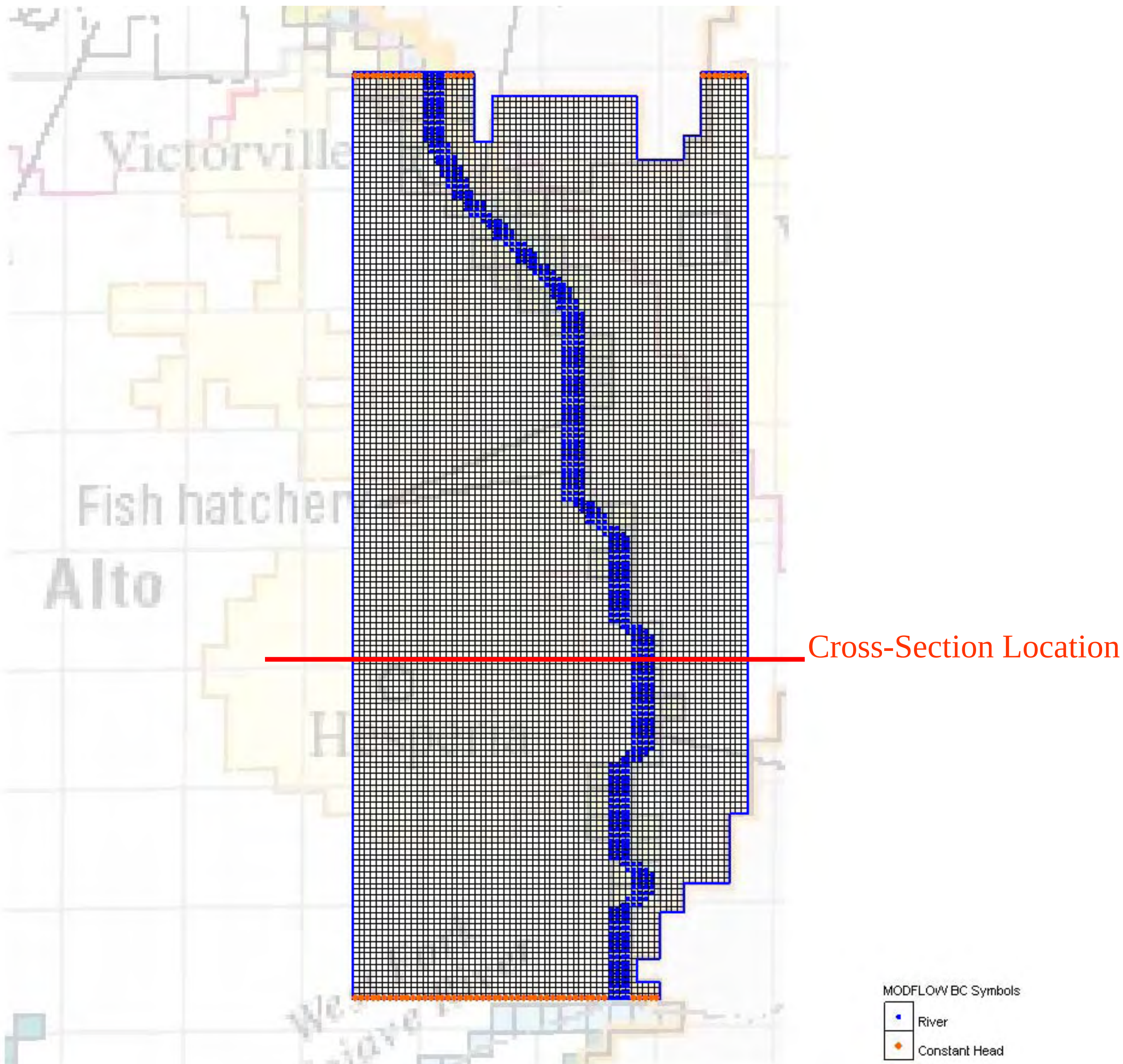

Figure 14 Cross-Section Location

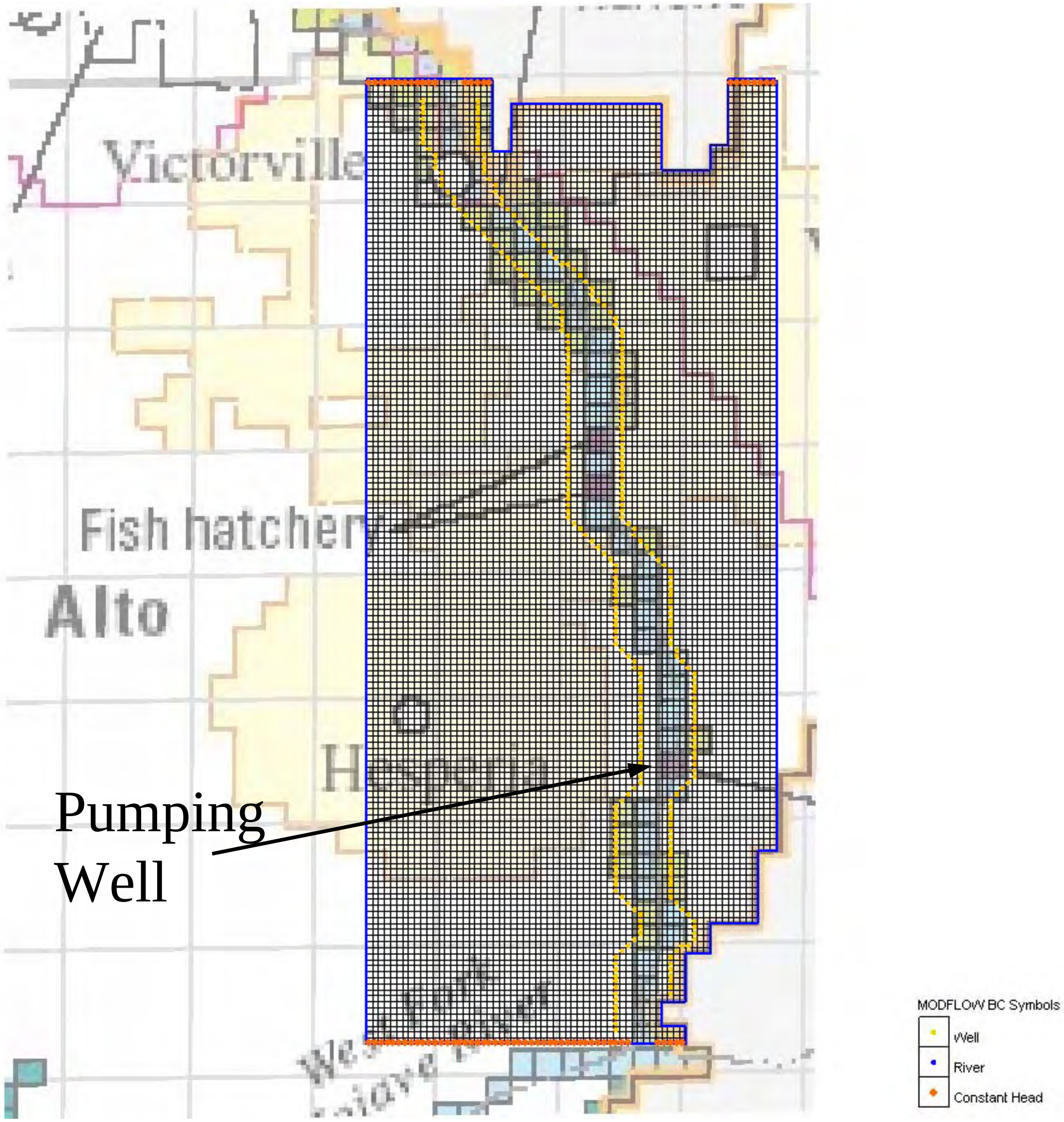

Figure 15 Pumping Well Location in Layer 2 (Scenario 2)

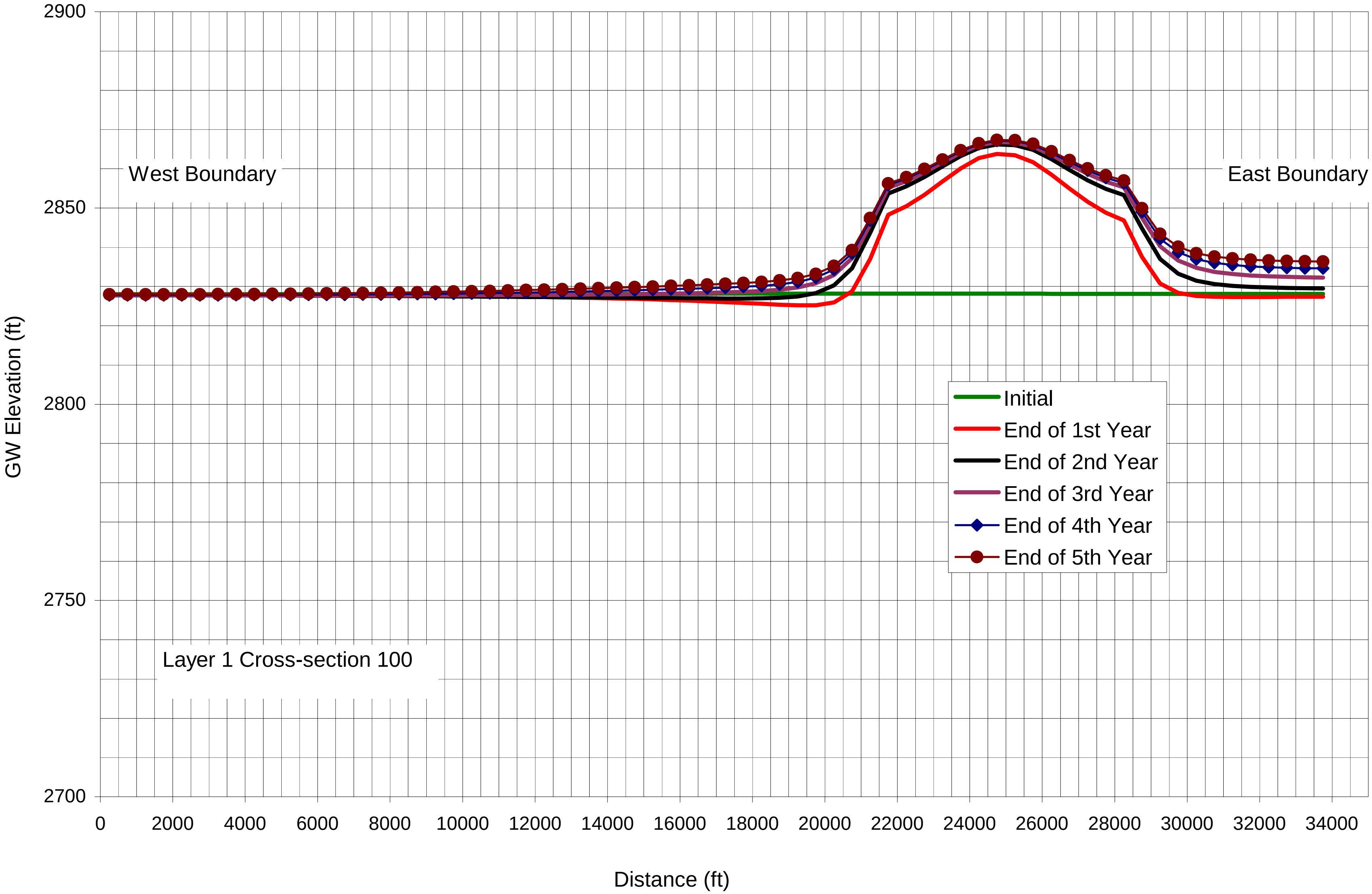

Figure 16 Layer 1 Groundwater Elevation (Pumping Scenario 2)

(Cross-section Location Shown in Figure 14)

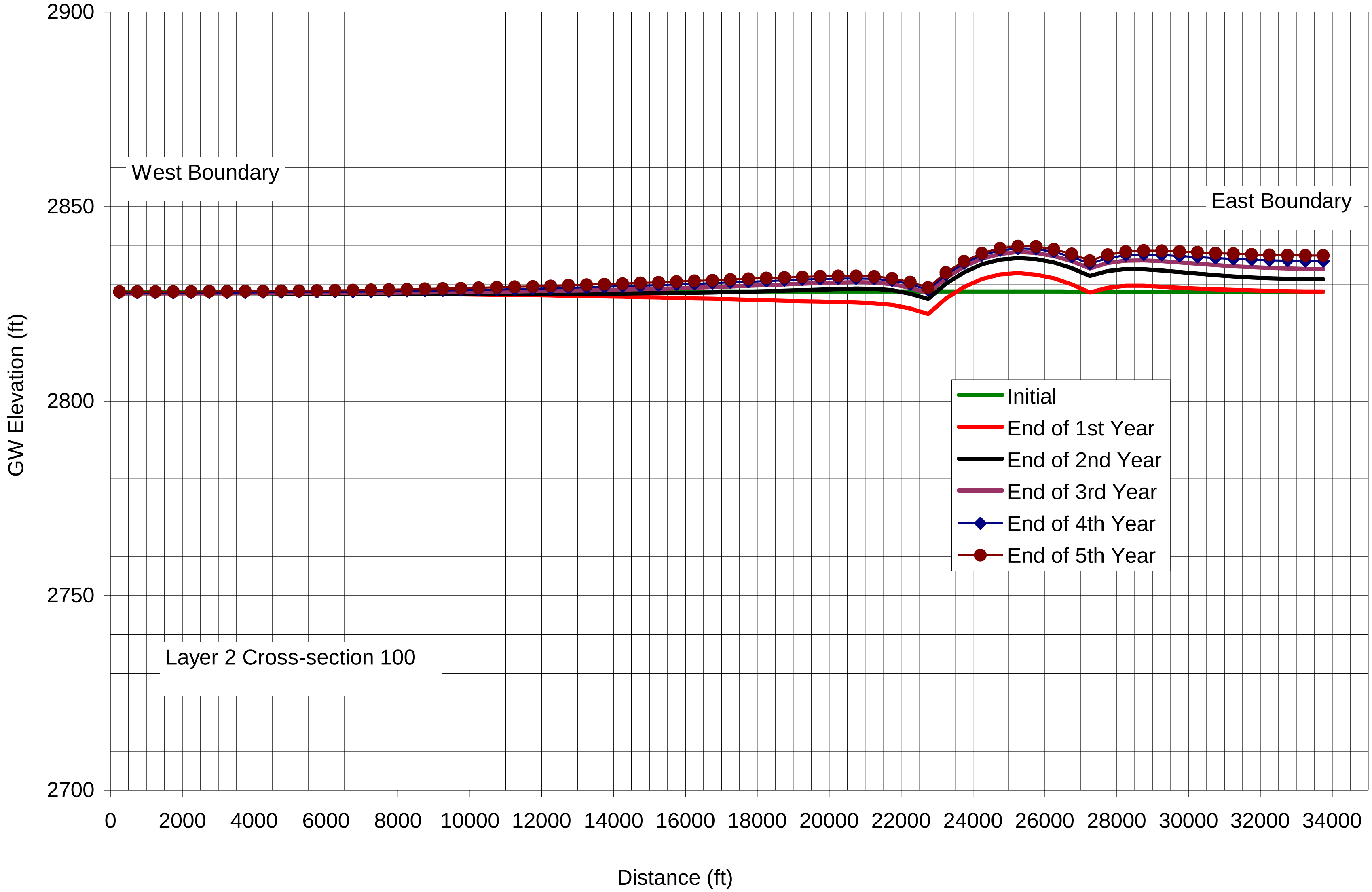

Figure 17 Layer 2 Groundwater Elevation (Pumping Scenario 2)

(Cross-section Location Shown in Figure 14)

Table 1 Average Monthly Recharge and Extraction of Scenario 2

(Based on model simulation)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total (1-year)
Artificial Recharge (af) From Mojave River	0	0	30,887	26,441	21,500	0	0	0	30,882	25,738	20,624	0	156,072
Extraction (af)	11,228	11,228	11,228	11,228	11,228	11,228	11,228	11,228	11,228	11,228	11,228	11,228	134,740

Appendix B

Cost Estimates

Cost for the Unnamed Wash Spreading at Mojave River @ 500 cfs				
Facility Description	**Quantities**	**Units**	**Unit Cost**	**Total Probable Cost**
Turnout/Diversion Structure off the California Aqueduct				
DWR Review/Appliction costs	1	LS	$60,000	$60,000
Turnout (365 cfs)	1	LS	$1,300,000	$1,300,000
Conveyance				
Pipeline (5,800 lf , 96-inch diameter)	5,800	LF	$576	$3,340,800
Natural Channel (15,800 lf)	15,800	LF	$10	$158,000
Perimeter Fence	2,000	LF	$12	$24,000
Hydraulic infrastructures				
Drop structures	3	Ea	$200,000	$600,000
Walk Bridge (Railroad Flatcar)	1	Ea	$50,000	$50,000
Road Bridge (Road name unknown part of new development)	1	LS	$1,350,000	$1,350,000
Arrowhead Road Siphon or Bridge	1	LS	$1,350,000	$1,350,000
Subtotals Bare Construction Cost				$8,232,800
Contingency		30%		$2,469,840
Subtotal Bare Construction Cost+Contingency				$10,702,640
Engineering & CM, Legal and Administration		25%		$2,675,660
Land Cost - Undeveloped	0	Acres	$7,500	$0
Acquisition Fee (10% of Land Cost)	1	LS	$0	$0
Total Probable Construction Cost				**$13,400,000**

Cost for Spreading along the State Water Project in Antelope Wash (Basins West of MBP)
Gross spreading area = 144 Acres, 27 cfs

Facility Description	Quantities	Units	Unit Cost	Total Probable Cost
Morongo Basin Pipeline Turnout				
DWR Review/Application Costs	1	Ea	$0	$0
Connection to existing 54 in line	1	Ea	$100,000	$100,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$25,000	$25,000
Dike Construction	357,500	CY	$3.00	$1,072,500
Training Dike	3,500	CY	$3.00	$10,500
Flood Channel Dike	54,000	CY	$3.00	$162,000
Interbasin Hydraulic Structures	31	Ea	$16,000	$496,000
Interbasin Hydraulic Weir Structures	30	Ea	$3,000	$90,000
Access Gates	8	Ea	$4,000	$32,000
Culverts	12	Ea	$10,000	$120,000
Chain Link Fence	22,600	LF	$12	$271,200
Distribution Hydraulic Structures				
Distribution Pipeline- 30 in. & Appurtenances ($4/dia. Inch)	5,990	LF	$120	$718,800
Butterfly valve 24 in	1	Ea	$5,000	$5,000
Major Hydraulic Structure with Energy Dissipater	2	Ea	$22,000	$44,000
Water Meter - vault and installation	1	Ea	$35,000	$35,000
Wells				
Wells (drill, 225 HP VTP&M/well, meters and valves, depth=700ft)	0	Ea	$750,000	$0
Subtotals Bare Construction Cost				$3,182,000
Contingency		30%		$954,600
Subtotal Bare Construction Cost+Contingency				$4,136,600
Engineering & CM, Legal and Administration		25%		$1,034,150
Land Cost - Undeveloped	144	Acres	$15,000	$2,160,000
Acquisition Fee (10% of Land Cost)	1	LS	$216,000	$216,000
Total Probable Construction Cost				**$7,546,750**

Cost for Spreading along the State Water Project in Antelope Wash (Basins East of MBP)
Gross spreading area = 101 Acres

Facility Description	Quantities	Units	Unit Cost	Total Probable Cost
Turnout				
DWR Review/Application Costs	1	Ea	$0	$0
20 cfs Turnout - Connection to new 30-inch line	1	Ea	$10,000	$10,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$0	$0
Dike Construction	152,500	CY	$3.00	$457,500
Training Dike	0	CY	$3.00	$0
Flood Channel Dike	33,500	CY	$3.00	$100,500
Interbasin Hydraulic Structures	25	Ea	$16,000	$400,000
Interbasin Hydraulic Weir Structures	24	Ea	$3,000	$72,000
Access Gates	6	Ea	$4,000	$24,000
Siphons	1	Ea	$10,000	$10,000
Chain Link Fence	17,200	LF	$12	$206,400
Distribution Hydraulic Structures				
Distribution Pipeline- 24 in. RCP & Appurtenances ($4/dia. Inch)	150	LF	$96	$14,400
Butterfly valve 24 in	1	Ea	$5,000	$5,000
Major Hydraulic Structure with Energy Dissipater	1	Ea	$22,000	$22,000
Water Meter - vault and installation	0	Ea	$35,000	$35,000
Wells				
Wells drill	0	LF	$750,000	$0
Subtotals Bare Construction Cost				$1,356,800
Contingency		30%		$407,040
Subtotal Bare Construction Cost+Contingency				$1,763,840
Engineering & CM, Legal and Administration		25%		$440,960
Land Cost - Undeveloped	101	Acres	$15,000	$1,515,000
Acquisition Fee (10% of Land Cost)	1	LS	$151,500	$151,500
Total Probable Construction Cost				**$3,871,300**

Cost for Spreading along the State Water Project in Oro Grande Wash
Gross spreading area = 25 Acres

Facility Description	Quantities	Units	Unit Cost	Total Probable Cost
SWP Turnout				
DWR Review/Application Costs	1	Ea	$60,000	$60,000
5 cfs Turnout	1	Ea	$300,000	$300,000
Pump Station (TDH=163, 132 hp)	1	Ea	$200,000	$200,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$15,000	$15,000
Dike Construction	62,066	CY	$3.00	$186,198
Training Dike	607	CY	$3.00	$1,821
Flood Channel Dike	9,400	CY	$3.00	$28,200
Interbasin Hydraulic Structures	6	Ea	$16,000	$96,000
Interbasin Hydraulic Weir Structures	5	Ea	$3,000	$15,000
Access Gates	4	Ea	$4,000	$16,000
Culverts	0	Ea	$10,000	$0
Chain Link Fence	3,900	LF	$12	$46,800
Distribution Hydraulic Structures				
Distribution Pipeline- 16 in. & Appurtenances ($4/dia. Inch)	7,600	LF	$64	$486,400
Butterfly valve 16 in	1	Ea	$3,000	$3,000
Hydraulic Structure with Energy Dissipater	2	Ea	$16,000	$32,000
Wells				
Wells (drill, 225 HP VTP&M/well, meters and valves, depth=700ft)	0	Ea	$750,000	$0
Subtotals Bare Construction Cost				$1,486,419
Contingency		30%		$445,926
Subtotal Bare Construction Cost+Contingency				$1,932,345
Engineering & CM, Legal and Administration		25%		$483,086
Land Cost - Undeveloped	25	Acres	$10,000	$250,000
Acquisition Fee (10% of Land Cost)	1	LS	$25,000	$25,000
Total Probable Construction Cost				**$2,690,431**

Cost for Spreading along the State Water Project in Cedar Avenue Basin
Gross spreading area = 60 Acres

Facility Description	Quantities	Units	Unit Cost	Total Probable Cost
SWP Turnout				
DWR Review/Application Costs	1	Ea	$60,000	$60,000
15 cfs Turnout	1	Ea	$380,000	$380,000
Pump Station (TDH=64, 156 hp)	1	Ea	$200,000	$200,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$25,000	$25,000
Dike Construction	108,000	CY	$3.00	$324,000
Training Dike	11,000	CY	$3.00	$33,000
Interbasin Weir Structures	13	Ea	$3,000	$39,000
Interbasin Hydraulic Structures	18	Ea	$16,000	$288,000
Access Gates	2	Ea	$4,000	$8,000
Chain Link Fence	9,300	LF	$12	$111,600
Distribution Hydraulic Structures				
Distribution Pipeline- 24in. RCP & Appurtenances ($4/dia. Inch)	3,000	LF	$96	$288,000
Butterfly valve 24 in	1	Ea	$5,000	$5,000
Hydraulic Structure with Energy Dissipater	2	Ea	$16,000	$32,000
Wells				
Wells (drill, 750 HP VTP&M/well, meters and valves, depth=800ft)	2	Ea	$750,000	$1,500,000
Subtotals Bare Construction Cost				$3,293,600
Contingency		30%		$988,080
Subtotal Bare Construction Cost+Contingency				$4,281,680
Engineering & CM, Legal and Administration		25%		$1,070,420
Land Cost - Undeveloped	60	Acres	$20,000	$1,200,000
Acquisition Fee (10% of Land Cost)	1	LS	$120,000	$120,000
Total Probable Construction Cost				**$6,672,100**

Cost for Spreading along the State Water Project in Land Locked Lands
Gross spreading area = 45 Acres

Facility Description	Quantities	Units	Unit Cost	Total Probable Cost
SWP Turnout				
DWR Review/Application Costs	1	Ea	$60,000	$60,000
10 cfs Turnout	1	Ea	$360,000	$360,000
Pump Station	1	Ea	$200,000	$200,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$25,000	$25,000
Dike Construction	108,000	CY	$3.00	$324,000
Training Dike	11,000	CY	$3.00	$33,000
Interbasin Weir Structures	13	Ea	$3,000	$39,000
Interbasin Hydraulic Structures	10	Ea	$16,000	$160,000
Access Gates	2	Ea	$4,000	$8,000
Chain Link Fence	9,300	LF	$12	$111,600
Distribution Hydraulic Structures				
Distribution Pipeline- 21in. RCP & Appurtenances ($4/dia inch)	3,000	LF	$84	$252,000
Butterfly valve 21 in	1	Ea	$4,500	$4,500
Hydraulic Structure with Energy Dissipater	2	Ea	$16,000	$32,000
Wells				
Wells (drill, 750 HP VTP&M/well, meters and valves, depth=800ft)	2	Ea	$750,000	$1,500,000
Subtotals Bare Construction Cost				$3,109,100
Contingency		30%		$932,730
Subtotal Bare Construction Cost+Contingency				$4,041,830
Engineering & CM, Legal and Administration		25%		$1,010,458
Land Cost - Undeveloped	45	Acres	$20,000	$900,000
Acquisition Fee (10% of Land Cost)	1	LS	$90,000	$90,000
Total Probable Construction Cost				**$6,042,288**

Cost for Spreading along the State Water Project in Ranchero Road Detention Basin Gross spreading area = 60 Acres				
Facility Description	**Quantities**	**Units**	**Unit Cost**	**Total Probable Cost**
Morongo Basin Pipeline Turnout				
DWR Review/Application Costs	0	Ea	$0	$0
10 cfs Turnout	1	Ea	$100,000	$100,000
Spreading Grounds				
Clearing and Grubbing	0	LS	$0	$0
Dike Construction	0	CY	$0.00	$0
Training Dike	0	CY	$0.00	$0
Interbasin Weir Structures	0	Ea	$0.00	$0
Interbasin Hydraulic Weir Structures	0	Ea	$0.00	$0
Access Gates	0	Ea	$0.00	$0
Chain Link Fence	0	LF	$0.00	$0
Distribution Hydraulic Structures				
Distribution Pipeline- 21in. & Appurtenances	0	LF	$0	$0
Butterfly valve 21 in	0	Ea	$0	$0
Major Hydraulic Structure with Energy Dissipater	0	Ea	$0	$0
Wells				
Wells (drill, 750 HP VTP&M/well, meters and valves, depth=800ft)	0	Ea	$750,000	$0
Subtotals Bare Construction Cost City of Hesperia Master Plan				$9,100,000
Contingency		30%		$2,730,000
Subtotal Bare Construction Cost+Contingency				$11,830,000
Engineering & CM, Legal and Administration		25%		$2,957,500
Land Cost - Undeveloped	0	Acres	$20,000	$0
Acquisition Fee (10% of Land Cost)	1	LS	$0	$0
Total Probable Construction Cost				**$14,787,500**

Cost for Spreading along the Mojave River Pipeline				
Gross spreading area = 545 Acres				
Facility Description	**Quantities**	**Units**	**Unit Cost**	**Total Probable Cost**
Spreading Grounds				
Clearing and Grubbing	1	LS	$40,000	$40,000
Dike Construction	838,942	CY	$3.00	$2,516,826
Interbasin Hydraulic Structures	156	Ea	$16,000	$2,496,000
Interbasin Hydraulic Structures Weir	156	Ea	$3,000	$468,000
Access Gates	2	Ea	$4,000	$8,000
Chain Link Fence	20,302	LF	$12	$243,624
Turnouts off the Mojave River Pipeline				
Butterfly valve 48 inch and 48x48x48 tee (70 cfs Turnout)	1	Ea	$50,000	$50,000
Butterfly valve 48	1	Ea	$16,000	$16,000
Butterfly valve 39 inch and 48x48x39 tee (30 cfs Turnout)	1	Ea	$40,000	$40,000
Distribution Hydraulic Structures				
Distribution Pipeline- 39 in. & Appurtenances	300	LF	$234	$70,200
Throtttling valve 27 in.	1	Ea	$12,500	$12,500
Butterfly valve 27 in	1	Ea	$12,500	$12,500
Butterfly valve 24 in	1	Ea	$6,000	$6,000
Butterfly valve 15 in	1	Ea	$3,500	$3,500
Major Hydraulic Structure with Energy Dissipater	2	Ea	$22,000	$44,000
Hydraulic Structures off the channel	3	Ea	$30,000	$90,000
Water Meter for 27 inch line - vault and installation	1	Ea	$20,000	$20,000
Major Hydraulic Structure in channel (downstream)	1	Ea	$40,000	$40,000
Wells				
Wells, 750 ft deep VTP&M/well (Design and Construction)	23	Ea	$750,000	$17,250,000
12 inch steel pipeline @ $4.5/dia-inch	25,307	LF	$54	$1,366,578
15 inch steel pipeline @ $4.5/dia-inch	2,144	LF	$68	$144,720
18 inch steel pipeline @ $4.5/dia-inch	1,110	LF	$81	$89,910
21 inch steel pipeline @ $4.5/dia-inch	2,875	LF	$95	$271,688
24 inch steel pipeline @ $4.5/dia-inch	2,307	LF	$108	$249,156
27 inch steel pipeline @ $4.5/dia-inch	3,961	LF	$122	$481,262
Subtotals Bare Construction Cost				$26,030,463
Contingency		30%		$7,809,139
Subtotal Bare Construction Cost+Contingency				$33,839,602
Engineering & CM, Legal and Administration		25%		$8,459,900
Land Cost - Undeveloped	545	Acres	$15,000	$8,175,000
Acquisition Fee (10% of Land Cost)	1	LS	$817,500	$817,500
Total Probable Construction Cost				**$51,292,002**

Cost for Spreading along the California Aqueduct in Oeste Subarea				
Gross spreading area = 545 Acres				
Facility Description	**Quantities**	**Units**	**Unit Cost**	**Total Probable Cost**
SWP Turnout				
DWR Review/Application Costs	1	Ea	$60,000	$60,000
100 cfs Turnout	1	Ea	$800,000	$800,000
Spreading Grounds				
Clearing and Grubbing	1	LS	$50,000	$50,000
Dike Construction	838,942	CY	$3.00	$2,516,826
Interbasin Hydraulic Structures	312	Ea	$16,000	$4,992,000
Access Gates	4	Ea	$4,000	$16,000
Chain Link Fence	20,302	LF	$12	$243,624
Distribution Hydraulic Structures				
Major Hydraulic Structure with Energy Dissipater	1	Ea	$22,000	$22,000
Hydraulic Structures off the storm channel	3	Ea	$30,000	$90,000
Hwy 18 - Pipe crossing	1	LS		
Major Hydraulic Structure in channel (downstream)	1	Ea	$40,000	$40,000
Water Meter for 48 inch return line - vault and installation	1	Ea	$35,000	$35,000
Return Pipeline				
18 inch steel pipeline @ $6/dia-inch	1,760	LF	$108	$190,080
24 inch steel pipeline @ $6/dia-inch	1,760	LF	$144	$253,440
30 inch steel pipeline @ $6/dia-inch	1,760	LF	$180	$316,800
48 inch steel pipeline @ $6/dia-inch	1,760	LF	$288	$506,880
Pipeline Appurtenances @ $6/dia-inch	1	LS	$63,360	$63,360
Wells				
Wells, 750 HP VTP&M/well (Design and Construction)	23	Ea	$750,000	$17,250,000
12 inch steel pipeline @ $4.5/dia-inch	25,307	LF	$54	$1,366,578
15 inch steel pipeline @ $4.5/dia-inch	2,144	LF	$68	$144,720
18 inch steel pipeline @ $4.5/dia-inch	1,110	LF	$81	$89,910
21 inch steel pipeline @ $4.5/dia-inch	2,875	LF	$95	$271,688
24 inch steel pipeline @ $4.5/dia-inch	2,307	LF	$108	$249,156
27 inch steel pipeline @ $4.5/dia-inch	3,961	LF	$122	$481,262
Subtotals Bare Construction Cost				$30,049,323
Contingency		30%		$9,014,797
Subtotal Bare Construction Cost+Contingency				$39,064,120
Engineering & CM, Legal and Administration		25%		$9,766,030
Land Cost - Undeveloped	545	Acres	$10,000	$5,450,000
Acquisition Fee (10% of Land Cost)	1	LS	$545,000	$545,000
Total Probable Construction Cost				**$54,825,150**

Cost for the Upper Mojave River Pipeline and Well Field up to 45,000 AF/year return (22 wells)				
Facility Description	**Quantities**	**Units**	**Unit Cost**	**Total Probable Cost**
DWR Turnout				
Application Fee	1	LS	60000	$60,000
70 cfs Turnout plus application fee	1	LS	600000	$600,000
Distribution Hydraulic Structures				
Main Pipeline- 45 in. & Appurtenances	45,600	LF	$270	$12,312,000
Laterals and appurtenances (2 Turnout locations, various diameters, meters, vaults, 9,120 lf)	1	LS	$2,094,440	$2,094,440
Pump Stations				
3 Pumping Plants (combined TDH= 650 ft., 6,100 hp)	6,100	Hp	$1,000	$6,100,000
Storage Tanks (2 hr storage, 66 cfs, 4 MG)	3	Ea	$1,350,000	$4,050,000
Wells				
22 wells, meters, valves, and manifold (depth 500 ft., approximately 90 hp each)	22	Ea	$750,000	$16,500,000
Collection Pipeline (various diameters @ $6 per diameter inch, 22,710 lf)	1	LS	$3,960,000	$3,960,000
Monitoring Wells	5	Ea	$70,000	$350,000
Spreading Grounds South of Rocks Springs Turnout				
Connection to Morongo Basin Pipeline	1	LS	100,000	$100,000
earthwork, structures, clearing (net area 64 acres)	1	LS	200,000	$200,000
Pipeline (7200 lf., 42-inch diameter, 74 cfs, 8 fps)	7,200	Lf	$252	$1,814,400
Subtotals Bare Construction Cost				$48,140,840
Contingency		30%		$14,442,252
Subtotal Bare Construction Cost+Contingency				$62,583,092
Engineering & CM, Legal and Administration		25%		$15,645,773
Land Cost - Undeveloped	100	Acres	$20,000	$2,000,000
Total Probable Construction Cost				**$80,200,000**