Appendix A
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Appendix B
Groundwater Model Development

See attached CD.

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Mission Creek and Garnet Hill
Water Management Plan

Groundwater Flow Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea, Riverside County, California

January 2013

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SECTION 1.0 EXECUTIVE SUMMARY

As part of a settlement agreement between Mission Springs Water District (MSWD), Coachella Valley Water District (CVWD), and the Desert Water Agency (DWA), these agencies agreed to prepare a Water Management Plan for the Mission Creek and Garnet Hill subbasins of the Coachella Valley Groundwater Basin (CVGB). Groundwater modeling is required to evaluate various alternatives that will be developed as part of the Water Management Plan for the Mission Creek and Garnet Hill subbasins. The objective of the modeling effort is to support management decisions on a regional basis. The modeling effort is intended to identify general trends in the groundwater system and potential effects from various water management alternatives that will be developed as part of the Water Management Planning process. The initial phase of the modeling effort was the development of a conceptual model of the groundwater basin. The conceptual model provided a physical description of the Mission Creek and Garnet Hill subbasins and the factors that influence groundwater flow in the subbasins, the conceptual model is discussed below.

Following development of the conceptual model, a numerical model was developed (see Section 1.2), calibrated with historical data and was then used to evaluate various management alternatives (see Section 1.3) and the relative impacts these management alternatives would have on groundwater levels in the Mission Creek and Garnet Hill subbasins for the period between 2010 and 2045.

1.1 Conceptual Model

A conceptual model of a groundwater flow and hydrologic system is an interpretation or working description of the characteristics and dynamics of the physical hydrogeologic system. The purpose of the conceptual model is to consolidate site and regional hydrogeologic and hydrologic data into a set of assumptions and concepts that can be evaluated quantitatively.

Groundwater in the CVGB occurs in the alluvium, terrace deposits, and older sedimentary units that fill the valley. The CVGB is bounded on the north and east by the non-water bearing crystalline rocks of the San Bernardino and Little San Bernardino Mountains and on the west by the crystalline rocks of the Santa Rosa and San Jacinto Mountains. The northern boundary is formed by the San Gorgonio Pass. The Mecca Hills and the Salton Sea form the southern boundary. The faults that cross the valley form partial barriers to groundwater flow and interrupt the overall flow of groundwater in the valley. The two subbasins of interest in this report are the Mission Creek and Garnet Hill subbasins and are briefly described below. The Palm Springs subarea of the Whitewater River Subbasin is also discussed lies downgradient of the Garnet Hill Subbasin and groundwater levels in the subarea have an influence on flow from the Garnet Hill Subbasin.

1.1.1 Mission Creek Subbasin

The Mission Creek Subbasin is bounded on the north by the Mission Creek Fault and on the south by the Banning Fault. To the west, the subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills and the Mission Creek Fault. Artesian conditions have historically been present near a narrow strip along the northwest portion of the Seven Palms Ridge (DWR1964), allowing for the development of a unique Willow-Mesquite biological community that includes phreatophytes. Depth to groundwater in other parts of the sub-basin averages 300 feet below ground surface.

The Mission Creek Subbasin is filled with Holocene and late Pleistocene unconsolidated sediments eroded from the San Bernardino and Little San Bernardino Mountains. There are three significant water-bearing sedimentary deposits recognized in the subbasin: Pleistocene Cabazon Fanglomerate and Pleistocene to Holocene Older alluvium and alluvial deposits. These deposits are generally coarse sand and gravel, poorly sorted alluvial fan and pediment deposits that coalesce with one another.

The Mission Creek Subbasin is considered an unconfined[1] aquifer with a saturated thickness of 1,200 feet or more and an estimated total storage capacity on the order of 2.6 million acre-feet (af) (DWR, 1964). The groundwater estimated to be in storage for the subbasin is 1.4 million af (MSWD, 2006a). The subbasin is naturally recharged by surface and subsurface flow from the Mission Creek, Dry, and Big Morongo Washes, Painted Hills, and surrounding mountain drainages. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge. Total 2009 inflow to the Mission Creek Subbasin is estimated at 23,500 acre-feet per year (afy).

The primary outflow from the Mission Creek Subbasin is through groundwater production for domestic, commercial and agricultural use. While groundwater production has varied over the years, it generally has been increasing from approximately 2,000 afy in the 1970s to over 15,000 afy in 2006. In addition, outflow occurs across the Banning Fault to the Garnet Hill Subbasin and has been estimated at 7,400 afy (1936 steady-state conditions [see Table 1]); outflow also occurs across the semi-waterbearing rocks in the southeastern edge of the subbasin at rate of approximately 3,500 afy (1936 steady-state conditions [see Table 1]). Lastly, the consumption of groundwater by phreatophytes in the southern end of the subbasin has been estimated at 1,400 afy (1936 steady-state conditions [see Table 1]). Total 2009 outflow from the Mission Creek Subbasin has been estimated to be approximately 27,800 afy (Psomas, 2012). Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -4,300 afy (Psomas, 2009) which would indicate that the subbasin lost water from storage.

Water level declines have been apparent in the Mission Creek Subbasin since the early 1960s and, in the 1970s, when the United States Geological Survey (USGS) sponsored the development of groundwater analog models to assist the DWA and CVWD in their water management decisions regarding importing water for groundwater recharge (Tyley, 1971; Tyley, 1974). Water levels have declined in portions of the Mission Creek Subbasin approximately 100 feet between the years 1936 and 2003. Based on previously prepared estimates, cumulative change in storage between 1936 and 2003 ranges between -100,000 to -174,000 af.

1.1.2 Garnet Hill Subbasin

The Garnet Hill Subbasin is bounded on the north by the Banning Fault and on the south by the Garnet Hill Fault. To the west, the subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills. An estimated 24,900 afy of groundwater moves laterally across the constrictive Garnet Hill Fault to the Palm Springs Subarea of the Whitewater River Subbasin (Psomas, 2012).

The Garnet Hill Subbasin is considered an unconfined aquifer with a saturated thickness of 1,000 feet or more and an estimated total storage capacity on the order of 1.0 million af (DWR, 1964). The subbasin is naturally recharged by subsurface flow from the Mission Creek Subbasin and runoff from the Whitewater River watershed on the west. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge but is considered very small. Total 2009 inflow to the Garnet Hill Subbasin is estimated at 25,150 af (Psomas, 2012).

[1] An aquifer that has groundwater that has a water table. That is groundwater that is not confined under pressure beneath a confining bed (AGI, 2005).

The primary outflow from the Garnet Hill Subbasin is through the Garnet Hill Fault to the Palm Springs Subarea. In addition, limited groundwater production for domestic, agricultural and commercial use also occurs but has only recently been of any significance. Groundwater production has varied over the years, ranging from a high of over 4,000 afy in the early 1950s to less than 50 afy in the mid-1980s. Currently, groundwater production is estimated at between 300-500 afy. Total 2009 outflow from the Garnet Hill Subbasin has been estimated to be approximately 25,400 afy. Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -250 afy which would indicate that for 2009, the subbasin had a slight storage loss.

1.1.3 Whitewater River Subbasin

The Whitewater River Subbasin comprises the major portion of the floor of the Coachella Valley and encompasses approximately 400 square miles. Beginning approximately one mile west of the junction of State Highway 111 and Interstate 10, the Whitewater River Subbasin extends southeast approximately 70 miles to the Salton Sea. The subbasin is bordered on the southwest by the Santa Rosa and San Jacinto Mountains, and is separated from the Garnet Hill, Mission Creek and Desert Hot Springs subbasins to the north and east by the Garnet Hill and San Andreas faults and Indio Hills.

The limit of the Whitewater River Subbasin along the base of the San Jacinto Mountains and the northeast portion of the Santa Rosa Mountains coincides with the Coachella Valley groundwater basin boundary. The Whitewater River Subbasin in this vicinity includes only the Recent terraces and alluvial fans. The Palm Springs Subarea constitutes the principal recharge area of the Whitewater River Subbasin.

The Palm Springs Subarea of the Whitewater River Subbasin is bounded by the San Gorgonio Subbasin to the west, the Garnet Hill Fault to the north, the San Jacinto Mountains to the south, and an arbitrary line running from the Indio Hills to the San Jacinto Mountains across the valley floor.

The Palm Springs Subarea is considered an unconfined aquifer with a saturated thickness of 1,000 feet or more and an estimated total storage capacity on the order of 4.6 million af. The subbasin is naturally recharged by subsurface flow from the Garnet Hill Subbasin and runoff from the Whitewater River watershed on the west. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge. Total 2009 inflow to the Palm Springs Subarea is estimated at 105,100 af (Psomas, 2012).

The primary outflows from the Palm Springs Subarea are pumping and subsurface flow to the lower portion of the Whitewater River Subbasin. Groundwater production has varied over the years, ranging from 2,000 to 4,000 afy in the early 1950s to over 50,000 afy in 2009. Total 2009 outflow from the Palm Springs Subarea has been estimated to be approximately 108,400 afy (Psomas, 2012). Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -3,300 afy (Psomas, 2012), which would indicate that for 2009, the Palm Springs Subarea had a slight loss of storage.

1.2 Model Development and Calibration

Computer models are used to simulate the flow of water in groundwater basins. Model calibration is the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observations of the ground-water flow system. Model calibration involves developing and refining estimates of boundary condition heads and flows (fluxes), and aquifer parameters to improve correspondence between measured data and simulated results. Successful calibration demonstrates the ability of the model (based on the current understanding of the hydrogeologic system) to simulate historical water levels and fluxes throughout the basin with a reasonable degree of accuracy.

1.2.1 Steady-State Calibration

Calibration often necessitates reconstruction of portions of the numerical model, resulting in changes or refinements in the initial conceptual model. Both possibilities introduce iteration into the modeling process whereby the modeler revisits previous steps to achieve a better representation of the physical system. Inflow and outflow rates, transmissivities and fault conductances were refined via the model calibration process. The parameters refined by calibration are listed in Table 1, along with prior estimates of the parameters (Psomas, 2012).

Statistical analysis was performed on the residual values (the difference between the actual value and the observed value) to assess the range in values and standard deviation of the residuals. The goal is to have the standard deviation of errors divided by the range in observations less than 10 percent. The statistical analysis indicated a value of 1 percent and is considered excellent for the steady-state calibration process.

1.2.2 Transient Calibration

Calibration of a groundwater flow model to a single set of field measurements (steady-state calibration) does not guarantee uniqueness[2]. In order to reduce the problem of nonuniqueness, the model calculations are compared to another set of observations that represent a different set of boundary conditions or stresses. This process is referred to as verification and represents the transient calibration process.

As previously stated, the transient calibration process uses the steady-state calibrated hydraulic conductivity values along with the initial heads and fault conductances, and then applies other sets of “stresses” that includes natural inflows from precipitation, artificial recharge and return flows as well as outflows from pumpage over the time period 1936 through 2009. The calibration targets are specific wells where periodic water level data have been collected during the same period. The focus on the transient calibration process is storativity.

The model was run in transient state and calibrated (using standard methods [ASTM D5490-93, D5981-96]) to measured water levels in the period 1936 through 2009. Data on groundwater production, groundwater levels and artificial recharge amounts, were available in this historical period. The data show significant changes in groundwater levels, both up and down, owing to major historical shifts in both pumpage and recharge. The goal was to simulate these important historical changes, thereby providing a rigorous test of the ability of the model to adequately simulate effects of future fluctuations in pumpage and recharge.

Two goals are set for the transient calibration. The first goal is to have the model values track the same general trend as the observed values. During the transient calibration process, inflow used for final calibration represented reductions from previous estimates to achieve better agreement between historical and modeled water levels.

[2] The number of different distinct hydrologic conditions that a given set of input aquifer hydraulic properties is capable of representing is an important qualitative measure of the performance of a model. It is usually better to calibrate to multiple hydrologic conditions, if the conditions are truly distinct. Matching different hydrologic conditions is one way to address nonuniqueness, because one set of heads can be matched with the proper ratio of ground-water flow rates to hydraulic conductivities; whereas, when the flow rates are changed, representing a different condition, then the range of hydraulic conductivities that produce acceptable residuals becomes much more limited (ASTM, 2002).

TABLE 1

HYDROLOGIC BUDGET FOR THE MISSION CREEK AND GARNET HILL SUBBASINS, & PALM SPRINGS SUBAREA

RECHARGE AND DISCHARGE	MISSION CREEK SUBBASIN (acre-feet/year)			GARNET HILL SUBBASIN (acre-feet/year)			PALM SPRINGS SUBAREA (acre-feet/year)		
	Conceptual Model	Steady-State Calibration	Transient Calibration	Conceptual Model	Steady-State Calibration	Transient Calibration	Conceptual Model	Steady-State Calibration	Transient Calibration
RECHARGE (INFLOW)									
UNDERFLOW FROM									
Desert Hot Springs Subbasin	1,800	2,150	1,844	---	---	---	---	---	---
Mission Creek Subbasin	---	---	---	7,400	8,250	varies (see App. E)	---	---	---
Garnet Hill Subbasin	---	---	---	---	---	---	24,900	25,050	varies (see App. E)
San Gorgonio Subbasin	---	---	---	---	---	---	8,900	8,270	varies (see App. E)
PERCOLATION from									
Mountain Front Recharge and Stream Underflow	10,500	10,500	7,500	17,500	16,800	varies (see App. E)	24,580	32,650	varies (see App. E)
Artificial Recharge (includes return flows)	---	---	varies (see App. E)	---	---	varies (see App. E)	---	---	varies (see App. E)
TOTAL INFLOW	**12,300**	**12,650**	**Varies (a)**	**24,900**	**25,050**	**Varies (a)**	**58,380**	**65,970**	**Varies (a)**
DISCHARGE (OUTFLOW)									
UNDERFLOW TO GARNET HILL SUBBASIN	7,400	8,250	varies (see App. E)	---	---	---	---	---	varies (see App. E) (f)
UNDERFLOW TO PALM SPRINGS SUBAREA	---	---	---	24,900	25,050	varies (see App. E)	---	---	---
UNDERFLOW TO SEMIWATER-BEARING ROCKS IN SOUTHEASTERN PORTION OF SUBBASIN	3,500	3,000	varies (see App. E)	---	---	---	---	---	---
UNDERFLOW TO LOWER WHITEWATER SUBBASIN	---	---	---	---	---	---	58,380	65,970	varies (see App. E)
EVAPOTRANSPIRATION	1,400	1,400	varies (see App. E)	---	---	---	---	---	---
GROUNDWATER PRODUCTION	---	---	varies (see App. E)	---	---	varies (see App. E)	---	---	varies (see App. E)
TOTAL OUTFLOW	**12,300**	**12,650**	**Varies (a)**	**24,900**	**25,050**	**Varies (a)**	**58,380**	**65,970**	**Varies (a)**
INFLOW-OUTFLOW	**0**	**0**	**Varies (a)**	**0**	**0**	**Varies (a)**	**0**	**0**	**Varies (a)**
MODEL CONSTRUCTION									
Model Grid (270 rows [75 active] x 86 columns)	Based on model grid of Fogg/O'Neill CVWD Model (CVWD, 2000)								
Cell Size =1,000 feet x 1,000 feet	Based on cell size of Fogg/O'Neill CVWD Model (CVWD, 2000)								
Layers (4)	Based on layers contained in Fogg/O'Neill CVWD Model (CVWD, 2000)								
Transmissivity	2,000 to 300,000 gpd/ft (b)		2,000 to 897,000 gpd/ft	10,000 to 50,000 gpd/ft (c)		8,000 to 57,000 gpd/ft	30,000 to 748,000 gpd/ft (e)		30,000 to 748,000 gpd/ft
Hydraulic Conductivity - Horizontal (K_h)	2 to 300 gpd/ft^2 (d)		2 to 897 gpd/ft^2	10 to 50 gpd/ft^2 (d)		8 to 57 ft/day	30 to 748 gpd/ft^2 (e)		30 to 748 gpd/ft^2
	0.3 to 40 ft/day (d)		0.25 to 120 ft/day	1.3 to 6.7 ft/day (d)		1.0 to 7.6 ft/day	4-100 ft/day (e)		4-100 ft/day
Hydraulic Conductivity - Vertical	varies	0.1 to .01 x K_h	0.1 to .01 x K_h	varies	0.1 to .01 x K_h	0.1 to .01 x K_h	varies	0.1 to .01 x K_h	0.1 to .01 x K_h
Storage Coefficient	0.08 to 0.18 (c)		0.12-0.19	0.15 to 0.18 (c)		0.1 to 0.2	0.06 to 0.13		0.06 to 0.13

Notes:

a - Varies with time period and deficits/surplus are made up through change in storage within the aquifer.

b - Derived from Tyley (1974) and DWA (2008).

c - Derived from Tyley (1974).

d - Derived from Tyley (1974) and estimated aquifer thickness of 1,000 feet.

e - From Fogg/O'Neill CVWD Model (CVWD, 2000).

f - The modeling suggests that in certain rare situations when high artificial recharge occurs in the Palm Springs Sub-Area, groundwater levels can rise in the Palm Springs Sub-Area such that underflow can occur into the Garnet Hill Subbasin (see Appendix E).

The original calibration model results (using the 10,500 afy of natural recharge value) showed a lesser degree of groundwater level decline and an increasing divergence than was observed in the observation wells, indicating that more water was staying in the basin than under actual conditions. Further calibration work resulted in refinement of the mountain front recharge (reduced to 7,500 afy) and Mission Creek Fault inflow estimate (reduced to 1,844 afy) which corrected this imbalance and resulted in very good water level calibration.

The second goal is to conduct a statistical analysis of the residual values (similar to the steady-state evaluation process) and to achieve a standard deviation of errors divided by the range in observations of less than 10 percent. The statistical analysis indicated a value of 3 percent and is considered excellent for the transient calibration process.

Psomas contracted with Mr. Michael McDonald with McDonald & Morrissey to conduct the model peer review. Mr. McDonald was one of the original developers of MODFLOW while at the USGS and has been conducting peer reviews and developing groundwater models for various entities since 1990. A summary of Mr. McDonald's conclusions are as follows.

> The conceptual model report has described the system to be simulated in a manner consistent with the available observations. The components of the water budget estimated by Psomas seem reasonable. The [extraction] rates reported by responsible public agencies are presumably accurate. That would be especially true for pumping which is concentrated and readily observed and measured. Septic and irrigation return flows and artificial recharge are relatively concentrated and generally reported as a reasonable small proportion of supply. Mountain front recharge is estimated from precipitation records using a fairly conventional and reasonable approach however it is the reviewer's experience that this approach is likely to underestimate the magnitude of such recharge. The model developed for this project should be useful in establishing the impacts from changes in recharge and discharge.

1.3 Alternatives Analysis

The calibrated transient groundwater model was used to test the response of the Mission Creek and Garnet Hill subbasins to various supply stresses for the period 2010 through 2045. A groundwater model is an approximation of actual conditions. The accuracy of the model results depends on the accuracy of the input data. The transient groundwater model boundary inflows from the final run of the transient model were used as the initial input for the alternative modeling effort. In addition, assumptions were made regarding future conditions including areas related to area growth and future climatic conditions. The groundwater model is useful for predicting the relative changes to conditions but should not be used to predict the exact value for a given parameter (such as groundwater level) at a given future time. The reader is directed to Section 10, *Model Assumptions and Limitations* for additional clarification on the limitations and interpretation of the results.

Groundwater modeling was performed for the following scenarios:

- Groundwater Model Run No. 1: Baseline Run
- Groundwater Model Run No. 2: Stabilize Water Levels
- Groundwater Model Run No. 3: Variable Hydrology
- Groundwater Model Run No. 4: Increase Groundwater Levels

Each of the aforementioned Groundwater Model runs makes assumptions regarding the following components of inflow/outflow to the Mission Creek and Garnet Hill Subbasins:

- Water demand;
- Groundwater production;
- Wastewater production, wastewater treatment flows, and return flows;
- Natural inflows; and
- Artificial recharge including Whitewater River artificial recharge.

These assumptions were reported in *Technical Memorandum: Assumptions for Groundwater Model Runs* (MWH, 2012) and are summarized in Table 2. The results of the modeling using the assumptions described in Table 2 and Appendix D are as follows.

For Groundwater Model Run No. 1 (Baseline Run), results indicate that groundwater levels in the main portion of the Mission Creek Subbasin decline by approximately 70 feet in 2045 compared to 2010. This corresponds to a reduction of approximately 162,000 af in cumulative groundwater storage in 2045. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 50,000 af in 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 500 afy in 2045. The reduction in the outflows across the Banning Fault can be attributed to lowered groundwater levels along the Banning Fault in the Mission Creek Subbasin relative to groundwater levels on the Garnet Hill Subbasin side of the Banning Fault. Outflows across the Garnet Hill Fault to the Whitewater River Subbasin are approximately 20,000 afy in 2045 and are largely a pass-through of natural and imported water flowing in the Whitewater River.

For Groundwater Model Run No. 2 (Stabilize Groundwater Levels), the results indicate that groundwater levels in the Mission Creek Subbasin increase by approximately 10 feet in 2045 compared to 2010 levels. This corresponds to an increase of approximately 100,000 af in cumulative groundwater storage in 2045. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045. Outflows across the Garnet Hill Fault are approximately 20,000 afy in 2045.

For Groundwater Model Run No. 3 (Variable Hydrology), the cumulative groundwater storage increases up to 200,000 af between 2010 and 2018 and decreases to approximately 40,000 af between 2018 and 2038. The fluctuation in groundwater levels between 2018 and 2038 in the Mission Creek Subbasin is approximately 70 feet. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045. An increase in groundwater levels in the Whitewater River Subbasin reduces outflows from the Garnet Hill Subbasin in this model run.

For Groundwater Model Run No. 4 (Increase Water Levels), the cumulative groundwater storage increases up to 154,000 af between 2010 and 2015 and decreases to approximately -2,000 af between 2015 and 2045. The fluctuation in groundwater levels between 2015 and 2045 in the Mission Creek Subbasin is approximately -30 feet. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 38,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,100 afy in 2010 to 3,800 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045.

Table 2
Assumptions for Various Input Parameters for Groundwater Model Runs Nos. 1, 2, 3, & 4
Mission Creek and Garnet Hill Subbasins (derived from MWH, 2012)

Component	Groundwater Model Run # 1 (Baseline)	Groundwater Model Run # 2 (Stabilize to 2010 Water Levels)	Groundwater Model Run # 3 (Variable Hydrology)	Groundwater Model Run # 4 (Increase Groundwater Levels)
Demand Assumptions	• CVAG projections • Demand: 15K AFY in 2010; 38K AFY in 2045 • 20 percent urban conservation by 2020 • Indoor demands are 40 % of total urban demand • Outdoor demands are 60 % of total urban demand • No new fish farms; demand constant to 2045 • Two new golf courses:1st in 2020; 2nd in 2030 • Industrial: Indigo Power Plant and CPV Sentinel (online 2013)	*Same as Groundwater Model Run # 1*	*Same as Groundwater Model Run # 1*	• No growth scenario • Demand: 15K AFY in 2010; 12K AFY in 2045 • 20% urban conservation by 2020 • 20% conservation for fish farms and golf courses • Indoor demands are 40% of total urban demand • Outdoor demands are 60% of total urban demand • No new fish farms or golf courses • Industrial: Indigo Power Plant and CPV Sentinel (online 2013)
Groundwater Production	• 14 existing municipal wells (11,630 AFY) • Existing large private producers o Three fish farms (245 AFY) o Four golf courses (2,700 AFY) o One industrial (387 AFY) • Future Production o Municipal Production – 21 new groundwater wells; each well has an annual production capacity of 1,000 AFY o Future large private producers ▪ Two golf courses (1,890 AFY in 2045) ▪ One industrial facility (CPV Sentinel) (550 AFY)	*Same as Groundwater Model Run # 1*	*Same as Groundwater Model Run # 1*	• 14 existing municipal wells (11,630 AFY) • Existing large private producers o Three fish farms (245 AFY) o Four golf courses (2,700 AFY) o One industrial (387 AFY)
Return Flows*	• MSWD Indoor Use – 97 percent returns • MSWD Outdoor Use – 20 percent returns • CVWD Indoor Use – 97 percent returns • CVWD Outdoor Use – 20 percent returns • Fish farms – 80 percent returns • Golf courses – 20 percent returns • Wastewater Treatment Plants (WWTPs) o Horton WWTP return flows to Mission Creek Subbasin (MCSB) o Regional WWTP return flows to Garnet Hill Subbasin (GHSB)	• MSWD Indoor Use – 97 percent returns • MSWD Outdoor Use – 20 percent returns • CVWD Indoor Use – 97 percent returns • CVWD Outdoor Use – 20 percent returns • Fish farms – 80 percent returns • Golf courses – 20 percent returns • WWTPs o Horton WWTP return flows to MCSB o Regional WWTP return flows to MCSB	*Same as Groundwater Model Run # 2*	• MSWD Indoor Use – 97 percent returns • MSWD Outdoor Use – 20 percent returns • CVWD Indoor Use – 97 percent returns • CVWD Outdoor Use – 20 percent returns • Fish farms – 80 percent returns • Golf courses – 20 percent returns • WWTPs o Horton WWTP return flows to Mission Creek Subbasin
Natural Inflows	• Long-term average natural inflows	*Same as Groundwater Model Run # 1*	*Same as Groundwater Model Run # 1*	*Same as Groundwater Model Run # 1*
Artificial Recharge Assumptions**	• Average hydrology • SWP reliability declines from 60 percent in 2010 to 50 percent by 2030 and remains at that level through 2045 (see MWH, 2012) • Assumes MWD call-back of 100,000 AFY Table A in four wettest out of every 10 years: o Additional recharge for CPV Sentinel production based on the following schedule: 6,100 AF in 2011, 3,000 AFY each in 2021 through 2023, 600 AFY each in 2041 through 2045	• Average hydrology • Additional recharge for CPV Sentinel production based on the following schedule: o 6,100 AF in 2011, o 3,000 AFY each in 2021 through 2023 o 600 AFY each in 2041 through 2045	• Variable hydrology o Wet years from 2011 to 2018 o No recharge from 2019 to 2028 o Dry years from 2029 to 2037 o Wet years from 2038 to 2045 • Recharge Schedule for CPV Sentinel same as Model Run #1 • Total volume imported water recharge same as Model Run # 2	• Variable hydrology o Wet years from 2011 to 2015 o No recharge from 2016 to 2040 o 600 AFY from 2029 to 2037 • Recharge Schedule for CPV Sentinel same as Model Run #1
Whitewater Artificial Recharge Assumptions	• SWP Exchange – Whitewater River pro-rata share of CVWD and DWA average SWP Table Deliveries. Amount decreases due to decreased SWP reliability (60% to 50%) and increased share of pumping in Mission Creek Subbasin • Colorado River Water – Portion of 35,000 AFY SWP water available under the QSA not used for Mid-Valley Pipeline project plus portion of desalinated drain water delivered in East Valley that offsets Colorado River Water (QSA) deliveries within CVWD's ID-1. • Natural Runoff – Portion of runoff from Whitewater River recharged at Whitewater recharge facilities • 17% of SWP Exchange and CR water and 38% of natural runoff assumed to recharge in Whitewater River channel with balance in spreading grounds (see MWH, 2012).	*Same as Groundwater Model Run # 1*	• Variable hydrology o Wet years from 2011 to 2018 o No recharge from 2019 to 2028 o Dry years from 2029 to 2037 o Wet years from 2038 to 2045	*Same as Groundwater Model Run #3*
Wastewater Treatment Flows	• 3.8 mgd (4,300 AFY) to Horton WWTP (percolation to MCSB) • 3.7 mgd (4,100 AFY) to the proposed Regional WWTP (wastewater [WW] percolation to GHSB)	• 3.0 mgd (3,400 AFY) to Horton WWTP (percolation to MCSB) • 4.5 mgd (5,000 AFY) to the proposed Regional WWTP (WW percolation to GHSB)	*Same as Groundwater Model Run # 2*	• 3.0 mgd (3,400 AFY) to Horton WWTP (percolation to MCSB)

NOTES: *Assume no recycled water available. All wastewater is percolated as indicated in table. Septic Assumptions for all Model Runs: CVWD customers will remain on septic. All MSWD customers (except for 500) will be on sewer by 2045.
**Assumes all artificial recharge water currently available through water purchase agreements or State Water project Allocations remains unchanged through 2045.

The following observations and conclusions can be drawn based on the results of the groundwater modeling:

- It is observed that recharge water accumulates near the Mission Creek recharge facility causing mounding in that area. The cause of this accumulation could be a change in the geologic structure of the basin caused by faulting or changes in bedrock depth, or simply by hydrogeologic constraints such as insufficient transmissivity to convey the water away from the recharge site in the time period analyzed. Additional monitoring near the Mission Creek recharge facility is required to validate this observation.
- As levels in the upgradient groundwater basin increase due to increased storage, outflows to downgradient basins will also increase. The relationship between basin storage and outflow is not linear due to the accumulation of water near the recharge area.
- Variability in imported water deliveries from one year to the next will have an impact on groundwater storage and water level fluctuations. In addition, it is difficult to predict future hydrologic regimes both locally (for natural recharge) and remotely (for Colorado River derived artificial recharge) due to long term climatic change. Consequently and given subbasin prevailing conditions at any given time, it may be more judicious to recharge when artificial recharge water is available than to anticipate that it will always be available.
- Percolation of wastewater from the proposed Regional Wastewater Treatment Plant in the Garnet Hill Subbasin would have an impact on groundwater levels in that basin at the proposed location and anticipated recharge amounts.

SECTION
2.0 INTRODUCTION

As part of a settlement agreement between CVWD, the DWA and MSWD, the agencies agreed to prepare a Water Management Plan for the Mission Creek and Garnet Hill subbasins of the Coachella Valley Groundwater Basin (CVGB). Groundwater modeling is required to evaluate various alternatives that will be developed as part of the Water Management Plan for the Mission Creek and Garnet Hill subbasins. The objective of the modeling effort is to support management decisions on a regional basis. The modeling effort is intended to identify general trends in the groundwater system and potential effects from various water management alternatives that will be developed as part of the Water Management Planning process. The initial phase of the modeling effort is development of a conceptual model of the groundwater basin. The conceptual model provides a physical description of the Mission Creek and Garnet Hill subbasins and the factors that influence groundwater flow in the subbasins.

To the extent possible, the conceptual model was developed using existing data. In instances where available data was deficient, assumptions were developed and are described along with the basis for the assumptions and are presented in Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin. The conceptual model is the basis for the numerical model.

2.1 Managing Agencies

CVWD, DWA, and MSWD are cooperatively developing a Water Management Plan for the Mission Creek and Garnet Hill subbasins. The location of the districts in relation to the subbasins is depicted in Figure 1. A brief description of the water districts is provided below.

2.1.1 Coachella Valley Water District

The Coachella Valley Water District (CVWD) was formed in 1918 under the County Water District Act provisions of the California Water Code. The Coachella Valley Stormwater District was formed in 1915. The two districts merged in 1937. CVWD now encompasses approximately 637,000 acres, mostly within Riverside County, but also extending into northern Imperial and northeastern San Diego counties (Figure 1). CVWD is a State Water project (SWP) contractor and hold priority 3 rights to Colorado River water. CVWD provides domestic water, non-potable water, wastewater, stormwater and drainage services to customers within its service area.

2.1.2 Desert Water Agency

The Desert Water Agency (DWA) was established in the late 1950s by voters in the Palm Springs area. The DWA is a wholesale distributor of State Water Project water.

To resolve the absence of direct delivery of SWP water to the Coachella Valley, CVWD and DWA exchange their State Water Project water allocation with the Metropolitan Water District of Southern California (MWD) for a like amount of Colorado River water, which is delivered to recharge basins in the Palm Springs Subarea of the Whitewater River and Mission Creek subbasins.

2.1.3 Mission Springs Water District

The Mission Springs Water District (MSWD) was established in 1953 and was formerly known as Desert Hot Springs County Water District. The District's service area comprises 135 square miles including the

City of Desert Hot Springs, 10 smaller communities in Riverside County, and communities in the City of Palm Springs. The District's water source is 100 percent groundwater, drawn from nine active production wells, providing water service to approximately 23,000 people as well as sewer service to approximately 8,000 people in Desert Hot Springs, Desert Crest Country Club and Dillon Mobile Home Park.

2.2 Purpose and Objectives

The purpose of the numerical model is to evaluate the groundwater basin response to various alternatives as part of the Water Management Plan for the Mission Creek and Garnet Hill subbasins. The objectives of numerical model include the following:

- Conduct a management level evaluation of selected alternatives for managing groundwater in the Mission Creek and Garnet Hill subbasins;
- Provide information on the sensitivity of the system to variations in various parameters so that, if appropriate, more resources can be allocated to reduce the uncertainty;
- Assist in the design/improvement of the monitoring network so that effective management of the subbasins can be performed.

SECTION
3.0 CONCEPTUAL MODEL

A conceptual model of a groundwater flow and hydrologic system is an interpretation or working description of the characteristics and dynamics of the physical hydrogeologic system. The purpose of the conceptual model is to consolidate site and regional hydrogeologic and hydrologic data into a set of assumptions and concepts that can be evaluated quantitatively. Development of the conceptual model requires the collection and analysis of hydrogeologic and hydrologic data pertinent to the aquifer system under investigation (ASTM, 2004).

The hydrogeology of the CVGB and its subbasins have been described in numerous publications by the U. S. Geological Survey (USGS) (e.g., Tyley, 1974; Reichard and Meadows, 1992), California Department of Water Resources (DWR) (1964), in consultants' studies for the water districts in the area (Slade, 2000; GSi/water, 2006; MWH, 2002 and 2005; Psomas, 2004 and 2006), and by other parties. To the extent possible, the conceptual model was developed using the aforementioned reports and studies. In instances where available data was deficient, assumptions were developed and are described along with the basis for the assumptions and are presented in Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill subbasins and Palm Springs Subarea of the Whitewater River Subbasin (Psomas, 2012), which forms the basis of the conceptual described in this report.

Groundwater in the CVGB occurs in the alluvium, terrace deposits, and older sedimentary units that fill the valley. The CVGB is bounded on the north and east by the non-water bearing crystalline rocks of the San Bernardino and Little San Bernardino Mountains and on the west by the crystalline rocks of the Santa Rosa and San Jacinto Mountains. The northern boundary is formed by the San Gorgonio Pass. The Mecca Hills and the Salton Sea form the southern boundary. The faults that cross the valley form partial barriers to groundwater flow and interrupt the overall flow of groundwater in the valley, which occurs from northwest to southeast and are indicated in Figure 2 and Figure 3. Based on the faults in the area and their effect on groundwater flow, the USGS, the DWR, and the California Regional Water Quality Control Board (RWQCB) have divided the CVGB into five groundwater subbasins. The subbasins are shown on Figure 4 and are as follows:

1. Whitewater River [referred to as Indio Subbasin in Bulletin 118] Subbasin (7-21.01 - RWQCB designation)
2. Mission Creek Subbasin (7-21.02)
3. Desert Hot Springs Subbasin (7-21.03)
4. San Gorgornio Pass (7-21.04)
5. Garnet Hill Subbasin [included as a subarea of the Indio Subbasin in Bulletin 118]

These subbasins are typically long and relatively narrow, and extend from northwest to southeast between the mountains and the various branches of the San Andreas Fault zone. Of the five subbasins, the Garnet Hill is the smallest and least developed. The Whitewater River Subbasin is by far the largest, and is the most developed of the subbasins in the CVGB. A detailed description of the geology and hydrogeology of the basins is provided in Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill subbasins and Palm Springs Subarea of the Whitewater River Subbasin (Psomas, 2012). A summary of the conceptual model used to create the numerical model is provided below.

3.1 Mission Creek Subbasin

The Mission Creek Subbasin is bounded on the north by the Mission Creek Fault and on the south by the Banning Fault. To the west, the subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills and the Mission Creek Fault. Artesian conditions have historically been present near a narrow strip along the northwest portion of the Seven Palms Ridge (DWR, 1964), allowing for the development of a unique Willow-Mesquite biological community that includes phreatophytes. Depth to groundwater in other parts of the sub-basin averages 300 feet below ground surface.

The Mission Creek Subbasin is filled with Holocene and late Pleistocene unconsolidated sediments eroded from the San Bernardino and Little San Bernardino Mountains. There are three significant water-bearing sedimentary deposits recognized in the subbasin: Pleistocene Cabazon Fanglomerate and Pleistocene to Holocene Older alluvium and alluvial deposits. These deposits are generally coarse sand and gravel, poorly sorted alluvial fan and pediment deposits that coalesce with one another.

The Mission Creek Subbasin is considered an unconfined aquifer with a saturated thickness of 1,200 feet or more and an estimated total storage capacity on the order of 2.6 million af (DWR, 1964). The groundwater estimated to be in storage for the subbasin is 1.4 million af (MSWD, 2006a). The subbasin is naturally recharged by surface and subsurface flow from the Mission Creek, Dry, and Big Morongo Washes, the Painted Hills, and surrounding mountain drainages. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge. Total 2009 inflow to the Mission Creek Subbasin is estimated at 23,500 afy.

The primary outflow from the Mission Creek Subbasin is through groundwater production for domestic, agricultural and commercial use. While groundwater production has varied over the years, it generally has been increasing from approximately 2,000 afy in the 1970s to over 15,000 afy in 2006. In addition, outflow occurs across the Banning Fault to the Garnet Hill Subbasin and has been estimated at 7,400 afy (1936 steady-state conditions [see Table 1]) outflow also occurs across the semi-waterbearing rocks in the southeastern edge of the subbasin at a rate of approximately 3,500 afy (1936 steady-state conditions [see Table 1]). Lastly, the consumption of groundwater by phreatophytes in the southern end of the subbasin has been estimated at 1,400 afy. Total 2009 outflow from the Mission Creek Subbasin has been estimated to be approximately 27,800 afy (Psomas, 2012). Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -4,300 afy which would indicate that the subbasin lost water from storage. Table 3 presents a summary of the conceptual model estimated inflows and outflows of the Mission Creek Subbasin and the basis of estimates.

Water level declines have been apparent in the Mission Creek Subbasin since the early 1960s and, in the 1970s, when the United States Geological Survey (USGS) sponsored the development of groundwater analog models to assist the DWA and CVWD in their water management decisions regarding importing water for groundwater recharge (Tyley, 1971; Tyley, 1974). Water levels have declined in portions of the Mission Creek Subbasin approximately 100 feet between the years 1936 and 2003. Based on previously prepared estimates, cumulative change in storage between 1936 and 2003 ranges between -100,000 to -174,000 af.

3.2 Garnet Hill Subbasin

The Garnet Hill Subbasin is bounded on the north by the Banning Fault and on the south by the Garnet Hill Fault. An estimated 24,900 afy of groundwater moves laterally across the constrictive Garnet Hill Fault to the Palm Springs Subarea of the Whitewater River Subbasin. To the west, the Garnet Hill Subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills.

TABLE 3

CONCEPTUAL GROUNDWATER HYDROLOGIC BUDGETS (1936 & 2009) FOR THE MISSION CREEK AND GARNET HILL SUBBASINS, & PALM SPRINGS SUBAREA

CONDITION (Year)	RECHARGE AND DISCHARGE	MISSION CREEK SUBBASIN (acre-feet/year)	BASIS OF ESTIMATE	GARNET HILL SUBBASIN (acre-feet/year)	BASIS OF ESTIMATE	PALM SPRINGS SUBAREA (acre-feet/year)	BASIS OF ESTIMATE
Steady-State Conditions (1936)	**RECHARGE (INFLOW)**						
	UNDERFLOW FROM						
	Desert Hot Springs Subbasin	1,800	Mayer, 2008	---	---	---	---
	Mission Creek Subbasin	---	---	7,400	From Mission Creek Budget	---	---
	Garnet Hill Subbasin	---	---	---	---	24,900	From Garnet Hill Budget
	San Gorgonio Subbasin	---	---	---	---	8,900	MWH Tech Memo, 2010
	PERCOLATION from						
	Mountain Front Recharge and Stream Underflow	10,500	Calculated from isohyetals	17,500	Calculated from isohyetals	24,580	MWH Tech Memo, 2010
	TOTAL INFLOW	**12,300**	---	**24,900**	---	**58,380**	---
	DISCHARGE (OUTFLOW)						
	UNDERFLOW TO GARNET HILL SUBBASIN	7,400	Calculated from balance of inflow	---	---	---	---
	UNDERFLOW TO PALM SPRINGS SUBAREA	---	---	24,900	Calculated from balance of inflow	---	---
	UNDERFLOW TO SEMIWATER-BEARING ROCKS IN SOUTHEASTERN PORTION OF SUBBASIN	3,500	Estimated based on 1936 contours and balance of inflow	---	---	---	---
	UNDERFLOW TO LOWER WHITEWATER SUBBASIN	---	---	---	---	58,380	Calculated from balance of inflow.
	EVAPOTRANSPIRATION	1,400	Tyley, 1974	0	Tyley, 1974	---	---
	TOTAL OUTFLOW	**12,300**	---	**24,900**	---	**58,380**	---
	INFLOW-OUTFLOW	**0**	---	**0**	---	**0**	
2009 Conditions (Average)	**RECHARGE (INFLOW)**						
	UNDERFLOW FROM						
	Desert Hot Springs Subbasin	1,800	Tyley, 1974	---	---	---	---
	Mission Creek Subbasin	---	---	7,400	From Mission Creek budget.	---	---
	Garnet Hill Subbasin	---	---	---	---	24,900	From Garnet Hill budget.
	San Gorgonio Subbasin	---	---	---	---	8,900	MWH Tech Memo, 2010
	PERCOLATION from						
	Septic and Irrigation Return Flows	2,930	MWH, 2010.	250	MWH, 2010.	Included with mountain front recharge	MWH, 2010.
	Horton and Desert Crest Infiltration Ponds	1,013	MWH, 2010.	0	---	---	---
	Mountain Front Recharge and Stream Underflow	10,500	From 1936 budget estimate.	17,500	Calculated from isoheytals	24,580	MWH Tech Memo, 2010
	Artificial Recharge Facilities (Ave. for 2002-2009)	7,259	MWH, 2010.	---	---	46,694	MWH Tech Memo, 2010
	TOTAL INFLOW	**23,502**	---	**25,150**	---	**105,074**	---
	DISCHARGE (OUTFLOW)						
	UNDERFLOW TO GARNET HILL SUBBASIN	7,400	From 1936 budget estimate.	---	---	---	---
	UNDERFLOW TO PALM SPRINGS SUBAREA	---	---	24,900	From 1936 budget estimate.	---	---
	UNDERFLOW TO SEMIWATER-BEARING ROCKS IN SOUTHEASTERN PORTION OF SUBBASIN	3,500	From 1936 budget estimate.	---	---	---	---
	UNDERFLOW TO LOWER WHITEWATER SUBBASIN	---	---	---	---	58,380	Estimated from 1936
	PUMPAGE	15,500	Pumping records from CVWD, DWA, & MSWD	500	Pumping records from CVWD, DWA, & MSWD	50,000	Pumping records from CVWD, DWA, & MSWD
	EVAPOTRANSPIRATION	1,400	Tyley, 1974	0	Tyley, 1974	---	---
	TOTAL OUTFLOW	**27,800**	---	**25,400**	---	**108,380**	---
	INFLOW-OUTFLOW	**-4,298**	---	**-250**	---	**-3,306**	---

The Garnet Hill Subbasin is considered an unconfined aquifer with a saturated thickness of 1,000 feet or more and an estimated total storage capacity on the order of 1.0 million af. The subbasin is naturally recharged by subsurface flow from the Mission Creek Subbasin and runoff from the Whitewater River watershed on the west. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge but is considered very small. Total 2009 inflow to the Garnet Hill Subbasin is estimated at 25,150 af.

The primary outflows from the Garnet Hill Subbasin are across the Garnet Hill Fault to the Palm Springs Subarea. In addition, limited groundwater production for domestic, agricultural and commercial use also occurs but has only recently been of any significance. Groundwater production has varied over the years, ranging from a high of over 4,000 afy in the early 1950s to less than 50 afy in the mid-1980s. Currently, groundwater production is estimated at between 300-500 afy.

Total 2009 outflow from the Garnet Hill Subbasin has been estimated to be approximately 25,400 afy. Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -250 afy which would indicate that for 2009, the subbasin had a slightly negative balance.

3.3 Whitewater River Subbasin

The Whitewater River Subbasin comprises the major portion of the floor of the Coachella Valley and encompasses approximately 400 square miles. Beginning approximately one mile west of the junction of State Highway 111 and Interstate 10, the Whitewater River Subbasin extends southeast approximately 70 miles to the Salton Sea. The subbasin is bordered on the southwest by the Santa Rosa and San Jacinto Mountains, and is separated from Garnet Hill, Mission Creek and Desert Hot Springs subbasins to the north and east by the Garnet Hill and San Andreas faults.

The limit of the Whitewater River Subbasin along the base of the San Jacinto Mountains and the northeast portion of the Santa Rosa Mountains coincides with the CVGB boundary. The Whitewater River Subbasin in this vicinity includes only the Recent and late Pleistocene terraces and alluvial fans. The Palm Springs Subarea constitutes the recharge area of the Whitewater River Subbasin.

The Palm Springs Subarea is bounded by the San Gorgonio Subbasin to the west, the Garnet Hill Fault to the north, the San Jacinto Mountains to the south, and an arbitrary line running from the Indio Hills to the San Jacinto Mountains across the valley floor. Along the periphery of the entire valley, and in the upper valley from the San Gorgonio Pass to Cathedral City, heterogeneous alluvial fan and stream wash deposits are found containing relatively small amounts of fine-grained materials. Thicknesses of the fan deposits commonly exceed 1,000 ft. Recent deposits, possibly 300 to 400 ft. thick overlie the Ocotillo Conglomerate. In general, groundwater is unconfined, and the major sources of recharge to the aquifer are mountain front recharge and streamflow infiltration, and subsurface inflow from San Gorgonio Pass.

The Palm Springs Subarea has an estimated total storage capacity on the order of 4.6 million af. The subbasin is naturally recharged by subsurface flow from the Garnet Hill Subbasin and runoff from the Whitewater River watershed on the west. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge. Total 2009 inflow to the Palm Springs Subarea is estimated at 105,100 af. Table 3 presents a summary of the estimated inflows and outflows of the Palm Springs Subarea and the basis of estimates.

SECTION
4.0 COMPUTER CODE

The construction of a groundwater flow model is the process of transforming the conceptual model into a mathematical form. The ground-water flow model typically consists of two parts, the computer code and the data set. The following discussion provides a brief discussion of the modeling code used to construct the model. The data set is described in Section 5.0.

4.1 Code Selection

The numerical model is implemented with the computer code MODFLOW (McDonald and Harbaugh, 1988), which simulates groundwater flow in three dimensions using a block-centered finite difference approach. The code conforms to modern theory and standard practice for solving the equations of groundwater flow. The code was selected to maintain consistency with the existing groundwater model developed for the greater Coachella Valley by CVWD in 2000 (MWH, 2000).

4.2 Code Description

Assuming that the fluid density is constant, the principal axes of hydraulic conductivity are aligned with the coordinate directions, and the aquifer is homogeneous and isotropic, the vertically averaged groundwater flow equation is based on Bear (1979):

$$\frac{S}{T}\frac{\partial h}{\partial t} = \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} - W$$

where S is the storage coefficient, T is the transmissivity of the aquifer (T=Kb) along the x and y coordinate axes, b is the aquifer saturated thickness, K is the hydraulic conductivity, h is the piezometric head, t is time, and W is a volumetric flux per unit area and represents sources or sinks of water. The assumption of constant fluid density ignores the significant differences in temperature and concentrations of dissolved solids in groundwater across the study area.

The numerical model used for this study is MODFLOW, a well-known, quasi-three-dimensional groundwater-flow modeling program (McDonald and Harbaugh 1988) based on the aforementioned equation. The MODFLOW horizontal flow barrier (HFB) package was utilized to simulate the effect of the various faults on groundwater flow. The HFB package essentially simulates the fault via a leakance term between two horizontally adjacent finite-difference cells. The HFB package is based on the assumption that the fault is vertically oriented and that the flow through the adjacent cells is horizontal. The fault hydraulic properties are input as a conductance, $K^* = K_f / h_f$; where K_f and h_f are the fault hydraulic conductivity and thickness in the direction normal to flow, respectively.

SECTION

5.0 NUMERICAL GROUNDWATER FLOW MODEL CONSTRUCTION

The model construction process includes building the data set utilized by the computer code. Fundamental components of a ground-water flow model include: dimensionality, discretization, boundary and initial conditions, and hydraulic properties (ASTM, 2004). The following discussion presents the data sets used to construct the numerical model.

5.1 Model Grid

The model grid used for this investigation is a subset of the groundwater model grid developed for the greater Coachella Valley by CVWD in 2000 (MWH, 2000). The CVWD model consists of a three-dimensional, finite-difference mesh of blocks called cells. The original model mesh consisted of 270 rows, 86 columns and 4 layers.

The area covered by the numerical groundwater model (the model domain) is shown on Figure 5. The upstream ends of the model domain correspond to the following:

- San Gorgonio Pass area
- Upper Whitewater River drainage area
- Upper Mission Creek drainage area
- Desert Hot Springs Subbasin at the Mission Creek fault

The downstream end of the model domain is defined as row 75 of the CVWD model and represents the southern end of the Palms Springs Subarea of the Whitewater River Subbasin and was located along an area that did not contain significant production or recharge facilities.

The model consists of a three-dimensional, finite-difference mesh of blocks called cells, the locations of which are described in terms of the 75 (of the original 270) rows, 86 columns and 4 layers in the mesh. At the center of each cell there is a point called a node at which the groundwater head is calculated. Consistent with the original CVWD model, this model has a node spacing of 1,000 ft. in the x-y plane, and variable vertical node spacing representing variable thicknesses of the corresponding aquifer. The original model contained 4 layers for the purpose of modeling conditions in the lower Whitewater River Subbasin. While these layers do not exist in the Mission Creek and Garnet Hill subbasins, the layers were preserved from the original CVWD model to permit basin wide use of the model. The mesh is oriented along the length of the valley, coinciding with the principal direction of regional groundwater flow.

Figure 5 shows the horizontal layout of the mesh for layer 1, the uppermost layer. The shaded cells around the perimeter are inactive (no-flow) cells and define the x-y plane geometry of the flow region. The inactive cells lie in areas of low-permeability, consolidated to semiconsolidated rocks or in adjacent subbasins (San Gorgonio and Desert Hot Springs) that are substantially isolated from the Garnet Hill and Mission Creek subbasins by faults (see Tyley, 1974). The 12,360 active cells represent unconfined aquifer system in the Recent and Pleistocene sedimentary fill.

5.2 Hydraulic Parameters

Hydraulic parameters include aquifer thickness, hydraulic conductivity and storage coefficient. These parameters affect the rate of groundwater movement and the volume of water taken into and released from storage. Descriptions of the conceptual model used to estimate the initial parameter values in the model are provided in *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* (Psomas, 2012). Refinements to initial parameter values were made during model calibration.

5.2.1 Aquifer Thickness

Elevation of the tops and bottoms of model layers are referenced to land surface elevations, and hence the topography, which is obtained primarily from USGS digital elevation models (DEM) and topographic maps of the Desert Hot Springs area. Total aquifer thickness then follows from elevations assigned to the mesh layers.

In the Palm Springs Subarea, aquifer thickness was based upon the inputs from the CVWD model. For the Mission Creek and Garnet Hill subbasins, an aquifer thickness of 1,000 feet was used. The 1,000 ft. thickness was calculated from the 1936 groundwater contours as reported by Tyley (1974) (see Figure 6). A groundwater surface was extrapolated from the contours and an elevation of the centroid of each cell was obtained from the grid surface. The bottom elevation of the aquifer surface was calculated by subtracting 1,000 feet from the centroid value. In some instances, the 1,000 feet was reduced due to rise in the basement bedrock elevation in the upper reaches of Mission Creek Subbasin (see Psomas, 2012). The minimum aquifer thickness in the upper reaches of the Mission Creek Subbasin was approximately 700 feet.

The model tracks the location of the water table relative to the layer elevations. If the water table drops below the bottom of a layer at a location, the corresponding cell in that layer is made inactive. If the water table later rises above the layer bottom, the cell is reactivated.

5.2.2 Hydraulic Conductivity

The parameter relating movement of groundwater through a porous media under a unit hydraulic gradient is known as hydraulic conductivity (K) and depends on the size and arrangement of the water transmitting pores (or rock fractures) within a geologic formation, and on dynamic characteristics of the fluid such as kinematic viscosity and specific weight. The hydraulic conductivity of different geologic materials varies and is greatest with materials with high effective porosity (percent of the total volume of a given mass of soil that consists of interconnected interstices e.g., sand and gravels) and lowest for materials with low effective porosity such as silts and clays.

Hydraulic conductivity can be expressed in the model with directional components (e.g. in the x-direction, y-direction, and z-direction [vertically]). For the purposes of the modeling effort, the alluvial materials at any one cell were assumed to be equal horizontally (each individual cell in the model was assumed to have equal hydraulic conductivity in the x or y direction and heterogeneous in the horizontal to vertical direction (x&y to z). The following discusses how the horizontal and vertical hydraulic conductivities of the model were developed.

5.2.2.1 Horizontal Hydraulic Conductivity

The ability of an aquifer to transmit water through a unit width of the aquifer is referred to as transmissivity (*T*) and is defined as the rate of flow (e.g., gallons per day) moving through a unit width of the entire saturated thickness of an aquifer and is equal to the horizontal hydraulic conductivity multiplied by the aquifer's saturated thickness (*b*), or

$$T = Kb$$

Transmissivity of the subbasins has been previously estimated by others (Tyley 1971, GTC 1979, Mayer & May 1996, Slade 2000). However, DWA updated Tyley's (1974) estimate of transmissivity in the

Mission Creek Subbasin from aquifer tests obtained from production wells. The model employed these updated values initially with slight modifications during the calibration process. The initial values are presented in *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* (Psomas, 2012). The transmissivity maps were overlaid on the model grid and centroid values of transmissivity was obtained for each active cell in layer 1. The transmissivity value was divided by the aquifer thickness and the correspondingly computed horizontal hydraulic conductivity (K_x) was applied to each cell and repeated for each cell in the underlying layers.

5.2.2.2 Vertical Hydraulic Conductivity

Vertical hydraulic conductivity was (K_z) calculated as being equal to K_x times 0.1 or 10 percent of the horizontal hydraulic conductivity (K_x). A sensitivity analysis was conducted with K_z equal to K_x times 0.01 or 1 percent of the horizontal hydraulic conductivity and is discussed in Section 6.0.

5.2.3 Storativity

Distribution of storativity (S) from Tyley (1974) (see *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* [Psomas, 2012]) was initially used in the subbasins for all model layers; these values were subsequently modified during the transient calibration process.

5.3 Boundary Conditions

Inflows/outflows including boundary conditions are used anywhere in the model domain to account for water entering or leaving that domain. Boundary conditions account for sources of water such as natural recharge, artificial recharge ponds and subsurface inflow or outflow from or to adjacent subbasins, and wells and drains where groundwater discharges from the flow system. Model input data describing each set of boundary conditions were developed for the 64 stress periods (see Section 5.6 Stress periods) that define conditions from 1936-2009.

The active domain of the model is bounded by the San Gorgonio Pass on the western edge of the Palm Springs Subarea (northwest), the Whitewater River drainage (northwest corner of Garnet Hill Subbasin), the Mission Creek drainage area (Northern boundary), the Mission Creek Fault (western boundary of the Desert Hot Springs Subbasin), the Indio Hills (southern boundary of Mission Creek Subbasin, and row 75 of the original CVWD model grid. This area is shown in Figure 7. The upper boundary of the flow system is the water table; processes affecting this boundary include recharge (both natural and artificial), pumpage and evapotranspiration from natural vegetation.

Brief descriptions of the model boundary conditions and the methods used to estimate the boundary heads and fluxes are discussed in this section and are presented in Table 4. Some boundary conditions represent flows that are input to the model, such as pumpage and recharge (both natural and artificial). Others, such as drains, evapotranspiration, and the Palm Springs Subarea southern boundary, are head-dependent boundaries where flows are computed by MODFLOW.

5.3.1 Natural Recharge

Recharge to the groundwater system from natural sources includes precipitation on the valley floor, infiltration of runoff from precipitation in the mountains that includes streamflow infiltration and subsurface inflow and referred to as mountain front recharge, and inflows from adjacent groundwater basins.

5.3.1.1 Inflow from San Gorgonio Pass

The San Gorgonio Pass Subbasin (DWR, 1964) is located northwest of the valley proper; groundwater flows from the subbasin into the Palm Springs Subarea across a buried bedrock ridge about one mile west of the junction of Interstate 10 and State Highway 111. Drainage within the pass area is tributary to Coachella Valley via the San Gorgonio River that enters the Whitewater River channel above Windy Point. However, there are no data available on streamflow in the San Gorgonio River near Windy Point.

The conceptual model (see Table 4) estimated that the subsurface flow from the San Gorgonio Subbasin to the Palm Springs Subarea was approximately 8,900 afy at pre-pumping (1936) conditions based on MWH (2010). Following steady-state calibration of the numerical model, flux between the two subbasins was estimated at 8,270 afy.

A time-variant specified head boundary condition was used to model inflow from the San Gorgonio Pass for the period 1936-96. Measured groundwater levels in the vicinity of the boundary were used to specify the time-dependent head.

5.3.1.2 Infiltration of Mountain Front Recharge

Streamflow infiltration and subsurface inflow from mountain watersheds (or mountain-front recharge) from precipitation in the San Bernardino and Little San Bernardino mountains are the primary recharge areas for the Mission Creek and Garnet Hill subbasins. The San Jacinto and San Bernardino Mountains are the primary sources of natural recharge to the Palm Springs Subarea. The total volume of tributary inflow varies dramatically from season to season and year to year, due to wide variations in precipitation within the various watersheds. For instance, precipitation on the valley floor averages 4 inches per year whereas in the San Bernardino Mountains average annual precipitation in some portions of the watersheds can exceed 40 inches (see *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* [Psomas, 2012]). Even with the high average precipitation rates in the upper watersheds, perennial streamflow in the lower reaches are practically non-existent.

The average annual tributary inflow to the study area during the 74-year model calibration period was estimated for each of the mountain watersheds. For the Whitewater River Subbasin, MWH estimated recharge from mountain runoff by an approach similar to that used by DWR (1964), which involved correlating annual watershed precipitation and runoff. In wet periods, considerably larger amounts of runoff are produced per unit of precipitation than in dry periods. Evapotranspiration and other losses consume a larger fraction of precipitation in dry years than in wet years. In addition, in dry periods, substantial precipitation is required to overcome soil moisture deficits before runoff occurs. Where available, gaged streamflow was used. The method used to estimate runoff from ungaged watersheds involved defining watershed boundaries and determining tributary areas, estimating the average precipitation for the base period 1931-61 for each watershed (DWR 1964), estimating the annual precipitation (1936-96) for each watershed using precipitation indices, and estimating the annual runoff for each watershed using rainfall-runoff curves derived from gauged watersheds in the San Jacinto Mountains. Except for the Whitewater River watershed, 90 percent of the estimated runoff was attributed to streamflow infiltration, and 10 percent of the estimated runoff was attributed to mountain-front recharge.

For the Mission Creek and Garnet Hill subbasins, mountain front recharge was calculated using Maxey-Eakin method (see *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* [Psomas, 2012]). This empirical method predicts the volume of aquifer recharge to a desert basin that results from precipitation in mountain watersheds. The method has been applied to over 200 basins in Nevada and other Western states and has been validated by comparison with other methods of recharge estimation in Nevada. Maxey et al (1949) used an isohyetal map to divide their study area into five zones of average precipitation, based on the following ranges: less than 8 inches, 8–12 inches, 12–15 inches, 15–20 inches, and over 20 inches. The percentage of precipitation from the successive zones that recharged the groundwater aquifer was estimated as 0, 3, 7, 15, and 25 percent, respectively. The percentages were developed by iterative calibration of 13 other watersheds in Nevada.

Subsurface inflow from mountain watersheds was distributed to perimeter cells of the model located in canyons and along mountain fronts as shown on Figure 8. For the Palm Springs Subarea, recharge from infiltration of streamflow was distributed to model cells differently depending on if the year was relatively wet (greater than 1,000 af of Whitewater River flow at Indio), or relatively dry. With the exception of the Whitewater River, flow beyond mountain-front areas is normally limited to infrequent storm events in wet years. Therefore, recharge from infiltration of streamflow during dry years on major tributaries, and for all years on minor tributaries, was distributed to the perimeter model cells shown on Figure 8. During wet years, there can be significant tributary flow beyond the mountain-front areas and eventually to the Whitewater River. In these years, recharge from streamflow on major tributaries was distributed to the streamflow recharge cells (Figure 8) located along the stream channel downstream from the mountain front recharge cells.

For the Mission Creek and Garnet Hill subbasins, mountain front recharge occurs primarily upgradient of the model grid and consequently, flow was distributed equally along the selected cells and the northern edge of the grid/subbasin boundary.

5.3.1.2.1 Palm Springs Subarea

As part of the original modeling effort conducted for the Coachella Valley, MWH (2011) conducted an evaluation of the Whitewater River Subbasin and the sources of natural groundwater recharge associated with mountain front recharge from precipitation. In summary, MWH estimated the volume of tributary inflow of surface and groundwater from the mountain watersheds from rainfall-runoff curves that were developed for six of the local watersheds for which sufficient streamflow data were available.

Total average annual mountain front recharge to the Palm Springs Subarea is 24,580 afy for the 1936-1992 calibration period. The amount of recharge varied during the historical period depending on amount of precipitation above/below the average precipitation for the Snow Creek drainage area.

5.3.1.2.2 Mission Creek Subbasin

Using the Maxey-Eakin method, total estimated average recharge amounted to 10,500 afy which equates to approximately 15 percent of the total rainfall falling on the watersheds. Groundwater level data collected in the Mission Creek Subbasin did not indicate temporal changes in water levels related to wet/dry years, the average estimated recharge of 10,500 afy was used for all stress periods during the transient modeling activities.

5.3.1.2.3 Garnet Hill Subbasin

Using the Maxey Eakin method, total estimated average recharge amounted to 17,500 afy which equates to approximately 22 percent of the total rainfall falling on the watersheds. Only limited streamflow data (1948-79) was available for Whitewater River and groundwater level data collected in the Garnet Hill Subbasin did not indicate temporal changes in water levels related to wet/dry years, the average estimated recharge of 17,500 afy was used for all stress periods during the transient modeling activities.

5.3.1.3 Precipitation on the Valley Floor

Precipitation on the valley floor is not a major source of groundwater recharge due to the low annual rainfall. According to DWR (1964), the average annual precipitation on the valley floor for the 30-year period 1930-60 is about 4.5 inches. This amount of precipitation is normally consumed by direct evaporation or by evapotranspiration from native desert vegetation. During extremely wet periods, precipitation in excess of evapotranspiration and soil moisture deficits may result in both runoff and groundwater recharge; however, this occurs infrequently, and the anticipated recharge rates are small. Thus, such recharge is neglected in the model. These assumptions are consistent with the results of deep percolation studies reported by DWR (1930 & 1964).

5.3.2 Artificial Recharge

Since 1973, CVWD and DWA have received SWP water through an exchange agreement with Metropolitan. Water released from Metropolitan's Colorado River Aqueduct flows down the (Whitewater River channel to the recharge ponds near Windy Point. A portion of the water infiltrates along the channel, and some evaporates from the ponds before percolating to the water table. Estimates of the amount lost to infiltration in the channel and that to evaporation from the ponds were made for the model (MWH, 2011). Recharge rates were computed for the infiltration along the channel and at the recharge ponds, and applied in the model as infiltration rates to the uppermost model layer using the recharge package. Note that in the three years 1985-87, over 650,000 af of water was released to the Whitewater River. From 1980-87, groundwater levels in the artificial recharge area increased over 350 ft.

5.3.3 Return Flows

Return flows are that part of the applied water that percolates back into the groundwater system. Return flows from municipal pumpage were estimated to be a percentage of pumping rates based on assumptions made in the USGS modeling studies, and an analysis of return flows in the Palm Springs subarea from the CVWD study (Fogg et al, 2000) and what was estimated for the Mission Creek and Garnet Hill subbasins (see *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* [Psomas, 2012]). Other return flows in the model include irrigation returns from diversions of streamflow, and returns from recycled wastewater. Return flows were assigned as infiltration rates to the uppermost model layer and are depicted in Figure 9.

5.3.4 Faults

Geologic structures within the area of investigation have a marked influence on the occurrence and movement of groundwater. Principal structural features of Coachella Valley are faults of the northwest-trending San Andreas Fault system (Banning and Garnet Hill faults), and associated drag and compressional folds.

Large subparallel and branching faults present in Coachella Valley are part of the San Andreas Fault zone. They have developed from a general north-south regional stress that began in late Tertiary time and continues today. Although movement within the San Andreas Fault Zone is predominantly right lateral (the southwest block moving northwest relative to the northeast block), vertical displacement has also depressed the southwest block.

Faults of the San Andreas Fault system act as partial barriers to groundwater movement, affecting both water quality conditions and the depth at which groundwater occurs. The occurrences of thermal waters in Coachella Valley are related to faulting. Folding of sedimentary formations in the hills and along the mountains has exposed Tertiary formations which generally limit groundwater movement. Pleistocene formations structurally uplifted above the water table have been dewatered, reducing the area of effective groundwater storage and yield.

TABLE 1

HYDROLOGIC BUDGET FOR THE MISSION CREEK AND GARNET HILL SUBBASINS, & PALM SPRINGS SUBAREA

RECHARGE AND DISCHARGE	MISSION CREEK SUBBASIN (acre-feet/year)			GARNET HILL SUBBASIN (acre-feet/year)			PALM SPRINGS SUBAREA (acre-feet/year)		
	Conceptual Model	Steady-State Calibration	Transient Calibration	Conceptual Model	Steady-State Calibration	Transient Calibration	Conceptual Model	Steady-State Calibration	Transient Calibration
RECHARGE (INFLOW)									
UNDERFLOW FROM									
Desert Hot Springs Subbasin	1,800	2,150	1,844	---	---	---	---	---	---
Mission Creek Subbasin	---	---	---	7,400	8,250	varies (see App. E)	---	---	---
Garnet Hill Subbasin	---	---	---	---	---	---	24,900	25,050	varies (see App. E)
San Gorgonio Subbasin	---	---	---	---	---	---	8,900	8,270	varies (see App. E)
PERCOLATION from									
Mountain Front Recharge and Stream Underflow	10,500	10,500	7,500	17,500	16,800	varies (see App. E)	24,580	32,650	varies (see App. E)
Artificial Recharge (includes return flows)	---	---	varies (see App. E)	---	---	varies (see App. E)	---	---	varies (see App. E)
TOTAL INFLOW	**12,300**	**12,650**	**Varies (a)**	**24,900**	**25,050**	**Varies (a)**	**58,380**	**65,970**	**Varies (a)**
DISCHARGE (OUTFLOW)									
UNDERFLOW TO GARNET HILL SUBBASIN	7,400	8,250	varies (see App. E)	---	---	---	---	---	varies (see App. E) (f)
UNDERFLOW TO PALM SPRINGS SUBAREA	---	---	---	24,900	25,050	varies (see App. E)	---	---	---
UNDERFLOW TO SEMIWATER-BEARING ROCKS IN SOUTHEASTERN PORTION OF SUBBASIN	3,500	3,000	varies (see App. E)	---	---	---	---	---	---
UNDERFLOW TO LOWER WHITEWATER SUBBASIN	---	---	---	---	---	---	58,380	65,970	varies (see App. E)
EVAPOTRANSPIRATION	1,400	1,400	varies (see App. E)	---	---	---	---	---	---
GROUNDWATER PRODUCTION	---	---	varies (see App. E)	---	---	varies (see App. E)	---	---	varies (see App. E)
TOTAL OUTFLOW	**12,300**	**12,650**	**Varies (a)**	**24,900**	**25,050**	**Varies (a)**	**58,380**	**65,970**	**Varies (a)**
INFLOW-OUTFLOW	**0**	**0**	**Varies (a)**	**0**	**0**	**Varies (a)**	**0**	**0**	**Varies (a)**
MODEL CONSTRUCTION									
Model Grid (270 rows [75 active] x 86 columns)	Based on model grid of Fogg/O'Neill CVWD Model (CVWD, 2000)								
Cell Size =1,000 feet x 1,000 feet	Based on cell size of Fogg/O'Neill CVWD Model (CVWD, 2000)								
Layers (4)	Based on layers contained in Fogg/O'Neill CVWD Model (CVWD, 2000)								
Transmissivity	2,000 to 300,000 gpd/ft (b)		2,000 to 897,000 gpd/ft	10,000 to 50,000 gpd/ft (c)		8,000 to 57,000 gpd/ft	30,000 to 748,000 gpd/ft (e)		30,000 to 748,000 gpd/ft
Hydraulic Conductivity - Horizontal (K_h)	2 to 300 gpd/ft^2 (d)		2 to 897 gpd/ft^2	10 to 50 gpd/ft^2 (d)		8 to 57 ft/day	30 to 748 gpd/ft^2 (e)		30 to 748 gpd/ft^2
	0.3 to 40 ft/day (d)		0.25 to 120 ft/day	1.3 to 6.7 ft/day (d)		1.0 to 7.6 ft/day	4-100 ft/day (e)		4-100 ft/day
Hydraulic Conductivity - Vertical	varies	0.1 to .01 x K_h	0.1 to .01 x K_h	varies	0.1 to .01 x K_h	0.1 to .01 x K_h	varies	0.1 to .01 x K_h	0.1 to .01 x K_h
Storage Coefficient	0.08 to 0.18 (c)		0.12-0.19	0.15 to 0.18 (c)		0.1 to 0.2	0.06 to 0.13		0.06 to 0.13

Notes:

a - Varies with time period and deficits/surplus are made up through change in storage within the aquifer.

b - Derived from Tyley (1974) and DWA (2008).

c - Derived from Tyley (1974).

d - Derived from Tyley (1974) and estimated aquifer thickness of 1,000 feet.

e - From Fogg/O'Neill CVWD Model (CVWD, 2000).

f - The modeling suggests that in certain rare situations when high artificial recharge occurs in the Palm Springs Sub-Area, groundwater levels can rise in the Palm Springs Sub-Area such that underflow can occur into the Garnet Hill Subbasin (see Appendix E).

Faults of the San Andreas system, which are partial barriers to groundwater movement within Coachella Valley, include the San Andreas, Mission Creek, Banning, and Garnet Hill faults. In addition, buried faults probably account for the localized water quality differences and high groundwater temperature in some areas. Several related faults are present in the highland and hill areas. The three major faults controlling groundwater movement in the model area include the Mission Creek, Banning, and Garnet Hill faults and are discussed below.

5.3.4.1 Mission Creek Fault

As previously discussed, the Mission Creek Fault is an effective groundwater barrier where it crosses the alluvial basin between the Little San Bernardino Mountains and the Indio Hills. Various investigators have estimated the flux between the Desert Hot Springs Subbasin and the Mission Creek Subbasin. Tyley (1974) indicated that flow was probably occurring but indicated that it was insignificant. Mayer (2008) indicated that the flux estimated after calibration of a numerical model was 1,790 afy (0.07 m^3/s).

The conceptual model (see Table 4) estimated that the flux across the fault between the Desert Hot Springs Subbasin and the Mission Creek Subbasin was approximately 1,800 afy at pre-pumping (1936) conditions. Following steady-state calibration of the numerical model, flux across the fault was estimated at 2,150 afy. Wells were used to simulate the flux of groundwater flow occurring across the fault.

5.3.4.2 Banning Fault

The Banning Fault forms the partial barrier between the Mission Creek and Garnet Hill subbasins, although there is some flow from the Mission Creek Subbasin to the Garnet Hill Subbasin (MWH, 2005). Tyley (1974) estimated the flux across the Banning Fault to be approximately 2,000 afy. Mayer (2008) estimated the flux to be approximately 4,600 afy (0.18 m^3/s).

The conceptual model (see Table 3) estimated that the flux across the fault between the Mission Creek Subbasin and the Garnet Hill Subbasin was approximately 7,400 afy at pre-pumping (1936) conditions based on balance of inflow. Following steady-state calibration of the numerical model, flux across the fault was estimated at 8,250 afy.

5.3.4.3 Garnet Hill Fault

The Garnet Hill Fault (Figure 3) is located about 1.5 miles south of, and is oriented generally parallel to the Banning Fault. DWR (1964) suggested that the fault has not displaced Recent alluvium, but is effective as a barrier to groundwater flow below depths of 100 ft., based on water level measurements across the fault. The area between the Garnet Hill Fault and the Banning Fault is the Garnet Hill Subbasin. The few wells present in the Garnet Hill Subbasin indicate that water levels are higher in the subbasin than in the adjacent Palm Springs Subarea of the Whitewater River Subbasin opposite the Garnet Hill Fault.

The conceptual model (see Table 4) estimated that the flux across the fault between the Garnet Hill Subbasin and the Palm Springs Subarea was approximately 24,900 afy at pre-pumping (1936) conditions based on balance of inflow. Following steady-state calibration of the numerical model, flux across the fault was estimated at 25,050 afy.

5.3.5 Pumpage

Groundwater extraction from production wells is presently the largest component of outflow from the Mission Creek and Palm Springs subarea whereas it constitutes only a fraction of the outflow from the Garnet Hill Subbasin. Other components of discharge that were evaluated for each subbasin include native vegetation evapotranspiration, and subsurface outflow.

Historical pumpage in the Palm Springs subarea was obtained primarily from previous USGS modeling efforts up to 1967, and from CVWD and DWA well meter data for 1984-2009. Annual pumpage data not available throughout the historic period were estimated by O'Neill (2010) and is documented in Appendix A. For the Mission Creek and Garnet Hill subbasins, CVWD, DWA and MSWD supplied production records for each of the wells. A compilation of the production data along with well designation and model cell coordinates are presented in Table B-1 in Appendix B. Figure 10 presents the location of wells used as part of this study. Principal uses of groundwater production in the upper valley include municipal and domestic use, golf course irrigation aquaculture (fish farms) and nurseries.

5.3.6 Indio Hills Subsurface Flow

As previously indicated, underflow from the Mission Creek Subbasin across the Banning Fault has been estimated at 2,000 afy by Tyley (1974). However, preliminary mass balance calculations suggest a value of approximately 7,400 afy. In addition, previous investigators have indicated that groundwater flow through the semi-waterbearing rocks at the southeastern end of the subbasin was inconsequential. However, examination of the groundwater contours and mass balance calculations suggested that approximately 3,500 afy is exiting the basin in this area (Psomas, 2012). A drain boundary condition was designated for this area and is depicted in Figure 7.

5.3.7 Evapotranspiration

Groundwater losses to evapotranspiration (ET) by phreatophytes on undeveloped lands are accounted for with an ET boundary condition in the model. Native vegetation on undeveloped lands receives its water supply from direct precipitation and soil water. High evaporation rates and soil water deficits are common conditions to much of the undeveloped land of the Coachella Valley that is underlain by a deep water table. Plants on these lands will transpire little water. However, on undeveloped lands underlain by a shallow water table, phreatophytes receive much of their water from groundwater within reach of their roots and the quantities of water transpired can be substantial.

Only a portion of the Mission Creek Subbasin has a sufficiently shallow groundwater table at the southern end of the subbasin (see *Technical Memorandum: Conceptual Groundwater Model of the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasin* [Psomas, 2012]) to support phreatophytes. Mayer and May (1998) estimated the total area populated by phreatophytes to be 1,123 acres. Mesquite is the dominant phreatophyte found along the Mission Creek and Banning faults. The amount of water extracted from the aquifer by the phreatophytes was estimated using the approach of Lines and Bilhorn (1996) who have estimated transpiration losses from phreatophytes in the Mojave Desert. Lines and Bilhorn (1996) estimated that the annual water consumption by mesquite was 1.3 afy/acre. This method used in the Mojave Desert seems to correlate well to the Mission Creek Subbasin area. Using these values an approximation of 1,400 afy is estimated as loss from the Mission Creek Subbasin due to evapotranspiration. Figure 11 presents the location of cells where evapotranspiration was estimated to occur.

5.4 Initial Conditions

Simulation of groundwater flow in Coachella Valley begins in 1936 when sufficient water level data and data needed to estimate pumpage throughout the valley were available. The year 1936 was also the starting time for the USGS model simulations in the upper valley (Tyley 1974).

A groundwater elevation contour map of the entire valley was created for 1936 and heads from this map were input as initial conditions to the model (Figure 6). These heads are based on water level measurements in wells tapping the unconfined aquifer in the upper valley, and were assigned to model layer 4.

5.5 Selection of Calibration Targets

A calibration target consists of the best estimate of a value of groundwater head. Establishment of calibration targets and acceptable residuals or residual statistics depends on the degree of fidelity (the degree to which the model application is designed to resemble the physical hydrogeologic system) proposed for a particular model application. The goal of the modeling work was to develop a model with a high degree of fidelity based on the current understanding of the physical hydrogeologic system. Correspondingly, calibration target locations were biased in areas where historical water level information was available. The following provides a brief overview of the selection of various calibration target locations for both the steady-state and transient calibration efforts.

5.5.1 Steady-State Calibration

Steady-state calibration was based on the groundwater contour map created for 1936 (Figure 6). Calibration targets were spaced evenly throughout the model with water levels based on the 1936 conceptual contours. Targets were spaced approximately 6,000 feet apart in the Mission Creek Subbasin and 3,000 feet apart in the Garnet Hill Subbasin. Modeled drawdown contours were also used during calibration to determine the difference between simulated water levels and the initial water levels generated for 1936.

5.5.2 Transient Calibration

Transient calibration targets were based on historic water level data for wells within the modeled area. This includes eighteen locations within Mission Creek Subbasin, four locations within Garnet Hill Subbasin, and nine locations in the Palm Springs subarea. In some instances, wells were located within the same model cell. In this case historical records were combined or the longest record was used to generate one target at the cell.

5.6 Stress Periods

Stress periods were developed for the model to simulate historical conditions. The model calibration period was established a 1936-2009. Table 4 presents the designated stress periods, years represented and days within each stress period.

Table 5
Summary of Stress Periods used in Transient Model Calibration

STRESS PERIOD	YEAR REPRESENTED	DAYS PER STRESS PERIOD	CUMULATIVE YEARS
1	1936-1940	1825	5
2	1941-1945	1825	10
3	1946-1948	1095	13
4	1949	365	14
5	1950	365	15
6	1951	365	16
7	1952	365	17
8	1953	365	18
9	1954	365	19
10	1955	365	20
11	1956	365	21
12	1957	365	22
13	1958	365	23
14	1959	365	24
15	1960	365	25
16	1961	365	26
17	1962	365	27
18	1963	365	28
19	1964	365	29
20	1965	365	30
21	1966	365	31
22	1967	365	32
23	1968	365	33
24	1969	365	34
25	1970	365	35
26	1971	365	36
27	1972	365	37
28	1973	365	38
29	1974	365	39
30	1975	365	40
31	1976	365	41
32	1977	365	42
33	1978	365	43
34	1979	365	44
35	1980	365	45
36	1981	365	46
37	1982	365	47
38	1983	365	48
39	1984	365	49
40	1985	365	50
41	1986	365	51
42	1987	365	52
43	1988	365	53
44	1989	365	54
45	1990	365	55
46	1991	365	56
47	1992	365	57
48	1993	365	58
49	1994	365	59
50	1995	365	60
51	1996	365	61
52	1997	365	62
53	1998	365	63
54	1999	365	64
55	2000	365	65
56	2001	365	66
57	2002	365	67
58	2003	365	68
59	2004	365	69
60	2005	365	70
61	2006	365	71
62	2007	365	72
63	2008	365	73
64	2009	365	74

SECTION
6.0 MODEL CALIBRATION AND HISTORICAL SIMULATION RESULTS

Model calibration is the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observations of the groundwater flow system. Model calibration involves developing and refining estimates of boundary condition heads and fluxes, and aquifer parameters to improve correspondence between measured data and simulated results. Successful calibration demonstrates the ability of the model (based on the current understanding of the hydrogeologic system) to simulate historic water levels and fluxes throughout the basin.

Groundwater Vistas (Environmental Simulations, Inc., 2007) for Microsoft Windows was the groundwater modeling environment used to conduct the modeling activities described in this report. The model calibration consisted of two phases: a steady-state calibration based on observations collected in 1936 when little or no pumping was occurring and a transient calibration based on observations from 1937 through 2009.

6.1 Steady State Calibration

Initially, the model was run under steady-state conditions using the estimated average inflow/outflows for each subbasin along with the initial heads developed for the 1936 period. The steady-state calibration focuses on refining estimates of hydraulic conductivity (or transmissivity) whereas the transient calibration focuses on refining estimates of storativity.

6.1.1 Revision of Conceptual Model Inflows/Outflows

Calibration often necessitates reconstruction of portions of the numerical model, resulting in changes or refinements in the initial conceptual model. Both possibilities introduce iteration into the modeling process whereby the modeler revisits previous steps to achieve a better representation of the physical system. Inflow and outflow rates, hydraulic conductivity and fault conductances were refined via model calibration. It was assumed that the mass balance estimates for inflow and outflow in the conceptual model have a higher level of confidence than the aquifer characteristics. As such, the main parameters adjusted during calibration were hydraulic conductivity and fault conductances. Magnitudes of all parameters adjusted were moderate and were consistent with available data and the conceptual model.

The parameters refined by calibration are listed in Table 4, along with prior estimates of the parameters. Prior estimates for inflows and outflows were obtained as described previously in the conceptual model section.

6.1.2 Residual Analysis

The "observations" used in the calibration procedure consist of the published map of groundwater contours in 1936 by Tyley (1974). Calibration targets were selected as described in Section 5.5, *Selection of Calibration Targets*. Initially, manual calibration was performed by manually changing the input values, and rerunning the modeling program. This provides insight to the sensitivity of the model and the direction where the emphasis is placed. Once a reasonable approximation is achieved, calibration progresses to parameter estimation using automated techniques.

Best parameter estimates were found using the PEST package for nonlinear parameter estimation (Doherty 1994). The PEST package is based on the Gauss-Marquardt-Levenberg method. The objective of the parameter estimation is to find the minimum global sum of the squares of the residuals (SSR) between the observations and the model predictions, as in:

$$SSR = \sum_{i=1}^{N} (h_i^{model} - h_i^{obs})^2$$

where N is the number of observations and h^{model} and h^{obs} are the groundwater elevations obtained from model simulations and from observations, respectively. Optimum parameter values are constrained to lie between individually specified upper and lower bounds. The uniqueness and optimality of the parameter estimates were tested by repeating the calibrations using a range of starting points for the parameter estimates.

A comparison was made between the observed versus the computed groundwater elevations for the completed steady state calibration and is depicted in Figure 12. As can be observed, the computed groundwater elevations closely matched the observed (based on 1936 groundwater contours) groundwater elevations for the model under steady-state conditions.

In addition, a statistical analysis was performed on the residual values to assess the range in values and standard deviation of the residuals. The goal is to have the standard deviation of errors divided by the range in observations less than 10 percent. Table 6 presents the statistical values for the residual generated as part of the steady-state calibration process. The value of 1 percent is considered excellent for the steady-state calibration process.

Table 6
Statistical Summary of Residuals (SSR) for Steady-State Calibration of Numerical Model

Component	Value
SSR	1,064
Standard Deviation of Errors (SDE)	6.72
Range in Observations	624
SDE/Range	.01 or 1%

6.1.3 Sensitivity Analysis

Sensitivity analysis is a quantitative method of determining the effect of parameter variation on model results. The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses, and boundary conditions. It is a means to identify the model inputs that have the most influence on model calibration and predictions.

During the steady-state calibration process, various parameters were varied to assess the model's sensitivity to the various parameters. The results indicate that the model is the most sensitive to variations in the conductance across the horizontal flow barrier boundaries used to simulate the Banning and Garnet Hill Faults. This is especially true for water levels in the Garnet Hill Subbasin which is bounded on both sides by these two faults. Model results were less sensitive to variations in hydraulic conductivity. A sensitivity analysis will be conducted during the predictive simulations to assess the sensitivity of predictive results to the variation of model parameters.

6.2 Transient Calibration

Calibration of a groundwater flow model to a single set of field measurements (steady-state calibration) does not guarantee a unique solution. In order to reduce the potential for non-uniqueness, the model calculations are compared to another set of observations that represent a different set of boundary conditions or stresses. This process is referred to as verification and represents the transient calibration process.

As previously stated, the transient calibration process uses the steady-state calibrated hydraulic conductivity values along with the initial heads and fault conductances, and then applies other sets of "stresses" that includes natural inflows from precipitation, artificial recharge and return flows as well as outflows from pumpage over the time period 1936 through 2009. The calibration targets are specific wells where periodic water level data have been collected during the same period.

The model was run in transient state and calibrated (using standard methods [ASTM D5490-93, D5981-96]) to measured water levels in the period 1936 through 2009. Data on groundwater production, groundwater levels and artificial recharge amounts, were available in this historical period. The data show significant changes in groundwater levels, both up and down, owing to major historical shifts in both pumpage and recharge. The goal was to simulate these important historical changes, thereby providing a rigorous test of the ability of the model to adequately simulate effects of future fluctuations in pumpage and recharge.

Two goals are set for the transient calibration. The first goal is to have the model values track the same general trend as the observed values. During the transient calibration process, inflow used for final calibration represented reductions from previous estimates to achieve better agreement between historical and modeled water levels. The original calibration model results (using the 10,500 afy of natural recharge value) showed a lesser degree of groundwater level decline and an increasing divergence than was observed in the observation wells, indicating that more water was staying in the basin than under actual conditions. Further calibration work resulted in refinement of the mountain front recharge (reduced to 7,500 afy) and Mission Creek Fault inflow estimate (reduced to 1,844 afy) which corrected this imbalance and resulted in very good water level calibration.

6.2.1 Residuals Analysis

The "observations" used in the calibration procedure consist of the specific wells where periodic water level data have been collected during the same period. Calibration targets were selected as described in Section 5.5, *Selection of Calibration Targets*. Initially, manual calibration was performed by manually changing the storativity values, rerunning the modeling program. This provides insight to the sensitivity of the model and the direction where the emphasis is placed. Once a reasonable approximation is achieved, calibration progresses to parameter estimation using PEST as previously described.

The model was run in transient state and calibrated, using standard methods (ASTM D5490-93, D5981-96), to measured water levels in the period 1936 through 2009. Data on groundwater production, groundwater levels and artificial recharge amounts, were available during this historical period. The data show significant changes in groundwater levels, both up and down, owing to major historical shifts in both pumpage and recharge. The goal was to simulate these important historical changes, thereby providing a rigorous test of the ability of the model to adequately simulate effects of future fluctuations in pumpage and recharge.

Two goals are set for the transient calibration. The first goal is to have the model values track the same general trend as the observed values. A comparison was made between the observed versus the computed groundwater elevations for the completed transient calibration and is depicted in Figure 13. As can be observed, the computed groundwater elevations closely matched the observed (for all stress periods: 1936-2009) groundwater elevations for the model under transient conditions. In addition, plots of observed versus computed groundwater elevations for Mission Creek and Garnet Hill subbasins, and the Palm Springs Subarea were developed and are presented in Figures 14 through 16. Only selected wells had observations that extended for the entire calibration period and one well in the Mission Creek Subbasin, 03S/04E-12B1 was observed to have a good correlation between observed versus computed and is presented in Figure 14. Garnet Hill Subbasin had significantly fewer wells and plots of observed versus computed groundwater elevations are presented in Figure 15. Garnet Hill Subbasin wells tracked similarly but with a greater residual in some stress periods versus others. As previously stated, groundwater elevations were highly sensitive to changes in flux across the fault boundaries. Given the lack of data in the Garnet Hill Subbasin, some of the greater residual errors may be associated with the uncertainty in the initial groundwater elevations in the model, the close proximity of some of the wells to the fault boundaries as well as the uncertainty in the flux that may be occurring across the fault boundaries.

The second goal is to conduct a statistical analysis of the residual values (similar to the steady-state evaluation process) and to achieve a standard deviation of errors divided by the range in observations of less than 10 percent.

Table 7 presents the statistical values for the residual generated as part of the transient calibration process. A value of 10 percent is considered good for the transient calibration process.

Table 7
Statistical Summary of Residuals for Transient Calibration of Numerical Model

Component	Value
SSR	455,430
Standard Deviation of Errors (SDE)	20.058
Range in Observations	640
SDE/Range	.03 or 3%

The SDE/Range result (3 percent) is considered good to excellent, despite the complexities inherent to the upper Coachella Valley groundwater system.

6.2.2 Sensitivity Analysis

The sensitivity analysis is a quantitative method of determining the effect of parameter variation on model results. The first step in conducting a sensitivity analysis is to identify which model inputs should be varied. The presumption is that some variables (well production, artificial recharge) are highly accurate (based on historical record keeping) while others have been estimated within reasonable bounds (natural recharge, fault conductance, transmissivity, storage coefficient, evapotranspiration). Table 8 presents a summary of the variables and whether they were considered as part of the sensitivity analysis.

Table 8
Variables Considered as Part of Sensitivity Analysis in Mission Creek and Garnet Hill Subbasins

Model Inputs	Basis of Values*	Sensitivity Analysis	Sensitivity Range	Comments
Hydraulic Conductivity	Derived from Tyley, 1974 & DWA, 2008.	Yes	½ to 2 times transient value	---
Storage Coefficient	Tyley, 1974	Yes	½ to 2 times transient value	---
Artificial Recharge	Basin Records	No	---	Model input considered to be accurate
Natural Recharge	Calculated from isohyetals	Yes	½ to 2 times transient value	---
Evapotranspiration	Tyley, 1974	Yes	½ to 2 times transient value	---
Fault Conductance	Calculated from balance of inflow	Yes	½ to 2 times transient value	---
Well Production	Basin Records	No	---	Model input considered to be accurate

Notes:
*From transient calibration model.

The purpose of the analysis was to determine the type of sensitivities that would result in changes to specific parameters and assess what affect (if any) would occur to the outcome of the model results. ASTM (2002) has developed four types of sensitivities and they are summarized in Table 9.

Table 9
Summary of Sensitivity Types

Sensitivity Type	Input Variable	Residual Statistics	Model Conclusions
Type I	When Input variable is changed and results in the following	Little or No change	Little or No change
Type II		Significant change	Little or No change
Type III		Significant change	Significant changes
Type IV		Little or No change	Significant changes

A Type IV sensitivity generally requires additional data collection to decrease the range of possible values for the input that causes the Type IV sensitivity (ASTM, 2002).

Once the variables are selected, a specified range is provided and a table is developed of the statistical values of each of the variables and are compared with the original transient calibration for each of the subbasins. Table 10 presents a summary of the sensitivity analysis. The results suggest that the Mission Creek Subbasin is sensitive (Type III) to variations in hydraulic conductivity, natural recharge, storage coefficient, and fault conductance and least sensitive (Type I) to evapotranspiration changes within the ranges tested and the locations selected for analysis. The Garnet Hill Subbasin was observed to have similar sensitivities with fault conductance (Type III) and hydraulic conductivity, storage coefficient and evapotranspiration (Type I). One input variable which had a Type IV sensitivity was natural recharge. This probably relates to the fact that the recharge in the southeastern portion of the Garnet Hill Subbasin is dependent on water passing through the fault from recharge in the Mission Creek Subbasin. Given the small size of the subbasin and the lack of historical information in the Garnet Hill Subbasin, overall impacts on water levels in the Garnet Hill Subbasin from various alternatives should be used with caution.

Table 10

Sensitivity Statistics for Selected Variables for the Mission Creek and Garnet Hill Subbasins

Subbasin	Model Inputs	Hydraulic Conductivity			Storage Coefficient			Natural Recharge			Evapotranspiration			Fault Conductance*		
		Value of Transient			Value of Transient			Value of Transient			Value of Transient			Value of Transient		
		0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2	0.5	1	2
Mission Creek	Maximum Residual	24.9	16.3	30.8	50.5	16.3	4.00	57.4	16.3	2.14	15.9	16.3	16.9	0.88	16.3	67.3
	Minimum Residual	-32.8	-30.9	-23.1	-6.4	-30.9	-54.0	-5.8	-30.9	-107.7	-31.3	-30.9	-30.2	-74.3	-30.9	4.08
	Residual Mean	2.73	-1.41	6.18	21.5	-1.41	-19.2	24.8	-1.41	-60.7	-1.81	-1.41	-0.63	-39.9	-1.41	41.9
	Standard Deviation of Residuals	7.77	5.81	9.17	12.6	5.81	8.6	14.1	5.81	23.5	5.85	5.81	5.75	10.1	5.81	11.3
	SDE/Range	7.8%	5.6%	10.5%	23.6%	5.6%	19.9%	27.0%	5.6%	61.6%	5.8%	5.6%	5.5%	39.0%	5.6%	41.1%
	Sensitivity Type**	Type III			Type III			Type III			Type I			Type III		
Garnet Hill	Maximum Residual	59.3	53.2	53	44.8	53.2	68.8	58.1	53.2	42.8	53.1	53.2	53.5	33.4	53.2	58.2
	Minimum Residual	-40.1	-48.8	-55.0	-69.0	-48.8	-47.1	-41.6	-48.8	-65.8	-48.9	-48.8	-48.6	-101.5	-48.8	-35.8
	Residual Mean	3.92	2.79	1.71	8.05	2.79	-8.32	8.75	2.79	-11.2	2.62	2.79	3.12	24.3	2.79	18.8
	Standard Deviation of Residuals	23.4	18.92	21.78	26.2	18.9	20.3	20.3	18.9	18.8	18.9	18.9	18.9	23.9	18.9	22.3
	SDE/Range	7.2%	5.8%	6.7%	8.3%	5.8%	6.7%	6.7%	5.8%	6.7%	5.8%	5.8%	5.8%	10.3%	5.8%	8.9%
	Sensitivity Type**	Type I			Type I			Type IV			Type I			Type III		

*Banning and Garnet Hill Faults Only

** As per ASTM (2002).

In addition, hydrographs were plotted for each of the variables and compared to water levels obtained during the transient calibration process and are presented in Appendix D (Figures D-1, D-2, and D-3). As expected, the predicted water levels for the altered variables fell above or below the calibrated water levels for all variables with the exception of evapotranspiration. Changes to the evapotranspiration values had only a marginal effect on water levels in the two subbasins.

The final part of the sensitivity analysis is to observe what variations might occur in the groundwater elevations if the variables where altered in the Predictive model and is discussed in Section 8.6.

SECTION
7.0 PEER REVIEW

Psomas contracted with Mr. Michael McDonald with McDonald & Morrissey to conduct the model peer review. Mr. McDonald was one of the original developers of MODFLOW while at the USGS and has been conducting peer reviews and developing groundwater models for various entities since 1990. The peer review process involved the following steps:

a. Mr. McDonald was provided copies of the Conceptual Model report, the numerical model construction, the CVWD Overview Model Report (Fogg et al, 2000), and the USGS Report (Tyley, 1974).
b. Mr. McDonald conducted a site reconnaissance of the upper Mission Creek Subbasin including the recharge basins, major faults, and recharge areas.
c. Mr. McDonald engaged in discussions on how the model was constructed and reliability/basis of the various elements of the conceptual model and how it was represented in the numerical model;
d. Mr. McDonald engaged in discussions regarding the intended end use of the model for assisting in developing management decisions regarding management of the Mission Creek and Garnet Hill subbasins.

Mr. McDonald prepared a report (see Appendix C) describing his understanding of the model and comments regarding the conceptual model and the implementation in the numerical model. Mr. McDonald's conclusions were:

1. The conceptual model report has described the system to be simulated in a manner consistent with the available observations. It relies on plausible estimates of inflows and outflows to the groundwater system.
2. The accuracy of the model can be evaluated primarily on its reliance on good estimates of the magnitude of inflows and outflows. Identifying conductive and storage parameters is of secondary value. The components of the water budget estimated by Psomas seem reasonable.
3. The [extraction] rates reported by responsible public agencies are presumably accurate. That would be especially true for pumping which is concentrated and readily observed and measured. Septic and irrigation return flows and artificial recharge are relatively concentrated and generally reported as a reasonable small proportion of supply. Mountain front recharge is estimated from precipitation records using a fairly conventional and reasonable approach however it is the reviewer's experience that this approach is likely to underestimate the magnitude of such recharge.
4. Estimates of inflow to Mission Creek Subbasin from Desert Hot Springs Subbasin and outflow from Mission Creek Subbasin to the semi-waterbearing rocks are dependent on conductivity values that can only be estimated. Those inflows and outflows could easily be in error by a factor of 2. Fortunately, they are small relative to other flows and therefore unlikely to significantly affect the overall mass budget.
5. Estimates of flows across faults are also dependent on conductivity values that are difficult to estimate but also are constrained by balancing mass. They are therefore likely to be reliable.
6. The model developed for this project should be useful in establishing the impacts from changes in recharge and discharge.

SECTION
8.0 RESULTS OF PREDICTIVE SIMULATIONS

The various alternatives selected for analysis are documented in Technical Memorandum 7: Evaluation of Management Plan Alternatives –Draft by MWH (2011). The document refers to the Planning Area that is defined in Technical Memorandum 2: Planning Area and Resources (MWH, 2010) and generally includes the areas encompassed by the Mission Creek and Garnet Hill subbasins and all land that is hydrologically tributary.

The calibrated transient groundwater model was used to test the response of the Mission Creek and Garnet Hill subbasins to various supply stresses for the period 2010 through 2045. A groundwater model is an approximation of actual conditions. The accuracy of the model results depends on the accuracy of the input data. The transient groundwater model boundary inflows from the final run of the transient model were used as the initial input for the alternative modeling effort. In addition, assumptions were made regarding future conditions including areas related to area growth and future climatic conditions. The groundwater model is useful for predicting the relative changes to conditions but should not be used to predict the exact value for a given parameter (such as groundwater level) at a given future time. The reader is directed to Section 10, *Model Assumptions and Limitations* for additional clarification on the limitations and interpretation of the results.

Groundwater modeling is performed to test the response of the Mission Creek and Garnet Hill subbasins to various supply stresses. Groundwater modeling was performed for the following scenarios:

- Groundwater Model Run No. 1: Baseline Run
- Groundwater Model Run No. 2: Stabilize Water Levels
- Groundwater Model Run No. 3: Test Basin Response to Variable Hydrology
- Groundwater Model Run No. 4: Increase Groundwater Levels

The results of the groundwater model are briefly described below:

8.1 Common Assumptions for the Groundwater Model Runs 1, 2, 3 and 4

The following common assumptions are included in the development of the overall assumptions for groundwater model runs nos. 1, 2, 3 and 4 and are explained in Technical Memorandum 7: Evaluation of Management Plan Alternatives –Draft by MWH (2011):

- High growth scenario will occur in the Planning Area (see MWH, 2010)
- 20 percent reduction in urban demand will be achieved by 2020 per SB 7X7
- New wells are included in the model to meet future demand requirements
- In MSWD's service area, all customers currently connected to the septic system will be connected to a sewer system. All future customers will be connected to the sewer system.

Each of the aforementioned Groundwater Model runs makes assumptions regarding the following components of inflow/outflow to the Mission Creek and Garnet Hill Subbasins:

- Water demand;
- Groundwater production;
- Wastewater production, wastewater treatment flows, and return flows;
- Natural inflows; and
- Artificial recharge including Whitewater River artificial recharge.

These assumptions were reported in *Technical Memorandum: Assumptions for Groundwater Model Runs* (MWH, 2012) and are summarized in Table 2. The results of the modeling using the assumptions described in Table 2 and Appendix E are as follows.

8.2 Groundwater Model Run No. 1

Groundwater Model Run No. 1 simulates the impacts of not implementing any additional water management activities in the Planning Area on the groundwater basins. Imported water supplies are available to the Planning Area under existing Table A (see http://www.water.ca.gov/swpao) conditions at assumed 50 percent reliability and allocated based on the formula specified in the 2004 Settlement Agreement. Imported water recharge is approximately 10,330 afy in 2045 for the Mission Creek Subbasin. Wastewater treated at the MSWD's proposed Regional Plant is percolated in the Garnet Hill Subbasin.

Assumptions for inflow/outflow for the Mission Creek and Garnet Hill subbasins are summarized in Tables E-1 and E-2, respectively in Appendix E. The results from this model run indicate that groundwater levels in the main portion of the Mission Creek Subbasin decline by approximately 70 feet in 2045 compared to 2010 levels and are depicted in Figure 17 and for selected wells depicted in Figure 18. This corresponds to a reduction of approximately 162,000 af in cumulative groundwater storage in 2045 (see Figure 19). Decreases in the northwest portion of the Mission Creek Subbasin are due to reduction in recharge in the Mission Creek recharge. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 50,000 af in 2045 (see Figure 20). Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 500 afy in 2045. The reduction in the outflows across the Banning Fault can be attributed to lowered groundwater levels along the Banning Fault in the Mission Creek Subbasin relative to groundwater levels on the Garnet Hill Subbasin side of the Banning Fault and increased groundwater levels in the Garnet Hill Subbasin from the Regional Wastewater Plant. Outflows across the Garnet Hill Fault to the Whitewater River Subbasin are approximately 20,000 afy in 2045 and are largely a pass-through of natural and imported water flowing in the Whitewater River.

8.3 Groundwater Model Run No. 2

The objective of this model run is to stabilize groundwater levels in the Mission Creek Subbasin (see MWH, 2011). This model run assumes that sufficient imported water is available or can be acquired to stabilize groundwater levels in the Mission Creek Subbasin. Imported water recharge is approximately 25,000 afy in 2045. Wastewater treated at MSWD's Regional Plant is percolated into the Mission Creek Subbasin. New wells are included in the model to meet future demand requirements.

Assumptions for inflow/outflow for the Mission Creek and Garnet Hill subbasins are summarized in Tables E-3 and E-4, respectively in Appendix E. The results from this model run indicate that groundwater levels in the Mission Creek Subbasin increase by as much as 10 feet in 2045 throughout the main portion of the subbasin as compared to 2010 levels and are depicted in Figure 21 and for selected wells depicted in Figure 18. This corresponds to an increase of approximately 100,000 af in cumulative groundwater storage in 2045 (see Figure 19). Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045 (see Figure 20) which equates to an increase of approximately 20 feet through much of the subbasin. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045 due the larger increases in water levels on the Garnet Hill Subbasin side as opposed to the Mission Creek Subbasin. Outflows across the Garnet Hill Fault are approximately 20,000 afy in 2045.

8.4 Groundwater Model Run No. 3

The objective of this model run is to evaluate the response of the Mission Creek and Garnet Hill subbasins under extreme hydrologies, i.e., prolonged wet and dry cycles (MWH, 2011). This run is intended to indicate a possible maximum range in groundwater levels under such conditions. The overall volume of imported water recharge for this model run is equal to the overall volume of imported water recharge for Groundwater Model Run No. 2. Groundwater Model Run No. 3 assumes annual recharge of 35,000 afy for the periods 2011-2017 and 2038-2045. There is no recharge for the period 2018-2028. Low or dry year recharge is assumed for the period 2029-2037. Wastewater treated at the Regional Plant is percolated in the Mission Creek Subbasin. New wells are included in the model to meet future demand requirements.

Assumptions for inflow/outflow for the Mission Creek and Garnet Hill subbasins are summarized in Tables E-5 and E-6, respectively in Appendix E. Cumulative groundwater storage increases up to 200,000 af between 2010 and 2018 and decreases to approximately -40,000 af between 2018 and 2038 (see Figure 19). After 2038 through to 2045, the Mission Creek Subbasin experiences an increase in storage and ends the period at an increase of 90, 000 af. The fluctuation in groundwater levels between 2018 and 2038 in the Mission Creek Subbasin is approximately 70 feet and is depicted in Figure 22 and for selected wells depicted in Figure 18. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045 (see Figure 20). Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045. An increase in groundwater levels in the Whitewater River Subbasin reduces outflows from the Garnet Hill Subbasin in this model run.

8.5 Groundwater Model Run No. 4

The objective of this model run is to evaluate the response of the Mission Creek and Garnet Hill subbasins under a “no growth” scenario and a variable hydrology similar to Groundwater Model Run No. 3 (MWH, 2011). Wastewater treated at the Regional Plant is percolated in the Mission Creek Subbasin. No new wells are included in the model to meet future demand requirements.

Assumptions for inflow/outflow for the Mission Creek and Garnet Hill subbasins are summarized in Tables E-7 and E-8, respectively in Appendix E. Cumulative groundwater storage increases up to 154,000 af between 2010 and 2015 and decreases to approximately -2,000 af between 2015 and 2045 (see Figure 19). The fluctuation in groundwater levels between 2015 and 2045 in the Mission Creek Subbasin ranges from -10 to -30 feet and is depicted in Figure 23 and for selected wells depicted in Figure 18. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 38,000 af between 2010 and 2045 (see Figure 20). Outflows across the Banning Fault reduce from approximately 4,100 afy in 2010 to 3,800 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045.

8.6 Sensitivity Analysis

The objective of this model run is to assess what changes to the predictions might occur if some of the variables identified in the model calibration process were varied in a similar manner as indicated in section 6.2.2. Groundwater Model Run No. 2 was selected for the sensitivity analysis and the five input variables identified in Section 6.2.2 were modified and hydrographs were developed for a representative well in the Mission Creek and Garnet Hill subbasins. Appendix D presents the results of the sensitivity analysis.

8.6.1 Mission Creek Subbasin

The sensitivity analysis suggested that natural recharge and hydraulic conductivity had the largest effect on water levels in the Mission Creek Subbasin (see Appendix D, Figures D-4 and D-5) with cumulative difference in water level from the Alternative No. 2 modeled water levels of as much as 40 feet over the modeled period. Storage coefficient and fault conductance had cumulative difference in water level from the Alternative No. 2 modeled water levels that varied from 10 to 20 feet over the modeled period. The sensitivity analysis for Evapotranspiration suggested that there was little or no cumulative difference in water level over the modeled period.

As previously indicated in Table 10, the variations in the hydraulic conductivity, natural recharge, storage coefficient and fault conductance variables above and below what was used in the calibrated model had Type III sensitivity (outside of calibration) and corresponding the water level variation associated with these changes in the variables is deemed not significant.

8.6.2 Garnet Hill Subbasin

The sensitivity analysis suggested that fault conductance had the largest effect on water levels in the Garnet Hill Subbasin with cumulative difference in water level from the Alternative No. 2 modeled water levels of as much as 20 feet over the modeled period. Hydraulic conductivity, natural recharge and storage coefficient had cumulative difference in water level from the Alternative No. 2 modeled water levels that varied from 5 to 10 feet. The sensitivity analysis for Evapotranspiration suggested that there was little or no cumulative difference in water levels over the modeled period.

As previously indicated in Table 10, the variations in the fault conductance variable above and below what was used in the calibrated model had Type III sensitivity (outside of calibration) and corresponding the water level variation associated with these changes in the variable is deemed not significant. The variations in natural recharge (associated with the Mission Creek Subbasin) indicated a Type IV sensitivity. This relates to the buildup of water levels in the Mission Creek Subbasin, which in turn, increases flow through the Banning Fault and into the Garnet Hill Subbasin. Overall, due the lack of historical information in the Garnet Hill Subbasin, the effects of changes to various variables is not well understood and the model should be used with caution for long term planning in the Garnet Hill Subbasin. Continued monitoring and additional data collection would assist in reducing the uncertainty regarding potential effects on the Garnet Hill Subbasin from various management strategies.

SECTION

9.0 CONCLUSIONS

Groundwater in the CVGB occurs in the alluvium, terrace deposits, and older sedimentary units that fill the valley. The CVGB is bounded on the north and east by the non-water bearing crystalline rocks of the San Bernardino and Little San Bernardino Mountains and on the west by the crystalline rocks of the Santa Rosa and San Jacinto Mountains. The northern boundary is formed by the San Gorgonio Pass. The Mecca Hills and the Salton Sea form the southern boundary. The faults that cross the valley form partial barriers to groundwater flow and interrupt the overall flow of groundwater in the valley. The two subbasins of interest in this report are the Mission Creek and Garnet Hill subbasins and are briefly described below. The Palm Springs subarea of the Whitewater River Subbasin is also discussed lies downgradient of the Garnet Hill Subbasin and groundwater levels in the subarea have an influence on flow from the Garnet Hill Subbasin.

Calibration of the groundwater flow model to a single set of field measurements (steady-state calibration) was successful. A statistical analysis was performed on the residual values to assess the range in values and standard deviation of the residuals. The goal is to have the standard deviation of errors divided by the range in observations of less than 10 percent. The resulting value of 1 percent for the steady-state calibration is considered excellent.

In order to reduce the problem of nonuniqueness, a transient calibration was performed that involved comparison another set of observations that represent a different set of boundary conditions or stresses. The transient calibration process uses the steady-state calibrated hydraulic conductivity values along with the initial heads and fault conductances, and then applies other sets of “stresses” that includes natural inflows from precipitation, artificial recharge and return flows as well as outflows from pumpage over the time period 1936 through 2009.

The model was run in transient state and calibrated, using standard methods (ASTM D5490-93, D5981-96), to measured water levels in the period 1936 through 2009. Data on groundwater production, groundwater levels and artificial recharge amounts, were available in this historical period. The data show significant changes in groundwater levels, both up and down, owing to major historical shifts in both pumpage and recharge. The goal was to simulate these important historical changes, thereby providing a rigorous test of the ability of the model to adequately simulate effects of future fluctuations in pumpage and recharge.

Two goals are set for the transient calibration. The first goal is to have the model values track the same general trend as the observed values. During the transient calibration process, inflow used for final calibration represented reductions from previous estimates to achieve better agreement between historical and modeled water levels. The original calibration model results (using the 10,500 afy of natural recharge value) showed a lesser degree of groundwater level decline and an increasing divergence than was observed in the observation wells, indicating that more water was staying in the basin than under actual conditions. Further calibration work resulted in refinement of the mountain front recharge (reduced to 7,500 afy) and Mission Creek Fault inflow estimate (reduced to 1,844 afy) which corrected this imbalance and resulted in very good water level calibration.

The second goal is to conduct a statistical analysis of the residual values (similar to the steady-state evaluation process) and to achieve a standard deviation of errors divided by the range in observations of less than 10 percent. The statistical analysis indicated a value of 3 percent and is considered excellent for the transient calibration process.

Psomas contracted with Mr. Michael McDonald with McDonald & Morrissey to conduct the model peer review. Mr. McDonald was one of the original developers of MODFLOW while at the USGS and has been conducting peer reviews and developing groundwater models for various entities since 1990. A summary of Mr. McDonald's conclusions are as follows.

> The conceptual model report has described the system to be simulated in a manner consistent with the available observations. The components of the water budget estimated by Psomas seem reasonable. The [extraction] rates reported by responsible public agencies are presumably accurate. That would be especially true for pumping which is concentrated and readily observed and measured. Septic and irrigation return flows and artificial recharge are relatively concentrated and generally reported as a reasonable small proportion of supply. Mountain front recharge is estimated from precipitation records using a fairly conventional and reasonable approach however it is the reviewer's experience that this approach is likely to underestimate the magnitude of such recharge. The model developed for this project should be useful in establishing the impacts from changes in recharge and discharge.

The calibrated groundwater model was used to test the response of the Mission Creek and Garnet Hill subbasins to various supply stresses for the period 2010 through 2045. Groundwater modeling was performed for the following scenarios:

- Groundwater Model Run No. 1: Baseline Run
- Groundwater Model Run No. 2: Stabilize Water Levels
- Groundwater Model Run No. 3: Variable Hydrology
- Groundwater Model Run No. 4: Increase Groundwater Levels

Each of the aforementioned Groundwater Model runs makes assumptions regarding the following components of inflow/outflow to the Mission Creek and Garnet Hill Subbasins:

- Water demand;
- Groundwater production;
- Wastewater production, wastewater treatment flows, and return flows;
- Natural inflows; and
- Artificial recharge including Whitewater River artificial recharge.

These assumptions were reported in *Technical Memorandum: Assumptions for Groundwater Model Runs* (MWH, 2012) and are summarized in Table 2. The results of the modeling using the assumptions described in Table 2 and Appendix D are as follows.

For Groundwater Model Run No. 1 (Baseline Run), results indicate that groundwater levels in the main portion of the Mission Creek Subbasin decline by approximately 70 feet in 2045 compared to 2010. This corresponds to a reduction of approximately 162,000 af in cumulative groundwater storage in 2045. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 50,000 af in 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 500 afy in 2045. The reduction in the outflows across the Banning Fault can be attributed to lowered groundwater levels along the Banning Fault in the Mission Creek Subbasin relative to groundwater levels on the Garnet Hill Subbasin side of the Banning Fault. Outflows across the Garnet Hill Fault to the Whitewater

River Subbasin are approximately 20,000 afy in 2045 and are largely a pass-through of natural and imported water flowing in the Whitewater River.

For Groundwater Model Run No. 2 (Stabilize Groundwater Levels), the results indicate that groundwater levels in the Mission Creek Subbasin increase by approximately 10 feet in 2045 compared to 2010 levels. This corresponds to an increase of approximately 100,000 af in cumulative groundwater storage in 2045. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045. Outflows across the Garnet Hill Fault are approximately 20,000 afy in 2045.

For Groundwater Model Run No. 3 (Variable Hydrology), the cumulative groundwater storage increases up to 200,000 af between 2010 and 2018 and decreases to approximately 40,000 af between 2018 and 2038. The fluctuation in groundwater levels between 2018 and 2038 in the Mission Creek Subbasin is approximately 70 feet. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 45,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,000 afy in 2010 to 3,000 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045. An increase in groundwater levels in the Whitewater River Subbasin reduces outflows from the Garnet Hill Subbasin in this model run.

For Groundwater Model Run No. 4 (Increase Water Levels), the cumulative groundwater storage increases up to 154,000 af between 2010 and 2015 and decreases to approximately -2,000 af between 2015 and 2045. The fluctuation in groundwater levels between 2015 and 2045 in the Mission Creek Subbasin is approximately -30 feet. Cumulative groundwater storage in the Garnet Hill Subbasin increases by approximately 38,000 af between 2010 and 2045. Outflows across the Banning Fault reduce from approximately 4,100 afy in 2010 to 3,800 afy in 2045. Outflows across the Garnet Hill Fault are approximately 15,000 afy in 2045.

The following observations and conclusions can be drawn based on the results of the groundwater modeling:

- It is observed that recharge water accumulates near the recharge facility causing mounding in that area. The cause of this accumulation could be a change in the geologic structure of the basin caused by faulting or changes in bedrock depth, or simply by hydrogeologic constraints as defined in the model such as insufficient transmissivity to convey the water away from the recharge site in the time period analyzed. Additional monitoring near the Mission Creek recharge facility is required to validate this observation.
- As groundwater levels in the upgradient groundwater basin increase as a result of increased storage and downgradient subbasins groundwater levels remain unchanged or decreased, outflows to downgradient basins will increase. The relationship between basin storage and outflow is not linear due to the accumulation of water near the recharge areas.
- Variability in imported water deliveries from one year to the next will have an impact on groundwater storage and water level fluctuations. In addition, it is difficult to predict future hydrologic regimes both locally (for natural recharge) and remotely (for Colorado River derived artificial recharge) due to long term climatic change. Consequently and given subbasin prevailing conditions at any given time, it may be more judicious to recharge when artificial recharge water is available than to anticipate that it will always be available.
- Percolation of wastewater from the proposed Regional Plant in the Garnet Hill Subbasin would have an impact on groundwater levels in that basin at the proposed location and anticipated recharge amounts.

SECTION
10.0 MODEL ASSUMPTIONS AND LIMITATIONS

The modeling was completed in accordance with the following technical methodology and assumptions:

- No subsurface soil or groundwater investigations were performed as part of this scope of services. Accordingly, Psomas' interpretations and recommendations are based solely on our analyses of available data from previous investigations and reports.

- The aquifer formation is composed of porous media, with groundwater flow obeying Darcy's law.

- MSWD, CVWD, and DWA provided information on production wells and annual production from various wells throughout the subbasins as part of this study. The information was not checked for accuracy.

- CVWD supplied artificial recharge values for the Mission Creek and Whitewater River recharge areas;

- MWH supplied information on return flows, location of return flow components as well as recharge rates of artificial recharge and return flows.

Model Limitations

- A groundwater model is an approximation of actual conditions. The accuracy of the model results depends on the accuracy of the input data. The groundwater model grid used for this study was based upon the existing grid system developed by Fogg et al (2000). The input data used in the numerical model was based upon available historical and site specific hydrological data to determine groundwater flow direction, contributing recharge areas to the upper Coachella Valley groundwater system, and spreading basin water deliveries. A correct interpretation of the model results should consider the following:

    - Model parameters such as hydraulic conductivity are applied uniformly to a model cell. The assumption of homogeneity may cause inaccuracies because field conditions, geologic formations, and climatic conditions are typically heterogeneous.
    - The groundwater model was discretized using a grid with cells measuring 1,000 feet by 1,000 feet. Model results are evaluated on a regional basin scale and should not be used for detailed analyses such as simulating water level drawdown near a single well.
    - Well pumping rates used in the groundwater model were average annual rates for municipal and private wells.
    - The groundwater model is useful for predicting the relative changes to conditions but should not be used to predict the exact value for a given parameter (such as groundwater level) at a given time.

SECTION

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FIGURES

Appendix A
Technical Memorandum Upper Coachella Valley Historical Pumping Estimates

TECHNICAL MEMORANDUM

DRAFT

TO: PATTI REYES

FROM: GERALD O'NEILL, PG, CHG

SUBJECT: UPPER COACHELLA VALLEY HISTORICAL GROUNDWATER PUMPING ESTIMATES

DATE: 11/19/2010

CC: DAVE RINGEL, MICHAEL DONOVAN

This memo documents the sources of data used in developing the historical groundwater pumping estimates for calibrating the upper valley portion of the CVWD groundwater flow model (Fogg et al. 2000). In preparing this memo, the historical files were reviewed, and the various data that were used to develop the pumping estimates were characterized according to the source of the data.

Much effort went into developing the pumping database for the model calibration. Data were gathered from all available sources (e.g., CVWD, USGS, SWRCB, DWA) and compiled in a database program. The data were plotted and checked against other data where overlapping data were available. An initial set of estimates was prepared for the model calibration; later, the calibration process suggested that improved estimates over the initial set were needed, and then additional effort was spent on developing more realistic pumping estimates for time periods where data were scarce or uncertain, e.g., 1968-83. After filtering out duplicates and uncertain data, and developing best estimates based upon available information, interpolation was used to estimate missing data. Interpolation was performed only between data deemed reliable. The improved estimates yielded a significantly improved calibration.

A summary of the results of these efforts is presented below in table and chart format. Only the final data used in the model calibration database are presented. Note that while some data are indicated as being sourced from USGS, e.g., (Tyley, 1974), that does not necessarily mean the data can be found in the referenced publication. For example, USGS studies typically reported NET groundwater pumping (pumping less return), while here the estimated pumping is presented without subtracting return flows. Also, the historical pumping used in the USGS models had to be reconstructed from raw data in the USGS files, as the data were unavailable in digital format. Because the pumping occurred over a large area where development at different locations took place at different rates and at different times, any missing pumping data were estimated by interpolating between "known" data at specific wells, to account for the different location, place and time issues.

The following table shows the resulting historical municipal and domestic use groundwater pumping estimates for the upper Coachella Valley. The data are characterized by agency, either CVWD or DWA, and the source of the data is listed next to the data. Where CVWD or DWA are reported as the source of the data, the data were obtained from agency engineering reports or provided directly by CVWD staff. "Interpolated" means that a linear trend was applied to estimate the missing or incomplete values at the in-between times.

The following figure shows a chart of the data from the table. The different symbol patterns shown in the legend depict the pumping estimates from different sources. Historical pumping estimates for DWA and CVWD are plotted separately; the total is also plotted.

Table 1. Historical Groundwater Pumping (acre-ft) in Upper Coachella Valley

Year	CVWD Pumping	Source of Data	DWA Pumping	Source of Data	Total Upper Valley Pumping
1936	8301.99	USGS (Tyley, 1974)	19.56	USGS (Tyley, 1974)	8321.55
1937	8672.13	USGS (Tyley, 1974)	19.34	USGS (Tyley, 1974)	8691.47
1938	8931.78	USGS (Tyley, 1974)	18.88	USGS (Tyley, 1974)	8950.66
1939	9071.52	USGS (Tyley, 1974)	18.88	USGS (Tyley, 1974)	9090.40
1940	9361.24	USGS (Tyley, 1974)	19.12	USGS (Tyley, 1974)	9380.36
1941	9151.30	USGS (Tyley, 1974)	18.88	USGS (Tyley, 1974)	9170.18
1942	9526.67	USGS (Tyley, 1974)	19.78	USGS (Tyley, 1974)	9546.45
1943	9675.02	USGS (Tyley, 1974)	19.56	USGS (Tyley, 1974)	9694.58
1944	10891.14	USGS (Tyley, 1974)	20.22	USGS (Tyley, 1974)	10911.36
1945	12533.89	USGS (Tyley, 1974)	27.34	USGS (Tyley, 1974)	12561.23
1946	16049.74	USGS (Tyley, 1974)	41.56	USGS (Tyley, 1974)	16091.30
1947	19341.78	USGS (Tyley, 1974)	45.56	USGS (Tyley, 1974)	19387.34
1948	21624.21	USGS (Tyley, 1974)	258.00	USGS (Tyley, 1974)	21882.21
1949	24343.65	USGS (Tyley, 1974)	408.46	USGS (Tyley, 1974)	24752.11
1950	27643.97	USGS (Tyley, 1974)	705.42	USGS (Tyley, 1974)	28349.39
1951	29349.09	USGS (Tyley, 1974)	832.30	USGS (Tyley, 1974)	30181.39
1952	31414.98	USGS (Tyley, 1974)	547.40	USGS (Tyley, 1974)	31962.38
1953	34502.13	USGS (Tyley, 1974)	993.52	USGS (Tyley, 1974)	35495.65
1954	38772.05	USGS (Tyley, 1974)	968.52	USGS (Tyley, 1974)	39740.57
1955	44711.50	USGS (Tyley, 1974)	1133.24	USGS (Tyley, 1974)	45844.74
1956	51892.54	USGS (Tyley, 1974)	1212.98	USGS (Tyley, 1974)	53105.52
1957	54650.34	USGS (Tyley, 1974)	1400.26	USGS (Tyley, 1974)	56050.60
1958	56756.07	USGS (Tyley, 1974)	3120.88	USGS (Tyley, 1974)	59876.95
1959	61578.89	USGS (Tyley, 1974)	4124.74	USGS (Tyley, 1974)	65703.63
1960	67395.78	USGS (Tyley, 1974)	5524.22	USGS (Tyley, 1974)	72920.00
1961	72017.28	USGS (Tyley, 1974)	6718.44	USGS (Tyley, 1974)	78735.72
1962	75067.00	USGS (Tyley, 1974)	8348.39	USGS (Tyley, 1974)	83415.39
1963	75112.72	USGS (Tyley, 1974)	8415.17	USGS (Tyley, 1974)	83527.89
1964	80759.91	USGS (Tyley, 1974)	8851.63	USGS (Tyley, 1974)	89611.54
1965	79486.57	USGS (Tyley, 1974)	9584.16	USGS (Tyley, 1974)	89070.73

Year	CVWD Pumping	Source of Data	DWA Pumping	Source of Data	Total Upper Valley Pumping
1966	79400.19	USGS (Tyley, 1974)	9582.05	USGS (Tyley, 1974)	88982.24
1967	75711.26	USGS (Tyley, 1974)	9970.39	USGS (Tyley, 1974)	85681.65
1968	77283.43	interpolated	9555.37	USGS (Swain, 1978)	86838.80
1969	78855.59	interpolated	9659.25	USGS (Swain, 1978)	88514.84
1970	80427.76	interpolated	11071.19	USGS (Swain, 1978)	91498.95
1971	81999.93	interpolated	10378.81	USGS (Swain, 1978)	92378.74
1972	83572.10	interpolated	12156.10	USGS (Swain, 1978)	95728.20
1973	85144.26	interpolated	12574.14	USGS (Swain, 1978)	97718.40
1974	86716.43	interpolated	15101.20	interpolated	101817.63
1975	88288.60	interpolated	17613.26	interpolated	105901.86
1976	89860.76	interpolated	20125.32	interpolated	109986.08
1977	91432.93	interpolated	22637.38	interpolated	114070.31
1978	93005.10	interpolated	25149.44	interpolated	118154.54
1979	94577.26	interpolated	27660.50	USGS (Reichard & Meadows, 1992)	122237.76
1980	96149.43	interpolated	29284.00	USGS (Reichard & Meadows, 1992)	125433.43
1981	97721.60	interpolated	30197.50	USGS (Reichard & Meadows, 1992)	127919.10
1982	99293.77	interpolated	29835.00	USGS (Reichard & Meadows, 1992)	129128.77
1983	100865.93	interpolated	31769.00	USGS (Reichard & Meadows, 1992)	132634.93
1984	102438.10	CVWD	35373.50	USGS (Reichard & Meadows, 1992)	137811.60
1985	108475.20	CVWD	37899.50	USGS (Reichard & Meadows, 1992)	146374.70
1986	114120.20	CVWD	38777.00	USGS (Reichard & Meadows, 1992)	152897.20
1987	123904.30	CVWD	44799.92	DWA	168704.22
1988	123913.40	CVWD	47593.26	DWA	171506.66
1989	123922.50	CVWD	47125.67	DWA	171048.17
1990	135915.10	CVWD	45396.29	DWA	181311.39
1991	125389.30	CVWD	42728.42	DWA	168117.72
1992	128485.70	CVWD	42492.82	DWA	170978.52

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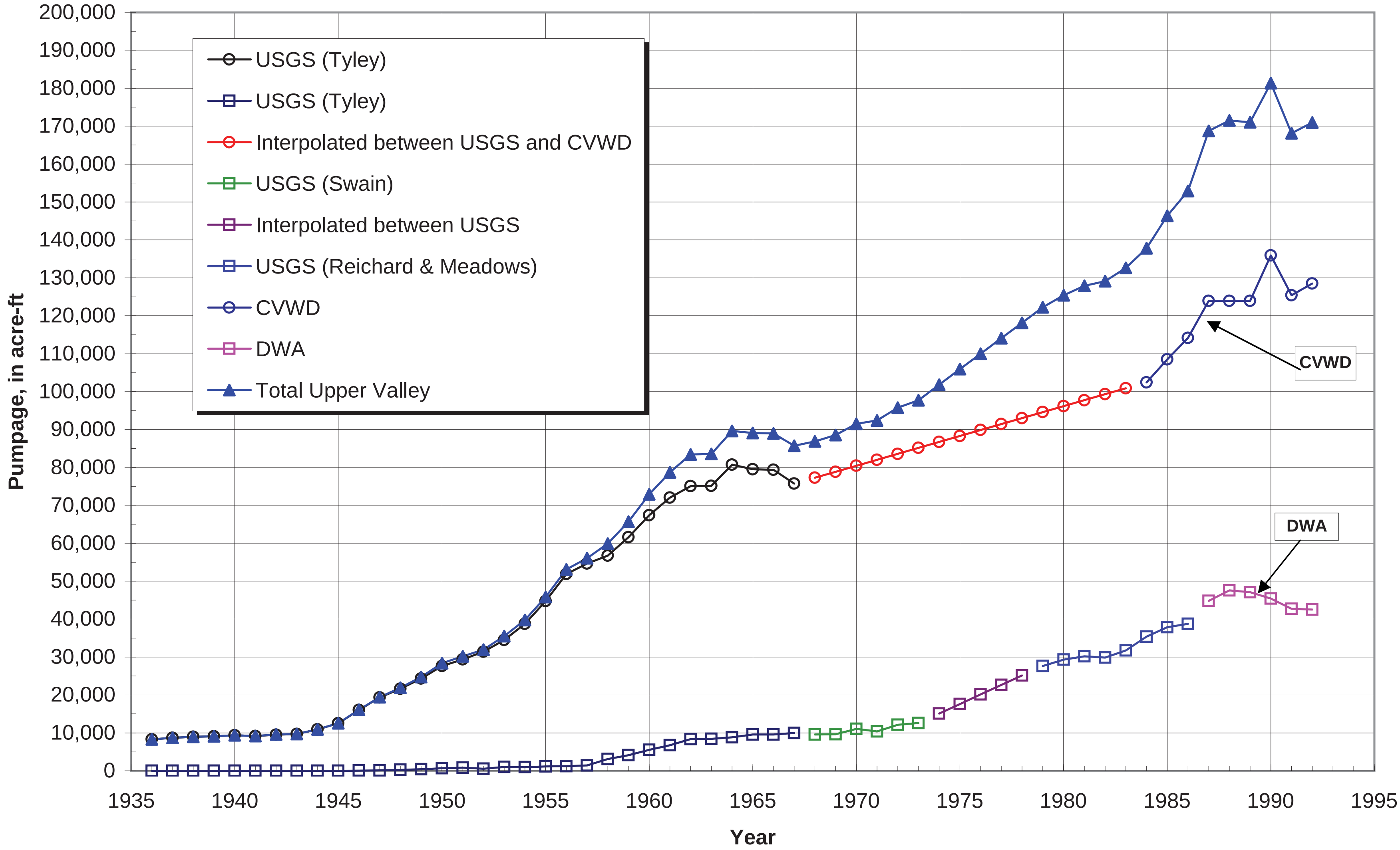
Components of Historical Upper Valley Pumpage Database



Appendix B
Estimated Pumpage from Various Production Wells in the Mission Creek and Garnet Hill Subbasins and Palm Springs Subarea of the Whitewater River Subbasins

TABLE B-1
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUBBASINS

PRODUCTION BY YEAR (acre-feet)

SUBBASIN	WELL NUMBER(S)	MODEL LOCATION (row,column)	1936-1940	1941-1945	1946-1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Garnet Hill	3S/3E-02B	6,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/3E-02C	5,37	0	0	0	16	0	240	0	0	2	0	0	0	10	0	0
	3S/3E-02P1&2	8,35	0	0	0	967	1,086	119	1,594	1,064	1,413	1,056	104	240	60	90	888
	3S/3E-11K1	11,33	0	0	133	410	250	145	1	156	120	132	258	0	0	62	0
	3S/4E-07M1	17,37	0	0	3,085	2,710	2,710	2,710	2,710	2,710	0	2,710	306	227	0	0	0
	3S/4E-13N1	44,52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-13Q1	44,51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-14J1	40,50	0	0	145	0	0	0	0	423	0	0	557	93	74	247	484
	3S/4E-17K2	27,39	0	0	0	0	0	0	0	0	9	9	9	9	8	8	9
		Total	**0**	**0**	**3,363**	**4,103**	**4,046**	**3,214**	**4,305**	**4,353**	**1,544**	**3,907**	**1,234**	**569**	**152**	**407**	**1,381**
Mission Creek	2S/4E-17K1	6,63	0	0	1,003	0	0	0	0	0	0	0	4	4	4	0	0
	2S/4E-23N1&2	21,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-25P	29,66	0	0	0	0	0	0	50	3	3	25	25	11	5	0	0
	2S/4E-26C1	24,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-26D1	23,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-35B1	28,61	0	0	0	0	0	0	0	0	0	25	25	19	0	0	0
	2S/4E-35J	30,62	0	0	0	0	0	0	0	150	3	0	25	46	28	0	0
	2S/4E-36D1	30,64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-36D2	29,64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-36K1	33,64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/5E-31P2	37,65	0	0	800	0	0	0	0	0	280	0	1	45	0	0	0
	3S/4E-11A2	35,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11B2	35,55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11L1	34,51	0	0	50	75	25	25	25	25	25	25	25	17	12	52	68
	3S/4E-11L2	35,52	0	0	150	75	75	3	75	25	75	75	75	0	0	51	83
	3S/4E-11L3	34,52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11L4	34,53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11M1	35,51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11P1	36,50	0	0	0	0	0	0	0	0	170	0	278	280	0	125	150
	3S/4E-12B1&2	39,59	0	0	0	0	0	372	0	0	0	0	0	0	0	5	238
	3S/4E-12C1	38,58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-12F1	38,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-12H1	40,57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-12H2	40,58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-08P1&2	48,61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15L1	59,65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15N1	58,62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15N3	58,63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15R1	62,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15R2	61,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-16M1	54,60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-17K1	52,59	0	0	0	0	0	0	0	0	18	0	0	232	7	74	91
	3S/5E-17M1	50,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-17N1	50,56	0	0	0	0	0	0	298	510	0	0	0	25	29	32	0
	3S/5E-18J1	48,56	0	0	0	0	0	0	0	0	0	0	0	150	0	10	0
	3S/5E-18L1	46,54	0	0	0	0	0	0	0	0	0	0	0	4	8	12	15
	3S/5E-18N	46,52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-18P	47,53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-21K1	59,58	0	0	0	0	25	25	300	25	25	25	25	27	27	0	0
		Total	**0**	**0**	**2,003**	**150**	**125**	**425**	**748**	**738**	**599**	**175**	**483**	**860**	**120**	**361**	**645**
		CVWD Reported	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SUBBASIN	WELL NUMBER(S)	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Garnet Hill	3S/3E-02B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/3E-02C	0	0	0	0	0	0	220	0	3	14	2	75	0	0	0	0	0	0	0	0
	3S/3E-02P1&2	413	35	731	3	348	645	314	637	160	763	493	35	830	686	730	529	573	0	0	578
	3S/3E-11K1	0	150	0	0	0	0	323	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-07M1	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-13N1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-13Q1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-14J1	1,581	2,012	1,198	1,014	1,311	203	0	0	0	0	0	136	0	107	0	656	698	0	0	0
	3S/4E-17K2	9	8	8	8	8	17	17	16	15	14	13	12	11	18	20	41	39	55	27	19
	Total	**2,003**	**2,365**	**1,937**	**1,025**	**1,667**	**865**	**874**	**653**	**178**	**791**	**508**	**258**	**841**	**811**	**750**	**1,226**	**1,310**	**55**	**27**	**597**
Mission Creek	2S/4E-17K1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-23N1&2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	323	225	454	413	565	293
	2S/4E-25P	44	61	19	22	26	320	0	0	5	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-26C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-26D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/4E-35B1	44	61	19	84	26	320	44	28	130	46	0	104	0	0	0	0	0	0	0	0
	2S/4E-35J	45	61	19	22	26	320	0	0	0	0	0	19	0	0	0	0	0	0	0	0
	2S/4E-36D1	0	0	0	0	0	0	0	0	0	478	1,221	1,425	1,437	1,460	971	582	918	465	627	1,119
	2S/4E-36D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	663	449	960	962	1,297
	2S/4E-36K1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2S/5E-31P2	0	267	643	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11A2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11B2	0	0	0	0	0	0	0	0	0	5	4	5	8	10	8	7	5	8	2	0
	3S/4E-11L1	45	84	357	22	26	320	67	160	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11L2	45	61	19	22	26	320	104	28	83	87	56	19	0	0	0	0	0	0	0	0
	3S/4E-11L3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11L4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-11M1	0	0	0	0	0	0	0	0	0	0	60	158	178	244	261	258	268	328	286	354
	3S/4E-11P1	108	60	0	261	25	320	66	349	0	0	0	583	0	0	0	0	0	0	0	0
	3S/4E-12B1&2	44	496	0	750	26	264	122	84	18	81	92	0	170	276	75	230	238	280	500	553
	3S/4E-12C1	0	0	0	0	0	4	259	84	593	80	92	0	171	276	75	230	238	280	250	277
	3S/4E-12F1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-12H1	45	60	0	22	26	244	66	83	87	80	92	545	170	276	75	230	239	280	250	277
	3S/4E-12H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-08P1&2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15L1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15N1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15N3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15R1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-15R2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-16M1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	4
	3S/5E-17K1	44	61	11	10	11	7	66	83	87	81	92	710	0	0	0	0	0	0	0	0
	3S/5E-17M1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/5E-17N1	365	2	12	0	11	7	11	83	87	81	93	180	0	0	0	0	0	0	0	0
	3S/5E-18J1	0	0	0	0	48	111	1,586	48	48	48	48	0	3	3	3	3	0	0	0	0
	3S/5E-18L1	400	23	23	23	24	599	72	645	423	31	27	250	27	0	12	8	12	12	0	12
	3S/5E-18N	0	0	0	36	36	36	37	35	33	30	28	26	24	22	20	17	15	13	11	9
	3S/5E-18P	0	0	0	21	23	23	29	27	26	24	22	20	19	17	15	14	12	10	9	7
	3S/5E-21K1	0	0	0	0	0	0	0	0	169	0	0	0	0	0	0	0	0	0	0	0
	Total	**1,229**	**1,297**	**1,122**	**1,295**	**360**	**3,215**	**2,529**	**1,737**	**1,788**	**1,152**	**1,927**	**4,045**	**2,207**	**2,584**	**2,096**	**2,467**	**2,848**	**3,169**	**3,461**	**4,201**
	CVWD Reported	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,253	3,565	4,021

TABLE B-1
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUBBASINS

SUBBASIN	WELL NUMBER(S)	MODEL LOCATION (row,column)	PRODUCTION BY YEAR (acre-feet) 1936-1940	1941-1945	1946-1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
	3S/3E-10N1	6,26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/3E-10P1&2	7,27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	7	9	11	13	113
	3S/3E-15C	7,26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	11	15	20	25	30	84
	3S/3E-17AorG	2,20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/3E-17K	3,18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/3E-24J1	23,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-30C1	27,28	0	0	0	0	0	0	0	0	0	66	66	129	95	65	81	81	86	98	103	113	116	131	154	151	205	175	197	180	176	173	169	165	162	283	215
	3S/4E-30D	26,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	158	178
	3S/4E-34H1&2	45,35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	429	857
	3S/4E-34R1	47,33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	138	206	275	343	411	334
	3S/4E-35J1&2	50,37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-35M1	47,34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3S/4E-35R1&2	51,36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	0	1,234	2,490
	3S/4E-36L	52,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360	502
	3S/4E-36M1	51,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	831	895	1,406	1,668	1,901	2,072	2,327	1,679	1,768	1,918	1,868	1,148	1,443	1,342	1,178	1,015	851	687	524	293	5
	3S/4E-36Q1&2	54,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,290	1,390	2,220	2,676	3,100	3,382	3,744	2,640	3,064	3,326	3,236	1,984	1,512	2,326	1,396	418	508	2,226	1,538	774	761
	4S/4E-01B1&2	55,37	0	0	0	0	0	0	0	0	0	0	0	207	1,799	1,811	1,854	1,855	1,852	1,916	2,148	1,660	1,422	1,535	1,477	1,477	1,477	1,477	1,477	1,477	1,411	1,346	1,280	1,214	1,149	1,083	1,028
	4S/4E-01N1	56,33	0	0	0	0	0	0	0	0	0	0	163	231	212	391	386	386	741	1,832	2,942	2,857	2,869	2,908	2,737	2,566	2,395	2,224	2,053	1,882	1,711	1,540	1,368	1,197	1,026	855	684
	4S/4E-02B1	51,34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640	1,280	1,919	2,558	3,198	3,837	4,202
	4S/4E-10J	53,25	0	0	24	98	217	279	116	265	234	271	343	262	289	571	698	1,041	824	481	395	428	366	448	421	395	369	342	316	290	263	237	211	184	158	132	105
	4S/4E-11K1	56,28	0	0	24	98	217	279	116	265	234	271	343	262	289	571	698	1,041	824	481	395	428	366	448	421	395	369	342	316	290	263	237	211	184	158	132	105
	4S/4E-11P	56,26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,608	2,495
	4S/4E-11Q1&2	57,27	0	0	48	196	433	557	232	530	467	543	685	523	577	1,142	1,396	2,082	1,648	962	790	856	731	896	895	1,067	972	1,521	1,636	2,028	2,124	2,221	2,318	2,414	2,511	858	266
	4S/4E-11R1	58,28	0	0	24	98	217	279	116	265	234	271	343	262	289	571	698	1,041	824	481	395	428	366	448	421	395	369	342	316	290	263	237	211	184	158	132	105
	4S/4E-13C1	61,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-13D	60,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	362	724	1,085	1,446	1,808	2,169	2,295
	4S/4E-13Q	64,26	0	0	4	24	44	40	40	40	39	39	40	78	111	271	286	187	329	565	301	370	506	482	453	425	397	368	340	312	283	255	227	198	170	142	113
	4S/4E-14Q1	60,23	0	0	94	107	125	223	64	208	264	565	1,183	1,001	868	1,168	1,124	1,224	969	902	981	811	930	933	878	823	768	713	659	604	549	494	439	384	329	274	220
	4S/4E-14R1	61,24	0	0	4	24	44	40	40	40	39	39	40	78	111	271	286	187	329	565	301	370	506	482	468	544	611	364	609	795	663	531	398	266	133	1,785	2,026
	4S/4E-23A	62,24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	536
	4S/4E-23C	60,21	0	0	94	107	125	223	64	208	264	565	1,183	1,001	868	1,168	1,124	1,224	969	902	981	811	930	933	878	823	768	713	659	604	549	494	439	384	329	274	220
	4S/4E-23D1	59,20	0	0	560	178	192	255	121	577	440	741	238	158	1,934	0	436	155	428	399	281	153	244	254	678	475	430	308	1,406	134	19	0	0	0	0	0	0
	4S/4E-23E1	60,19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-23F	61,20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	164	327	490	653	816	980	826
	4S/4E-23R	65,20	0	0	94	107	125	223	64	208	264	565	1,183	1,001	868	1,168	1,124	1,224	969	902	981	811	930	933	878	823	768	713	659	604	549	494	439	384	329	274	220
Upper Whitewater	4S/4E-24D1	63,23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	433	864	1,296	1,727	2,159	2,591	2,533
	4S/4E-24E1	64,22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-24H1	67,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-25C1	68,20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-25D1	66,19	0	0	0	0	0	0	0	0	0	98	99	98	94	95	97	86	108	109	571	1,422	1,143	1,390	1,308	1,226	1,145	1,063	981	899	818	736	654	572	491	2,669	2,716
	4S/4E-26A1	65,19	0	0	0	0	0	0	0	0	0	98	99	98	94	95	97	86	108	109	571	1,422	1,143	1,390	1,464	1,675	2,283	2,332	3,107	2,870	2,768	2,667	2,565	2,463	2,362	2,760	2,357
	4S/4E-26G1	65,17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/4E-26H	66,17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	376	751	1,126	1,501	1,876	2,251	2,342
	4S/4E-34R	67,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	12	471	449	493	520	490	459	429	398	367	337	306	275	245	214	184	153	122
	4S/4E-35A1	69,14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	832	756	715	675	675	908	783	644	840	792	789	697	632	567	503	438	373	308	340
	4S/4E-35B1&2	68,14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	232	832	756	715	675	675	908	783	644	840	792	789	697	757	816	875	935	995	1,054	997
	4S/4E-35L1	68,11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	12	471	449	493	520	499	413	463	450	555	520	565	610	655	700	745	790	792
	4S/5E-03P1	73,47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	22	33	44	55	66	77	88	99	110	121	132	143
	4S/5E-04F1	67,46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	429	923	1,874	2,085	2,113	2,145	1,508	1,289	1,281	1,272	1,264	1,255	1,247	1,238	1,230	1,221	1,213	1,204	1,196	1,187	1,179
	4S/5E-04N1	68,43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	84	127	169	211	253	295	337	380	422	464	506	548
	4S/5E-05A1	64,45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-05K1	65,42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	215	461	937	1,042	1,056	1,073	754	645	635	625	615	605	595	585	575	565	555	545	535	525	515
	4S/5E-07R1	66,34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-08A1	68,41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	119	179	239	298	358	418	477	537	596	656	716	775
	4S/5E-08D1	65,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-08L1	67,37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	15	22	29	36	44	51	58	66	73	80	87	95
	4S/5E-08R1	70,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-09A	72,44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	530	695	646	591	642	553	178	168	157	147	136	126	115	105	94	84	73	63	52	42
	4S/5E-09B2	71,43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	530	695	646	591	642	553	178	234	291	347	404	460	517	573	630	686	743	799	856	912
	4S/5E-09F1&3	71,42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	530	695	646	591	642	553	178	168	157	147	136	126	115	105	94	84	73	63	52	42
	4S/5E-09R1	74,41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-16N	75,35	0	0	0	0	0	0	0	0	0	38	38	31	12	42	55	55	61	60	62	44	126	382	360	337	315	292	270	247	225	202	180	157	135	112	90
	4S/5E-17H1	72,36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-17P1	72,32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-17Q2	73,33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4S/5E-19D1	67,27	0	0	4	24	44	40	40	40	39	39	40	78	111	271	286	187	329	565	301	370	506	482	468	544	611	364	609	795	663	531	398	266	133	5	0
	4S/5E-19E1	68,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	653	1,862
	4S/5E-30B	73,24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	147	14
	4S/5E-30C1	72,24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	160	319	366	382	206	203	328	362	349	606	529	453	376	300	223	184	207
	5S/4E-02G	72,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	12	471	449	493	520	490	459	429	398	367	337	306	275	245	214	184	153	122
		Total	0	0	975	1,061	1,782	2,439	1,014	2,647	2,518	4,210	6,085	5,495	8,620	9,670	13,491	17,885	21,605	22,317	25,439	26,967	26,387	25,020	25,049	24,951	25,562	22,996	24,934	24,452	24,453	24,490	25,614	28,365	28,711	37,464	39,729

TABLE B-1
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUBBASINS

		MODEL LOCATION	PRODUCTION BY YEAR (acre-feet)																												
SUBBASIN	WELL NUMBER(S)	(row,column)	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	TOTAL
Garnet Hill	3S/3E-02B	6,38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	516	330	0	846
	3S/3E-02C	5,37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	582
	3S/3E-02P1&2	8,35	578	575	555	0	0	570	555	538	441	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20,996
	3S/3E-11K1	11,33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,140
	3S/4E-07M1	17,37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20,038
	3S/4E-13N1	44,52	0	0	0	0	0	0	0	0	0	0	0	878	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	878
	3S/4E-13Q1	44,51	0	0	0	0	0	0	55	65	65	66	50	50	57	55	64	66	76	43	58	72	62	75	74	54	70	61	74	46	81	1,438
	3S/4E-14J1	40,50	0	0	25	0	0	0	25	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	11,047
	3S/4E-17K2	27,39	24	27	0	46	43	32	31	30	37	39	38	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	825
		Total	**602**	**602**	**580**	**46**	**43**	**602**	**666**	**633**	**553**	**105**	**88**	**969**	**57**	**55**	**64**	**66**	**76**	**43**	**58**	**72**	**62**	**75**	**74**	**54**	**70**	**61**	**590**	**376**	**129**	**58,789**
Mission Creek	2S/4E-17K1	6,63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,015
	2S/4E-23N1&2	21,66	317	236	245	301	277	836	890	1,027	1,042	380	532	383	328	447	499	445	487	405	374	409	396	416	468	761	766	777	752	90	0	16,557
	2S/4E-25P	29,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	619
	2S/4E-26C1	24,66	0	0	0	0	0	0	0	0	0	0	402	670	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	964	2,037
	2S/4E-26D1	23,66	0	0	0	0	0	0	0	0	375	551	402	670	827	872	871	975	1,045	1,233	1,302	1,210	1,260	1,368	1,324	1,507	1,548	1,705	1,345	1,326	0	21,717
	2S/4E-35B1	28,61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	975
	2S/4E-35J	30,62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	764
	2S/4E-36D1	30,64	1,219	1,090	877	1,006	1,184	792	649	679	1,233	1,038	1,473	2,145	1,421	874	933	358	403	1,304	981	1,633	1,684	1,715	1,776	1,963	2,323	2,078	1,314	929	1,080	46,853
	2S/4E-36D2	29,64	1,047	1,035	1,566	0	1,494	1,399	1,550	1,777	1,456	2,258	1,752	1,664	1,838	1,366	1,030	1,891	1,967	1,190	1,392	719	986	611	876	1,315	1,126	927	1,563	2,433	1,356	44,173
	2S/4E-36K1	33,64	0	0	0	0	0	0	0	0	0	0	0	0	274	1,411	1,432	1,397	1,260	1,125	1,338	1,575	1,256	1,664	1,824	1,950	1,983	2,134	1,796	1,429	1,775	25,623
	2S/5E-31P2	37,65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,036
	3S/4E-11A2	35,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	519	1,844	1,097	972	494	4,926
	3S/4E-11B2	35,55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62
	3S/4E-11L1	34,51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,530
	3S/4E-11L2	35,52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,632
	3S/4E-11L3	34,52	104	265	289	947	1,039	1,252	1,394	1,352	1,566	1,564	1,442	1,325	1,645	1,320	312	484	397	430	458	379	449	498	484	501	656	450	494	518	1,041	23,055
	3S/4E-11L4	34,53	0	0	0	0	0	0	0	0	0	0	0	0	0	498	1,810	1,734	1,609	1,652	1,744	1,929	1,811	1,829	1,815	2,041	1,672	1,220	1,410	1,362	1,756	25,893
	3S/4E-11M1	35,51	207	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,625
	3S/4E-11P1	36,50	0	0	0	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,862
	3S/4E-12B1&2	39,59	0	292	230	516	814	661	665	1,748	2,210	2,145	1,215	846	493	910	1,358	142	109	695	739	737	69	735	792	701	520	810	790	732	574	27,158
	3S/4E-12C1	38,58	0	1,010	1,212	1,399	1,334	1,498	0	555	396	368	1,077	1,310	910	1,796	980	539	95	349	610	321	120	436	470	731	477	324	195	311	678	22,410
	3S/4E-12F1	38,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	793	403	766	728	1,251	926	1,510	1,176	1,138	1,112	1,073	1,054	1,774	1,423	15,126
	3S/4E-12H1	40,57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,147
	3S/4E-12H2	40,58	0	0	0	0	0	0	1	0	0	0	0	32	1,124	158	527	1,363	1,497	948	927	867	1,310	715	1,013	957	848	1,028	1,080	282	880	15,556
	3S/5E-08P1&2	48,61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	50	50	50	29	231
	3S/5E-15L1	59,65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	36	0	0	0	72
	3S/5E-15N1	58,62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	13	18
	3S/5E-15N3	58,63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	38	0	0	0	77
	3S/5E-15R1	62,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	162	182	110	455
	3S/5E-15R2	61,66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10
	3S/5E-16M1	54,60	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136
	3S/5E-17K1	52,59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,685
	3S/5E-17M1	50,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	198	573	560	618	559	469	2,977
	3S/5E-17N1	50,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	591	654	522	578	574	4,910
	3S/5E-18J1	48,56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,109
	3S/5E-18L1	46,54	12	12	12	12	12	12	25	10	10	10	10	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,871
	3S/5E-18N	46,52	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	441
	3S/5E-18P	47,53	5	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	328
	3S/5E-21K1	59,58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	673
		Total	**2,918**	**3,970**	**4,446**	**4,268**	**6,153**	**6,449**	**5,174**	**7,146**	**8,287**	**8,313**	**8,305**	**9,116**	**8,860**	**9,652**	**9,753**	**10,121**	**9,272**	**10,095**	**10,594**	**11,031**	**10,267**	**11,497**	**12,017**	**13,929**	**14,839**	**15,710**	**14,244**	**13,528**	**13,228**	**325,344**
		CVWD Reported	4,299	3,932	4,421	5,655	5,707	6,437	6,717	7,136	8,296	8,302	7,778	8,375	8,861	9,676	10,102	10,562	9,899	10,291	10,974	11,838	12,350	13,968	13,768	16,697	16,315	17,751	17,007	16,270	15,156	**308,379**

TABLE B-1
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUBBASINS

SUBBASIN	WELL NUMBER(S)	MODEL LOCATION (row,column)	PRODUCTION BY YEAR (acre-feet) 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	TOTAL
	3S/3E-10N1	6,26	0	0	0	0	0	0	0	0	0	0	0	0	0	80	401	412	436	112	111	102	108	125	110	118	88	109	117	134	113	2,674
	3S/3E-10P1&2	7,27	187	79	10	10	22	44	126	168	164	135	167	146	106	14	7	7	7	46	26	40	11	218	431	126	0	0	0	0	304	2,758
	3S/3E-15C	7,26	107	107	105	107	110	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	835
	3S/3E-17AorG	2,20	0	0	0	0	0	0	85	88	73	100	96	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	751
	3S/3E-17K	3,18	0	0	0	0	0	0	33	30	37	37	38	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	216
	3S/3E-24J1	23,28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	761	1,072	1,130	864	0	0	3,826
	3S/4E-30C1	27,28	205	237	217	243	221	233	208	214	0	0	0	0	0	0	0	0	210	210	191	209	206	213	227	383	289	407	304	387	367	9,016
	3S/4E-30D	26,28	187	159	155	164	173	187	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,361
	3S/4E-34H1&2	45,35	1,089	2,509	2,179	2,701	2,754	2,311	1,730	769	857	881	0	0	0	0	0	0	881	2,482	3,248	3,274	1,735	1,863	1,476	2,844	1,702	1,240	1,491	2,022	2,804	46,130
	3S/4E-34R1	47,33	441	615	411	36	564	1,120	1,511	24	0	799	894	867	599	1,253	889	914	854	876	485	958	519	633	153	496	812	902	133	377	0	19,912
	3S/4E-35J1&2	50,37	0	0	0	0	0	0	0	0	0	0	0	5,415	8,301	6,684	5,784	5,946	7,517	7,268	6,804	5,770	4,460	6,789	5,988	4,604	3,936	5,792	6,356	3,848	2,594	103,853
	3S/4E-35M1	47,34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,367	1,637	703	221	3,928
	3S/4E-35R1&2	51,36	2,796	4,923	5,794	4,826	0	0	5,807	6,554	6,886	4,988	4,518	3,343	2,043	1,771	3,355	3,449	1,070	1,235	2,324	2,538	5,105	3,741	3,893	4,283	4,254	4,474	2,315	1,222	1,996	103,232
	3S/4E-36L	52,38	466	234	27	131	209	156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,085
	3S/4E-36M1	51,38	506	33	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	189	0	0	0	0	0	27,566
	3S/4E-36Q1&2	54,38	1,150	270	1	452	383	334	585	0	1,012	65	1	3	0	0	0	0	0	0	0	0	0	0	0	0	5,048	4,906	5,448	6,632	5,112	74,914
	4S/4E-01B1&2	55,37	889	872	1,050	1,259	1,393	1,467	1,211	1,398	1,003	798	1,125	1,171	1,096	1,091	1,079	1,079	1,011	1,063	978	1,206	933	760	763	520	648	261	282	0	0	61,839
	4S/4E-01N1	56,33	513	342	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39,182
	4S/4E-02B1	51,34	3,995	3,569	3,522	3,792	3,136	2,576	4,522	4,906	4,941	4,716	4,491	2,484	2,467	3,643	2,355	2,421	2,027	864	975	1,946	1,767	1,205	2,422	2,880	2,020	1,215	1,723	1,300	600	96,113
	4S/4E-10J	53,25	79	53	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,230
	4S/4E-11K1	56,28	79	53	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,230
	4S/4E-11P	56,26	2,788	2,382	1,708	1,350	1,224	1,198	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,753
	4S/4E-11Q1&2	57,27	311	317	1	133	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	256	145	0	262	124	13	0	0	0	37,695
	4S/4E-11R1	58,28	79	53	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,230
	4S/4E-13C1	61,28	0	0	0	0	0	0	2,099	2,202	2,264	1,882	918	1,069	512	496	793	815	1,168	784	402	417	1,022	1,369	948	1,384	997	973	811	832	1,728	25,883
	4S/4E-13D	60,28	2,512	2,347	2,469	2,188	1,980	2,488	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23,873
	4S/4E-13Q	64,26	85	57	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,648
	4S/4E-14Q1	60,23	165	110	55	1,661	944	770	738	981	705	1,856	1,315	1,464	1,505	0	0	0	1,650	1,278	850	1,437	1,930	2,215	1,452	1,523	1,649	2,416	2,306	1,829	985	54,668
	4S/4E-14R1	61,24	1,100	1,160	1,189	917	2,667	1,907	2,787	2,865	0	0	0	0	0	0	0	0	2,050	2,123	1,622	1,477	2,418	2,667	2,388	2,543	2,626	2,055	2,421	2,621	2,305	56,893
	4S/4E-23A	62,24	1,157	1,174	665	171	905	1,696	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,306
	4S/4E-23C	60,21	165	110	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,209
	4S/4E-23D1	59,20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,194
	4S/4E-23E1	60,19	0	0	0	0	0	0	541	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	541
	4S/4E-23F	61,20	183	837	1,350	1,452	1,874	1,868	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,822
	4S/4E-23R	65,20	165	110	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,209
Upper Whitewater	4S/4E-24D1	63,23	1,748	1,800	2,840	3,325	2,987	3,074	4,033	2,790	2,959	3,286	3,289	3,597	3,842	2,033	2,637	2,711	2,450	1,240	2,769	2,626	3,010	3,077	2,799	3,327	2,594	2,263	3,258	3,075	2,493	93,536
	4S/4E-24E1	64,22	0	0	0	0	0	0	123	2,551	3,848	3,300	2,944	2,760	2,430	2,254	2,121	2,181	2,914	3,580	3,712	3,783	3,296	2,828	2,636	3,367	2,369	2,409	3,239	2,633	2,643	63,921
	4S/4E-24H1	67,25	0	0	0	0	0	0	3,438	3,009	3,446	3,662	2,767	1,049	898	2,870	2,438	2,506	1,510	491	965	894	1,206	1,284	862	690	1,560	2,486	2,856	1,431	216	42,535
	4S/4E-25C1	68,20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,283	1,028	2,311
	4S/4E-25D1	66,19	2,910	2,609	2,545	2,631	2,226	1,713	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35,322
	4S/4E-26A1	65,19	2,856	2,778	3,027	2,332	2,159	2,277	2,340	0	0	0	0	0	0	0	0	0	2,970	2,311	3,200	2,881	2,965	2,891	2,568	1,990	2,078	2,218	2,058	2,330	1,796	87,110
	4S/4E-26G1	65,17	0	0	0	0	0	0	3,131	3,943	3,343	4,181	3,897	2,859	1,902	4,091	3,141	3,229	3,500	3,869	3,667	3,583	2,533	2,961	3,427	3,340	788	0	0	0	0	61,385
	4S/4E-26H	66,17	2,895	2,866	3,013	2,966	3,481	3,953	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29,397
	4S/4E-34R	67,8	92	61	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,121
	4S/4E-35A1	69,14	361	366	357	465	576	588	6	93	228	25	28	21	152	212	212	0	202	258	526	553	536	244	28	0	0	0	0	0	0	18,534
	4S/4E-35B1&2	68,14	826	825	918	916	742	611	1,189	1,019	1,079	885	945	1,028	663	996	956	956	939	871	943	685	895	972	945	1,039	952	1,035	1,057	1,008	1,042	42,705
	4S/4E-35L1	68,11	872	806	926	999	928	900	982	985	872	899	920	933	886	654	635	635	575	641	610	313	8	0	0	0	0	0	0	0	0	25,695
	4S/5E-03P1	73,47	154	165	176	187	175	194	186	201	216	253	226	211	175	187	258	299	303	330	335	219	33	18	24	58	17	9	32	50	6	5,693
	4S/5E-04F1	67,46	1,170	1,162	1,153	1,145	1,658	1,056	1,098	953	807	1,034	705	609	828	799	503	208	771	581	1,030	753	952	613	160	821	284	5	314	1,245	1,105	51,875
	4S/5E-04N1	68,43	591	633	675	717	575	958	1,248	1,639	2,030	1,295	716	2	5	3	27	19	14	523	1,603	2,053	1,908	2,215	979	2,102	2,329	2,637	2,048	1,982	2,279	37,643
	4S/5E-05A1	64,45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,411	2,908	2,631	44	6,994
	4S/5E-05K1	65,42	505	495	485	475	741	627	73	36	4,529	999	98	121	26	127	70	0	22	508	1,292	220	70	73	211	245	450	405	87	0	0	26,646
	4S/5E-07R1	66,34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,156	1,133	578	80	790	1,031	4,767
	4S/5E-08A1	68,41	835	895	954	1,014	1,159	1,065	984	1,004	1,024	978	952	860	876	909	856	564	979	907	1,083	1,077	912	921	791	871	1,135	930	991	936	944	32,833
	4S/5E-08D1	65,38	0	0	0	0	0	0	1,642	1,894	2,146	1,618	1,996	2,246	1,867	1,418	1,980	1,542	1,689	2,099	2,424	1,983	2,060	2,508	1,980	2,283	1,078	1,549	691	1,963	2,375	43,030
	4S/5E-08L1	67,37	102	109	117	124	437	228	370	369	369	990	834	883	916	942	867	919	930	908	1,261	952	1,111	958	956	877	454	819	705	476	336	19,981
	4S/5E-08R1	70,38	0	0	0	0	0	0	0	0	0	334	1,472	2,060	1,802	1,698	2,130	1,385	2,071	1,633	1,532	1,601	1,706	2,155	1,744	1,748	1,570	1,717	1,540	3,502	3,169	36,568
	4S/5E-09A	72,44	31	21	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,258
	4S/5E-09B2	71,43	969	1,025	1,082	1,138	964	565	707	848	664	405	995	884	0	0	0	0	873	1,046	1,174	1,014	1,198	1,250	778	851	1,135	1,135	1,003	998	1,086	35,073
	4S/5E-09F1&3	71,42	31	21	10	915	1,889	3,006	2,937	2,868	2,224	1,839	1,830	1,968	2,822	1,344	2,542	0	2,117	2,235	2,387	2,228	2,249	1,867	1,492	1,824	2,536	2,397	2,072	2,458	2,623	59,924
	4S/5E-09R1	74,41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	149	1,862	2,607	2,693	2,039	2,364	2,138	13,851
	4S/5E-16N	75,35	67	45	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,062
	4S/5E-17H1	72,36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,267	1,381	1,102	1,383	1,334	1,058	1,154	1,124	1,090	1,513	1,271	13,676
	4S/5E-17P1	72,32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,842	4,197	4,064	3,293	3,685	3,542	3,248	2,370	2,499	1,971	2,681	1,401	34,793
	4S/5E-17Q2	73,33	0	0	0	0	0	0	109	2,154	3,438	4,002	3,077	1,303	2,106	2,379	3,778	3,884	1,524	2,975	2,285	1,817	2,996	2,414	3,083	3,453	2,269	1,786	3,363	2,057	1,952	58,205
	4S/5E-19D1	67,27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,180
	4S/5E-19E1	68,25	2,959	3,634	3,768	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,879
	4S/5E-30B	73,24	22	100	180	206	209	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	879
	4S/5E-30C1	72,24	196	213	196	195	182	196	156	156	0	0	0	0	0	0	0	0	216	180	217	197	192	190	177	149	154	135	128	157	132	9,295
	5S/4E-02G	72,8	92	61	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,121
		Total	**41,686**	**43,399**	**43,814**	**41,345**	**39,648**	**39,474**	**46,733**	**46,712**	**51,166**	**46,242**	**41,255**	**39,704**	**38,823**	**37,947**	**39,814**	**36,080**	**45,448**	**47,370**	**56,493**	**54,251**	**54,699**	**56,463**	**50,915**	**59,273**	**56,279**	**59,496**	**59,736**	**59,470**	**50,240**	**1,966,374**

Appendix C
Review of Psomas Ground Water Modeling Project of Mission Creek and Garnet Hill Subbasins of the Coachella Basin

Review of PSOMAS Ground Water Modeling Project of Mission Creek and Garnet Hill Sub-basins of the Coachella Basin

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November 18, 2010

Introduction

This document constitutes the review of the ground-water modeling effort being conducted by PSOMAS for the Desert Water Agency, Coachella Valley Water District and the Mission Springs Water District. The model is being developed to evaluate recharge and discharge that the agencies are considering as part of a Water Management Plan. Although the focus of the model is the interrelated ground-water systems underlying the Mission Creek and Garnet Hill Sub-basins of the Coachella Valley it also covers part of the Whitewater Sub-basin.

This review consisted of 1) --- preliminary reading of an interim version of a description of the conceptual model prepared by PSOMAS and model report of the Coachella Valley by Fogg et al (2000) for background, 2) --- meetings with PSOMAS personnel engaged in the project 3) --- a daylong tour of the sub-basins and 4) --- review of all documents and preparation of this report.

The Ground Water System of the Project Area

The Coachella Valley, extends in a northwest/southeast direction from Cabazon, California to the Salton Sea is surrounded on three sides by mountains and is drained by the Whitewater River. For the sake of this review a local North will be defined with a bearing of 45 degrees east of true north.

The groundwater system of the Coachella Valley is contained, primarily, in poorly consolidated and unconsolidated valley sediments. The sediments, as much as 2400 feet are underlain by consolidated rocks which have limited hydraulic conductivity. The natural source of water to the ground is from precipitation that flows off the surrounding mountains. There are in, addition, flows from artificial sources such as return flow from irrigation and sewers. There is little or no recharge from precipitation directly on to the basin floor. The major aquifer in the basin is a confined aquifer that occupies the lower half of the basin. Unconsolidated deposits in the upper end of the basin contain a significant amount of water; it is those sediments that form the groundwater system that is the subject of this project.

A conceptual model report prepared by PSOMAS as part of this project contains a detailed listing of flows into and out of each Sub-basin. It also contains estimates of the magnitudes of each flow. The estimates are drawn from previous investigations and in some cases from independent analyses by PSOMAS. This description relies on those estimates.

The Coachella Basin is viewed as consisting of 5 sub-basins: the Whitewater River Sub-basin, the Garnet Hill Sub-basin, the Mission Creek Sub-basin, the Desert Hot Springs Sub-basin and the San Gorgornio Sub-basin. The two sub-basins that are the focus of this project are underlain by the unconsolidated, unconfined aquifer. They are represented in the model along with a portion of the Whitewater Sub-basin that is also underlain only by the unconsolidated, unconfined aquifer.

The Mission Creek Sub-basin is bounded by 2 faults: on the north by the Mission Creek Fault which separates it from the mountain front and the Desert Hot Springs Sub-basin and on the south by the Banning Fault which separates it from the Garnet Hill Sub-basin. Both faults appear to inhibit the flow of groundwater. A portion of the north boundary separates the Mission Creek Sub-basin from the mountain front the other portion separates it from the Desert Hot Springs Sun-basin.

The predevelopment inflows of water into the Mission Creek Sub-basin are flow from the mountain front --- about 10,000 af/y and flow across the Mission Creek fault from the Desert Hot Springs Sub-basin --- about 2,000 af/y. Predevelopment flows out of the Mission Creek Sub-basin are: across the Banning Fault into the Garnet Hill Sub-basin --- about 7,500 af/y, southeast into what are known as the semipermeable rocks --- about 3,500 af/y and evapotranspiration by phreatophytes --- about 1,500 af/y. Since development water pumped by production wells has become the major outflow of water --- about 15,000 af/y. It is somewhat offset by return flow and infiltration of water imported into the basin --- about 4,000 af/y. The imbalance between inflows and outflows under development conditions is expected to have come from a combination of reduced flow out to the Garnet Hill Sub-basin and the impermeable rocks and reduction of water in storage in the aquifer.

The Garnet Hill Sub-basin is also bounded by 2 faults: it is bounded on the north by the Banning fault which separates it from the Mission Creek Sub-basin and the mountain front and it is bounded on the south by the Garnet Hill Fault which separates it from the Whitewater Sub-basin. Predevelopment inflow to the Garnet Hill Sub-basin is flow from the mountain front --- about 17,500 af/y and flow across the

Banning Fault from the Mission Creek Sub-basin --- about 7,500 af/y. Outflows were across the Garnet Fault into the Whitewater Sub-basin --- about 25,000 af/y. There has little development of water resources in the Garnet Hill Sub-basin so current inflows and outflows are similar to those in predevelopment times. An exception is expected to be inflow from Mission Creek Sub-basin where pumping has, presumably intercepted water that would otherwise have flowed into the Garnet Hill Sub-basin.

The Model

The subject model covers a portion of the Coachella Basin containing the Mission Creek and Garnet Hill Sub-basins and part of the Whitewater Basin. Part of that area ---the Garnet Hill Basin --- was covered by the basin-wide model by Fogg et al (2000). At the request of the agencies the grid used by Fogg et al. (2000) is being used for the subject model. Only the 75 most upgradient of the 270 rows of the grid, however, are used to actively simulate the system in the subject model. The balance of the rows are inactive. Model cells that had been inactive in the Fogg et al (2000) model are activated in this model to represent the Mission Creek Sub-basin. The saturated materials are represented as 4 layers with identical hydraulic conductivity distributions.

The report

A conceptual model report has been prepared that describes the boundaries, aquifer material, and sources and sinks for water. It is intended to be an appendix of the model report. The rough estimates of flows into basins given above were based on estimates specified in the conceptual model report.

Those estimates cites model reports by Fogg et al (2000) and Tyley (1974).

The PSOMAS model report is reported to be well under way but is not ready to be considered in this review

Comments

1) The conceptual model is the first aspect of the project to be documented. This is good practice in that it serves as a basis for building the numerical model. The conceptual model report seems to be complete. It could, however, be made more useful if it had a discussion and illustration showing the relationship between this model and the Fogg et al (2000) and Tyley (1974) models using consistent naming conventions for the geologic formations.

2) An abbreviated version of the conceptual model report with several illustrations should be included in the body of the Numerical model report.

3) The conceptual model report should include a table showing the mass balance of the Fogg et al (2000) and Tyley (1974) studies to give the reader a feel for the relation between the local and regional systems.

4) The approach taken by PSOMAS in constructing the model has been to simulate steady conditions similar to those prevailing in 1936 then simulating the transient conditions that prevailed between 1936 and 2009 as a response to pumping. Calibration will consist of: 1) --- referencing other projects in the area to identify reliable estimates of all flows into and out of the area being modeled and the hydraulic parameters of the aquifer material, then 2) --- modifying hydraulic parameters in an attempt to match calculated and observed water levels then if a suitable match can not be

made 3) --- modifying estimates of inflows and outflows to achieve a match. This approach accommodates the recognition that the estimates of inflows and outflows are, on the whole, more likely to be accurate than the estimates of hydraulic parameters.

5) It should be noted that there is no way to actually measure most of the flows into or out of the system or any of the hydraulic parameters of the aquifer material. It is possible, however, to estimate flows by analysis of external systems or reference to work done by others. Similarly estimates of hydraulic parameters can be estimated by aquifer tests, reference to other studies and observation of grain size and sorting. An exception to that generalization is discharge to production wells which I understand is relatively accurate.

6) It should also be noted that calibration by matching calculated to observed water levels can help to ensure that hydraulic parameters are consistent with flows but it can not determine if one or the other is accurate.

7) In light of the above an effort should be made to collect field observations that will help improve estimates of flow.

8) To estimate recharge to the aquifer from the mountain front PSOMAS has used an approach developed by Maxey and Eakin of the USGS. The approach is widely used throughout the Great Basin Province. This reviewer's experience suggests that it underestimates recharge by about 30%. Some time in the future there should be an effort made to find data that may either justify the Maxey Eakin numbers or support revising them.

9) In the transient model it is probably safe to represent mountain front recharge with an estimate of long term

average. Alternatively annual values of mountain front recharge could be approximated with estimates that vary about the long term mean but as a function of observed precipitation at one or two representative stations.

10) Reliance on Tyley (1974) should be treated carefully. If time permits Tyley's basis for calculated flows should be checked. If it relies on aquifer or fault conductive term be sure that such terms reported by Tyley are consistent with those presented in this model.

Conclusions

This model development project is well under way. The conceptual model report has described the system to be simulated in a manner consistent with the available observations. It relies on plausible estimates of inflows and outflows to the groundwater system.

Since the model is to be used to estimate water availability magnitude of inflows and outflows are crucial. Magnitude of hydraulic parameters would be expected to just affect timing of impacts.

The accuracy of this model can be evaluated primarily on its reliance on good estimates of the magnitude of inflows and outflows. Identifying conductive and storage parameters is of secondary value. The components of the water budget estimated by PSOMAS seem reasonable.

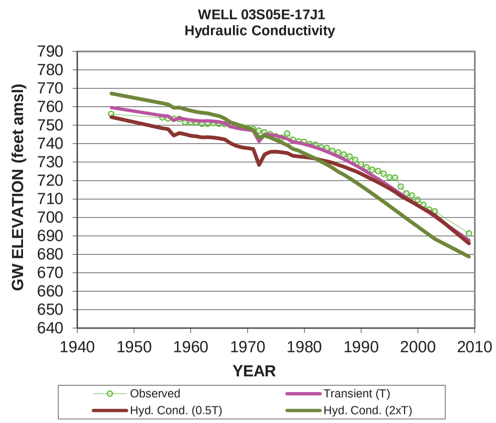
The rates reported by responsible public agencies are, presumably quite accurate. That would be especially true for pumping which is concentrated and readily observed and measured. Septic and irrigation return flows and artificial recharge are relatively concentrated and generally reported as a reasonable small proportion of supply. Mountain front recharge is estimated from precipitation records using a fairly conventional and reasonable approach however it is the reviewers experience that this approach is likely to underestimate the magnitude of such recharge.

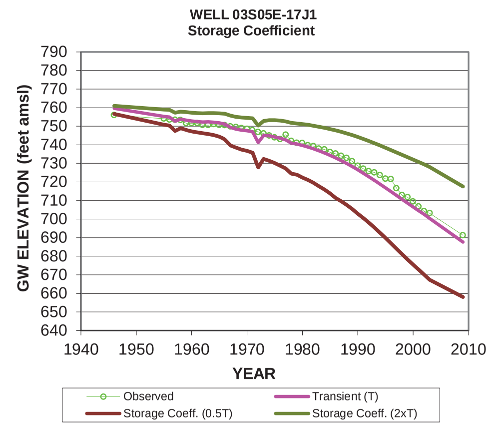
Estimates of inflow to Mission Creek Sub-basin from Desert Hot Springs Sub-basin and outflow from Mission Creek Sub-basin to the Semi-water-bearing rocks are dependent on conductivity values that can only be estimated. Those inflows and outflows could easily be in error by a factor of 2. Fortunately they are small relative to other flows and therefore unlikely to significantly affect the overall mass budget.

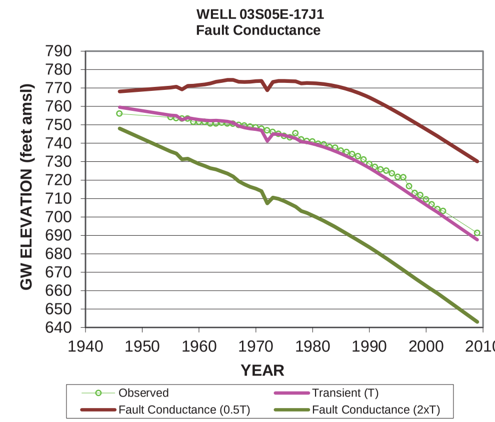
Estimates of flows across faults are also dependent on conductivity values that are difficult to estimate but also are constrained by balancing mass. They are therefore likely to be reliable.

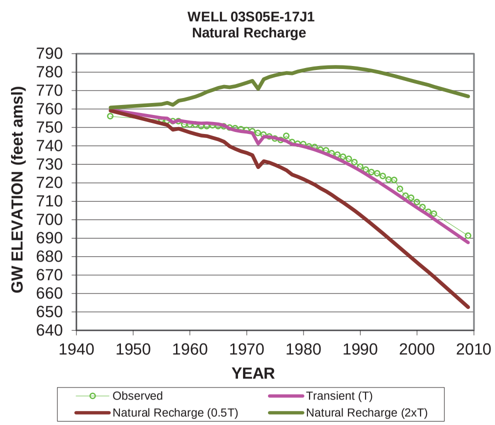
The model developed for this project should be useful in establishing the impacts from changes in recharge and discharge.

Appendix D
Sensitivity Graphs









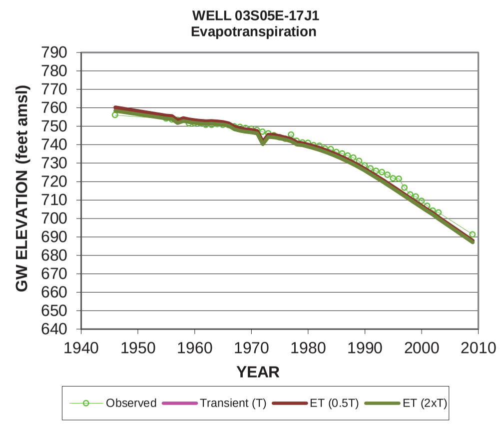


FIGURE D-1
Transient Model Sensitivity Hydrographs of Well 03S05E-17J in Mission Creek Subbasin

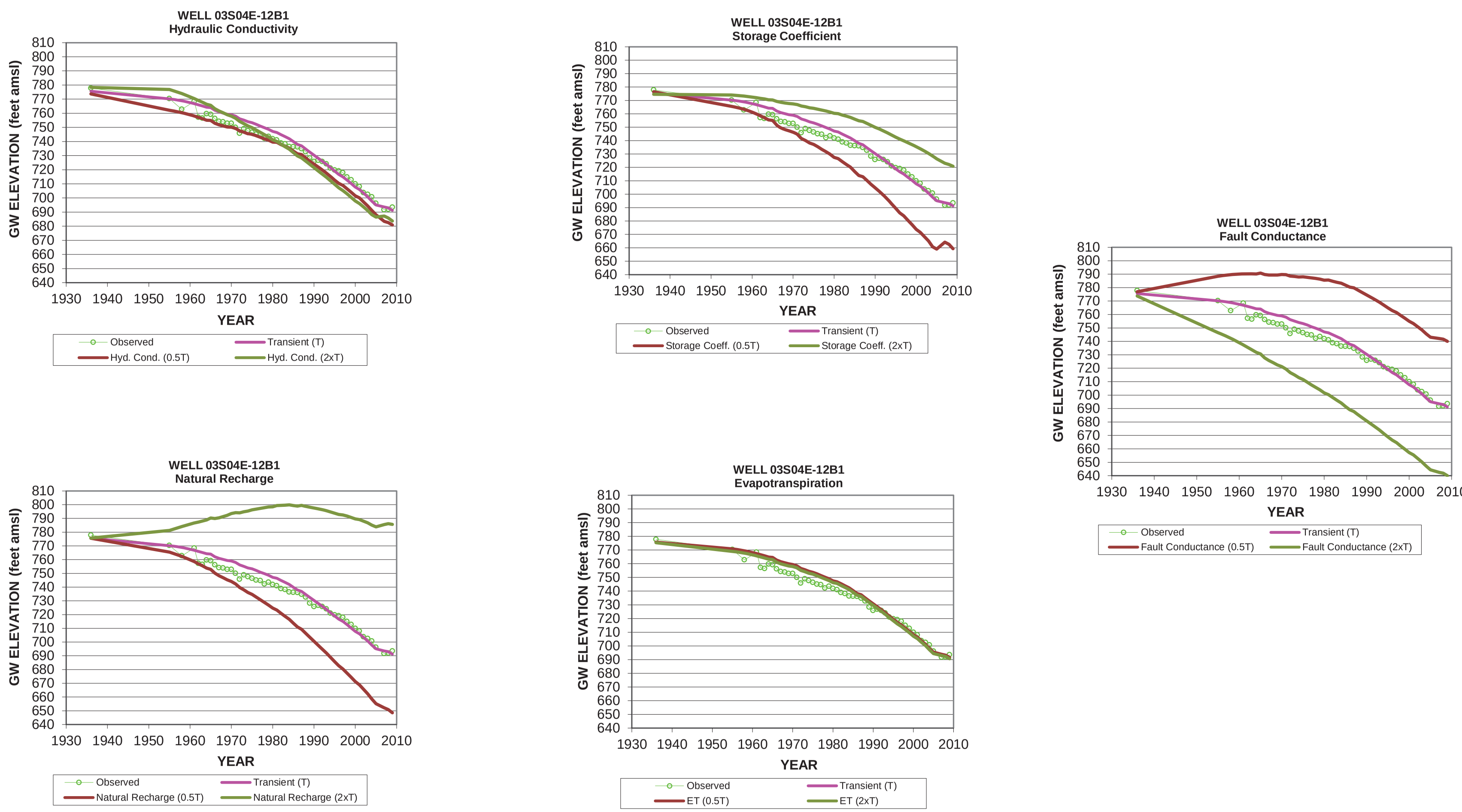


FIGURE D-2
Transient Model Sensitivity Hydrographs of Well 03S04E-12B1 in Mission Creek Subbasin

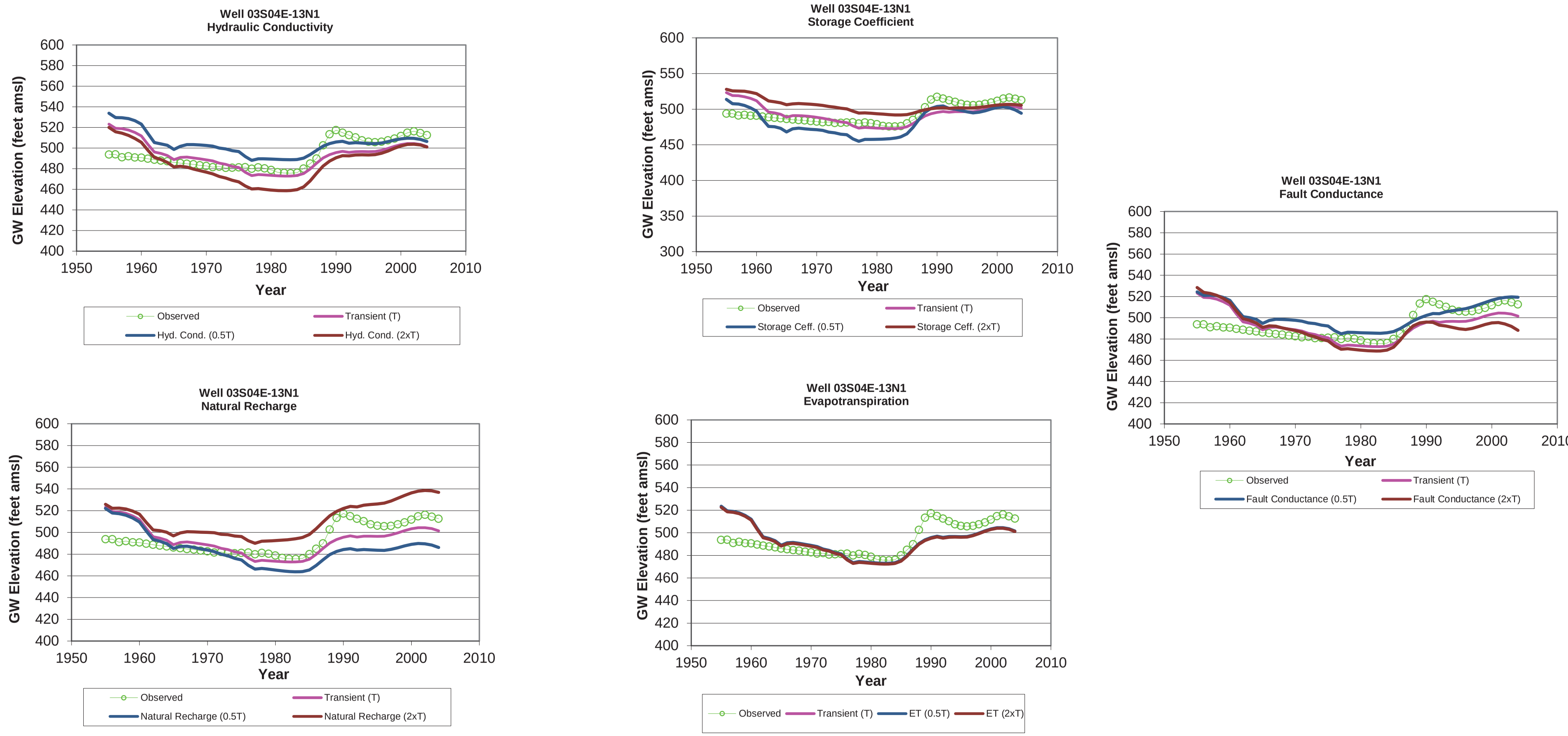
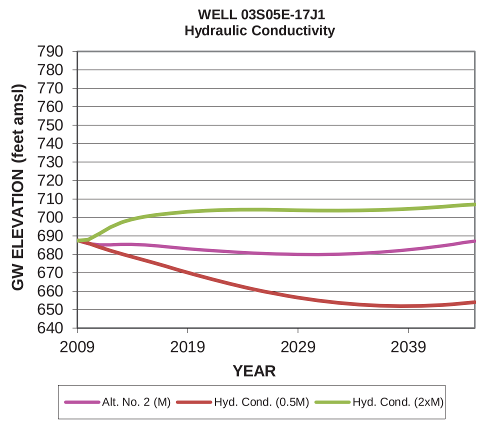
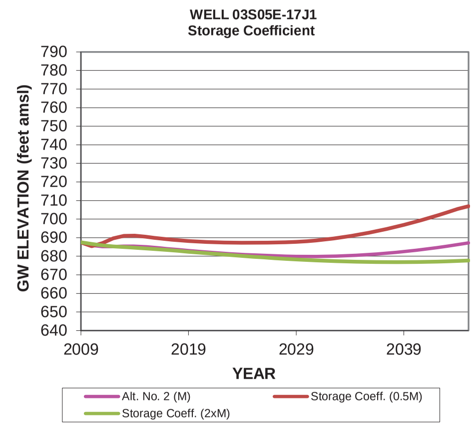
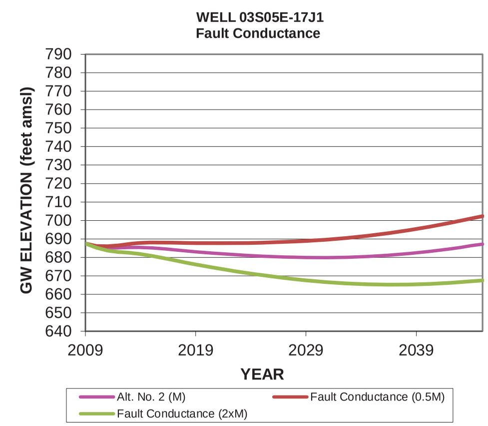
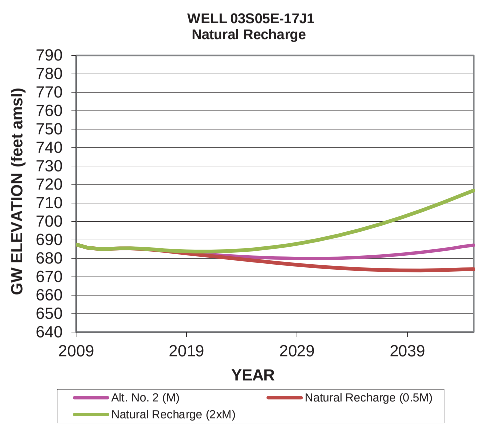


FIGURE D-3
Transient Model Sensitivity Hydrographs of Well 03S04E-13N1 in Garnet Hill Subbasin









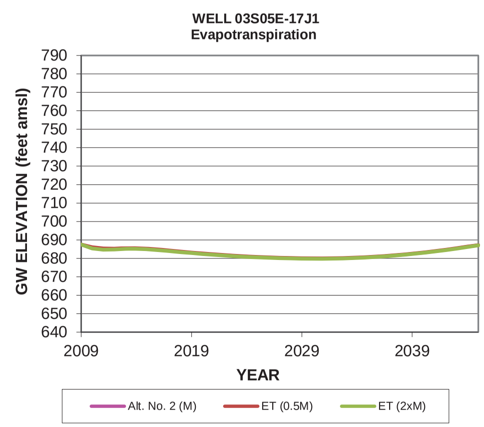
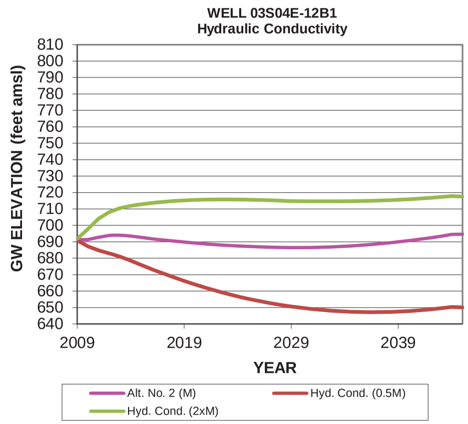
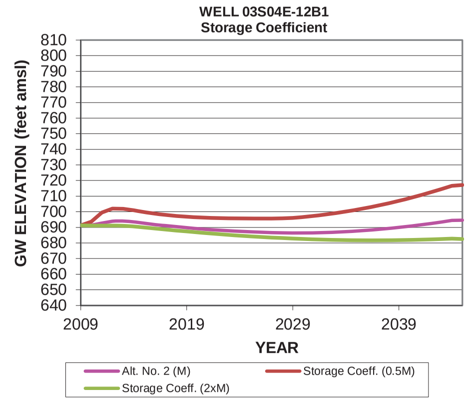
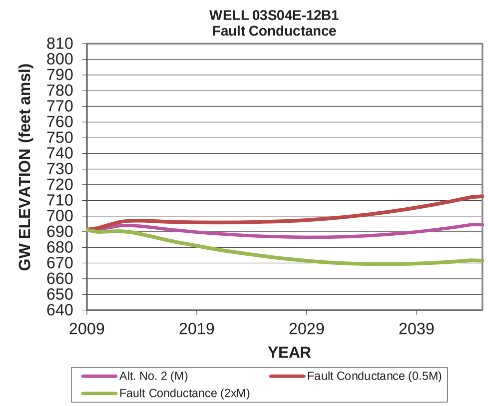
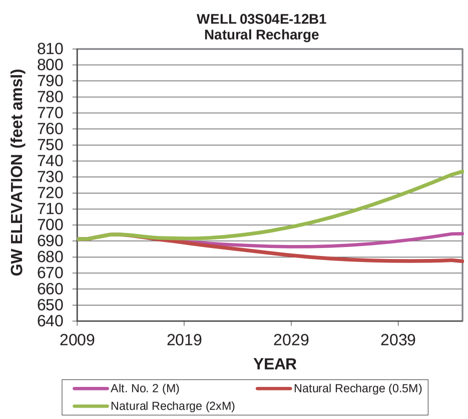


FIGURE D-4
Alternative No. 2 Sensitivity Hydrographs of Well 03S05E-17J in Mission Creek Subbasin









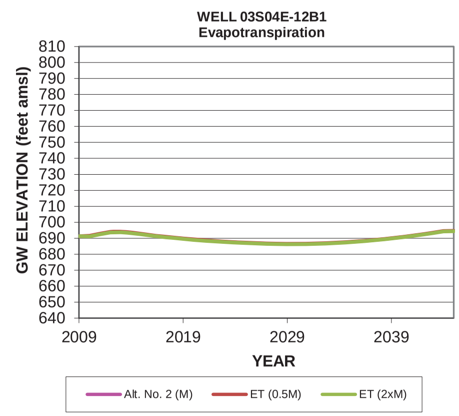


FIGURE D-5
Alternative No. 2 Sensitivity Hydrographs of Well 03S04E-12B1 in Mission Creek Subbasin

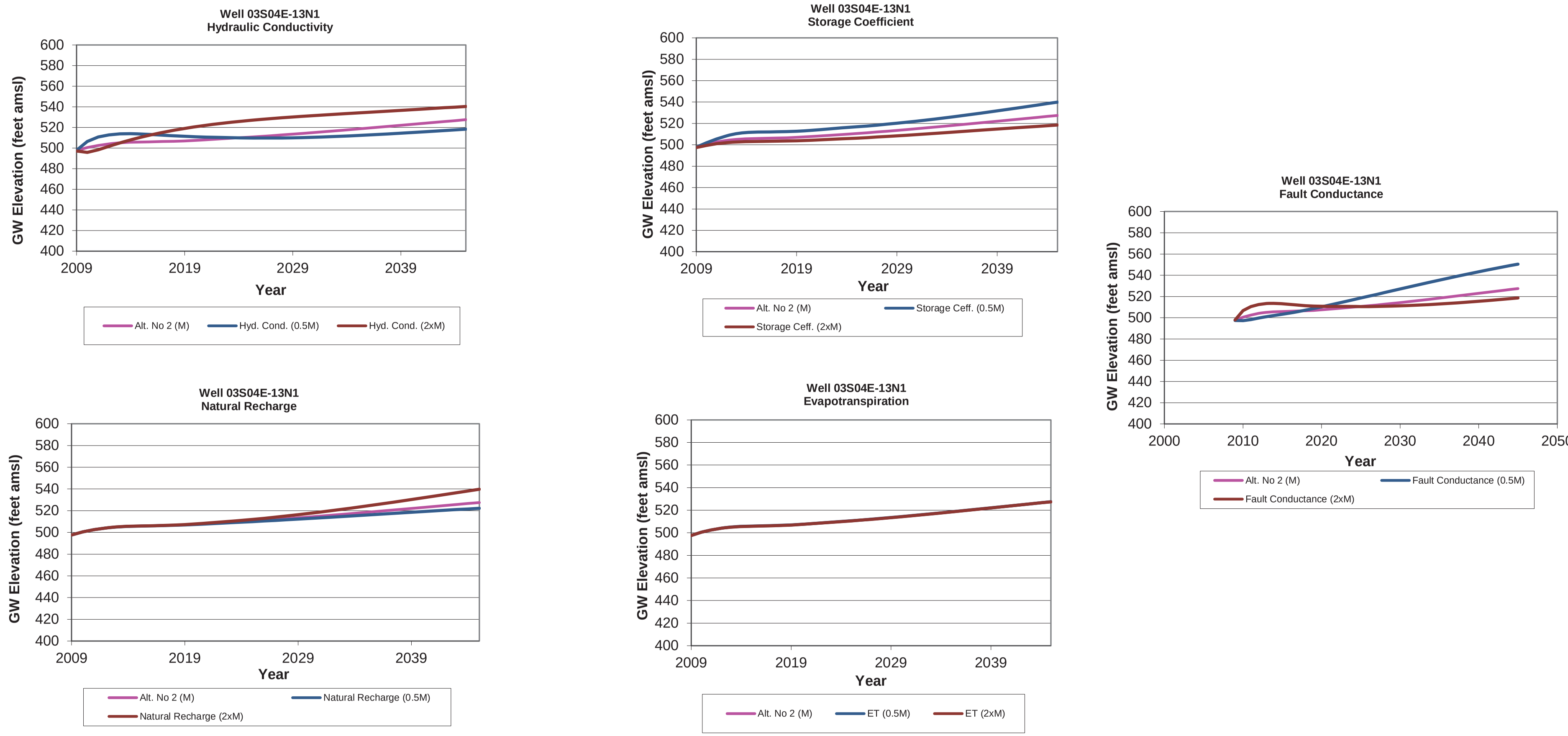


FIGURE D-6
Alternative No. 2 Sensitivity Hydrographs of Well 03S04E-13N1 in Garnet Hill Subbasin

Appendix E
Inflow/Outflow Assumptions Used for Groundwater Model Runs Nos. 1, 2, 3, & 4

Table E-1
Inflow/Outflow Assumptions Used for Transient Calibration
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet) (a)	Artificial Recharge (acre-feet) (b)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
1	1936-1940	9,344	0	6,408	1,675	0	1,220
2	1941-1945	9,344	0	6,356	1,567	0	1,220
3	1946-1948	9,344	0	6,408	583	1,100	1,401
4	1949	9,344	0	6,411	1,524	192	1,219
5	1950	9,344	0	6,450	598	138	1,399
6	1951	9,344	0	6,480	599	467	1,398
7	1952	9,344	0	6,515	530	823	1,391
8	1953	9,344	0	6,614	570	812	1,393
9	1954	9,344	0	6,607	585	703	1,394
10	1955	9,344	0	6,644	1,445	236	1,218
11	1956	9,344	0	6,773	603	554	1,394
12	1957	9,344	0	6,770	602	965	1,393
13	1958	9,344	0	6,875	520	149	1,371
14	1959	9,344	0	6,890	644	397	1,391
15	1960	9,344	0	6,961	1,015	712	1,265
16	1961	9,344	0	7,189	626	1,438	1,390
17	1962	9,344	0	7,358	646	1,494	1,389
18	1963	9,344	0	7,344	635	1,255	1,388
19	1964	9,344	8	7,363	617	1,409	1,388
20	1965	9,344	9	7,465	700	385	1,307
21	1966	9,344	9	7,301	569	3,766	1,327
22	1967	9,344	10	7,270	670	2,741	1,327
23	1968	9,344	10	7,280	703	1,873	1,326
24	1969	9,344	9	7,304	636	1,937	1,323
25	1970	9,344	8	7,331	720	1,243	1,322
26	1971	9,344	8	7,332	757	2,355	1,324
27	1972	9,344	7	7,315	783	4,424	1,316
28	1973	9,344	7	7,323	796	2,405	1,316
29	1974	9,344	6	7,341	821	2,818	1,310
30	1975	9,344	5	7,340	838	2,288	1,307
31	1976	9,344	5	7,432	846	2,698	1,307
32	1977	9,344	4	7,466	744	3,117	1,307
33	1978	9,344	585	7,374	866	3,472	1,299
34	1979	9,344	675	7,349	863	3,796	1,299
35	1980	9,344	722	7,307	846	4,609	1,290
36	1981	9,344	756	7,290	863	3,201	1,290
37	1982	9,344	735	7,240	855	4,366	1,282
38	1983	9,344	823	7,189	880	4,885	1,274

Table E-1
Inflow/Outflow Assumptions Used for Transient Calibration
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet) (a)	Artificial Recharge (acre-feet) (b)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
39	1984	9,344	957	7,101	864	4,695	1,272
40	1985	9,344	979	6,971	890	6,768	1,263
41	1986	9,344	1,064	6,770	880	7,097	1,257
42	1987	9,344	1,198	6,536	897	5,690	1,249
43	1988	9,344	1,433	6,243	897	7,860	1,240
44	1989	9,344	1,617	5,991	930	9,133	1,232
45	1990	9,344	1,651	5,798	964	9,133	1,223
46	1991	9,344	1,575	5,648	972	9,133	1,215
47	1992	9,344	1,662	5,536	968	10,028	1,202
48	1993	9,344	1,751	5,430	938	9,720	1,198
49	1994	9,344	1,934	5,328	950	10,617	1,183
50	1995	9,344	1,934	5,238	966	10,728	1,168
51	1996	9,344	2,019	5,136	922	11,144	1,156
52	1997	9,344	1,936	5,036	1,047	10,223	1,131
53	1998	9,344	2,036	4,893	1,106	11,144	1,106
54	1999	9,344	2,120	4,734	1,064	11,647	1,089
55	2000	9,344	2,204	4,567	1,081	12,150	1,064
56	2001	9,344	2,240	4,447	1,108	11,293	1,046
57	2002	9,344	7,065	4,330	1,132	12,647	1,022
58	2003	9,344	2,596	4,247	1,096	14,023	1,003
59	2004	9,344	9,580	4,171	1,108	17,124	978
60	2005	9,344	28,025	4,120	1,115	17,416	951
61	2006	9,344	23,113	4,084	1,121	18,284	928
62	2007	9,344	4,155	4,086	1,129	17,003	917
63	2008	9,344	2,750	4,054	1,134	16,657	904
64	2009	9,344	5,867	4,020	1,130	16,045	889

Notes:

a - Includes underflow from Desert Hot Springs Subbasin of 1,844 acre-feet and 7,500 AF of mountain front recharge in Mission Creek Subbasin.

b - Includes return flows.

Table E-2
Inflow/Outflow Assumptions Used for Transient Calibration
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
1	1936-1940	6,408	16,820	23,561	0
2	1941-1945	6,356	19,399	23,567	0
3	1946-1948	6,400	6,757	21,866	3,363
4	1949	6,411	2,775	21,306	4,103
5	1950	6,442	1,763	20,848	4,046
6	1951	6,472	1,296	20,455	3,214
7	1952	6,507	7,119	19,888	4,305
8	1953	6,606	5,241	19,427	4,353
9	1954	6,598	7,881	19,565	1,544
10	1955	6,644	6,297	18,956	3,907
11	1956	6,763	3,512	19,132	1,234
12	1957	6,760	3,643	19,120	569
13	1958	6,811	23,825	19,212	152
14	1959	6,877	10,095	19,365	407
15	1960	6,961	8,087	19,451	1,381
16	1961	7,175	5,646	19,503	2,003
17	1962	7,344	3,753	19,415	2,365
18	1963	7,330	2,531	19,347	1,937
19	1964	7,349	2,369	19,312	1,061
20	1965	7,465	15,462	19,186	1,703
21	1966	7,301	5,027	18,958	901
22	1967	7,271	19,587	18,995	911
23	1968	7,280	15,826	19,354	688
24	1969	7,304	20,367	18,029	211
25	1970	7,331	22,204	19,012	821
26	1971	7,334	13,959	19,637	536
27	1972	7,311	10,011	20,090	284
28	1973	7,327	11,098	19,972	865
29	1974	7,341	8,544	19,595	833
30	1975	7,343	5,412	19,101	770
31	1976	7,433	3,536	18,935	1,243
32	1977	7,462	5,018	19,373	1,325
33	1978	7,374	22,320	18,139	68
34	1979	7,345	15,938	17,712	38
35	1980	7,304	21,356	16,943	605
36	1981	7,292	21,597	16,916	609
37	1982	7,239	24,392	17,464	607
38	1983	7,184	23,641	15,690	582
39	1984	7,101	23,004	14,128	46

Table E-2
Inflow/Outflow Assumptions Used for Transient Calibration
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
40	1985	14,190*	40,100	7,509	43
41	1986	17,106*	25,553	6,097	602
42	1987	9,231*	9,720	6,618	666
43	1988	6,246	2,022	12,763	633
44	1989	5,994	2,981	15,763	553
45	1990	5,798	3,819	16,492	105
46	1991	5,649	4,100	18,837	88
47	1992	5,536	20,581	17,864	969
48	1993	5,430	19,227	16,536	57
49	1994	5,328	20,599	18,318	55
50	1995	5,238	15,574	17,320	64
51	1996	5,239	23,771	12,884	66
52	1997	5,049	20,292	13,499	76
53	1998	5,088	20,297	12,209	43
54	1999	4,732	20,311	13,954	58
55	2000	4,568	20,308	16,026	72
56	2001	4,447	20,309	20,995	62
57	2002	4,330	20,313	22,021	75
58	2003	4,248	20,278	24,545	74
59	2004	4,171	20,570	25,493	54
60	2005	4,120	20,335	18,401	70
61	2006	4,084	20,335	18,738	61
62	2007	4,086	20,332	22,699	590
63	2008	4,054	20,328	24,747	376
64	2009	4,020	20,498	23,959	129

Notes:
* - Subbasin receiving flow across Garnet Hill Fault from Palm Springs Sub-Area of Whitewater River Subbain during heavy artificial recharge period.

Table E-3
Inflow/Outflow Assumptions Used for Transient Calibration
Palm Springs Sub-Area

Stress Period	Year	Subsurface Inflow from San Gorgonio Subbasin (acre-feet)	Subsurface Inflow across Garnet Hill Fault (acre-feet) (a)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet) (b)	Subsurface Outflow across Row 75 of the Model (bottom of Palm Springs Sub-Area (acre-feet) (c)	Groundwater Production (acre-feet)
1	1936-1940	8,660	23,561	32,654	0	63,427	0
2	1941-1945	7,316	23,566	34,027	0	62,254	0
3	1946-1948	7,215	21,866	14,108	0	53,557	975
4	1949	7,240	21,306	13,901	0	56,504	1,061
5	1950	7,324	20,848	11,247	0	54,862	1,782
6	1951	7,357	20,455	16,344	0	53,700	2,439
7	1952	7,307	19,888	35,393	0	57,362	1,014
8	1953	7,286	19,427	12,858	0	55,955	2,647
9	1954	7,344	19,565	23,754	0	56,433	2,518
10	1955	7,407	18,956	16,535	0	54,517	4,172
11	1956	7,449	19,132	13,679	1	52,660	6,047
12	1957	7,441	19,120	18,999	1	52,689	5,464
13	1958	7,275	19,212	45,496	0	55,755	8,608
14	1959	7,110	19,365	17,855	0	54,000	9,628
15	1960	7,181	19,451	16,739	0	50,826	13,436
16	1961	7,291	19,503	16,518	0	48,239	17,830
17	1962	7,308	19,415	21,487	0	46,283	21,544
18	1963	7,324	19,347	20,687	1	44,771	22,257
19	1964	7,338	19,312	21,869	1	44,563	25,377
20	1965	7,078	19,186	46,864	1	44,493	26,923
21	1966	6,950	18,958	29,930	1	48,289	26,261
22	1967	7,005	18,995	30,862	1	44,920	24,638
23	1968	7,097	19,354	22,820	0	43,758	24,689
24	1969	7,209	18,029	102,920	0	59,829	24,614
25	1970	7,604	19,012	27,669	0	43,519	25,248
26	1971	7,751	19,637	27,075	0	45,255	22,704
27	1972	7,798	20,090	21,176	0	44,413	24,664
28	1973	7,821	19,972	36,663	0	44,273	24,205
29	1974	7,863	19,595	39,773	0	44,756	24,228
30	1975	7,857	19,101	43,907	0	44,993	24,288
31	1976	7,921	18,935	37,616	0	47,861	25,434
32	1977	8,017	19,373	28,214	0	45,593	28,208
33	1978	7,883	18,139	90,500	0	55,457	28,577
34	1979	8,099	17,712	74,251	0	52,411	28,868
35	1980	8,443	16,943	108,910	0	61,830	29,355
36	1981	8,554	16,916	72,604	0	51,941	30,811
37	1982	8,672	17,464	88,877	0	59,328	30,616
38	1983	8,236	15,690	152,772	0	76,294	31,998
39	1984	8,193	14,128	134,362	0	67,184	32,317
40	1985	6,978	7,509	352,610	7,220	79,419	30,172
41	1986	5,295	6,097	335,653	10,340	110,345	30,956
42	1987	4,304	6,618	150,586	2,696	127,386	47,607

Table E-3
Inflow/Outflow Assumptions Used for Transient Calibration
Palm Springs Sub-Area

Stress Period	Year	Subsurface Inflow from San Gorgonio Subbasin (acre-feet)	Subsurface Inflow across Garnet Hill Fault (acre-feet) (a)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet) (b)	Subsurface Outflow across Row 75 of the Model (bottom of Palm Springs Sub-Area (acre-feet) (c)	Groundwater Production (acre-feet)
43	1988	3,766	12,763	40,063	0	122,398	50,097
44	1989	3,461	15,763	51,221	0	104,830	49,428
45	1990	3,537	16,492	76,280	0	89,801	51,774
46	1991	3,680	18,837	42,388	0	86,935	44,461
47	1992	5,143	17,864	93,009	0	81,338	41,291
48	1993	3,757	16,536	129,938	0	84,410	42,903
49	1994	4,040	18,318	77,131	0	78,979	43,450
50	1995	4,410	17,320	122,725	0	86,845	41,964
51	1996	4,403	12,884	190,048	102	84,592	42,681
52	1997	4,354	13,499	141,335	8	86,906	45,448
53	1998	3,972	12,208	182,985	194	83,774	47,371
54	1999	3,904	13,953	114,126	0	84,607	56,494
55	2000	7,042	16,247	96,735	0	89,063	54,250
56	2001	4,194	20,994	28,293	0	81,285	54,699
57	2002	4,580	22,019	57,272	0	71,099	56,463
58	2003	4,990	24,563	28,310	0	64,776	50,915
59	2004	5,265	25,491	22,186	0	44,814	59,274
60	2005	5,258	18,398	233,052	0	61,696	56,279
61	2006	5,100	18,735	129,621	0	63,548	59,496
62	2007	5,017	22,696	43,848	0	65,926	59,737
63	2008	5,004	24,744	47,019	0	60,520	59,470
64	2009	5,061	23,955	56,800	0	51,530	50,239

Notes:

a - This value indicates the entire length of the fault from western edge of the Indio Hills to the western edge of Whitewater River.
b - The modeling suggested that in certain instances when substantial recharge is occurring in the Palm Springs Sub-Area recharge area, groundwater levels rose up to permit groundwater flow across the Garnet Hill Fault back into the upper portion of the Garnet Hill Subbasin.

c - This represents the outflow across Row 75 of the model which is the approximate lower boundary of the Palm Springs Sub-Area of the Whitewater River Subbasin.

Table E-4
Inflow/Outflow Assumptions Used for Model Run No. 1
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet)	Artificial Recharge* (acre-feet)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
1	2010	9,344	36,269	3,997	1,083	14,306	882
2	2011	9,344	15,389	4,000	1,044	15,660	884
3	2012	9,344	10,311	3,978	1,019	17,013	889
4	2013	9,344	11,232	3,910	1,002	18,642	891
5	2014	9,344	12,275	3,821	988	20,270	887
6	2015	9,344	13,342	3,728	974	21,624	878
7	2016	9,344	14,100	3,639	960	22,100	868
8	2017	9,344	14,491	3,557	945	22,575	856
9	2018	9,344	14,889	3,480	930	23,051	845
10	2019	9,344	15,660	3,407	915	23,526	833
11	2020	9,344	15,827	3,331	901	24,632	822
12	2021	9,344	19,425	3,256	886	25,149	810
13	2022	9,344	19,765	3,189	872	25,666	799
14	2023	9,344	20,105	3,131	858	26,182	790
15	2024	9,344	17,505	3,077	846	26,699	781
16	2025	9,344	17,845	3,019	834	27,216	772
17	2026	9,344	18,230	2,963	822	27,758	763
18	2027	9,344	18,447	2,901	810	28,300	753
19	2028	9,344	18,472	2,819	797	28,842	742
20	2029	9,344	18,490	2,724	784	29,384	730
21	2030	9,344	18,630	2,622	769	30,556	717
22	2031	9,344	18,870	2,515	755	30,951	704
23	2032	9,344	18,937	2,409	739	31,346	690
24	2033	9,344	19,003	2,302	724	31,741	675
25	2034	9,344	19,068	2,192	707	32,136	660
26	2035	9,344	19,131	2,082	690	32,531	645
27	2036	9,344	19,185	1,976	673	32,926	629
28	2037	9,344	19,251	1,869	656	33,321	613
29	2038	9,344	19,315	1,762	638	33,716	597
30	2039	9,344	19,379	1,660	620	34,111	581
31	2040	9,344	19,568	1,559	602	35,136	564
32	2041	9,344	20,389	1,459	584	35,516	547
33	2042	9,344	20,444	1,358	565	35,894	530
34	2043	9,344	20,499	1,257	547	36,273	513
35	2044	9,344	20,553	1,156	528	36,653	495
36	2045	9,344	20,606	1,055	509	37,032	478

Notes:
* Includes return flows.

Table E-5
Inflow/Outflow Assumptions Used for Model Run No. 1
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
1	2010	3,997	22,251	14,722	675
2	2011	4,000	17,459	17,725	675
3	2012	3,978	17,485	18,556	675
4	2013	3,910	17,423	19,106	675
5	2014	3,821	17,400	19,444	675
6	2015	3,728	17,061	20,278	675
7	2016	3,639	17,128	20,572	675
8	2017	3,557	17,170	20,716	675
9	2018	3,480	17,563	20,042	675
10	2019	3,407	17,611	19,692	675
11	2020	3,331	17,641	19,453	675
12	2021	3,256	17,514	19,601	675
13	2022	3,189	17,514	19,663	675
14	2023	3,131	17,513	19,722	675
15	2024	3,077	17,512	19,780	675
16	2025	3,019	17,510	19,837	675
17	2026	2,963	17,647	19,619	675
18	2027	2,901	17,701	19,545	675
19	2028	2,819	17,948	19,521	675
20	2029	2,724	18,208	19,515	675
21	2030	2,622	18,456	19,565	675
22	2031	2,515	18,737	19,552	675
23	2032	2,409	18,968	19,518	675
24	2033	2,302	19,200	19,474	675
25	2034	2,192	19,434	19,426	675
26	2035	2,082	19,673	19,376	675
27	2036	1,976	19,889	19,343	675
28	2037	1,869	20,097	19,307	675
29	2038	1,762	20,306	19,271	675
30	2039	1,660	20,517	19,237	675
31	2040	1,559	20,731	19,206	675
32	2041	1,459	20,922	19,210	675
33	2042	1,358	21,111	19,230	675
34	2043	1,257	21,302	19,260	675
35	2044	1,156	21,496	19,298	675
36	2045	1,055	21,692	19,348	675

Table E-6
Inflow/Outflow Assumptions Used for Model Run No. 2
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet)	Artificial Recharge* (acre-feet)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
1	2010	9,344	36,269	3,997	1,083	14,306	882
2	2011	9,344	15,455	4,000	1,044	15,660	884
3	2012	9,344	13,640	3,981	1,019	17,013	889
4	2013	9,344	15,326	3,925	1,002	18,642	892
5	2014	9,344	17,015	3,857	989	20,270	891
6	2015	9,344	18,437	3,793	978	21,624	887
7	2016	9,344	18,977	3,736	968	22,100	881
8	2017	9,344	19,465	3,689	958	22,575	877
9	2018	9,344	19,955	3,647	950	23,051	872
10	2019	9,344	20,083	3,608	942	23,526	868
11	2020	9,344	21,552	3,566	936	24,632	865
12	2021	9,344	22,145	3,525	931	25,149	861
13	2022	9,344	22,673	3,488	928	25,666	858
14	2023	9,344	23,199	3,453	925	26,182	855
15	2024	9,344	23,667	3,419	923	26,699	852
16	2025	9,344	24,194	3,387	922	27,216	850
17	2026	9,344	24,747	3,359	922	27,758	848
18	2027	9,344	25,339	3,333	921	28,300	847
19	2028	9,344	26,121	3,309	922	28,842	846
20	2029	9,344	26,907	3,287	923	29,384	845
21	2030	9,344	28,320	3,267	924	30,556	844
22	2031	9,344	28,966	3,249	927	30,951	844
23	2032	9,344	29,557	3,236	930	31,346	845
24	2033	9,344	30,152	3,224	935	31,741	846
25	2034	9,344	30,749	3,214	941	32,136	848
26	2035	9,344	31,350	3,205	948	32,531	850
27	2036	9,344	31,950	3,199	956	32,926	853
28	2037	9,344	32,537	3,194	966	33,321	856
29	2038	9,344	33,129	3,190	977	33,716	859
30	2039	9,344	33,723	3,189	989	34,111	863
31	2040	9,344	34,940	3,188	1,002	35,136	867
32	2041	9,344	35,534	3,191	1,017	35,516	872
33	2042	9,344	36,114	3,196	1,033	35,894	877
34	2043	9,344	36,697	3,202	1,050	36,273	883
35	2044	9,344	37,282	3,210	1,068	36,653	889
36	2045	9,344	36,212	3,183	1,086	37,032	892

Notes:

* Includes return flows.

Table E-7
Inflow/Outflow Assumptions Used for Model Run No. 2
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
1	2010	3,997	22,251	14,722	675
2	2011	4,000	17,459	17,725	675
3	2012	3,981	17,485	18,556	675
4	2013	3,925	17,423	19,107	675
5	2014	3,857	17,400	19,445	675
6	2015	3,793	17,061	20,281	675
7	2016	3,736	17,128	20,578	675
8	2017	3,689	17,170	20,727	675
9	2018	3,647	17,563	20,059	675
10	2019	3,608	17,611	19,717	675
11	2020	3,566	17,641	19,488	675
12	2021	3,525	17,514	19,646	675
13	2022	3,488	17,514	19,720	675
14	2023	3,453	17,513	19,792	675
15	2024	3,419	17,512	19,864	675
16	2025	3,387	17,510	19,936	675
17	2026	3,359	17,647	19,732	675
18	2027	3,333	17,657	19,675	675
19	2028	3,309	17,666	19,660	675
20	2029	3,287	17,683	19,656	675
21	2030	3,267	17,682	19,700	675
22	2031	3,249	17,721	19,674	675
23	2032	3,236	17,759	19,623	675
24	2033	3,224	17,796	19,556	675
25	2034	3,214	17,833	19,482	675
26	2035	3,205	17,870	19,404	675
27	2036	3,199	17,887	19,340	675
28	2037	3,194	17,906	19,272	675
29	2038	3,190	17,922	19,203	675
30	2039	3,189	17,939	19,135	675
31	2040	3,188	17,956	19,068	675
32	2041	3,191	17,949	19,036	675
33	2042	3,196	17,941	19,020	675
34	2043	3,202	17,934	19,014	675
35	2044	3,210	17,926	19,015	675
36	2045	3,183	17,918	19,028	675

Table E-8
Inflow/Outflow Assumptions Used for Model Run No. 3
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet)	Artificial Recharge* (acre-feet)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
1	2010	9,344	36,269	3,997	1,083	14,306	882
2	2011	9,344	39,101	4,014	1,044	15,660	885
3	2012	9,344	39,494	4,054	1,022	17,013	898
4	2013	9,344	39,897	4,085	1,013	18,642	920
5	2014	9,344	40,310	4,107	1,015	20,270	946
6	2015	9,344	40,731	4,123	1,029	21,624	975
7	2016	9,344	40,908	4,135	1,050	22,100	1,006
8	2017	9,344	41,088	4,147	1,078	22,575	1,035
9	2018	9,344	28,598	4,158	1,113	23,051	1,057
10	2019	9,344	6,458	4,151	1,153	23,526	1,071
11	2020	9,344	6,773	4,101	1,191	24,632	1,079
12	2021	9,344	6,985	4,034	1,224	25,149	1,080
13	2022	9,344	7,200	3,969	1,249	25,666	1,077
14	2023	9,344	7,418	3,907	1,265	26,182	1,071
15	2024	9,344	7,640	3,850	1,273	26,699	1,059
16	2025	9,344	7,865	3,796	1,273	27,216	1,041
17	2026	9,344	8,137	3,746	1,267	27,758	1,017
18	2027	9,344	8,413	3,695	1,254	28,300	989
19	2028	9,344	8,693	3,643	1,236	28,842	961
20	2029	9,344	17,726	3,589	1,214	29,384	931
21	2030	9,344	17,709	3,533	1,188	30,556	903
22	2031	9,344	18,029	3,469	1,160	30,951	878
23	2032	9,344	13,002	3,394	1,132	31,346	855
24	2033	9,344	18,719	3,308	1,103	31,741	832
25	2034	9,344	19,291	3,217	1,074	32,136	809
26	2035	9,344	20,529	3,123	1,044	32,531	788
27	2036	9,344	19,197	3,024	1,015	32,926	768
28	2037	9,344	21,763	2,921	987	33,321	749
29	2038	9,344	46,135	2,838	960	33,716	732
30	2039	9,344	46,357	2,813	935	34,111	722
31	2040	9,344	46,707	2,833	917	35,136	723
32	2041	9,344	46,926	2,875	907	35,516	734
33	2042	9,344	47,148	2,926	907	35,894	750
34	2043	9,344	47,372	2,981	914	36,273	771
35	2044	9,344	47,599	3,036	928	36,653	793
36	2045	9,344	46,170	3,052	948	37,032	813

Notes:

* Includes return flows.

Table E-9
Inflow/Outflow Assumptions Used for Model Run No. 3
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
1	2010	3,997	22,251	14,722	675
2	2011	4,014	17,466	13,874	675
3	2012	4,054	17,467	12,786	675
4	2013	4,085	17,462	12,104	675
5	2014	4,107	17,450	11,669	675
6	2015	4,123	17,431	11,900	675
7	2016	4,135	17,465	11,959	675
8	2017	4,147	17,498	12,014	675
9	2018	4,158	17,531	19,827	675
10	2019	4,151	17,563	23,244	675
11	2020	4,101	17,596	25,291	675
12	2021	4,034	17,530	26,860	675
13	2022	3,969	17,442	27,786	675
14	2023	3,907	17,353	28,332	675
15	2024	3,850	17,263	28,618	675
16	2025	3,796	17,569	28,640	675
17	2026	3,746	17,770	28,362	675
18	2027	3,695	17,801	28,141	675
19	2028	3,643	17,830	27,911	675
20	2029	3,589	17,860	24,479	675
21	2030	3,533	17,888	22,797	675
22	2031	3,469	17,912	21,608	675
23	2032	3,394	17,934	22,702	675
24	2033	3,308	17,956	20,910	675
25	2034	3,217	17,977	19,874	675
26	2035	3,123	17,999	18,778	675
27	2036	3,024	18,000	18,707	675
28	2037	2,921	18,002	17,586	675
29	2038	2,838	18,003	16,836	675
30	2039	2,813	18,005	16,347	675
31	2040	2,833	18,006	16,010	675
32	2041	2,875	17,998	15,777	675
33	2042	2,926	17,991	15,621	675
34	2043	2,981	17,983	15,520	675
35	2044	3,036	17,975	15,460	675
36	2045	3,052	17,967	15,438	675

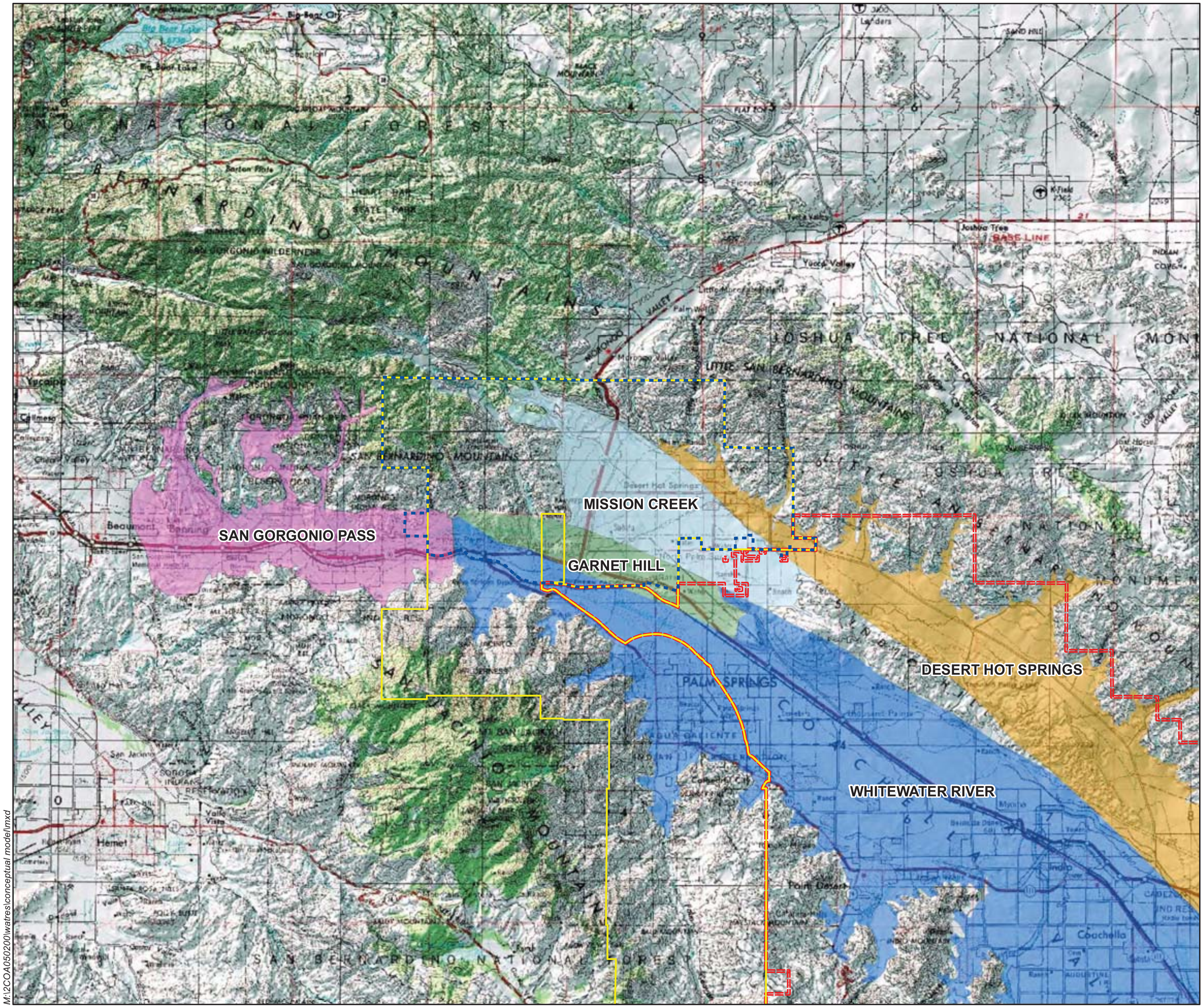
Table E-10
Inflow/Outflow Assumptions Used for Model Run No. 4
Mission Creek Subbasin

Stress Period	Year	Natural Recharge (acre-feet)	Artificial Recharge* (acre-feet)	Subsurface Outflow across Banning Fault (acre-feet)	Subsurface Outflow beneath Indio Hills (acre-feet)	Groundwater Production (acre-feet)	Evapo-transpiration (acre-feet)
1	2010	9,344	35,845	4,117	1,071	14,329	883
2	2011	9,344	38,150	4,203	1,023	13,884	888
3	2012	9,344	38,052	4,309	993	13,438	906
4	2013	9,344	37,950	4,418	979	13,267	935
5	2014	9,344	37,846	4,523	980	13,096	972
6	2015	9,344	28,269	4,625	995	12,096	1,016
7	2016	9,344	3,357	4,667	1,020	12,096	1,048
8	2017	9,344	3,387	4,616	1,051	12,096	1,067
9	2018	9,344	3,416	4,518	1,081	12,096	1,076
10	2019	9,344	3,446	4,437	1,108	12,096	1,081
11	2020	9,344	3,476	4,394	1,129	12,096	1,083
12	2021	9,344	6,445	4,387	1,146	12,096	1,083
13	2022	9,344	6,475	4,413	1,159	12,096	1,082
14	2023	9,344	6,504	4,464	1,169	12,096	1,081
15	2024	9,344	3,594	4,528	1,176	12,096	1,080
16	2025	9,344	3,624	4,593	1,181	12,096	1,078
17	2026	9,344	3,653	4,655	1,184	12,096	1,076
18	2027	9,344	3,683	4,713	1,184	12,096	1,073
19	2028	9,344	3,712	4,765	1,181	12,096	1,069
20	2029	9,344	3,742	4,808	1,176	12,096	1,064
21	2030	9,344	3,772	4,828	1,170	12,096	1,058
22	2031	9,344	3,801	4,824	1,162	12,096	1,051
23	2032	9,344	3,831	4,802	1,152	12,096	1,044
24	2033	9,344	3,860	4,772	1,141	12,096	1,036
25	2034	9,344	3,890	4,732	1,129	12,096	1,027
26	2035	9,344	3,923	4,681	1,115	12,096	1,018
27	2036	9,344	3,949	4,618	1,101	12,096	1,009
28	2037	9,344	3,979	4,549	1,087	12,096	999
29	2038	9,344	4,008	4,471	1,072	12,096	990
30	2039	9,344	4,038	4,386	1,057	12,096	981
31	2040	9,344	4,068	4,295	1,041	12,096	973
32	2041	9,344	4,685	4,201	1,025	12,096	964
33	2042	9,344	4,715	4,107	1,010	12,096	956
34	2043	9,344	4,744	4,014	994	12,096	949
35	2044	9,344	4,774	3,922	979	12,096	942
36	2045	9,344	4,804	3,831	964	12,096	935

Notes:
* Includes return flows.

Table E-11
Inflow/Outflow Assumptions Used for Model Run No. 4
Garnet Hill Subbasin

Stress Period	Year	Subsurface Inflow across Banning Fault (acre-feet)	Natural and Artificial Recharge (acre-feet)	Subsurface Outflow across Garnet Hill Fault (acre-feet)	Groundwater Production (acre-feet)
1	2010	4,117	21,124	14,661	675
2	2011	4,203	16,328	13,755	664
3	2012	4,309	16,319	12,614	653
4	2013	4,418	16,311	11,886	642
5	2014	4,523	16,303	11,415	631
6	2015	4,625	16,295	11,618	620
7	2016	4,667	16,293	11,652	620
8	2017	4,616	16,291	11,685	620
9	2018	4,518	16,288	19,465	620
10	2019	4,437	16,286	22,851	620
11	2020	4,394	16,284	24,866	620
12	2021	4,387	16,186	26,401	620
13	2022	4,413	16,066	27,297	620
14	2023	4,464	15,946	27,818	620
15	2024	4,528	15,826	28,084	620
16	2025	4,593	16,102	28,093	620
17	2026	4,655	16,270	27,808	620
18	2027	4,713	16,268	27,583	620
19	2028	4,765	16,266	27,354	620
20	2029	4,808	16,263	23,930	620
21	2030	4,828	16,261	22,258	620
22	2031	4,824	16,259	21,080	620
23	2032	4,802	16,256	22,185	620
24	2033	4,772	16,254	20,408	620
25	2034	4,732	16,252	19,387	620
26	2035	4,681	16,250	18,307	620
27	2036	4,618	16,247	18,253	620
28	2037	4,549	16,245	17,150	620
29	2038	4,471	16,243	16,418	620
30	2039	4,386	16,240	15,947	620
31	2040	4,295	16,238	15,624	620
32	2041	4,201	16,236	15,400	620
33	2042	4,107	16,233	15,245	620
34	2043	4,014	16,231	15,139	620
35	2044	3,922	16,229	15,066	620
36	2045	3,831	16,226	15,024	620



Legend

Water Districts

- COACHELLA VALLEY WATER DISTRICT
- DESERT WATER AGENCY
- MISSION SPRINGS WATER DISTRICT

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER

Source: Base map from USA Topos
District boundaries from CVWD, DWA & MSWD.

N W E S

0 2.5 5 10 Miles

State Plane NAD 83 Zone 6

Location of Mission Creek-Garnet Hill Study Area

PSOMAS

Figure 1

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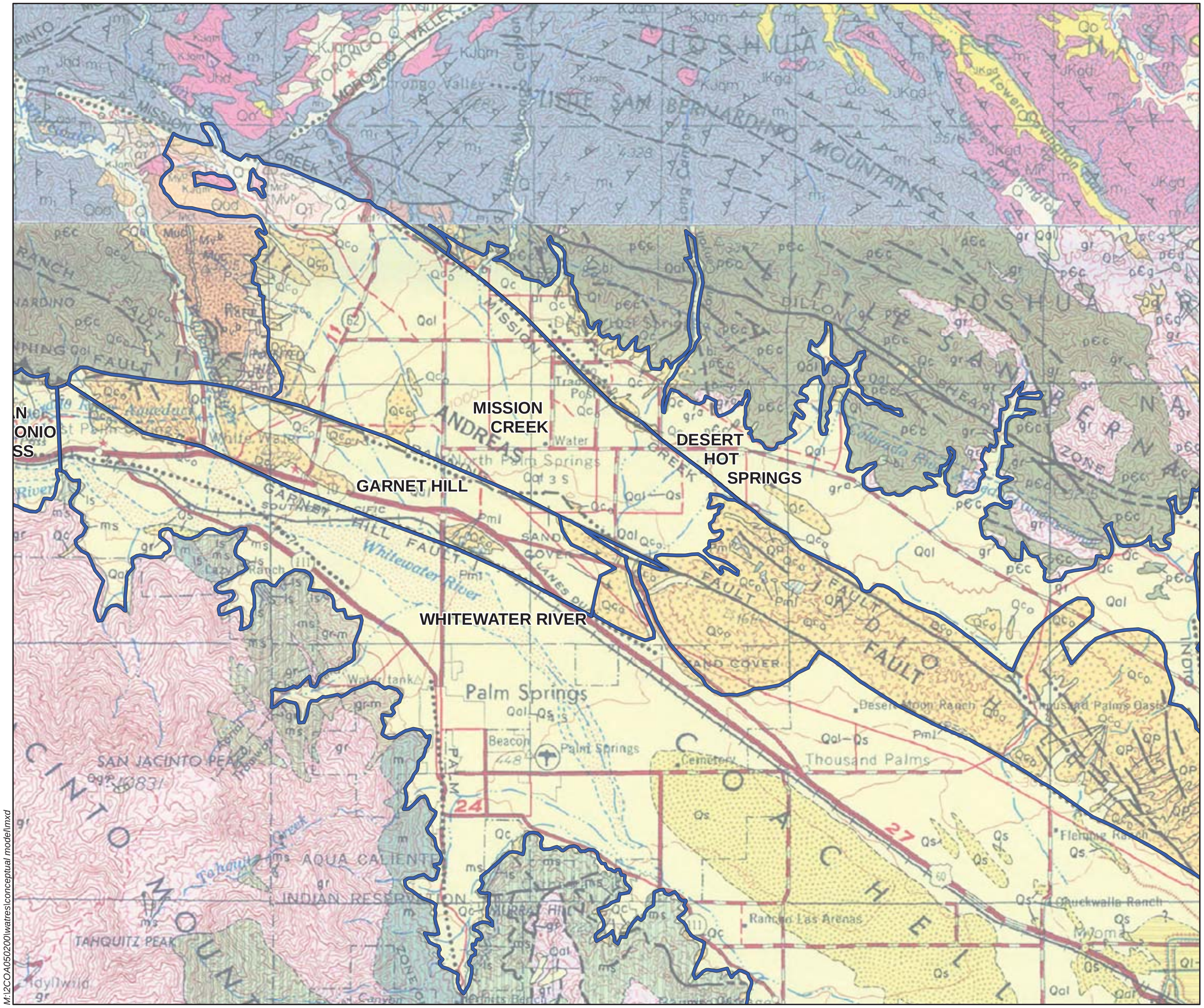

Legend

Coachella Valley Groundwater Subbasins

See Figure 5 for Geologic Units Legend

Source: CDMG Santa Ana & San Bernardino Scale:1:250,000 Geologic Maps, 1966.

N
W E
S

0 0.5 1 2 3 4 5 Miles

State Plane NAD 83 Zone 6

Regional Geologic Map

PSOMAS

Figure 2

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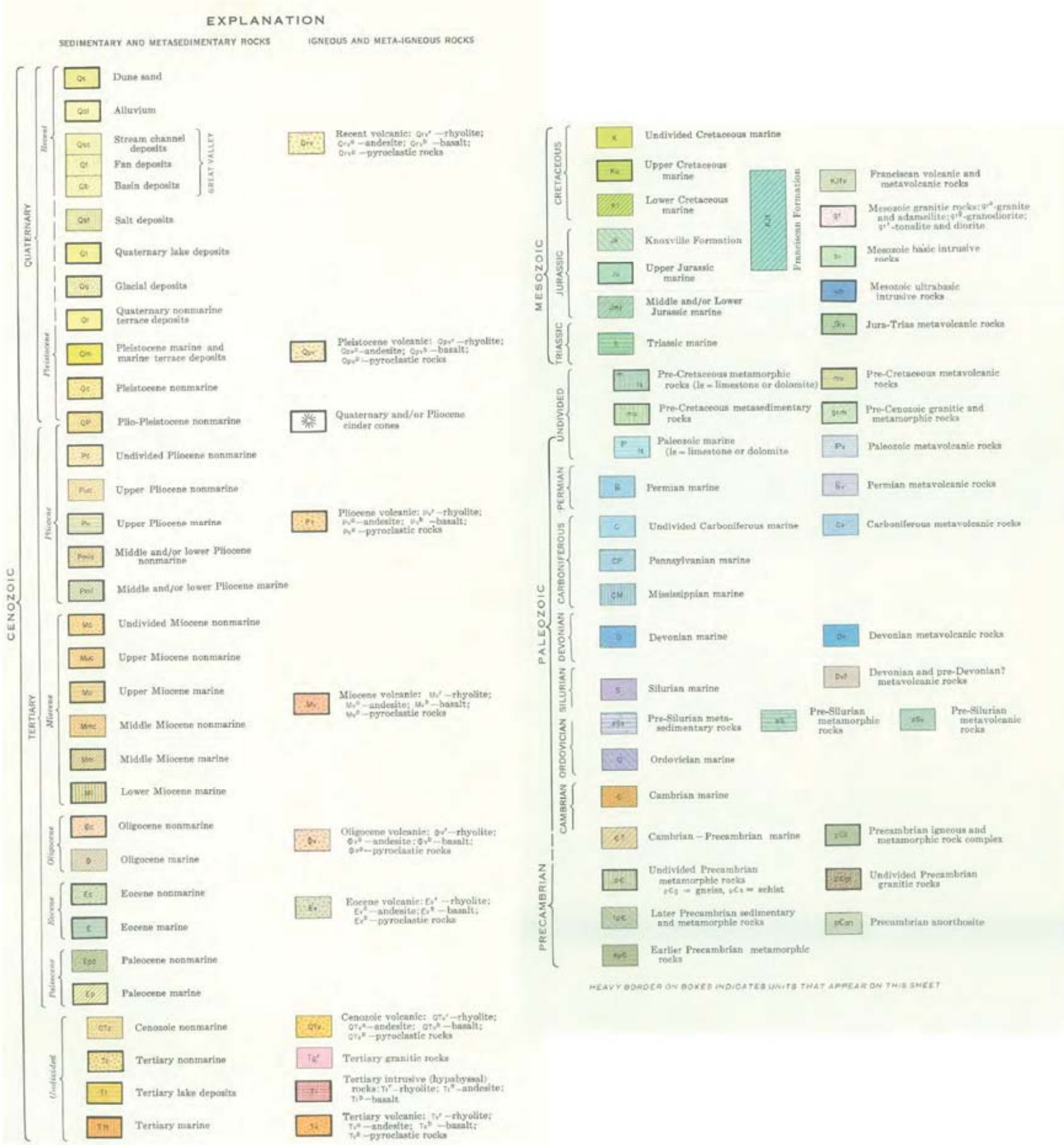
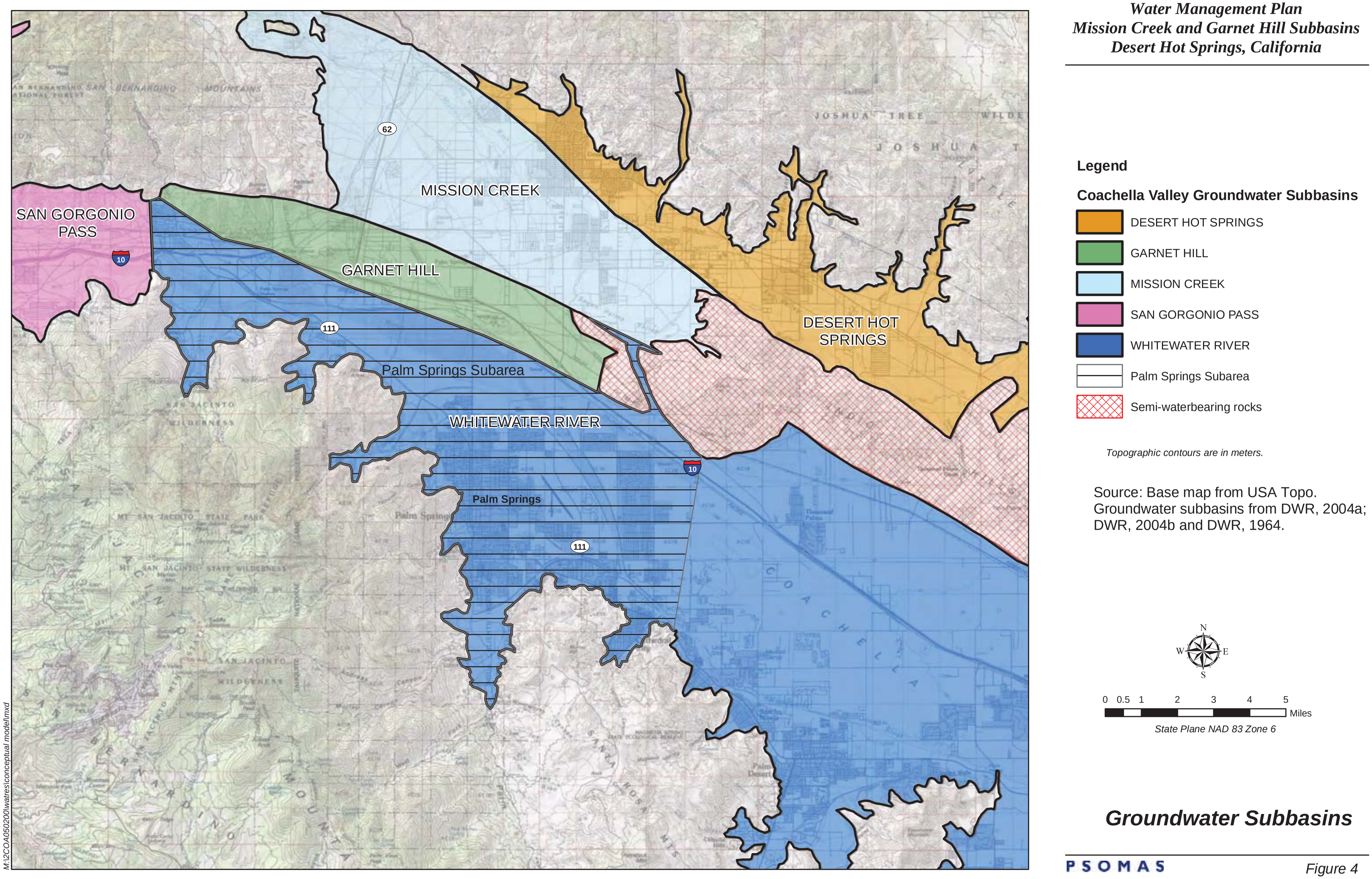


Source: CDMG Santa Ana 1:250,000 scale Geologic Map

Regional Geologic Map Legend

PSOMAS

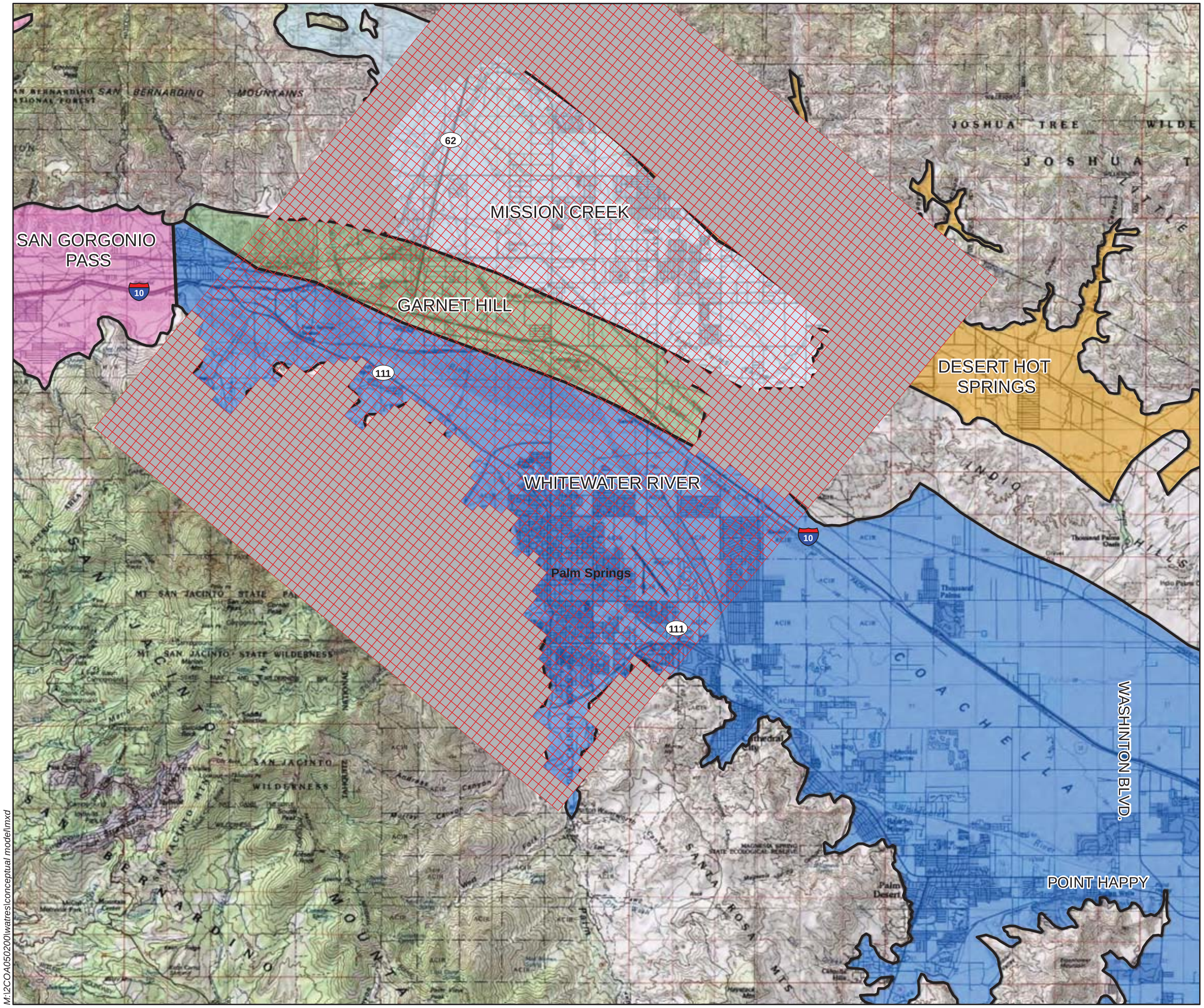
Figure 3



Groundwater Subbasins

PSOMAS

Figure 4



Legend

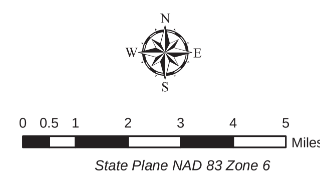
- Model Grid
- No Flow Cell

Coachella Valley Groundwater Subbasins

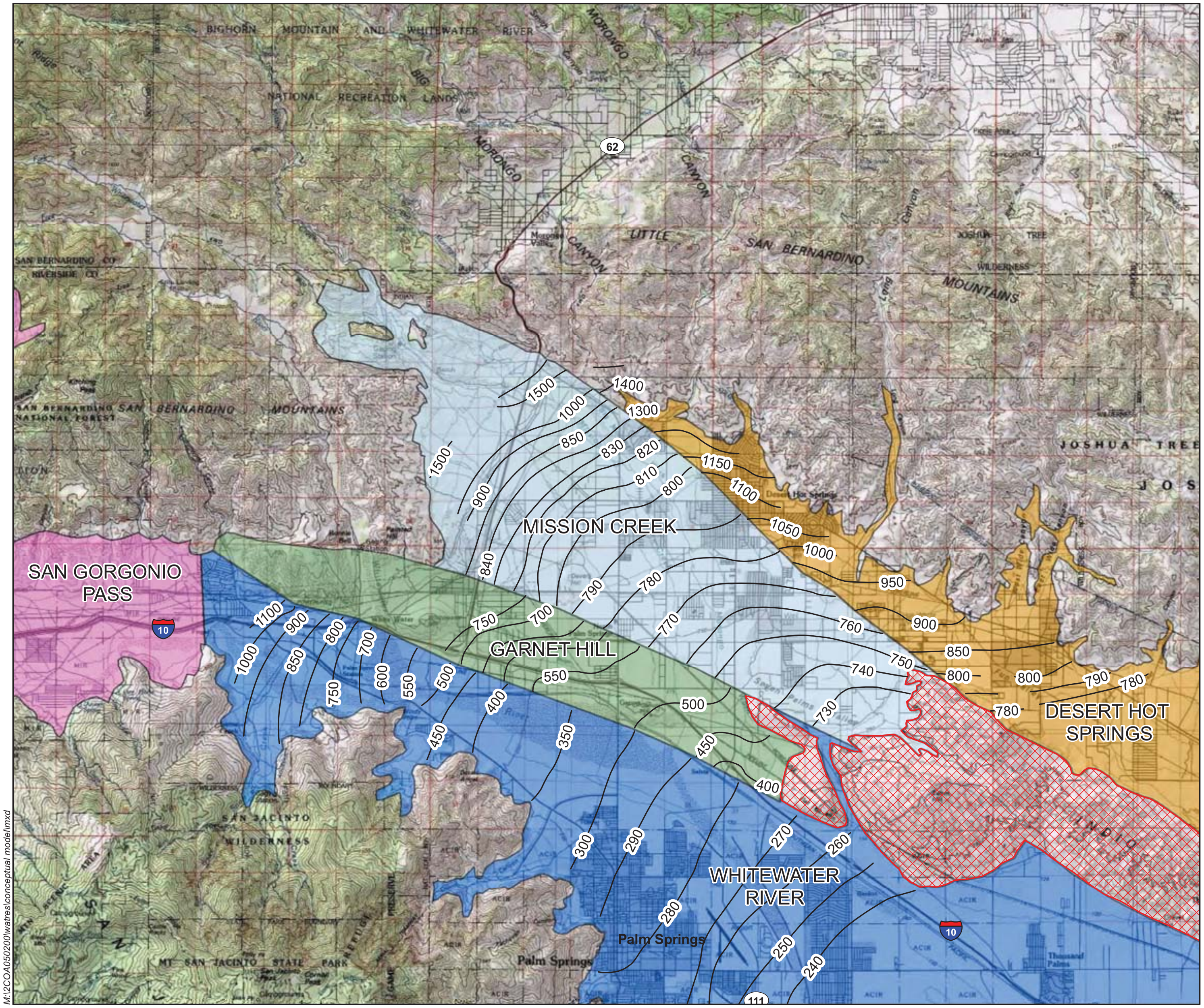
- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER

Topographic contours are in meters.

Source: Base map from USA Topo.
Groundwater subbasins from DWR, 2004a; DWR, 2004b; and DWR, 1964.
Model grid based on Fogg et al., 2000.



Numerical Model Grid and Groundwater Subbasins



Legend

Groundwater Elevation Contour (feet msl)

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER
- Semi-waterbearing rocks

Source:Tyley, 1974.

Topographic contours are in meters.

0 0.5 1 2 3 4 5 Miles

State Plane NAD 83 Zone 6

Contours of Measured Groundwater Elevations in 1936

PSOMAS

Figure 6

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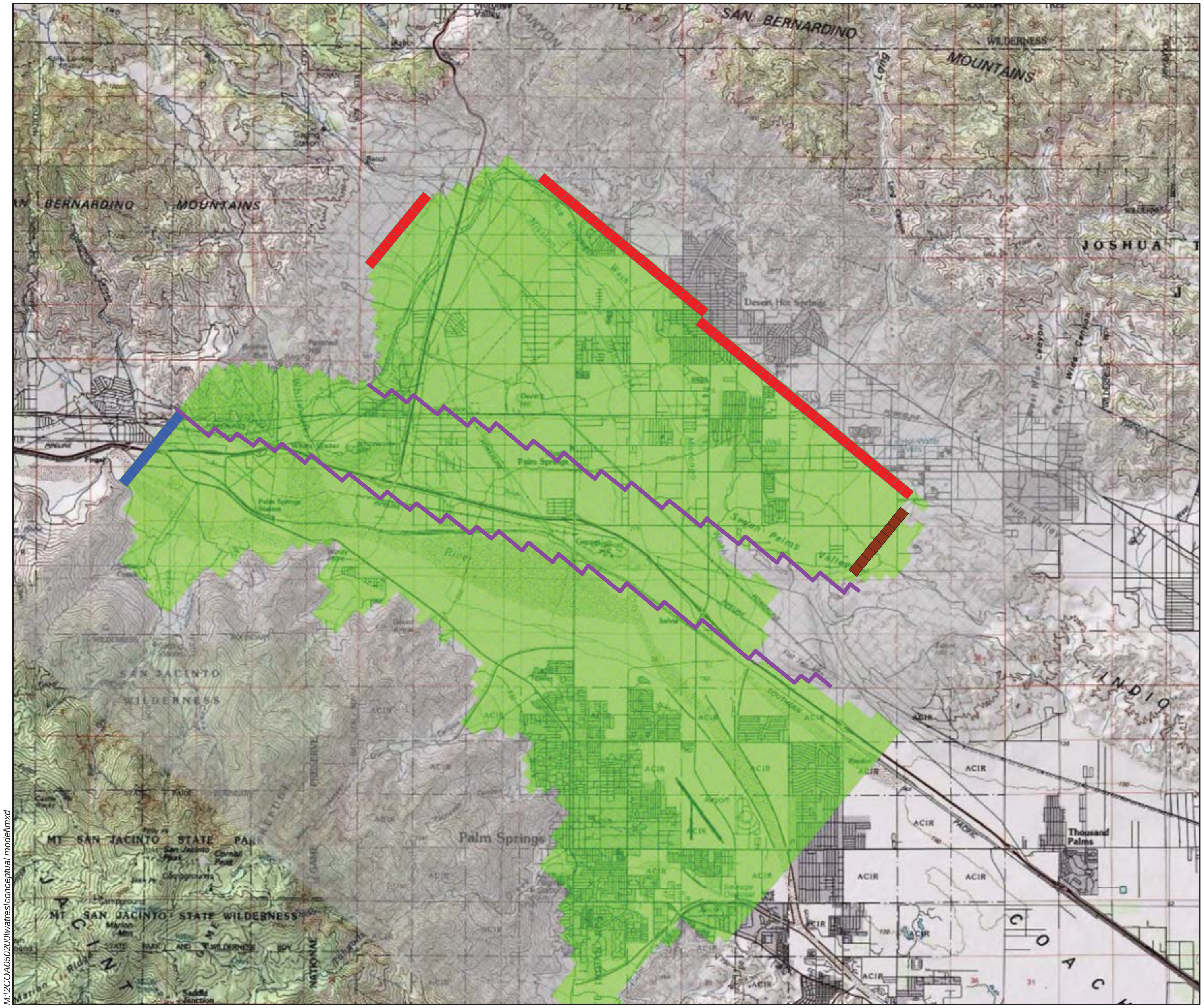
Water Management Plan
Mission Creek and Garnet Hill Subbasins
Desert Hot Springs, California



Legend

- Horizontal Flow Barrier
- Specified Flux
- Drain
- Specified Head

Model Grid

Cell Type

- Active
- No Flow

Topographic contours are in meters.

N W E S

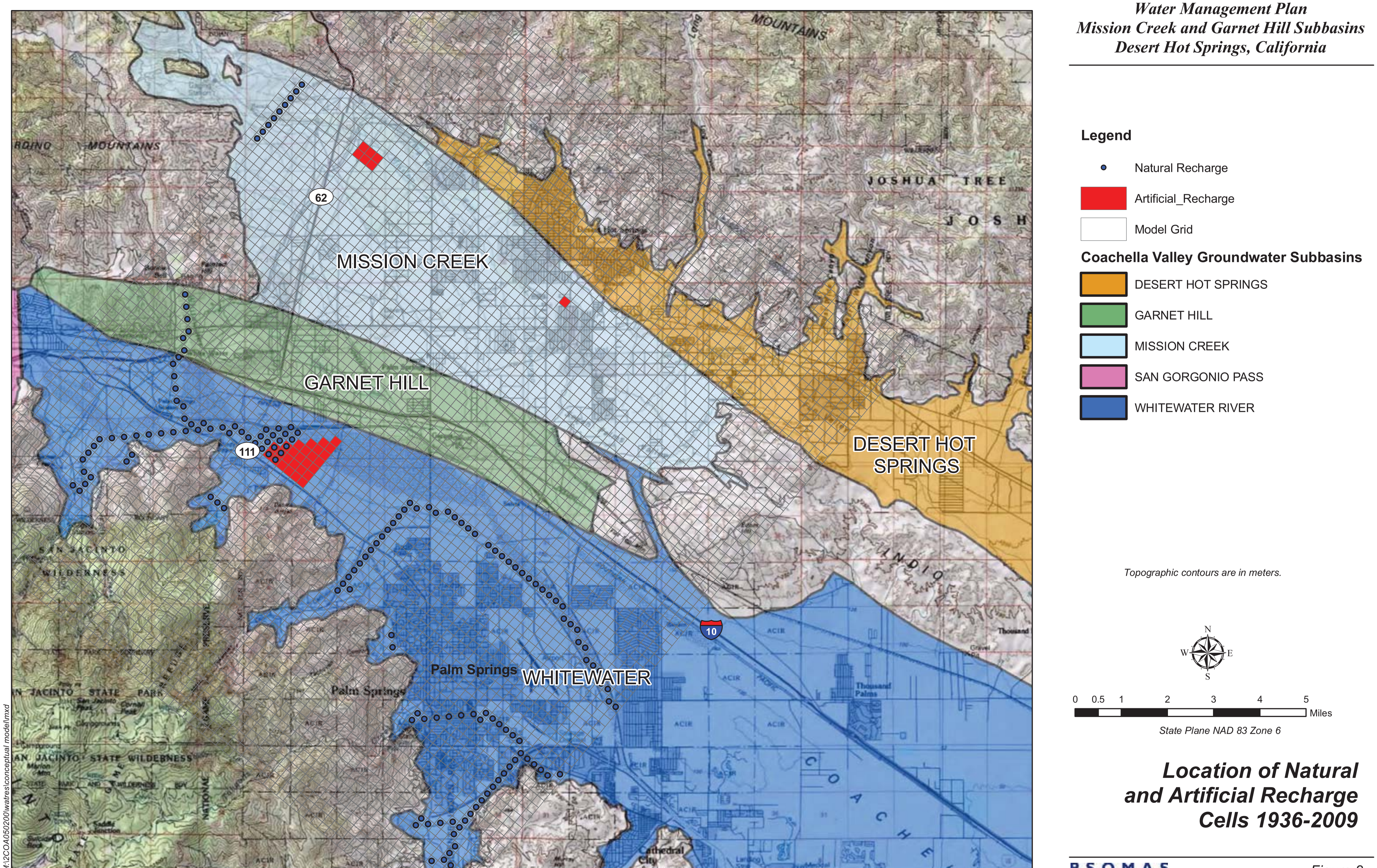
0 0.5 1 2 3 4 5 Miles

State Plane NAD 83 Zone 6

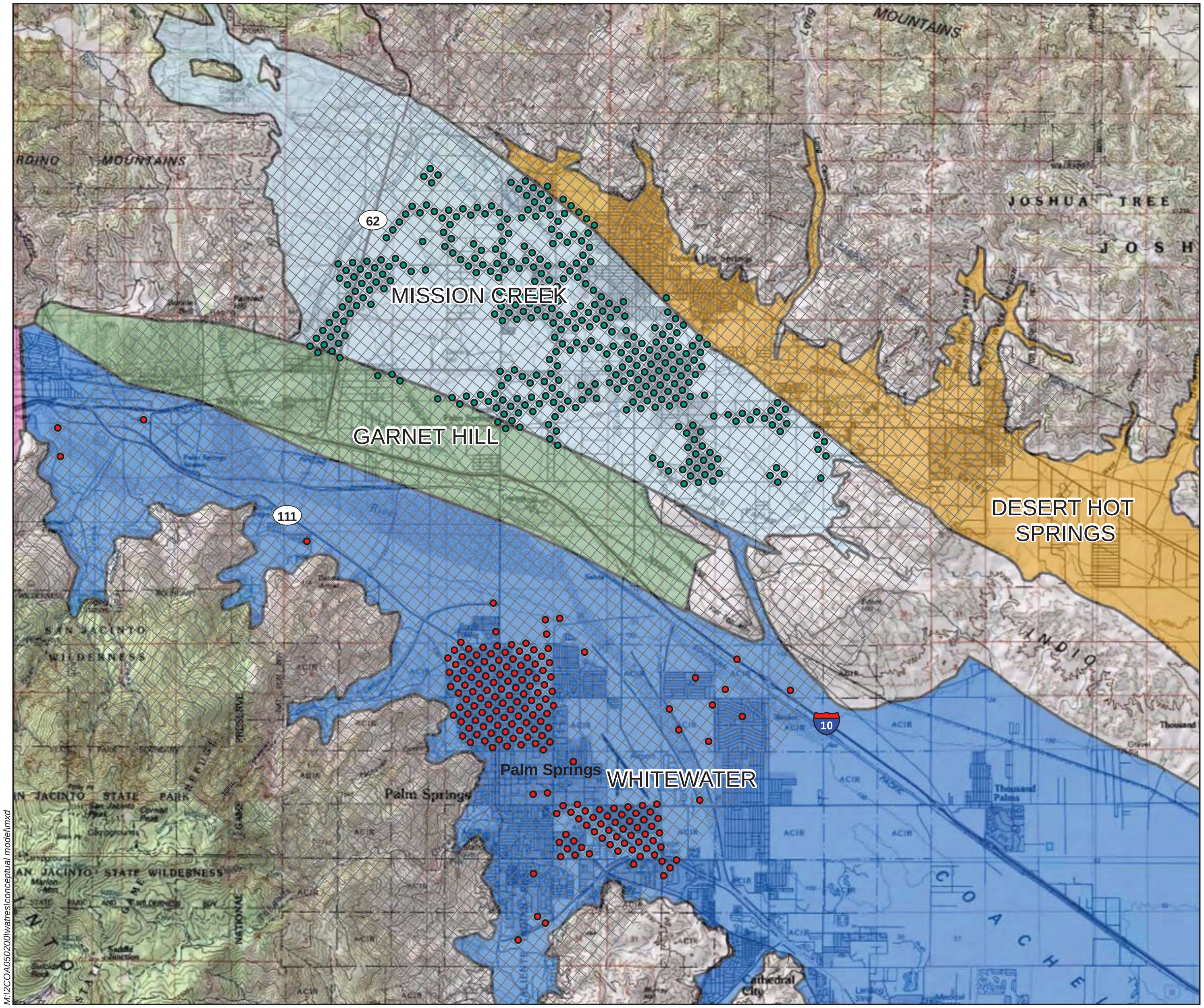
Model Mesh and Boundaries

PSOMAS

Figure 7



Location of Natural and Artificial Recharge Cells 1936-2009



Water Management Plan
Mission Creek and Garnet Hill Subbasins
Desert Hot Springs, California

Legend

- Mission Creek/Garnet Hill Return Flows
- Whitewater Return Flow
- Model Grid

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER

Topographic contours are in meters.

N E S W

0 0.5 1 2 3 4 5 Miles

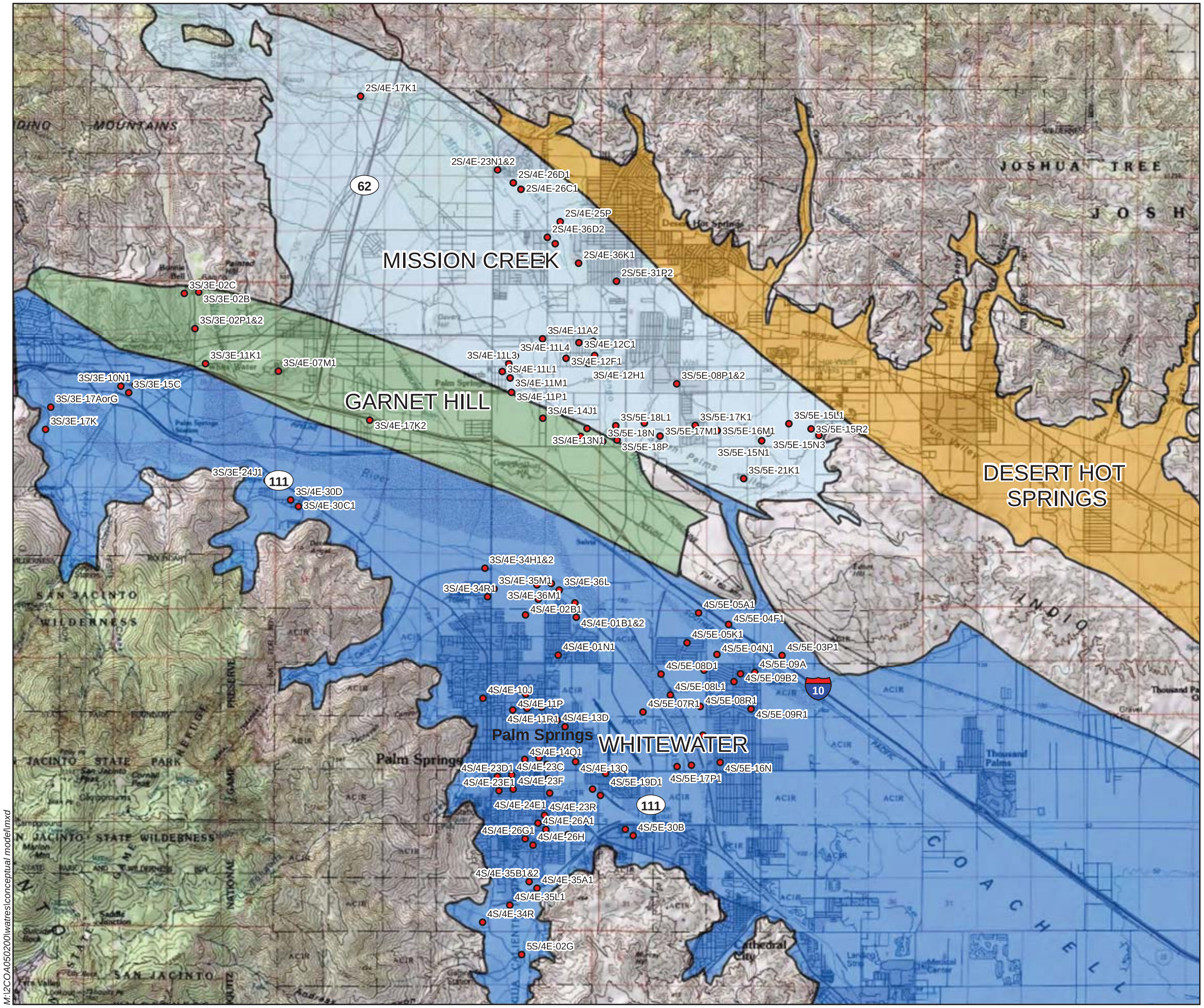
State Plane NAD 83 Zone 6

Location of Return Flow Cells 1936-2009

PSOMAS

Figure 9

M:\2COA050200\watres\conceptual model.mxd



Legend

- Production Wells

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER

Source: Base map from USA Topo.
Groundwater subbasins from DWR, 2004a;
DWR, 2004b; and DWR, 1964.
Well locations from Psomas, 2010
(see Appendix A and D).

Topographic contours are in meters.

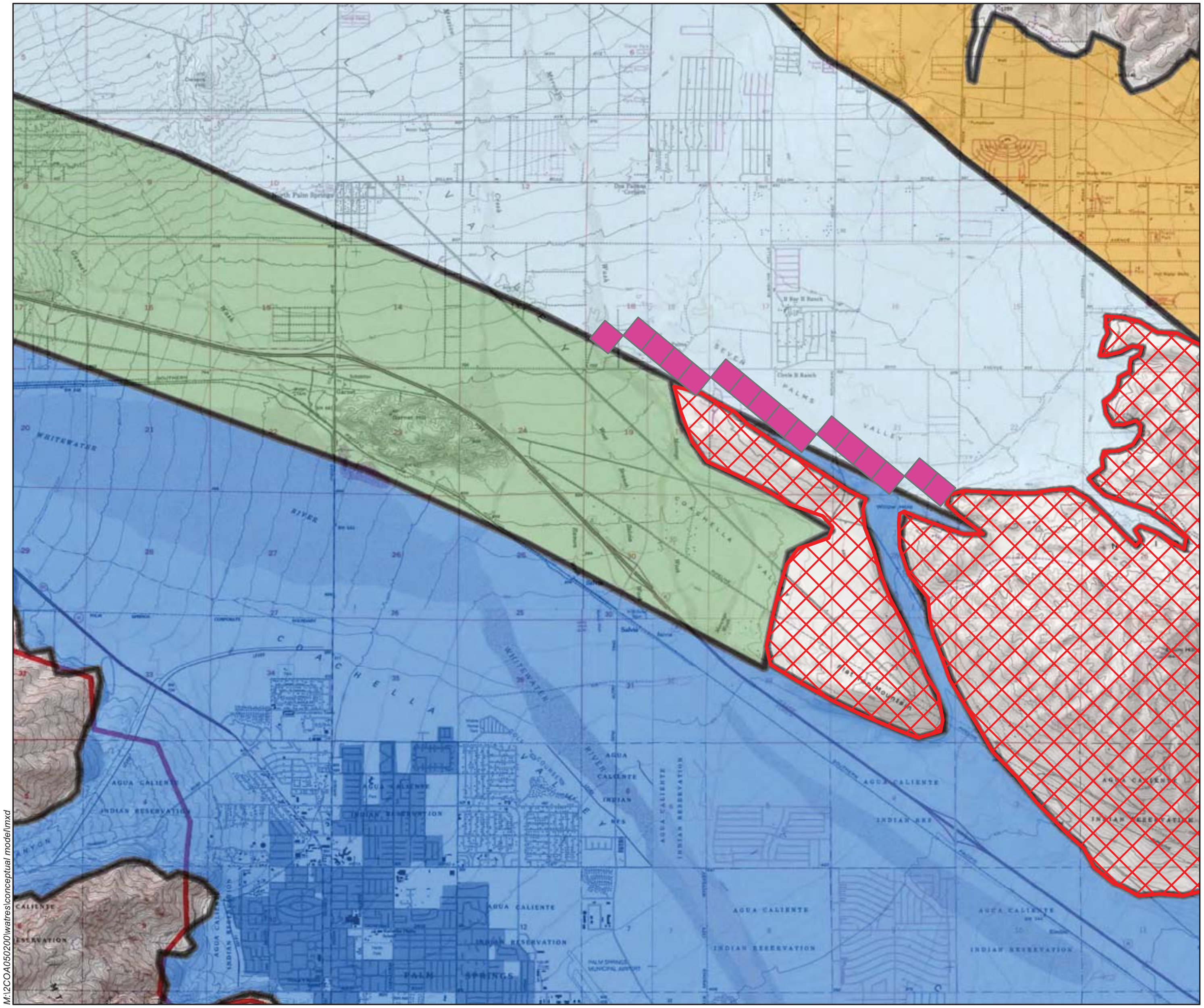
N W E S

0 0.5 1 2 3 Miles

State Plane NAD 83 Zone 6

Location of Wells with Production Information 1936-2009

M:\2COA050200\watres\conceptual model.mxd



Legend

Phreatophytes

Coachella Valley Groundwater Subbasins

DESERT HOT SPRINGS
GARNET HILL
MISSION CREEK
SAN GORGONIO PASS
WHITEWATER RIVER
Semi-waterbearing Rocks

Source: Base map from USA Topo.
Groundwater subbasins from DWR, 2004a; DWR, 2004b; and DWR, 1964.
Model grid based on Fogg et al., 2000.
Phreatophyte locations derived from Mayer, 2007.

Topographic contours are in meters.

N W E S

0 0.5 1 2 Miles

State Plane NAD 83 Zone 6

Location of Model Cells with Discharge Associated with Phreatophytes

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FIGURE 12
STEADY-STATE CALIBRATION: OBSERVED VS. COMPUTED GROUNDWATER ELEVATIONS

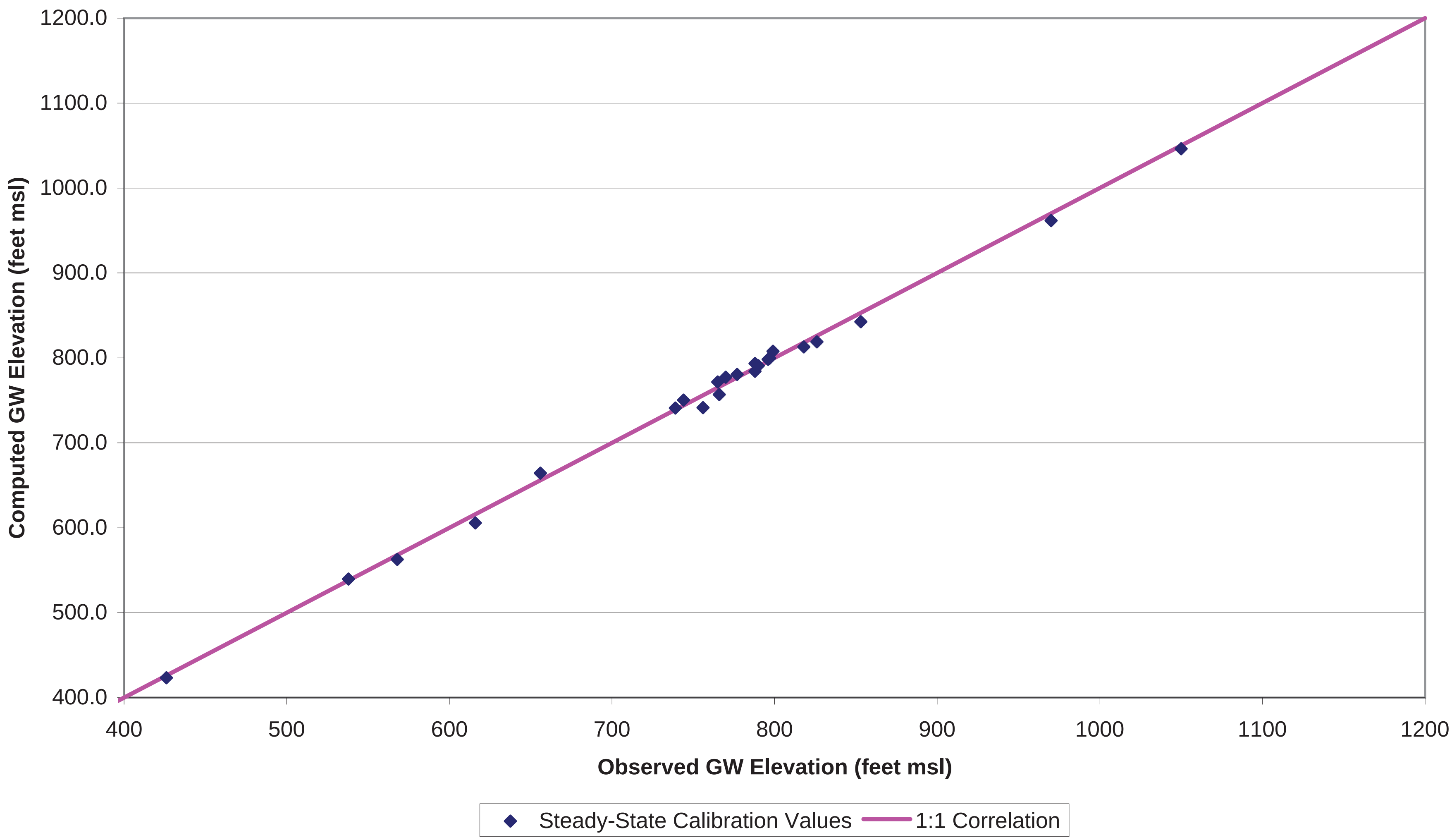
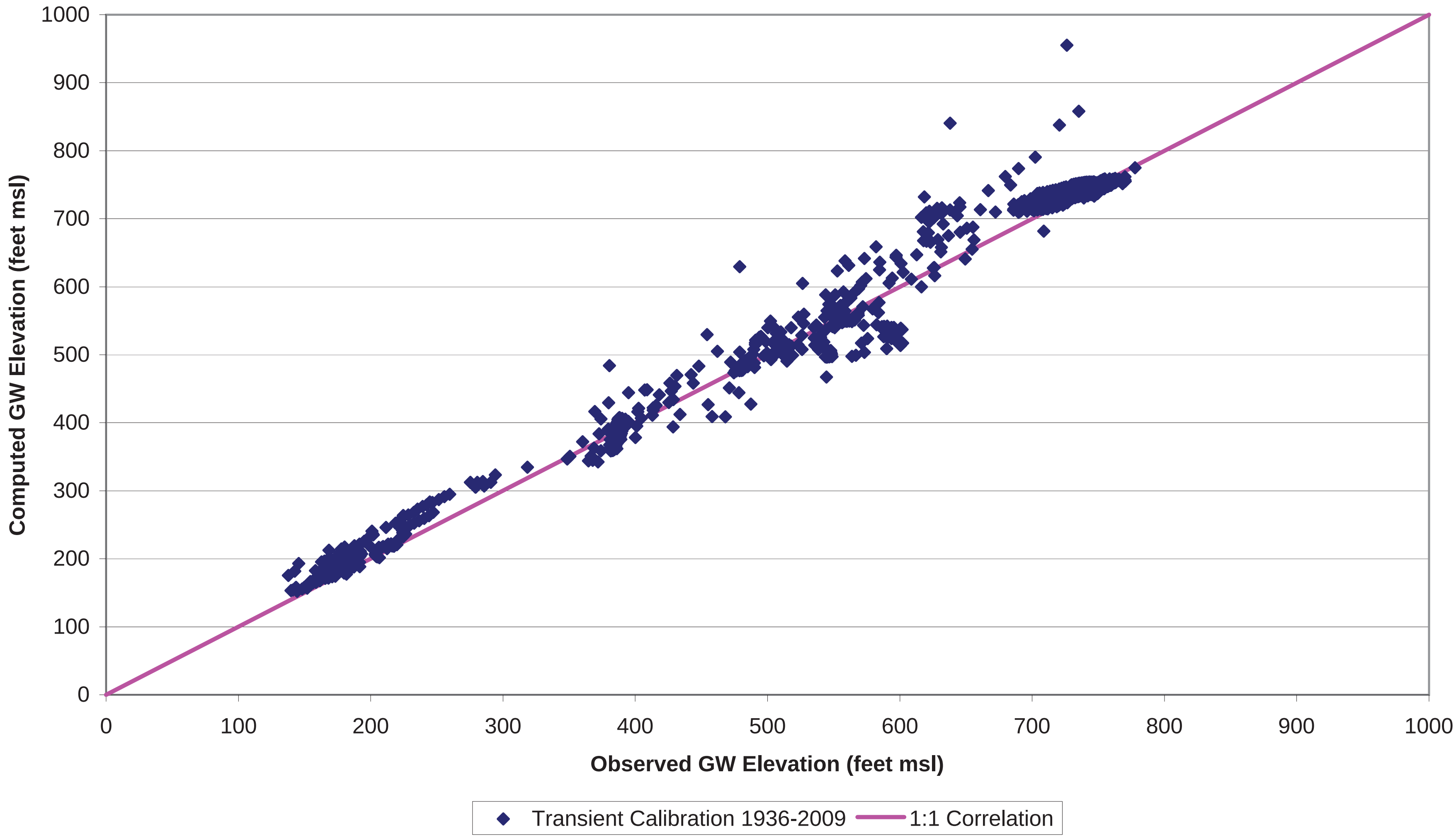
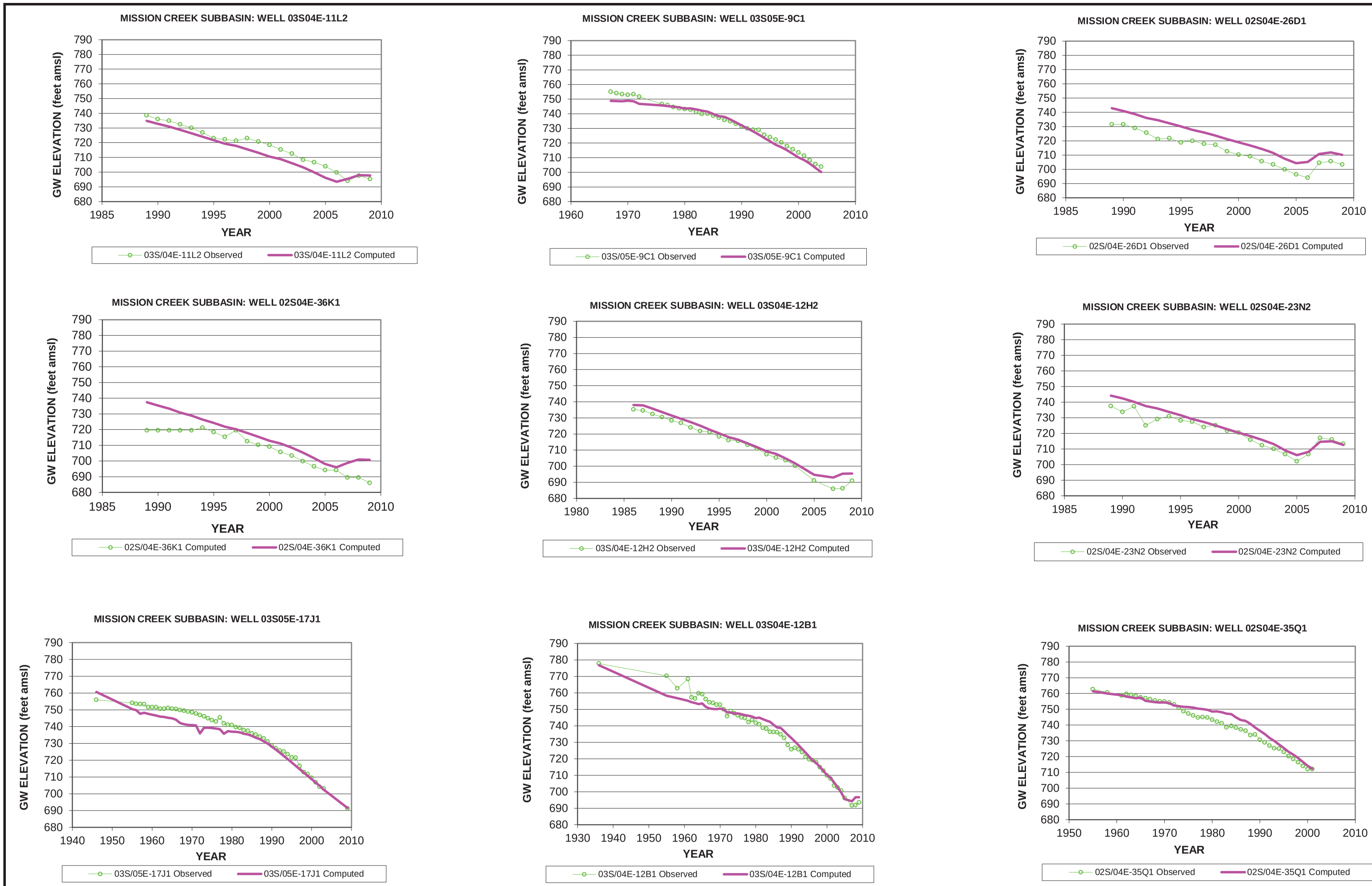


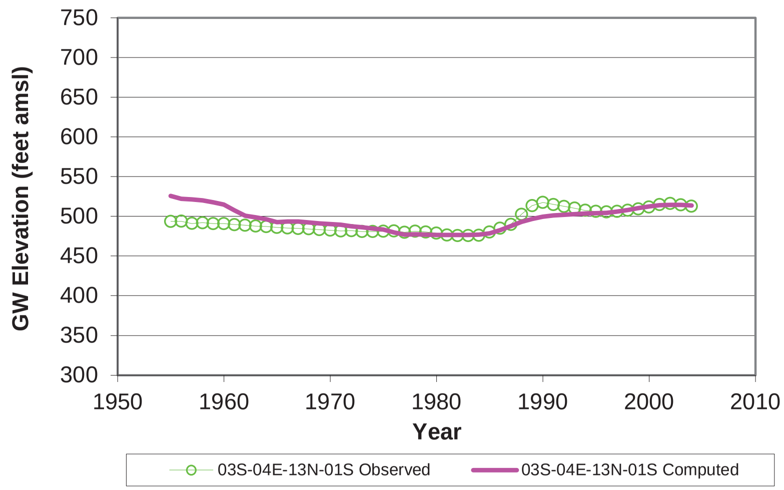
FIGURE 13
TRANSIENT CALIBRATION: OBSERVED VS COMPUTED GROUNDWATER ELEVATIONS



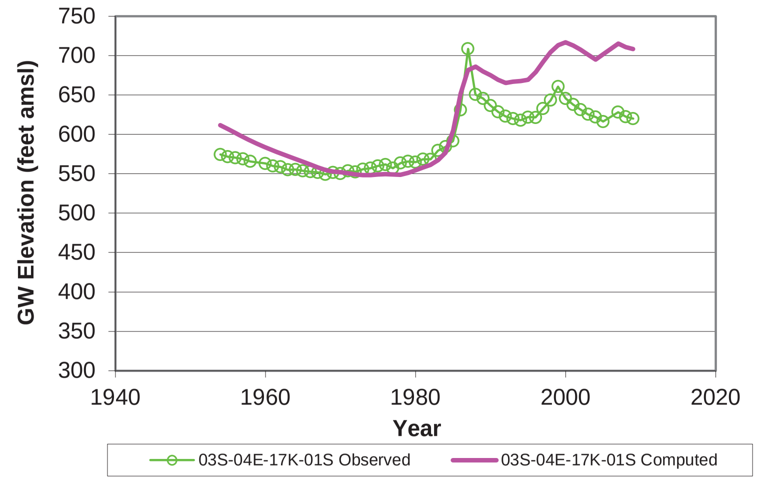


MISSION CREEK SUBBASIN HYDROGRAPHS
TRANSIENT MODEL RESULTS
FIGURE 14

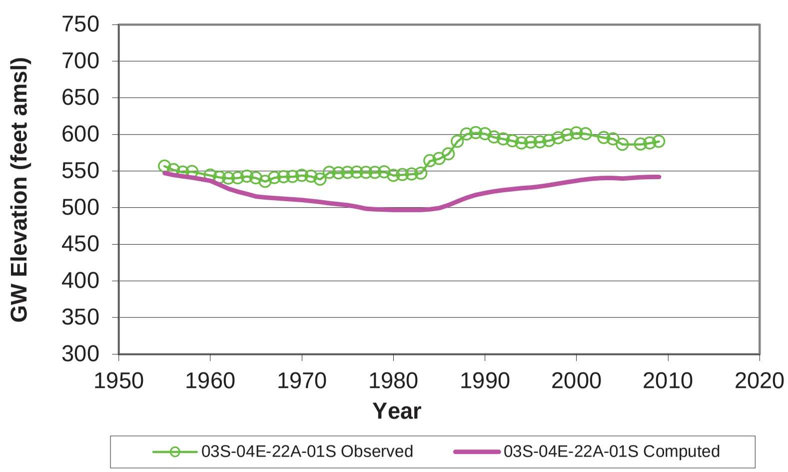
GARNET HILL SUBBASIN: 03S04E-13N1



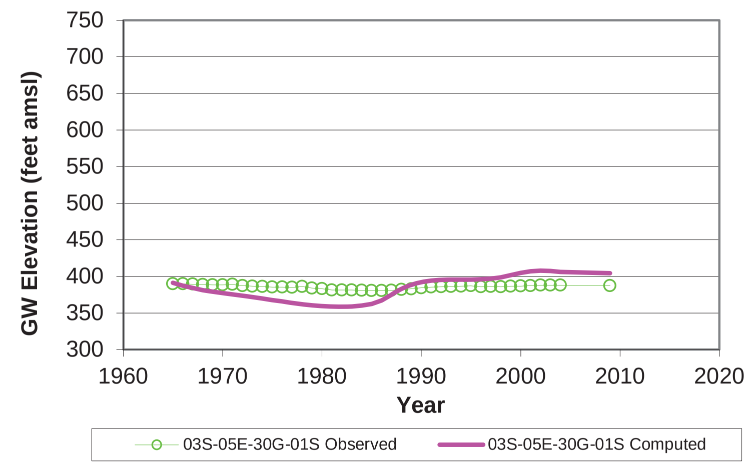
GARNET HILL SUBBASIN: WELL 03S04E-17K1



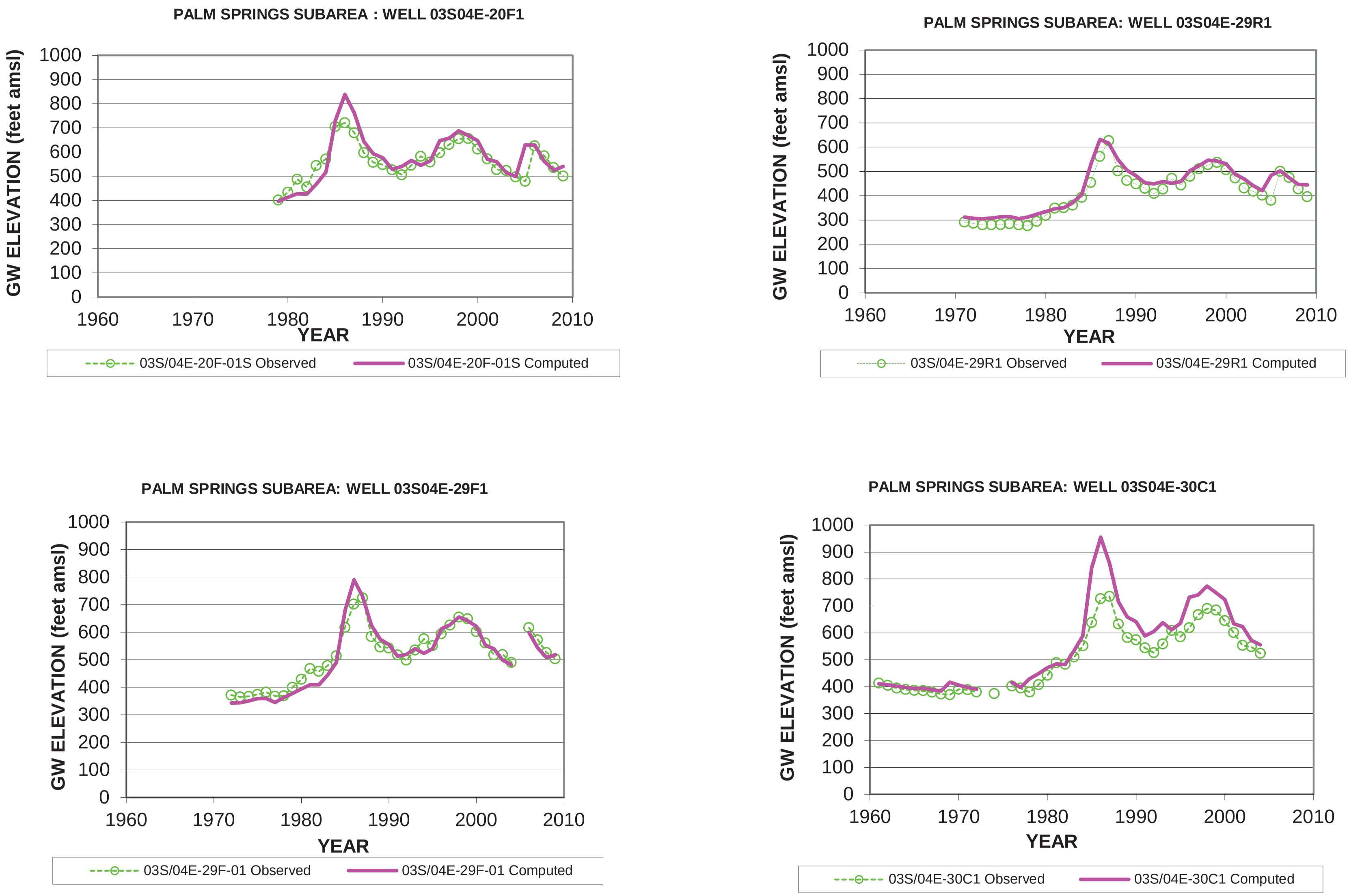
GARNET HILL SUBBASIN: WELL 03S04E-22A1



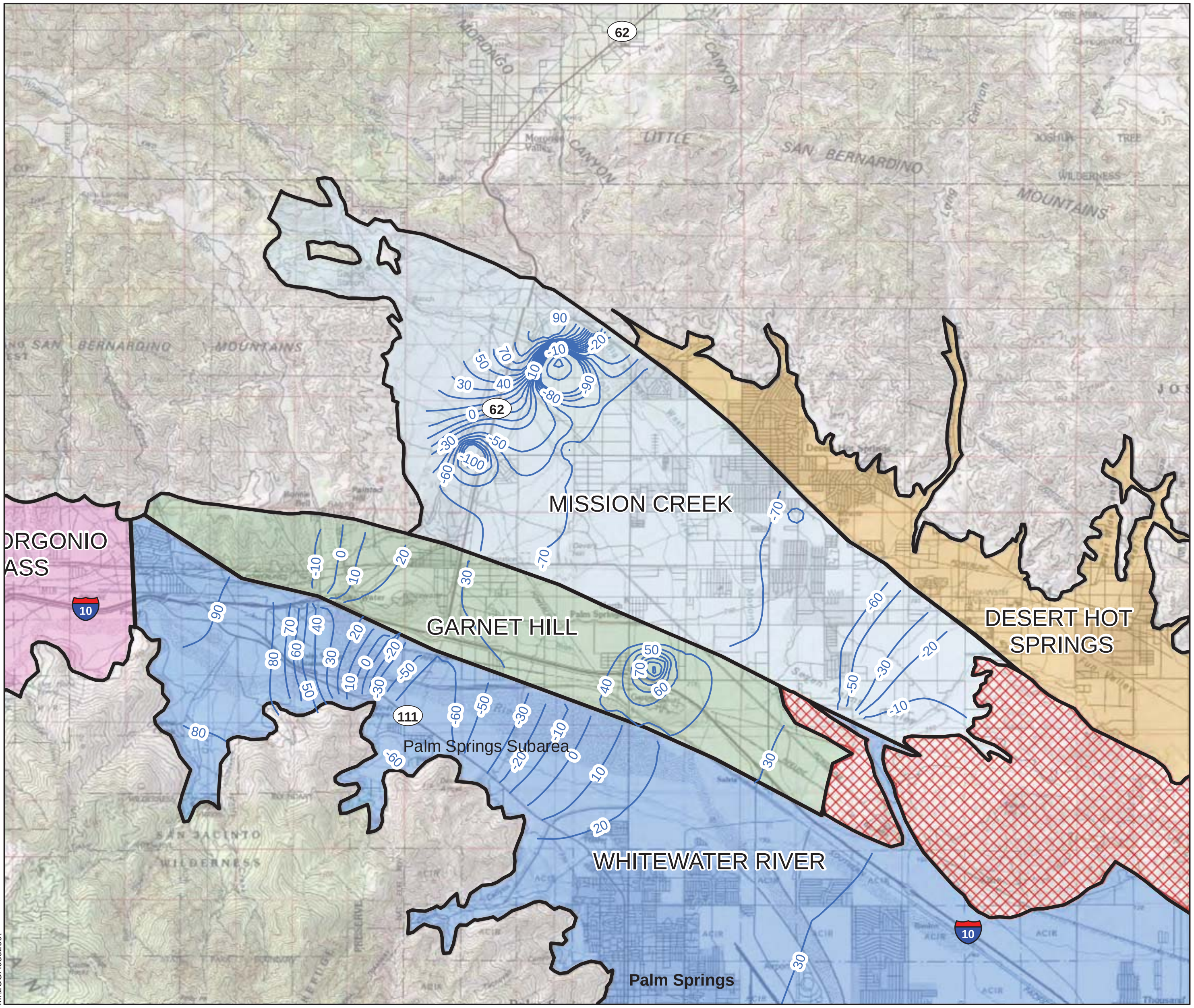
GARNET HILL SUBBASIN: WELL 03S05E-30G1



GARNET HILL SUBBASIN HYDROGRAPHS
TRANSIENT MODEL RESULTS
FIGURE 15



PALM SPRINGS SUBAREA HYDROGRAPHS
TRANSIENT MODEL RESULTS
FIGURE 16



Legend

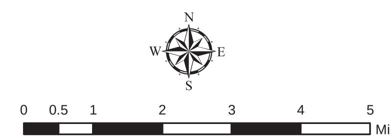
Groundwater Elevation Change (in feet)

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER
- Semi-waterbearing rocks

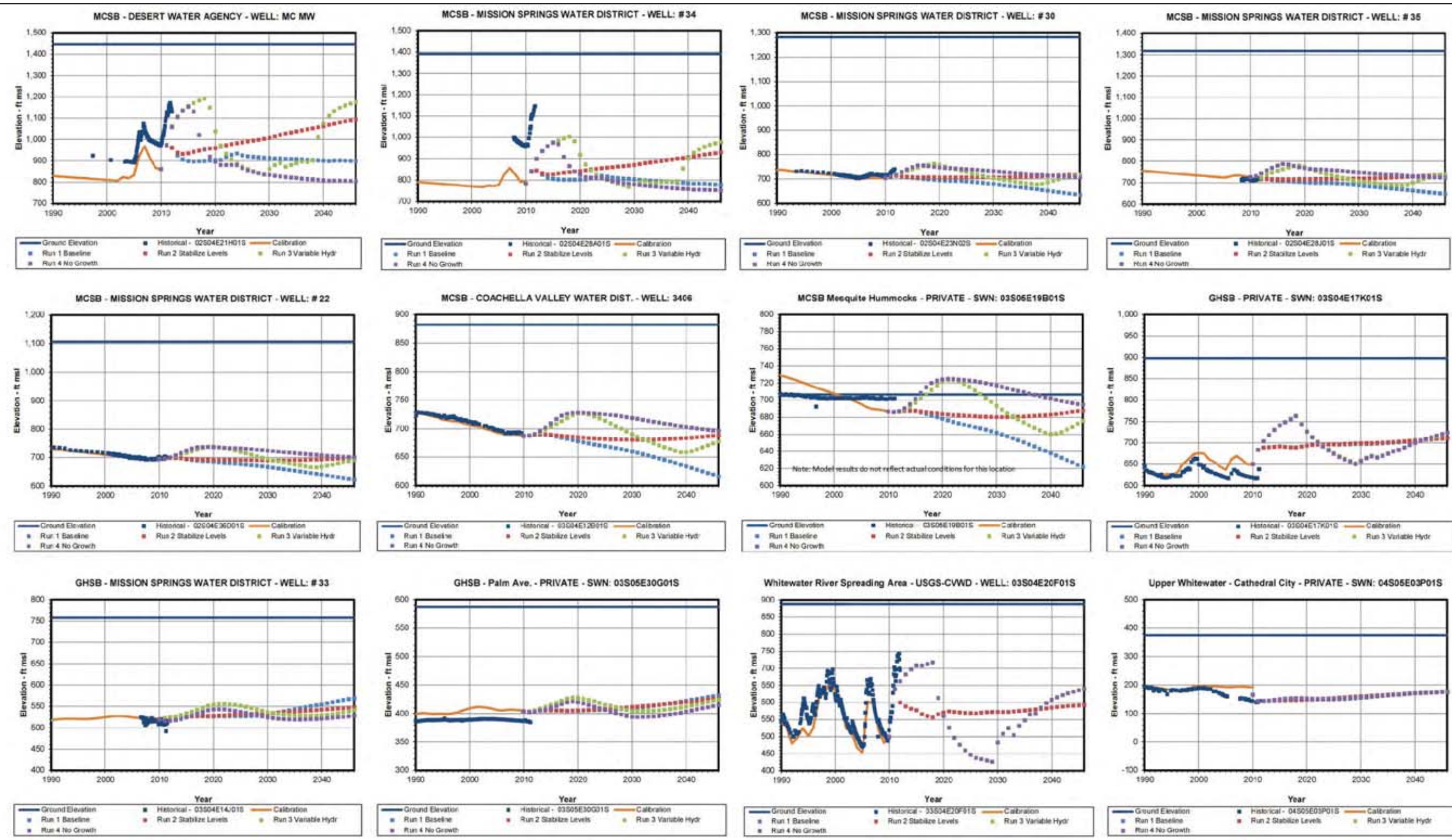
Topographic contours are in meters.

Source: Base map from USA Topo.
Groundwater subbasins from DWR, 2004a; DWR, 2004b and DWR, 1964.



State Plane NAD 83 Zone 6

Overall Change in Groundwater Levels for Model Run #1 (2010-2045)



Well Hydrographs for Mission Creek and Garnet Hill Subbasins Model Run Nos. 1, 2, 3, & 4

PSOMAS

Figure 18

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Figure 19
Cumulative Change in Storage - Mission Creek Subbasin

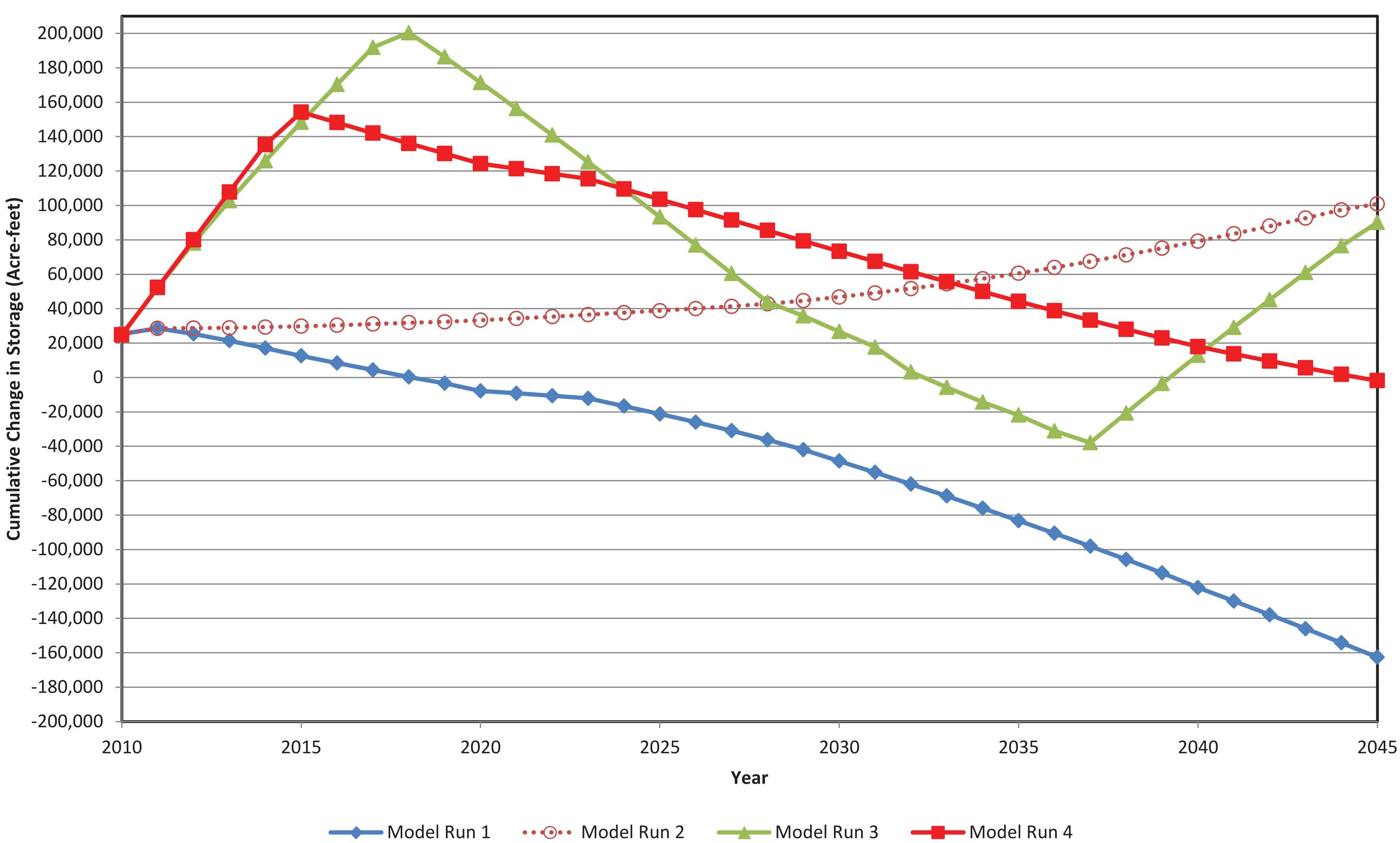
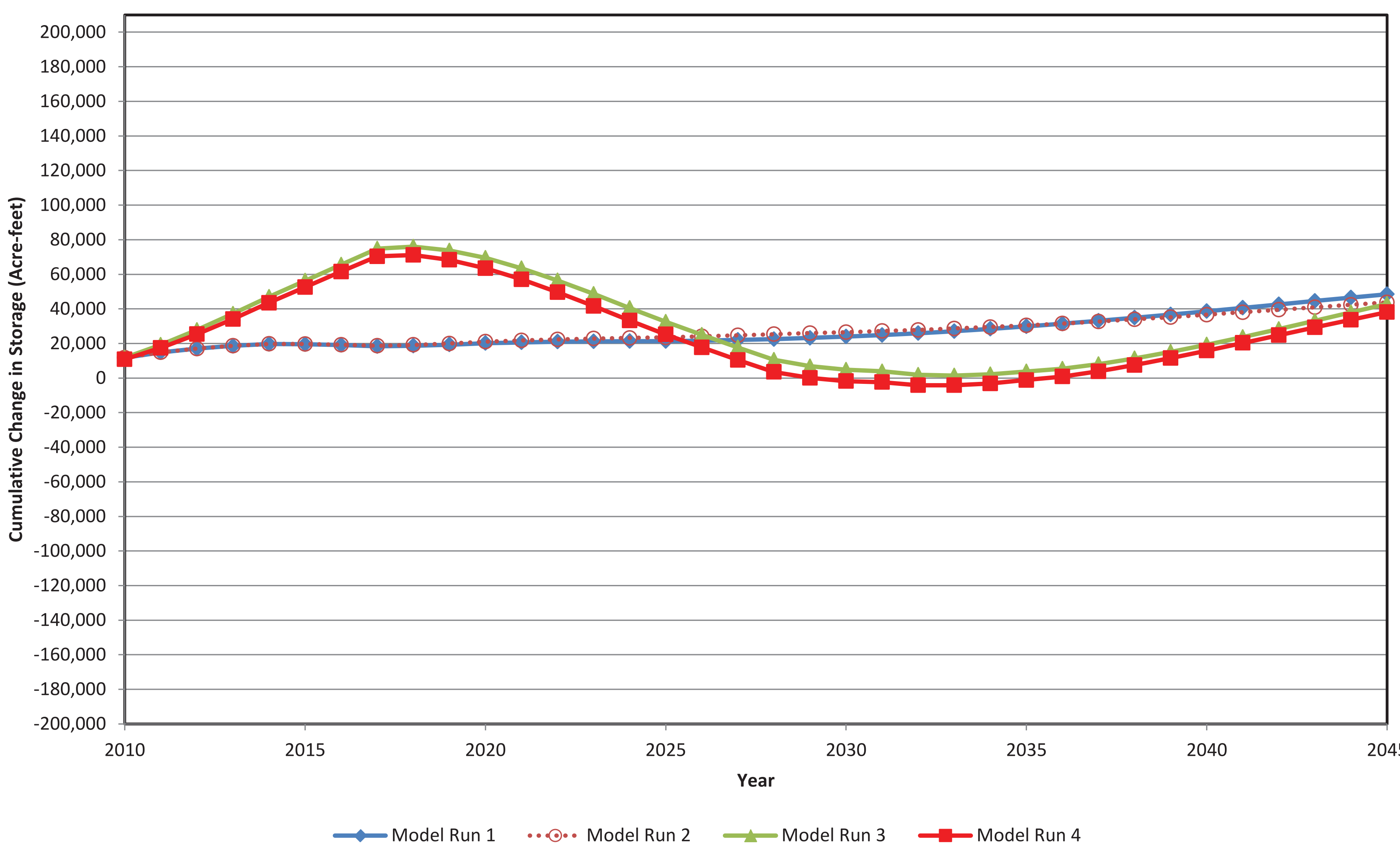
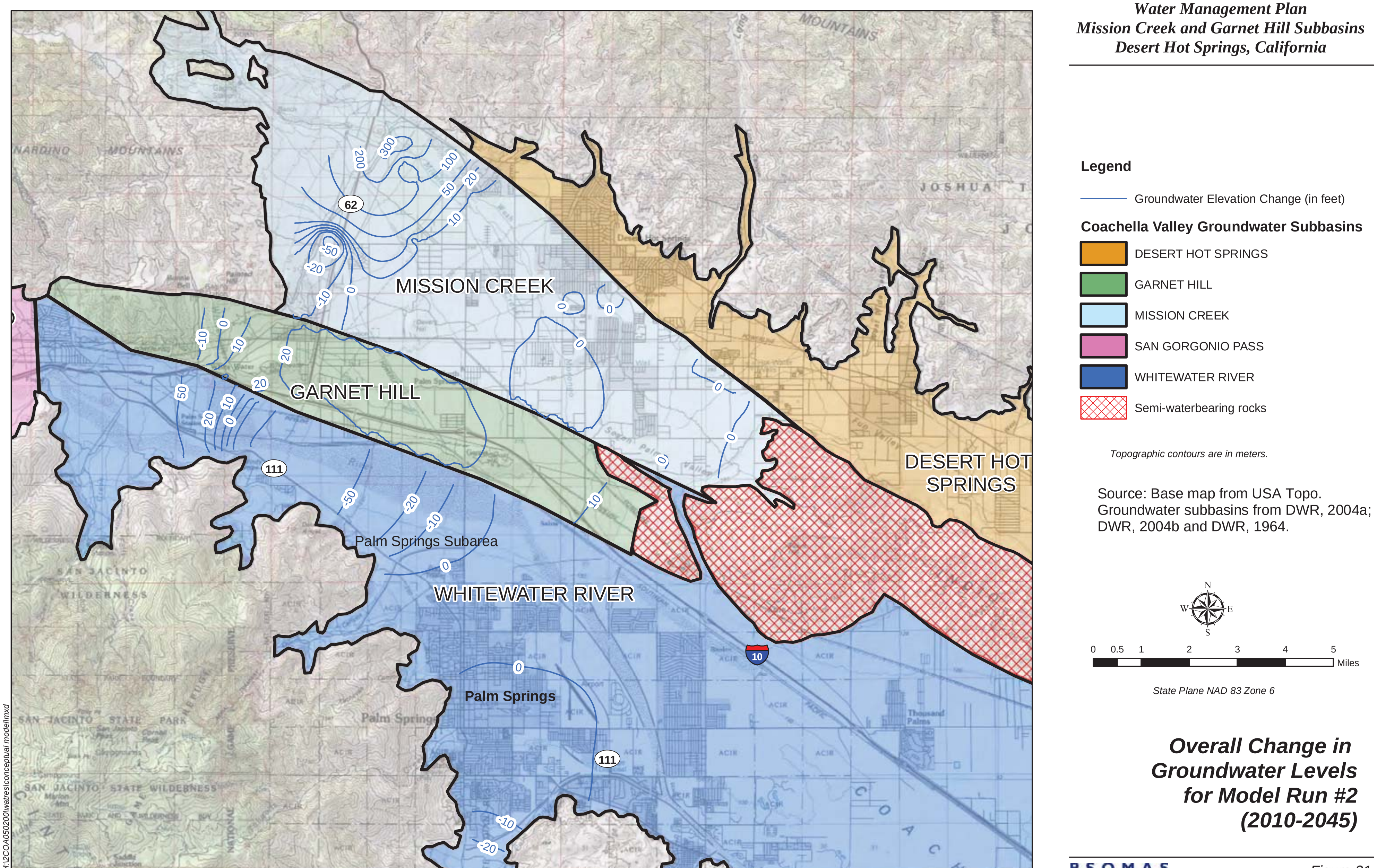


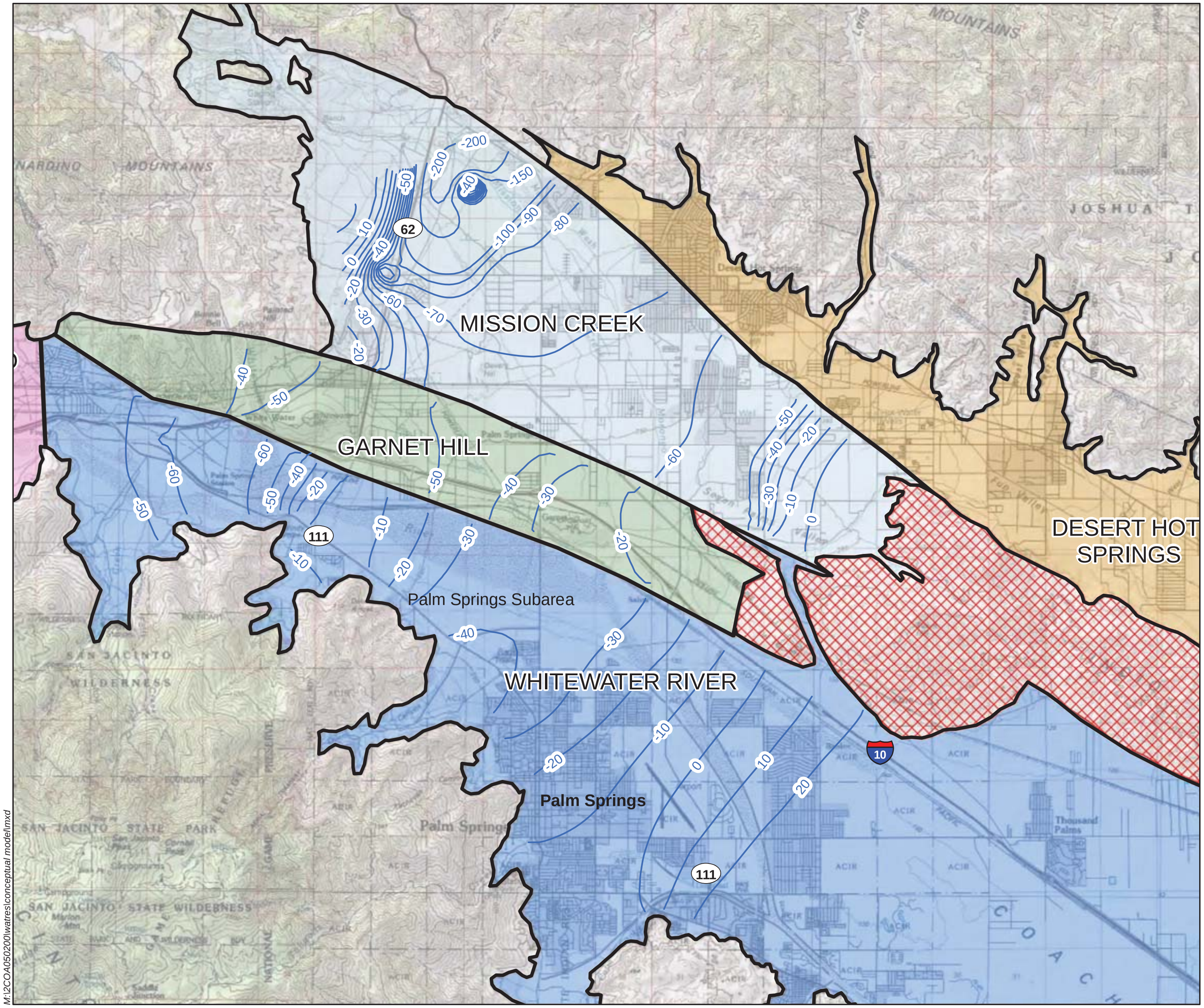
Figure 20
Cumulative Change in Storage - Garnet Hill Subbasin





Overall Change in Groundwater Levels for Model Run #2 (2010-2045)

PSOMAS



Legend

Groundwater Elevation Change (in feet)

Coachella Valley Groundwater Subbasins

- DESERT HOT SPRINGS
- GARNET HILL
- MISSION CREEK
- SAN GORGONIO PASS
- WHITEWATER RIVER
- Semi-waterbearing rocks

Topographic contours are in meters.

Source: Base map from USA Topo. Groundwater subbasins from DWR, 2004a; DWR, 2004b and DWR, 1964.

N W E S

0 0.5 1 2 3 4 5 Miles

State Plane NAD 83 Zone 6

Overall Change in Groundwater Levels for Model Run #3 (2018-2038)

PSOMAS

Figure 22

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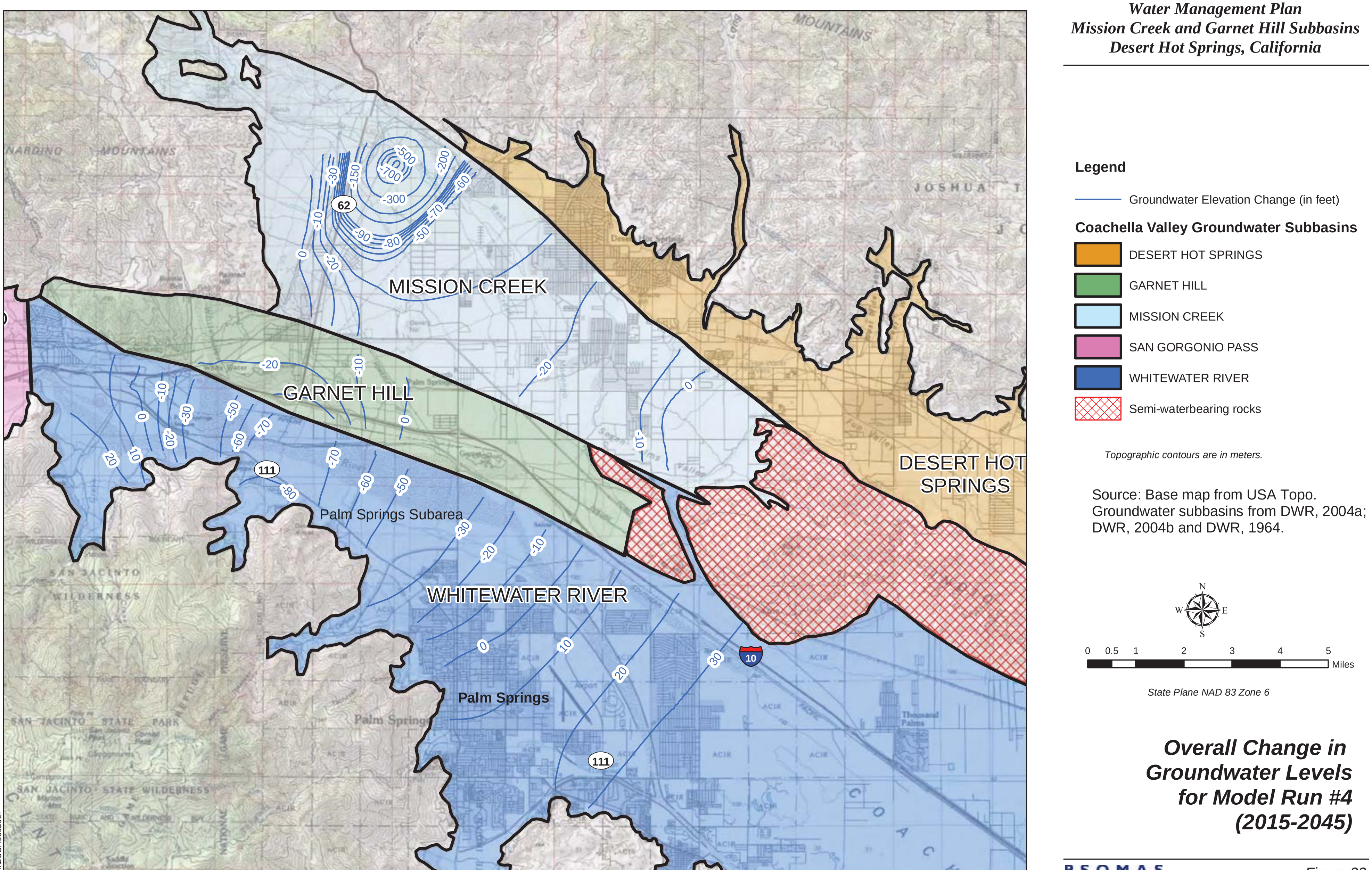

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Overall Change in Groundwater Levels for Model Run #4 (2015-2045)

PSOMAS

Figure 23

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Appendix C
Conservation Areas

The following discusses the sensitive species and habitats potentially affected in each conservation area within the Planning Area.

Whitewater Canyon Conservation Area

The Whitewater Canyon Conservation Area includes the Whitewater River and its watershed north of Interstate 10. Of the total 14,170 acres, approximately 11,707 acres are within the Planning Area. Portions of the San Bernardino Mountains are a sand source for the Whitewater River fluvial sand transport system. This system is an essential ecological process for several species. The core habitat for this Conservation Area contains riparian birds, desert tortoise, and the triple-ribbed milkvetch. A complete list of species can be found in Section 4.3.4 of the CVMSHCP. Historically, this Conservation Area contains the only confirmed habitat for the arroyo toad. The natural communities include: Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, Sonoran cottonwood-willow riparian forest, desert fan palm oasis woodland, semi-desert chaparral, chamise chaparral, and interior live oak chaparral. The Conservation Area also provides a biological corridor under Interstate 10 along the Whitewater River and serves as a linkage between the San Bernardino Mountains and Snow Creek/Windy Point Conservation Areas (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Triple-ribbed milkvetch, arroyo toad, and desert tortoise habitat preservation
- Sand source conservation in the San Bernardino Mountains for the maintenance of the blowsand ecosystem
- Maintain Whitewater River's current capacity for fluvial sand transport

Upper Mission Creek/Big Morongo Canyon Conservation Area

Due west of the Whitewater Canyon Conservation Area is the Upper Mission Creek/Big Morongo Canyon Conservation Area. This Conservation Area encompasses the Mission Creek watershed, Big Morongo Canyon watershed, portions of the Mission Creek flood control channel and the Morongo Wash within the City of Desert Hot Springs. Of the total 29,440 acres, approximately 25,941 acres are within the Planning Area. With the exception of the flood control areas and associated habitat conservation along the Morongo Wash, private land within the City of Desert Hot Springs is not included in this Conservation Area based on the decision of the Desert Hot Springs City Council.

The core habitat for this Conservation Area includes the largest habitat area for the Little San Bernardino Mountains linanthus, as well as habitat for the triple-ribbed milkvetch, Palm Spring pocket mouse, desert tortoise, and burrowing owl. A complete list of species can be found in Section 4.3.7 of the CVMSHCP. Historically, this Conservation Area contains the only confirmed habitat for the arroyo toad. The natural communities include: Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, Sonoran cottonwood-willow riparian forest, desert fan palm oasis woodland, semi-desert chaparral, chamise chaparral, and interior live oak chaparral. The Conservation Area also provides a biological corridor under Interstate 10 along the Whitewater River and serves as a linkage between the San Bernardino Mountains and Snow Creek/Windy Point Conservation Areas (CVMSHCP, 2009).

The major water-related objectives for this conservation area are:

- Preserve the Little San Bernardino Mountains linanthus, triple-ribbed milkvetch, desert tortoise, Palm Springs pocket mouse and the associated ecological processes
- Preserve fluvial sand transport areas in the Desert Hot Springs, Palm Springs, and Riverside County areas
- Conserve Le Conte's thrasher, Coachella Valley Jerusalem cricket, and burrowing owl habitats
- Maintain existing fluvial sand transport along Mission Creek Channel

Long Canyon Conservation Area

The Long Canyon Conservation Area includes the 100-year floodplain and extends southwest from the Long Canyon flood control channel to the northern boundary of the Willow Hole Preserve at 20th Avenue. Mountain View Road is the conservation area's westernmost boundary. The entire conservation area is located within the Planning Area and contains approximately 810 acres. As described in Section 4.3.9 of the CVMSHCP, this conservation area does not provide core habitat for any species, however other conserved habitat has been noted for the Coachella Valley milkvetch, Coachella Valley Jerusalem cricket, desert tortoise, burrowing owl, Le Conte's thrasher, Coachella Valley round-tailed ground squirrel, Palm Springs pocket mouse and potentially the flat-tailed horned lizard. Natural communities include the Sonoran creosote bush scrub and the Sonoran mixed woody and succulent scrub. The major objective for this conservation area is to provide fluvial sand transport in flood conditions to the Willow Hole Preserve (CVMSHCP, 2009).

West Deception Canyon Conservation Area

Located north of the Indio Hills, the West Deception Canyon Conservation Area is a significant sediment transportation area between the Little San Bernardino Mountains and the Thousand Palms Canyon and the Coachella Valley Fringe-toed Lizard Preserve (CVFTL). The entire conservation area is located within the Planning Area and contains approximately 4,150 acres. While this conservation area does not provide core habitat for any covered species, it does contain conserved habitat for the Coachella Valley milkvetch, desert tortoise, Le Conte's thrasher, Coachella Valley round-tailed ground squirrel, and the Palm Springs pocket mouse. Natural communities listed in Section 4.3.12 of the CVMSHCP include the Sonoran creosote bush scrub and the Mojave mixed woody scrub (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Maintain the natural erosion processes that provide sediment for the blowsand ecosystem
- Maintain existing fluvial sand transport in the West Deception Canyon

Indio Hills/Joshua Tree National Park Linkage Conservation Area

The Indio Hills/Joshua Tree National Park Linkage Conservation Area is bounded to the north by the Joshua Tree National Park, to the south by the Thousand Palms Conservation Area, to the east by includes the West Deception Canyon and to the east by the Desert Tortoise and Linkage Conservation Area. Of the total 13,410 acres, approximately 12,642 acres are within the Planning Area. Core habitat for the desert tortoise is included in this Conservation Area as described in Section 4.3.13 of the CVMSHCP. Other conserved habitat occurs here however the area is not large enough to maintain viable populations of species. Natural communities include Sonoran creosote bush scrub and Mojave mixed woody scrub. The Conservation Area provides a biological corridor between the Indio Hills and Joshua Tree National Park. This area is also classified as a contact zone between the Palm Spring pocket mouse and the little pock mouse. A separate biological corridor is located within the Pushawalla Canyon. The topographic Biological linkage between the National Park (5000') and the Indio Hills (near sea level) contributes to the climate-induced habitat and resulting biodiversity (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Desert tortoise and Le Conte's thrasher habitat preservation
- Maintain the Little San Bernardino Mountain wash current capacity for fluvial sand transport

Desert Tortoise and Linkage Conservation Area

The Desert Tortoise Linkage Conservation Area is located between the Mecca Hills to the west and the Orocopia Mountains Wilderness/Joshua Tree National Park to the east. Interstate 10 divides this conservation area. Of the total 89,900 acres, approximately 2,308 acres are within the Planning Area. In addition to providing core habitat for its namesake, this area contains other conserved habitat for the Le Conte's thrasher, Coachella Valley round-tailed ground squirrel, the Palm Springs pocket mouse and certain migratory riparian birds. A detailed list of species can be found in Section 4.3.17 of the CVMSHCP. Natural communities include the Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, and desert dry wash woodland.

The Conservation Area also provides a biological corridor under Interstate 10 and serves as a linkage between the Mecca Hills and Orocopia Mountain Wilderness with Joshua Tree Nation Park (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Desert tortoise, Mecca aster, Orocopia sage, Le Conte's thrasher habitat preservation
- Maintain current capacity for fluvial sand transport in the dry desert wash woodland for riparian birds

Indio Hills Palms Conservation Area

The Indio Hills Palms Conservation Area includes the Whitewater River and its watershed north of Interstate 10. Of the total 14,170 acres, approximately 1,446 acres are within the Planning Area. Portions of the San Bernardino Mountains are a sand source for the Whitewater River fluvial sand transport system. This system is an essential ecological process for several species. The core habitat for this Conservation Area contains riparian birds, desert tortoise, and the triple-ribbed milkvetch. A complete list of species can be found in Section 4.3.14 of the CVMSHCP. Historically, this Conservation Area contains the only confirmed habitat for the arroyo toad. The natural communities include: Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, Sonoran cottonwood-willow riparian forest, desert fan palm oasis woodland, semi-desert chaparral, chamise chaparral, and interior live oak chaparral. The Conservation Area also provides a biological corridor under Interstate 10 along the Whitewater River and serves as a linkage between the San Bernardino Mountains and Snow Creek/Windy Point Conservation Areas (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Mecca aster and Le Conte's thrasher habitat preservation
- Conservation of natural communities: desert dry wash woodland (riparian birds), mesquite hummocks (riparian birds), and desert fan palm oasis woodland (southern yellow bat)
- Maintain current capacity for fluvial sand transport in the dry desert wash woodland for riparian birds

Thousand Palms Conservation Area

The Thousand Palms Conservation Area includes the CVFTL Preserve and the Indio Hills sand source/transport. This area includes the proposed Whitewater River Flood Control Project and is the hottest and driest area of the Coachella Valley floor. Of the total 25,900 acres, approximately 7,379 acres are within the Planning Area. The core habitat for this Conservation Area contains the Coachella Valley milkvetch, Coachella Valley giant sand-treader cricket, Coachella Valley fringe-toed lizard, flat-tailed lizard, Coachella Valley round-tailed ground squirrel and the Palm Springs pocket mouse and Mecca aster habitat. A complete list of species can be found in Section 4.3.11 of the CVMSHCP. Additionally, the Le Conte thrasher and burrowing owl conserved habitat occurs in this area. The natural communities include active desert dunes, active desert sand fields, mesquite hummocks, Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, Sonoran cottonwood-willow riparian forest, desert dry wash woodland, and desert fan palm oasis woodland. The Conservation Area also provides biological corridors and linkages to the Willow Hole Conservation Area, Edom Hill Conservation Area, East Indio Hills Conservation Area, Indio Hills Palms Conservation and the Indio Hills/Joshua Tree National park Linkage Conservation Area. Desert bighorn sheep, bobcats, kit foxes searching for water, depend on the linkage from the National Park to the Indio Hills (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Habitat preservation for the species listed above
- Sand source conservation for the maintenance of the blowsand ecosystem
- Maintain current capacity for fluvial sand transport for washes in the Indio Hills for the Thousand Palms Conservation Area.
- Conserve groundwater levels necessary to maintain refugia locations for desert pupfish and natural communities listed above

Edom Hill Conservation Area

Located between the Willow Hole Preserve and the Thousand Palms Conservation Area, the Willow Hole Conservation Area is includes portions of the Indio Hills. Of the total 9,090 acres, approximately 1,119 acres are within the Planning Area. This area does not encompass core habitat for any covered species, however several conserved habitat area located here including: Coachella Valley milkvetch, Mecca aster, Coachella Valley giant sand-treader cricket, Coachella Valley Jerusalem cricket, Coachella Valley fringe-toed lizard, flat-tailed horned lizard, Coachella Valley round-tailed ground squirrel and the Palm Springs pocket mouse. A complete list of species can be found in Section 4.3.10 of the CVMSHCP. The natural communities include desert sand fields, Sonoran creosote bush scrub, and Sonoran mixed woody and succulent scrub.

The Conservation Area provides linkages between Willow Hole and Thousand Palms Conservation areas for the above listed species as well as their predators (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Habitat preservation for the species listed above
- Maintain current capacity for fluvial sand transport from Indio Hills
- Conserve sand source adjacent to the Thousand Palms Conservation Area

Willow Hole Conservation Area

The Willow Hole Conservation Area is bounded by the Upper Mission Creek/Big Morongo Canyon Conservation Area and the Long Canyon Conservation Area to the north, Edom Hill Conservation Area to the east. The southern edge is bounded by a connection of culverts under Interstate 10 to the Whitewater Floodplain Conservation Area. Of the total 5,600 acres, approximately 3,206 acres are within the Planning Area. The core habitat for this Conservation Area contains the Coachella Valley milkvetch, Coachella Valley fringe-toed lizard, Coachella Valley round-tailed ground squirrel and the Palm Springs pocket mouse. Long-term viability of the fringe-toed lizard requires movement between the wetter, cooler western portion of the conservation area with the hotter drier central and eastern portions. A complete list of species can be found in Section 4.3.8 of the CVMSHCP. Additionally, the Le Conte thrasher and burrowing owl conserved habitat occurs in this area. The natural communities include desert dunes, desert sand fields, mesquite hummocks, Sonoran creosote bush scrub, Sonoran mixed woody and succulent scrub, desert salt bush scrub, and desert fan palm oasis woodland. This area contains two of the largest natural communities in the entire MSHCP: mesquite hummocks and desert dunes. Groundwater levels, north of the fault dunes, is critical for the preservation of the mesquite hummocks here. In addition, the desert dunes natural communities are necessary for the fringe-toed lizard habitat and represents nearly 93% of desert dunes in the entire MSHCP.

The Conservation Area also provides biological corridors and linkages to the Willow Hole Conservation Area, Edom Hill Conservation Area, East Indio Hills Conservation Area, Indio Hills Palms Conservation and the Indio Hills/Joshua Tree National park Linkage Conservation Area. Desert bighorn sheep, bobcats, kit foxes searching for water, depend on the linkage from the National Park to the Indio Hills (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Habitat preservation for the species listed above
- Conserve fluvial and Aeolian sand transport areas in Cathedral City and Riverside County.
- Maintain current capacity for fluvial sand transport in Mission Creek and Morongo Wash to Willow Hole/Edom Hill Reserve. Also maintain fluvial transport in Mission Creek Channel.
- Conserve mesquite hummocks and desert dunes

Whitewater Floodplain Conservation Area

The Whitewater Floodplain Conservation Area includes portions of the Whitewater River floodplain south of Interstate 10. This area contains habitat east and southeast of the CVFTL Preserve, west and east sides of the Gene Autry Trail, and south and east areas of CVWD's spreading basins. Of the total 7,400 acres, approximately 1,241 acres are within the Planning Area.

The core habitat for this Conservation Area contains the Coachella Valley milkvetch, Coachella Valley giant sand-treader cricket, Coachella Valley fringe-toed lizard, Coachella Valley round-tailed ground squirrel and Palm Springs pocket mouse. A complete list of species can be found in Section 4.3.6 of the CVMSHCP. Historically, this Conservation Area contains the only confirmed habitat for the arroyo toad. The natural communities include various desert sand fields, Sonoran creosote bush scrub and Sonoran mixed woody and succulent scrub. After connecting with the San Gorgonio River, the Whitewater River provides fluvial sand transport to the Whitewater Floodplain Preserve.

The Whitewater River provides a natural biological corridor and linkage to the Snow Creek/Windy Point Conservation Area. As of the printing of the CVMSHCP, CVWD is designing a channel on the south side of Interstate 10 for Edom Wash and Willow Wash flows for sand transport and wildlife movement between Willow Hole and Whitewater Floodplain Conservation Areas (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Habitat preservation for the species listed above

- Conserve desert sand fields in the City of Palm Springs and unincorporated sections of Riverside County
- Maintain Whitewater River floodplain's current capacity for fluvial sand transport

Stubbe and Cottonwood Canyons Conservation Area

The Stubbe and Cottonwood Canyons Conservation Area includes the northwest portion of Garnet Hill subbasin, north of Interstate 10 and west of Whitewater Canyon. This area also includes alluvial fans from Stubbe Canyon and Cottonwood Canyons. Of the total 9,840 acres, approximately 6,173 acres are within the Planning Area.

This conservation area contains the most dense population of desert tortoise in the entire MSHCP. Other species include the Coachella Valley milkvetch, Coachella Valley giant sand-treader cricket, Coachella Valley fringe-toed lizard, Coachella Valley round-tailed ground squirrel and Palm Springs pocket mouse. A complete list of species can be found in Section 4.3.6 of the CVMSHCP. Historically, this Conservation Area contains the only confirmed habitat for the arroyo toad. The natural communities include various desert sand fields, Sonoran creosote bush scrub and Sonoran mixed woody and succulent scrub. After connecting with the San Gorgonio River, the Whitewater River provides fluvial sand transport to the Whitewater Floodplain Preserve. However, when Colorado River water is diverted into the Whitewater River, sediment particles are trapped in the recharge basins and restrict the flow and affect sensitive habitat. This conservation area provides a biological corridor and linkage between the San Jacinto and Santa Rosa Mountains and the San Bernardino Mountains (CVMSHCP, 2009).

The major water related objectives for this conservation area are:

- Conserve Le Conte's thrasher nesting sites and burrowing owl burrows habitat.
- Conserve Sonoran cottonwood-will riparian forest and desert dry wash woodland for riparian birds.
- Conserve sand source areas in the San Bernardino Mountains for the blowsand ecosystem.
- Maintain Stubbe Canyon Wash's current capacity for fluvial sand transport.

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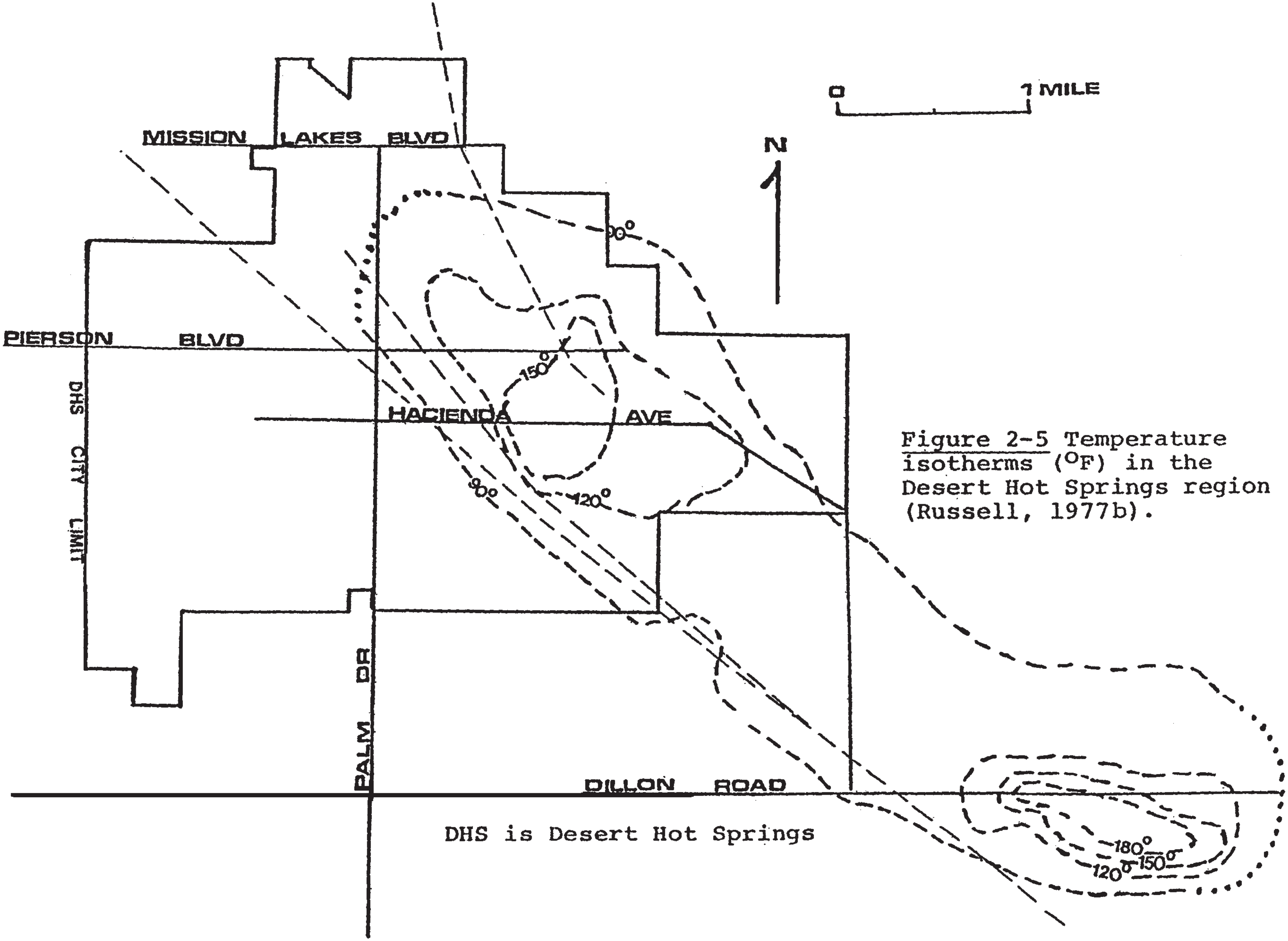
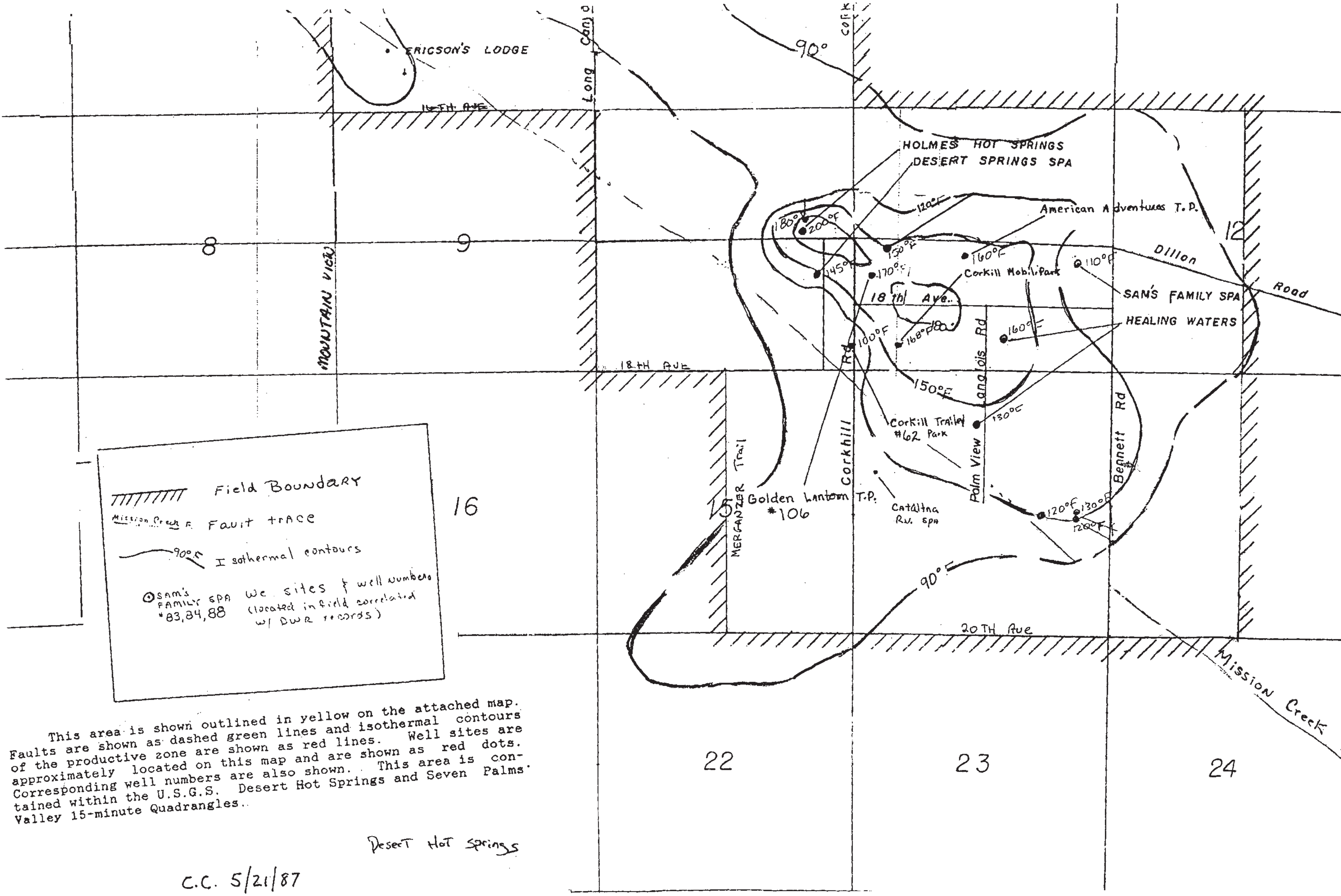
Appendix D
Hot Water Maps



<u>Figure 2-5</u> Temperature isotherms (°F) in the Desert Hot Springs region (Russell, 1977b).

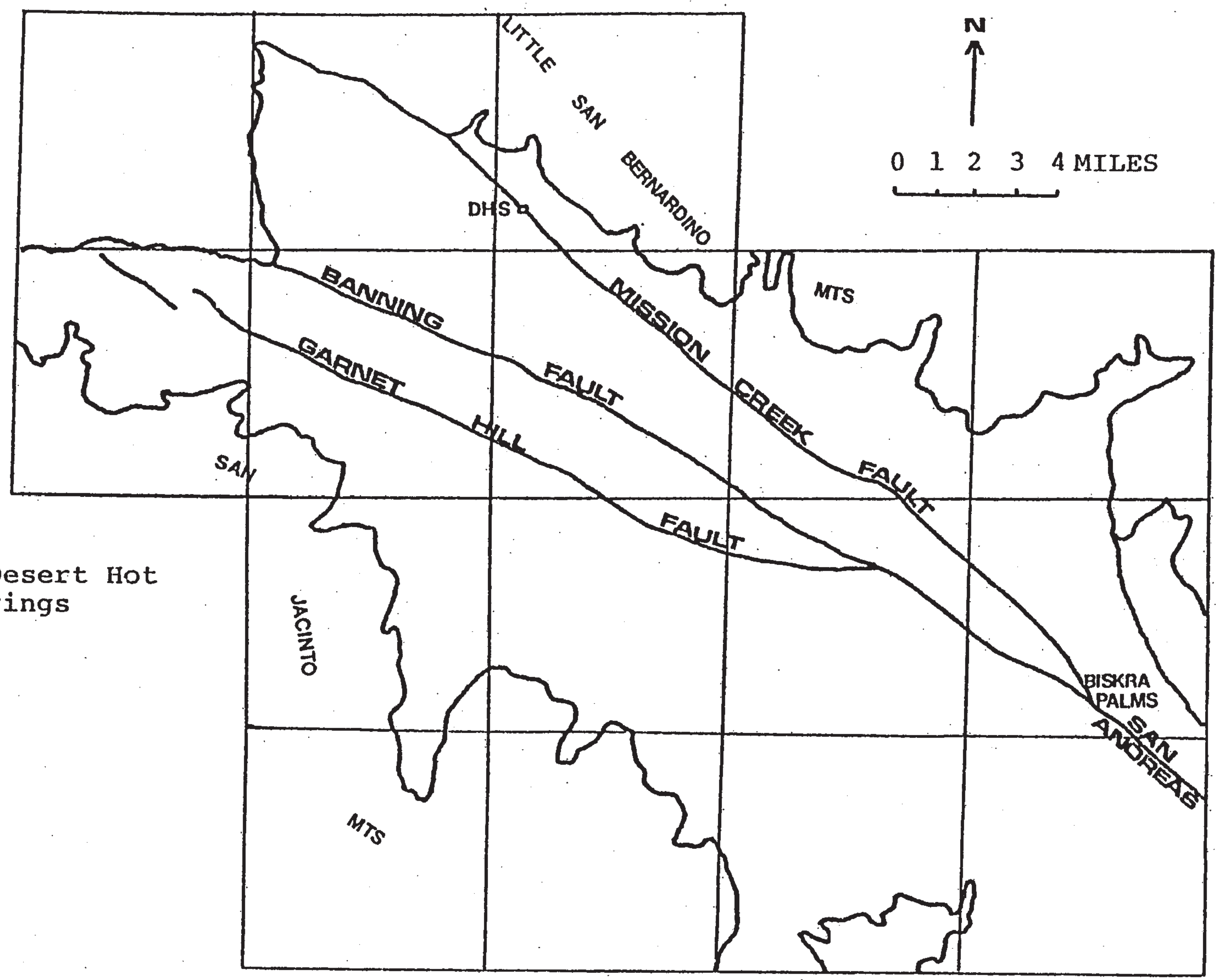
The resource temperature is higher in the Dillon Road area than those in Desert Hot Springs.



This area is shown outlined in yellow on the attached map. Faults are shown as dashed green lines and isothermal contours of the productive zone are shown as red lines. Well sites are approximately located on this map and are shown as red dots. Corresponding well numbers are also shown. This area is contained within the U.S.G.S. Desert Hot Springs and Seven Palms Valley 15-minute Quadrangles.

Desert Hot Springs

C.C. 5/21/87



DHS is Desert Hot Springs

Figure 2-2 Structure of the upper Coachella Valley (DWR, 1964).

Appendix E
Monitoring and Reporting Program

This appendix describes the recommended monitoring program for the Mission Creek and Garnet Hill Subbasins Water Management Plan (WMP). The recommended actions are summarized in **Section 7 – Recommended Plan**.

Purpose of the Monitoring Program

The Coachella Valley Water District (CVWD), Desert Water Agency (DWA), and the Mission Springs Water District (MSWD) currently collect production, water level, and water quality data from production and monitoring wells to monitor groundwater conditions in the Mission Creek and Garnet Hill subbasins. The primary purposes of the monitoring program are to:

- Assess progress toward meeting the basin management objectives,
- Fill gaps in the understanding of the groundwater resource, and
- Provide information for refinement of conceptual and numerical models.

Data gaps discussed in previous TMs include water levels and water quality in portions of the basins, precipitation, and subsidence monitoring. Recommendations in this TM also include methods for storing, retrieving, and analyzing groundwater data that can be accessed by the three participating agencies.

The following goals are established for the basin monitoring program:

1. Document changes in groundwater levels and storage in the basin over time.
2. Document the effects of imported recharge water in the basin.
3. Document groundwater quality changes and provide an early warning of potential quality degradation.
4. Obtain a better understanding of natural groundwater recharge in the groundwater basin.
5. Fill data gaps in groundwater basin conceptual model.
6. Provide data for future groundwater model refinement.
7. Comply with State laws and regulations.

Monitoring Plan Organization

This monitoring plan describes the existing and proposed monitoring activities for the Study Area as follows:

- Precipitation
- Surface Flow
- Groundwater Replenishment
- Groundwater Production
- Groundwater Levels

- Water Quality
- Inelastic Land Surface Subsidence
- Other Investigations
- Data Management and Reporting

PRECIPITATION

Groundwater in the Mission Creek and Garnet Hill subbasins is naturally recharged by precipitation and runoff from the local mountains. Precipitation in this arid region on average varies from 4 inches in the desert areas to up to 30 inches in the nearby mountain regions annually (California Department of Water Resources, 1964). Most of the precipitation that occurs directly over the groundwater basins either evaporates or is consumed by native vegetation within the basins, contributing little water to the groundwater supply. Precipitation falling as rain or snow at the higher mountain elevations within the surrounding watersheds evaporates, is transpired by native vegetation, infiltrates in the mountains contributing to subsurface inflow or runs off into the creeks and eventually percolates into the Mission Creek subbasin or into the downstream Garnet Hill and Whitewater River subbasins.

Existing Monitoring

There are no "official" National Weather Service (NWS) cooperative weather stations within the study area; however, there is a NWS cooperative station at Palm Springs Airport. **Table E-1** presents a list of precipitation gauges in and near the Planning Area. All of these stations are Automated Local Evaluation in Real Time (ALERT) flood warning gauges operated by CVWD, Riverside County Flood Control and Water Conservation District (RCFCWCD) and San Bernardino County Flood Control District (SBCFCD) (National Oceanic and Atmospheric Agency, 2011) (SBCFCD, 2012). ALERT stations typically do not have the same level of data quality control as cooperative weather stations. The location of existing precipitation stations in the Planning Area are shown on **Figure E-1**. Additional ALERT stations located within the mountain watersheds are not shown on this figure.

The California Department of Water Resources (DWR) maintains the California Irrigation Management Information System (CIMIS), a network of over 120 automated weather stations in the state of California (California Department of Water Resources, 2011). CIMIS weather stations collect weather data on a minute-by-minute basis, calculate hourly and daily values and store them in the dataloggers for daily transmission to a DWR computer. Once the data is transmitted, the central computer analyzes it for quality, calculates reference evapotranspiration (ETo - for grass reference and ETr - for alfalfa) and other intermediate parameters, flags the data (if necessary), and stores them in the CIMIS database. These data are then made available to the public on the CIMIS website (www.cimis.water.ca.gov/cimis/welcome.jsp). The nearest CIMIS station to the Planning Area is Station 118 located in Cathedral City.

Table E-1
Active Precipitation Gauges in the Planning Area

Name	Station Type	ID No.	Latitude	Longitude	Elevation (ft)	Operator	Frequency	Record Start
Big Morongo Canyon	ALERT[1]	7016	34.0822° N	116.6058° W	3,659	SBCFCD	Daily	7/24/2006
Desert Hot Springs East [2]	ALERT	57	N/A	N/A	N/A	RCFCWCD	Daily	?
East Morongo	ALERT	3480	34.0981° N	116.5261° W	3,040	RCFCWCD	Daily	?
Lower Tahquitz Creek	ALERT	3286	33.8111° N	116.5492° W	560	RCFCWCD	Daily	?
Mission Creek	ALERT	3271	34.0111° N	116.6272° W	2,400	RCFCWCD	Daily	?
Morongo Ridge	ALERT	7017	34.1477° N	116.6786° W	8,070	SBCFCD	Daily	7/24/2006
Morongo Valley PO	ALERT	9010	34.0451° N	116.5822° W	2,580	SBCFCD	Daily	4/15/1991
Raywood Flat	ALERT	3468	34.0467° N	116.8231° W	7,070	RCFCWCD	Daily	?
Tick Ridge	ALERT	3200	33.9778° N	116.7703° W	4,560	RCFCWCD	Daily	?
Upper Mission Creek	ALERT	3460	34.1192° N	116.7300° W	8,120	RCFCWCD	Daily	?
Upper Morongo Creek	ALERT	3290	34.1522° N	116.6911° W	8,520	RCFCWCD	Daily	?
West Morongo Valley	ALERT	3220	34.0689° N	116.5744° W	3,280	RCFCWCD	Daily	?
Whitewater Trout Farm	ALERT	3151	33.9875° N	116.6572° W	2,200	CVWD	Daily	?
Wide Canyon Dam	ALERT	3281	33.9344° N	116.3908° W	1,530	RCFCWCD	Daily	?
Windy Point	ALERT	3445	33.8992° N	116.6222° W	1,060	CVWD	Daily	?

References: (National Oceanic and Atmospheric Agency, 2011), (RCFCWCD, 2011), (SBCFCD, 2012)

1. ALERT – Automated Local Evaluation in Real Time flood warning gauges
2. Location and elevation not available (N/A) on RCFCWCD website. May be the same as Wide Canyon Dam.

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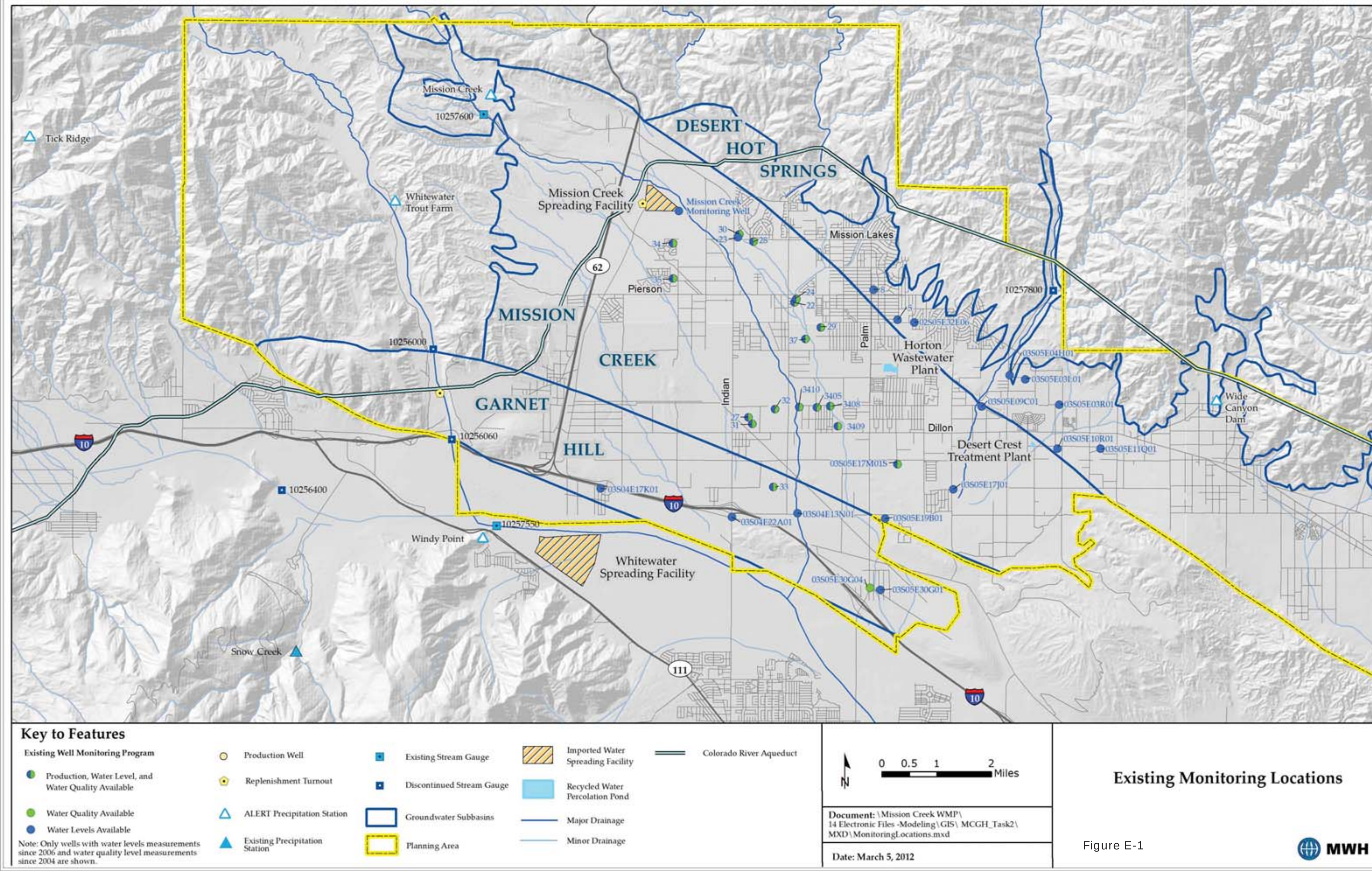

DESERT HOT SPRINGS
MISSION CREEK
GARNET HILL
Mission Creek
10257600
Tick Ridge
Whitewater Trout Farm
Mission Creek Spreading Facility
Mission Creek Monitoring Well
Mission Lakes
Pierson
62
10256000
10256060
10256400
10257550
10257800
Windy Point
Snow Creek
Whitewater Spreading Facility
111
10
Indian
Palm
Horton Wastewater Plant
Dillon
Desert Crest Treatment Plant
Wide Canyon Dam
03S04E17K01
03S04E22A01
03S04E13N01
03S05E19B01
03S05E17M01S
03S05E17J01
03S05E30G04
03S05E30G01
03S05E09C01
03S05E03R01
03S05E03L01
03S05E04H01
03S05E10R01
03S05E11Q01
02S05E32E06
3410
3405
3408
3409
Key to Features
Existing Well Monitoring Program
Production, Water Level, and Water Quality Available
Water Quality Available
Water Levels Available
Note: Only wells with water levels measurements since 2006 and water quality level measurements since 2004 are shown.
Production Well
Replenishment Turnout
ALERT Precipitation Station
Existing Precipitation Station
Existing Stream Gauge
Discontinued Stream Gauge
Groundwater Subbasins
Planning Area
Imported Water Spreading Facility
Recycled Water Percolation Pond
Major Drainage
Minor Drainage
Colorado River Aqueduct
0 0.5 1 2 Miles
N
Document: \Mission Creek WMP\ 14 Electronic Files -Modeling\GIS\ MCGH_Task2\ MXD\MonitoringLocations.mxd
Date: March 5, 2012
Existing Monitoring Locations
MWH

Figure E-1

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Proposed Monitoring

Since runoff generated by mountain-front precipitation is a significant component of basin recharge (Psomas, 2011), it is recommended that available precipitation data be collected, summarized and reported annually in the Engineer's Reports prepared by DWA and CVWD. Data from the ALERT stations could also be useful in documenting precipitation and deriving runoff relationships in the future. Because a significant number of ALERT stations already exist within or near the contributing watersheds, no additional precipitation stations are recommended at this time.

Since the Mission Creek/Garnet Hill area is more prone to hot windy conditions than other parts of the Coachella Valley, CIMIS data for Cathedral City may not be representative of conditions in Desert Hot Springs. It is recommended that a CIMIS weather station be located in Desert Hot Springs area to provide more reliable evapotranspiration data for irrigation scheduling. The cost of a CIMIS station is approximately $6,000 to $9,000 including installation. The station could potentially be sited at one of the golf courses or other suitable large irrigated area in the Planning Area as shown on **Figure E-2** or at the Mission Creek Spreading Facility.

SURFACE FLOW

Surface water flow in the Planning Area consists of ephemeral or intermittent streams originating from the surrounding mountains. Surface water features that contribute to groundwater recharge in the Mission Creek subbasin during periods of high runoff or flash flooding include Mission Creek, Dry Morongo Wash, Little Morongo Creek, Big Morongo Canyon, Long Canyon and Wide Canyon. Mission Creek is the only stream that flows to the valley floor on a somewhat consistent basis. The stream flow usually disappears upstream of Highway 62, except in years of higher runoff when flow has been observed south of Pierson Avenue. Streams flowing through Morongo Valley, Big Morongo, Little Morongo, and Long Canyon may periodically reach the valley floor for short periods of time when there are localized, intense storms in the mountains (Mayer & May, 1998).

The Whitewater River flows across the Garnet Hill subbasin before reaching the Whitewater River subbasin. Non-flood stage flows from the Whitewater River that reach the valley floor are diverted to the Whitewater Spreading Facility. The Mission Creek channel flows across the Garnet Hill subbasin, but it is not believed to contribute significant recharge since it is predominantly dry in the reaches that cross the subbasin. There are no other significant surface water sources that flow into the Garnet Hill subbasin. Psomas estimated recharge from the Whitewater River into the Garnet Hill subbasin based on groundwater modeling for the current WMP (Psomas, 2011). However, no data was available to confirm the modeling assumptions regarding recharge of the Garnet Hill subbasin beyond groundwater level response.

Existing Monitoring

The United States Geological Survey (USGS) currently maintains streamflow gauges in the Planning Area on Mission Creek and the Whitewater River as indicated in **Table E-2**. In the past, the USGS maintained gauges at five additional locations as shown in **Table E-2**.

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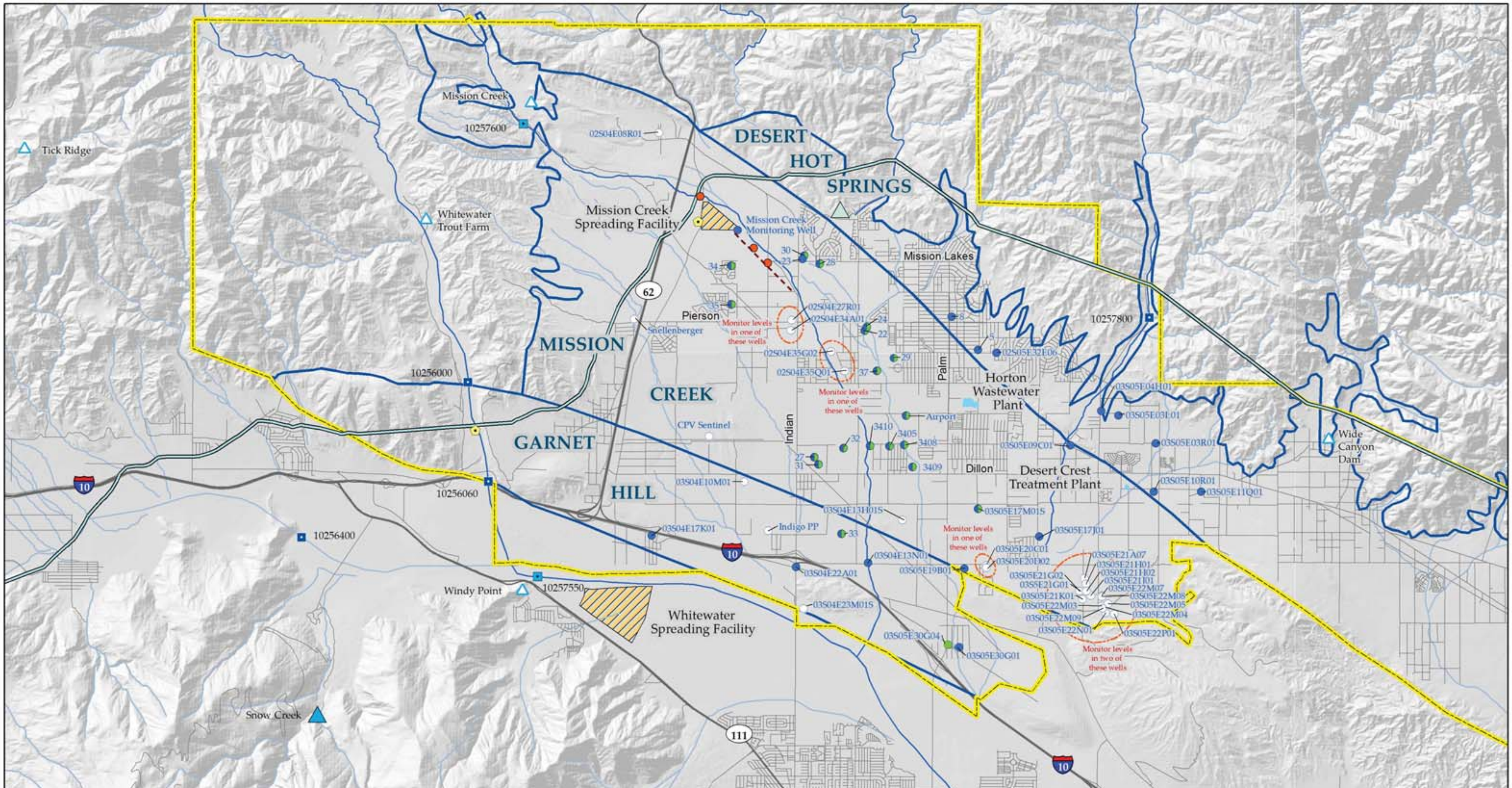

Key to Features

Existing Well Monitoring Program

- Production, Water Level, and Water Quality Available
- Water Quality Available
- Water Levels Available

Groundwater Monitoring Well

- Existing Well Recommended for Monitoring
- Recommended New Monitoring Well (Water Levels Only)

- Existing Flow Monitoring Station
- Proposed Flow Monitoring Station
- Discontinued Stream Gauge
- Replenishment Turnout
- Proposed CIMIS Station
- Existing Precipitation Station
- ALERT Precipitation Station
- Groundwater Subbasins
- Planning Area
- Imported Water Spreading Facility
- Recycled Water Percolation Pond
- Colorado River Aqueduct
- Major Drainage
- Minor Drainage
- Geophysical Study Site Recommendation

N

0 0.5 1 2 Miles

Document: \Mission Creek WMP\
14 Electronic Files -Modeling\GIS\ MCGH_Task2\
MXD\MonitoringLocations.mxd

Date: March 5, 2012

Proposed and Potential Monitoring Recommendations

Figure E-2

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Table E-2
Stream Gauges in the Planning Area

Name	Station Type	ID No.	Latitude	Longitude	Elevation (ft)	Operator	Period of Record	Frequency
Active Gauges								
Mission Creek Near Desert Hot Springs	Water Stage Recorder	10257600	34°00'40"N	116°37'38"W	2,400	USGS	10/1967-Present	Continuous
Whitewater River at Windy Point Main Channel	Water Stage Recorder	10257548	33°53'56"N	116°37'13"W	1,040	USGS	10/1998-Present	Continuous
Whitewater River at Windy Point Overflow Channel	Water Stage Recorder	10257549	33°53'56"N	116°37'13"W	1,040	USGS	10/1998-Present	Continuous
Whitewater River at Windy Point near White Water	Combined Records	10257550	33°53'56"N	116°37'13"W	1,040	USGS	10/1984-9/1987, 10/1989-Present	Continuous
Discontinued Gauges								
Long Creek near Desert Hot Springs	None	10257800	33°57'53"N	116°26'35"	1,560	USGS	1963-71	--
Whitewater River at White Water	None	10256000	33°56'48"N	116°38'24"W	1,610	USGS	10/1948 - 9/1979	--
Whitewater Mutual Water Company Diversion at Whitewater	None	10256050	33°56'44"N	116°38'25"W		USGS	10/1966-70, 1971-73, 1975-10/81	--
Whitewater River at White Water Cutoff at Whitewater [1]	None	10256060	33°55'31"N	116°38'07"W	1,360	USGS	10/1985 – 9/1897, 10/1988 – 9/1990-9/1993	Periodic manual gauging
San Gorgonio River near Whitewater	None	10256400	33°55'08"N	116°41'52"W	1,320	USGS	1966-73, 1975-78	--

1 The USGS periodically measures flow rate manually at this location.

Pertinent to this water management plan is the gauge on the Whitewater River at the Whitewater Cutoff. While this gauge was discontinued in 1993, the USGS continues to monitor flows periodically at this location. Stream gauging on Long Creek was discontinued in 1971. Only one significant flow event was detected on Long Creek (340 cfs for 1 day) while this gauge was active. The locations of the existing and discontinued stream gauging stations are shown on **Figure E-1**.

Proposed Monitoring

A significant amount of recharge to the Garnet Hill subbasin is believed to occur from infiltration along the Whitewater River channel. To better understand surface flow and recharge in the Garnet Hill subbasin, it is recommended that flows be monitored at two additional points along the Whitewater River: at the Banning fault (near the old USGS gauge 10256000) and at the old Whitewater Cutoff gauging station (USGS gauge 10256060). This could be accomplished by establishing either permanent gauging stations or conducting periodic manual stream gauging during periods of storm flow. These data, in combination with the Metropolitan Water District of Southern California (Metropolitan) metered releases from the Colorado River Aqueduct and the existing USGS gauge at Windy Point, could be used to assess flow losses in each reach of the river and indicate the amount of recharge occurring. Contemporaneous flow measurements for an extended period of time would provide the best results and allow analysis of relationships between flow volume and recharge.

As shown on **Figure E-1**, there is only one active stream gauging station in the Mission Creek subbasin. Other significant watersheds providing natural inflow are Little Morongo Creek, Long Canyon and Wide Canyon. While gauges at these locations could potentially provide useful information on the amount of water entering the groundwater basin, it is uncertain if the benefits are sufficient to outweigh the costs. If it is determined that the cost of constructing and maintaining additional stream gauges is too high, it is recommended that monitoring wells near these locations be constructed to document groundwater levels near the tributary watersheds.

GROUNDWATER REPLENISHMENT

The enabling legislation of CVWD and DWA require reporting of the source and amount of replenishment water provided to the basin for the purpose of recovering the cost of replenishment through a pumping assessment. Currently, the Metropolitan Water District of Southern California (Metropolitan) maintains metering structures at the Whitewater River and Mission Creek turnouts from its Colorado River Aqueduct. Meter readings at these locations are used to determine the amount of SWP Exchange water delivered at each location. CVWD and DWA use these readings to determine the amounts of water replenished and report those amounts in the annual engineering surveys and reports for each area of benefit. No changes to the replenishment metering are recommended at this time.

GROUNDWATER PRODUCTION

Accurate monitoring of groundwater production within the Planning Area is critical to evaluating the basin water balance and for equitable assessment of replenishment costs among groundwater pumpers. The enabling legislation of CVWD and DWA has almost identical requirements for the metering and reporting of production within the defined areas of replenishment benefit as follows with differences noted:

- "Production" or "produce" means the extraction of groundwater by pumping or any other method within the boundaries of the agency, or the diversion within the agency of surface supplies which naturally replenish the groundwater supplies within the agency and are used therein.

- "Minimal pumper" means any producer who produces 10 or fewer acre-feet in any year [for DWA – 25 or fewer acre-feet in any year for CVWD]. Minimal pumpers are exempt from any replenishment assessments and reporting provisions.

  Each producer shall file a sworn statement setting forth the total quantity of water production in acre-feet subject to the replenishment assessment, and shall be reported as of the end of the month immediately preceding the payment date. The statement shall identify separately the production from each well or other water-producing facility, and shall also include a general description or number locating the well or water-producing facility, the method or basis of the measurement or computation of production, and any other information the agency may require.

- If the agency or district has an agreement with any producer whereby the agency or district regularly reads and maintains the water-measuring devices which record the production of the producer, the producer shall be exempt from the production reporting provisions. In lieu thereof, the agency shall send the producer notice of its production and the amount of the replenishment assessment or installment due.

- It is unlawful to produce water from within any area of benefit after one year following the levy of a replenishment assessment within the area, unless the well or other water-producing facility producing the water has a water-measuring device affixed thereto which is capable of measuring and registering the accumulated amount of water produced. This provision is not applicable to minimal pumpers. Violation is punishable by a fine, imprisonment in the county jail, or both fine and imprisonment.

Reference: Desert Water Agency Water Replenishment Assessments (California Water Code Appendix Chapter 100 , 2011); Coachella Valley Water District Water Replenishment Assessments (California Water Code Sections 31630-31639 , 2011).

Existing Monitoring

Currently, all municipal production wells within the Mission Creek subbasin are metered with the production reported monthly to DWA or CVWD, respectively. Based on recent Engineer's Reports prepared by CVWD and DWA, there are seven active private wells in the CVWD area and five active private wells in the DWA area. However, not all private wells may be metered, most likely because they are minimal producers. It is not clear if those private wells with reported production are metered; some flows may be estimated by the owner. Wells that are currently monitored for production are listed in **Table E-3**. CVWD and DWA conducted surveys of groundwater producers in the Mission Creek subbasin when the replenishment assessment was established to determine which wells were actively producing groundwater.

Table E-3
Existing Groundwater Production Monitoring

Subbasin	State Well Number	Owner	Owner's Well Number	Monitored for Production	Reporting Frequency
MC	02S04E23L01S	Mission Lakes Country Club	2	Yes	Monthly
MC	02S04E23L02S	Mission Lakes Country Club	1	Yes	Monthly
MC	02S04E23L03S	Mission Lakes Country Club	3	Yes	Monthly
MC	02S04E23N01S	MSWD	23	No	Out of Service
MC	02S04E23N02S	MSWD	30	Yes	Monthly
MC	02S04E26C01S	MSWD	28	Yes	Monthly
MC	02S04E28A01S	MSWD	34	Yes	Monthly
MC	02S04E28J01S	MSWD	35	No	Not Equipped
MC	02S04E36D01S	MSWD	22	Yes	Monthly
MC	02S04E36D02S	MSWD	24	Yes	Monthly
MC	02S04E36K01S	MSWD	29	Yes	Monthly
MC	02S04E36P01S	MSWD	37	Yes	Monthly
MC	02S05E31H01S	MSWD	5	No	Out of Service
MC	03S04E11A02S	MSWD	32	Yes	Monthly
MC	03S04E11L01S	MSWD	27	Yes	Monthly
MC	03S04E11L04S	MSWD	31	Yes	Monthly
MC	03S04E12B01S	CVWD	3406	No	Out of Service
MC	03S04E12B02S	CVWD	3408	Yes	Monthly
MC	03S04E12C01S	CVWD	3405	Yes	Monthly
MC	03S04E12F01S	CVWD	3410	Yes	Monthly
MC	03S04E12H02S	CVWD	3409	Yes	Monthly
MC	03S05E05Q01S	Hidden Springs Country Club		Yes	Monthly
MC	03S05E08B01S	Sands RV Country Club		Yes	Monthly
MC	03S05E08P01S	Bluebeyond Fisheries	DOM 1	(1)	Monthly
MC	03S05E08P02S	Bluebeyond Fisheries	BF 2	(1)	Monthly
MC	03S05E15L01S	Too Many Palms	Grn Gold	(2)	(2)
MC	03S05E15N01S	Too Many Palms	LG Kincade	(1)	Monthly
MC	03S05E15N03S	Too Many Palms	Donna Rose	(2)	(2)
MC	03S05E15R01S	Desert Springs Aquaculture Inc	2	Yes	Monthly
MC	03S05E15R02S	Desert Springs Aquaculture Inc	1	Yes	Monthly
MC	03S05E17M01S	Desert Dunes Golf Course	1	Yes	Monthly
MC	03S05E17N01S	Desert Dunes Golf Course	2	Yes	Monthly
GH	03S04E14J01S	MSWD	33	Yes	(3)

1. Production may be estimated.
2. Production status unknown.
3. Well is not located within Mission Creek Subbasin Area of Benefit (AOB) for replenishment assessment. However, MSWD monitors production.

Proposed Monitoring

It is recommended that the following steps be taken to improve groundwater production monitoring:

1) Update the existing canvasses of private wells in the Mission Creek and Garnet Hill subbasins to determine their location, operational status (active, inactive, abandoned, destroyed), whether a meter is installed and whether production is being reported. This will ensure an accurate picture of the number of wells in the Planning Area.
2) For those wells having meters that are actively being pumped, verify that production is being routinely reported based on meter readings.
3) For those wells without meters (except for minimal pumpers), make arrangements for installation of a production meter and routine reporting of production.
4) For those wells of minimal producers, conduct a periodic evaluation (frequency to be determined by CVWD and DWA) to determine whether the producer continues to qualify as a minimal producer. If the producer no longer qualifies, require the installation of a suitable metering device and production reporting.
5) For those wells that are no longer being pumped, evaluate whether the well could be used for groundwater level or quality monitoring.
6) For those inactive wells whose physical condition prevents their use for monitoring, offer to cap or destroy the well to prevent safety hazards or water quality degradation.

GROUNDWATER LEVELS

Groundwater level changes provide a direct indication of changes in groundwater storage within the Planning Area. From the early 1980s through 2009, groundwater levels in the Planning Area have been declining at a rate of 1 - 2 ft/yr (CVWD and MSWD, unpublished water level data).

Over the past two years, groundwater level monitoring took on greater emphasis statewide. In November 2009, the California Legislature amended the Water Code with SBx7-6, mandating a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal, the amendment requires collaboration between local monitoring entities and DWR to collect groundwater elevation data. Collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources.

In accordance with this amendment to the Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins, monitoring levels at non-potable water production wells. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. DWR’s role is to coordinate the CASGEM program, to work cooperatively with local entities, and to maintain the collected elevation data in a readily and widely available public database. DWR will also continue its current network of groundwater monitoring as funding allows.

The law anticipates that the monitoring of groundwater elevations required by the enacted legislation will be done by local entities. The law requires local entities to notify DWR in writing by January 1, 2011 if the local agency or party seeks to assume groundwater monitoring functions in accordance with the law. CVWD and MSWD have been designated as monitoring entities for their respective portions of the Desert Hot Springs and Mission Creek subbasins; CVWD has been designated as the monitoring entity for the CVWD portion of the Whitewater River (Indio) Subbasin while DWA has received conditional designation for the DWA portion of the Whitewater River (Indio) Subbasin. Monitoring for CASGEM is to be in accordance with DWR's Guidelines (California Department of Water Resources, 2010).

Existing Monitoring

CVWD and MSWD monitor groundwater levels in wells within the study area. Ten wells are monitoring in Desert Hot Springs Subbasin, 22 wells are monitored in the Mission Creek subbasin and six wells are monitored in the Garnet Hill Subbasin as shown in **Table E-4**. MSWD monitoring is limited to District wells with levels taken monthly. CVWD monitors both its own wells and a number of private wells with water levels taken three times per year.

Currently, no wells are monitored in the portion of the Mission Creek subbasin located west of Indian Ave. and south of Pierson Blvd. Similarly, no wells located west of SR 62 are monitored limiting water level data in the western portion of the basin. Monitoring of additional private wells in this area (if available) would improve the understanding of groundwater flow and the effects of natural recharge in this portion of the subbasin. Additional monitoring wells near the Mission Creek Spreading Basin would provide better information on the movement of recharge water and may help determine whether the observed mounding is the result of a subsurface geologic feature (such as faulting or offset in the basement rocks), a change in the permeability or storativity or temporary mounding.

A limited number of wells are monitored in the Garnet Hill Subbasin, principally due to a lack of wells. Selection or installation of additional monitoring wells would provide a better picture of water level changes within this subbasin.

Proposed Monitoring

Based on review of existing wells and the distribution of currently monitored wells, a list of prospective additional wells has been identified that could be included in the groundwater level monitoring program as shown in **Table E-5**. Because the status and physical condition of these wells are unknown, it is recommended that these wells be evaluated for suitability for inclusion in the monitoring program.

DWR has established recommendations regarding the frequency of water level monitoring in its CASGEM Guidelines (California Department of Water Resources, 2010). To capture seasonal variations, a minimum of two readings per year are required coinciding with the high and low water-level times of year for each basin. However, quarterly or monthly readings would provide a better understanding of seasonal fluctuations.

Table E-4
Existing Groundwater Level and Quality Monitoring

Subbasin	State Well Number	Owner	Owner's Well Number	Monitored for Levels	Frequency	Monitored for Quality	Frequency
DHS	02S05E30Q05S	MSWD	8	Yes[1]	2 per year	?	--
DHS	02S05E31H01S	MSWD	5	Yes[1]	2 per year	?	
DHS	02S05E32E06S	Howard		Yes	3 per year	No	--
DHS	02S05E33E05S	Dorothy & Orville Smith		Yes	3 per year	No	--
DHS	03S05E03L01S	Erwin And Assoc.		Yes	3 per year	No	--
DHS	03S05E03R01S	Johnson		Yes	3 per year	No	--
DHS	03S05E04H01S	Tru Wall Const.		Yes	3 per year	No	--
DHS	03S05E10R01S	Knudsen		Yes[1]	3 per year	No	--
DHS	03S05E11Q01S	William W. Tarbutton		Yes	3 per year	No	--
DHS	03S06E21F02S	Manthei Bros.		Yes[1]	3 per year	No	--
DHS	03S06E25Q01S	Honig		Yes[1]	3 per year	No	--
DHS	03S06E26P01S	M. J. Grieshaber		Yes	3 per year	No	--
MC	02S04E21H01S	DWA	Mission Creek Monitoring Well	Yes	Monthly	No	--
MC	02S04E23N01S	MSWD	23	Yes[1]	Monthly	Yes	Triennially[2]
MC	02S04E23N02S	MSWD	30	Yes	Monthly	Yes	Triennially[2]
MC	02S04E26C01S	MSWD	28	Yes	Monthly	Yes	Triennially[2]
MC	02S04E28A01S	MSWD	34	Yes	Monthly	Yes	Triennially[2]
MC	02S04E28J01S	MSWD	35	Yes	Monthly	Yes	Triennially[2]
MC	02S04E36D01S	MSWD	22	Yes	Monthly	Yes	Triennially[2]
MC	02S04E36D02S	MSWD	24	Yes	Monthly	Yes	Triennially[2]
MC	02S04E36K01S	MSWD	29	Yes	Monthly	Yes	Triennially[2]
MC	02S04E36P01S	MSWD	37	Yes	Monthly	Yes	Triennially[2]
MC	03S04E11A02S	MSWD	32	Yes	Monthly	Yes	Triennially[2]
MC	03S04E11L01S	MSWD	27	Yes	Monthly	Yes	Triennially[2]
MC	03S04E11L04S	MSWD	31	Yes	Monthly	Yes	Triennially[2]
MC	03S04E12B01S	CVWD	3406	No	--	No	--
MC	03S04E12B02S	CVWD	3408	Yes[1]	3 per year	Yes	Triennially[2]
MC	03S04E12C01S	CVWD	3405	Yes	3 per year	Yes	Triennially[2]
MC	03S04E12F01S	CVWD	3410	Yes	3 per year	Yes	Triennially[2]
MC	03S04E12H02S	CVWD	3409	Yes	3 per year	Yes	Triennially[2]
MC	03S05E09C01S	KLATT		Yes	3 per year	No	--
MC	03S05E17J01S	CVWD (?)	3518	Yes[1]	3 per year	No	--
MC	03S05E17M01S	Desert Dunes Golf Course	1	Yes	3 per year	Yes	Every six years

Table E-4 (continued)
Existing Groundwater Level and Quality Monitoring

Subbasin	State Well Number	Owner	Owner's Well Number	Monitored for Levels	Frequency	Monitored for Quality	Frequency
MC	03S05E19B01S	Cronholm		Yes	3 per year	No	--
GH	03S04E13N01S	Duryea		Yes	3 per year	No	--
GH	03S04E13N02S	Unknown		Yes	3 per year	No	--
GH	03S04E14J01S	MSWD	33	Yes	Monthly	Yes	Triennially[2]
GH	03S04E17K01S	Valley View MWC		Yes	3 per year	No	--
GH	03S04E22A01S	Margolias		Yes	3 per year	Yes	Periodically
GH	03S05E30G01S	Frank Mack		Yes	3 per year	Yes	Periodically
GH	03S05E30G04S	Jack in the Box		No	--	Yes	Periodically

1 CASGEM Well.
2 CDPH requires triennial monitoring for general minerals, metals, radiological and regulated organics (VOCs and SOCs) and annual monitoring of nitrate.

Table E-5
List of Potential Wells for Monitoring

Subbasin	State Well Number	Owner [1]	Status	Purpose	Comment
MC	02S04E08R01S	Will Claiborne	926 ft deep, drilled 1989	Subsurface inflow upstream of recharge basin	Mission Creek West of SR 62 and Indian
MC	02S04E18D02S 02S04E18D03S	TW Burnham	Unknown	Subsurface inflow from Mission Creek	Mission Creek 2 mi NW of SR 62
MC	02S04E18F01S	Mrs A K Walters	Drilled 1965	Subsurface inflow from Mission Creek	Mission Creek 2 mi NW of SR 62
MC	02S04E18R01S	TW Burnham	Unknown	Subsurface inflow from Mission Creek	Mission Creek 1 mi NW of SR 62
MC	02S04E27R01S	Norman Lamaroux	Unknown	Improved water level contours between MSWD's Wells 35 and 24	Select one of these wells
MC	02S04E34A01S	Edwards	Unknown, Drilled 1966		
MC	02S04E32C01S	Snellenberger (?)	Unknown; Not in CVWD records	Subsurface inflow and water level west of SR 62	West of SR 62 near Pierson
MC	02S04E35G02S	Park West Mobil Park	Well deepened to 495 ft	Improved water level contours west of MSWD's Well 37	Select one of these wells
MC	02S04E35Q01S	MSWD – Well 13	May be dry – capped per CVWD records		
MC	03S04E01K01S	MSWD Airport	?	CASGEM Well – improved water level contours	Recent MSWD acquisition, only levels are monitored monthly
MC	03S04E04N__S	CPV Sentinel	New well; not in CVWD records	Improved water level contours west of Indian Ave.	Recently constructed; SWN unknown
MC	03S05E04M01S	Dr Aiken/USGS[2]	Unknown	Improved water level contours near Mission Creek fault	May be monitored by USGS
MC	03S05E09C01S	Klatt	Unknown	Improved water level contours near Mission Creek fault	Near Mission Creek fault
MC	03S05E20C01S	Mr O Scarcelli	Unknown, drilled 1978	Improved water level contours near Banning fault	Select one of these wells
MC	03S05E20D02S	Durst	Unknown, drilled 1978		
MC	03S05E21A07S	Jay Schultz	Unknown, drilled 2003	Improved water level contours near Mission Creek fault in Willow Hole area	Select one well from this group
MC	03S05E21G01S	Mary Herzog	Unknown, drilled 1970		
MC	03S05E21G02S	Ron Studebacker	Unknown, drilled 1978		
MC	03S05E21H01S	Charles Ross	Unknown, drilled 1978		
MC	03S05E21H02S	James Stanley	Unknown		
MC	03S05E21J01S	Blanche Kelly	Unknown, drilled 1991		
MC	03S05E21K01S	Peterson	Unknown, old log		

Table E-5 (Continued)
List of Potential Wells for Monitoring

Subbasin	State Well Number	Owner [1]	Status	Purpose	Comment
MC	03S05E22M03S	Leon Mason	Inactive per CVWD records	Improved water level contours in Willow Hole area	Select one well from this group
MC	03S05E22M04S	Tom Svenneby	Unknown, drilled 1981		
MC	03S05E22M05S	John Guldseth	Unknown, drilled 1983		
MC	03S05E22M07S	William Stapely	Unknown, no log		
MC	03S05E22M08S	William Stapely	Unknown		
MC	03S05E22M09S	Keith McGraw	Unknown, drilled 2000		
MC	03S05E22N01S	John Barker	Unknown, drilled 1981		
MC	03S05E22P01S	M G Astleford	Unknown, drilled 1981		
GH	03S04E10M01S	Bill Adams	Unknown, drilled 1997	Improved water level contours near Banning fault south of Devers Hills	
GH	03S04E15___S	Indigo Power Plant	Location uncertain, no log in CVWD records	Improved water level contours west of Indian Ave.	SWN unknown

1. Name of well owner based on CVWD master well records for the Coachella Valley.
2. Well shown in CASGEM database as monitored by USGS. No data available.

Since many of the monitored wells are active production wells, it is important that the monitoring protocols are such that reasonably accurate static water levels are obtained to reduce the influence of pumping. The CASGEM guidelines recommend avoiding the use of production wells. As a general recommendation, measurements should not be collected until 24 hours after pumping has ceased; however, site-specific conditions may require deviating from this recommendation.

In addition to selection of existing wells for improved distribution of water level measurements, it is recommended that several dedicated monitoring wells be established. Near the Mission Creek Spreading Basin, it is recommended that construction of at least two monitoring wells be considered near the Mission Creek channel between the existing monitoring well to a point roughly halfway between MSWD's Wells 34 and 30. Additional wells in this area would provide a better indication of the extent of mounding due to recharge operations and allow tracking of water quality changes to document the movement of imported recharge water in the aquifer. The cost of a monitoring well comparable to the existing DWA well is approximately $200,000.

Currently, all of the groundwater level data in the subbasin are collected manually. To collect more accurate water level data on a regular basis during both static and pumping conditions, it would be ideal for all production wells to have transducers and data loggers installed to measure the groundwater levels. It is recommended that existing and proposed monitoring wells near the Mission Creek Spreading Basins also have transducers and data loggers installed to allow for regular monitoring of groundwater levels. For phasing purposes, priority should be given to installing transducers and data loggers at the wells closer to the recharge basins than those further away to detect the more variable water levels associated with recharge activities. Such data would be valuable for future groundwater model calibration. The cost of a typical water level transducer and data logger installation is about $1,000.

WATER QUALITY

Because many of the wells in the basin are used for public water supply, an extensive record of water quality data is available for most wells. Water purveyors have compiled available historic water quality data for constituents monitored as required by CDPH under CCR Title 22.

Existing Monitoring

In accordance with current CDPH monitoring schedules, CVWD and MSWD are required to monitor water quality for physical constituents, general minerals, metals, radiological constituents and regulated organic compounds at least once every three years and annually for nitrate. If previous analyses demonstrate that the quality is near or exceeds the maximum contaminant level (MCL) for any constituent, then more frequent monitoring may be required. For example, MSWD is required to monitor Well 34 monthly for uranium. If monitoring consistently shows results that are significantly below the pertinent MCL, then monitoring frequency may be reduced or waived at the discretion of CDPH. MSWD also samples its wells on a monthly basis for temperature, pH and TDS when taking water level readings.

Small water systems sample less frequently depending on the level of constituents compared to the MCL. Private wells are not typically monitored on a routine basis; however, CVWD monitors several wells in the Mission Creek subbasin approximately once every five to six years.

This level of monitoring is sufficient under existing regulatory guidelines to ensure that the public is provided with a safe and reliable drinking water supply. However, additional water quality monitoring would be useful for assessing quality changes over time.

Proposed Monitoring

Since the current monitoring programs of MSWD and CVWD are sufficient for regulatory compliance, no changes are recommended. More frequent monitoring of private wells for temperature, TDS and general minerals would provide a better indication of water quality variations across the Study Area. It is recommended that the Mission Creek Monitoring Well and future monitoring wells near the recharge basins be analyzed monthly for TDS and possibly sulfate to track the movement of imported recharge water in the basin. Consideration should be given to construction of nested monitoring wells to allow collection of water samples at varying depths. Nested wells may also provide information on uranium occurrence and movement with depth in the aquifer.

It is recommended that wells selected for monitoring of recharge water have a general mineral analysis on an annual basis. Wells previously identified with radiological constituents have radiological constituents analyzed on an annual basis. Surface water sources, such as Mission Creek, should have water quality evaluated for general minerals at least on a triennial basis. This data would provide data for future evaluation of subbasin water quality. The cost of a general mineral analysis is approximately $250 per sample.

LAND SUBSIDENCE

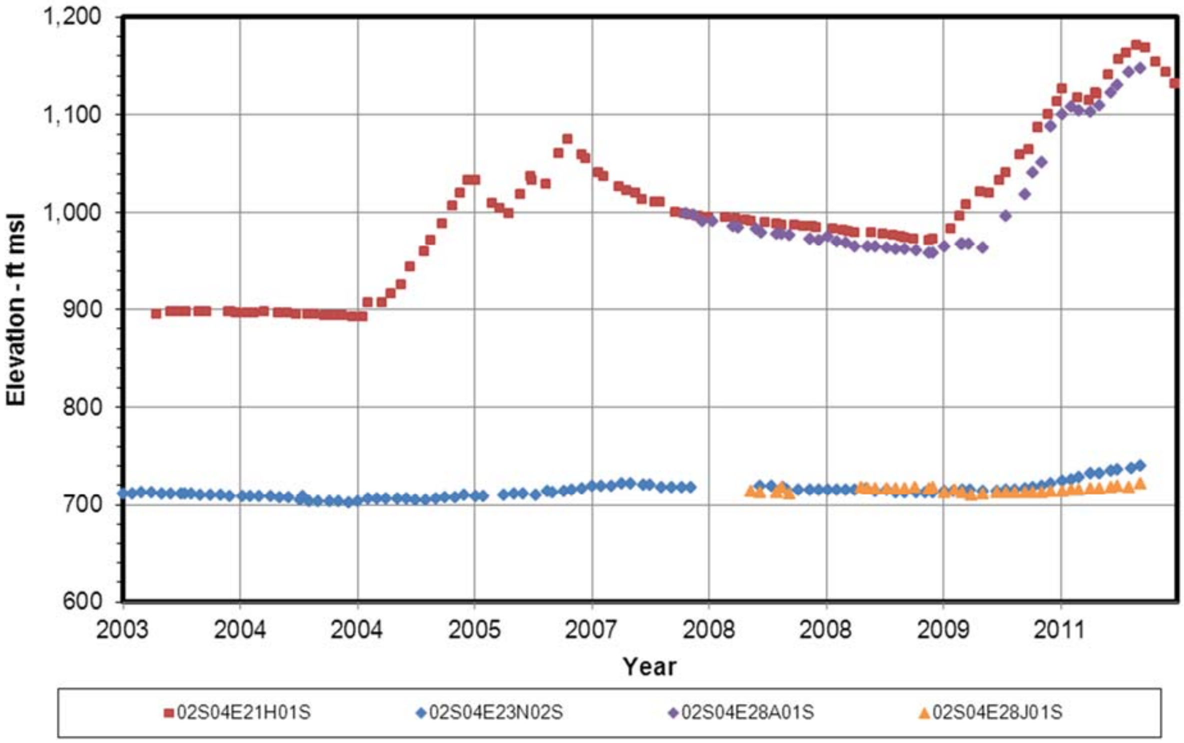
Land subsidence is the lowering of the ground surface due to groundwater withdrawal or seismic activity. Declining groundwater levels can contribute to or induce land subsidence in aquifer systems that contain a significant fraction of unconsolidated fine-grained sediments (silts and clays). Land subsidence can disrupt surface drainage, cause earth fissures, and damage wells, buildings, roads, and utility infrastructure. Seismically-induced movements may cause subsidence on the depressed side of a fault, or relatively small-scale subsidence can also occur when dry soils are saturated with water due to seismic activity.

Land subsidence has not been observed in the Study Area. The coarse-grained sediments (predominantly sand and gravel) of the Study Area do not appear to be susceptible to subsidence as are fine-grained sediments such as silt and clays that comprise large portions of the East Coachella Valley. To determine if continued groundwater extractions could lead to subsidence, a network of benchmarks could be established in the Planning Area and ground surface elevations at these benchmarks be surveyed on a five-year interval to determine if subsidence is occurring. Alternatively, remote sensing techniques such as interferometric synthetic aperture radar (InSAR) can be used to detect changes in land surface elevations using satellite-based. Since subsidence is not currently a concern for the Planning Area, no additional action is recommended at this time.

OTHER INVESTIGATIONS

As discussed previously, groundwater mounding near the recharge basin has been observed, especially in response to the high volumes of recharge in 2010 and 2011. As shown on **Figure E-3**, groundwater level monitoring in wells near the recharge basin show inconsistent results among wells leading to questions about the direction of flow and effect of the recharge.

Figure E-3
Well Hydrographs near the Mission Creek Spreading Basins



For example, water levels in the DWA monitoring well (SWN 02S04E21H01S) and MSWD's Well 34 (SWN 02S04E28A01S) (located about 0.6 miles apart) show similar levels and closely correlate to the amount of water recharged. However, water levels observed in MSWD Wells 30 (SWN 02S04E23N02S) and 35 (SWN 02S04E28J01S), each of which are located about 1.1-1.2 miles downgradient, show water levels between 190 and 425 ft lower with much reduced effect of the recharge indicated. Whether this difference is due to the mounding of water near the recharge basin or due to a hydrogeologic constraint is uncertain.

As described previously, construction of additional monitoring wells near the recharge basins would provide better data to define the recharge mound. In addition, a seismic refraction/reflection survey could be conducted between the recharge basins and the downgradient wells to determine if faulting or other hydrogeologic constraints are affecting the movement of recharge water. The cost of seismic refraction/reflection surveys is approximately $15,000 per 1,000 ft. The approximate cost of a survey in this area might be in the range of $100,000 - $200,000. Data from this survey could be used in conjunction with the monitoring well construction to determine the presence or absence of faults or other geologic structures in the area that may affect recharge water movement. It is recommended that the agencies investigate conducting a seismic survey in conjunction with monitoring well construction in this area.

DATA MANAGEMENT AND REPORTING

Collection of data without reporting limits the usefulness of the data. Periodic data analysis allows evaluation of the current plan's on-going ability to meet the water management objectives and provides the water agencies with information to adaptively adjust the management activities in response to changing conditions.

Data Management

Currently, there is no centralized database for the storage and analysis of groundwater data. Each agency maintains their data in-house. Little opportunity exists for collaboration and sharing of observations unless a major investigation such as this water management plan is undertaken. A similar situation exists for the remainder of the Coachella Valley.

It is recommended that CVWD, DWA and MSWD work through the Coachella Valley Regional Water Management Group and other interested parties to establish a valley-wide water resources database that would be accessible to all participating entities. As a minimum, the database should be capable of storing well ownership data, well logs, groundwater production, water level and water quality data. The database should also be capable of interfacing with other outside database systems as needed for reporting and utilizing common data. The database should have suitable access control to keep some data, such as well logs, confidential where required by State law. The scope of the database should be developed jointly by the CVRWMG.

Reporting

The current mechanism for reporting on groundwater basin conditions is the annual engineers report on water supply and replenishment assessment prepared by CVWD and DWA. Per state law, these reports currently are required contain the following elements:

- the condition of the groundwater supplies,
- the need for replenishment,
- recommendations for any replenishment program,
- the source and amount of replenishment water,
- the cost of purchasing or producing, transporting, and spreading this water,
- the cost of "in lieu" programs, including incentives to use Colorado River water or reclaimed water in place of groundwater,
- the area or areas benefited by the replenishment program , either directly or indirectly,
- the amount of water production produced in each area during the prior year, and
- the amount of assessment to be levied upon all production within the benefited area or areas.

It is proposed that the following additional information be incorporated in these reports, as appropriate, to provide additional data to water managers:

- annual precipitation and stream flow data to better document natural inflows to the groundwater basins;
- the amounts of in-lieu recharge that takes place through the delivery of recycled or imported water to reduce groundwater production;
- the total amounts of imported water delivered to users in each subbasin (if any);
- additional groundwater level hydrographs for wells in each subbasin to better indicate the changes in groundwater levels; and
- an accounting of the amounts of water stored in each subbasin on behalf of other entities including but not limited to Metropolitan and IID.

In recent years, CVWD and DWA have more closely coordinated the preparation of the engineer's report for their respective areas of benefit to minimize conflicting information. This practice should continue.

The Management Committee for the Mission Creek and Garnet Hill subbasins meets quarterly as specified in the Settlement Agreement. In recent meetings, replenishment status reports and groundwater levels at selected wells have been presented. This practice should continue in the future.

Periodic Groundwater Model Updates

A groundwater model of the Mission Creek, Garnet Hill and northern Whitewater River subbasins was prepared in conjunction with this Water Management Plan. The groundwater modeling report noted some limitations regarding the model including the accuracy of calibration near the Mission Creek Spreading Basins and in the Garnet Hill subbasin (Psomas, 2011). Additionally, the Mission Creek-Garnet Hill groundwater model does not currently include the Desert Hot Springs subbasin. It is recommended that this model and the Coachella Valley model be merged into a single groundwater model and that the Desert Hot Springs subbasin be added. This will ensure that model boundaries are accurately represented and avoid potentially conflicting results between the models. These modifications will require recalibration of the combined model.

It is also recommended that a planning interface and database be developed that can be linked with land use plans, development and agricultural activities to better distribute pumping and return flows to the model. Additionally, it is recommended that a water quality (solute transport) model capable of simulating the changes in salinity and possibly other conservative water quality parameters be developed and calibrated. This latter effort should be done in conjunction with the preparation of a valley-wide salt/nutrient management plan.

CONCLUSION

CVWD, DWA, and MSWD are encouraged to adopt the data monitoring, management and reporting recommendations described in this TM. Basin-wide participation and collaboration will provide a proactive strategy for the early detection issues related to groundwater levels, quality, and inelastic surface subsidence.

Appendix F
Financing Options

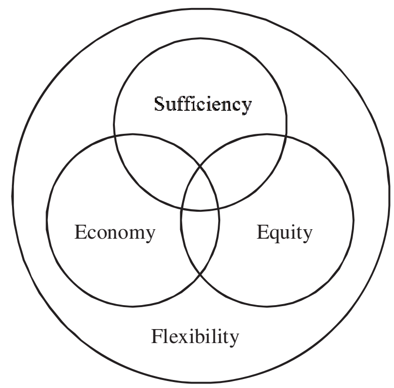
This section describes various financing sources available for the implementation of the Mission Springs/Garnet Hill Water Management Plan (WMP). The purpose of this section is to identify potential options for financing capital projects identified in the WMP that might be pursued by one of the three agencies, either as an individual agency, or jointly, to fund capital projects. No prioritization, ranking, or economic evaluation has been performed for any of these financing options.

FINANCE OBJECTIVES

Successful financing of large capital programs consistently depends on optimizing three financing objectives:

- Produce capital in sufficient amounts when needed;
- Produce capital at lowest cost; and
- Produce capital with greatest equity among customers, including the principle that growth-pay-for-growth.

Because the implementation of the Water Management Plan will involve program refinement over the years, financial planning should also have flexibility to accommodate changes in law, system requirements, capital requirements, constituency requirements, and the methodologies available to the water management group to generate funds.



Financing Objectives

FUNDING SOURCES

There are several possible funding sources available for the successful implementation of the WMP, including pay-as-you-go, Drinking Water State Revolving Fund Loan Program, general obligation bonds, revenue bonds, Certificates of Participation, commercial paper (short term notes), assessment bonds, Mello-Roos Community Facilities Act, developer impact or connection fees, replenishment assessment, and other state grants and loans. These methods are further described below.

Pay-As-You-Go

Pay-as-you-go funding requires that an agency (or group of agencies) have adequate revenue generation or reserves to fund capital improvements and would be funded by water rates or more of one the Plan participants. Reserves can be built up in advance to pay for future facility requirements by raising fees prior to the need for capital facilities. The funds can provide for either all or part of the capital costs. Using pay-as-you-go funding reduces the overall costs of capital facilities by avoiding the costs associated with arranging financing (bond issue costs, legal and financial advisers, etc.) as well as interest on borrowed money.

Pay-as-you-go funding often leads to inequities since customers today are paying the full costs for facilities that will provide benefits to future customers. To achieve a more equitable sharing of the cost burden, other funding sources usually are utilized in addition to pay-as-you-go, due to the differences in timing between accumulation of reserves and the capital spending requirements.

Drinking Water State Revolving Fund Loan Program

Through a jointly financed program between the federal EPA and the State of California, the Drinking Water State Revolving Fund (DWSRF) Loan Program can provide low interest loans to water utilities to help pay for improvements and are loaned to a single water agency. Under the program, loans are issued for up to 20 years at a fixed interest rate equal to 50 percent of the State's average interest rate paid on general obligation bonds sold during the previous calendar year. Repayment under the program must begin within six months after completion of the project.

Generally, loans are limited to $20 million for any one project, with a cap of $30 million available to a single water utility in a single fiscal year. These amounts may be modified if it is determined that excess funds are available that cannot otherwise be obligated before the EPA obligation deadline.

Loans are granted based on a set of ranking criteria that give highest priority to projects that resolve deficiencies having direct health implications. Also high on the priority list is insufficient water source capacity that results in water outages. Funds are allocated to applicants based on the priority categories until all funds are obligated. Since the program began in May 1998 through March 30, 2010, 2010 CDPH has closed 207 loans totaling $895 million cumulatively (USEPA, 2010).

General Obligation Bonds

General Obligation (G.O.) bonds are backed by the full faith and credit of the issuer. As such, they also carry the pledge of the issuer to use its taxing authority to guarantee payment of interest and principal. The issuer's general obligation pledge is usually regarded by both investors and ratings agencies as the highest form of security for bond issues.
Because G.O. bonds are viewed as having lower risk than other types of bonds, they are usually issued at lower interest rates, have fewer costs for marketing and issuance, and do not require the restrictive covenants, special reserves, and higher debt service coverages typical of other types of bond issues. However, issuance of G.O. bonds requires electoral approval by two-thirds of the voters, and election campaigns can be very expensive.

The ultimate security for G.O. bonds is the pledge to impose a property tax to pay for debt service. G.O. bonds are typically issued by a single water agency. Use of property taxes, assessed on the value of property, may not fairly distribute the cost burden in line with the benefits received by the customers. While the ability to use the taxing authority exists, the water agency seeking G.O. bonds could choose to fund the debt service from other sources of revenues, such as water rates or from development impact fees. Use of development impact fees to pay the debt service would provide the most equitable matching of benefits with costs, since debt service on projects that benefit primarily new customers would be paid from fees collected from those new customers.

G.O. bonds are attractive due to lower interest rates, fewer restrictions, greater market acceptance, and lower issuing costs. However, the difficulties in securing a two-thirds majority of the qualified electorate make them less attractive than other alternatives, such as revenue bonds and certificates of participation.

Revenue Bonds

Revenue bonds are long-term debt obligations for which the revenue stream of the issuer is pledged for payment of principal and interest. Because revenue bonds are not secured by the full credit or taxing authority of the issuing agency, they are not perceived as being as secure as general obligation (G. O.) bonds. Since revenue bonds are perceived to have less security and are therefore considered riskier, they are typically sold at a slightly higher interest rate (frequently in the range of 0.5 percent to 1.0 percent higher) than the G.O. bonds. The security pledged is that the system will be operated in such a way that sufficient revenues will be generated to meet debt service obligations.

Typically, issuers provide the necessary assurances to bondholders that funds will be available to meet debt service requirements through two mechanisms. The first is provision of a debt service reserve fund or a surety. The debt service reserve fund is usually established from the proceeds of the bond issue. The amount held in reserve in most cases is based on either the maximum debt service due in any one year during the term of the bonds or the average annual debt service over the term. The funds are deposited with a trustee to be available in the event the issuer is otherwise incapable of meeting its debt service obligations in any year. The issuer pledges that any funds withdrawn from the reserve will be replenished within a short period, usually within a year.

The second assurance made by the borrower is a pledge to maintain a specified minimum coverage ratio on its outstanding revenue bond debt. The coverage ratio is determined by dividing the net revenues of the borrower by the annual revenue bond debt service for the year, where net revenues are defined as gross revenues less operation and maintenance expenses. Based on this, the perceived risk minimum coverage ratios are usually within the range of 1.1 to 1.3, meaning that net revenues would have to be from 110 percent to 130 percent of the amount of revenue bond debt service. To the extent that the borrower can demonstrate achievement of coverage ratios higher than required, the marketability and interest rates on new issues may be more favorable.

Issuance of revenue bonds may be authorized pursuant to the provisions of the Revenue Bond Law of 1941. Specific authority to issue a specified amount in revenue bonds requires approval by a simple majority of voters casting ballots, and would typically be limited to a single agency seeking a revenue bond. To limit costs (and risks) associated with seeking approval through elections, authorization is typically sought for the maximum amount of bonds that will be needed over the planning period. Upon receiving authorization, the agency actually issues bonds as needed, up to the authorized amount.

Certificates of Participation

Certificates of Participation (COPs) are a form of lease-purchase financing that has the same basic features of revenue bonds except they do not require an election. COPs represent participation in an installment purchase agreement through marketable notes, with ownership remaining with the agency. COPs typically involve four different parties — the public agency as the lessee, a private leasing company as the lessor, a bank as trustee and an underwriter who markets the certificates. Because there are more parties involved, the initial cost of issuance for the COP and level of administrative effort may be greater than for bond issues. Due to the widespread acceptance of COPs in financial markets, COPs are usually easier to issue than other forms of lease purchase financing, such as lease revenue bonds.

The certificates are usually issued in $5,000 denominations, with the revenue stream from lease payments as the source of payment to the certificate holders. From the standpoint of the agency as the lessee, any and all revenue sources can be applied to payment of the obligation, not just revenues from the projects financed, thereby providing more flexibility. Unlike revenue bonds, COPs do not require a vote of the electorate and have no bond reserve requirements, although establishing a reserve may enhance marketability. In addition, since they are not technically debt instruments, COP issues do not count against debt limitations for the agency.

While interest costs may be marginally higher than for revenue bonds, a COP transaction is a flexible and useful form of financing that should be considered for financing of the WMP projects. COP transactions would be typically limited to a single water agency obtaining a COP for a specific project.

Commercial Paper (Short Term Notes)

To smooth out capital spending flows without the costs of frequent bond issues, many public agencies have moved to use of short-term commercial paper debt. As with bonds issued by the public agencies, commercial paper instruments are typically tax-exempt debt, thus providing a lower interest cost to the agency than would prevail if the commercial paper were taxable. Commercial paper is usually issued for terms ranging from as short as a few days to as long as a year depending on market conditions. As the paper matures, it is resold (“rolled over”) at the then prevailing market rate. Consequently, the paper can in effect “float” over an extended time, being constantly renewed. The short-term rates paid on commercial paper are frequently much lower than those on longer term debt.

The primary advantage in using commercial paper is to provide interim funding of capital projects when revenues and reserves are insufficient to fund capital projects fully. In this scenario either (1) the total amount needed is too small to justify a bond issue or (2) the funds are not currently available, but will be building up (within two to five years) to a level sufficient to repay the borrowing. Commercial paper funding can provide the “bridge” to smooth out the fund flows. As with other forms of debt funding, there are costs associated with commercial paper issuance. Many of the costs are similar to those of issuing bonds. With commercial paper, however, there is often a requirement that a line of credit be established that will guarantee payment of the commercial paper should it not be possible to roll the paper over at any given maturity date. The cost of the credit line is usually based on the full amount of commercial paper authorized, whether issued or not, so the total commercial paper authorization must be carefully determined to maximize the benefit while minimizing costs.

While the interest rate for a particular commercial paper issue is fixed until its maturity, the short maturities and frequent rollovers of the debt effectively make commercial paper much like a long-term variable rate bond. Consequently, there is some exposure to interest rate risk in using commercial paper as a funding mechanism. However, unless inflationary pressure is great, the risk is relatively low.

The strategy now being used by a number of water agencies is to issue commercial paper up to the authorized limit, then pay-off the commercial paper outstanding through a revenue bond issue. The water agency gets the benefit of low short-term interest rates while still being able to convert to long term fixed rates through the bond issue. This is an appropriate strategy during relatively stable interest rate environments, but not when interest rates are rising or expected to rise substantially.

Commercial paper programs are typically limited to a single water agency, and the agency pursuing commercial paper will need to confer with their legal and financial advisors to determine if sufficient authorization currently exists to implement a commercial paper program.

Property Related Debt

For many years, California has allowed a form of financing where the properties that benefit from projects pay debt service in proportion to the benefit received. The California Streets and Highways Code allows bonds to be sold under the 1911 Improvement Act or 1913 Municipal Improvement Act, under the procedure of the 1913 Act and the 1931 Majority Protest Act. Mello Roos Community Facilities District Act (1982) financing is a variation of this theme. Assessment financing, as the method was called, is useful for allocating shares of cost and debt service to properties within specific areas (called assessment districts) within which all of the financed project's benefit accrued and is typically used for smaller areas to finance specific projects. Although the methods still are legal, the voting requirement of the Tax Payers' Right to Vote Act (Proposition 218) has made the procedure less attractive.

Private Sector Equity

Some utilities find it convenient to enter into agreements with a private sector service provider to perform a certain well-defined functions. The service provider provides the assets as well as human resources, materials, supplies and other costs of business and includes those costs in the amount charged to the utility. This procedure becomes, *de facto*, a financing technique for the utility in that the capital cost of the assets are financed by the private sector service provider since the assets are owned by it. The financing is not always less expensive—the private firm may finance under different terms, including paying income taxes. The specifics can depend much on the firm's other portfolio aspects–but the method does reduce the capital requirement to be financed by the utility and may for greater flexibility and creativity than other financing options.

Specific projects for engaging a private sector equity participant have not been identified. Further, any cost savings associated with this approach might depend on the specific projects, so this approach is not considered further in this financing plan. Again, this method can be a valuable tool for application in certain situations and should be considered when appropriate.

Developer Impact or Connection Fees

Developer impact fees or connection fees are commonly used to finance water system extensions and to recover previous facility costs that benefit future growth. The use of the developer fees to recover facility costs, already incurred or planned, that are necessary to serve new customers is appropriate. The level for the developer fees is determined by the overall cost level necessary to support growth, the allocation of these costs to the various benefit zones, the amount of fees already collected from new connections, and the number of new connections expected in each of the benefit zones. Each individual water agency can set connection fees for various components of new water connections such as water supply, storage, transmission and distribution pipelines.

Replenishment Assessment Charge

Sections 31630 to 31639 of the California Water Code (Code) authorize CVWD to levy and collect a Replenishment Assessment Charge (RAC) for the purpose of replenishing groundwater supplies within its areas of jurisdiction. DWA's enabling legislation has essentially the same language and uses a Replenishment Assessment Rate (RAR) (California Water Code Appendix Chapter 100 – Desert Water Agency Law). The RAC is a monetary charge that is uniformly applied to extractions of groundwater within certain specified geographic boundaries (areas of benefit) for repayments of an imported or recycled water supply purchased to supplement naturally existing water supplies. Charges for the water supply are limited to certain specified costs. DWA collects the RAR from all pumpers within its defined area of benefit of the Mission Creek subbasin who pump greater than 10 acre-ft. CVWD currents collects the RAC from all pumpers within its area of benefit of the Mission Creek subbasin who pump greater than 25 acre-ft. The RAC is based on the amount of water produced per year. The RAC might be a viable option for funding some of the projects identified in the MSGH WMP and would be implemented by DWA and CVWD.

Water Recycling Funding Program

Water Recycling Funding Program of the State Water Resources Control Board (SWRCB) provides funding assistance for the planning, design and construction of water recycling projects that will help alleviate the demand on state or local potable water supplies. The mission of the Water Recycling Funding Program (WRFP) is "to promote the beneficial use of treated municipal wastewater (water recycling) in order to augment fresh water supplies in California by providing technical and financial assistance to agencies and other stakeholders in support of water recycling projects and research." The WRFP is funded through Proposition 50, Proposition 13, and the State Revolving Fund (SRF) Loan Program.

It is understood that the funds for the Proposition 50 program are currently fully subscribed to but applications are still being accepted in anticipation of the 2012 Water Bond. Funding is currently available from the SWRCB for Recycled Water Planning Grants for recycled water planning studies for a 50 percent matching grant, up to $75,000. WRFP funding assistance would be obtained by a single water agency.

Integrated Regional Water Management Plan (IRWMP) Grants

California DWR has a number of IRWM grant program funding opportunities. Current IRWM grant programs include: planning, implementation, and stormwater flood management. DWR's IRWM Grant Programs are managed within DWR's Division of IRWM by the Financial Assistance Branch with assistance from the Regional Planning Branch and regional offices (IRWMP website). The funding provided under this program is through Proposition 50, Proposition 84, and Proposition 1E. The agencies participating in this Plan currently are pursuing IRWM grants through the Coachella Valley Regional Water Management Group (CVRWMG); the likelihood of obtaining grants improve for regional projects benefitting multiple stakeholders.

Federal Funding

Federal funding for recycled water projects is available through the U. S. Bureau of Reclamation, Title XVI Program. The Title XVI Program makes funds available to eligible projects (water reclamation and reuse of municipal, industrial, domestic and agricultural wastewater, and naturally impaired ground and surface waters, and for design and construction of demonstration and permanent facilities to reclaim and reuse wastewater) in the form of grants. The Program funds up to 25 percent of the total project cost. U. S. Army Corp of Engineers (USACE) funding is available, for flood damage reduction, aquatic system restoration, and certain eligible municipal & industrial water supply projects. This funding is through USACE's Civil Works Program and projects under this program are financed upfront by the Federal government with 100 percent of the cost to be repaid with interest over a period of 30-50 years. USACE funding is also available to certain rural and small communities to fund water supply projects via USACE's Environmental Infrastructure authorizations. Projects covered under this program are typically design and construction of drinking water and wastewater infrastructure, surface water protection and development. Financing under the environmental infrastructure authorizations is typically 75 percent federal and 25 percent non-federal.

2012 Water Bond

Potential future funding might be available through other state implemented bond measures such as the 2012 California Water Bond. The measure, also known as the Safe, Clean, and Reliable Drinking Water Supply Act of 2012 is on the November 6, 2012 ballot in California as a legislatively-referred bond act. The bond measure if passed will allow the state government to borrow $11.1 Billion to overhaul the state's water system and includes funding for drought relief projects, disadvantaged communities, integrated regional water management projects, water storage projects, groundwater protection and cleanup, ecosystem restoration, and water recycling and advanced treatment technology projects. The water management group should explore the possibility of securing funding through this measure if it is passed in 2012.

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