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HIGH DESERT POWER PROJECT
WATER BANKING MODEL
TECHNICAL REVIEW OF COMPLIANCE SUBMITTALS AND STAFF MODIFICATIONS FOR CONDITION OF CERTIFICATION SOIL & WATER-9

APRIL 20, 2004
PREPARED FOR THE CALIFORNIA ENERGY COMMISSION
PREPARED BY LDBOND & ASSOCIATES

1. INTRODUCTION

This report describes work performed for the California Energy Commission (CEC) by LDBond & Associates (LDBond) associated with the modification of the High Desert Power Project (HDPP) Water Banking Model. The purpose of this in-house report is two-fold.

The first objective of this report is to provide the CEC with a summary assessment of the model-modification work performed for Soil & Water-9 by the project owner, Constellation/High Desert Power Project LLC. The assessment described in this report is a compilation of memos, emails and presentations provided to the CEC by LDBond in 2003 and 2004, to date.

The second objective is to describe the in-house modifications of the HDPP Water Banking Model performed by LDBond. These modifications were conducted to provide the CEC with a provisional version of the Model, as described in Soil & Water-8 and Soil & Water-9.

This report also includes two appendices. The first appendix provides the full text of Soil & Water-8 and Soil & Water-9. The second appendix provides a description of the development, limitations and features of the HDPP Water Banking Model.

2. MODIFICTION OF HDPP WATER BANKING MODEL

As described in Appendix B, Development, Limitations and Features of the HDPP Water Banking Model, the HDPP Model is not a stand-alone model. The aquifer parameters and geometry of the HDPP Model developed during the HDPP certification process were based on a preliminary version of the USGS Mojave River Basin groundwater model (USGS Model) (Stamos, 2001), which was not yet completed at the time of certification. Accordingly, Soil & Water-9 specifies post-certification modifications of the HDPP Water Banking Model to update the model with the finalized USGS Model values. Soil & Water-9 specifies tasks for both the project owner and the CEC staff. The project owner is required to “modify the HDPP model grid to accommodate the representation of gradational changes in the hydraulic conductivity of the Regional Aquifer, in conformance with the USGS Mojave River Groundwater Basin model.” The CEC Staff is required to “revise the HDPP model…to incorporate the gradational changes in the hydraulic conductivity of the Regional Aquifer represented in the USGS Mojave River Groundwater Basin model." Soil & Water-8 specifies one additional model-modification task for the CEC staff. Soil & Water-8 requires the CEC staff to revise the HDPP Model to reflect the results of the HDPP aquifer test analyses.

2.1 Provisional Status of Model Modifications

The modifications described in this report are provisional because they include work products produced in-house that were to be performed by the project owner, as specified in Soil & Water-8 and Soil & Water-9. The provisional work for Soil & Water-8 depends on the in-house calculation of site-specific aquifer parameter values from the HDPP aquifer tests, which was work that was to be performed by the project owner. The provisional work for Soil & Water-9 depends on in-house corrections of errors in the model grid modifications submitted by the project owner. The modification work assigned to staff in Soil & Water-9 is contingent on the work assigned to the project owner. If the project owner's final grid modifications and final aquifer test results that are approved by the CEC vary significantly from the in-house work, staff will have to revise the aquifer parameter values currently assigned to the HDPP Water Banking Model accordingly.

2.2 Technical Review of Project Owner's Compliance Submittals for Soil & Water-9

The project owner's initial submittal for Soil & Water-9 significantly deviated from the requirements of the condition and the structure of both the HDPP Model that was adopted at certification and the USGS Model. Rather than submitting a simple modification of the original HDPP grid that conformed to the USGS Model, the project owner constructed a new model based on a new interpretation of the regional geology developed by the project owner. The model included a four-layer aquifer system and grid, new aquifer parameters and new boundary conditions. Most importantly, this new model included a regional aquitard that formed a hydraulic barrier between the project's pumping zone from the Mojave River and the Mojave River Alluvial Aquifer. Inclusion of a regional aquitard was important because if such an aquitard did exist it would significantly limit any impacts of the project's water bank on the Mojave River. However, no such aquitard was identified or represented in the USGS Model. Furthermore, the project owner was not able to provide any other previously published documentation or any new evidence that conclusively demonstrated the presence of a regional aquitard in the upper portion of the aquifer system. Consequently, this first submittal was not approved by the CEC because it overstepped the requirements of the condition and proposed to integrate unproven factors into the model. Although the project owner's reinterpretation of the regional geology and proposal to restructure of the model became the primary focus of the model update process, the project owner did provide a revised grid for the HDPP Model in March 2003.

The revised grid submitted by the project owner in March 2003 was limited to a two-layers and generally conformed to the original HDPP Model grid and the USGS Model grid. Figures 1 through 4 provide a comparison of the grid structure for the original HDPP Model grid, the USGS Model grid and the revised March 2003 grid. Figures 1 and 2 show the structure and extent of the upper and lower layers of original HDPP Model grid, adopted by the CEC. The March 2003 grid accommodated most of the aquifer parameters represented in the USGS Model and did not include the new geologic interpretation that was included in the December submittal. Figure 3 show the boundaries and primary features of the USGS Model, including the extent of the two model layers (USGS layer 1 corresponding to the upper layer of the HDPP Model and the USGS layer 2 corresponding to the lower layer of the HDPP Model.) Figure 4 shows the configuration of the revised grid submitted in March 2003. The March 2003 grid did include one modification that was approved by the CEC; the model domain was extended to the western and southern boundary of the Alto subarea, defined in the USGS Model (Figure 5), to accommodate the final HDPP well locations, which were located south of the original proposed locations. Finally, although the March 2002 grid generally conformed to the USGS Model, this submittal contained two critical omissions from the grid and included an inconsistency in the geographic coordinates of the grid.

2.2.1 Detailed Description of Errors and Omissions in March 2003 Grid

Staff determined that two critical fault features associated with the Mojave River Narrows had been omitted from the revised March 2003 grid. The first omission was the Narrows Fault, which borders the west side of the Mojave River between the upper and lower Narrows. The second omission was the uplifted bedrock fault block beneath the Narrows, which directly underlies the Mojave River Alluvial Aquifer. These two omissions are important because the Narrows Fault and the uplifted fault block significantly restrict the interactions between the Regional Aquifer and the Mojave River at the Narrows, as indicated in the geologic map and cross-section developed by the USGS (Figure 6). Both of the fault and the uplifted bedrock were represented in the preliminary USGS Model, the original HDPP Model (Figures 1 and 2) and the published USGS Model (Figure 3). However, the grid submitted in March 2003 completely omitted the Narrows Fault (Figure 7) and extended the lower layer of the Regional Aquifer beneath the Mojave River between the Narrows (Figure 8).

The omission of these two fault features would have a significant effect on the results of water bank assessments. If the Narrows Fault were to be omitted from the HDPP Model, model simulations would indicate that water injected by the HDPP Water Bank would dissipate (discharge) much more rapidly to the Mojave River than would actually occur. Correspondingly, the simulations would indicate that project pumping would draw water from the Mojave River much more rapidly than would actually occur.

The March 2000 submittal also included a minor problem with the coordinates specified for the grid. The geographic coordinates of the grid submitted in March were based on a metric coordinate system that were inconsistent with the vertical coordinate units specified for the model, which are in English units. In addition, all of the original HDPP Model coordinates and the USGS Model coordinates use English coordinates. Although the March 2003 coordinate input file included a conversion factor, which reconciled the units read by the computer program, using mixed units made cross-referencing to the other models, geographic-referencing to physical land features, and error-checking unnecessarily complex and less accurate.

2.2.2 Detailed Description of Approved Additions to March 2003 Grid

The only significant addition to the March 2003 grid was an expansion of the southern and western boundaries of the model. A comparison of Figure 1, which shows the area of the original grid, and Figure 4, which shows the area of the March 2003 grid, indicates the extent of the expansion. Staff pre-approved this modification which expanded the HDPP grid to the southern and northwestern boundaries of the groundwater basin and to the western boundary of the Altos subarea, as defined in the USGS Model (Figure 5). This modification of the original boundaries of the HDPP Model was appropriate because the actual HDPP project wells were constructed south of the proposed well sites and were too close to the original southwest model boundary. The wells were too close to the model boundary because the area of influence of the actual project wells was likely to extend beyond the original model boundary.

2.2.3 Soil & Water-9 Submittal - Conclusions and Recommendations

The project owner's December 2002 submittal completely failed to meet the requirements of Soil & Water-9. Although the project owner's March 2003 grid was a significant improvement from the December submittal, the grid was not useable, as submitted, because of the omission of the two fault features. In addition, although easily replaced, the horizontal coordinates of the grid were inconsistent with the vertical coordinates and aquifer parameter units of the HDPP Model, as well as all of the units in the USGS Model, and reduced the spatial accuracy of model. Therefore, owing to these errors and inconsistencies, the project owner's submittal for Soil & Water-9 was inadequate and remains incomplete.

2.3 Staff Modifications to the HDPP Model

As described previously, the CEC staff is required to update the overall aquifer parameter values in the HDPP Model in accordance with the finalized aquifer parameter values in the published USGS Model and to update the HDPP well-field parameters to reflect the results of the HDPP aquifer tests. The staff's work to update the aquifer parameters of the HDPP Model is contingent on the project owner's completion of the aquifer tests, the aquifer test analyses, and the update of the HDPP Model grid. Beginning in December 2002 through December 2003, all of the project owner's submittals for these tasks have contained significant, uncorrected errors. For this reason, staff could not complete their required work on the HDPP Model.

However, over the same period, the project owner repeatedly voiced concern that the water banking requirements specified in the conditions of certification were unattainable, based on the project owner's own modeling assessments. Therefore, in response to the project owner's concerns, the CEC staff requested in December 2003 that LDBond complete a provisional update of the aquifer parameter assignments to the grid and evaluate a five-year projection of anticipated water bank operations, based an in-house analysis of the aquifer tests that appeared to be least flawed and an in-house correction of the errors in the March 2003 grid. The in-house analysis of the aquifer tests and the results of the five-year assessment have been described in previous documents (LDBond, 3/9/2004 and LDBond, 1/21/2003). The following sections describe the corrections to the March 2003 grid and the update of the aquifer parameter assignments.

2.3.1 Staff Corrections to HDPP Grid

The following list summarizes staff revisions to the HDPP Model grid that was submitted by the project owner (March 2003).

- Incorporation of the Narrows Fault;
- Representation of the bedrock uplift beneath the Narrows;
- Recalculated the HDPP grid coordinates;

- Correction of coordinate registration of nodes representing the HDPP project wells, the Mojave River and the basin boundaries; and
- Adjustment of node alignments to accommodate geo-referenced transfer of USGS data.

Staff corrected project owner's omission by reconfiguring the grid to add the Narrows Fault to the model (Figure 9). Incorporation of the Narrows Fault into the March 2003 HDPP Model grid required a major adjustment of node locations. Faults are represented in the HDPP Model by a narrow band of elements that are assigned low values for hydraulic conductivity. A comparison of the staff-modified grid in Figure 9 to the grid provided by the project owner (Figure 4**)** shows how the staff enlarged the elements between the HDPP well field and the Mojave River to create a narrow band of elements on the west side of the Mojave River to represent the fault in the upper layer of the model. Changes in the grid needed to add the Narrows Fault to the model also required additional adjustment of node alignments to accommodate the gradational changes in USGS aquifer parameters.

Staff corrected the error in the lower layer of the March 2003 grid to represent the bedrock that directly underlies the Narrows Fault, the Mojave River, and the Mojave River Alluvial Aquifer. The Regional Aquifer does not extend beneath the Narrows, as shown in the USGS geologic map and cross for the region (Figure 6). Figure 3 shows how the Regional Aquifer represented by the lower layer (labeled Model layer 2) in the USGS Model does not extend beneath the Narrows. Although the first version of the HDPP Model developed by the Applicant contained the same error of extending the Regional Aquifer beneath the Narrows, the final version of the HDPP Model adopted at certification inactivated the elements in the lower layer to represent the uplifted bedrock beneath the Narrows (Figure 2). This same approach was used by staff to modify the March 2003 grid. Figure 10 shows the inactive elements in the lower layer assigned by the staff, which represent the uplifted bedrock and the absence of the Regional Aquifer beneath the Narrows, corresponding to the aquifer conditions represented to the USGS Model.

Staff also recalculated the HDPP grid coordinates and adjusted the registration of the nodes. The horizontal coordinates for the grid submitted by the project owner was based on a metric coordinate system and the vertical coordinates were based on English units. The original HDPP Model and the USGS Model use English units (feet) for all grid coordinates and aquifer parameter values. Accordingly, staff recalculated the horizontal grid coordinates using the California Coordinate system, which uses English units. Use of the California Coordinate system enabled staff to use consistent set of units throughout the model, to directly register the nodes to geographic features, such as the Mojave River, and to perform a direct translation of the coordinates of aquifer data from the USGS model.

Staff also verified the coordinates for the HDPP wells and corrected the modeled locations of the wells, as needed.

2.3.2 Staff Modifications of Aquifer Parameters

The modification of the aquifer parameter values of the HDPP Model was performed in two steps, which correspond to the requirements of Soil & Water-9 and Soil & Water-8. The first step was to update the aquifer parameter values in the HDPP Model to correspond to the finalized aquifer parameter values in the USGS Model. The second step was to modify the aquifer parameters in the area of the HDPP well field to reflect the results of the staff's in-house analysis of the HDPP aquifer tests.

2.3.2.1 USGS-Based Update of Aquifer Parameters

The USGS Model, based on the groundwater program MODFLOW (McDonald and Harbaugh, 1988), and the HDPP Model, based on the groundwater program FEMFLOW3D (Durbin and Bond, 1997), represent the characteristics of the aquifer using different, but roughly equivalent, terms. Both models represent the aquifer system in two layers. The USGS Model defines the aquifer's characteristics in terms of transmissivity, anisotropy, specific storage and specific yield, which are assigned to each cell in the model. The thicknesses of the aquifer layers in the USGS Model are not explicit, although a representative, uniform thickness is assumed for each layer. Non-transmissive faults are represented as low-permeability horizontal-flow barriers located between model cells in the USGS Model. In comparison, the HDPP Model defines the aquifer characteristics in terms thickness, horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage and specific yield, which are assigned to each element in the model. Non-transmissive faults are represented in the HDPP Model with low-conductivity elements.

The thickness of the layers is the key parameter that was used to translate the aquifer parameter values of transmissivity, anisotropy, and specific storage used in the USGS Model to calculate the values of horizontal hydraulic conductivity, vertical hydraulic conductivity and specific storage in the HDPP Model. The inputs to the two models are different primarily because the HDPP model uses specified thickness to internally calculate the aquifer parameter terms that are calculated externally in the USGS Model. This means that if the end-product term, such as transmissivity, is the same in both models, the specific thickness used in either model does not affect the results. Therefore, although the thickness of the actual aquifer system in the HDPP area is not uniform, staff concluded that an accurate translation of the USGS aquifer values would be more easily verified if the same uniform thicknesses of upper and lower layers the USGS Model were applied to the updated HDPP Model. Accordingly, the HDPP Model was assigned the same thicknesses as the USGS Model, a uniform thickness of 100 feet for the upper layer and a uniform thickness of 700 feet for the lower layer.

Translating the USGS aquifer parameters to the HDPP Model involve two steps, in most cases. The first step is to translate the USGS parameter terms to HDPP parameter terms. Using the thickness of the USGS Model, the aquifer parameter values of transmissivity, specific yield and specific storage in the USGS Model can be directly translated into values of horizontal hydraulic conductivity, specific storage and specific yield in the HDPP Model. Although vertical permeability and flow barriers are represented in the USGS Model and the HDPP Model using somewhat different mathematical approaches, simple formulas to translate these terms yield reasonably equivalent values. The values of thickness, transmissivity and anisotropy in the USGS Model can be used to calculate values of vertical hydraulic conductivity for the HDPP Model. The hydraulic characteristic assigned to the USGS fault barriers can be used to calculate the hydraulic conductivity of the HDPP Model fault elements. The second step is to translate the distribution of parameter values from the USGS cells to the HDPP elements. USGS cells are volumetric units of the model that are equivalent to the HDPP elements, the volumetric units of the HDPP Model. However, the USGS cells are not the same size or shape as the HDPP elements. Therefore, spatial averaging is used to assign the parameter values from the USGS cells to the HDPP elements. The following discussion describes how each of these aquifer parameters for each model layer was translated from the USGS Model to the HDPP Model.

Transmissivity is defined as horizontal hydraulic conductivity multiplied times thickness. Accordingly, the transmissivity of each cell in the USGS Model was first translated to hydraulic conductivity by dividing transmissivity of each cell by the thickness of the layer. The second step was to assign these hydraulic conductivity values from the USGS Model cells to the corresponding elements in the HDPP Model. Averaged values of the cells, weighted by area, were applied to each element. Two sets of figures illustrate the aquifer values for these three steps for the upper and lower layers of the models. Figure 11 shows the transmissivity values for the upper layer (layer 1) of the USGS Model. Figure 12 shows the calculated horizontal hydraulic conductivity for the upper layer of the USGS Model within the boundaries of the HDPP Model, assuming a thickness of 100 feet. Figure 13 shows the averaged horizontal hydraulic conductivity values assigned to the upper layer of elements of the HDPP Model. The next three figures show the corresponding values for the lower layer of the models. Figure 14 shows the transmissivity values for the lower layer (layer 2) of the USGS Model. Figure 15 shows the calculated horizontal hydraulic conductivity for the lower layer of the USGS Model within the boundaries of the HDPP Model, assuming a thickness of 700 feet. Figure 16 shows the averaged horizontal hydraulic conductivity values assigned to the lower layer of elements of the HDPP Model.

The USGS Model and the HDPP Model use somewhat different mathematical approaches to calculate vertical flow of water through the aquifer system. Vertical flow is controlled by vertical hydraulic conductivities, thickness and hydraulic head differences within the aquifer. Input to the USGS Model specifies these aquifer parameters in terms of vertical leakance between the two layers, calculated using the following equation (modified from McDonald and Harbaugh, 1988, p. 5-13):

$$V\mathit{cont} = 2/\{[B_1^2/(T_1 \text{ x } a_1)] + [B_2^2/(T_2 \text{ x } a_2)]$$

where

$V\mathit{cont}$ is the leakance between model layers $[t^{-1}]$
B_1 is the thickness of upper model layer (assumed equal to 100 feet),
B_2 is the thickness of lower model layer (assumed equal to 700 feet),
T_1 is the transmissivity of upper model layer [K/t],
T_2 is the transmissivity of lower model layer [K/t],
a_1 is the vertical-to-horizontal anisotropy of the upper layer, and
a_2 is the vertical-to-horizontal anisotropy of the lower layer.

In contrast to the USGS Model, the HDPP Model calls for input of the parameters that are components of the USGS vertical leakance term, specifically the thickness and the effective vertical hydraulic conductivity for each layer. Effective vertical hydraulic conductivity of each layer can be defined as the transmissivity multiplied by anisotropy of each cell and divided by thickness of the layer. The USGS Model identifies anisotropy values for each of the cells of the upper layer of the model (Figure 17). Using the USGS anisotropy values (Figure 17) and the transmissivity values (Figure 11) of the upper layer, staff calculated vertical hydraulic conductivities for each cell of the upper layer USGS Model (Figure 18). Figure 19 shows the averaged vertical hydraulic conductivity values that were then assigned to the upper layer of elements of the HDPP Model. The USGS assumed a uniform vertical-to-horizontal anisotropy of 1:10 for the lower layer of the USGS Model. Using the transmissivity (Figure 14), anisotropy and thickness values, staff calculated the vertical hydraulic conductivities for each of the USGS cells of the lower layer within the boundaries of the HDPP Model (Figure 20). Figure 21 shows the averaged vertical hydraulic conductivity values assigned to the lower layer of elements of the HDPP Model.

The USGS Model identifies specific yield values for each of the cells of the upper layer of the model (Figure 22), which can be directly assigned to the upper layer of elements of the HDPP Model (Figure 23). Specific yield is a physical property of aquifers that only applies to the uppermost, unconfined layer of an aquifer. As with the hydraulic conductivity values, averaged specific yield values for the cells, weighted by area, were applied to each element of the HDPP Model.

The USGS Model assumes a uniform specific storage value of 1×10^{-6} ft^{-1} for the lower layer of the model, which equals a storage coefficient of 7×10^{-4} for an assumed thickness of 700 feet. (Storage coefficient equals specific storage multiplied by thickness.) Since the same thicknesses are assumed for both the USGS Model and the HDPP Model, a specific storage value of 1×10^{-6} ft^{-1} for the lower layer of the HDPP Model. No storage coefficient is assigned to the upper layer of the USGS Model, presumably because this parameter has a negligible effect in the upper, unconfined portion of an aquifer. However, because specific storage is a required parameter for all layers in the HDPP Model, a value of 1×10^{-6} ft^{-1}, which represents a mid-range value for most aquifers, was also assigned to the upper layer of the HDPP Model.

Finally, as noted above, non-transmissive faults, which limit the rate of horizontal flow through the aquifer, are represented in the USGS Model and the HDPP Model using somewhat different mathematical approaches. In the USGS Model, flow barriers are located between model cells and are assumed to have negligible width. The USGS fault barriers are assigned a low-value hydraulic characteristic, defined in units of $feet^2$/day, to represent the limited transmissivity of the fault. The HDPP Model represents flow barriers with a series of narrow elements. The HDPP faults elements have a specified thickness and are assigned low values of hydraulic conductivity. To approximate the faults conditions represented in the USGS Model, the product of the horizontal thickness and hydraulic conductivity of the HDPP fault elements are set equal to the hydraulic characteristic values assigned to the USGS faults. All of the faults identified by the USGS that are within the HDPP Model boundaries, including the Narrows Fault, the Shadow Mountain Fault and the Adelanto Fault, are assigned a hydraulic characteristic of 1 x 10^{-6} feet^2/day in the USGS Model. (It should be noted that the Turner Springs Fault identified in the preliminary USGS Model and the original HDPP Model was better defined and identified as the Shadow Mountain Fault and the Adelanto Fault in the finalized USGS Report.) Correspondingly, the fault elements in the HDPP Model are assigned a thickness, parallel to flow, of 100 feet and are assigned a horizontal hydraulic conductivity of 1 x 10^{-8} feet/day (100 feet x 1 x 10^{-8} feet/day = 1 x 10^{-6} feet^2/day) in both the upper and lower layers of the model (Figures 13 and 16). Vertical hydraulic conductivity of the fault elements are also set equal to the horizontal hydraulic conductivity (Figures 19 and 21), and specific yield is assigned a value of 0.01 percent (Figure 23.)

Table 1 summarizes the range of aquifer parameter values used in the USGS Model and the translated values assigned to the updated HDPP Model.

TABLE 1. SUMMARY OF AQUIFER PARAMETERS VALUES USED IN USGS MODEL AND HDPP MODEL

	USGS Model Values*	**Conversion Equation**	**HDPP Model Value**
Upper Layer			
	transmissivity range: 50 to 60,000 feet^2/day	transmissivity/thickness = horizontal hydraulic conductivity (thickness = 100 feet)	horizontal hydraulic conductivity range: 0.5 to 600 feet/day
	anisotropy range: 0.0001 to 0.1 (vertical-to horizontal)	[(transmissivity/thickness) x anisotropy] = vertical hydraulic conductivity	vertical hydraulic conductivity range: 0.0005 to 60 feet/day
	specific yield range:5% to 39%		specific yield range:5% to 39%
	specific storage (not defined)		specific storage 1 x 10^{-6}/ft (assumed)
Lower Layer			
	transmissivity range: 300 to	transmissivity/thickness = horizontal hydraulic	horizontal hydraulic

	17,500 $feet^2$/day	conductivity (thickness = 700 feet)	conductivity range: 0.43 to 25 feet/day
	anisotropy=0.1 (vertical-to horizontal)	[(transmissivity/thickness) x anisotropy] = vertical hydraulic conductivity	vertical hydraulic conductivity range: 0.043 to 2.5 feet/day
	specific storage 1×10^{-6}/ft		specific storage 1×10^{-6}/ft

* USGS Model values within HDPP Model boundaries.

2.3.2.2 Aquifer Test-Based Update of Aquifer Parameters

Using the results of the in-house HDPP aquifer test analyses performed CEC staff (LDBond, 3/9/2004), staff completed the aquifer parameter modifications to the HDPP Model by revising the aquifer parameter values in the vicinity of the HDPP well field, as specified in Soil & Water-8. The purpose of the aquifer tests was to evaluate the aquifer characteristics that are specific to the HDPP well field and to modify the USGS parameter values used in the HDPP Model to reflect these localized conditions. Table 2 provides a summary of the test results and model modifications for the aquifer parameters derived from the tests.

Overall, the aquifer tests provided the most information about the horizontal hydraulic conductivity and specific storage of the screened production interval, which corresponds to the lower layer of the HDPP Model, and the vertical hydraulic conductivity of the unscreened interval overlying the production interval, which corresponds to the upper layer of the HDPP Model. The test results indicated that hydraulic conductivities range from about 19 feet/day to 50 feet/day, which is somewhat higher than the equivalent value of 11 feet/day for the well-field area represented in the USGS Model. The test results indicated specific storage ranging from 5 x 10^{-06}/ft to 2 x 10^{-05}/ft, which is slightly higher than the equivalent value of 4.5 x 10^{-06}/ft for the well-field area represented in the USGS Model. The aquifer tests indicated that the USGS values for vertical hydraulic conductivity of the upper layer were reasonably accurate. No other changes to aquifer parameters were indicated by the tests.

To apply the results of the aquifer tests to the HDPP Model, the aquifer parameter values must be translated to account for the difference in thickness between the screened production zones, which range from 150 feet to 160 feet, and the lower layer of the HDPP Model, with a uniform thickness of 700 feet. The first step to translate horizontal hydraulic conductivity is to convert each test result value for horizontal hydraulic conductivity to transmissivity, using the thickness of production interval (horizontal hydraulic conductivity multiplied by thickness equals transmissivity). The second step is to convert transmissivity back to horizontal hydraulic conductivity using the thickness of the model. This same process is repeated to translate specific storage, based on the definition of storativity: storativity equals specific storage multiplied by thickness.

Once converted, the test results indicate that horizontal hydraulic conductivity in the area of HDPP Wells F and K is about 5 feet/day, which is two times higher than the USGS values. Horizontal hydraulic conductivity in the area of HDPP Well G is about 11 feet/day, which is four times higher than the USGS values. The converted specific storage values range from 1.15 x 10^{-06} to 5.46 x 10^{-06}, whish is only slightly higher than the USGS values.

TABLE 2. APPLICATION OF IN-HOUSE AQUIFER TEST RESULTS

TO HDPP MODEL UPDATE

HDPP Production Zone – Lower Layer Of USGS And HDPP Models	**USGS Values For HDPP Well Field**	**Well F Aquifer Test**	**Well K Aquifer Test**	**Well G Aquifer Test**
	Equivalent Values	**Aquifer Test Results[1]**		
Production Zone Thickness[2] (feet)	150 to 160	150	155	160
Horizontal Hydraulic Conductivity (ft/day)	11	27	19.4	49.5
Transmissivity (ft^2/day) (thickness x conductivity)	1750	4050	3007	7920
Specific Storage (1/ft)	4.5 x 10^{-06}	7.40 x 10^{-06}	5.20 x 10^{-06}	2.39 x 10^{-05}
Storativity Coefficient (thickness x specific storage)	7 x 10^{-04}	1.11 x 10^{-03}	8.06 x 10^{-04}	3.82 x 10^{-03}
	Model Values	**Converted Aquifer Test Values**		
HDPP Model Thickness (ft)	700	700	700	700
Transmissivity (ft^2/day)	1750	4050	3007	7920
Horizontal Hydraulic Conductivity (ft/day) (transmissivity/thickness)	2.5	5.8	4.3	11
Storativity Coefficient	7 x 10^{-04}	1.11 x 10^{-03}	8.06 x 10^{-04}	3.82 x 10^{-03}
Specific Storage (1/ft) (storativity/thickness)	1.0 x 10^{-06}	1.59 x 10^{-06}	1.15 x 10^{-06}	5.46 x 10^{-06}
		Parameter Value Adjustments Applied to HDPP Model		
Horizontal Hydraulic Conductivity (ft/day)		5	5	10
Specific Storage (1/ft) (no change)		1.0 x 10^{-06}	1.0 x 10^{-06}	1.0 x 10^{-06}

1. Source: Bond, L.D., 2004, High Desert Power Project Soil & Water-8 Technical Review of Compliance Submittals and In-House Assessment of Well-Field Aquifer Parameters, report prepared by LDBond & Associates for the California Energy Commission, 3/9/2004.
2. Source: Slade, R.C., 2002-2003, Report of Aquifer Testing and Injection Testing Aquifer Storage and Recovery Well F (12/19/2002), Report of Aquifer Testing and Injection Testing Aquifer Storage and Recovery Well G (12/18/2002), and Report of Aquifer Testing and Injection Testing Aquifer Storage and Recovery Well K (4/16/2003), prepared by Richard C. Slade & Associates LLC, consultant to Constellation/High Desert Power Project LLC, prepared for the California Energy Commission.

As recommended previously (LDBond 3/9/2004), the results of the aquifer tests were used in a limited manner to compensate for the decreased reliability of the HDPP aquifer test data. The USGS model delineates horizontal hydraulic conductivity zones. Rather than introducing new values into the model, the aquifer test values for horizontal hydraulic conductivity were rounded to the nearest USGS aquifer zone values. To modify the USGS-based horizontal hydraulic conductivity values for the lower layer of the HDPP Model, higher conductivity zones located east of the well field were expanded and extended to the west. Specifically, the 5-ft/day zone was extended to the west to encompass the area that includes HDPP Wells F and G and the 10-ft/day zone was extended to the west to encompass the area that includes HDPP Well G (Figure 24). In addition, in accordance with the uniform anisotropy for the lower layer that is specified by the USGS, vertical hydraulic conductivity values were also modified to correspond to the changes in horizontal hydraulic conductivity (Figure 25). (The design of the aquifer tests did not allow for the evaluation of vertical hydraulic conductivity values of the lower layer.) Specific storage values were not modified because the test results indicated values that were only slightly higher than the uniform USGS value of 1.0×10^{-06}/ft that was assigned to the lower layer of the Model.

3. CONCLUSIONS

This report completes the documentation of the staff's review of the project owner's modified model grid submittal for Soil & Water-9, of staff's in-house correction to the project owner's grid, and staff's provisional update of the aquifer parameter assignments to the HDPP Model. Staff's update of the aquifer parameters can be finalized when the aquifer tests, aquifer test analyses and the modification of the model grid, which were tasks assigned to the project operator in Soil & Water-8 and Soil & Water-9, are finalized. If the final grid modifications and final aquifer test results that are approved by the CEC vary significantly from the staff's in-house work, staff will have to revise the provisional HDPP Model aquifer parameter values described in this report.

REFERENCES:

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Durbin, T.J. and Bond, L.D., 1997, FEMFLOW3D: a finite-element program for the simulation of three-dimensional aquifers: U.S. Geological Survey Open-File Report 97-810, 338 p.

McDonald, M.G., and Harbaugh, A.W., 1988, A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water-Resources Investigation, book 6, Chap.A1, 576 p.

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APPENDIX A. CONDITIONS OF CERTIFICATION SOIL & WATER-8 AND SOIL & WATER-9

SOIL&WATER-8 The project owner shall conduct pumping tests in all project wells to establish *in situ* hydraulic parameters including transmissivity and storativity in the Regional Aquifer. From these parameters and the project well-log data, the project owner shall calculate the following site-specific values:

- effective horizontal hydraulic conductivity
- effective vertical hydraulic conductivity
- specific yield, if pumping tests indicate the aquifer is unconfined, or
- specific storage, if aquifer is confined.

Prior to conducting the pumping test, the project owner shall submit a work plan detailing the methodology to be used to conduct the proposed pumping tests and to calculate the specified parameters and values to the CEC CPM and to the CDFG for review and approval.

Based upon the information generated by the pumping tests, CEC Staff shall revise the HDPP model to reflect the results of the pumping tests. All modeling runs referred to in **SOIL&WATER-5** shall incorporate the results of these pumping tests, following approval by the CEC CPM determined pursuant to this Condition.

<u>Protocol:</u> The pumping tests shall provide data to calculate the *in situ* hydraulic parameters of the Regional Aquifer.

- At a minimum the pumping tests for all HDPP wells shall include the measurement of drawdown in at least one (1) non-pumping (observation) well that is screened at the same depth as the pumping well.
- Observation well(s) for each pumping test must be sufficiently close to the pumping well that pumping produces measurable drawdown of sufficient duration in the observation well(s) to analyze the site-specific hydraulic parameters including transmissivity and storativity in the Regional Aquifer.
- In addition, if the observation well data indicates a slow release of groundwater from storage, the pumping test shall be extended until the release from storage can be observed to stabilize in a plot of the data from the observation well(s). (For a description of the evaluation of storativity under slow release conditions, see Driscoll, F.G., 1986, Groundwater and Wells, H.M. Smyth, Inc., p. 229-230).

- Single well pumping tests and pumping tests that do not produce enough measurable drawdown in observation wells to conclusively calculate hydraulic parameters will not meet the Conditions of Certification.

Verification: The project owner shall submit to the CEC CPM and to the CDFG, six (6) months prior to the start of pumping tests, the work plan that details the methodology for conducting the proposed pumping tests on the seven (7) HDPP wells and for calculating the specified parameters and values. With the approval of the work plan by the CEC CPM, in consultation with the CDFG, the project owner shall perform the pumping tests following the CEC protocol. The CEC CPM shall provide notice that this material has been submitted to those identified on the project's compliance mailing list.

Within two (2) months after the completion of pumping tests, the project owner shall submit to the CEC CPM and to the CDFG a report detailing how the pumping tests were conducted and the results of the tests, including the calculation of: (1) the *in situ* hydraulic parameters of transmissivity and storativity for the Regional Aquifer; and (2) the site-specific values of effective horizontal hydraulic conductivity, effective vertical hydraulic conductivity, and specific yield and/or specific storage. The CEC CPM shall provide notice that this material has been submitted to those identified on the project's compliance mailing list.

SOIL&WATER-9 The project owner shall modify the HDPP model grid to accommodate the representation of gradational changes in the hydraulic conductivity of the Regional Aquifer, in conformance with the USGS Mojave River Groundwater Basin model.

The CEC Staff shall revise the HDPP model, using the modified grid, to incorporate the gradational changes in the hydraulic conductivity of the Regional Aquifer represented in the USGS Mojave River Groundwater Basin model.

All modeling runs referred to in **SOIL&WATER-5** shall incorporate the modifications of the model along with the model information obtained from the USGS following approval by the CEC CPM determined pursuant to this Condition.

Verification: The project owner shall submit the modified model grid input files (including updated versions of any other input files that are effected by the modification of the grid) within two (2) months after the construction of the HDPP wells to the CEC Staff for review and approval, in consultation with the CDFG. The CEC CPM shall provide notice that this material has been submitted to those identified on the project's compliance mailing list.

APPENDIX B. DEVELOPMENT, LIMITATIONS AND FEATURES OF HDPP WATER BANKING MODEL

The High Desert Power Project Water Banking Model, originally developed by the project Applicant during the certification process, was adopted to evaluate the operation of the project groundwater bank, which was adopted as the back-up water supply for the High Desert Power Project (HDPP).

The HDPP Water Bank Model (HDPP Model), as adopted in the Conditions of Certification, and the requirements of Condition of Certification Soil & Water-8 and Soil & Water-9 were highly contested during the compliance process from 2002 through 2003. Owing to a limited continuity in staffing and limited documentation, many issues that were raised during this period revisited proposals that had been evaluated and resolved during the certification process. To augment existing documentation, this appendix describes the development, limitations and features of the HDPP Water Bank Model. If modification of the HDPP Model that is not specified in the conditions or replacement of the HDPP Model is proposed again in the future, this review should provide information that will be useful in considering such proposals.

Development of HDPP Model

Although the HDPP Model may appear to be an overly-simplified approach, it was by far the best approach for evaluating project water bank operations that the Applicant proposed during the certification process. To lend perspective on the modeling approach adopted for the HDPP, a brief description of other proposals may be useful.

The Applicant's initial proposals for evaluating water banking operations included the use of a "cut-and-fill" (soil-excavation) program to model mounding effect of injection to and withdrawal from the groundwater system and the use of straight-line projections of historic groundwater level trends to identify the groundwater level change caused by project injection and pumping operations.

The first proposal, the use of a soil excavation program to represent groundwater dynamics, assumed that the physics of fluids are the same as the physics of solids. The CEC and CDFG rejected this approach because the physics of fluids and solids are distinctly different.

The second proposal to use a simple projection of historical groundwater level trends was based on the assumption that the future rate of change of urban water development, of agricultural water use, and of water losses from the Mojave River in the Victorville area would be identical to the historical rates of change for these factors over the 30-year life of the project. The CEC and CDFG rejected this second proposal because the Applicant could provide no evidence that future water use and streamflows would mirror historic conditions. In addition, the Applicant provided no evidence that the groundwater level response to historic conditions was linear.

Clearly these initial proposals failed to consider key factors that would determine the effect of water banking on the aquifer system, including the physics of groundwater flow.

The Applicant also had proposed to use a computational model to evaluate the water quality effects of project operations on groundwater. The model was based on FEMFLOW3D, a 3-dimensional groundwater modeling program (Durbin and Bond, 1997), which is designed to simulate the physics of fluid flow through porous media. The Applicant proposed to use the model to track the path of movement of the injected water within the aquifer. The CEC and CDFG rejected the use of the model for this purpose because it did not incorporate the drawdown effects of nearby VVWD wells, which would be a critical factor in determining the path of the specific injected water molecules through the aquifer system. However, although this model was inappropriate for evaluating the water quality impacts of the water bank, it did include the features needed to evaluate water-level impacts of the water bank. Therefore, this model, referred to in this report as the HDPP Water Banking Model, was adopted to evaluate the HDPP water banking operations.

The HDPP Model was adopted as a simple, single-purpose model. The purpose of the model was to evaluate the incremental changes in groundwater levels in response to actual project operations, which only requires an analysis of the pressure effects of project injection and pumping. Within most of the aquifer, the physics of the groundwater flow are relatively simple and the pressure effects can be calculated without including the drawdown effects of nearby wells. The pressure effects from pumping and injection from the project wells will largely determine how much groundwater levels will decrease or increase, relative to groundwater levels that would exist without the HDPP water bank. The HDPP Model has the capability of making accurate calculations of the changes in groundwater levels caused by the water banking operations in the vicinity of the project. However, near the Mojave River, the groundwater dynamics are more complex. The actual changes in groundwater levels near the river are controlled in part by river stage. The accuracy of the HDPP Model is limited in this area because the model assumes an active river only between the Narrows and represents the flows at the Narrows as a constant head boundary rather than representing fluctuating stage conditions.

This limitation was considered by technical staff during the certification process. The Applicant and the technical staff of the CEC, as well as the technical staff of the California Department of Fish and Game (CDFG) recognized that the representation of the river boundary conditions in the HDPP Model was an oversimplification of the physics of the actual system and considered other options. Participants did consider developing a more comprehensive model to evaluate the HDPP water bank, which would be more accurate but would also be much more complex and costly to develop, execute and maintain. However, the Applicant and the technical staff for CEC and CDFG mutually agreed that the error caused by this simplification would be small and did not warrant the cost and time required to develop and maintain a comprehensive model.

Limitations of the HDPP Model

Although the HDPP Model is adequate for the purpose for which it was designed, it is important to recognize some of the use-limitations of the HDPP Model. Specifically, it cannot be used to evaluate water quality conditions, groundwater gradients or depth to groundwater. It is not a comprehensive model and cannot be calibrated or used to evaluate aquifer parameters, such as transmissivity or specific yield.

As discussed above, the HDPP Model only calculates the incremental change in groundwater levels caused by project water banking operations. It simulates pumping and injection from the HDPP production wells only and quantifies inflows to and outflows from the Mojave River between the Narrows in response to project operations. It does not include any other pumping or recharge that occurs in the region. Therefore, it cannot calculate regional groundwater gradients necessary to calculate solute transport, which defines changes in water quality that might occur as a result of injection operations.

The HDPP Model cannot be used to calculate the depth to water in any part of the aquifer because it only calculates the incremental change in groundwater levels caused by project operations. The model includes no information on regional groundwater elevations. Therefore, the changes in water levels simulated by the model cannot be directly compared to groundwater elevation monitoring data.

Finally, the HDPP Model is not a stand-alone model. Because it lacks the capability to simulate groundwater elevations and contains no information on streamflows or other regional pumping or recharge, it cannot be used to evaluate aquifer parameters or to evaluate the structure or composition of the aquifer system. Given this limitation of the HDPP Model, the aquifer parameters and geometry of the HDPP Model must be defined independently from the model. The USGS Mojave River Basin groundwater model (USGS Model) (Stamos, 2001) was adopted for this project by the CEC to be the reference model for the HDPP Model.

The USGS Model is a comprehensive, calibrated regional groundwater model of the Mojave River Basin, which includes the sub-basin in which the HDPP is located. The USGS Model was developed to analyze the regional hydrodynamics and to provide a management tool "that could be used to estimate the effects that future stresses may have on the groundwater system, specifically, artificial recharge of imported water." The

USGS Model has been calibrated using measured stream-flow, pumping and water level data for 1931 through 1994 and has been verified with measured data for 1995 through 1999.

During the certification process, participants, including the Applicant, the CEC and the CDFG, specifically considered a proposal to use the USGS Model to evaluate the effects of the HDPP water bank. This proposal consisted of adopting the full USGS Model and would have required ongoing maintenance of the temporal data in the model, including pumping, stream flow and recharge. There were three advantages to this approach over the limited capabilities of the HDPP Model. First, the model could better represent the flow dynamics between the river and the groundwater system. Second, the model could be used to evaluate the changes in depth to groundwater with time and could be compared to monitored changes in groundwater levels. Third, it could be used to evaluate to movement of the water injected by HDPP. However, direct use of the USGS Model was eventually rejected for the same reasons of time and cost that the development of a comprehensive model for the project was rejected.

Features of the Original HDPP Water Banking Model

The original HDPP Model consisted of set of seven computer data input files. Three of the files represented the geometry and aquifer parameters of the local aquifer system, the Mojave River, and the major faults (GRID.DAT, AQUIFER.PRN, CHEAD.PRN). The geometry within the HDPP mod1eled area was based on the structure of the aquifer system defined in the preliminary USGS Model, which was not yet finalized at the time of HDPP certification. Aquifer parameters were also based on the values specified in the preliminary USGS Model. The other four input files (FLUX.PRN, FAULT.PRN, START.DAT and HEAD.DAT) represented the hydrology of the proposed project operations. The model was designed to simulate water banking operations for the proposed project wells on a monthly time step and calculated the project's incremental effect on groundwater levels and discharge to the Mojave River.

The model represented the portion of the aquifer system assumed to be influenced by project operations (Figure B1 and B2). The two primary members of the local aquifer identified in the preliminary USGS Model consisted of the Regional Aquifer, which included older undifferentiated alluvium and older alluvium of the ancestral Mojave River, and the Mojave River Alluvial Aquifer, which included younger and recent deposits of the Mojave River.

The boundaries of the HDPP Model included both physical boundaries of the aquifer system defined in the USGS Model and artificial boundaries defined by the Applicant. The northeastern boundary of the HDPP model extended to the edge of the basin along the east side of Mojave River, where the alluvial deposits of the aquifer pinch out at the base of Quartzite Mountain. The eastern boundary of the Model terminates along the

Apple Valley fault, which is a barrier to groundwater flow. South of the Apple Valley fault, the model boundary again extended to the edge of the basin along the east side of Mojave River. The northern and southern boundaries of the HDPP model did not extend to physical boundaries of the aquifer basin but, rather, were drawn to represent the assumed area of influence for project operations. The preliminary USGS Model, which covered the entire Mojave River Basin, extended far beyond the area of influence of the HDPP project operations.

Paralleling the structure of the aquifer system represented in preliminary USGS Model, the HDPP Model represented the aquifer system in two layers. This division facilitates delineation of the Regional Aquifer and the Mojave River Alluvial Aquifer. Near the Mojave River, the upper layer is used to represent the Mojave River Alluvial Aquifer and the lower layer represents the Regional Aquifer, which extends beneath the river alluvium, except between the Narrows where bedrock directly underlies the river alluvium. Beyond the extent of the Mojave River Alluvial Aquifer, where only the Regional Aquifer is present, the division of the aquifer into two layers facilitates the representation of depth of the proposed project well screens.

Table B1 provides a listing of the aquifer parameters values used in the original HDPP Model by the CEC staff, which were based on the values defined in the preliminary USGS Model (Final Staff Assessment, Soil & Water Resources Testimony 8/16/1999, Table 1).

Table B1: Groundwater Model Parameters for Original HDPP Model

Parameter	***Primary Analysis Values***
Regional Aquifer (upper layer)	
Horizontal Hydraulic Conductivity	8 feet/day
Vertical Hydraulic Conductivity	0.08 feet/day
Specific Storage	3.3E-06/feet
Specific Yield	0.12
Regional Aquifer (lower layer)	
Horizontal Hydraulic Conductivity	8 feet/day
Vertical Hydraulic Conductivity	0.08 feet/day
Specific Storage	3.3E-06/feet
Turner Springs Fault	
Horizontal Hydraulic Conductivity	0.08 feet/day
Vertical Hydraulic Conductivity	0.08 feet/day
Specific Yield	0.12
Specific Storage	3.3E-06/feet
Mojave River Alluvial Aquifer	
Horizontal Hydraulic Conductivity	200 feet/day
Vertical Hydraulic Conductivity	2 feet/day
Specific Yield	0.25
Specific Storage	3.3E-06/feet

The Applicant, the CEC and CDFG mutually agreed that the aquifer parameter values for the HDPP Model would be modified based on the published values used in the finalized USGS Model.

The original HDPP Model included the representation of three fault systems that functioned as significant groundwater flow barriers within the local aquifer system. The first fault, the Apple Valley Fault was represented as the eastern boundary of the model. The Turner Springs fault, located immediately north of the HDPP well field, was represented by low hydraulic conductivities and was assumed to significantly restrict the effect of project operations north of this fault. (The Turner Springs Fault identified in the preliminary USGS Model and the original HDPP Model was better defined and identified as the Shadow Mountain Fault and the Adelanto Fault in the finalized USGS Report.) The third fault, called the Narrows Fault, was located on the west side of the Mojave Narrows. At the time of certification, the USGS had not yet determined the extent to which this fault restricted groundwater flow. It was known at that time that within the Narrows, the Mojave River and the Mojave River Alluvial Aquifer rest directly on an uplifted block of bedrock, and the bedrock borders the east side of the river. The underlying bedrock block prevents direct flow between the lower layer of the Regional Aquifer and the Alluvial Aquifer such that only the upper layer of the Regional Aquifer contacts the Alluvial Aquifer. However, it was uncertain the extent to which the Narrows Fault further restricted east-west groundwater flow between the Mojave River Alluvial Aquifer and the Regional Aquifer. Accordingly, the original HDPP Model consisted of two versions of the model, one with and one without low hydraulic conductivities to represent the Narrows Fault.

As discussed previously, the Mojave River, which currently maintains constant year-round flows only between the Narrows, is represented as a constant-head boundary. Project operations that would cause a net incremental increase in groundwater levels adjacent to this boundary would generate discharge to the river and net incremental decrease in groundwater levels would cause recharge to the aquifer from the river.

The original HDPP Model was configured to represent seven proposed project wells. The geographic coordinates for each well was specified in the model. The depth and interval of well screen was identified by hydraulically linking the pairs of nodes in the model that represent the top and bottom elevation of the well screen. Injection and pumping from the project wells was represented by the monthly net flux (injection minus pumping) for each well, specified for monthly time-steps in the model.

Because the HDPP Model can only calculate the incremental change in groundwater levels caused by project water banking operations, changes in groundwater level were calculated relative to a datum level of zero. In other words, initial water levels were set to zero. The model then calculated the changes in groundwater levels caused by pumping and injection from the HDPP production wells. Correspondingly, the datum for the constant-head boundary representing the Mojave River at the Narrows was also set to zero.

From this information the HDPP Model calculated the monthly changes in groundwater levels throughout the aquifer and the discharge to or recharge from the Narrows in response to projected water banking operations. The model output also included a summary of the net flux for the project wells. During the certification process the HDPP Model was used to evaluate a range of potential project operation scenarios.

Features of the Finalized, Post-Certification HDPP Water Banking Model

The Conditions of Certification call for three simple modifications to the HDPP Model, which have been described in detail in the main text of this report. The three changes are (1) modification of the model grid to accommodate the finalized aquifer parameters represented in the finalized USGS Model, (2) the update the aquifer parameter values in the HDPP Model to correspond to the finalized aquifer parameter values in the USGS Model, and (3) modify the aquifer parameters in the area of the HDPP well field to reflect the results of the HDPP aquifer tests. Modifications to the grid and the aquifer parameters include modifications to reflect the faults that function as flow barriers within the aquifer system. In addition, the location of the project wells and the model boundary have been modified to reflect the finalized location of the actual project wells. Otherwise, the basic structure and assumptions of the HDPP Model has not been changed. The HDPP Model will be used during the life of the project to evaluate the amount of banked water available to the project on an ongoing basis, using reported operational data, as specified in Condition of Certification Soil & Water-5.

REFERENCES FOR APPENDIX B:

Durbin, T.J. and Bond, L.D., 1997, FEMFLOW3D: a finite-element program for the simulation of three-dimensional aquifers: U.S. Geological Survey Open-File Report 97-810, 338 p.

Stamos, C.L., Martin, P. Nishikawa, and Cox, B.F., 2001, Simulation of ground-water flow in the Mojave River basin, California: U.S. Geological Survey Water-Resources Investigations Report 01-4002, 276 p.