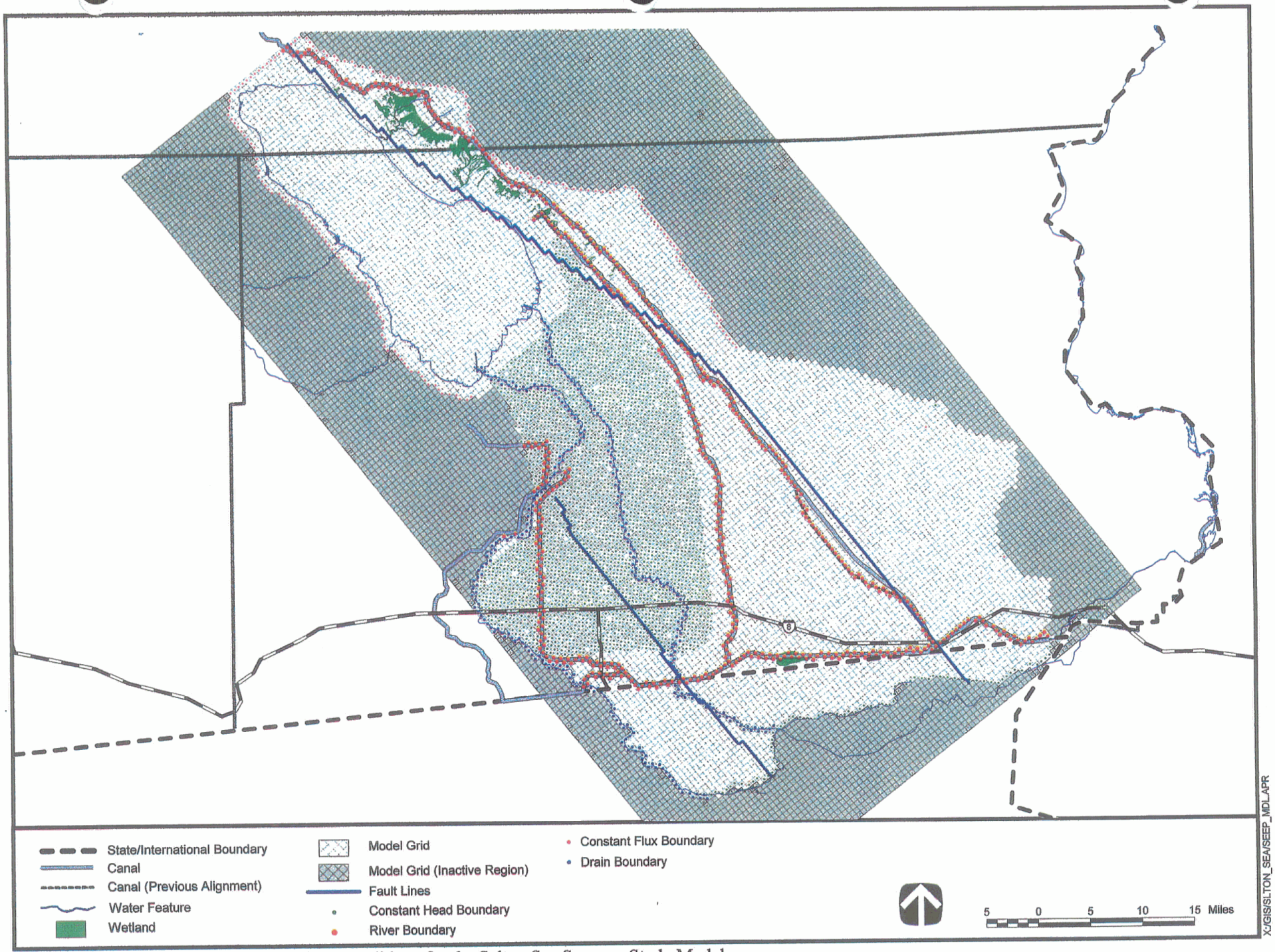


Figure 6-3 Location, Grid, and Boundary Conditions for the Salton Sea Seepage Study Model

- It includes hydrologic features such as the New River and La Mesa Drain; and
- It excludes areas with sparse data (limited data in Mexicali precluded modeling this area).

A grid block spacing of one-half mile was chosen due to the large area of the model grid and the need to adequately resolve the canals and wetlands of interest. A uniform model grid was selected to promote model stability and accuracy. The grid is rotated 38 degrees counter-clockwise from north in order to orient the model with the Coachella Canal and geologic features such as the San Andreas and San Jacinto faults. The model origin (lower left corner) is located at 2,294,218.77 feet Easting and 60,727.78 feet Northing (California State Plane Zone VI 1927).

6.1.1.2 Vertical Layering

Three horizontal layers are used in the model (Figure 6-4) to represent the three regional hydrostratigraphic units depicted in the cross-sections in Section 3: the shallower aquifer (Layer 1), the regional aquitard (Layer 2), and the deeper aquifer (Layer 3). The layer topography was based upon the layer stratigraphic data used in the Imperial County Model (Montgomery Watson 1995) upon verification relative to well logs and cross-sections in Section 3. Contours of layer elevation and thicknesses are given in Appendix F. Layer elevations were also modified slightly from the Imperial County Model to promote model stability, so that no model layers would be dry. The bottom of model Layer 1 was constrained to be a minimum of 120 feet below the water table contours (Figure 3-1) and the bottom of Layer 2 was constrained to be a minimum of 5 feet below the bottom of Layer 1. As a result, the deeper hydrostratigraphic units are represented with more than one model layer in the eastern model area as the shallower hydrostratigraphic units rise above the water table and became unsaturated. For example, in the east near Pilot Knob, all three model layers were used to represent the deepest unit since the two shallower units were unsaturated. The transition from hydrostratigraphic units represented as single model layers to hydrostratigraphic units represented as multiple model layers occurs roughly along the CB, where the upper two units become unsaturated. As shown in Figure 6-4, this causes the model layers east of the CB to be flatter than the stratigraphic layers because the water table in the East Mesa is flatter than the slope of the stratigraphic layers.

Near the Salt Creek wetlands and the Salton Sea, the Seepage Study model is calibrated to simulate heads above land surface. This agrees with conceptual model data showing flowing springs at Dos Palmas and

Andreas Springs, and groundwater seepage into the Salton Sea. However, simulated heads above land surface in an unconfined model layer can produce unrealistic simulations of groundwater flow and storage above land surface. These potential errors are addressed in the Seepage Study model by simulating Layer 1 as confined/unconfined in MODFLOW. The land surface is specified as the confining surface for the top of model Layer 1, and the confined storage coefficient of Layer 1 is specified as 1×10^{-5}. Thus, groundwater flow is not simulated above land surface, and groundwater storage simulated above land surface is insignificant.

6.1.1.3 Boundary Conditions

The model uses time-variant specified head, constant head, river, flux, general head, and drain boundary conditions as depicted in Figure 6-3. A time-variant specified head (Leake and Prudic, 1988) was used in the aquifer layers (i.e., Layers 1 and 3) along the La Mesa Drain and Alamo Canal. Specified heads were defined based upon historical water level contours in Mexicali Valley for 1965 (Figure 4-6), 1985, 1989, and 1993 (Figure 4-9). A constant head boundary was used in the shallowest layer in the IID area based upon the 6-foot depth of the IID tile drainage network. A general head boundary was used in the deepest layer in the east to represent the underflow into the model in the gaps between the Cargo Muchaho Mountains and Pilot Knob, and the Cargo Muchaho Mountains and Chocolate Mountains; these boundary fluxes were based upon published flow rates in this area (Olmsted *et al.* 1973). River boundaries were used in the shallow layer along the AAC, CB, and the East Highline Canal to represent canal seepage, allowing the model to accommodate the canal being either connected or disconnected from the water table. River boundaries also allowed the canal to lose or gain water, such as observed in the EHC. Drain boundaries were used in the shallow layer to represent the New and Alamo Rivers, which are primary groundwater sinks in the area.

Specified flux boundaries were used along sections of the Chocolate Mountains in the shallow layer to represent mountain front recharge and in the deepest layer to represent upwelling geothermal water. Specified flux boundaries were also used on the north and western shorelines of the Salton Sea to represent groundwater flux from Coachella Valley and the West Salton Sea Basin into the sea. No-flow boundaries were used at basin boundaries in the southeast and along the hydrologic streamline separating the groundwater flows on the east and west sides of the New River. A lake boundary (Council, 1998) was assigned in the shallow layer underneath the Salton Sea to simulate groundwater flux between the

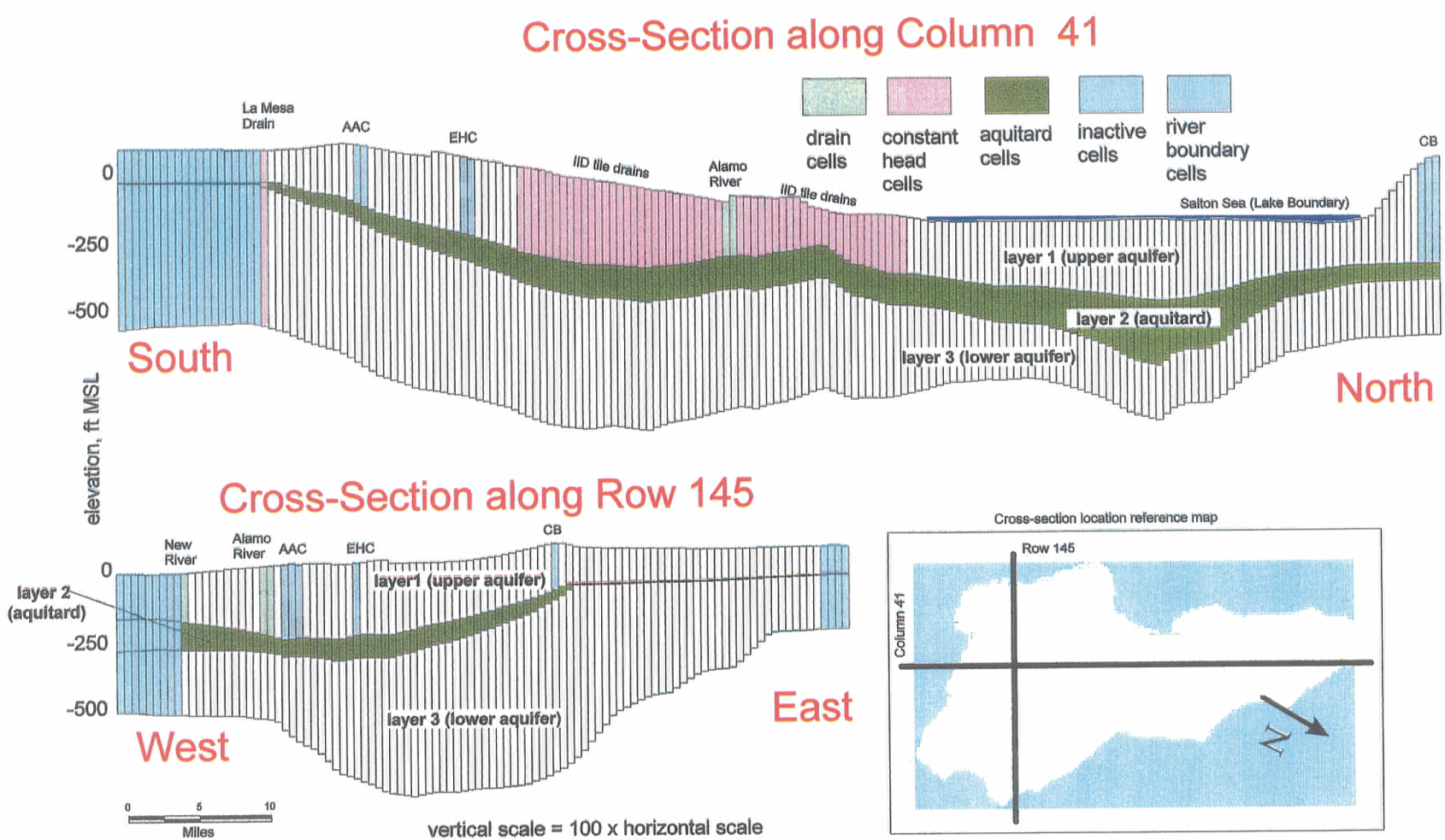


Figure 6-4 Vertical cross-section of model layers

aquifer and the sea, as well as the rising or falling sea elevation and shoreline associated with changes in the Salton Sea water balance. The San Andreas and Imperial Faults are also simulated as horizontal flow barriers (Hsieh and Freckleton, 1993) that restrict groundwater flow.

6.1.1.4 Recharge/Discharge Features

Net precipitation recharge in unirrigated areas was specified as diffuse recharge at a rate of 0.02 inches per year. Recharge and/or discharge in irrigated areas (IID) was not specified as a flux because this area was treated as a constant head boundary (see previous section). Net discharge from wetlands due to evapotranspiration was specified for the wetland areas identified in Section 2 using negative recharge for the steady-state simulation and the MODFLOW evapotranspiration feature during transient simulations.

6.1.1.5 Pumping Well Locations

Two pumping wells are located at the Mesquite and All American Mines (see Figure 3-3). No other large pumping wells are in the model area. Note that artesian discharges in wells and springs along the eastern model boundary near the Chocolate Mountains are effectively wells, however, because they are on the model boundary rather than internal to the model they are classified as flux boundary cells above.

6.1.1.6 Initial Conditions

Initial water levels for the steady-state simulation were taken from the water table contour map (see Figure 3-1), and were used for constant head boundaries during the steady-state calibration. Initial heads are required only as approximations for the steady-state solution elsewhere in the model, and the solution is relatively insensitive to them. Initial heads for the transient simulation were taken from the steady-state simulation head results.

Initial steady-state heads for the shallow Layer 1 were assigned directly from the water level data, while heads in the deeper layers were estimated based on the known relationship of heads in the shallower and deeper aquifers. Due to the limted number of deep observation wells, there was not enough data to develop a separate head contour map for the deeper layers. Heads in the deeper layers, however, were clearly higher in the area between the Alamo River and East Highline Canal as demonstrated in the plot

of aquifer head versus well depth in Eastern Imperial Valley (Figure 6-5). The Eastern Imperial Valley data generally falls into two groups: wells less than 200 feet in depth with a water level approximately 6 feet bgs, and wells over 300 feet in depth with an artesian water level approximately 20 feet above ground surface. Thus, the Eastern Imperial Valley data are indicative of groundwater discharge conditions (upward vertical flow). In contrast, the East Mesa data (Figure 6-5) do not show artesian conditions and generally are indicative of groundwater recharge conditions (downward vertical flow). The artesian conditions to the west are attributed to the thick and continuous aquitard in central and eastern Imperial Valley and the relationship of groundwater sources and sinks in this area. The downward vertical flow conditions in the east are attribuited to the aquitard thinning out and becoming laterally discontinuous in East Mesa, and the relationship of groundwater sources and sinks in this area. Based on these observations, initial steady-state heads for the deeper layer were estimated from the head in the shallow layer using the following empirical relation:

$$h_2 = h_1 + t_2 / 10$$

$$h_3 = h_1 + t_2 / 5$$

where

h_1 is the head in layer number 1; and

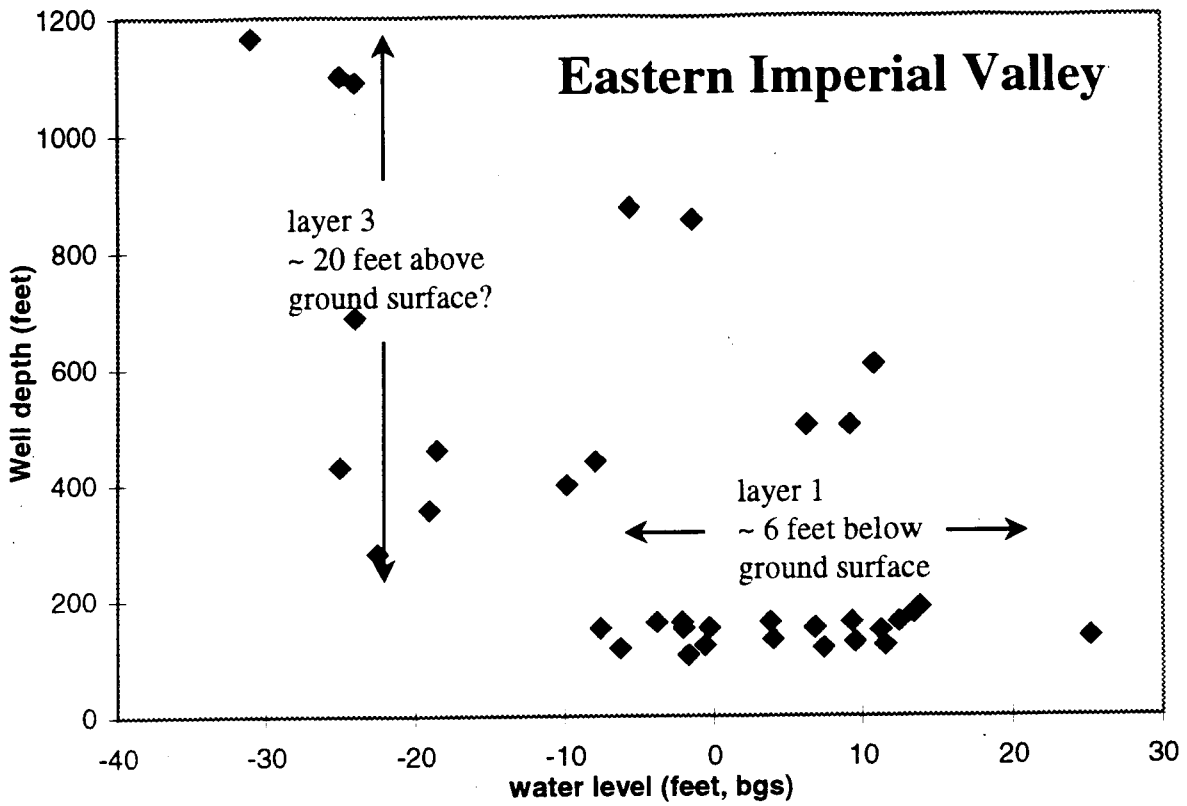
t_2 is the thickness in layer number 2

such that when the aquitard (Layer 2) is 125 feet thick in central Imperial Valley the head in the deeper aquifer (Layer 3) is 25 feet greater than the head in the shallow aquifer (Layer 1), and when the aquitard (Layer 2) is thin or absent in East Mesa the head in the deeper aquifer (Layer 3) is only slightly greater than or equal to the head in the shallow aquifer (Layer 1).

6.1.2 Model Parameters

6.1.2.1 Layer Topography

Layer elevations and thickness values were defined based on the three-layer stratigraphic model of Imperial Valley discussed in Section 6.1.1 and illustrated in Figure 6-4 and Appendix F.



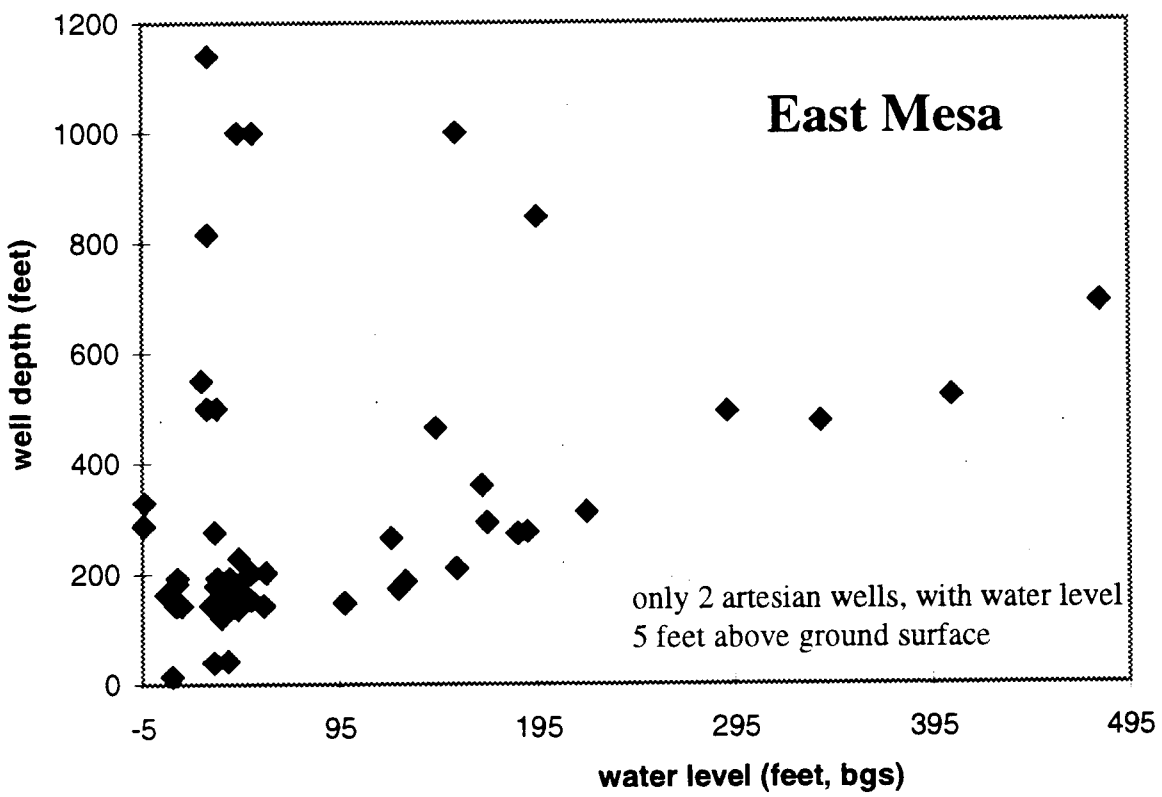


Figure 6-5 Aquifer Head Versus Well Depth in Imperial Valley and East Mesa

6.1.2.2 Hydraulic Conductivity

Initial hydraulic conductivity values for the seepage study model aquifer layers were defined based on a review of the hydraulic conductivity data in the USBR and Imperial County Groundwater models (Figure 6-1) and the USGS data (see Figure 3-7) (Loeltz *et al.* 1976). The hydraulic conductivity in all three sources show very similar trends with large values over 200 ft/day in the East Mesa and smaller values on the order of 2 ft/day in central Imperial Valley, which is a two order of magnitude difference. These variations are consistent with the permeable sands and gravels deposited in East Mesa and the relatively impermeable lake sediments of central Imperial Valley. Conductivity distributions in the USBR model appear to correlate well with geologic controls such as the expected sharp contrast in hydraulic conductivity values along the pre-historic Lake Cahuilla shoreline. The Imperial County Model hydraulic conductivity values reflect a smoothed version of this trend.

Initial hydraulic conductivity values for the seepage study model aquitard layer were defined as 1.0 ft/day based on typical values for the materials within the aquitard. The USBR model showed hydraulic conductivity values in the shallow aquifer that were eight times lower than the deeper aquifer, while the Imperial County Model showed nearly the same hydraulic conductivity values in the deeper and shallow aquifer. Upper and lower parameter ranges on each layer hydraulic conductivity were established at plus or minus 50 percent for the model calibration.

Based upon the available data and models, initial hydraulic conductivities prior to calibration were obtained from the deeper layer of the USBR model, except in the areas of the Salton Sea seepage study model that where outside the USBR model domain. In these areas, initial hydraulic conductivities prior to calibration were obtained from the Imperial County Groundwater model. The initial hydraulic conductivities for each unit were combined using thickness-weighted averaging where model layers transition from one unit to another (Section 6.1.1.2). The model hydraulic conductivity values were then modified within pre-established upper and lower parameter bounds during model calibration in order to match the observed water level and water budget data in the model area (see Section 6.2). The final calibrated hydraulic conductivity values for Layers 1, 2, and 3 are given in Figures 6-6, 6-7, and 6-8, respectively. The calibrated values are consistent with the available hydraulic conductivity data and geologic controls.

Vertical hydraulic conductivity for Layers 1 through 3 was assigned as 0.5, 0.04, and 1.0 feet/day, respectively, determined initially from estimated model leakance values.