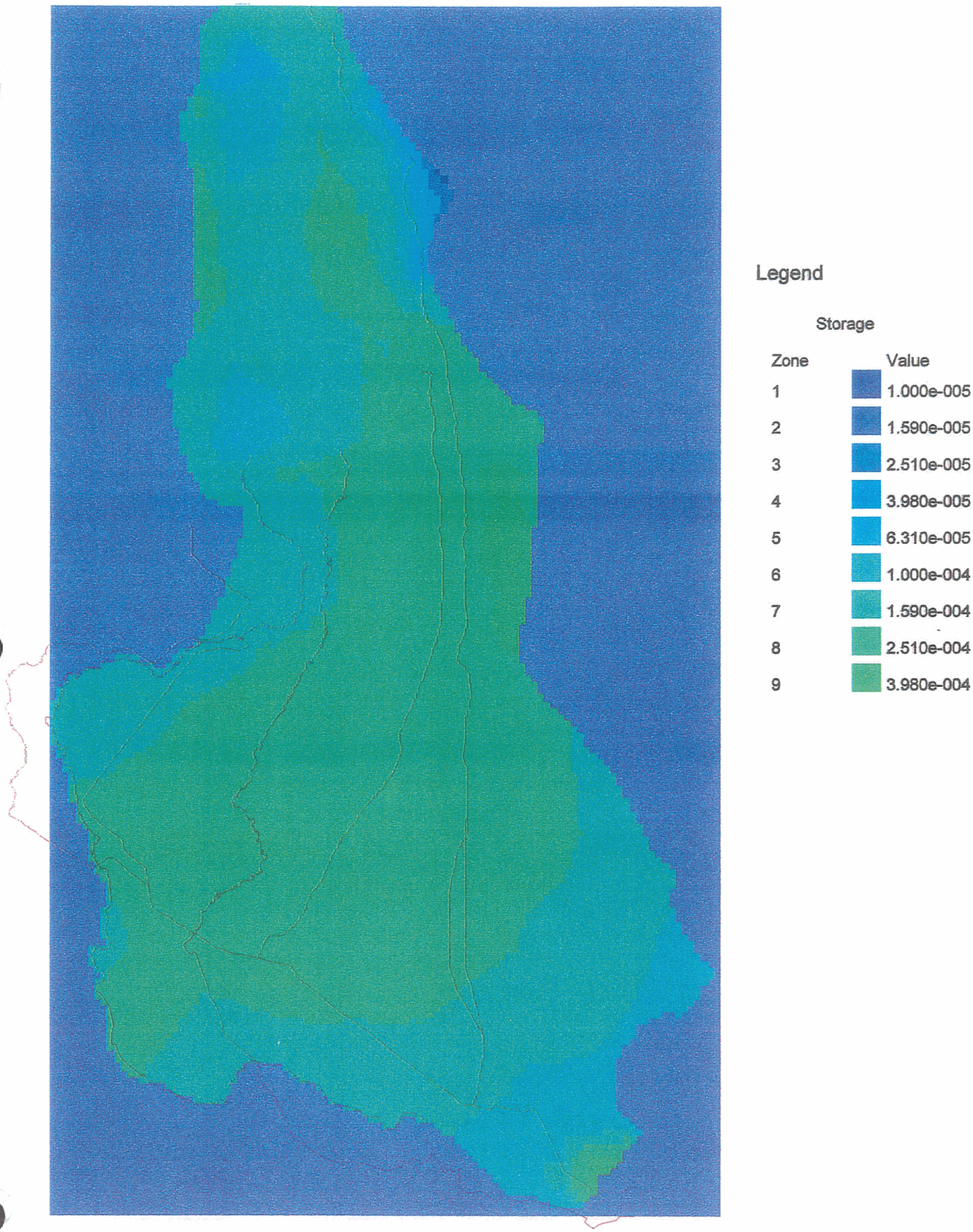


Figure 6-10. Calibrated Storativity for Layer 2

complex. The model can match the observed areal extent of a wetlands complex only approximately, due to the one-quarter square mile area of the model grid cells. In addition, the model input evapotranspiration rate may be greater than the effective rate determined from field data, because the extinction function within the model causes simulated evapotranspiration volumes to vary inversely with the depth to water. The modeled evapotranspiration rates were adjusted to compensate for these effects. The calibrated evapotranspiration rates are 10.07 ft/yr for the AAC, 4.65 ft/yr for the Salt Creek complex, and 5.0 ft/yr for the CB siphon 7 complex. The calibrated extinction depths are 20 feet for the AAC and 10 feet for the Salt Creek and CB siphon 7 complexes.

6.1.2.8 Allocation of Pumping Rates

The two pumping wells located at the Mesquite and All American Mines each have an extraction rate of 9,600 acre-feet per year based upon pumping data in the Imperial County Groundwater Model. No other large pumping wells are in the model area.

6.1.2.9 Fault Conductance

The San Andreas and Imperial Faults are simulated as horizontal flow barriers (Hsieh and Freckleton, 1993) at the locations given in Figure 6-3. The fault positions were determined based on the Imperial County Groundwater Model, and fault leakance values were determined by trial-and-error calibration to simulate the drop in water levels observed across the faults. Lower leakance values were used in Layers 2 and 3 than Layer 1 because fault permeability is expected to decrease with depth. Layer 1 leakance values for both faults are approximately 0.04 day^{-1}, and Layer 2 and 3 leakance values for both faults are approximately 0.0001 day^{-1}. The "hydraulic characteristic" which is input to the HFB package for Layer 1 is equal to the above fault leakance, and for Layers 2 and 3, is equal to the above leakance multiplied by the corresponding cell thickness.

6.2 MODEL CALIBRATION

6.2.1 Calibration Events

The Salton Sea seepage study groundwater conceptual model (Sections 3 - 5) and the numerical flow model design (Section 6.1) were used to construct a preliminary steady-state groundwater flow model

that was refined by calibration to two different known hydrologic stress periods. The first model calibration event is the period prior to lining the first 49 miles of the CB (1979) when all stresses imposed by AAC and CB seepage had stabilized since the canals began operating in the 1940s and 1950s. Seepage conditions near the canals, well hydrographs throughout the study area, water levels in Mexicali (Bureau of Reclamation 1991), and elevations of the Salton Sea (Thierry 1999) were relatively stable in 1960 to 1979, so steady-state conditions were chosen for the first calibration event. Also, the La Mesa Drain, which is the southern model boundary, should somewhat constrain heads along the toe of the Andrade Mesa from the fluctuations associated with pumping in Mexicali Valley.

The second model calibration event is the period following the lining the first 49 miles (1979) when stresses imposed by seepage from the first 49 miles of the CB seepage ceased. The hydrologic stress for this calibration would be shutting off the canal seepage along this reach, which would be calibrated against the draining water table beneath the CB canal. Because seepage conditions near the CB canal and well hydrographs throughout most of the East Mesa indicated water levels were continuously dropping due to the lining from 1979 until the early 1990s, a transient simulation from 1979 to 1999 was chosen for the second calibration event. This second calibration event also represents a validation of this model for predicting the effects of the AAC and CB lining projects.

Initial heads for the transient simulation were obtained from the 1979 steady-state simulation. The transient simulation was continued from 1999 to 2006, coinciding with the completion date of the AAC and CB canal lining projects. The predictive simulation extends from 2006 to 2026 and uses initial heads obtained from the end of the transient simulation.

6.2.2 Calibration Methodology

Key assumptions in the numerical model calibration were the following:

- Boundary heads and underflows along the La Mesa Drain can be represented by interpolating between the Mexicali water level contour data available for 1965, 1985, 1989, and 1993; and

- Steady-state conditions existed in the study area prior to lining the first 49 miles of the CB.

Model stress periods were designed to begin and end in the middle of a calendar year (e.g., July 1, 1979 to July 1, 1985). This accounts for time uncertainty associated with the model inputs. For example, water-level contours are reported by year only, so the precise dates of measurement are unknown.

The model layer elevations and thickness values were not used as calibration parameters except for the adjustments described in Section 6.1.1.2. The primary steady-state calibration parameters were aquifer hydraulic conductivity; canal and drain bed conductances; specified head values; and mountain front recharge rates. Hydraulic conductivity, storativity, canal bed conductances, and time-variant specified head values were also modified during the transient calibration. In addition, the Mesquite Mine pumping well was shut off during the 1979 steady-state simulation. The well was simulated to start pumping at the beginning of the transient simulation. Other than these modifications, the model was not modified from the initial design.

The primary calibration objective was to achieve close agreement with the conceptual model water budget (herein referred to as "observed" water budget data) given that the model objective is predicting changes in the water budget rather than changes in head. Achieving close agreement with the observed water level data was a secondary calibration objective, although the final comparison to measured water levels is good.

During calibration, contours of observed heads in Mexicali Valley (Figures 4-6 and 4-9) were found to be incompatible with estimated groundwater flux values at the La Mesa Drain (Table 3-1). The water-level contours in Mexicali Valley are thought to be precise only to within 15 feet. Thus, the contours were adjusted upwards within this 15-foot tolerance in order for the model to match estimated flux values at the La Mesa Drain. This adjustment, which is shown in Figure 6-11a through 6-11d, is within the estimated uncertainty of the water-level contours and is consistent with the calibration objective of matching the conceptual water budget.

6.2.3 Steady-State Calibration Results

The groundwater flow model was calibrated under steady state conditions using the boundary conditions and model parameters previously presented above. Final calibrated model parameters are given in the

Section 6.1 with the areal distribution of hydraulic conductivity in the aquifers and aquitard given in Figures 6-6, 6-7, and 6-8.

The steady-state model calibration results are given in Tables 6-1 and 6-2 and Figures 6-12 through 6-14. Table 6-1 compares the simulated and observed water budget. There is very good agreement, with the average difference between the simulated and observed water budget data being less than 10 percent and many items matching within 5 percent. Figure 6-12 shows a contour plot of the simulated and observed water levels in which the flow directions and gradient match quite well. The simulated water levels very near the canal are slightly lower than the measured values, although this is likely because the one-half-mile spacing of the model grid blocks cannot perfectly resolve the mounding right at the canals which are only 50 to 180 feet wide.

This is analogous to using a model to predict water levels in pumping wells, which due to the scale differences between the sizes of pumping wells and grid blocks, results in the model predicting a higher water level than measurements from a pumping well. The following mathematical method has been proposed to correct the grid block heads to heads measured in pumping wells (Andersson and Woessner 1992; Reeves *et al.* 1986):

$$h_w = h_{ij} - (Q/\pi T) \ln (r_b / r_w)$$

where

h_w is the head in the pumping well (ft)

h_{ij} is the head in the model grid block (ft)

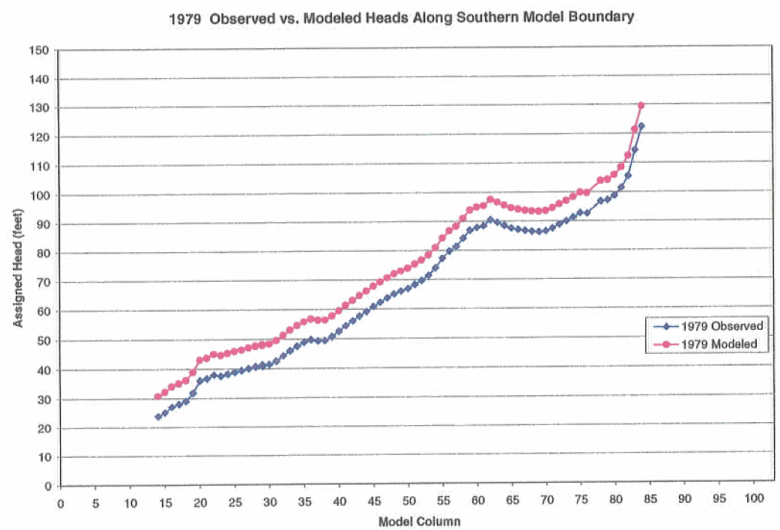
Q is the rate in the pumping well (ft^3/day)

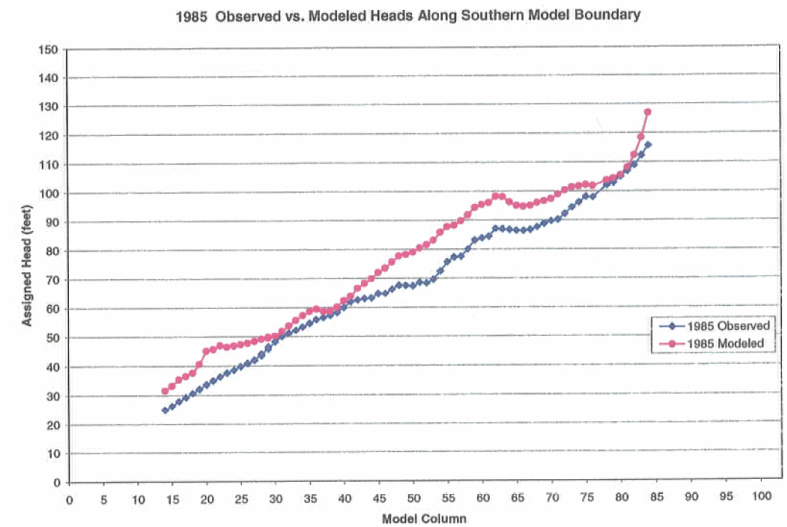
T is the aquifer hydraulic transmissivity (ft^2/day)

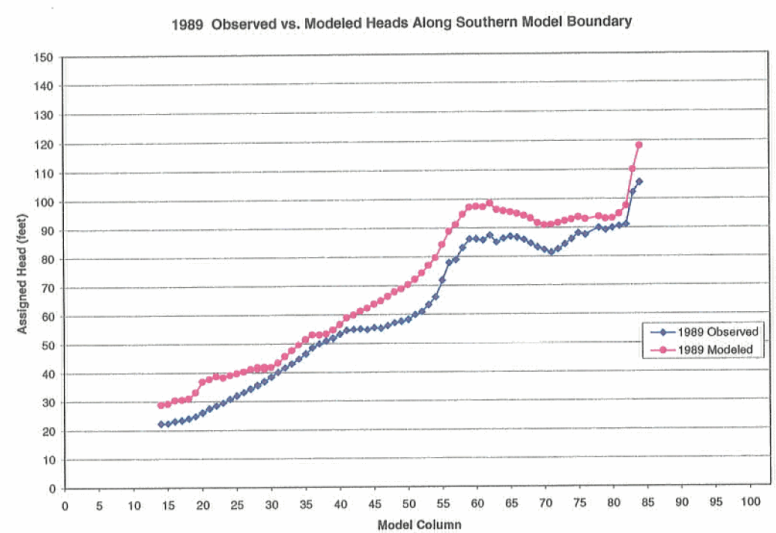
r_w is the radius of the pumping well (ft)

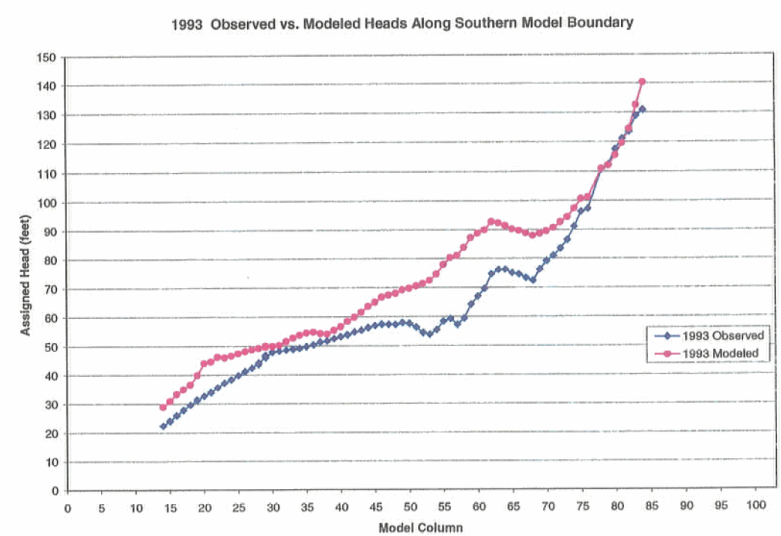
r_b is the equivalent radius of the model grid block (ft)

A similar correction methodology for a line rather than point source would be applicable to canals, but to our knowledge methods are not currently available for estimating this correction for a canal. Applying the well relation above to a canal, the correction factor would be 15 feet for a one-half mile grid with an equivalent radius of 1,489 feet, a seepage rate of 2.4×10^5 ft^3/day (4,000 acre-feet per year per mile canal









Figures 6-11A though D. Observed and Simulated Heads along La Mesa Drain Boundary

Table 6-1

Observed and Calibrated Model 1979 Water Balance

Feature Type	Name	Observed Rate (af/yr)	Modeled Rate[1] (af/yr)	Timing	Reference
Canal seepage	AAC, 1 mile west of Pilot Knob to Drop 2 (6:7)	70,100	**68,896**	1940 to ~ 1999	USBR 1991
	AAC, Drop 2 to EHC (8:10)	17,136	**16,084**	1940 to ~ 1988	USBR 1991
	CB, first 49 miles (12)	130,500	**130,579**	1948 to 1979	Fogg 1989
	CB, second 37 mile (13:18)	32,350	**32, 433**	1948 to ~ 1988	USBR 1992
Discharge into canal	EHC, drain seepage (19)	(10,413)	**(11,292)**	1948 to current	Fogg 1989
	EHC, canal seepage (20)	8,000	**6,975**		
Discharge into river	New River in USA (2)	(18,500)	**(18,250)**	1963 to 1997	IID gauge data
	Alamo River in USA (5)	(45,000)	**(45,249)**	1963 to 1997	IID gauge data
	La Mesa Drain	See below	See below	1960 to current	USBR 1991
Discharge to Salton Sea	East Shore	(8,000)		1960s	
	Imperial Valley	(2,000)		1960s	USGS 486 B
	Coachella Valley	(15,400)	(15,400)	1979	SSP Bulletin 108
	West Shore	(10,000)	(10,000)	1960s	
Evapotrans-piration	Coachella Branch	(38,010)	(37,941)	1948 to ~ 1988	USBR 1992
	Southern CB	(19,970)	(19,988)		
	AAC	(7,760)	(7,758)	1940 to 1988	USBR 1991
Mountain Front Stream and Geothermal Recharge	Salt Creek/Northern CB	> 13,660[2]	26,493		
	Southern CB	> 0[3]	10,000		
Underflow at boundaries	between Cargo Muchacho and Chocolate Mountains	2,000	**2,027**	1960s	
	between Cargo Muchacho and Pilot Knob Mountains	2,000	**2,115**	1960s	Olmsted 1973
	beneath La Mesa Drain, combined with Drain discharge	(> 78,600)[4]	**(90,064)**	1980 to 1993	AAC EIR/EIS
Pumpage	East mesa production wells	(9,250)	(9,250)	1970 to 1990	Montgomery Watson
Precipitation recharge	all unirrigated areas	1,000	~ 1,000		Skrivan 1997
Irrigation recharge	IID irrigation recharge combined with IID riverbed evapotranspiration and discharge into IID drains	50,000 (50,000) (?)		? 1987 to 1992	Schroeder *et al.* 1991 Boyle Engineering 1993
	Net Total	< 0	**(38,045)**		

Notes: [1] Model output values are shown in bold type. Values are rounded only to the nearest af/yr for convenience in verifying against model output files. Rounding to the nearest 1,000 af/yr is appropriate to indicate the degree of predictive accuracy.

[2] Based on sum of mountain front recharge plus rising geothermal water, minus discharge as Salt Creek baseflow (Table 3-3). "Greater than" sign signifies that available data are insufficient to estimate the applicable rate of rising geothermal water.

[3] Rising geothermal water is expected to exist east of the first 49 miles of the CB, but published estimates are not available.

[4] 1979 underflow is expected to be greater than the published value for 1980 to 1993, because the first 49 miles of the CB was lined after 1979.

length), an aquifer transmissivity of 40,000 ft^2/day, and a well radius of 0.75 feet. This correction factor is of the same order observed for observation wells immediately next to the AAC and CB canals.

Table 6-2

Salton Sea Observed and Modeled 1979 Water Budget

	Observed Value	Modeled Value[1]	Timing	Reference
Inflow from Groundwater Discharge	35,400 af/yr[2]	**41,338** af/yr	1979	SSP Bulletin 108
Surface Inflow	1,350,110 af/yr	1,350,138 af/yr	1979	Calculated[3]
Precipitation	31,500 af/yr	31,500 af/yr	1959 to 1962	USGS 486-C
Evaporation	(1,421,880) af/yr	(**1,422,975**) af/yr	1979	Univ. of Redlands Bathymetry
Stage	(227.75) ft. amsl[4]	(**227.64**) ft. amsl	1979	CRBC (Tostrud, 1997)
Evaporation Rate	5.78 ft/yr	5.78 ft/yr	1948 to 1962	USGS 486-C

Notes: [1] Model output values are shown in bold type. Values are rounded only to the nearest af/yr for convenience in verifying against model output files. Rounding to the nearest 1,000 af/yr is appropriate to indicate the degree of predictive accuracy.
[2] af/yr = acre-feet per year
[3] Observed Surface Inflow was computed to be consistent with the observed 1979 stage in a steady-state simulation. The Salton Sea was not actually in steady-state in 1979.
[4] amsl = above mean sea level

Figure 6-13 shows a contour plot model of the model error. Model error is typically less than 10 feet. In general, the model errors also appear to be randomly distributed throughout the domain.

Figure 6-14 shows a cross-plot of simulated and observed water levels, which shows a good correlation between the simulated and observed data. In some cases the water levels given in Figure 6-14 are taken from piezometers, which measure point values of head, rather than from monitoring wells, which measure average aquifer heads. This may introduce measurement errors of several feet in aquifers with a vertical gradient. However, since this model is regional in scope and calibration seeks to match heads within 10 feet, the error associated with calibrating the model to piezometer data should be small and reasonable given the regional scope of this investigation. Well locations for Figure 6-14 are shown in Appendix G. The wells are generally within the East Mesa and southern Imperial Valley areas, due to the limitations of available data. Thus calibration statistics derived from comparisons at well locations are representative of the East Mesa and southern Imperial Valley areas. The average model error is 1.35 feet, the absolute model error is 8 feet, the standard deviation of the error is 11.4 feet, and the relative model error (ratio of the error standard deviation to the head difference across the observation wells) (Anderson and Woessner 1992) is 4 percent. Fourteen of the 16 wells fall near the theoretical line (dashed),