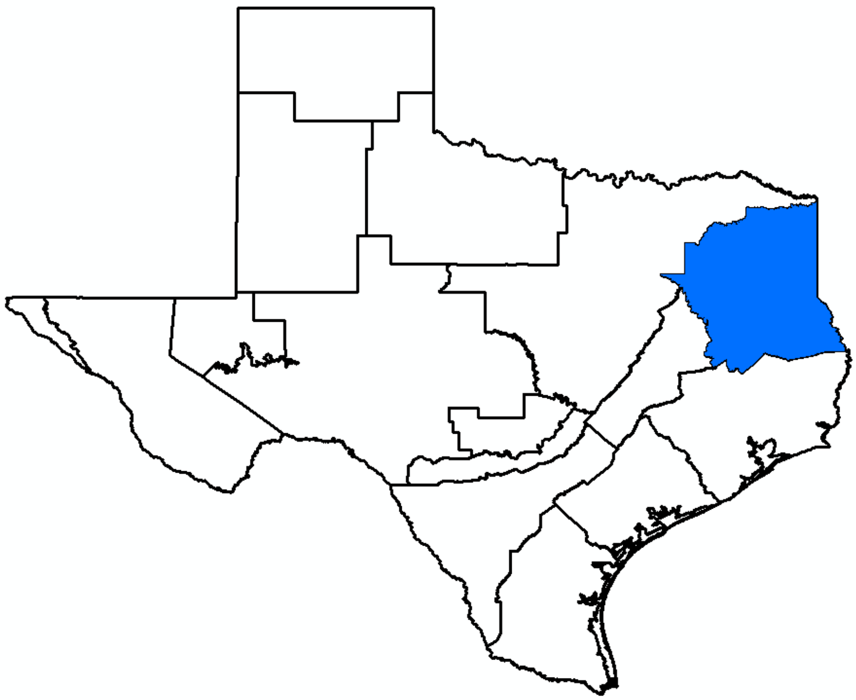
GMA 11 Technical Memorandum 16-01
Draft 1

Groundwater Availability Model for the Sparta, Queen City, and Carrizo-Wilcox Aquifers: Attempts to Update the Calibration Period



Prepared for:
Groundwater Management Area 11

Prepared by:
William R. Hutchison, Ph.D., P.E., P.G.
Independent Groundwater Consultant
9305 Jamaica Beach
Jamaica Beach, TX 77554
512-745-0599
billhutch@texasgw.com

March 21, 2016

Table of Contents

List of Tables

List of Figures

1.0 Introduction and Background

As part of the joint planning process for Groundwater Management Area 11, a scope-of-work dated July 2, 2015 was developed to complete seven initial model simulations. The results from this effort are documented in Technical Memorandum 15-01 (September 2, 2105). As described in that document, the objective was focused on addressing certain specific concerns regarding the regional water plan and the plans for Forestar in the joint planning process.

The seven scenarios included a base scenario (Scenario 4), three scenarios with lower pumping (Scenarios 1 to 3), and three scenarios with higher pumping (Scenarios 4 to 7). The objective was to include the pumping equal to the current modeled available groundwater (MAG), plus the planned Forestar project and all recommended and alternative strategies from the regional water plans (Region D and Region I) in the base case, and evaluate the sensitivity of pumping to higher and lower pumping from this assumed base condition.

The simulations were run from 2000 to 2070. The Groundwater Availability Model (GAM) for the area was calibrated from 1975 to 1999. Thus, the simulations simply started where the calibrated model ended, and continued through the planning period that is defined by the Texas Water Development Board guidelines for this round of joint planning.

The results showed that there were areas within GMA 11 with simulated rising water from 2000 to 2070. This was attributed to the fact that the last year of the calibration period (1999) was a dry year, and the simulation assumed average recharge conditions from 2000 to 2070. With no change in pumping in an area, it would be expected that groundwater levels would rise as a result of the increased recharge after 1999. In an attempt to address this issue, an attempt was made to extend the calibration period of the model to 2013.

At the November 4, 2015 meeting where the simulations were discussed, a recommendation was made to attempt to update the calibration period of the model to have a more recent starting date for desired future conditions, and to address negative drawdowns. The objective of this technical memorandum is to briefly document the attempts to update the calibration period of the model. In general, the attempt was unsuccessful. However, as developed in the technical memorandum, the effort yielded a better understanding of the limitations of the model for desired future condition development that can be used by GMA 11.

2.0 Model Calibration from 1975 to 2000

The groundwater availability model for the northern Sparta, Queen City, and Carrizo-Wilcox aquifers is documented in Kelley and others (2004), and represented an update to the model developed by Fryar and others (2003). The model was developed prior to the adoption of HB 1763 in 2005 (the legislation that mandated joint planning and the development of desired future conditions by the groundwater conservation districts).

In order to establish baseline calibration statistics, groundwater levels for the area were downloaded from the Texas Water Development Board database and compared with model output. The total number of groundwater level measurements used in this comparison was 2,256, and included only wells that were completed in one model layer (i.e. wells with screen completed in more than one layer, or for which there was no screen data were not included).

Summary statistics for this effort are summarized in Table 1, and a plot of actual vs. simulated groundwater elevations are presented in Figure 1.

Table 1. Calibration Statistics, 1975 to 1999

Residual Mean	-3.01
Absolute Residual Mean	29.04
Residual Std. Deviation	42.63
Sum of Squares	2416630.05
RMS Error	32.73
Min. Residual	-378.51
Max. Residual	175.11
Number of Observations	2256
Range in Observations	745.85
Scaled Residual Std. Deviation	0.0572
Scaled Absolute Residual Mean	0.0389
Scaled RMS Error	0.0439
Scaled Residual Mean	-0.0040

These statistics and the one to one plot provided a basis to compare efforts to update the calibration of the model period to 2013.

The model recalibration involved developing input data for the years 2000 to 2013 for parameters that vary with time (recharge, evapotranspiration, and pumping). Aquifer parameters (hydraulic conductivity, storativity, and specific yield) were not modified since these parameters do not vary with time.

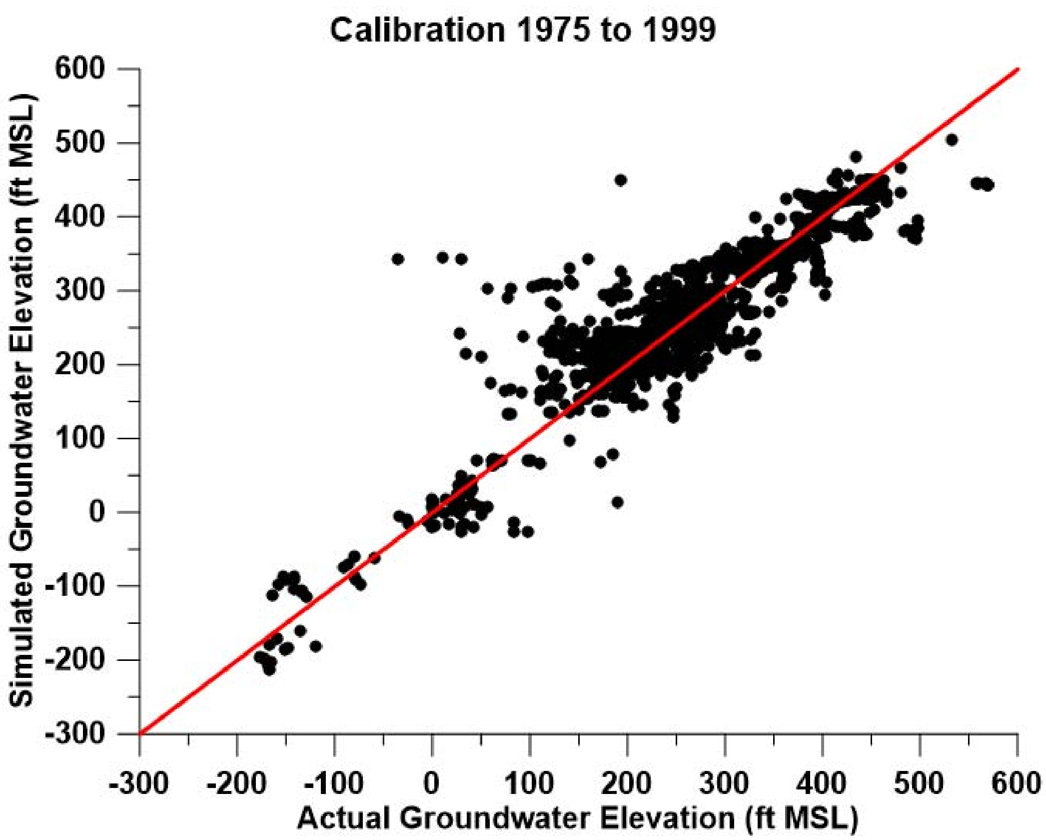


Figure 1. Actual vs. Simulation Groundwater Elevations, 1975 to 1999

3.0 Updated Recharge, Evapotranspiration, and Pumping Estimates

The role of recharge and evapotranspiration in this model is complex, and water budget analysis of the model shows that much of the recharge from rainfall is discharged quickly to evapotranspiration. It was important to remain consistent with this approach, and not attempt to improve the calibration statistics by changing the parameters to the extent that the updated calibration period would be considered a new model. Pumping estimates for 2000 to 2013 were developed during this process by two different methods as developed below.

3.1 Recharge

During the calibration period, recharge varied year to year as described in Kelley and others (2004, pg. 6-17). However, the spatial distribution of recharge is complex as described by Kelley and others (2004). A simple relationship was developed between annual rainfall and recharge, and is presented below in Figure 2.

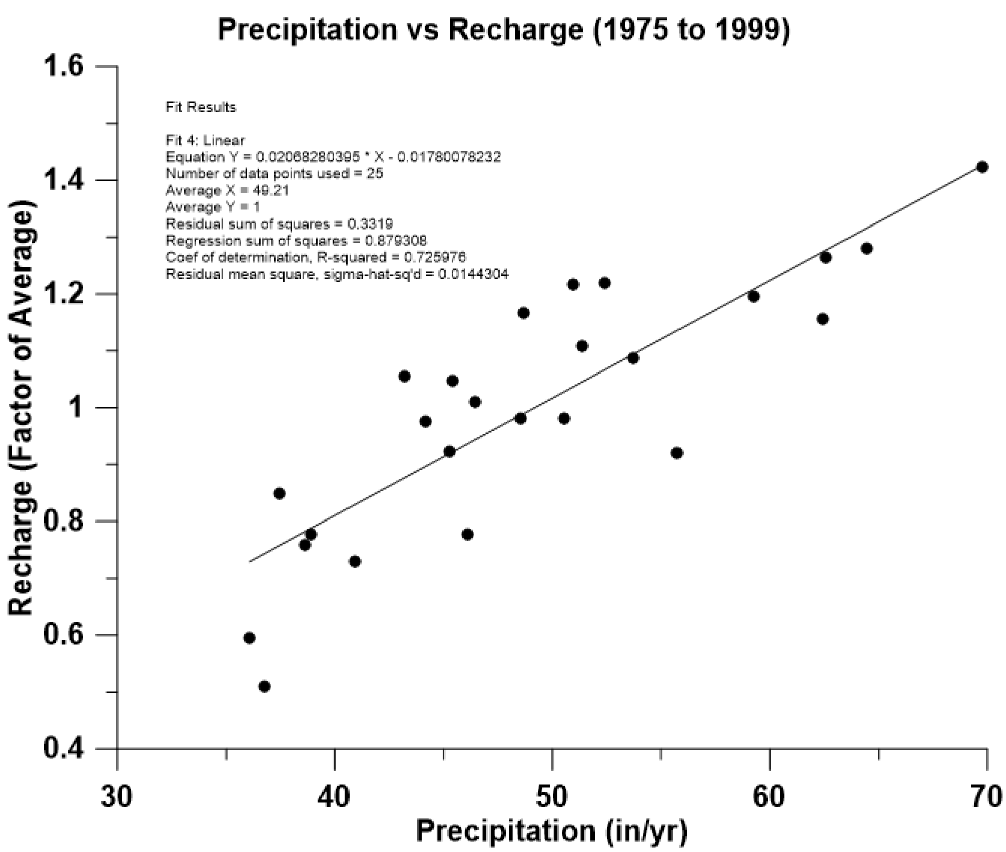


Figure 2. Precipitation vs. Recharge (1975 to 1999)

This method allows the development of a recharge array for the model. With a known annual rainfall, a multiplication factor was applied on a cell-by-cell basis to the average recharge array in the model.

During calibration, the factor was allowed to vary slightly (in accordance with the variation observed in Figure 2) in an attempt to improve the calibration fit.

3.2 Evapotranspiration

Similar to recharge, the evapotranspiration rate from 1975 to 1999 varied with precipitation as shown in Figure 3.

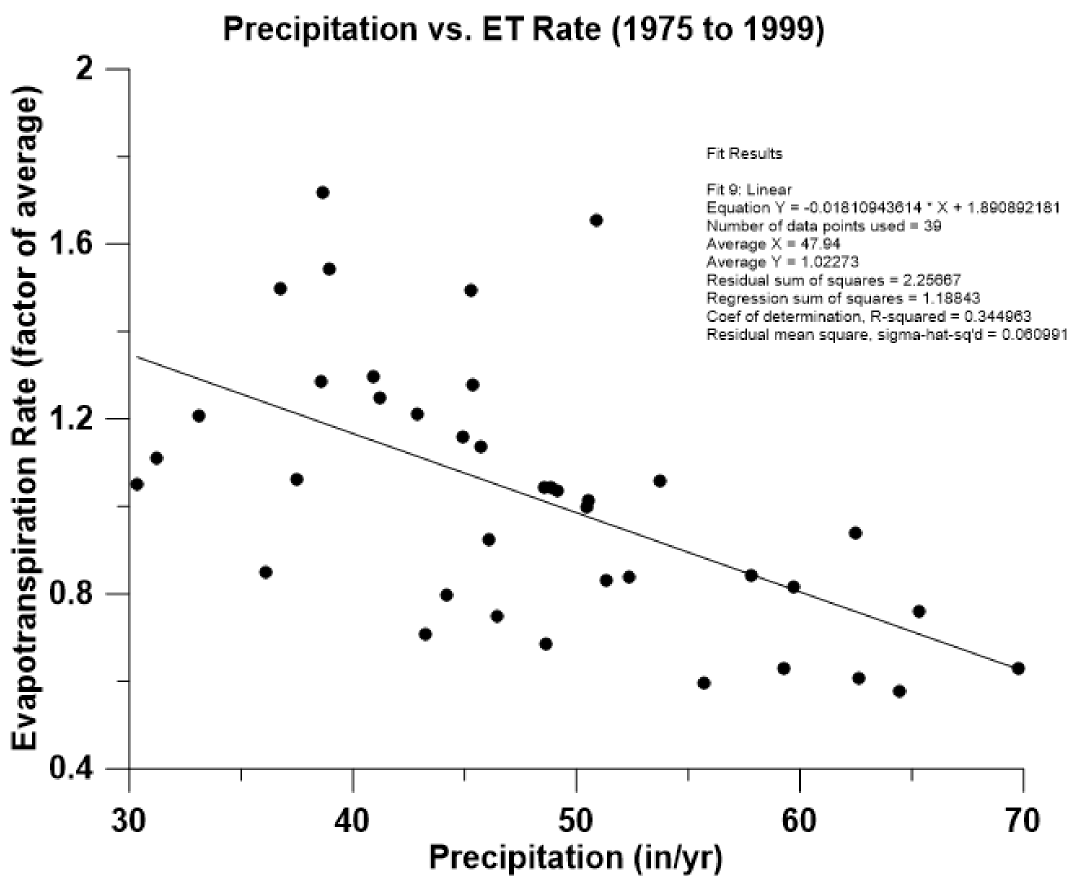


Figure 3. Precipitation vs. ET Rate (1975 to 1999)

MODFLOW requires a maximum rate be specified for each stress period. The model code then calculates the actual evapotranspiration based on groundwater level, the extinction depth and this maximum rate. For calibration purposes, the maximum ET rate was allowed to vary slightly in an attempt to improve the calibration fit.

3.3 Pumping Estimates

There were two attempts made to develop pumping estimates for model input from 2000 to 2013. Initially, the TWDB pumping estimates for each county were used. These estimates are documented in Technical Memorandum 15-01. The calibration procedure with these estimates were to adjust pumping by layer, by year, and by county.

After several runs using the TWDB estimates that yielded unsatisfactory results, the approach was substituted with initial estimates that were identical to the GAM estimates of pumping in 1999. This attempt was designed to leverage the existing calibration as much as possible and then make modifications, as needed, on a county-model layer scale for each year to improve the calibration fit.

4.0 Calibration Results

The attempts to update the calibration model consisted of establishing initial estimates for recharge, evapotranspiration maximum rate, and pumping, and then using PEST (an industry standard program that provides a means to automatically adjust parameters to improve calibration statistics).

Actual groundwater level measurements were obtained from the Texas Water Development Board database for groundwater elevations. A total of 1,292 groundwater elevation measurements from 2000 to 2013 were used. Only wells that were completed in a single model layer were used, based on comparing the screen elevations with the model layer top and bottom elevations.

Table 2 summarizes the PEST runs completed.

Table 2. Summary of PEST Runs

Run	Adjustable Parameters	Model Runs	Basis of Pumping Estimates
1	47	345	TWDB Database
2	61	473	TWDB Database
3	47	259	TWDB Database
4	47	403	TWDB Database
5	61	10	TWDB Database
6	61	12	TWDB Database
7	47	356	TWDB Database
8	1022	2177	Calibrated Model
9	742	3575	Calibrated Model

The results of PEST Run 7 and PEST Run 9 are presented in Table 3 (summary statistics) and Figures 4 and 5.

Table 3. Summary Statistics for PEST Run 7 and PEST Run 9

Parameter	TWDB Database	Calibrated Model (1999 Pumping)
Residual Mean	-12.36	-21.93
Absolute Residual Mean	36.97	43.56
Residual Std. Deviation	51.43	56.81
Sum of Squares	3611675.04	4788617.75
RMS Error	52.87	60.88
Min. Residual	-288.68	-299.05
Max. Residual	170.96	140.70
Number of Observations	1292	1292.00
Range in Observations	704.89	704.89
Scaled Residual Std. Deviation	0.0730	0.0806
Scaled Absolute Residual Mean	0.0524	0.0618
Scaled RMS Error	0.0750	0.0864
Scaled Residual Mean	-0.0175	-0.0311

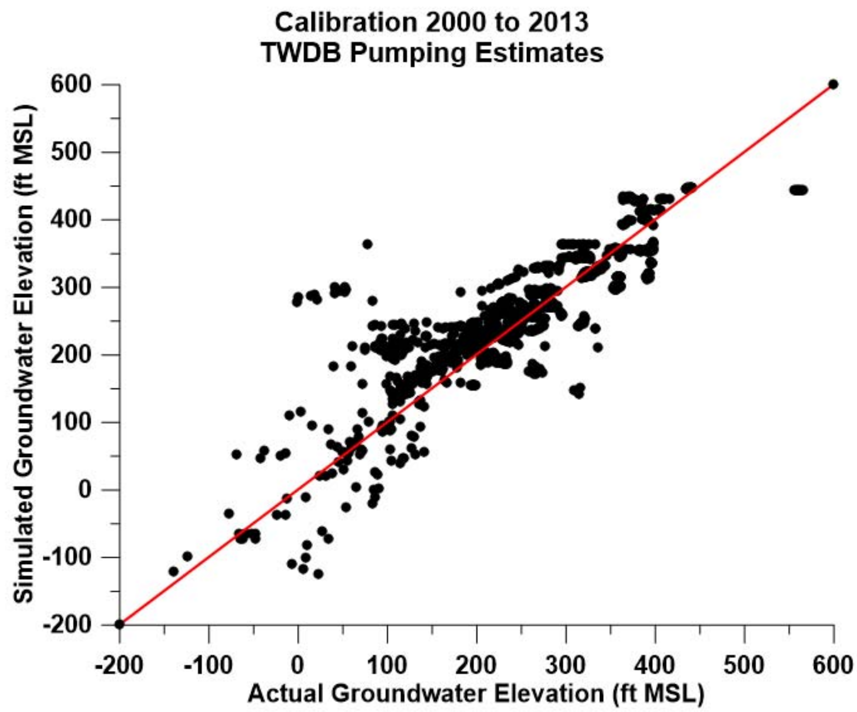


Figure 4. Actual vs. Simulated Groundwater Elevations (PEST Run 7)

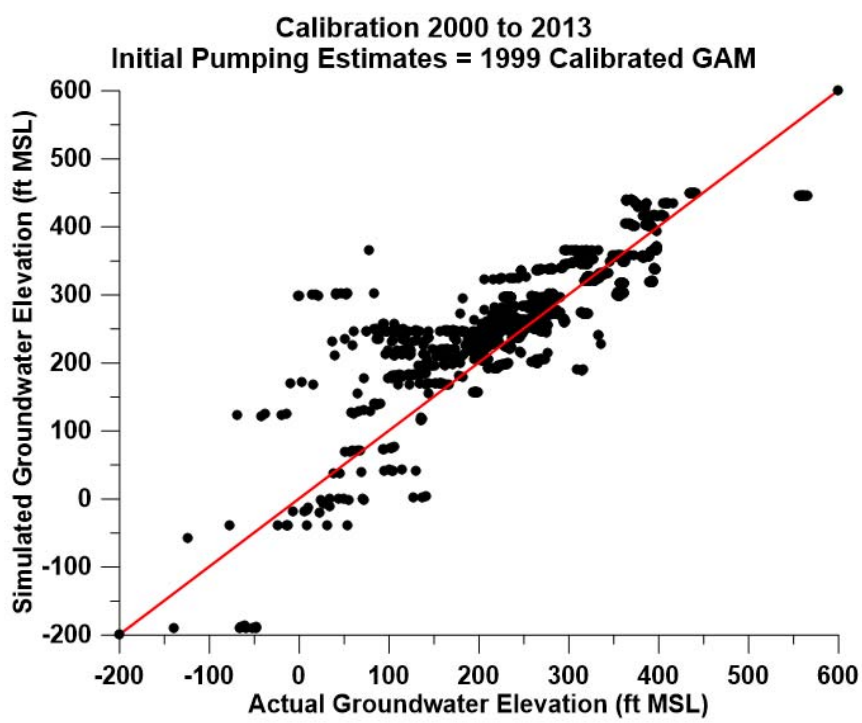


Figure 5. Actual vs. Simulated Groundwater Elevations (PEST Run 9)

5.0 Discussion of Results

The attempts at updating the calibration period did not yield calibration statistics that were the same or better than the calibration statistics from 1975 to 1999. Therefore, the updated period should not be used as a basis for predictive simulations or desired future conditions.

The inability to update the calibration period successfully appears to involve recharge in the outcrop area, and the discharge of that recharge by a combination of evapotranspiration, baseflow to surface water, and downgradient movement of the water into the downdip area of the model layers.

An evaluation of the water budgets for the Carrizo and Wilcox aquifers was made that differentiated the outcrop and downdip areas. The results are similar, and the results of the Carrizo Aquifer outcrop area are presented below.

Figure 6 shows the storage change and recharge for the Carrizo Aquifer outcrop area for both the calibration period (1975 to 1999) and for Scenario 4 of the predictive simulations that are documented in Technical Memorandum 15-01.

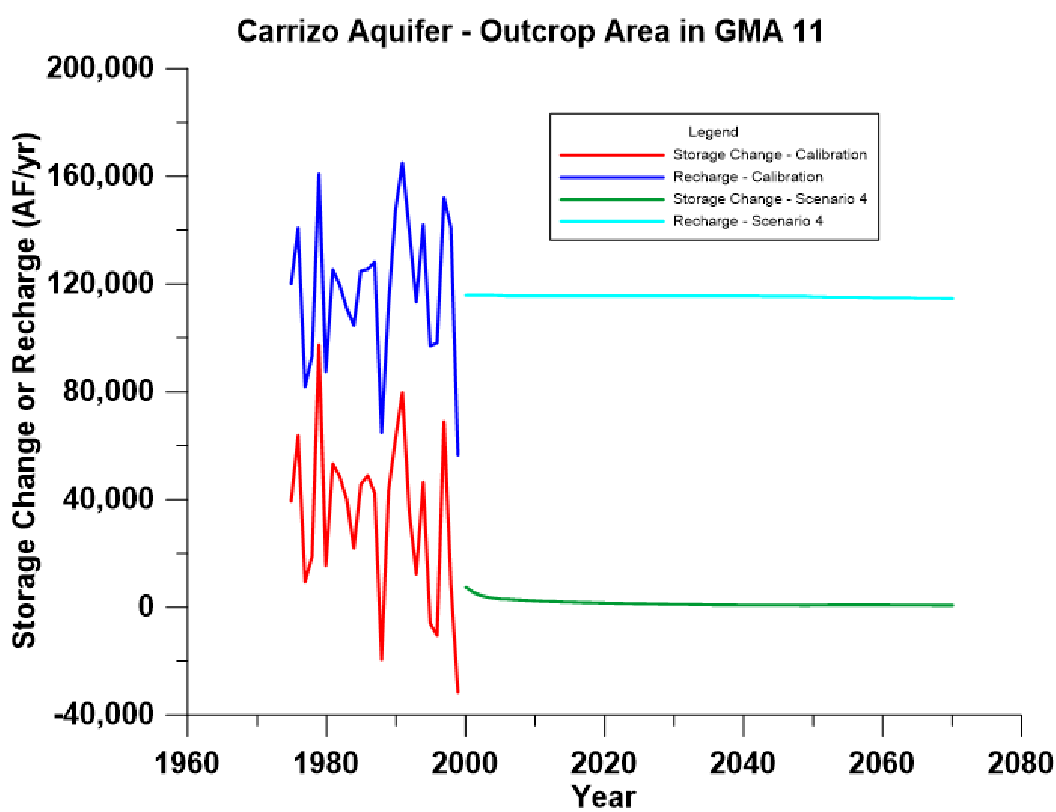


Figure 6. Storage and Recharge in Outcrop Area of Carrizo Aquifer

Note how the recharge and storage change from 1975 to 1999 are well correlated: when recharge is high, there is a rise in the storage, and when there is a decline in recharge, storage declines. However, also note that from 1975 to 1999, there are only three years with an overall storage decline. Overall, the model simulated rising groundwater levels in the outcrop of the Carrizo Aquifer.

In Scenario 4, the storage change is relatively constant, but above zero. The assumed constant recharge results in minimal variation, but the fact that the storage change is always positive means that there is a tendency for groundwater levels to rise from 2000 to 2070. If the recharge were adjusted to a lower value for simulations, it would be expected that the storage would also be lowered, possibly to the point where a storage decline would be observed. However, this would be a modeling artifact, and would not be consistent with the calibration of the model from 1975 to 1999.

Average water budgets for the outcrop area of the Carrizo Aquifer for the two periods is presented in Table 4.

Table 4. Water Budgets for Outcrop Area of Carrizo Aquifer

	1975-1999	2000-2070
Inflow		
Recharge	117,984	115,143
Reservoir	157	0
GMA 12	536	580
Total	118,676	115,723
Outflow		
Downdip	16,097	24,578
Vertical (Wilcox)	12,331	15,421
Pumping	4,253	12,610
Drain	167	649
ET	19,305	34,927
RIV	0	22
Stream	33,448	26,634
Total	85,600	114,841
Inflow-Outflow	33,076	882
Model Calculated Storage Change	33,075	882
Model Error	1	0

Please note that the recharge used in Scenario 4 is slightly less than the average recharge from 1975 to 1999. Also note that the pumping is almost tripled in Scenario 4 as compared to the calibration period. It would be expected that this magnitude of increased pumping would reduce storage, induce inflow, and capture natural outflow. However, natural outflow to the downdip area, the underlying Wilcox Aquifer (slightly), to springs (drain), to evapotranspiration. Stream discharge is less however.

The increase in evapotranspiration is likely a result of increased groundwater levels, as evidenced by the increasing storage. The fact that the downdip flow continues to increase suggests that the model is not simulating the downdip movement of water. If the water cannot exit the outcrop area at a sufficient rate, storage will continue to increase.

The model input files show that specific yield is assigned as a constant value for each layer. In the outcrop areas, the specific yield is used exclusively. In the downdip areas, storativity (which was assigned on a cell by cell basis) is used when the groundwater elevation is above the top of the aquifer. When the groundwater elevation drops below the top of the aquifer, the specific yield is used to estimate the groundwater elevation. The result of using the specific yield is that for a given amount of pumping, drawdown is less than when the storativity is used. Thus, there is less opportunity to lower groundwater levels and create hydraulic gradients when using the higher specific yield numbers.

An inspection of the model grid in the official aquifer boundary of the GMA 11 area yields a total of 58,269 cells in the downdip area of all aquifers. In 4,623 of these (about 8 percent), the 1999 groundwater elevation is below the top of the aquifer. Presumably, these are near the outcrop/downdip boundary. In these areas, the specific yield is used, and may not result in sufficient drawdown to develop a gradient that is strong enough to move water from the outcrop area to the downdip area.

This suggests that the rising water levels are a result of the inability of the model to discharge the water that comes from precipitation. The result is that the negative drawdowns in Scenario 4 as documented in Technical Memorandum 15-01 could, in reality, be considered zero drawdowns. This model limitation will be taken into account when using the results of a simulation in the development of desired future conditions.

6.0 References

Fryar, D., Senger, R., Deeds, N., Pickens, J, Jones, T., Whallon, A.J., and Dean, K.E., 2003. Groundwater Availability Model for the Northern Carrizo-Wilcox Aquifer. INTERA Incorporated report prepared for the Texas Water Development Board, January 31, 2003, 529p.

Kelley, V.A., Deeds, N.E., Fryar, D.G., and Nicot, J.P., 2004. Groundwater Availability Model for the Queen City and Sparta Aquifers. INTERA Incorporated report prepared for the Texas Water Development Board, October 2004, 867p.