A Comparison of the Old and New Groundwater Availability Models for the Hill Country Portion of the Edwards and Trinity Aquifers

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Purpose of Paper

The main purpose of this paper is to compare and contrast the old (Mace and others, 2000) and the new groundwater availability models (Jones and others, 2009) developed for the Trinity Aquifer located in the Hill Country. The new groundwater availability model was developed mainly to meet the following objectives: (1) include the Lower Trinity Aquifer as a fourth model layer that was absent in the old model, (2) allow recently released recharge information to be incorporated along the Cibolo Creek in parts of Bexar, Comal, and Kendall counties, and (3) calibrate the model over a longer historical time frame extending from 1980 through 1997 (as opposed to 1975, 1996, and 1997 in the old model) consistent with groundwater availability models for other regional aquifers developed by the Texas Water Development Board. Given that 1996 and 1997 are common to both the old and the new models, we compared the model results for these years that include cross-plots of simulated and measured water levels, calibration statistics, baseflow discharge to rivers, and relative distribution of various groundwater flow components.

Executive Summary

The old and the new groundwater availability models cover the same geographic areas of the Hill Country and include all or parts of Gillespie, Blanco, Travis, Hays, Comal, Kendall, Bexar, Medina, Bandera and Kerr counties. Both models simulate groundwater flow through the Edwards Group associated with the Edwards-Trinity (Plateau) Aquifer System and the Upper and Middle Trinity aquifers that form two of the three aquifers associated with the Trinity Aquifer. The new model also simulated flow through the Lower Trinity Aquifer.

Our analyses suggest minor regional differences in model results between the old and the new models. However, the model results can be highly variable locally, particularly in the eastern portion of the study area along the Balcones Fault Zone. These differences in simulated water levels are largely due to assignment of higher recharge and zonal hydraulic conductivities in the new model. The old model uses a distributed groundwater recharge approach based on baseflow coefficients and precipitation distribution; the new model takes into account a combination of parameters including precipitation distribution, measured river losses through Cibolo Creek, and fracturing of the aquifer materials along the Balcones Fault Zone to distribute recharge in multiple zones.

To evaluate the degree of fit between measured and simulated water levels for 1996 and 1997, calibration statistics were used. Calibration statistics suggest that the new model generally reproduces water levels better than the old model, particularly in the Edwards Group and Upper Trinity aquifers. For example, root mean squared error in the Edwards Group Aquifer is 26 feet and 21 feet for 1996, and 31 feet and 25 feet for 1997 in the old and new models, respectively. Similarly, the root mean squared error in the Upper Trinity Aquifer is 114 feet and 85 feet for 1996, and 119 feet and 121 feet for 1997 in the old and new models, respectively. An identical root mean squared error of 78 feet was observed for 1997 in the Middle Trinity Aquifer in both the old and new models. The root mean squared error slightly differs for 1996 in the Middle Trinity Aquifer, with values of 74 feet and 82 feet in the old and the new models, respectively. Examination of spatial distribution of these calibration residuals (differences between measured and simulated water levels) indicates that the new model better reproduces water levels in the Middle Trinity Aquifer in northern parts of Bexar and Comal counties for 1997.

From analysis of water budget calculations, we observed a total recharge of about 244,000 and 275,000 acre-feet per year in the old and new models, respectively, for 1996. Differences in recharge are much smaller between the old and new models for 1997. Recharge was estimated at about 419,000 and 423,000 acre-feet per year, in the old and new models, respectively, for 1997. Assignment of focused recharge locally along the Cibolo Creek and higher recharge along the Balcones Fault Zone allows more than twice the amount of water to flow across the eastern model boundary in the new model. Pumpage used in the old model is nearly double the amount used in the new model for both 1996 and 1997 potentially due to overestimation of the domestic pumping in the old model.

Comparison of estimated baseflow is affected by the different stress period lengths used in the two models. The old model used monthly stress periods, and thus, could track intra-annual fluctuations in baseflow. In contrast, the new model used annual stress periods. The new model reasonably reproduces annual average baseflow and long-term trends in changes in baseflow over the longer historical period of calibration (1980 through 1997) for most of the studied river sections.

Methods

The old model was calibrated for 1975, 1996, and 1997 whereas the new model was calibrated for 1980 through 1997. The old model uses monthly stress periods for 1996 and 1997 and the new model uses annual stress periods from 1980 through 1997. All results for 1996 and 1997 from the old model are reported annually by summing the monthly output data.

We ran the old (Mace and others, 2000) and the new (Jones and others, 2009) groundwater availability models for the Hill Country portion of the Trinity Aquifer. Both models were run in Processing MODFLOW for Windows (PMWIN, version 5.3: Chiang and Kinzelbach, 1998).

We exported the simulated water levels from Processing MODFLOW for Windows to ArcMap. We spatially joined the simulated water levels for 1996 and 1997 with the model grid in ArcMap to determine their spatial distributions within active parts of the model domain and calculated differences between simulated and measured water levels. We plotted the simulated and measured water levels for 1996 and 1997 in EXCEL. We calculated root mean squared error between the simulated and measured water levels for the Edwards Group, Upper, and Middle Trinity aquifers for 1996 and 1997 for both the old and new models. We used the following equation to calculate root mean squared error:

$$RMSE = [\frac{1}{n}\sum_{i=1}^{n}\left(h_m - h_s\right)_i^2]^{0.5}$$

where RMSE = root mean squared error, n= number of water level measurement points, h_m = measured water level elevation in feet, and h_s= simulated water level elevation in feet.

We downloaded water level elevation data for the Edwards Group, Upper Trinity, and Middle Trinity aquifers for 1996 and 1997 from the Texas Water Development Board's groundwater database. For the Edwards Group, we considered wells completed in the Fort Terrett and Segovia formations. For the Upper Trinity Aquifer, we considered wells completed in the upper member of the Glen Rose Limestone. For the Middle Trinity Aquifer, we considered wells screened within the Cow Creek Limestone, lower member of the Glen Rose Limestone, and Hensell Sand.

We also extracted water budget information from the zoned water budget output data in Processing MODFLOW for Windows. We extracted two water budget results: (1) for the entire model area and (2) model areas excluding Bexar County and included estimates for outflow to Bexar County. We excluded the water budget for Bexar County because the old model underestimated water levels, which resulted in numerous dry cells in predictive simulations, so we could compare water budgets without skewing the data.

Parameters and Assumptions

- See Mace and others (2000) for details on model construction, recharge, discharge, assumptions and limitation of the model. Version 1.03 of the old model was used for this run (Chowdhury, 2007). The new model was developed by Jones and others (2009).

- The old model has three layers: layer 1 represents the Edwards Group, layer 2 represents the Upper Trinity Aquifer, and layer 3 represents the Middle Trinity Aquifer. In addition to these three layers, the new model has a fourth layer representing the Lower Trinity Aquifer.

- The rivers, streams, and springs were simulated in both models using MODFLOW's Drain package.

- MODFLOW Drain package was also used to simulate spring flow along bedding contacts of the Edwards Group and the Upper Trinity Aquifer in the northwestern parts of the model area in both models. This resulted in the assignment of numerous drain cells along this outcrop contact.

- Reservoirs/lakes in the old model were simulated using constant heads. The new model used MODFLOW River package to simulate flow between the aquifer and reservoirs/lakes.

- MODFLOW General-Head Boundary package was used to simulate flow across the Trinity Aquifer and the Edwards Aquifer along the Balcones Fault Zone in both models.

Results

The model area consists of all or parts of Gillespie, Kerr, Bandera, Medina, Kendall, Bexar, Comal, Blanco, Hays, and Travis counties (Figure 1). The model area contains numerous rivers and creeks, most of which historically gain groundwater from the aquifer. Baseflow discharge that feeds most of the water courses in the area is a large component of streamflow (Mace and others, 2000). Pumpage assigned in the new model for 1996 and 1997 is nearly one-half of the values used in the old model probably due to overestimation of domestic pumping in the old model.

In the following sections, we report hydraulic conductivity used in the model layers, recharge distribution, various components of groundwater flow from water budget, cross-plots between simulated and measured water levels for the Edwards Group, Upper-, and Middle Trinity aquifers, root mean squared error for evaluating the degree of fit between the measured and simulated water levels, and baseflow estimates along selected reaches of the rivers from the old and the new models for 1996 and 1997.

Hydraulic Conductivity

Hydraulic conductivity is a measure of transmission capacity of the aquifer materials. Fine-grained sediments have lower hydraulic conductivity than coarser-grained sediments. Fracturing and dissolution of carbonate aquifer materials allow for development of higher hydraulic conductivity as observed in the eastern parts of the model area along the Balcones Fault Zone.

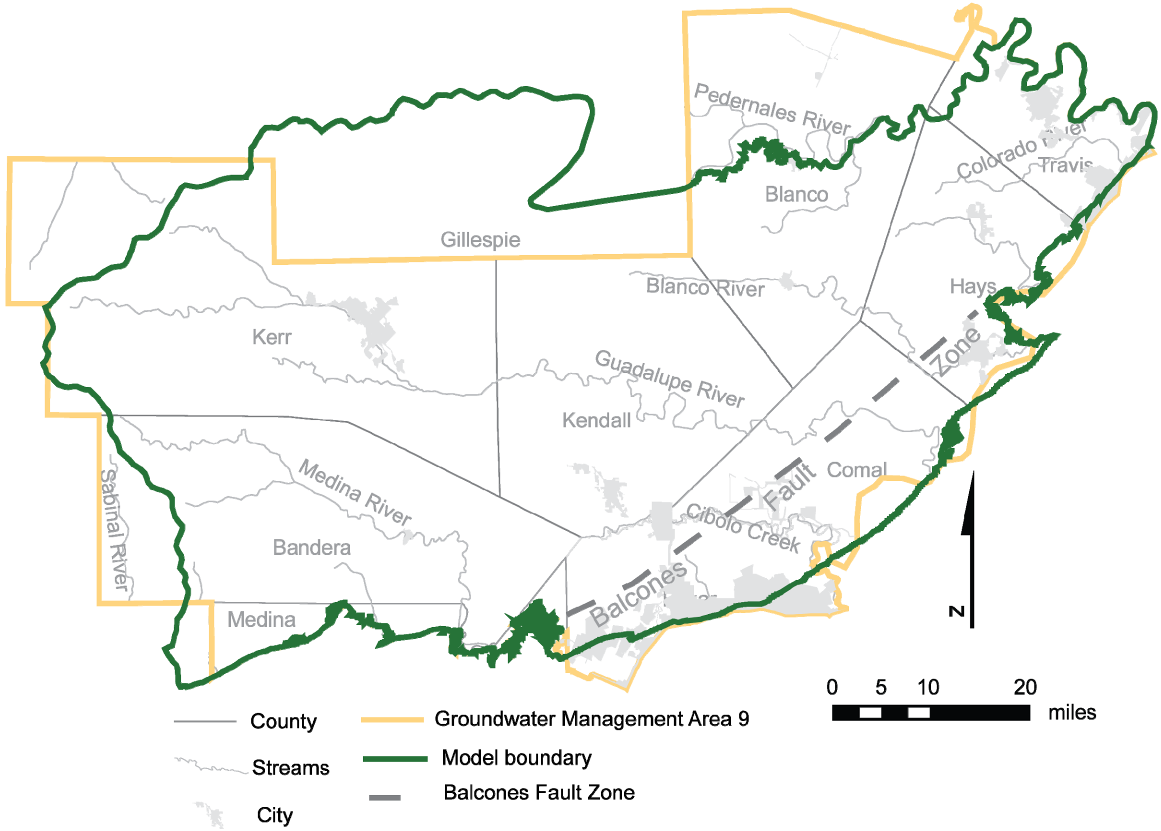


Figure 1. Map showing counties, streams, model boundary, and the outline of Groundwater Management Area 9. Note: model boundary and grid remains same for the old and the new models. The approximate western extent of the Balcones Fault Zone within the model area is also shown.

Hydraulic conductivity used in the new model is significantly higher than used in the old model. For example, a uniform distribution of hydraulic conductivity of 7 feet per day was used for the Edwards Group in the old model (Mace and others, 2000) and 11 feet per day was used in the new model (Jones and others, 2009), respectively. Similarly, a uniform distribution of hydraulic conductivity of 5 feet per day was used for the Upper Trinity Aquifer in the old model (Mace and others, 2000) and a zoned hydraulic conductivity with values ranging from 9 feet to 150 feet per day was assigned in the new model (Jones and others, 2009) (Figure 2). Most of these higher hydraulic conductivity values were assigned along the Balcones Fault Zone and along the Cibolo Creek. These higher hydraulic conductivity zones were assigned to allow rapid movement of groundwater through the fractured sections of the aquifers in the eastern part of the model area along the Balcones Fault Zone. A distributed hydraulic conductivity was assigned in the old model based on variogram analyses of specific capacity and pump test information for the Middle Trinity Aquifer and ranges from 1 to 10 feet per day for most of the model domain with high hydraulic conductivity values of 60 feet per day locally (Mace and others, 2000) (Figure 3a). Two zones of hydraulic conductivity of about 8 and 15 feet per day were assigned for the Middle Trinity Aquifer in the new model (Figure 3b). A hydraulic conductivity of 1.67 and 16.7 feet per day was assigned in the Lower Trinity Aquifer in the new model (Figure 4). The adjustments in hydraulic conductivity in the new model allowed additional flow to and from the Lower Trinity Aquifer to occur and control the higher recharge assigned along the Balcones Fault Zone.

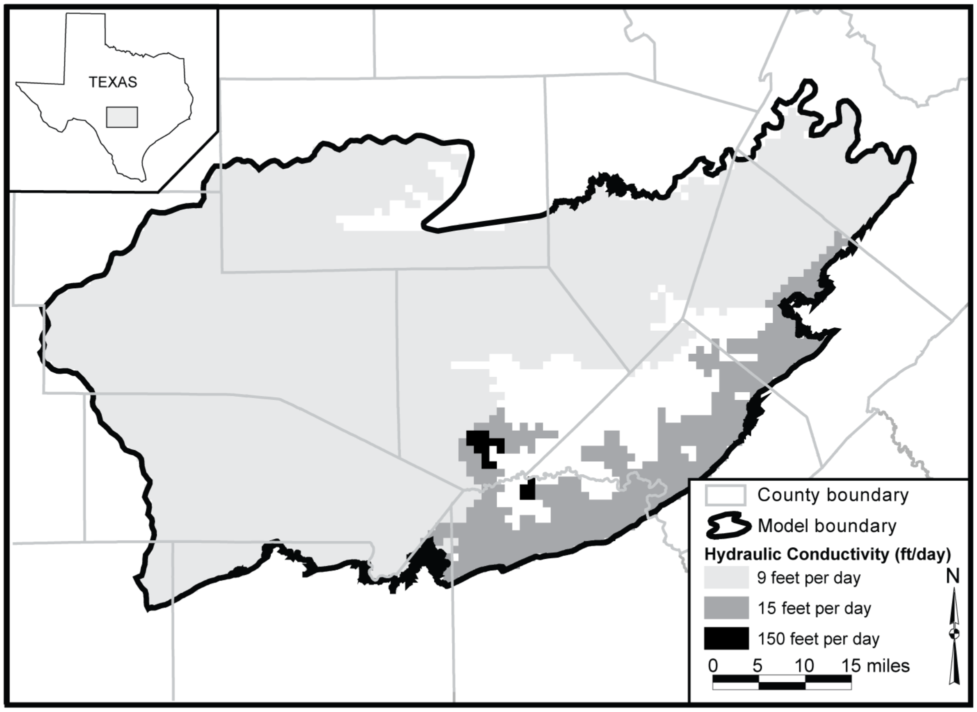
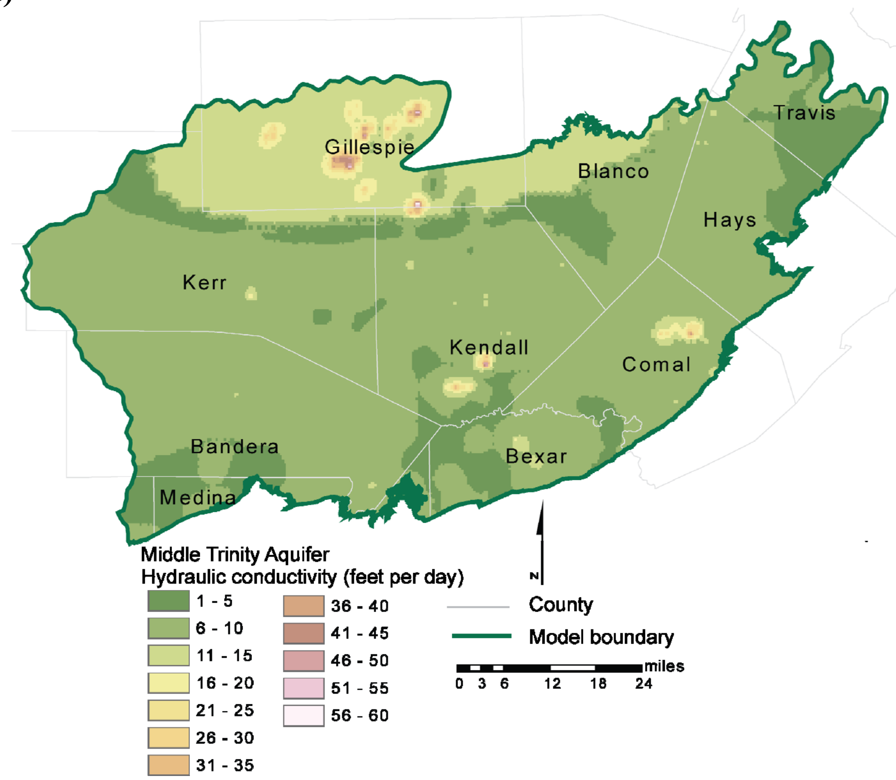


Figure 2. Distribution of hydraulic conductivity in the Upper Trinity Aquifer from the new model (from Jones and others, 2009).

(a)



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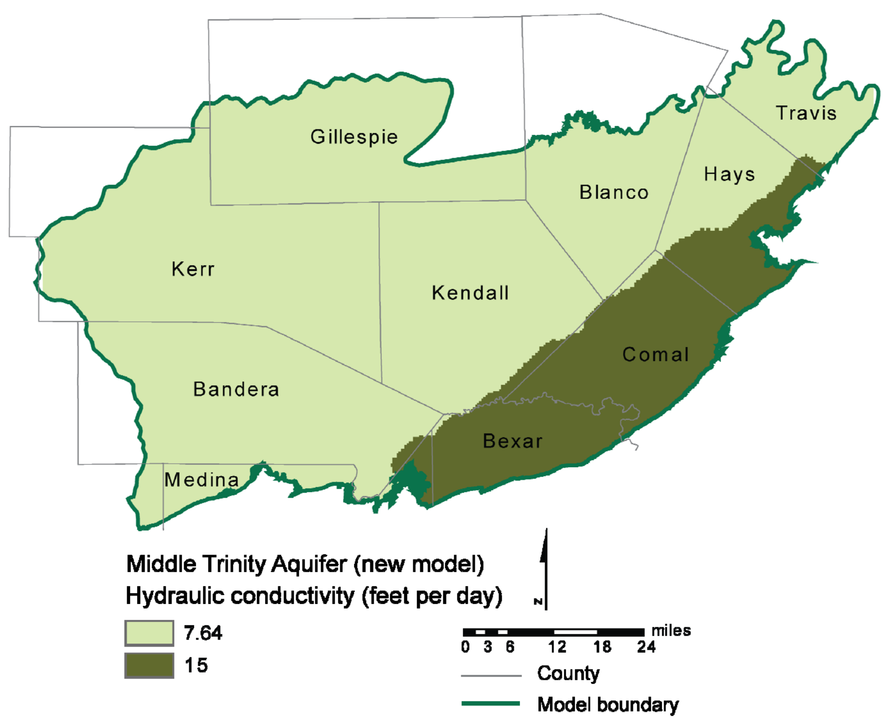


Figure 3. Distribution of hydraulic conductivity in the Middle Trinity Aquifer in the (a) old model (data from Mace and others, 2000) and (b) new model (data from Jones and others, 2009).

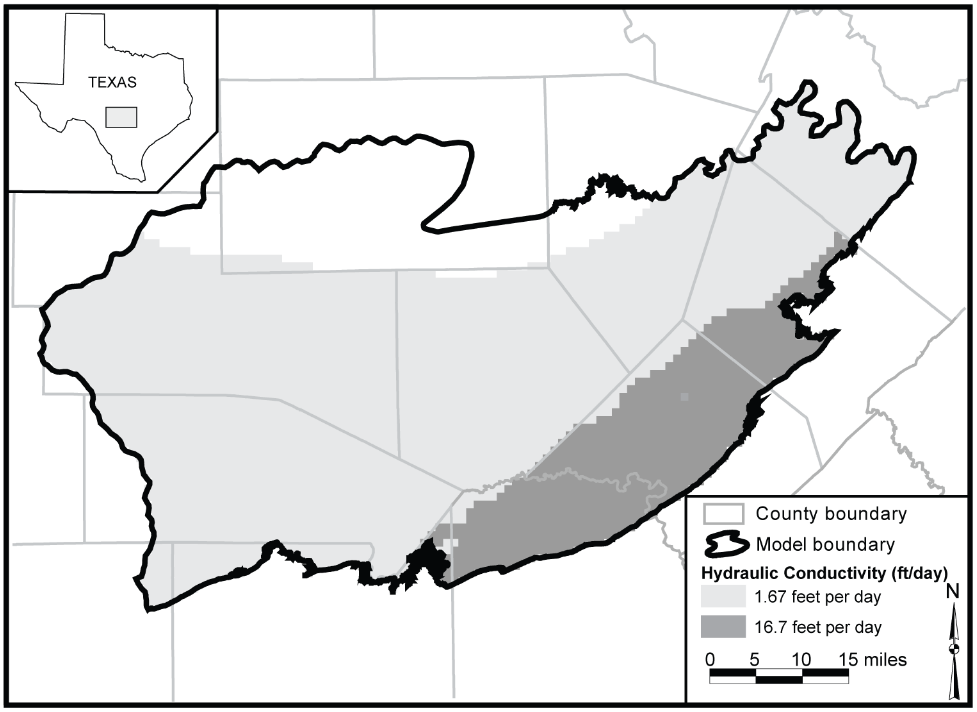


Figure 4. Distribution of hydraulic conductivity in the Lower Trinity Aquifer from the new model (from Jones and others, 2009).

Recharge

Groundwater recharge is the amount of precipitation water that infiltrates to the water table from the outcrop. Groundwater recharge may also occur through losing streams, such as Cibolo Creek, which recharge the aquifer system through the river bottom to the underlying aquifers. The groundwater recharge rate depends on a number of factors including precipitation amounts, hydraulic characteristics of the soils and aquifer materials, and topography. Precipitation amount, its spatial distribution, and baseflow coefficients from selected gazes were used in the development of groundwater recharge in the old model. In addition to the precipitation amount and its spatial distribution, hydraulic characteristics of the aquifer materials were used in the development of recharge in the new model.

There is a significant difference in spatial distribution of recharge between the two models (Figure 5). Recharge is more spatially distributed in the old model with values ranging from about 0.25 to 1.75 inches per year (Figure 5a). Recharge in the new model is zoned with values that range from about 0.67 to as much as 35 inches per year locally (Figure 5b). For most of the western part of the model area, a recharge amount of 0.75 inches per year was assigned in the new model and the higher recharge values were assigned along the Balcones Fault Zone and around Cibolo Creek.

(a)

(b)

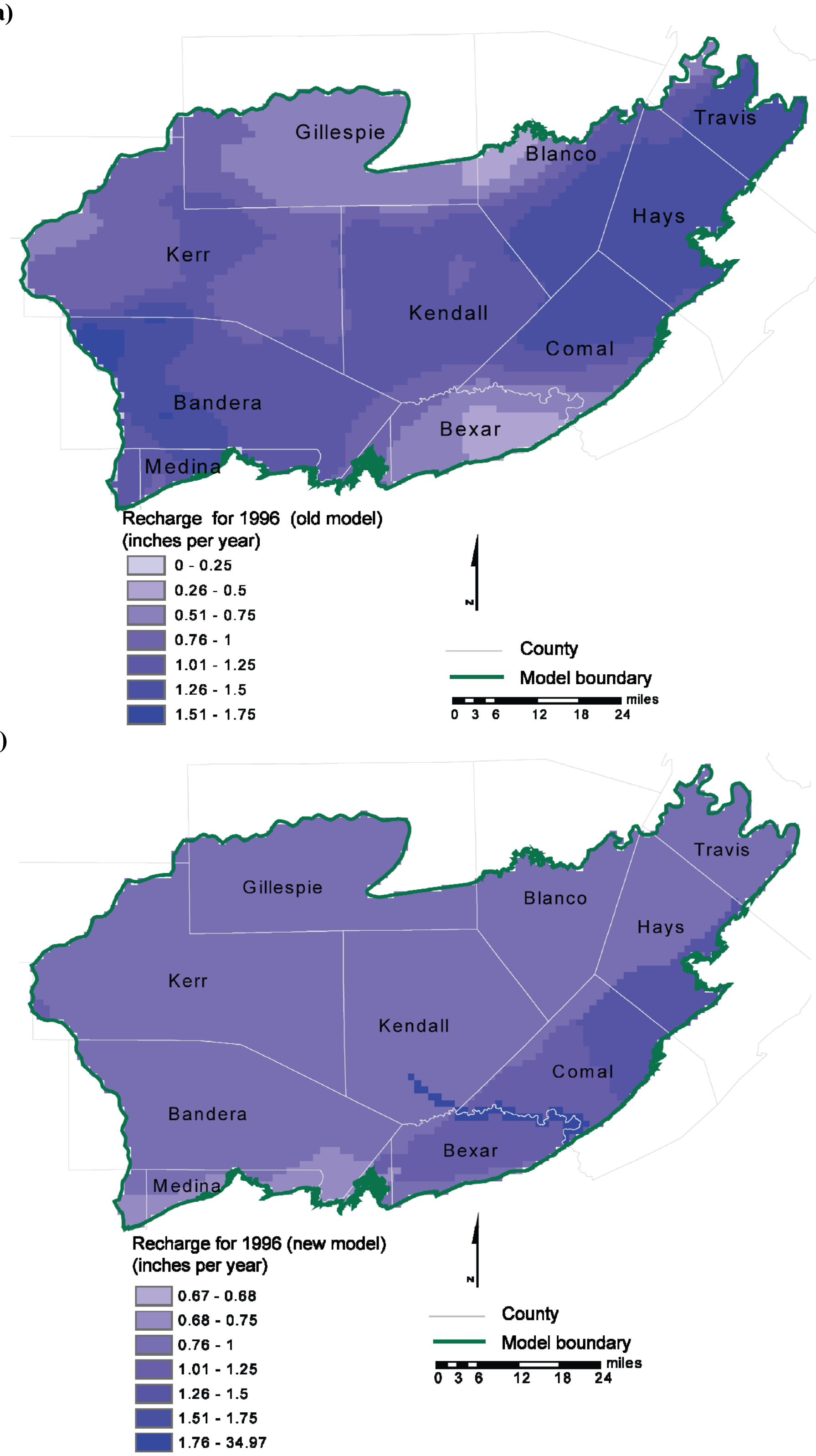


Figure 5. Distribution of recharge for 1996 in the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

Recent gain-loss studies indicate that the Cibolo Creek loses as much as 80,000 acre-feet per year of water into the underlying Trinity Aquifer (Ockerman, 2007). Therefore, the higher recharge amount assigned along the Balcones Fault Zone is well supported by gain-loss study as well as extensive fracturing of the aquifer materials that will readily allow infiltration of precipitation.

Groundwater Budget

The groundwater budget is an accounting of the different groundwater flow components into and out of a groundwater flow system. Groundwater budget analysis provides a better understanding of how the model is behaving in response to various stresses and recharge conditions. It also provides an opportunity to detect model error using calculated net inflows and outflows from the water budget data.

For comparison purposes, we plotted the net flows entering and leaving the aquifer system for the entire modeled area for both models (Figures 6, 7, 8, and 9 and Table 1). For 1996, results from the old and the new models show some differences in recharge, flow through the general head boundary along the Balcones Fault Zone, flow through the lakes/reservoirs, pumping, and changes in storage. Higher recharge assigned in the new model for 1996 results in more flow through the general head boundary and through the lakes/reservoirs located along the Balcones Fault Zone. Most of this additional recharge was included in the new model due to a recent study indicating greater recharge in the Cibolo Creek watershed in Bexar, Kendall, and Comal counties. For 1996, storage change is minimal in the old model suggesting that the aquifer is in near equilibrium; the new model shows a slight storage decline suggesting slightly lowered water levels in the aquifers. Given the lower than average precipitation in 1996, the slight storage decline would be expected as simulated by the new model as opposed to essentially no storage change in the old model. For 1997, all flow components are nearly similar between the old and the new model except for flow through the general head boundary, flow through lakes/reservoirs, and pumping (Figure 7). Precipitation in 1997 was higher than average, and resulted in higher recharge than that observed in 1996. This condition resulted in slight groundwater storage gains, and, consequently, higher groundwater levels.

We also summarized water budget parameters for the entire model area excluding Bexar County. We did this because of higher calibration errors for this area in the old model, which had greater potential for developing dry cells with the application of additional pumpage. To maintain a balanced water budget, we included estimated outflows from adjacent counties in the model area to Bexar County (Figures 8 and 9). We observed that outflow to Bexar County between the old and the new model is very similar for 1996 (13,368 and 18,931 acre-feet per year in the old and new model, respectively). However, a larger difference in outflow to Bexar County was observed for 1997 (16,548 and 54,801 acre-feet per year in the old and new models, respectively). These differences can be attributed to the assignment of higher recharge and hydraulic conductivity in the new model along the Balcones Fault Zone. Water budget data describing the different flow components of the groundwater flow system from the old and the new models are presented in Table 1.

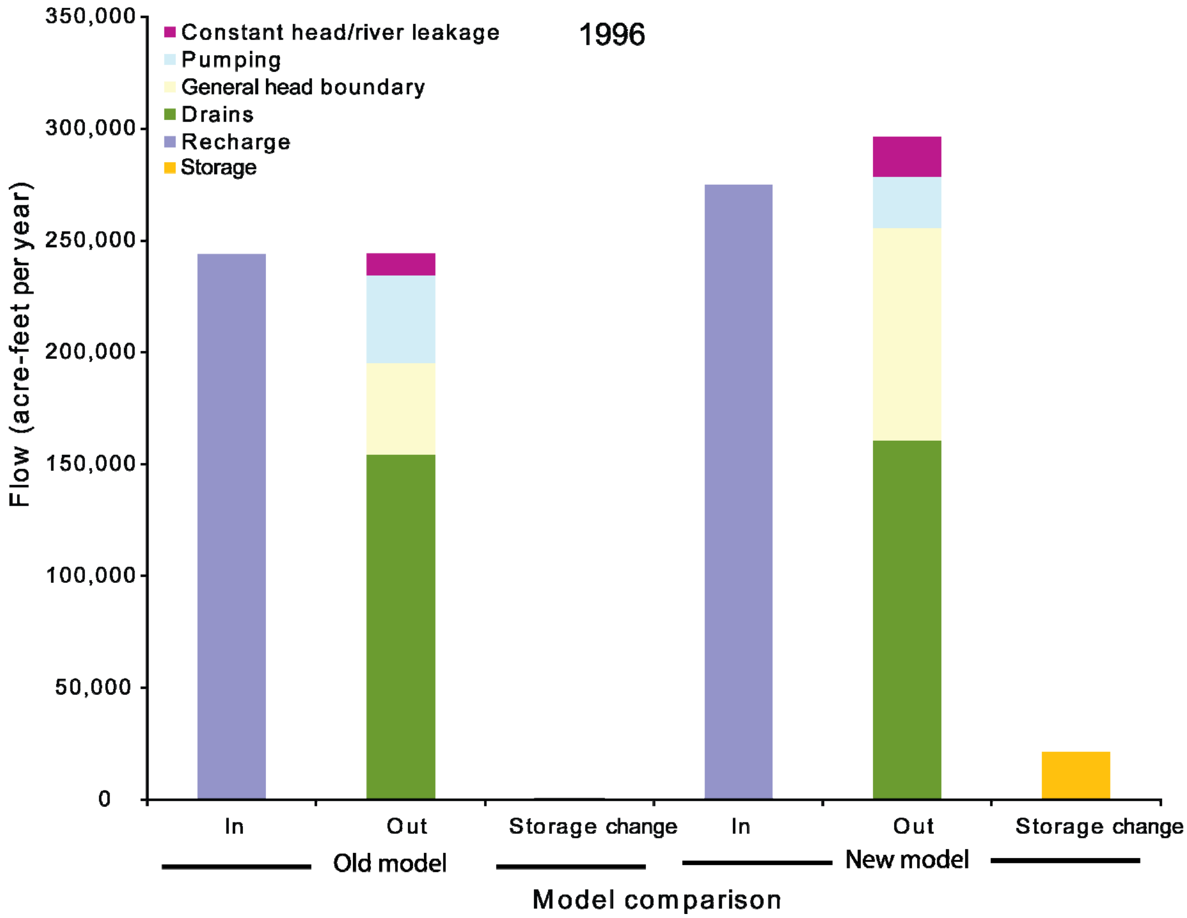


Figure 6. Comparison of various net groundwater flow components between the old and the new model for 1996.

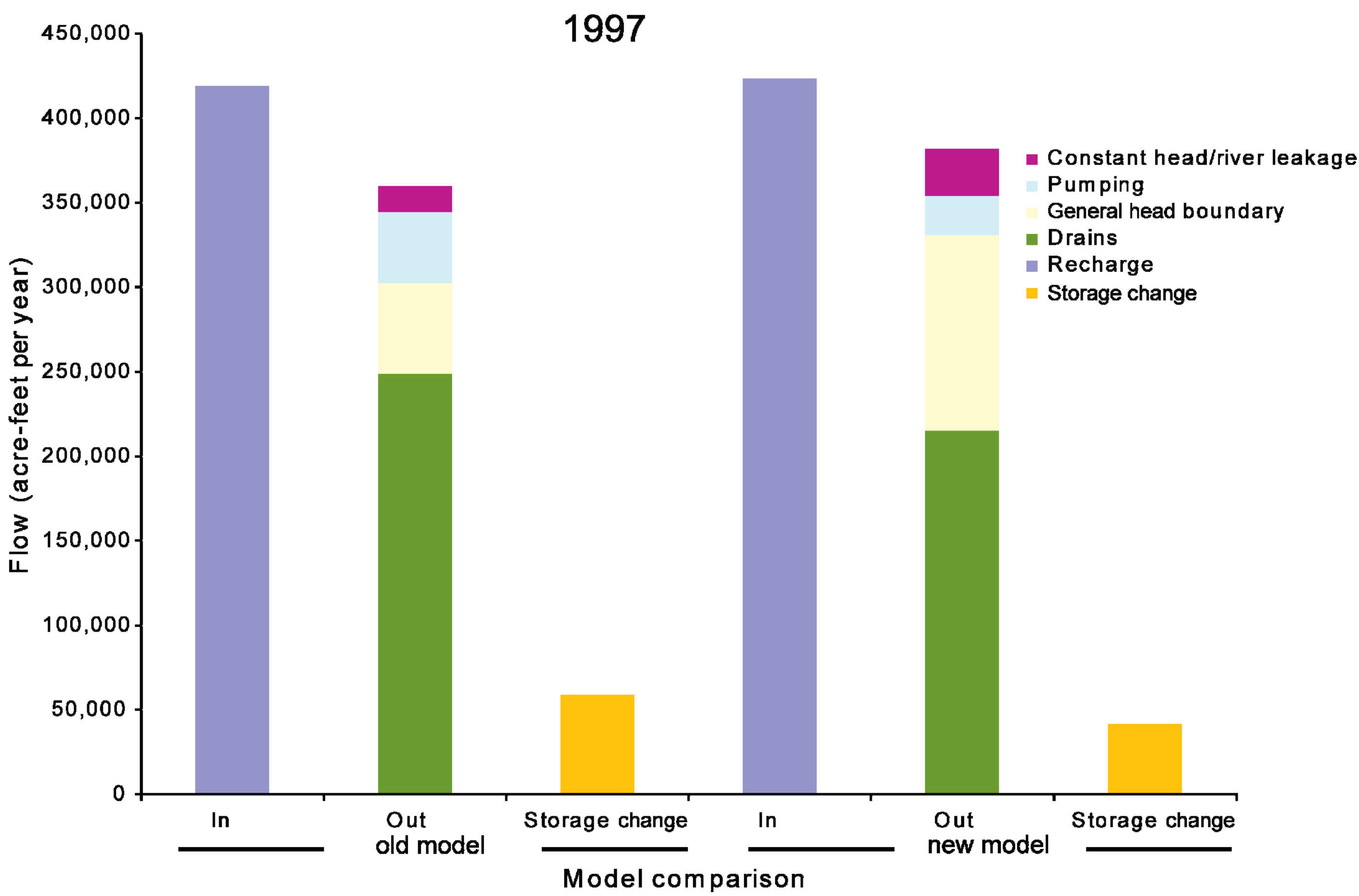


Figure 7. Comparison of various net groundwater flow components between the old and the new models for 1997.

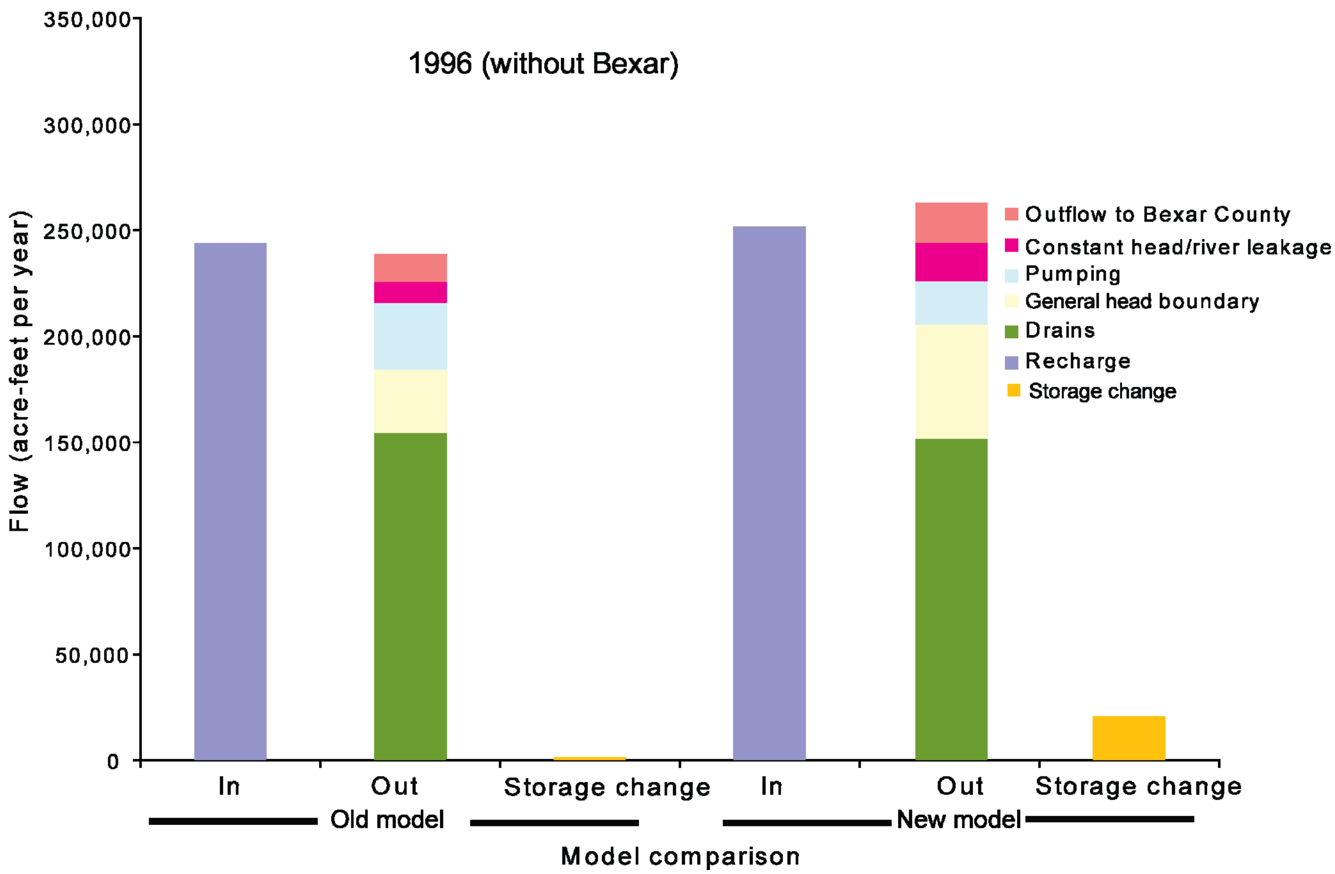


Figure 8. Comparison of various net groundwater flow components between the old and the new model for 1996 excluding Bexar County.

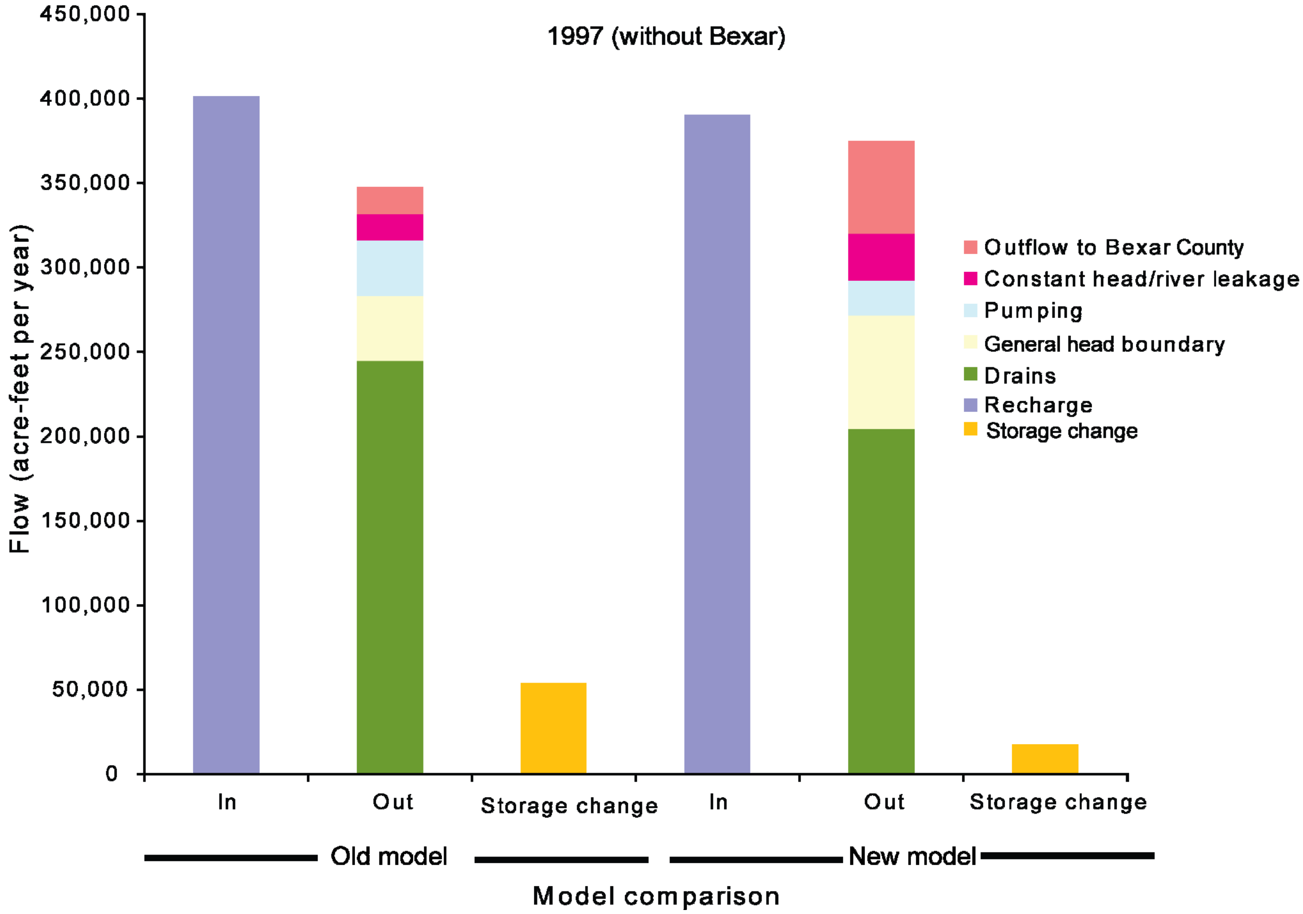


Figure 9. Comparison of various net groundwater flow components between the old and the new model for 1997 excluding Bexar County.

Table 1. Water budget results for 1996 and 1997 from the old and the new models for the entire model and also for model areas excluding Bexar County. Values are reported in acre-feet per year.

1996	**Flow over the entire model— old model**	**Flow over the entire model — new model**	**Flow excluding Bexar County — old model**	**Flow excluding Bexar County — new model**
Inflow				
Recharge	243,818	274,955	235,263	251,944
Total inflow	243,818	274,955	235,263	251,944
Outflow				
Flow to rivers and springs	154,186	160,494	153,320	151,424
Flow along the Balcones Fault Zone	40,757	94,893	28,840	54,013
Pumping	39,296	22,760	30,060	20,441
Flow to reservoirs/lakes	9,879	18,241	9,879	18,241
Outflow to Bexar County			13,368	18,931
Total outflow	244,118	296,388	235,467	263,050
Total inflow-total outflow	-300	-21,433	-204	-11,106
Storage change	131	21,370	1,796	20,635
[1]**Model error**	-169	-63	1,592	9,529
[2]**Model error (percent)**	-0.07%	-0.02%	0.67%	3.78%
1997	**Flow over the entire model— old model**	**Flow over the entire model — new model**	**Flow excluding Bexar County — old model**	**Flow excluding Bexar County — new model**
Inflow				
Recharge	418,893	423,261	401,461	390,413
Total inflow	418,893	423,261	401,461	390,413
Outflow				
Flow to rivers and springs	248,554	214,831	244,686	204,380
Flow along the Balcones Fault Zone	53,899	116,027	38,373	67,100
Pumping	41,851	22,914	32,870	20,571
Flow to reservoirs/lakes	15,496	27,948	15,496	27,947
Outflow to Bexar County			16,458	54,801
Total outflow	359,800	381,720	347,883	374,799
Total inflow-total outflow	59,093	41,541	53,578	15,614
Storage change	58,895	41,567	53,830	17,875
[1]**Model error**	198	-26	-252	-2,261
[2]**Model error (percent)**	0.05%	-0.01%	-0.06%	-0.58%

[1] Model error = differences between net total flow (total inflow-total outflow) and storage change.
[2] Model error (percent) = (Model error)/ (Total inflow) ×100

Water Levels

Water levels are one of the important calibration parameters and are used to compare the degree of fit between the measured and simulated water levels. Water-level elevations determine direction and magnitude of groundwater flow in the aquifer.

We plotted simulated and measured water levels for the Edwards Group, Upper-, and Middle Trinity aquifers for 1996 and 1997 from both the old and new models. We also calculated calibration statistics using root mean squared error between measured and simulated water levels for 1996 and 1997 from the old and new models (Table 2). The larger error indicates higher mismatch between the measured and simulated water levels. We observed that the new model does a better job in reproducing the water levels in the Edwards and Upper Trinity aquifers. Both models reproduce water levels in the Middle Trinity Aquifer relatively well..

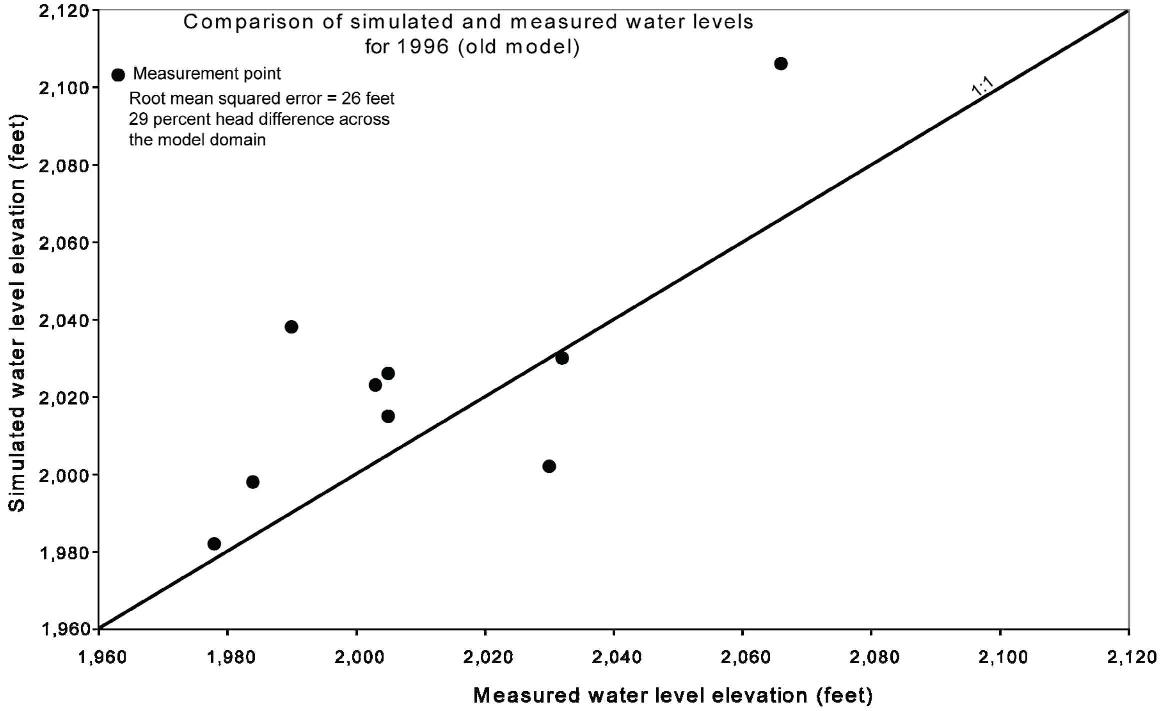
Cross-plots of simulated and measured water levels for the Edwards Group Aquifer for 1996 show root mean squared errors of 26 and 21 feet for the old and new models, respectively (Figure 10). These values translate to 26 and 21 percent of the head difference across the aquifer. Like in 1996, the new model better reproduces the water levels in the Edwards Aquifer in 1997 (root mean squared error of 25 feet) than the old model (root mean squared error of 31 feet) (Figure 11).

The new model also reproduces better the water levels in the Upper Trinity aquifer. Cross-plots of simulated and measured water levels for the Upper Trinity Aquifer for 1996 show root mean squared errors of 114 and 85 feet for the old and new models, respectively (Figure 12). These values translate to 22 and 16 percent of the head difference across the aquifer. Like in 1996, the new model better reproduce the water levels in the Upper Trinity Aquifer in 1997 (root mean squared error of 119 feet) than the old model (root mean squared error of 121 feet) (Figure 13).. The larger root mean squared error values suggest that Upper Trinity Aquifer is not as well calibrated as the Edwards Group and the Middle Trinity Aquifer. This is probably due to larger scale heterogeneity in the aquifer materials that could not be reproduced at the regional scale of the model. The Upper Trinity Aquifer also has intermittent perched sections that may prevent flow through porous continuums resulting in larger errors.

Cross-plots of simulated and measured water levels for the Middle Trinity Aquifer for 1996 show root mean squared errors of 73.5 and 82.4 feet for the old and new models, respectively.(Figure 14). These differences in calibration errors for 1996 between the old and the new models are minor, comprising 6.6 and 7.4 percent of the head differences of water levels across the model area. Calibration residuals (differences in measured and simulated water levels) for 1996 show some differences in residual distribution between the two models (Figure 15). The new model appears to somewhat overestimate simulated water levels in the western parts of the model area for 1996. However, the new model shows lower calibration residuals in Bexar County than the old model (Figure 15).

Cross-plots of simulated and measured water levels for the Middle Trinity Aquifer for 1997 shows nearly identical root mean squared errors of about 78 feet in both the old and new models.(Figure 16). Simulated water levels in the Middle Trinity Aquifer are slightly overestimated in both models over western parts of the model area (Figure 17). The new model does a better job in calibrating water levels in parts of Bexar and Comal counties for 1997 (Figure 17).

(a)



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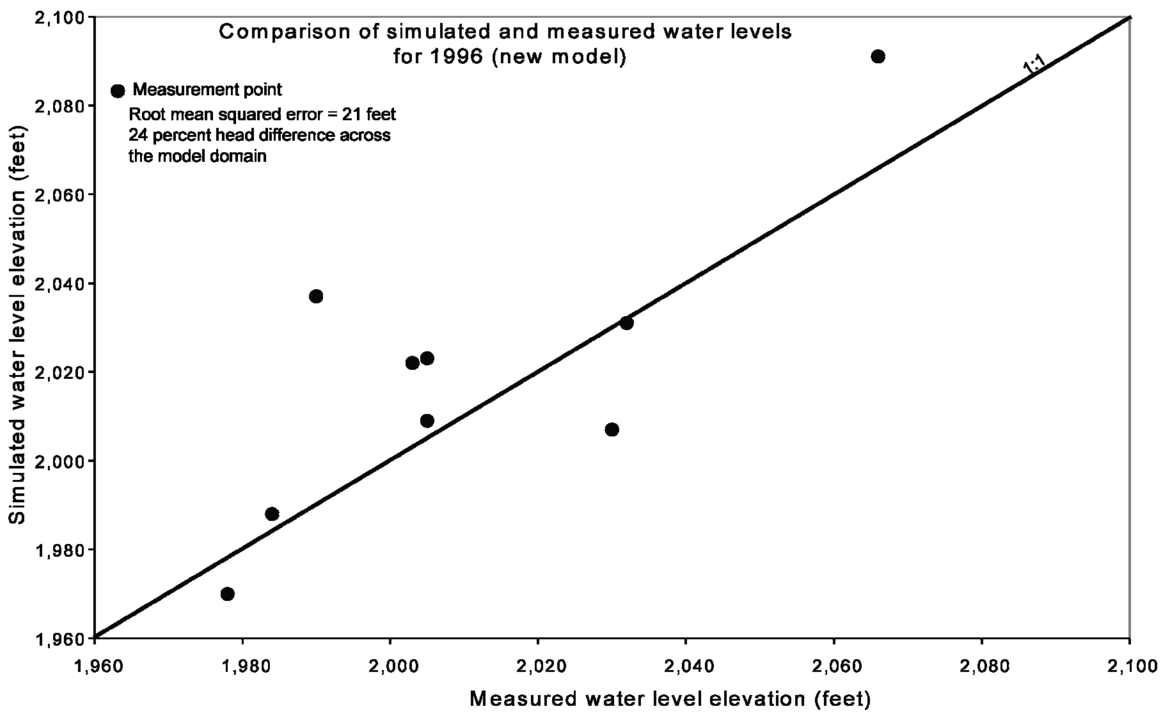
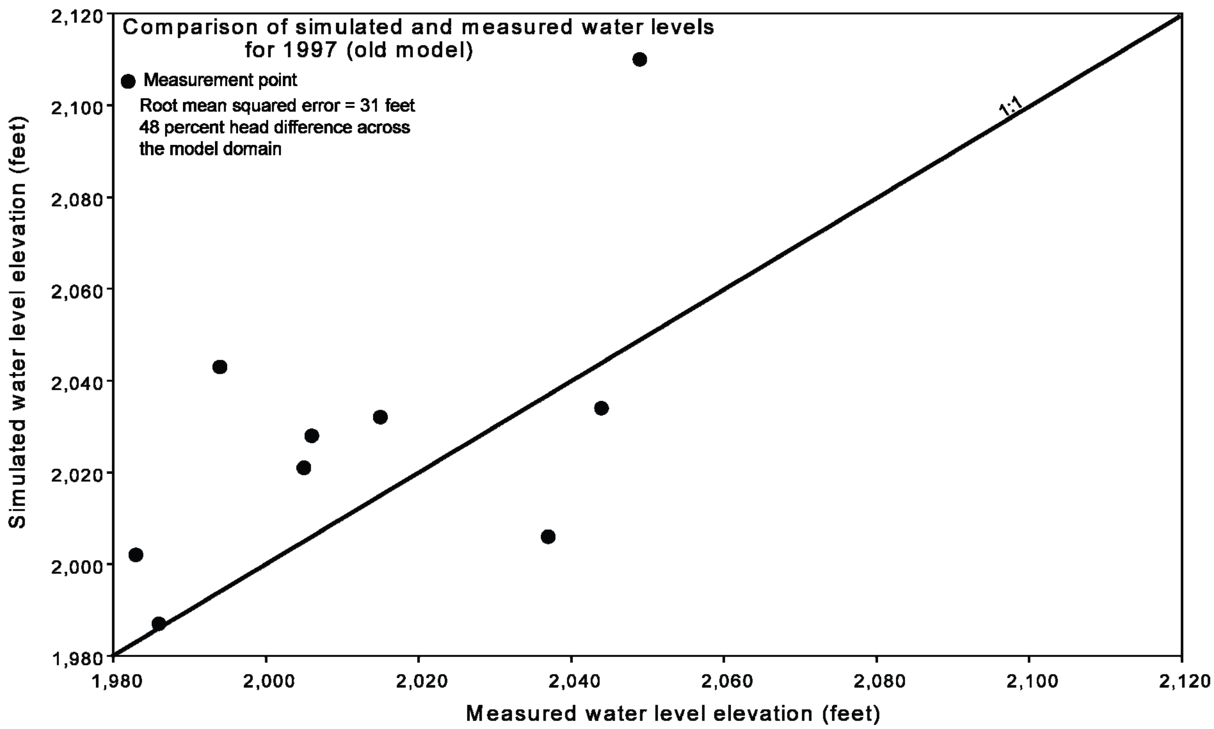


Figure 10. Cross-plot of simulated and measured water levels for 1996 for the Edwards Group Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009)

(a)



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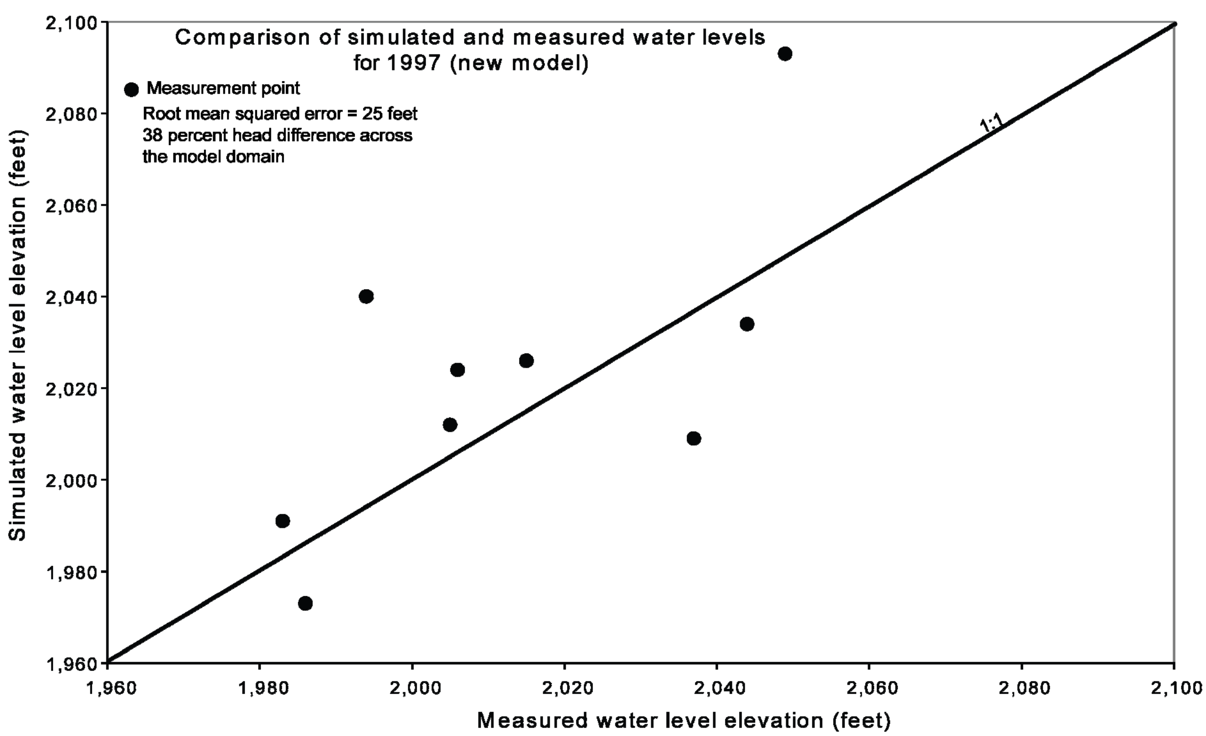
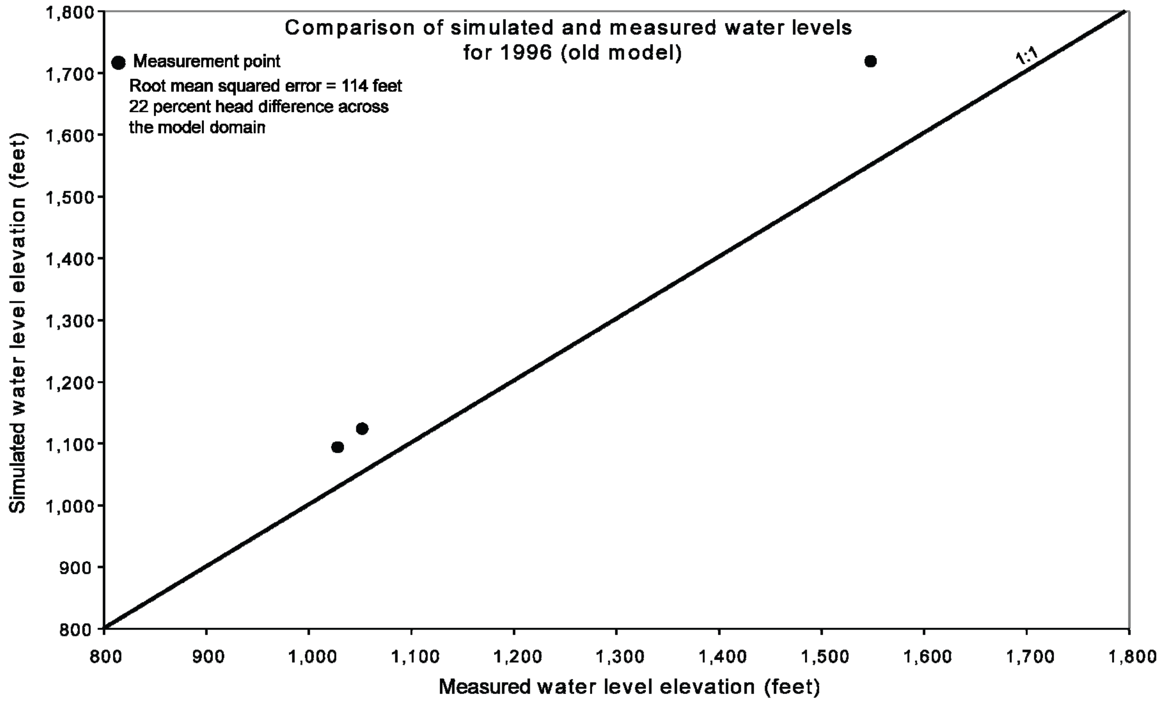


Figure 11. Cross-plot of simulated and measured water levels for 1997 for the Edwards Group Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009)

(a)



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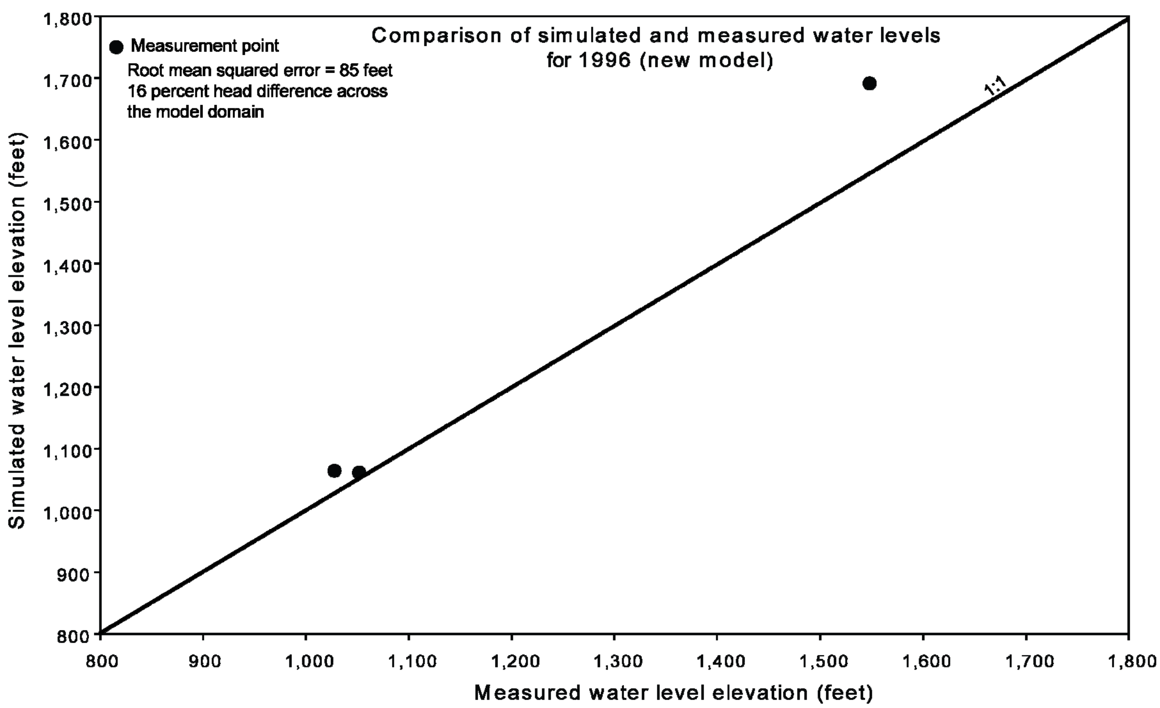
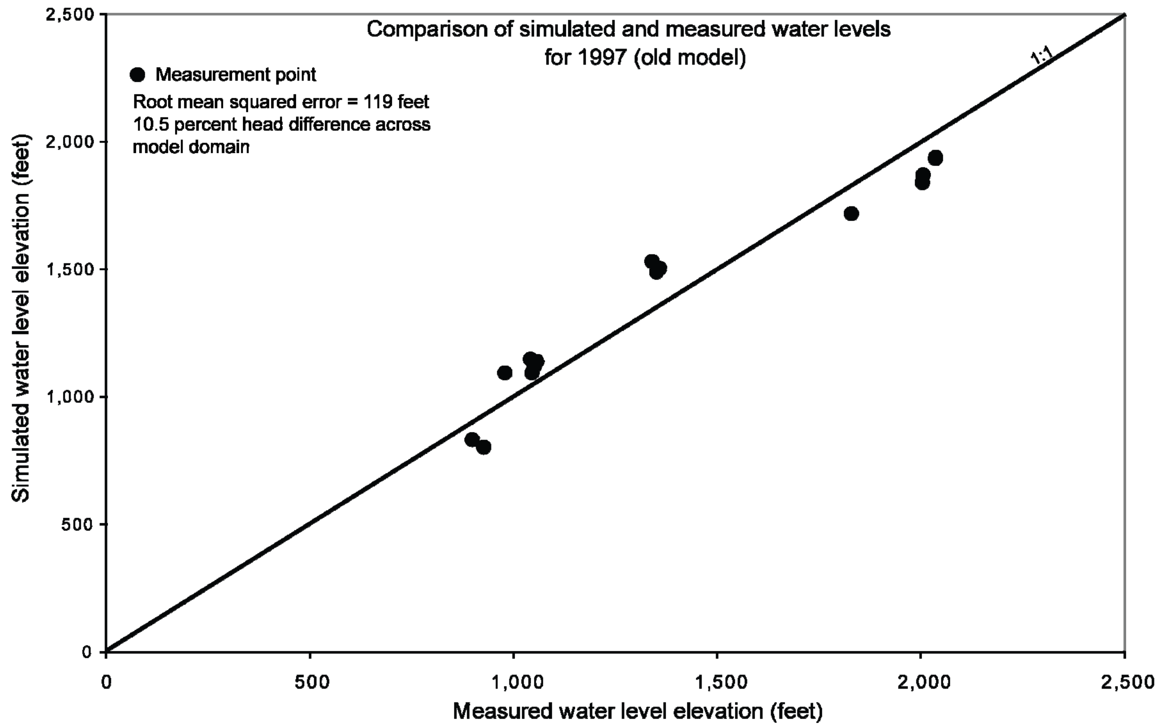


Figure 12. Cross-plot of simulated and measured water levels for 1996 for the Upper Trinity Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

(a)



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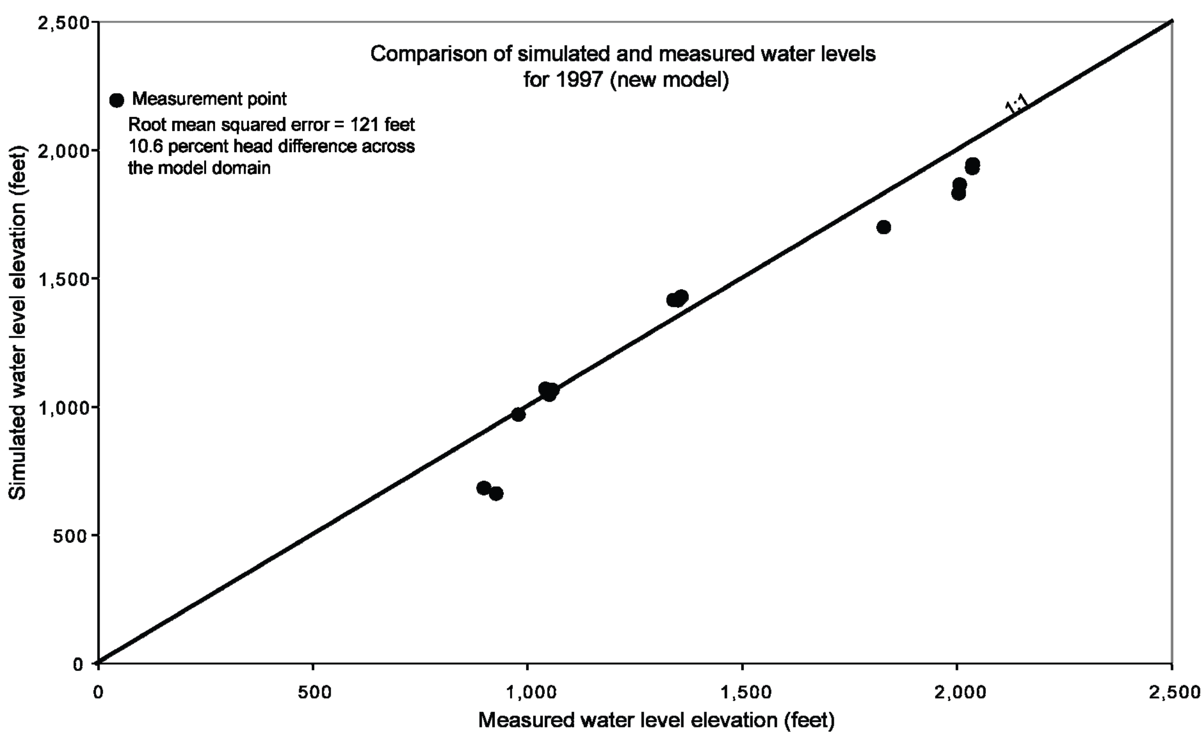
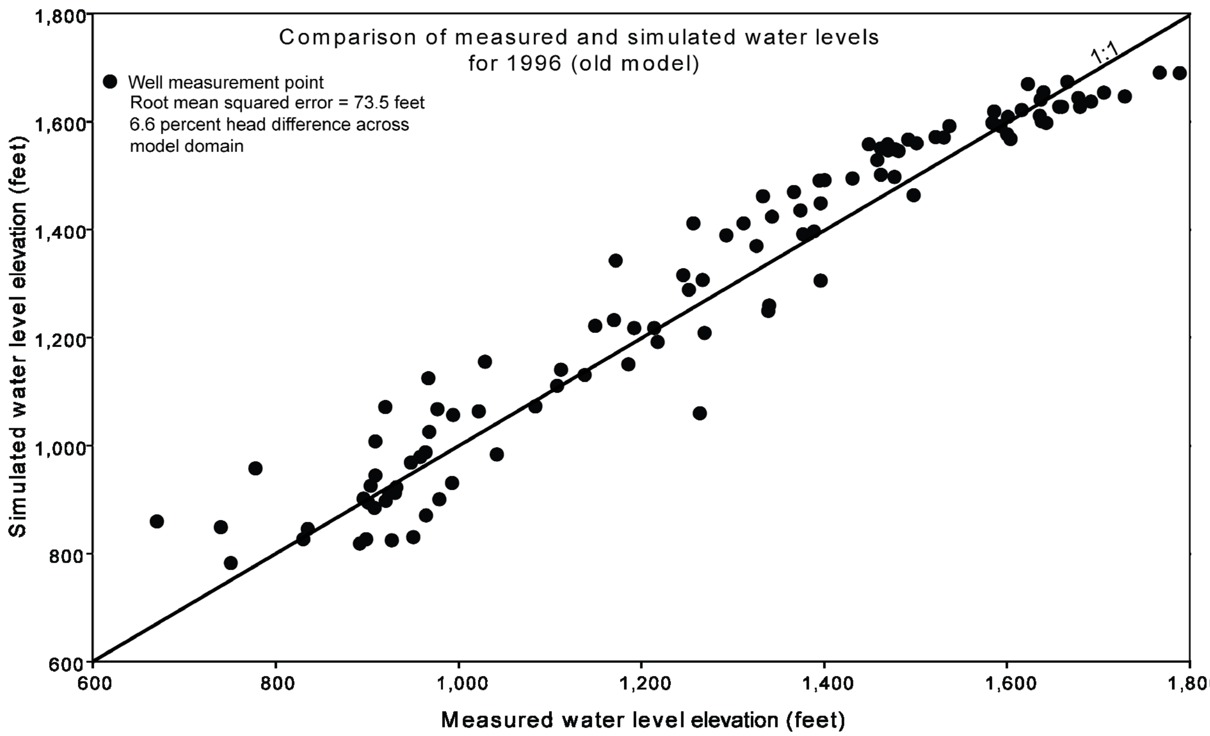


Figure 13. Cross-plot of simulated and measured water levels for 1997 for the Upper Trinity Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

(a)



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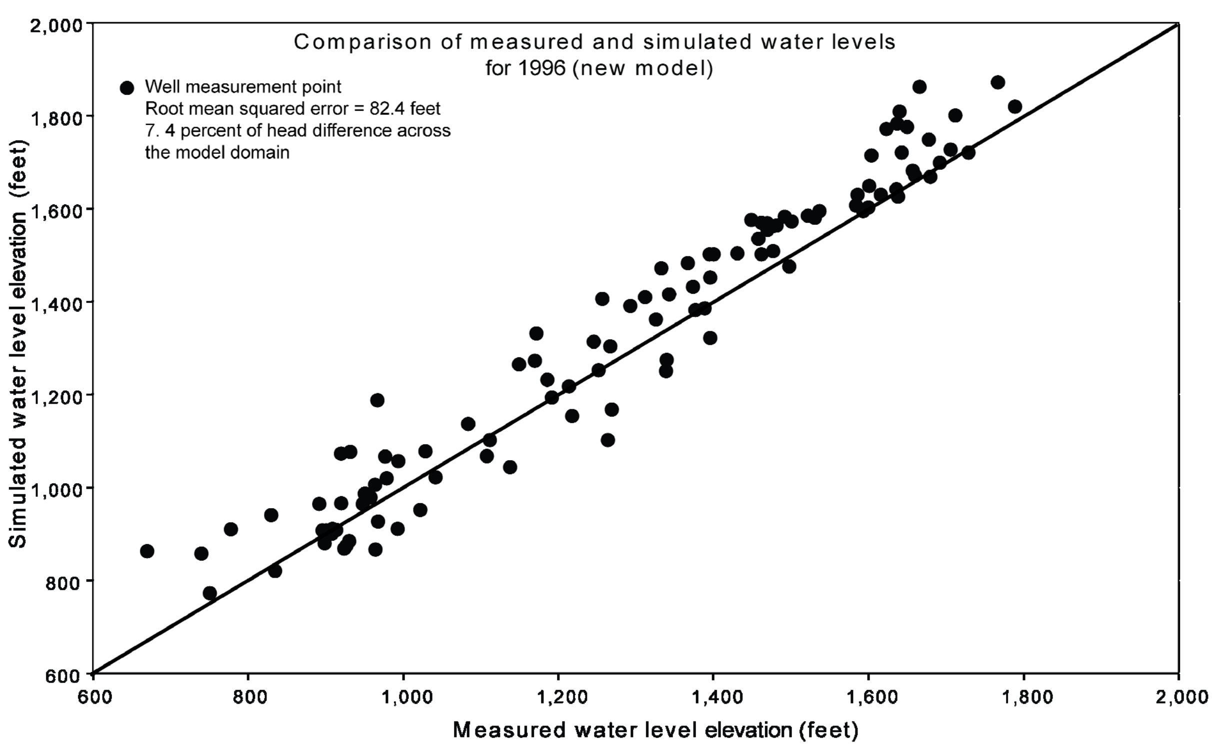
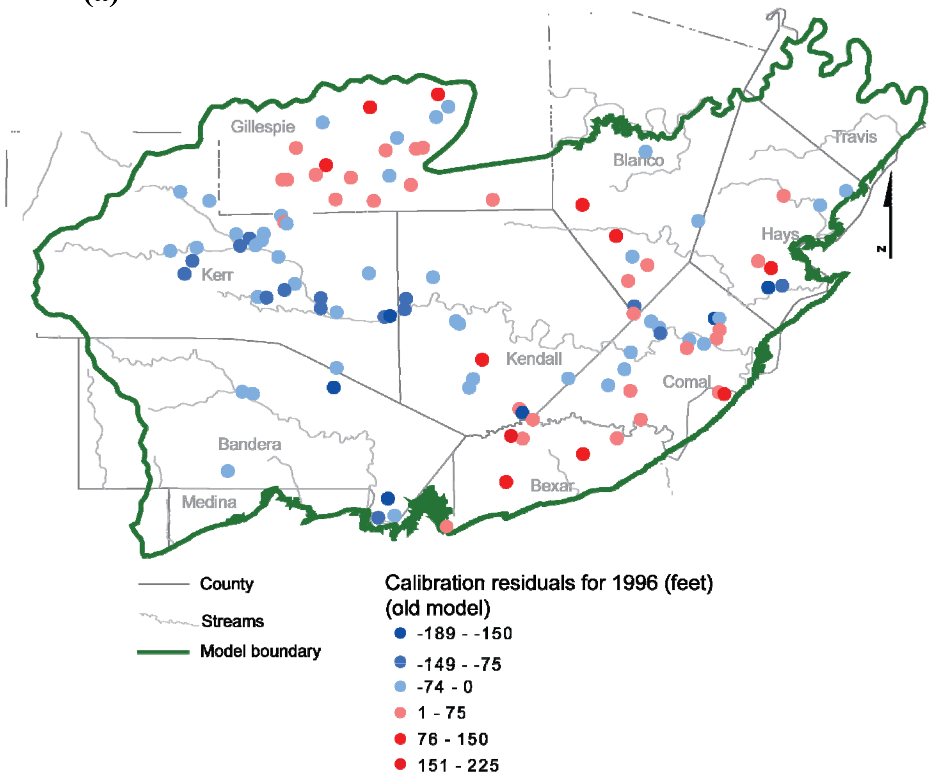


Figure 14. Cross-plot of simulated and measured water levels for 1996 for the Middle Trinity Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009) .

(a)



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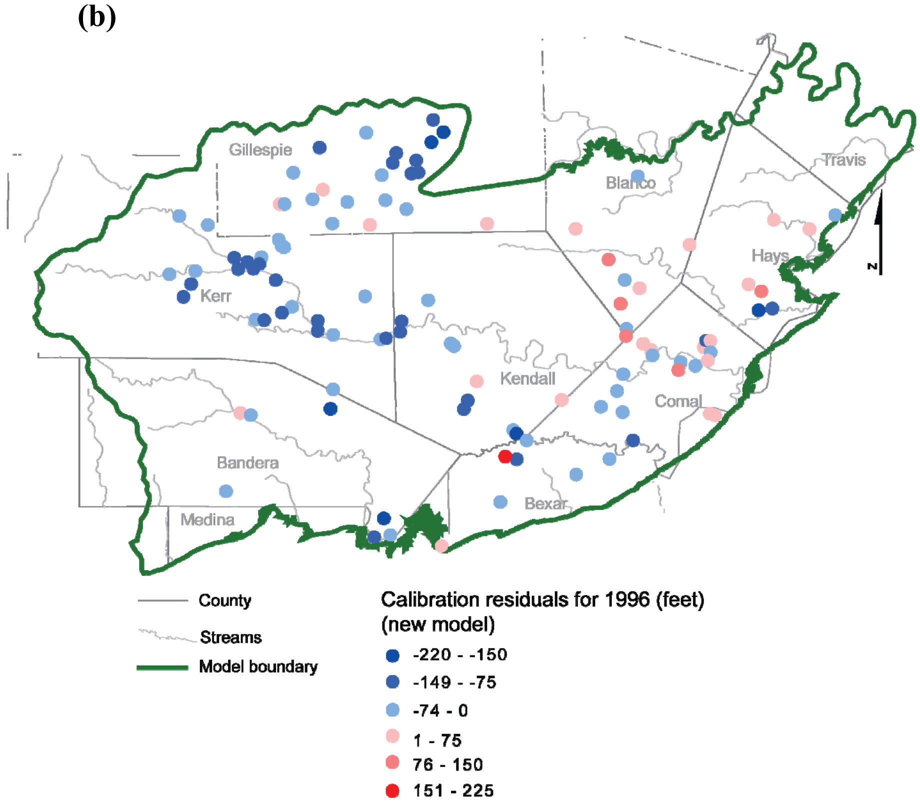
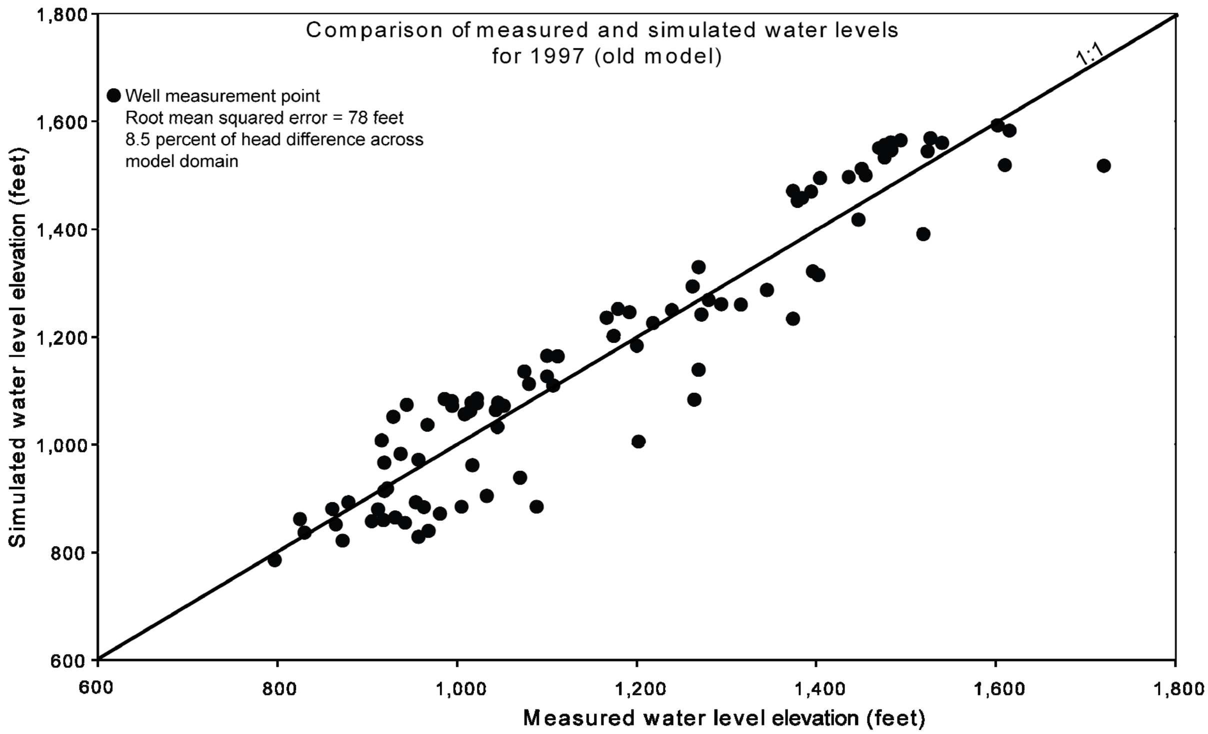


Figure 15. Map of calibration residuals (differences between measured and simulated water levels) in the Middle Trinity Aquifer for 1996 from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

(a)



(b)

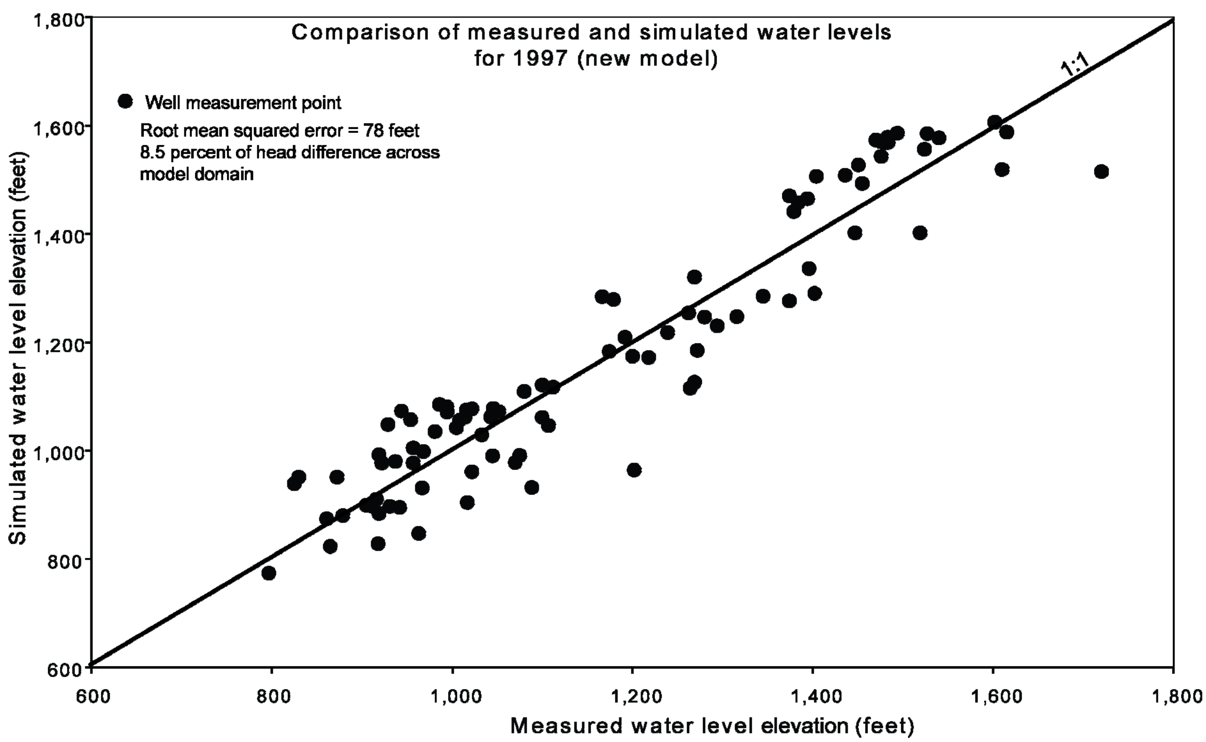
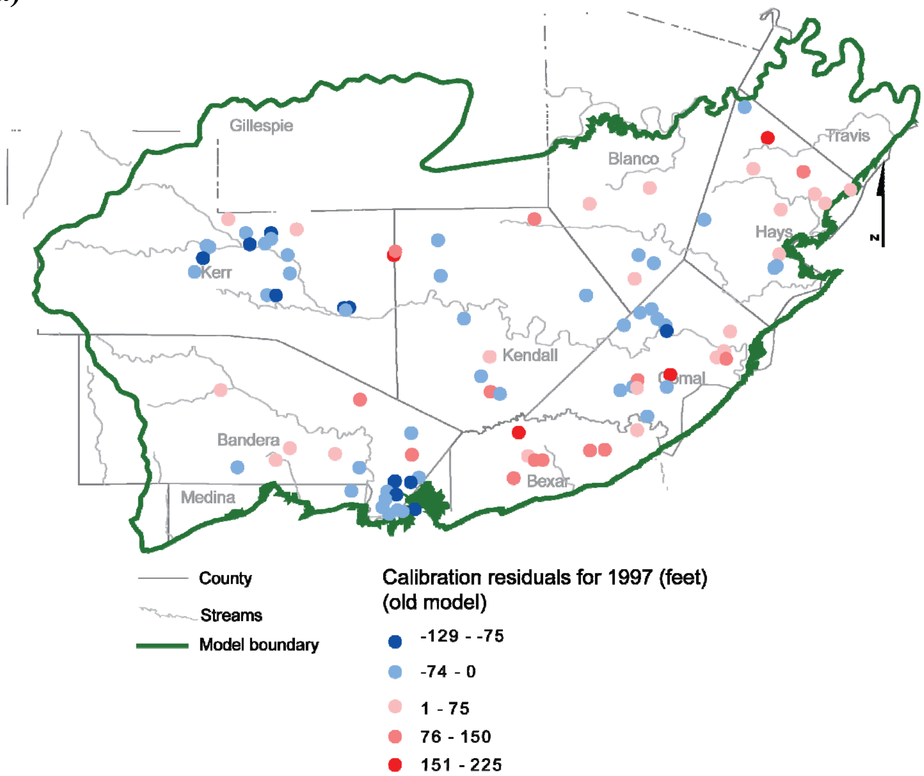


Figure 16. Cross-plot of simulated and measured water levels for 1997 for the Middle Trinity Aquifer from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

(a)



(b)

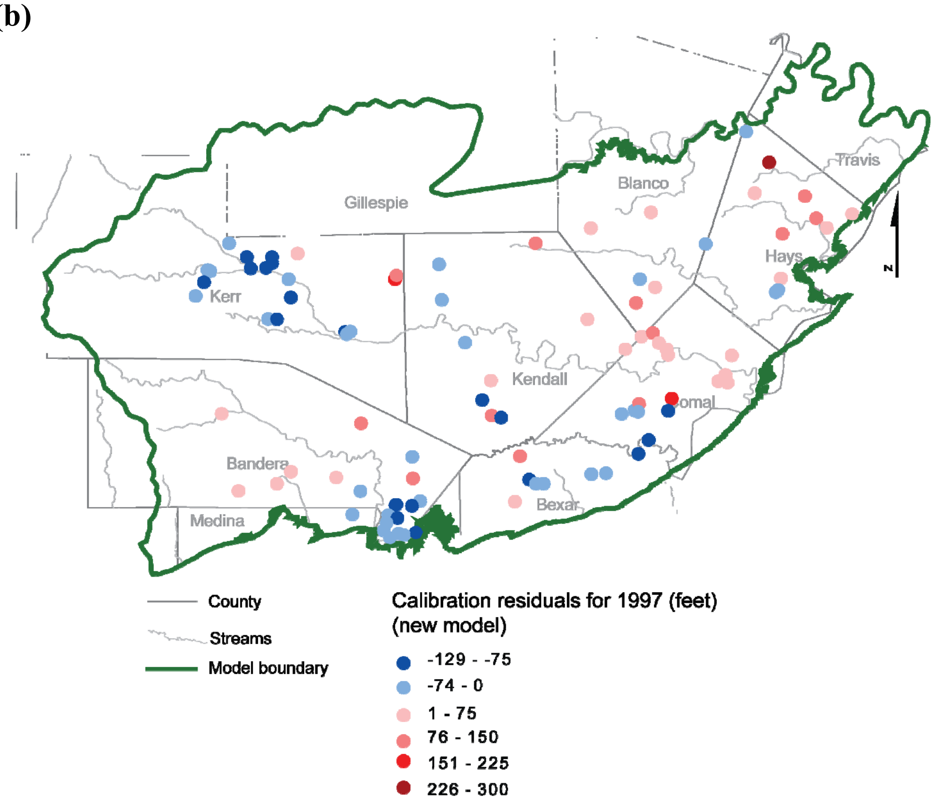


Figure 17. Map of calibration residuals (differences between measured and simulated water levels) in the Middle Trinity Aquifer for 1997 from the (a) old model (Mace and others, 2000) and (b) new model (Jones and others, 2009).

Table 2. Calibration statistics (root mean squared errors) for 1996 and 1997 for the Edwards Group, Upper Trinity, and Middle Trinity aquifers from the old and new models.

Aquifer	Root mean squared error 1996 (old model)	Root mean squared error 1996 (new model)	Root mean squared error 1997 (old model)	Root mean squared error 1997 (new model)
Edwards Group	26	21	31	25
Upper Trinity	114	85	119	121
Middle Trinity	74	82	78	78

Baseflow

Baseflow is the component of groundwater flow that naturally discharges to the rivers, springs, and lakes. Baseflow is often described as a portion of streamflow that is equal to the deep subsurface flow and delayed shallow subsurface flow. Baseflow commonly tracks along the bottom of a streamflow hydrograph. This groundwater discharge occurs when the water levels in the aquifer lie at higher elevations than a receiving water body allowing gravity drainage to occur. Given the hilly terrain of the Texas Hill Country, most of the rivers in the area are gaining and receive significant amount of baseflow from the aquifer.

We compared simulated baseflow for 1996 and 1997 from the old and the new models (Figures 18 through 24). We observed that baseflow from the old model is slightly higher than baseflow derived from the new model (Figures 18 through 24). However, a slightly higher baseflow in the old model is more attributed to the monthly stress periods used that better captures fluctuations in baseflow than the annual stress periods used in the new model that more aims at capturing average annual baseflow. The new model reasonably reproduces annual average baseflow and long-term trends in changes in baseflow over the longer historical period of calibration (1980 through 1997) for most of the studied river sections (Figures 18 through 24).

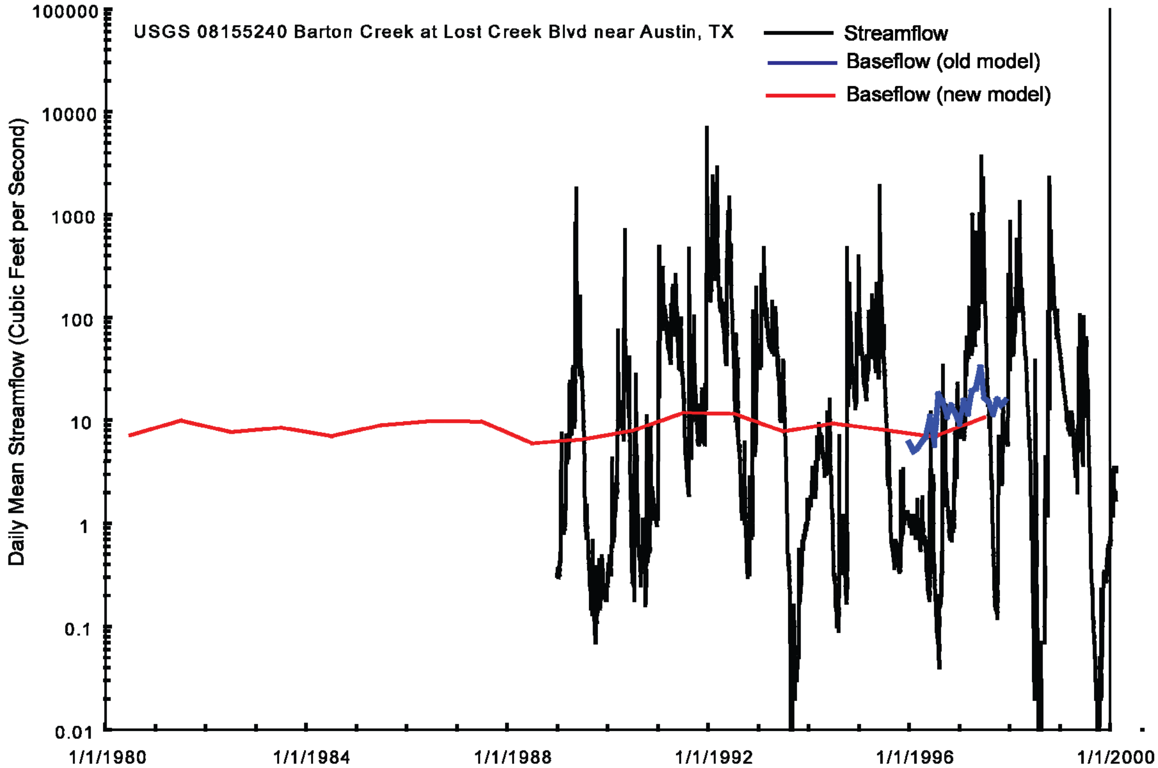


Figure 18. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Barton Creek at Lost Creek Boulevard.

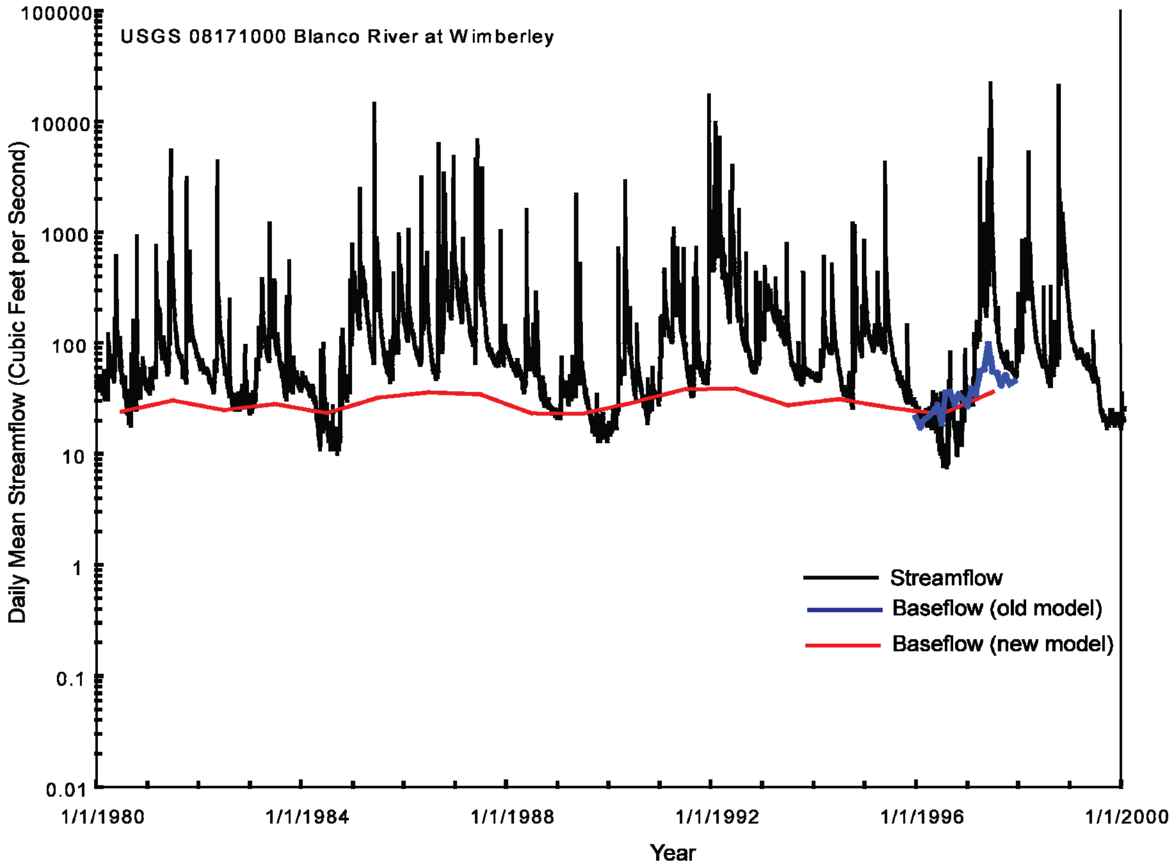


Figure 19. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Blanco River at Wimberly.

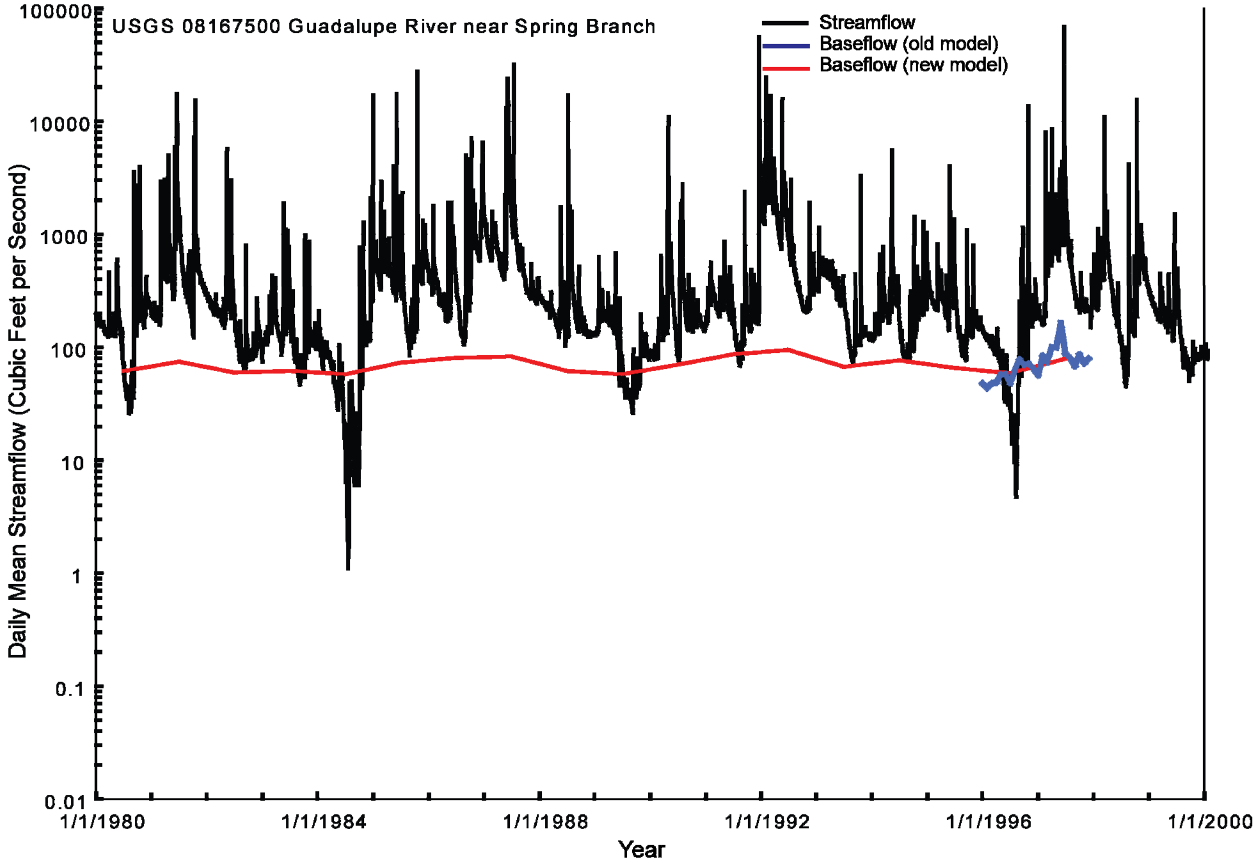


Figure 20. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Guadalupe River near Spring Branch.

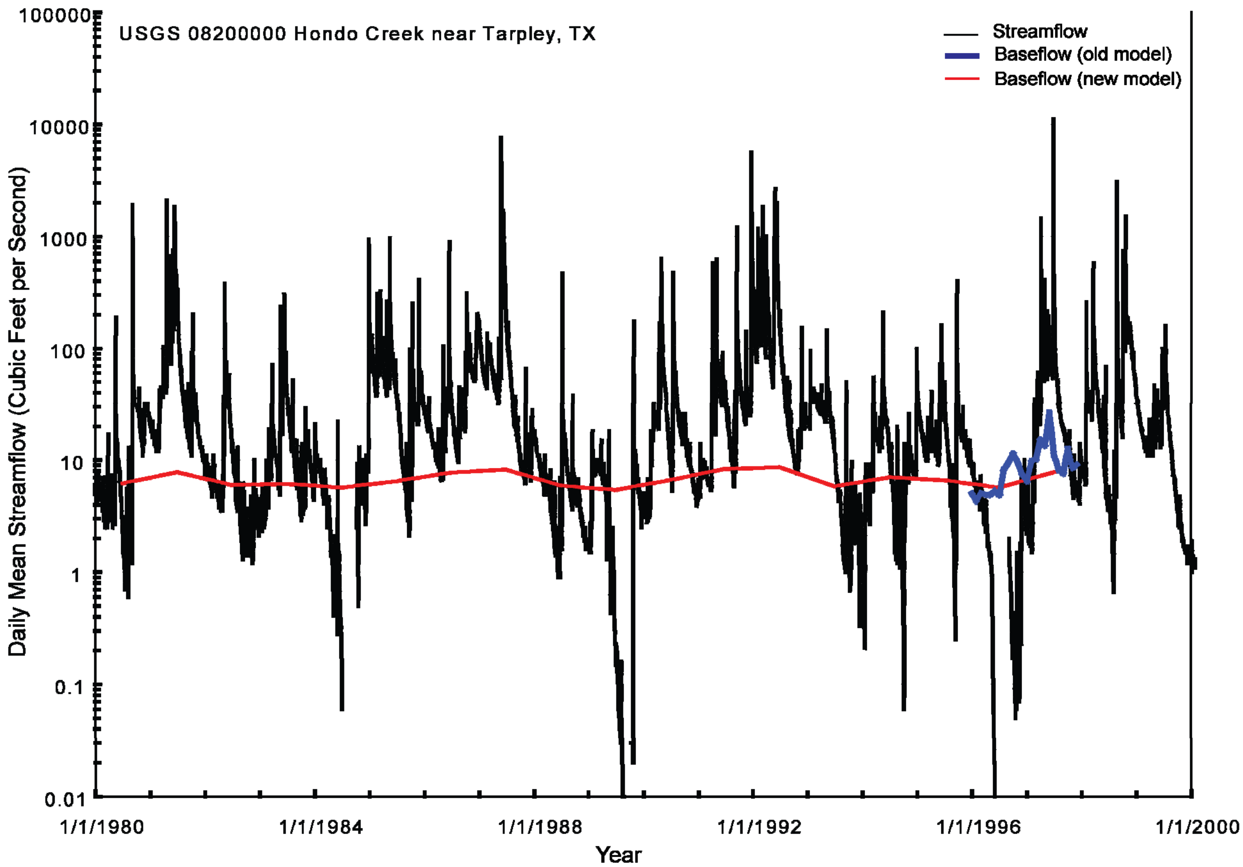


Figure 21. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Hondo Creek near Tarpley.

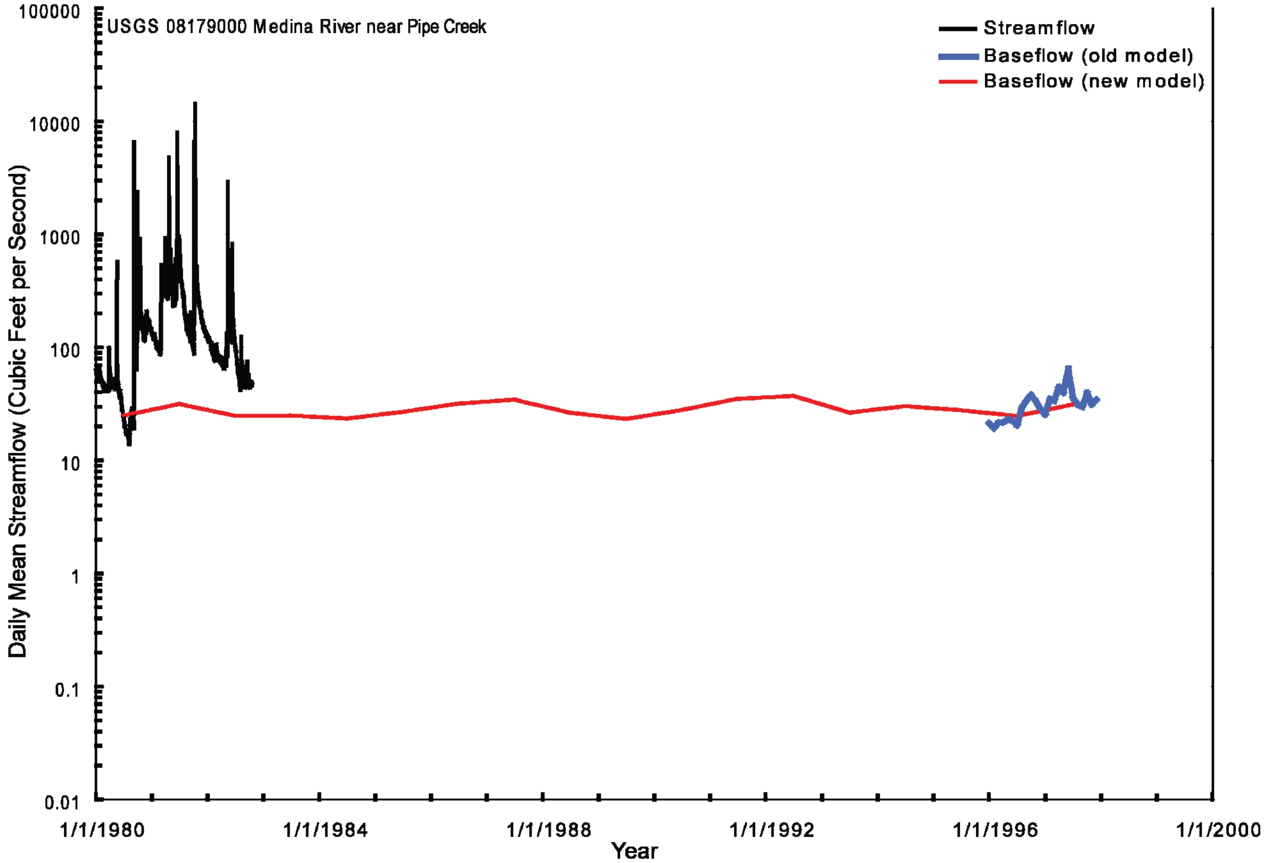


Figure 22. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Medina River near Pipe Creek.

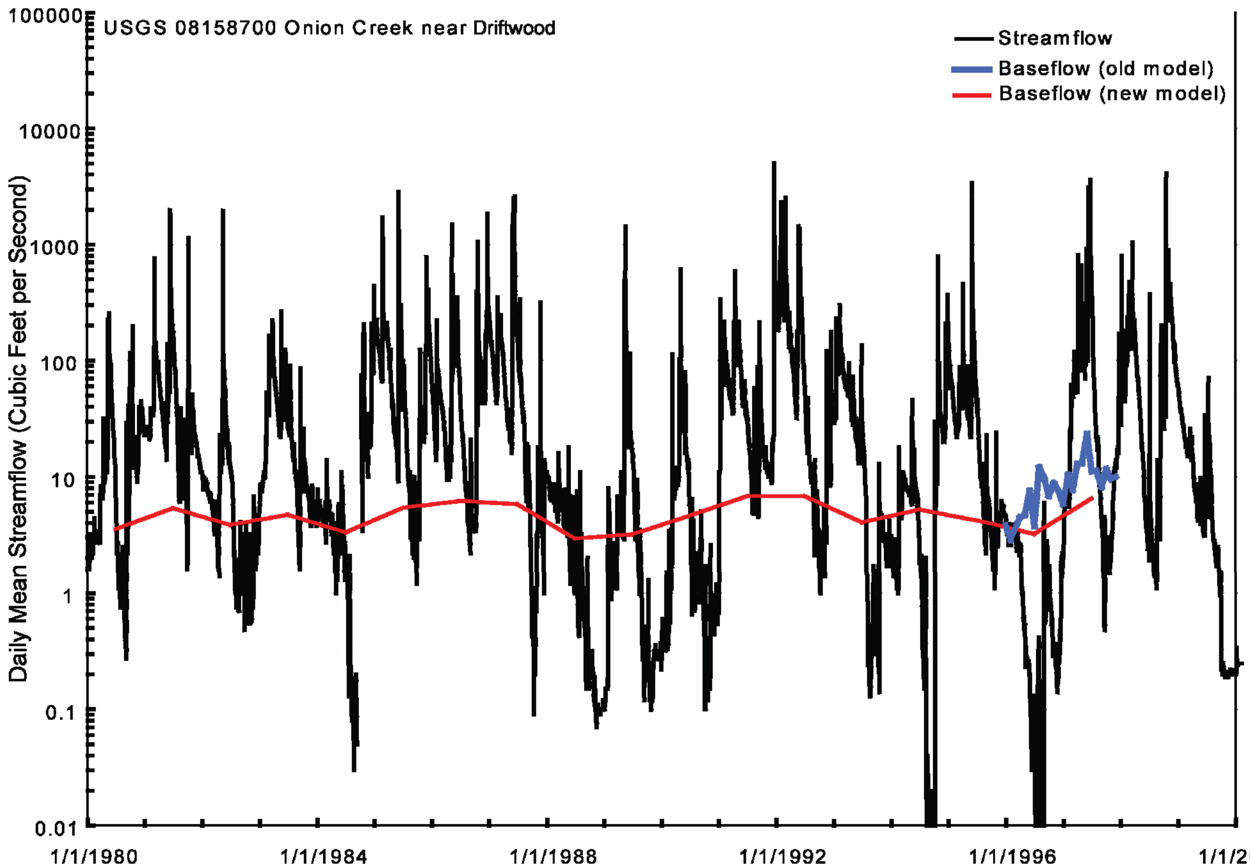


Figure 23. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Onion Creek near Driftwood.

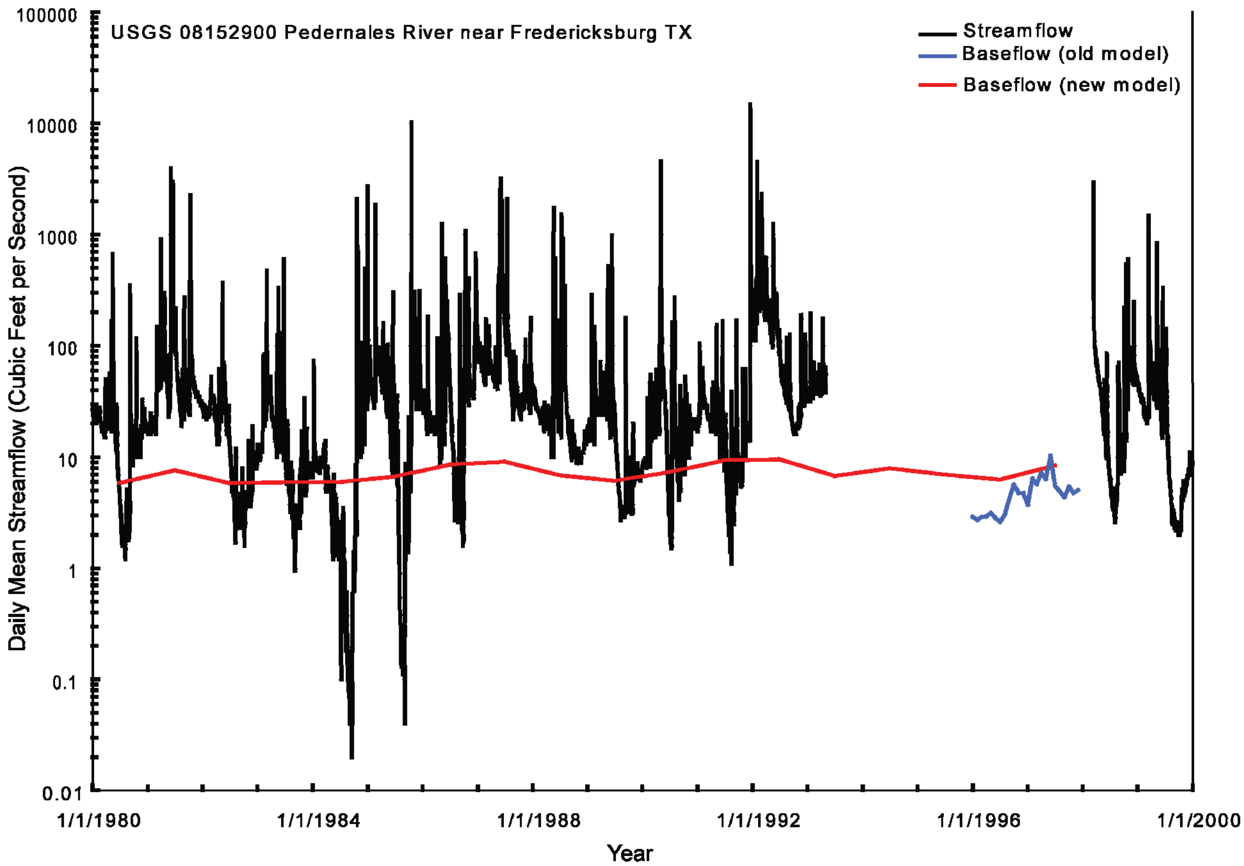


Figure 24. Comparison of estimated baseflow for 1996 and 1997 between the old and the new models for Pedernales River near Fredericksburg.

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