**GAM Predictions of the Effects of Baseline Pumping Plus
Proposed Pumping by Vista Ridge, End OP, Forestar, and LCRA**

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1.0 Introduction

This report examines the effects of pumping on groundwater and surface water in the Lost Pines Groundwater Conservation District (LPGCD), the Post Oak Savannah Groundwater Conservation District (POSGCD), and surrounding counties. The effects of pumping were estimated using the *Central Queen City and Sparta Groundwater Availability Model* (GAM).[1] The input files used to generate the results presented in this report were provided by the LPGCD[2], or are modifications of LPGCD-provided files. Figure 1 shows the geologic units represented in the GAM.

Two GAM simulations were performed. The first simulated baseline pumping alone. The second simulated baseline pumping, plus proposed or existing pumping by Vista Ridge, End Op L.P. (End Op), Forestar Real Estate Group (Forestar), and the Lower Colorado River Authority (LCRA).

2.0 Effects on Groundwater

2.1.1 Baseline Pumping

Baseline pumping is an estimate of the amount of past, present, and future pumping (not including proposed projects such as Vista Ridge, End Op, Forestar, and LCRA's current pumping). Baseline pumping data were provided by LPGCD.[3] Baseline pumping from the Simsboro Aquifer in the LPGCD and POSGCD is depicted in figure 2.

Baseline pumping will reduce hydraulic heads (i.e., water levels or hydraulic pressure) in the Hooper, Simsboro, Calvert Bluff, and Carrizo aquifers. The reductions in hydraulic head (drawdowns) are shown in figures 3 through 6.[4]

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[1] TWDB 2004; and LPGCD 2013. The GAM is based on the MODFLOW computer code developed by the U.S. Geological Survey (TWDB 2004, page 6-1).

[2] LPGCD 2013.

[3] Baseline pumping data are contained in the file Run50.wel (LPGCD 2013). Baseline pumping from the Simsboro in 2000 is approximately 11,300 acre-feet per year in the LPGCD and 12,200 acre-feet per year in the POSGCD. For 2060, baseline pumping is 40,400 acre-feet per year in the LPGCD and 48,500 acre-feet per year in the POSGCD.

[4] The GAM is the best tool available for estimating drawdowns in the LPGCD and the POSGCD. However, there is evidence that the manner in which faults are represented in the GAM causes the model to over-estimate drawdowns on the side of the fault where pumping takes place, and under-estimate drawdowns on the other side of the fault (Young, S., 2015). An updated GAM is being developed. Major purposes of the update are to improve the representation of faults, and to improve estimates of groundwater/surface water interaction (Young, S., and Harden, B., 2015). The updated GAM is scheduled to be released in December, 2017 (Young, S., and Harden, B., 2015).

2.1.2 Simsboro Aquifer DFCs

The LPGCD and the POSGCD have adopted Desired Future Conditions (DFCs) for the aquifers in their districts. The DFCs are average drawdowns that occur between the years 2000 and 2060.[5] The goal is to keep average drawdowns less than the DFC. New DFCs proposed for the Simsboro Aquifer by the LPGCD and the POSGCD are 256 feet and 318 feet, respectively.[6] Table 1 shows GAM predictions of average drawdowns from 2000 to 2060 in the LPGCD and the POSGCD.
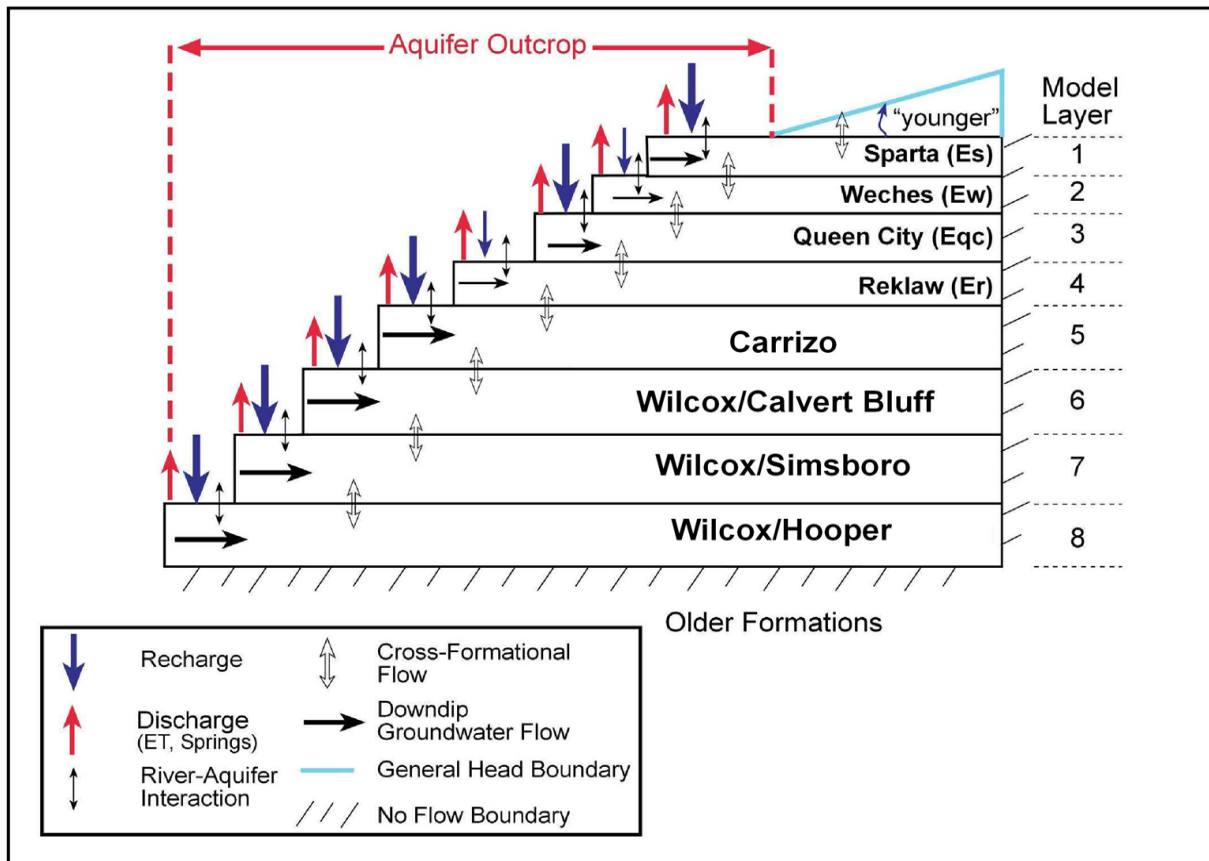

Figure 1
Geologic Units Represented in the GAM
(adapted from TWDB, 2004, figure 5.1)

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[5] GMA 12, 2010, appendix B, first page.
[6] If finally adopted, these value would replace the current DFCs of 237 feet for the LPGCD and 300 feet for the POSGCD (GMA 12, 2010, appendix B, Table B-1).

Table 1
GAM Predictions of Average Drawdowns in the
Simsboro Aquifer from 2000 to 2060 Due to Baseline Pumping

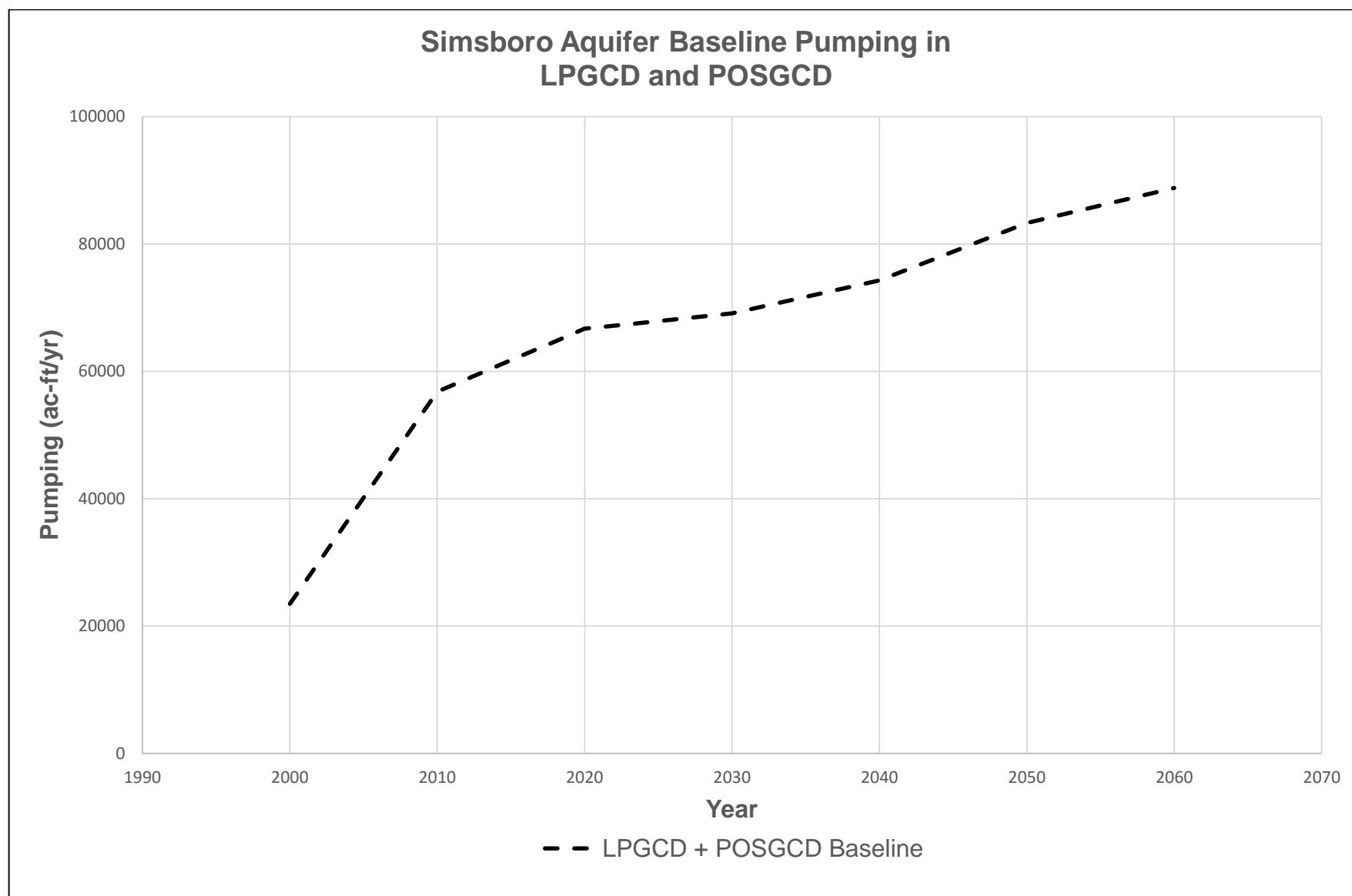| GCD	DFC (ft)	Baseline drawdown (ft)
LPGCD	256	209
POSGCD	318	279

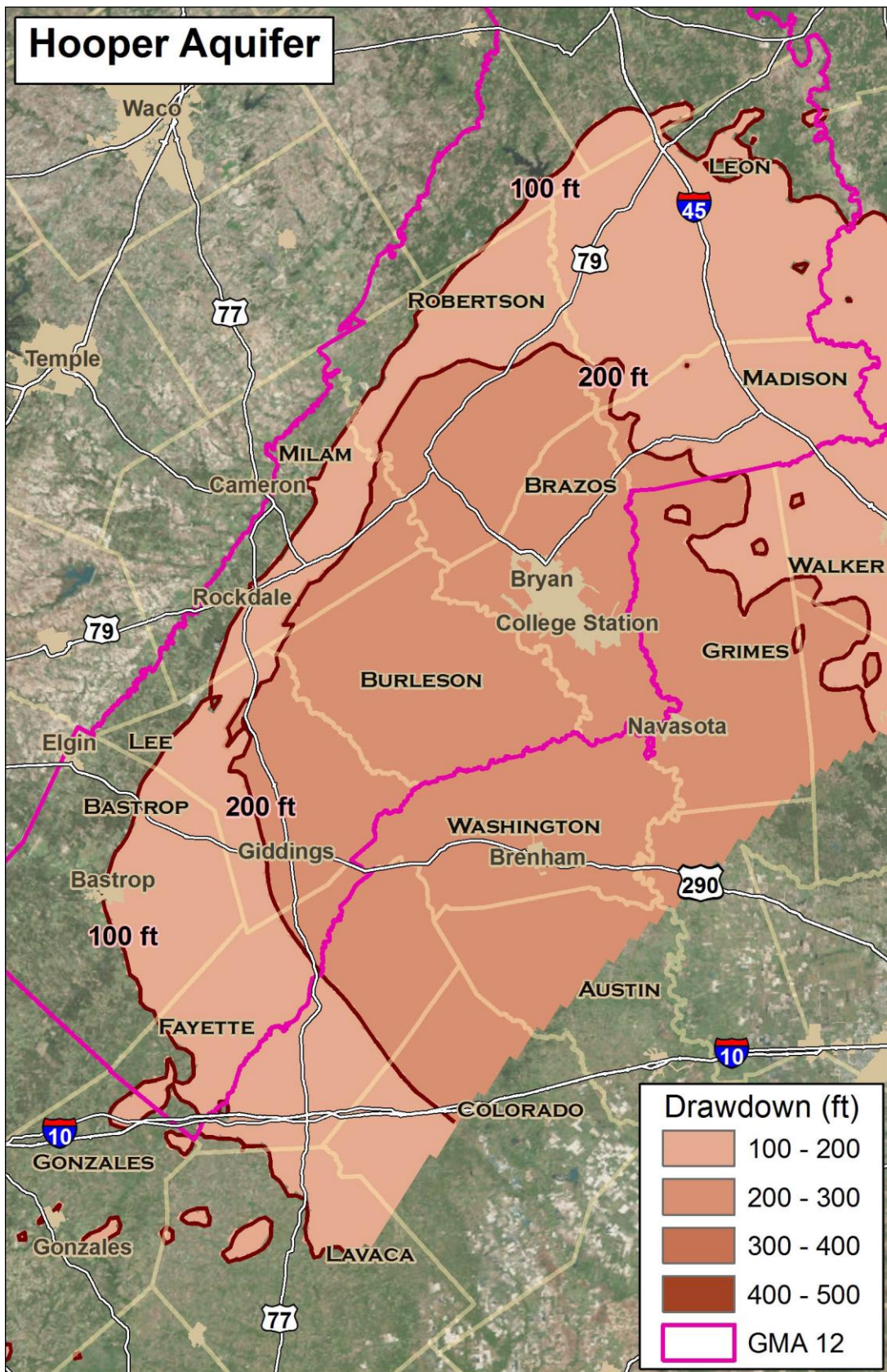**Figure 2**
Simsboro Aquifer baseline pumping

Figure 3
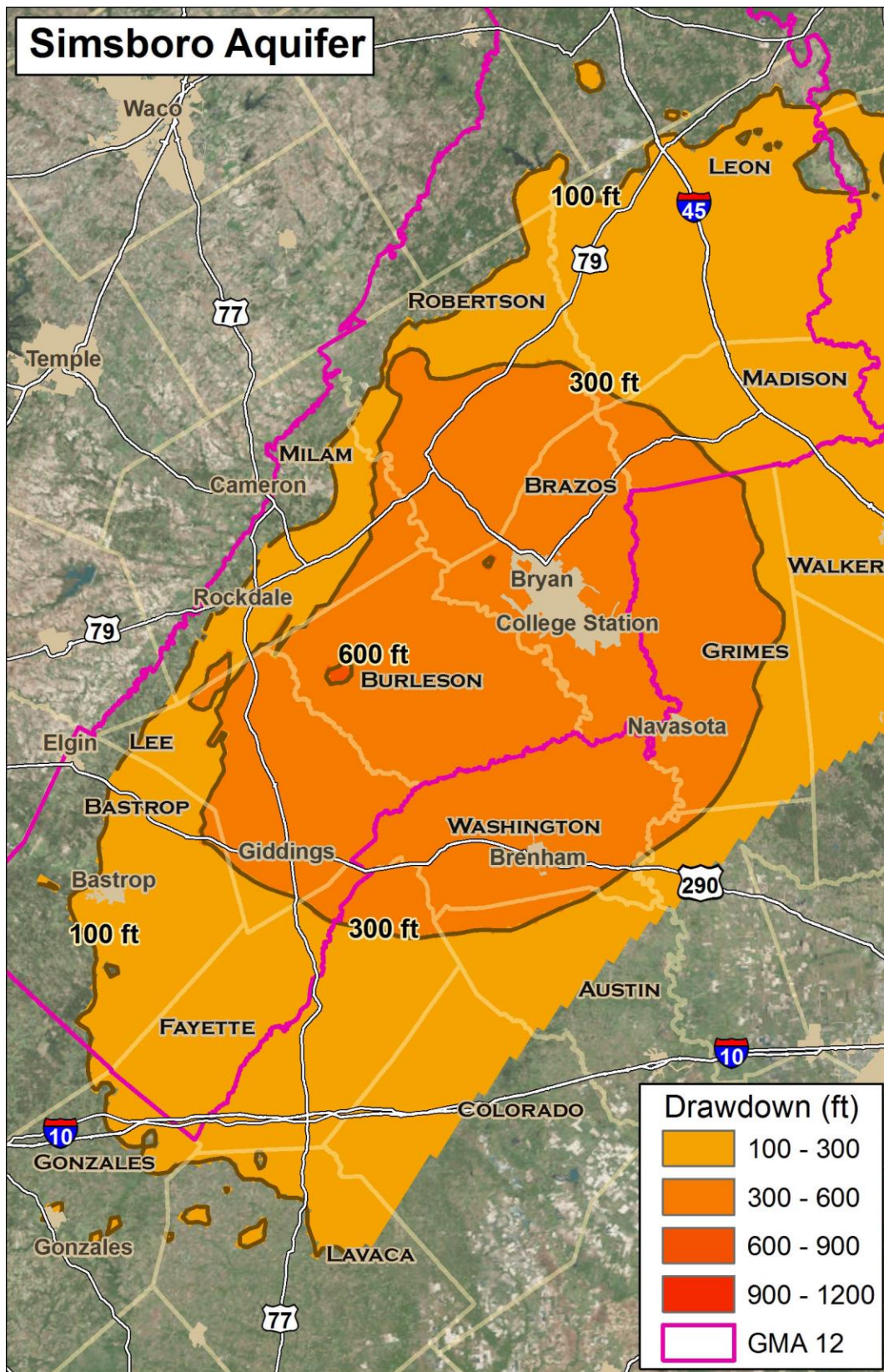**GAM predicted drawdowns in the Hooper Aquifer due to baseline pumping, 2000 - 2060**

Figure 4
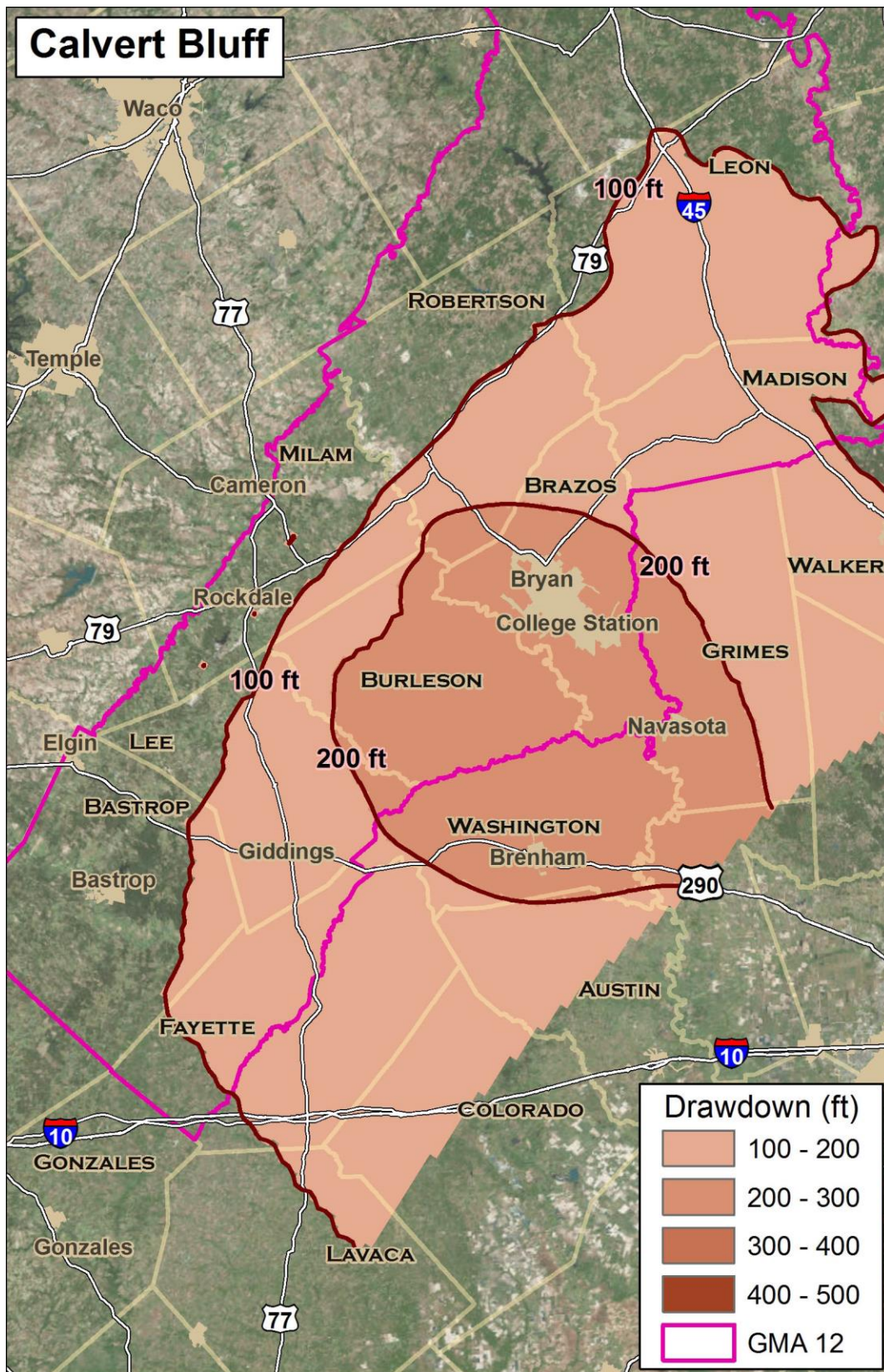**GAM predicted drawdowns in the Simsboro Aquifer due to baseline pumping**
2000 - 2060

Figure 5
GAM predicted drawdowns in the Calvert Bluff Aquifer due to baseline pumping
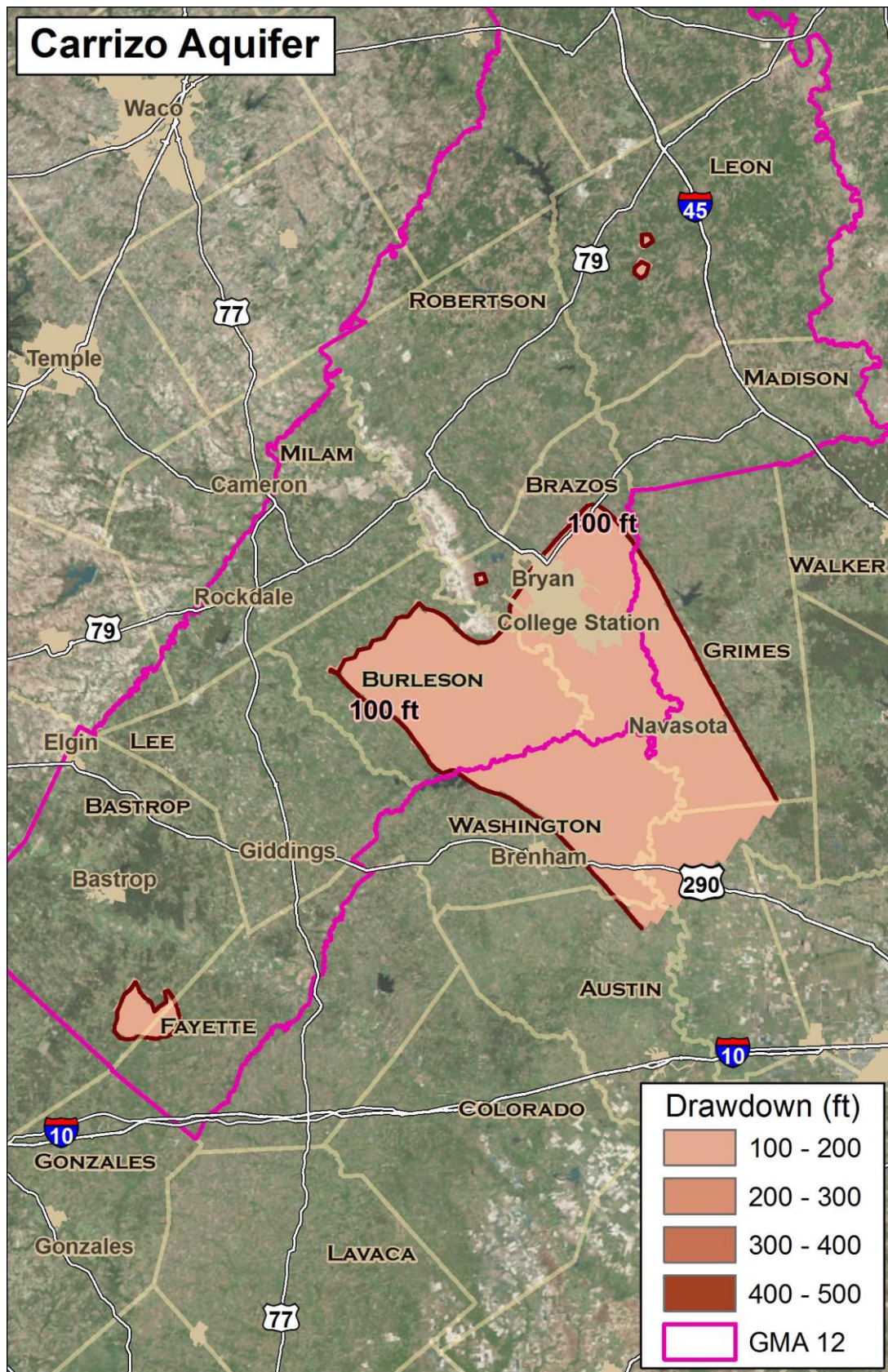**2000 - 2060**

Figure 6
GAM predicted drawdowns in the Carrizo Aquifer due to baseline pumping, 2000 - 2060

2.2.1 Baseline Plus Additional Pumping By Vista Ridge, End Op, Forestar, and LCRA

This section examines the effects of baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA.[7] Pumping rates are shown in table 2. Baseline pumping plus the additional pumping is depicted in figure 7.

Table 2
Groundwater Pumping by Vista Ridge, End Op, Forestar, and LCRA[8]

Entity	Pumping Rate (ac-ft/yr)	Pumping Period [9]	Source/Location
Vista Ridge	35,000	2020 - 2060	Simsboro, Burleson County
Vista Ridge	15,000	2020 - 2060	Carrizo, Burleson County
End Op	25,000	2018 - 2019	Simsboro, Bastrop (25%) and Lee (75%) counties
End Op	36,000	2020 - 2022	Simsboro, Bastrop (25%) and Lee (75%) counties
End Op	46,000	2023 - 2060	Simsboro, Bastrop (25%) and Lee (75%) counties
Forestar	Phase I – no withdrawals		Simsboro, Lee County
Forestar	Phase II – 12,000	2017 - 2019	Simsboro, Lee County
Forestar	Phase III – 20,000	2020 - 2022	Simsboro, Lee County
Forestar	Phase IV – 28,500	2023 - 2060	Simsboro, Lee County
LCRA	6,500	2015 – 2060	Simsboro, Bastrop County

Maps of drawdowns resulting from baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA are shown in figures 8 through 11.

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[7] End Op and the LPGCD have agreed to a settlement framework that, if finalized, would allow End Op to ramp-up pumping to 46,000 acre-feet per year (Austin American Statesman, September 10, 2015). Forestar has been given a permit that allows it to pump 12,000 acre-feet per year, and gives provisional approval to ramp-up pumping to 20,000 and 28,500 acre-feet per year, but only when certain conditions are met (LPGCD and Forestar 2015; and Austin American Statesman, December 22, 2015).

[8] This table shows the pumping rates and periods simulated with the GAM.

[9] Estimated dates for the commencement and duration of pumping are based on agreements between the GCDs and the pumpers (SAWS 2014, LPGCD and End Op 2015, and LPGCD and Forestar 2015).

2.2.2 Simsboro Aquifer DFCs

Baseline pumping plus the additional pumping would cause greater average drawdowns than baseline pumping alone. This would result in the proposed Simsboro DFCs being exceeded before 2060 (table 3).

Table 3
GAM Predictions of Average Drawdowns in the
Simsboro Aquifer from 2000 to 2060 Due to Baseline Pumping and
Pumping by Vista Ridge, End Op, Forestar, and LCRA

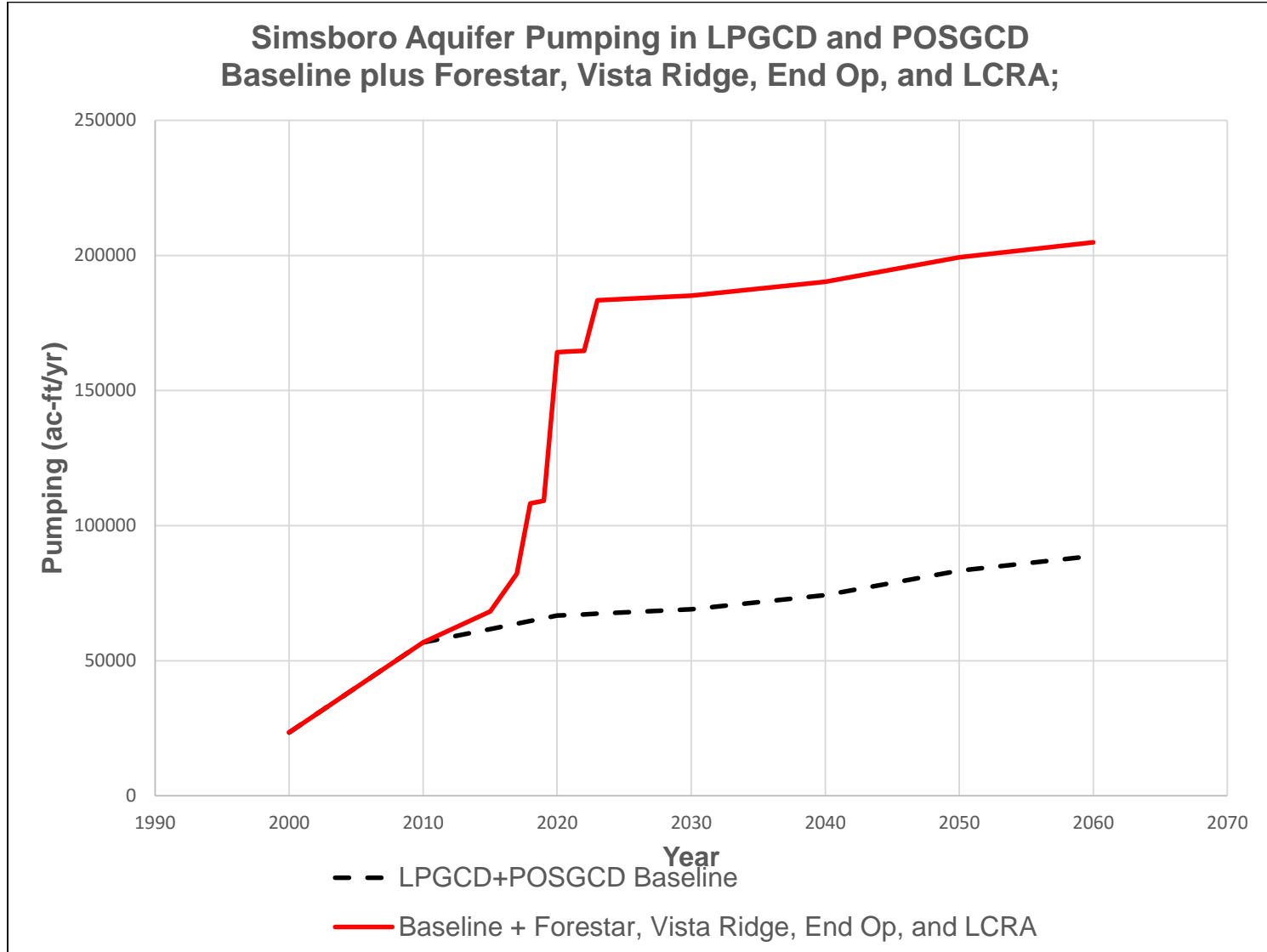| GCD	DFC (ft)	Baseline drawdown (ft)	Drawdown due to additional pumping (ft)	Baseline plus additional drawdown (ft)
LPGCD	256	209	296	505
POSGCD	318	279	238	517

Figure 7
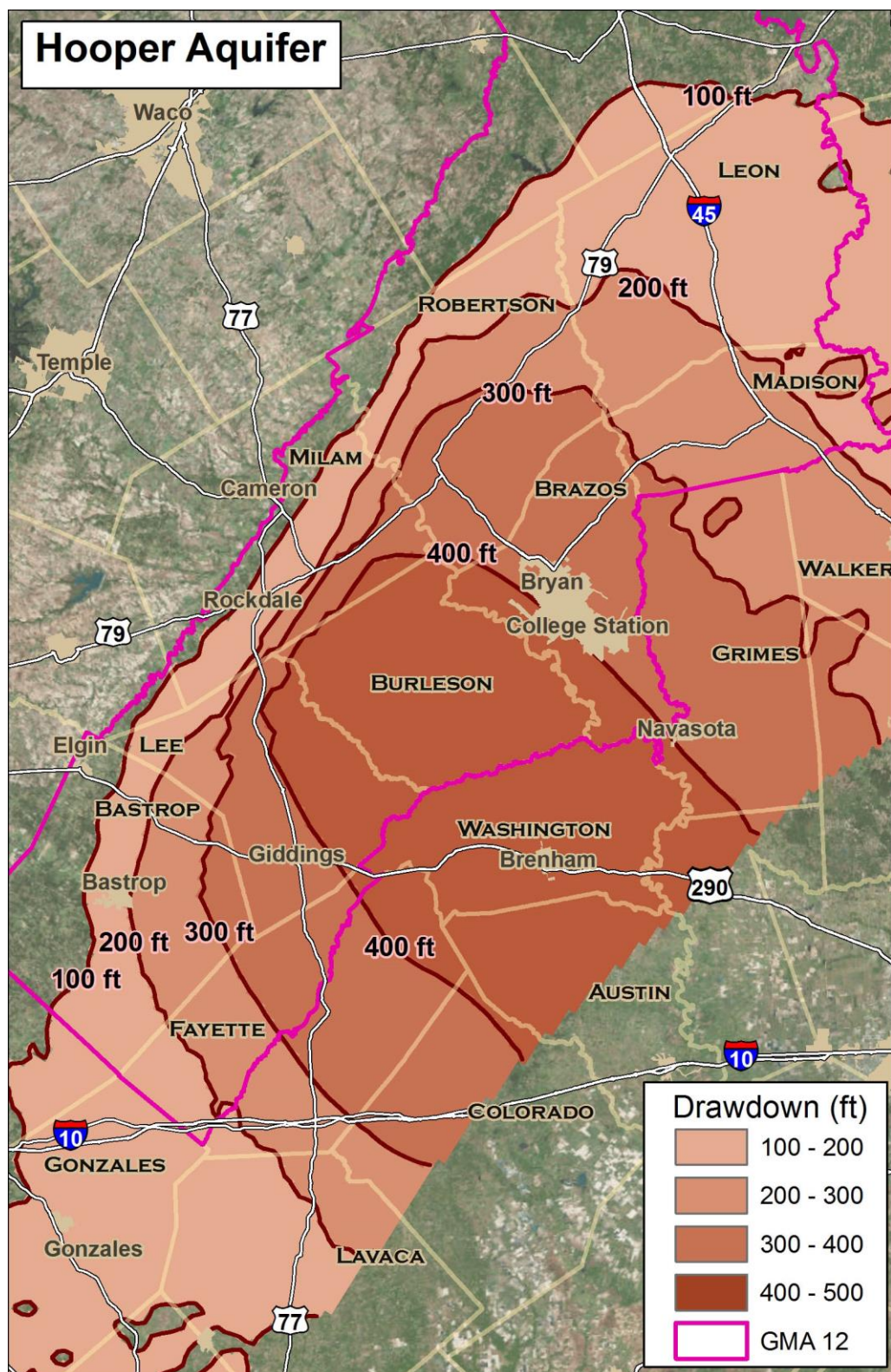Simsboro Aquifer pumping; baseline plus additional by Vista Ridge, End Op, Forestar, and LCRA

Figure 8
GAM predicted drawdowns in the Hooper Aquifer due to baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA, 2000 - 2060
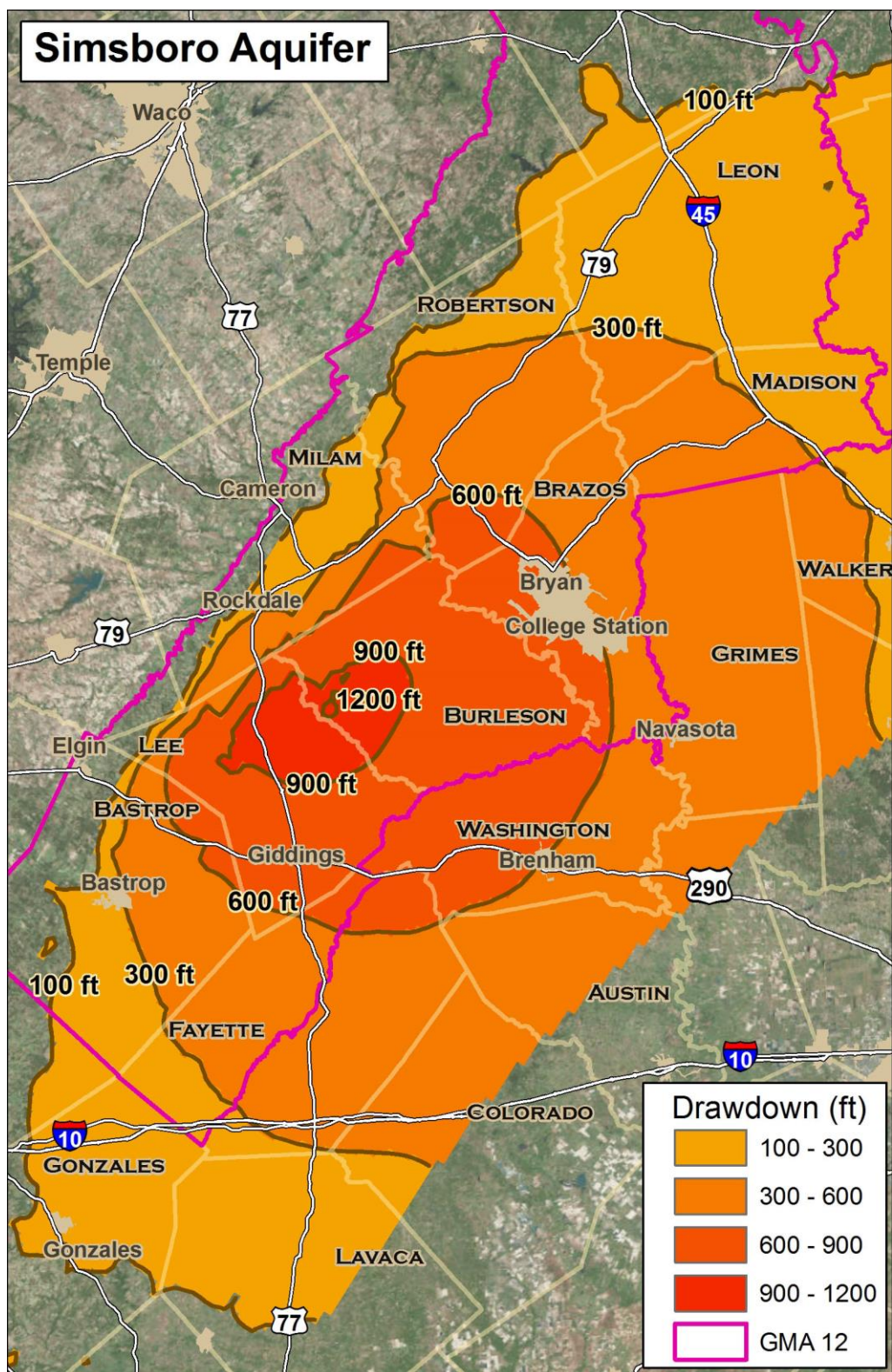
Figure 9
GAM predicted drawdowns in the Simsboro Aquifer due to baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA, 2000 - 2060
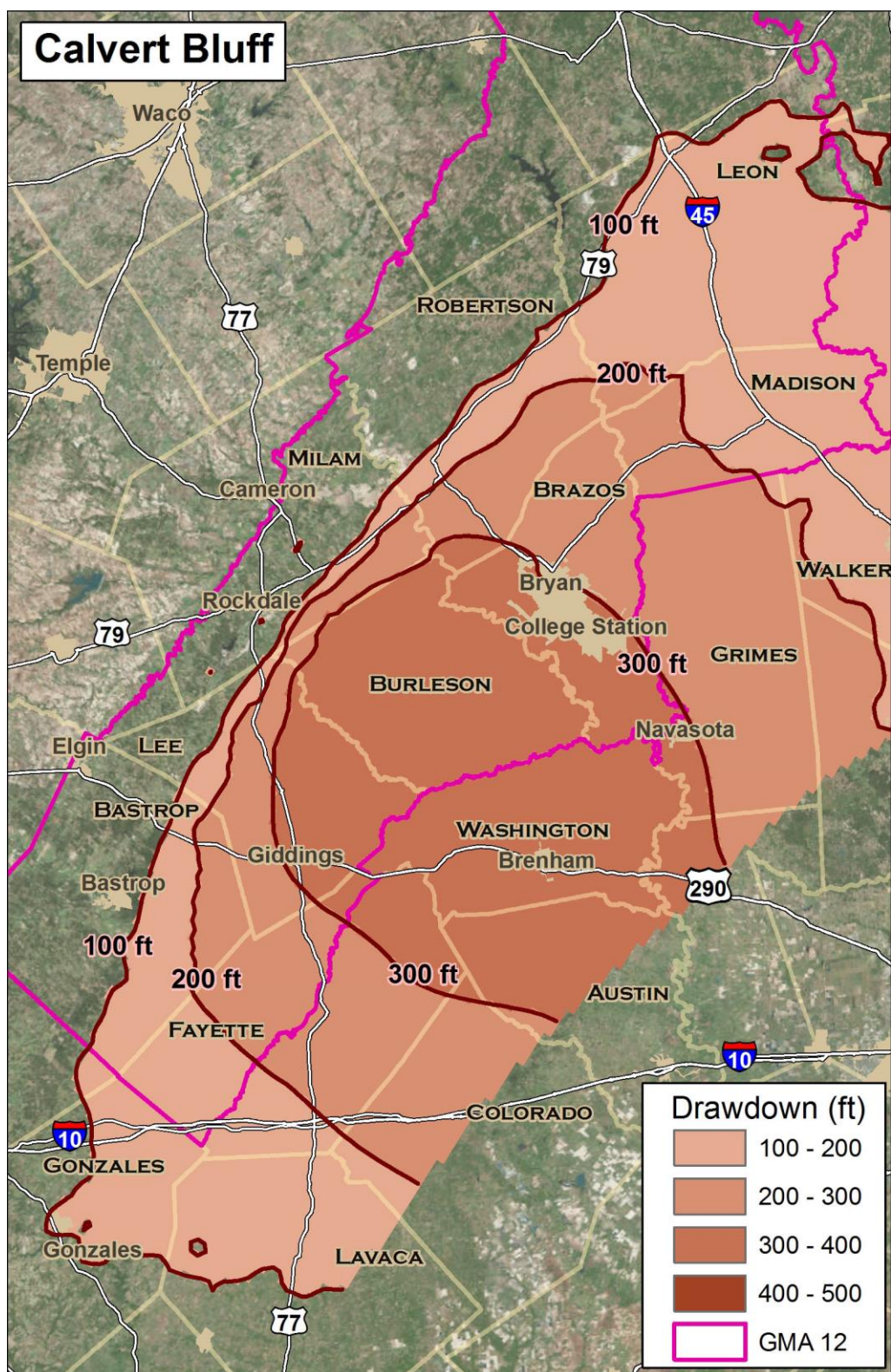
Figure 10
GAM predicted drawdowns in the Calvert Bluff Aquifer due to baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA, 2000 - 2060
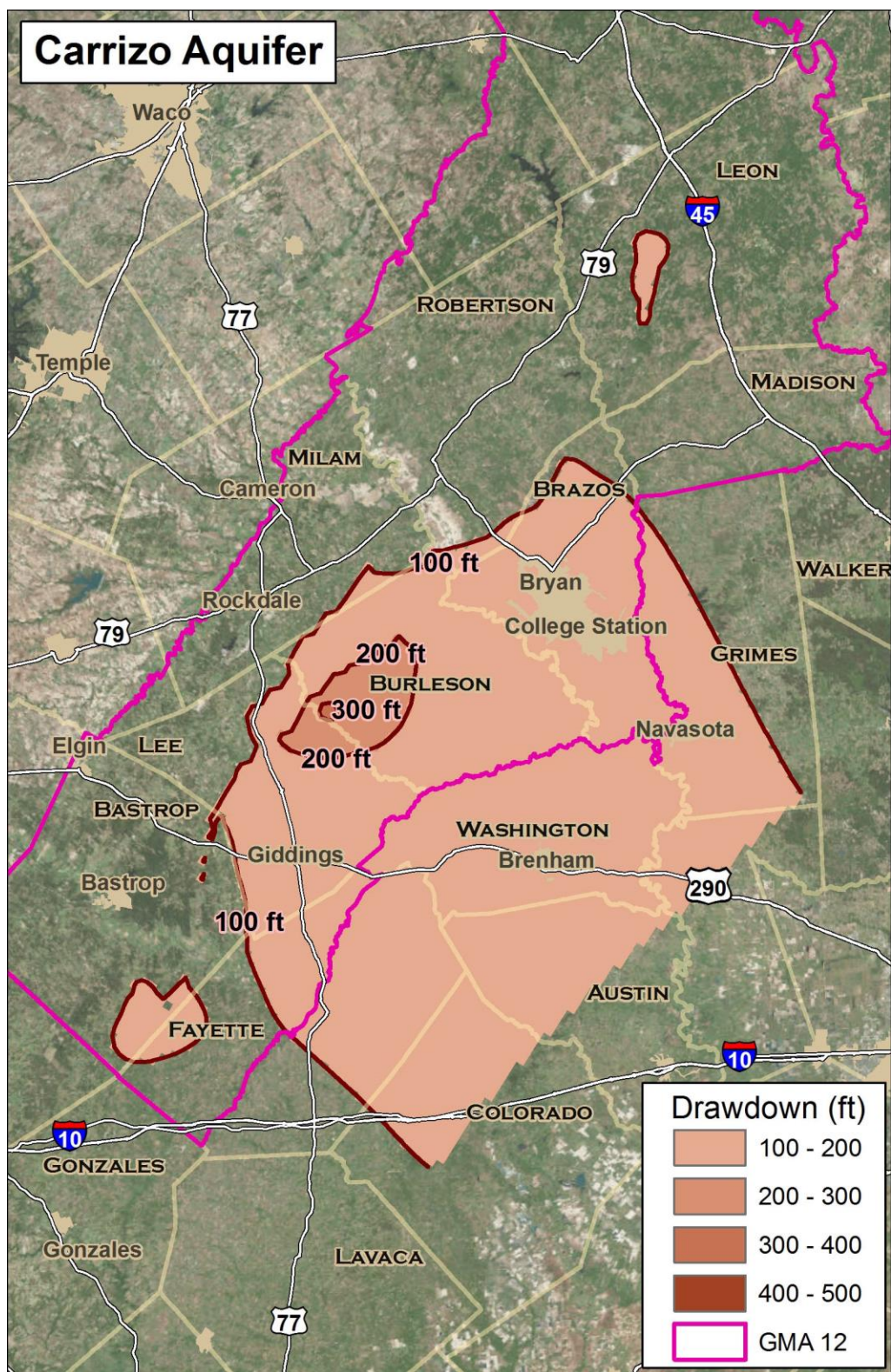
Figure 11
GAM predicted drawdowns in the Carrizo Aquifer due to baseline pumping plus additional pumping by Vista Ridge, End Op, Forestar, and LCRA, 2000 - 2060

3.0 Effects of pumping on groundwater discharge to the Colorado River

Groundwater discharge contributes to the flow of the Colorado River. In Bastrop County, measured groundwater discharge to the Colorado ranges from 22,000 to 43,000 acre-feet per year.[10] During normal times this represents about 2% of flow. However, during times of drought more than half the flow of the Colorado may be due to groundwater discharge.[11] Most of the discharge to the Colorado River appears to come from the Simsboro Aquifer.[12]

The GAM predicts that groundwater discharges to the Colorado River will decrease as a result of groundwater pumping. The decrease for baseline pumping, and for baseline plus Vista Ridge, End Op, Forestar, and LCRA pumping is shown in figure 5.

Although the GAM predicts the amount of groundwater discharge to the river over time, as well as trends in groundwater discharge, there is reason to believe that 1) the amount of discharge predicted by the GAM is not reliable, and 2) the trend predicted by the GAM is reliable[13]. The basis for these claims is presented in appendix 1.

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[10] 30 to 59 ft^3/s (Saunders, 2009, pages 1 – 3).
[11] Minimum flow measured at Bastrop = 75 ft^3/s = 54,000 acre-feet per year (USGS, 2002, page 261).
[12] Saunders, 2009, page 3.
[13] According to simulations by Huang et al., groundwater pumping in the region represented by the GAM will continue to reduce the discharge of groundwater to streams. Over a 50 year period, the percentage of pumped groundwater derived from streams will increase from about 18% to 24% (Huang et al., 2012, page 10 and figure 8).
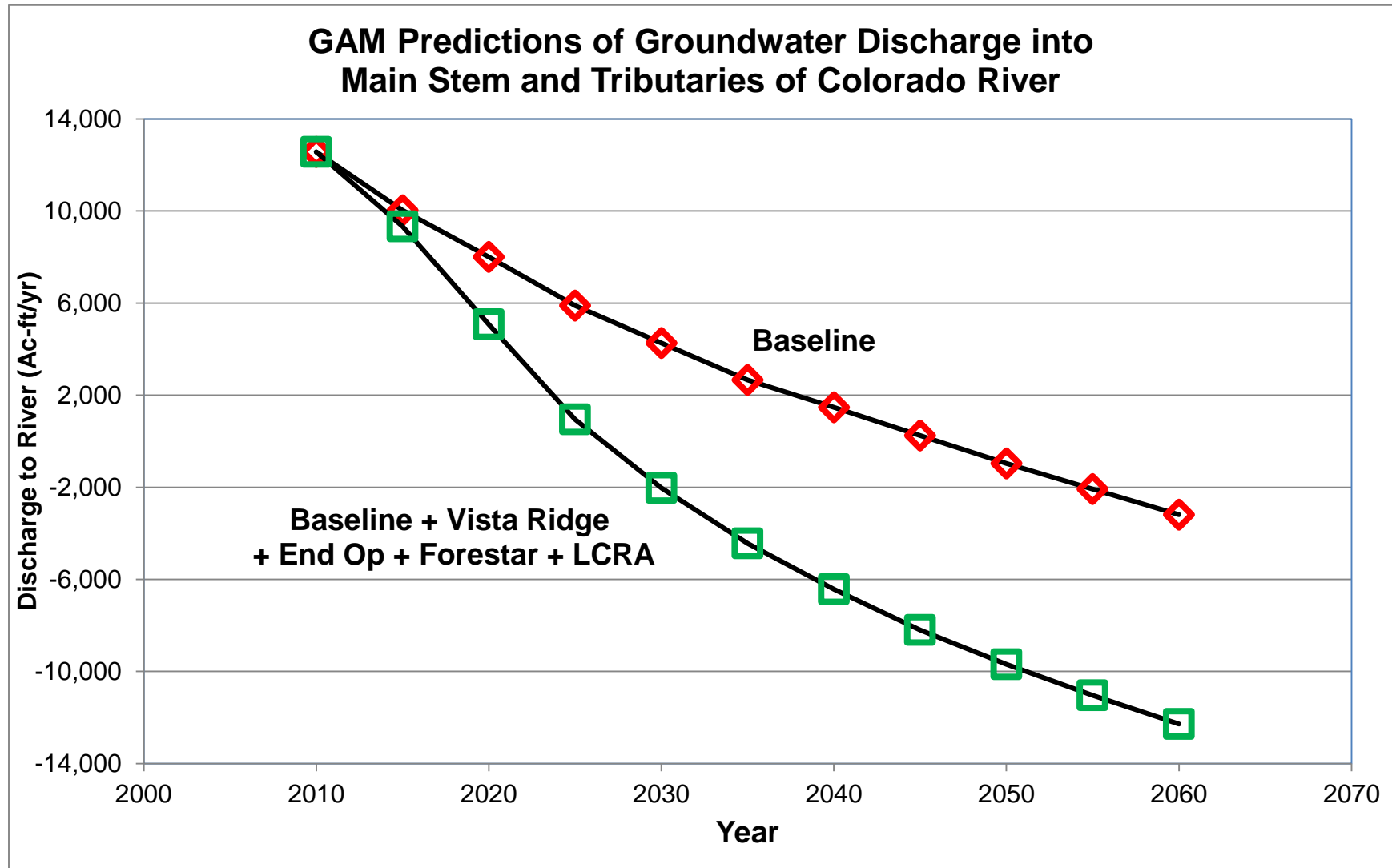
Figure 5
GAM Prediction of Groundwater Discharge to Colorado River

4.0 Conclusions

Baseline pumping will:

- Reduce hydraulic heads in the Hooper, Simsboro, Calvert Bluff, and Carrizo, aquifers.

- Where these aquifers are confined, the reduced heads would cause water levels in wells to decline.

- Where these aquifers are unconfined (recharge areas), the reduced heads would cause dewatering of portions of the aquifers.

- Reduce groundwater discharge to the Colorado River, thereby reducing its flow.

- Additional pumping by Vista Ridge, End Op, Forestar, and LCRA would result in greater head reductions than would baseline pumping alone, and a greater decrease in groundwater discharge to the Colorado River.

References

Deeds et al., 2006, (Neil Deeds, Van Kelley, P.G., Steven C. Young, and Geoffrey P. Saunders, P.G., C.G.W.P.), *Assessment of Shallow Recharge and Groundwater-Surface Water Interactions for the LSWP Study Region, Central Texas Coast*, in: Texas Water Development Board Report 365. *Aquifers of the Gulf Coast of Texas*, February 2006.

GMA 12, 2010, (Groundwater Management Area 12), *Resolution to Adopt Desired Future Conditions for Aquifer(s) in Groundwater Management 12*, August 11, 2010.

Huang et al., 2012, Yun Huang, Bridget R. Scanlon, Jean-Philippe Nicot, Robert C. Reedy, Alan R. Dutton, Van A. Kelley, Neil E. Deeds, *Sources of groundwater pumpage in a layered aquifer system in the Upper Gulf Coastal Plain, USA,* in Hydrogeology Journal, v. 20, pages 783–796, 13 April, 2012.

LPGCD, 2013, (Lost Pines Groundwater Conservation District), input, output, and summary files related to LPGCD's GAM runs.

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LPGCD and Forestar, 2015, Draft *Lost Pines Groundwater Conservation District Operation Permit, District Well Number: 5933122*, December, 2015.

Saunders, G.P., 2009, *Low-Flow Gain-Loss Study of the Colorado River in Bastrop County, Texas.*

SAWS, 2014, (San Antonio Water System), *Draft Vista Ridge Regional Supply Project Water Transmission and Purchase Agreement*, September 21, 2014.

TWDB, 2004, (Texas Water Development Board), *Groundwater Availability Models for the Queen City and Sparta Aquifers*, October, 2004.

USGS, 2002, (United States Geological Survey), Water Resources Data, Texas, Water Year 2001, Volume 4. *Colorado River Basin, Lavaca River Basin, and Intervening Coastal Basins,* Water-Data Report TX-01-4.

Young, Steven, 2015, *Comments Regarding Predictive Simulations 1 through 4 and Preliminary Evaluation of Potential DFCs for the Simsboro Aquifer*, presentation given at Milano Civic Center, Milam, TX, March 27, 2015.

Young, S., and Harden, B, 2015*, Effect of Faults on Groundwater Flow in the Carrizo-Wilcox Aquifer in Central Texas: Update the Central GAM for Sparta, Queen City, Carrizo-Wilcox Aquifers*, Stakeholder Meeting #1, November 20, 2015, Milano Civic Center.

Appendix 1

**Reliability of GAM Groundwater Discharge Predictions
Amount and Trend of Discharge to Streams**

<u>Note</u>: the GAM runs discussed in this appendix are for purposes of illustration. These runs did not simulate pumping by Vista Ridge, End Op, Forestar, or LCRA.

The GAM simulates the effects of groundwater pumping on groundwater discharges to streams. There are two questions regarding the simulations. First, can the GAM reliably predict the amount of discharge that will occur? Second, can the GAM reliably predict trends in the discharge?

A1: GAM predictions of amount of discharge

The answer to the first question appears to be no. Groundwater discharges to the Colorado River have been measured for the Carrizo-Wilcox Aquifer[14] in Bastrop County[15]. The measurements ranged from about 22,000 to 42,000 acre-feet per year (table A1).

**Table A1
Measured Groundwater Discharge to the Colorado River
From the Carrizo-Wilcox Aquifer in Bastrop County[16]**

Year	Discharge (cfs)	Discharge (ac-ft/yr)	Remarks
1918	36	26,060	USGS
1999	59	42,742	LCRA
2005	50	36,200	LCRA
2008	30	21,720	Saunders

However, between the years 2000 to 2010, the GAM predicts groundwater discharges between 8,000 and 12,000 acre-feet per year (figure A1). Clearly, these predictions are unreliable.

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[14] The Wilcox Aquifer consist of three parts: the Calvert Bluff, Simsboro, and Hooper aquifers.
[15] Saunders 2009.
[16] Saunders 2009, page 3; and Deeds et al. 2006, page 290.

GAM Predictions of Groundwater Discharge to Main Stem of Colorado River

(Using baseline file (Run 50) provided by LPGCD. Results for end of timestep ten in stream segments 36, 38, 40, and 46.)
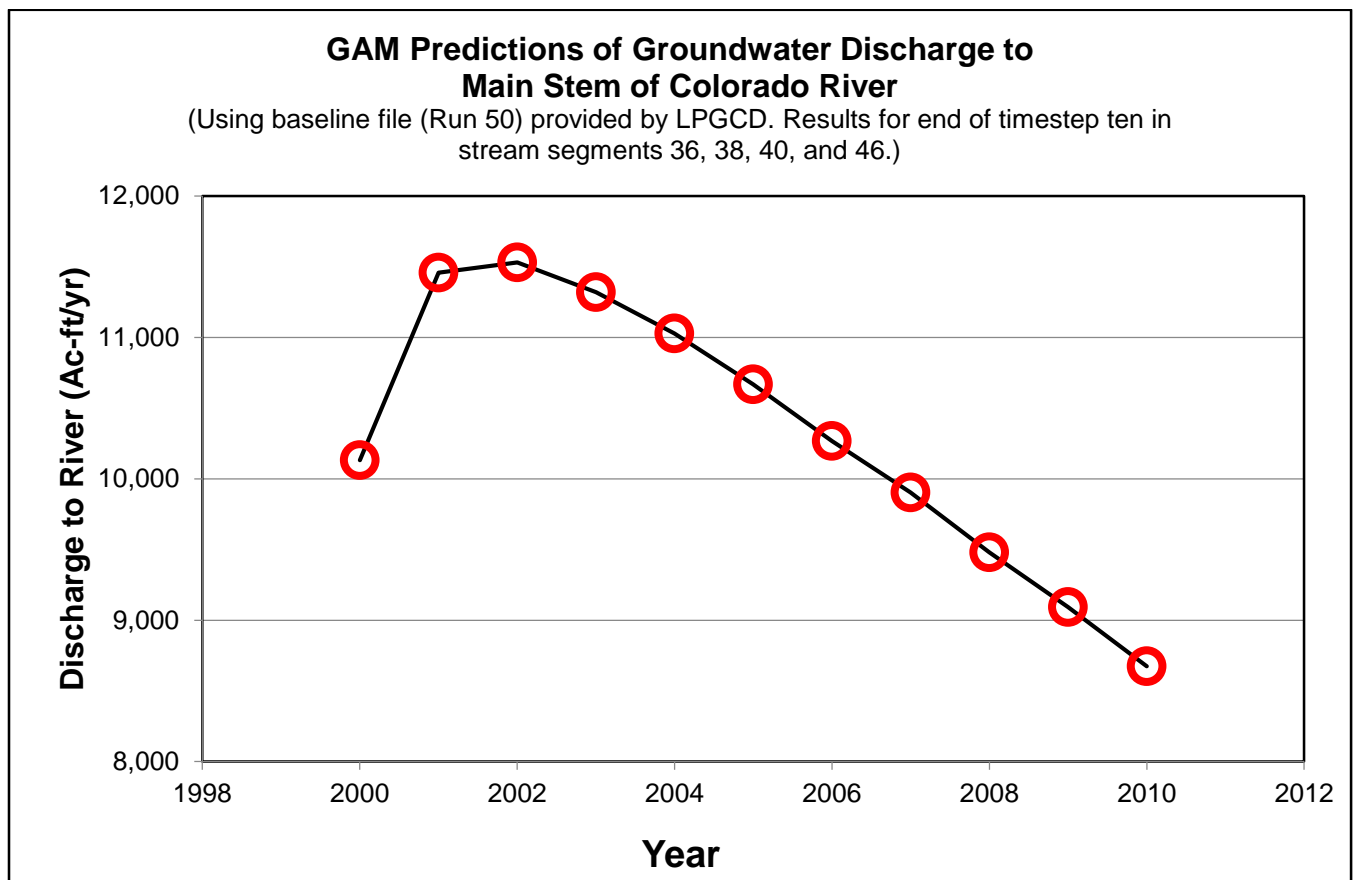
Figure A1
GAM Predicted Discharges to Colorado River

A2: GAM predictions of discharge trends

The answer to the second questions appears to be yes. This is because GAM results are consistent with what groundwater discharges would be expected to do in response to pumping. That is, we would expect the following:

- Pumping rates: higher groundwater pumping rates should result in less discharge to the river.

- Duration of pumping: longer durations should result in less discharge to the river.

- Distance of pumping: pumping closer to the river should have a greater effect than pumping farther from the river.

A2-1: Pumping rates

GAM predictions are consistent with the expectation regarding the effect of pumping rates. Figure A2 shows that the GAM predicts less discharge to the river when pumping is increased over baseline pumping rates, and more discharge when water is injected rather than pumped.
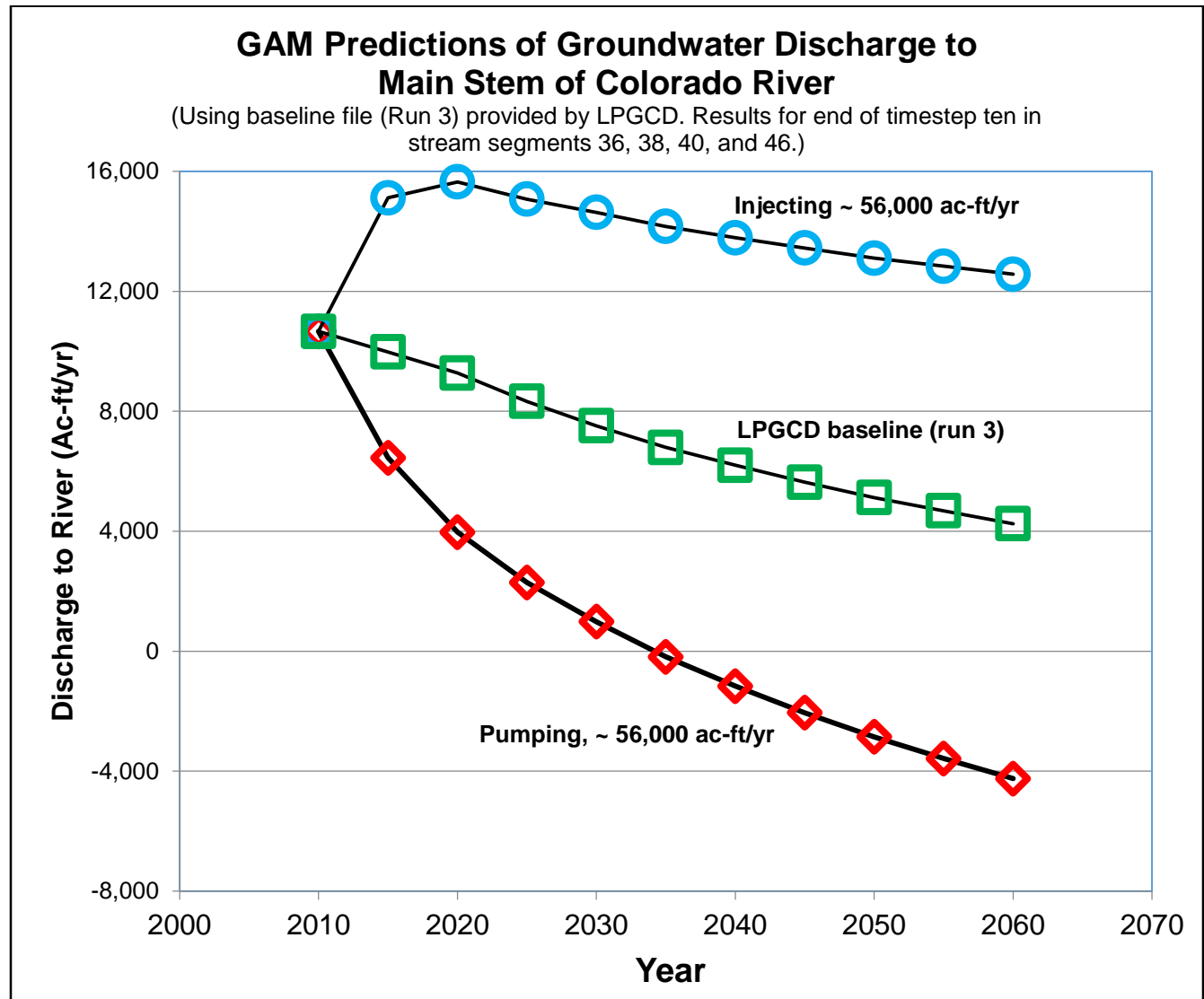

Figure A2
GAM Predicted Effects of Varying Pumping Rates and Pumping Duration

A2-2: Pumping duration

GAM predictions are consistent with the expectation regarding the effect of pumping duration. That is, greater durations result in less discharge to the river (figures A2 and A3).

A2-3: Distance of Pumping

GAM predictions are consistent with expectations regarding the effect of distance. Figure A3 illustrates the effects of pumping from four wells at a rate of 3400 acre-feet per year over baseline pumping rates. The GAM predicts less discharge for pumping wells that are adjacent to the river, than for pumping wells that are approximately one mile from the river.
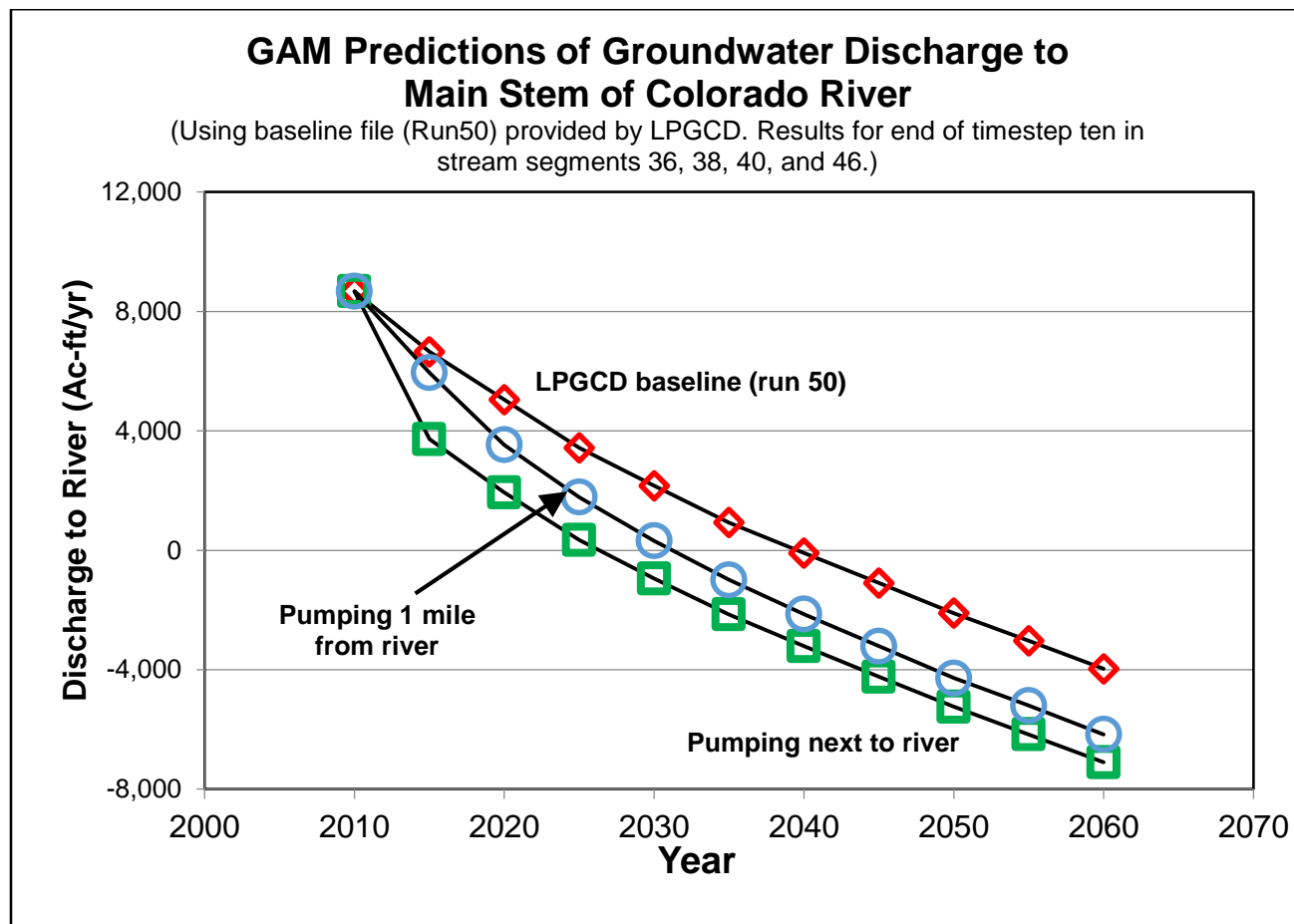
GAM Predictions of Groundwater Discharge to Main Stem of Colorado River
(Using baseline file (Run50) provided by LPGCD. Results for end of timestep ten in stream segments 36, 38, 40, and 46.)

Figure A3
GAM Predicted Effects of Pumping Distance

A-3: Conclusion

The results presented above indicate that the GAM does not reliably predict the effect of pumping on the amount of groundwater discharged to streams. It does, however, reliably predict the trends in groundwater discharge resulting from pumping.