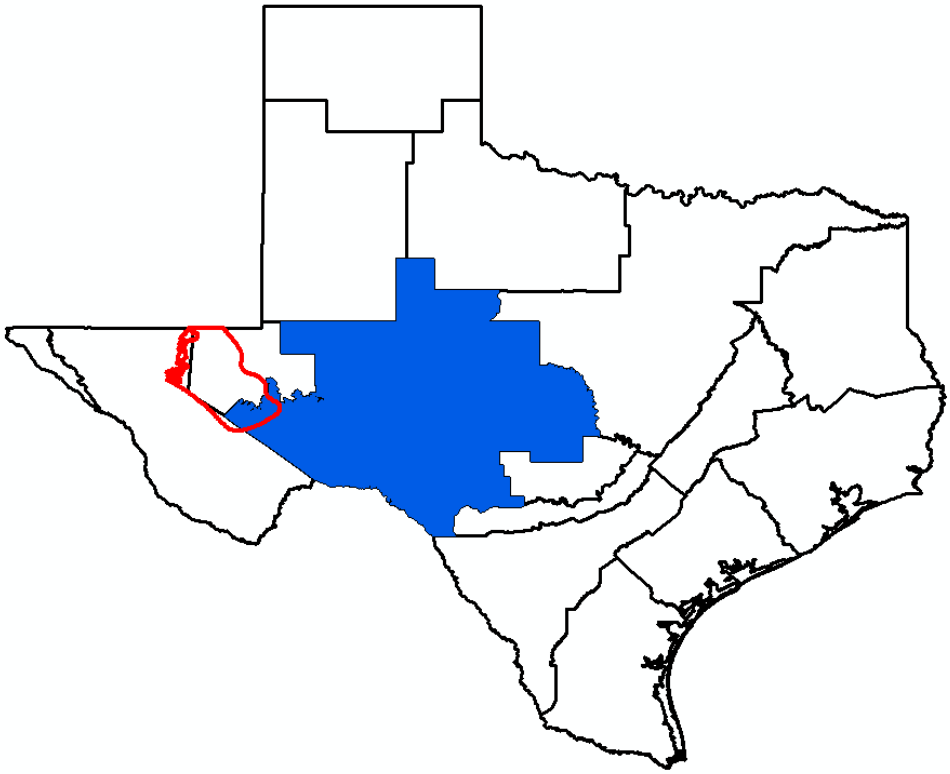
GMA 7 Technical Memorandum 15-05
Final

Rustler Aquifer: Nine Factor Documentation and Predictive Simulations with Rustler GAM



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Groundwater Management Area 7

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GMA 7 Technical Memorandum 15-05, Final
Rustler Aquifer: Nine Factor Documentation and Predictive Simulations with Rustler GAM

Geoscientist and Engineering Seal

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1.0 Introduction and Objective

This technical memorandum documents data and information related to the nine factors that GMA 7 must consider before developing and adopting a proposed desired future condition by May 1, 2016. This technical memorandum will become part of a more complete draft preliminary explanatory report that will be completed prior to the GMA 7 meeting currently scheduled for September 2015.

This technical memorandum also presents summary results from predictive simulations using the groundwater availability model of the Rustler Aquifer, which was released in 2012 (Ewing and others, 2012). As described below, the current desired future condition was established without the benefit of a groundwater model. The predictive simulations presented here can either form the quantitative basis of an updated desired future condition, or be modified to run additional simulations after review and discussion of these results.

1.1 Aquifer Description

As described in George and others (2011):

> *The Rustler Aquifer is a minor aquifer located in Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, and Ward counties. The aquifer consists of the carbonates and evaporites of the Rustler Formation, which is the youngest unit of the Late Permian Ochoan Series. The Rustler Formation is 250 to 670 feet thick and extends downdip into the subsurface toward the center of the Delaware Basin to the east. It becomes thinner along the eastern margin of the Delaware Basin and across the Central Basin Platform and Val Verde Basin. There it conformably overlies the Salado Formation. Groundwater occurs in partly dissolved dolomite, limestone, and gypsum. Most of the water production comes from fractures solution openings in the upper part of the formation. Although some parts of the aquifer produce freshwater containing less than 1,000 milligrams per liter of total dissolved solids, the water is generally slightly to moderately saline and contains total dissolved solids ranging between 1,000 and 4,600 milligrams per liter. The water is used primarily for irrigation, livestock, and waterflooding operations in oil-producing areas. Fluctuations in water levels over time most likely reflect long-term variations in water use patterns. The regional water planning groups in their 2006 Regional Water Plans did not propose any water management strategies for the Rustler Aquifer.*

1.2 Existing Desired Future Conditions

GMA 7 adopted a desired future condition for the Rustler Aquifer on July 29, 2010 as follows:

1. Total net decline in water levels within the Middle Pecos GCD at the end of the fifty year period shall not exceed 300 feet below water levels in the aquifer in the year 2010; and

2. The aquifer is not relevant for purposes of joint planning outside the boundaries of the Middle Pecos GCD.

The desired future condition was developed after considering a water budget analysis was that was completed on behalf of Middle Pecos GCD, and reviewed by the Texas Water Development Board (Bradley, 2011). A groundwater model of the aquifer was not available at the time of the initial desired future condition.

1.3 Overview of Process to Adopt a New Desired Future Condition

Senate Bill 660, adopted by the legislature in 2011, changed the process by which groundwater conservation districts within a groundwater management area develop and adopt desired future conditions. The new process includes nine steps as presented below:

- The groundwater conservation districts within a groundwater management area consider nine factors outlined in the statute.
- The groundwater conservation districts adopt a "proposed" desired future condition
- The "proposed" desired future condition is sent to each groundwater conservation district for a 90-day comment period, which includes a public hearing by each district
- After the comment period, each district compiles a summary report that summarizes the relevant comments and includes suggested revisions. This summary report is then submitted to the groundwater management area.
- The groundwater management area then meets to vote on a desired future condition.
- The groundwater management area prepares an "explanatory report".
- The desired future condition resolution and the explanatory report are then submitted to the Texas Water Development Board and the groundwater conservation districts within the groundwater management area.
- Districts then adopt desired future conditions that apply to that district.

The nine factors that must be considered before adopting a proposed desired future condition are:

1. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another.
2. The water supply needs and water management strategies included in the state water plan.
3. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator (of the Texas Water Development Board), and the average annual recharge, inflows and discharge.
4. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water.
5. The impact on subsidence.
6. Socioeconomic impacts reasonably expected to occur.
7. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002 (of the Texas Water Code).
8. The feasibility of achieving the desired future condition.
9. Any other information relevant to the specific desired future condition.

In addition to these nine factors, statute requires that the desired future condition provide a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area.

Legislation in 2013 set the deadline for a proposed desired future condition as May 1, 2016.

2.0 Nine Factor Information

2.1 Groundwater Demands and Uses

Table 1 summarizes groundwater demands and uses from 2000 to 2012 in the Rustler Aquifer in Pecos County. Note that the uses are irrigation and livestock. Data were obtained from the Texas Water Development Board historic pumping database:

http://www.twdb.state.tx.us/waterplanning/waterusesurvey/historical-pumpage.asp

Table 1. Historic Pumping from the Rustler Aquifer in Pecos County

Year	County	Aquifer	Irrigation	Livestock	Total
2000	PECOS	RUSTLER AQUIFER	2,085	4	2,089
2001	PECOS	RUSTLER AQUIFER	1,851	4	1,855
2002	PECOS	RUSTLER AQUIFER	1,764	3	1,767
2003	PECOS	RUSTLER AQUIFER	1,084	3	1,087
2004	PECOS	RUSTLER AQUIFER	1,223	14	1,237
2005	PECOS	RUSTLER AQUIFER	1,192	15	1,207
2006	PECOS	RUSTLER AQUIFER	1,783	17	1,800
2007	PECOS	RUSTLER AQUIFER	1,571	13	1,584
2008	PECOS	RUSTLER AQUIFER	1,639	15	1,654
2009	PECOS	RUSTLER AQUIFER	2,616	14	2,630
2010	PECOS	RUSTLER AQUIFER	3,533	14	3,547
2011	PECOS	RUSTLER AQUIFER	3,603	13	3,616
2012	PECOS	RUSTLER AQUIFER	3,175	12	3,187

The Modeled Available Groundwater for the Rustler Aquifer in Pecos County is 7,042 AF/yr. This is the amount of pumping that the Texas Water Development Board calculated that will achieve the desired future condition. A comparison of the modeled available groundwater and the historic pumping is presented in Figure 1.

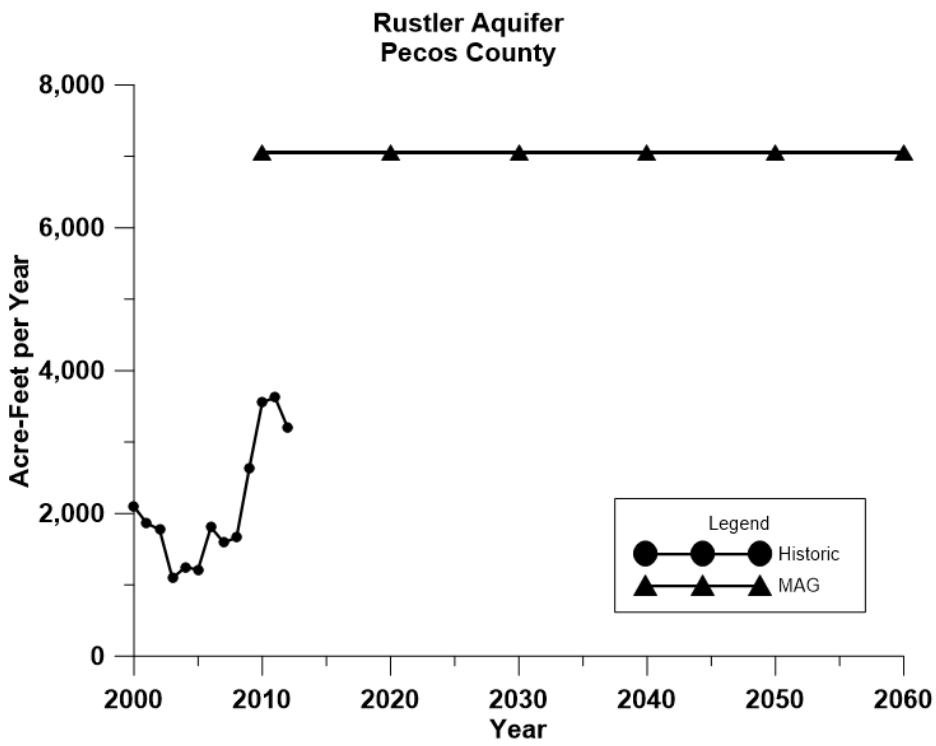


Figure 1. Historic Pumping and Modeled Available Groundwater (MAG)

2.2 Groundwater Supply Needs and Strategies

Total future demand in Pecos County is about 135,000 AF/yr, so it can be seen that the Rustler is a relatively minor source of supply. No water supply strategies are listed for the Rustler Aquifer in Pecos County in the 2011 Region F Water Plan.

2.3 Hydrologic Conditions, including Total Estimated Recoverable Storage

The groundwater budget for 2008 as presented by Ewing and others (2008) for the Pecos County portion of the Rustler Aquifer is presented in Table 2.

Please note that the estimated pumping plus flowing wells from Ewing and others (2012) is about the same as the estimated pumping use from the Texas Water Development Board historic pumping database (1,596 AF/yr vs. 1,654 AF/yr).

Jones and others (2013) documented the total estimated recoverable storage for the GMA 7 portion of the Rustler Aquifer in Pecos County. Total storage was estimated to be 5 million acre-feet. Total estimated recoverable storage was assumed to be between 25 percent and 75 percent of the total storage (between 1.25 and 3.75 million acre-feet).

Table 2. Groundwater Budget of Rustler Aquifer in Pecos County for 2008
Data from Ewing and others (2012)
All Values in AF/yr except as noted

Inflow	**Year 2008**
Lateral Flow from other Counties	2,761

Outflow	
Outflow to overlying formations	1,523
Pumping	220
Flowing Wells	1,254
Spring Flow	342
Total	3,339

Inflow-Outflow	578
Model Estimated Storage Decline	586
Model Error	8
Model Error (as a percent of inflow)	0.29

2.4 Other Environmental Impacts, including Impacts on Spring Flow

Table 2 above includes groundwater budget estimates of spring flow for 2008 as estimated by the Rustler Aquifer GAM. Additional information on impacts to spring flow will be provided when presenting the results of future simulations.

2.5 Other Factors

Subsidence is not an issue in the Rustler Aquifer in GMA 7. The factors related to socioeconomic impacts and private property rights will be covered in the draft preliminary explanatory report.

3.0 Rustler Aquifer Groundwater Availability Model Background

3.1 Overview

The groundwater availability model for the Rustler Aquifer simulates a two layer aquifer system. Layer 2 is the Rustler Aquifer, and the overlying Layer 1 of the model represents all younger overlying formations. The western portion of the model, in Culberson County, Reeves County and in New Mexico, only includes Layer 2, where the Rustler Aquifer crops out and receives recharge. East of the outcrop area, the Rustler Aquifer is confined and the interaction with the overlying units (in Layer 1) are handled with general head boundaries that vary with time. The transient model calibration period is 1919 to 2008.

Ewing and others (2011, pg. 11-3 and 11-4) discussed the use of the general head boundaries and other features of the model for predictive simulations. The pertinent discussion and recommendations are presented below:

> *The inflow rates used for the lateral boundary conditions and the stream stages and conductances used for the stream boundary conditions in the transient model for the historical period of the Rustler Aquifer represent long-term average values. These values are considered appropriate for use in any regional-scale applications of the Rustler Aquifer groundwater availability model in a predictive mode. The heads used for the general head boundary conditions to represent the Edwards-Trinity (Plateau) and Pecos Valley Alluvium aquifers vary temporarily (***sic***). Therefore, the heads used in the transient, historical model are inapplicable for use in a predictive model. In developing general-head boundary condition heads for a predictive model it is probably best to use predictive simulations of the Edwards-Trinity (Plateau) and Pecos Valley Alluvium aquifers. Two reasonable uses of the Edwards-Trinity (Plateau) and Pecos Valley Alluvium aquifers predictive model are available. The simulated heads from the predictive model could be used directly to set the heads for the layer 1 general head boundary condition. Alternately, the simulated drawdown from the predictive model could be used in conjunction with the late time general-head boundary heads from the transient model of the Rustler Aquifer.*

Ewing and others (2012) did not provide details on general head boundary variation during the calibration period (1919 to 2008). Although the discussion above recommended use of heads from the Edwards-Trinity (Plateau) and Pecos Valley Alluvium aquifer predictive simulations to set general head boundary heads in Layer 1, the report is not clear as to which model was used for these assignments. However, at the July 6, 2012 Stakeholder Advisory Forum (SAF3) meeting that discussed the Rustler Aquifer GAM, the following question and answer provided the necessary insight:

> ***Question****: Please clarify how heads were estimated for units above the Rustler.*
> ***Answer:*** *Used TWDB two-layer model and adjusted in places as appropriate and needed based upon observed heads at selected long-term hydrographs.*

GMA 7 used the alternative one layer model to simulate Edwards-Trinity (Plateau) conditions for purposes of desired future condition development, and GAM 3 used the alternative one layer model to simulate Pecos Valley Alluvium conditions for purposes of desired future condition development in 2010, and GMA 7 intends to use the alternative one layer model for desired future condition development in 2015-2016. If output from the alternative one layer model were used in the Rustler Aquifer GAM to populate the GHB head boundaries, differences may be introduced that may be due to difference in the models that may affect results. A simplified approach that may be more useful is described below.

3.2 General Head Boundary Position Relative to Layer 1 Bottom Elevation

Any predictive simulation using the Rustler Aquifer GAM requires the specification of GHB head for each annual stress period from 2009 to 2070. A review of the specification of GHB heads during the end of the calibration period (2005 to 2008) was completed to quantify the GHB head relative to the bottom elevation of Layer 1. The input files for the calibration period show that GHB specifications for 2005, 2006, 2007 and 2008 are the same. Figure 2 presents a histogram of the difference between GHB head and layer 1 bottom elevation.

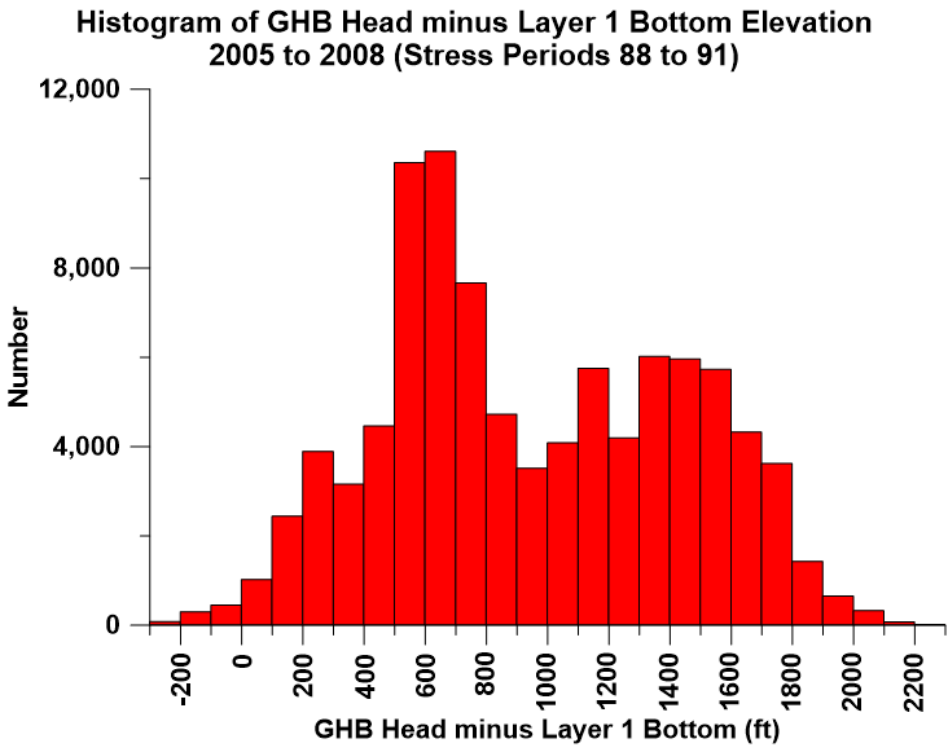


Figure 2. General Head Boundaries and Layer 1 Bottom Elevation

Note that of the over 94,000 GHB cells, about 750 have heads specified below the bottom of layer 1. This results in an inflow of water to layer 1 from the head boundary. These cells are located in the western portion of the model domain, well outside of GMA 7. Shi (2015b) noted that this the model developers used the simulated head from the Edwards-Trinity (Plateau) model that

happened to be below the layer bottom of this model. Shi (2015) further noted that it did not affect the model results.

Any general reduction in GHB heads for predictive simulations would need to consider specifying GHB heads below the bottom of layer 1.

3.3 General Head Boundary Variation during Calibration Period

In order to better understand the role of general head boundaries on changes in groundwater elevations in the Rustler Aquifer, general head boundaries at nine points were reviewed. Figure 3 presents the location of these points.

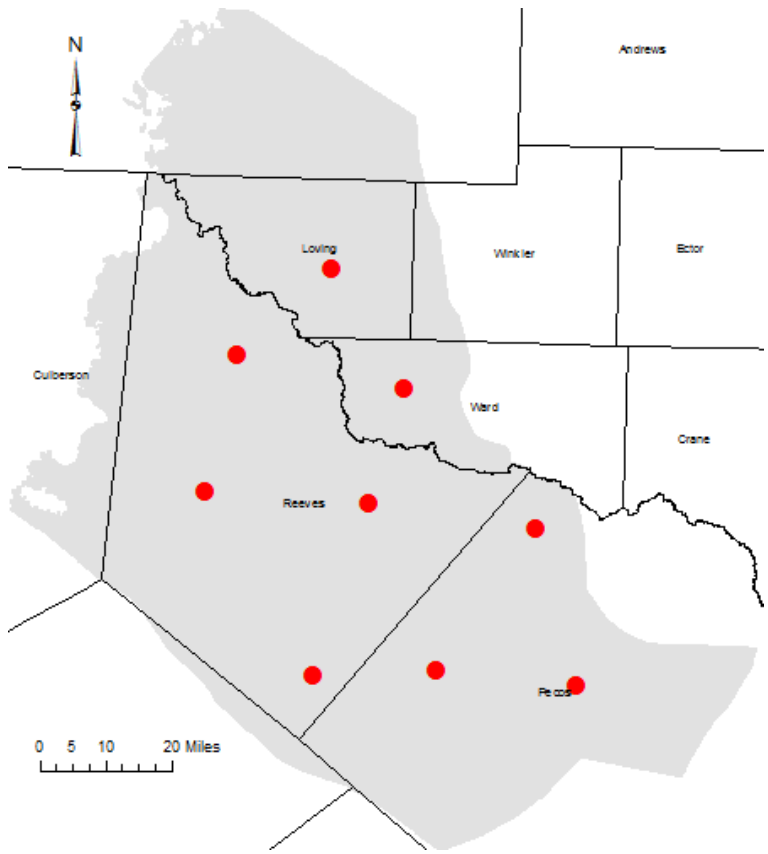


Figure 3. Location of Nine Points used in General Head Boundary Evaluation

Hydrographs of the individual points are presented in Appendix A. A small location map is shown with each hydrograph to provide a geographic reference. The hydrographs of assigned heads for the general head boundary typically show relatively constant heads from 1919 to the early 1940s, rapid decline from the 1940s to the 1970s or 1980s, and a fairly constant, if not increasing head condition from the 1980s to 2008.

Although the fluctuations are conceptualized to reflect changes in groundwater elevations in the overlying formations, the fluctuations are coincident with fluctuations in pumping in the Rustler as documented by Ewing and others (2012). The total pumping hydrograph for the Rustler Aquifer of Ewing and others (2012, pg. 4-140) is reproduced in Figure 4, and the pumping hydrograph of Pecos County of Ewing and others (2012, pg. 4-141) is reproduced in Figure 5.

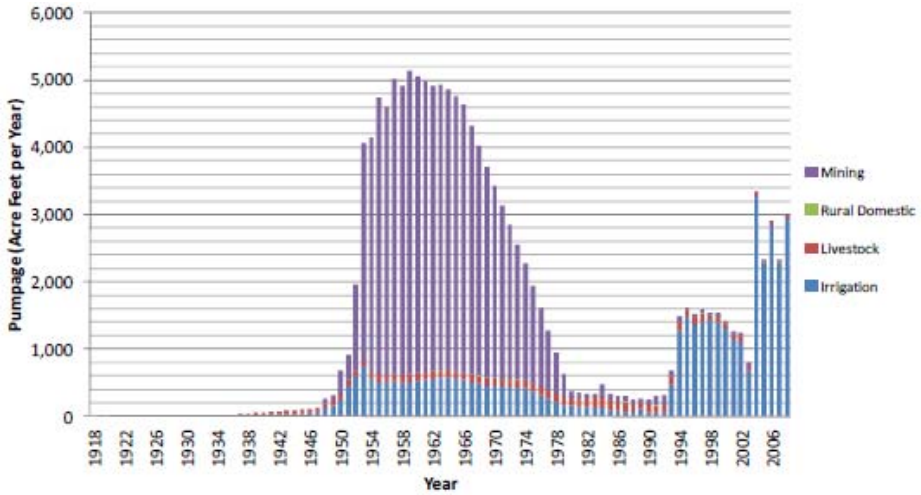


Figure 4. Total Pumping for the Rustler Aquifer (Ewing and other, 2012, Figure 4.7.4)

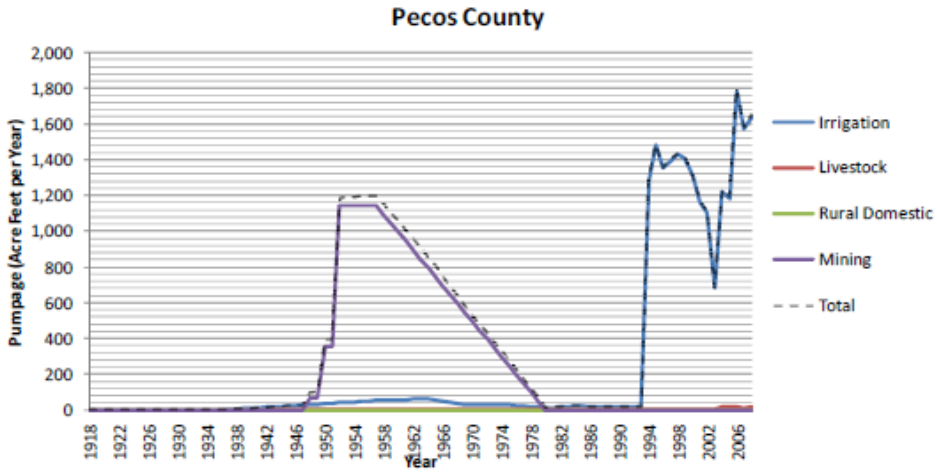


Figure 5. Total Pumping for the Pecos County Portion of the Rustler Aquifer (Ewing and others, 2012, Figure 4.7.7)

3.4 Sensitivity of GHB Changes for Predictive Simulations

Ewing and others (2012) provided the standard sensitivity analyses for a groundwater availability model in their report. These standard analyses did not include evaluating the sensitivity of changes in GHB boundary heads for predictive simulations. This section of the Technical Memorandum documents a series of five predictive simulations for the period 2009 to 2070:

- Scenario 1 – Use 2008 GHB heads for each year
- Scenario 2 – GHB heads decline from 2008 conditions 0.5 ft/yr
- Scenario 3 – GHB heads decline from 2008 conditions 1.0 ft/yr
- Scenario 4– GHB heads decline from 2008 conditions 1.5 ft/yr
- Scenario 5 – GHB heads decline from 2008 conditions 2.0 ft/yr

Pumping for these simulations was set equal to 2008 pumping and held constant.

Constraints on the annual decline of GHB boundaries included setting the areas where GHB heads are below layer 1 bottom elevation to the same as 2008 conditions (see discussion in Section 3.2), and not allowing any GHB head to fall below 20 feet above the bottom of layer 1.

Results of these simulations are summarized in Table 3, and include maximum drawdown in each county and average drawdown in each county.

Table 3. Maximum and Average Drawdown - GHB Sensitivity Simulations

County	Maximum Drawdown (ft)					Average Drawdown (ft)				
	GHB Scen 1	GHB Scen 2	GHB Scen 3	GHB Scen 4	GHB Scen 5	GHB Scen 1	GHB Scen 2	GHB Scen 3	GHB Scen 4	GHB Scen 5
Brewster	0	26	53	79	105	0	26	52	79	105
Culberson	5	29	57	84	112	0	5	8	11	14
Jeff Davis	18	29	56	84	112	5	27	50	72	94
Loving	6	32	62	93	124	2	28	54	80	106
New Mexico	19	28	56	84	111	0	12	23	34	44
Pecos (GMA 3)	80	87	94	101	122	25	38	51	64	77
Pecos (GMA 7)	45	53	61	83	110	2	19	37	55	74
Reeves	148	155	161	168	175	19	36	53	70	86
Ward	8	34	62	93	124	4	30	56	82	108
Winkler	8	34	59	85	111	6	31	57	82	107

For the GMA 7 portion of Pecos County, if GHB heads from 2008 were used throughout the simulation period of 2009 to 2070 for desired future condition purposes, maximum drawdown from 2008 to 2070 would be 45 feet, and average drawdown from 2008 to 2070 would be 2 feet. However, if GHB heads declined at a constant rate of one foot per year (Scenario 3), maximum drawdown in the GMA 7 portion of Pecos County would be 61 feet, and average drawdown would be 37 feet with no change in pumping.

4.0 Initial Simulations with the Rustler Aquifer GAM

The initial simulations with the Rustler Aquifer GAM consisted of assuming various pumping scenarios and estimating the drawdown. Assumptions also included declines in GHB heads in Layer 1 of the model. For these initial simulations, pumping distribution followed the distribution used for model calibration. During the calibration period, a total of 10,753 pumping wells were used during at least one stress period. A base pumping file for predictive simulations was created by taking the single highest annual pumping amount during the calibration period for each well. A summary of pumping totals from this base pumping file by county along with current modeled available groundwater values are shown in Table 4. The areas of pumping are generally shown in Figure 6, which is a reproduction from Ewing and others (2012, pg. 6-28).

Table 4. Summary of County Totals for Base Pumping File

County	Base Pumping (AF/yr)	Modeled Available Groundwater (AF/yr)
Loving	200	1,183
Pecos (GMA3)	3	3,466
Pecos (GMA7)	4,460	7,042
Reeves	2,387	1,976
Ward	0	555
Total	7,050	14,222

Please note that the location of the pumping in Loving County is not shown in Figure 6 because it was not included in the original model that is described in the report. Shi (2015a) that this pumping and an additional two pumping locations (200 AF/yr each) in Reeves County, were added to reverse the hydraulic gradient from upward to downward to be consistent with field measurements. Shi (2015a) further noted that TWDB adopted this version of the model with the additional pumping as the official GAM. This is the only change from the model described in Ewing and others (2012).

Also note that the pumping in the GMA 3 portion of Pecos County is only 3 AF/yr. If pumping is to increase to anything approaching the current MAG, additional pumping locations will be needed. This will need to be completed later after coordination with GMA 3/Middle Pecos GCD. Choice of locations will have an effect on drawdown in the GMA 7 portion of Pecos County, and these initial simulations do not include substantial pumping in the GMA 3 portion of Pecos County.

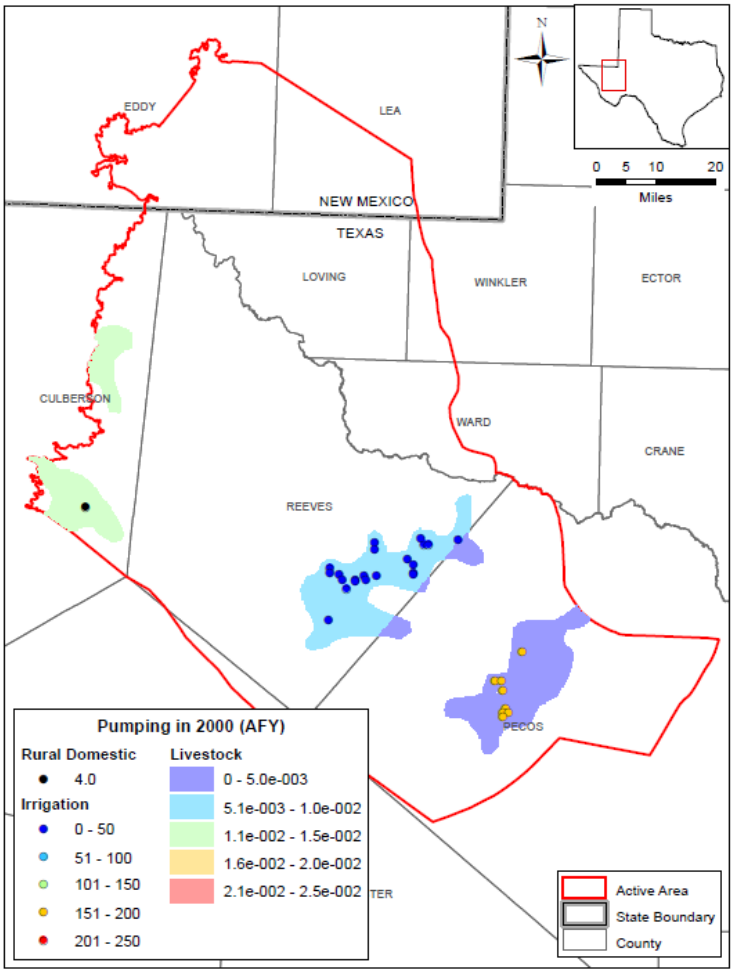


Figure 6. Pumping Distribution in 2000
From Ewing and others (2012, Figure 6.3.11)

4.1 Scenario Descriptions

The objective of these initial simulations is provide the groundwater conservation districts in Groundwater Management Area 11 an opportunity to evaluate alternatives, assess the sensitivity to increases or decreases in pumping, and provide a frame of reference for discussion of the balancing between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater. For these initial simulations, the base scenario assumed:

- Pumping in the GMA 7 portion of Pecos County equal to the current modeled available groundwater (Table 4)
- Pumping in Loving County, the GMA 3 portion of Pecos County, and Reeves County equal to the base pumping (Table 4)
- No pumping was assumed in Ward County

Additional pumping locations are needed in Loving County, and in the GMA 3 portion of Pecos County to simulate amounts approaching the modeled available groundwater. Pumping locations are also needed in Ward County. These will be made later in consultation with GMA 3 and the Middle Pecos GCD. These scenarios, therefore, will need to be updated in the future once GMA 3 has had input into the process.

Other scenarios include increases and decreases in pumping from these base amounts (except in Ward County) as shown below:

- Scenario 1 – 0.7*base pumping
- Scenario 2 – 0.8*base pumping
- Scenario 3 – 0.9*base pumping
- Scenario 4 – base pumping
- Scenario 5 – 1.1*base pumping
- Scenario 6 – 1.2*base pumping
- Scenario 7 – 1.3*base pumping

Pumping amounts by county are shown in Table 5.

Table 5. Summary of Pumping for Initial Scenarios

County	Scenario						
	1	2	3	4	5	6	7
Loving	140	160	180	200	220	240	260
Pecos(GMA3)	2	2	3	3	3	4	4
Pecos(GMA7)	4,929	5,634	6,338	7,042	7,746	8,450	9,155
Reeves	1,671	1,910	2,148	2,387	2,626	2,864	3,103
Ward	0	0	0	0	0	0	0
Total	6,742	7,706	8,669	9,632	10,595	11,558	12,522

Model input and output files for the predictive simulations are summarized in Table 6. Please note that the ** designation means that these are replace by the scenario number (e.g. Scenario 1 = 01).

Table 6. Predictive Simulation Input and Output Files

MODFLOW Package	Unit Number	File Name	Description
LIST	7	rstlrpred**.lst	Standard Output
BAS6	1	rstlrpred.bas	Set flags to suppress printing of IBOUND and starting heads, set IBOUND as external file, set initial heads as equal to heads from 2008 of calibration run and set as external file
DIS	29	rstlrpred.dis	Set number of stress periods to 62 (2009 to 2070)
UPW	11	rstlrpred.upw	Set flags to suppress printing of aquifer parameters
WEL	12	rstlrpred**.wel	Seven pumping scenarios (See Table 5 above)
GHB	15	rstlrpred2.ghb	Assumed 0.5 ft/yr decline in all GHBs
EVT	17	rstlrpred.evt	Set flags to suppress printing of parameters, reset number of stress periods
RCH	18	rstlrpred.rch	Set flags to suppress printing of parameters, reset number of stress periods
DRN	20	rstlrpred.drn	Set flags to suppress printing of parameters, reset number of stress periods
HFB6	26	RSTLR_tr.hfb	No change from calibration model
OC	22	rstlrpred.oc	Reset number of stress periods
NWT	23	RSTLR_tr.nwt	No change from calibration model
DATA(BINARY)	30	rstlrpred**.hds	Output of heads
DATA(BINARY)	31	rstlrpred**.ddn	Output of drawdown
DATA(BINARY)	50	rstlrpred**.cbb	Output of cell by cell flows
DATA	61	ib1.dat	IBOUND Layer 1 external file
DATA	62	ib2.dat	IBOUND Layer 2 external file
DATA	71	sp91hds1.dat	Starting heads external file (Layer 1 heads from Stress Period 91 of calibration run)
DATA	72	sp91hds2.dat	Starting heads external file (Layer 2 heads from Stress Period 91 of calibration run)

4.2 Simulation Results

Table 7 summarizes the maximum and average drawdown by county for each of the scenarios.

Table 7. Maximum and Average Drawdown of Seven Pumping Scenarios

County	Maximum Drawdown (2009 to 2070)						
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Brewster	48	52	55	59	62	66	69
Culberson	29	29	29	29	29	29	29
Jeff Davis	46	49	52	55	58	61	64
Loving	31	31	32	32	42	55	69
NM	28	28	28	28	28	28	28
Pecos3	199	228	257	287	316	346	375
Pecos7	284	324	365	405	446	486	527
Reeves	153	182	210	239	268	297	326
Ward	34	34	34	34	34	34	34
Winkler	34	34	34	34	34	34	34

County	Average Drawdown (2009 to 2070)						
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Brewster	47	50	54	57	60	63	66
Culberson	5	5	5	5	5	5	5
Jeff Davis	34	35	36	37	38	39	40
Loving	26	27	27	28	29	29	30
NM	12	12	12	12	12	12	12
Pecos3	57	61	65	69	72	76	80
Pecos7	70	78	86	94	102	110	118
Reeves	37	38	39	40	42	43	44
Ward	30	30	30	30	30	30	31
Winkler	31	31	31	31	32	32	32

Please note that for the GMA 7 portion of Pecos County, pumping the current modeled available groundwater (Scenario 4) results in a maximum drawdown of 405 feet, and an average drawdown of 94 feet. The current desired future condition is a drawdown of 300 feet from 2010 to 2060, and was based on a water budget calculation. The water budget approach cannot distinguish between an average drawdown and a maximum drawdown.

Also note that the drawdown results are affected by the assumption of GHB head decline. In these scenarios, a 0.5 ft/yr decline in GHB head boundaries was assumed. Thus, from Table 3 previously presented, 53 feet of the 405 feet of maximum drawdown is from the GHB boundary assumption, and 19 feet of the 94 feet of average drawdown is from the GHB boundary assumption.

Figure 7 graphically summarizes the relationship between pumping and maximum drawdown for the GMA 7 portion of Pecos County for all scenarios. Figure 8 graphically summarizes the relationship between pumping and average drawdown for the GMA 7 portion of Pecos County for all scenarios.

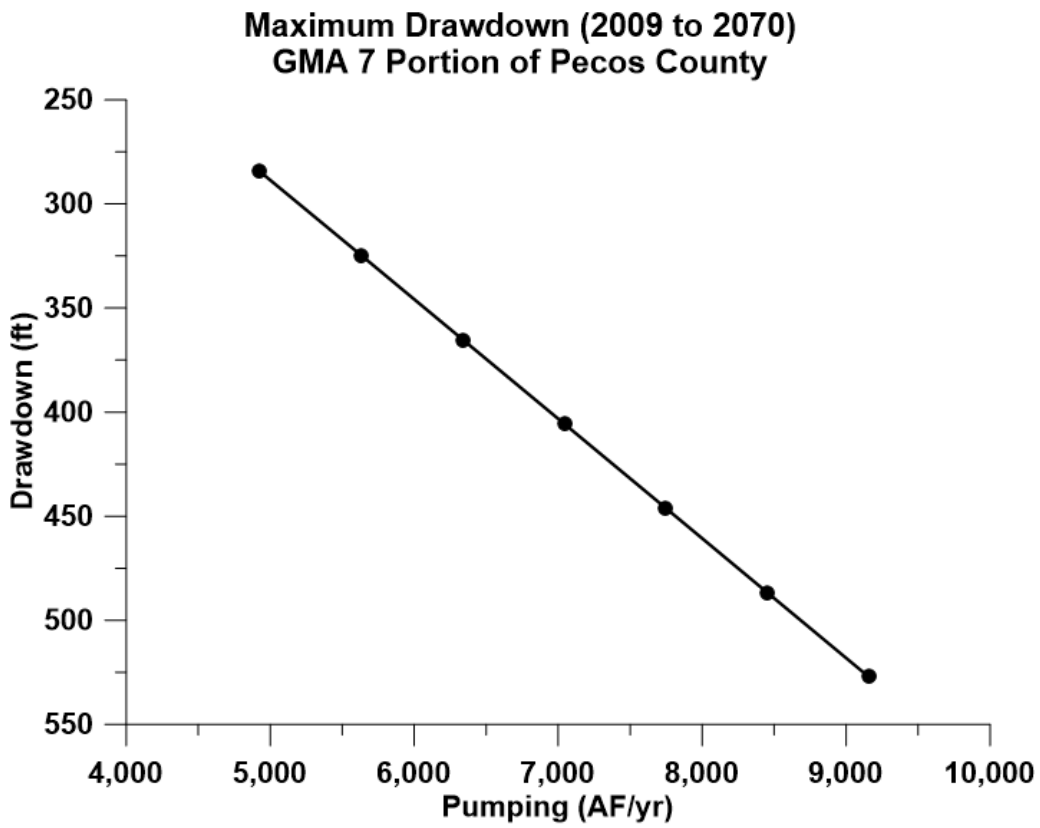


Figure 7. Pumping vs. Maximum Drawdown

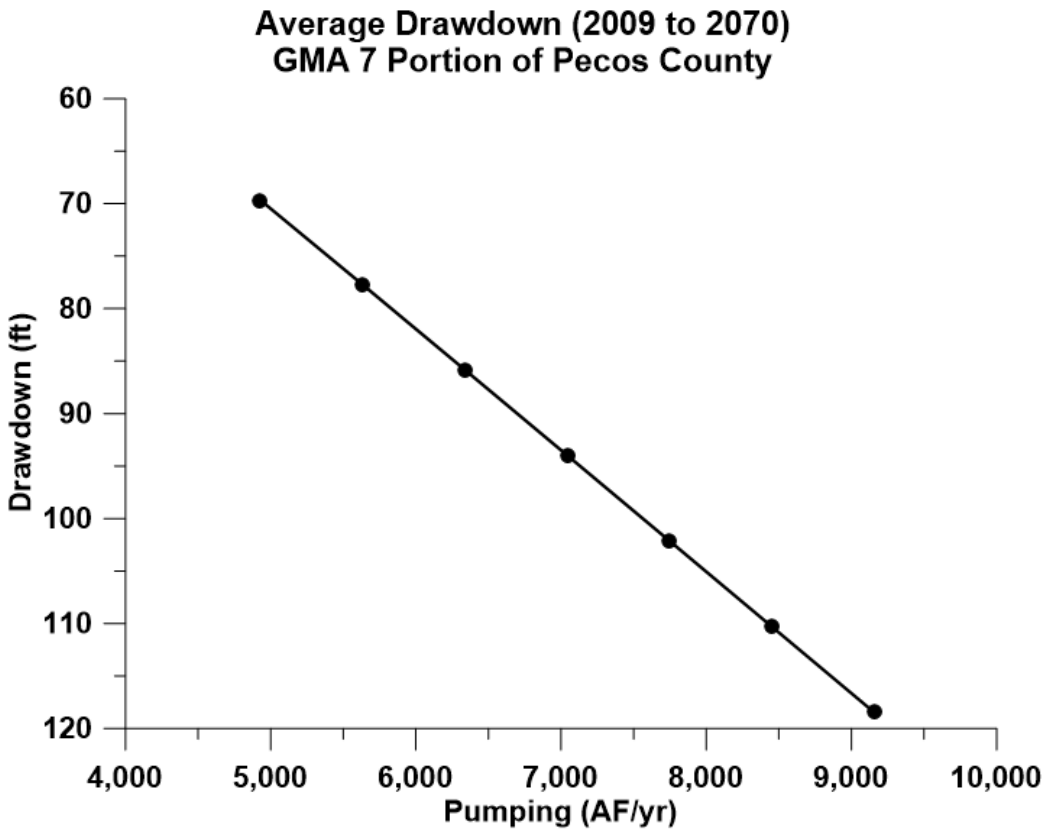


Figure 8. Pumping vs. Average Drawdown

Additional results from the simulations (e.g. impacts to springs and flowing wells) will be developed once a more complete set of simulations are completed after input from GMA 3.

4.3 Recommendations for Future Simulations

As described above, GMA 3 input is required to complete this effort. Specifically:

- Pumping locations in the GMA 3 portion of Pecos County need to be identified if additional pumping is required
- Pumping locations are needed in Loving County if additional pumping is required
- Pumping locations are needed in Ward County if pumping is required.

Also, input regarding an appropriate decline in GHB heads is needed.

5.0 References

Bradley, R.G., 2011, GTA Aquifer Assessment 10-13 MAG. Texas Water Development Board, Groundwater Technical Assistance Section, November 18, 2011, 8p.

Ewing, J.E., Kelley, V.A., Jones, T.L., Yan, T., Singh, A., Powers, D.W., Holt, R.M., and Sharp, J.M., 2012. Final Groundwater Availability Model Report for the Rustler Aquifer. Prepared for the Texas Water Development Board, 460p.

George, P.G., Mace, R.E., and Petrossian, R., 2011. Aquifers of Texas. Texas Water Development Board Report 380, July 2011, 182p.

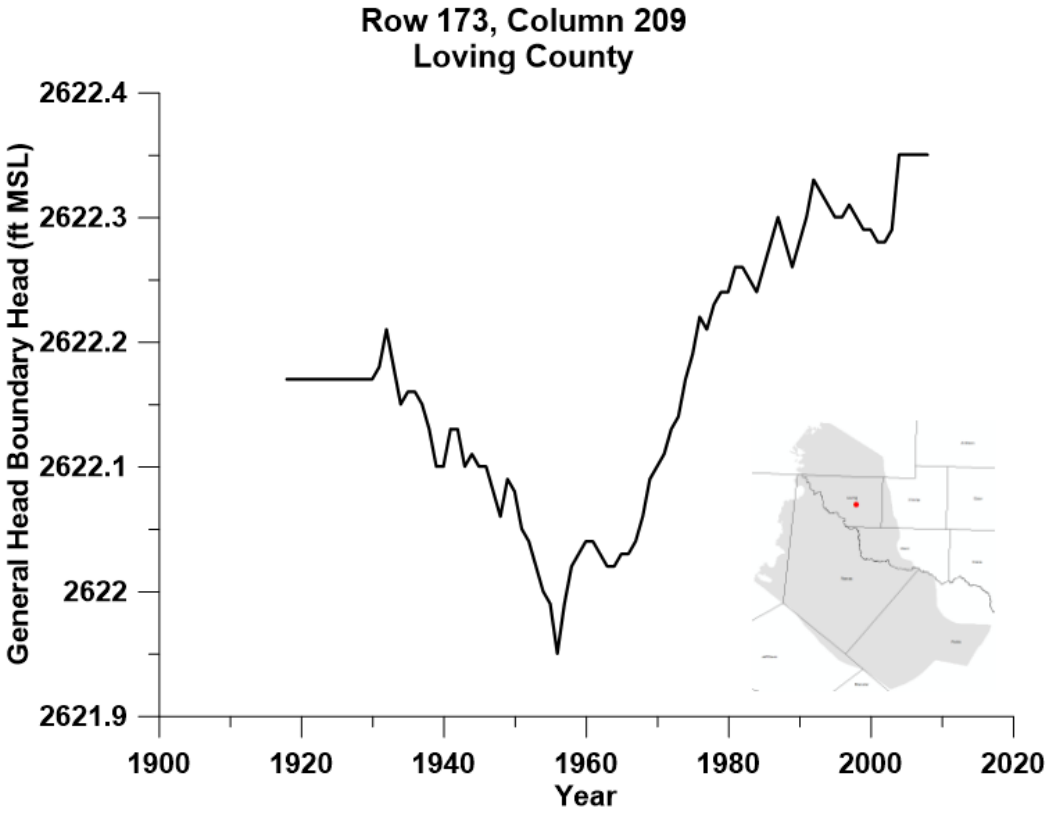
Jones, I.C., Bradley, R., Boghici, R., Kohlrenken, W., and Shi, J., GAM Task 13-030: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 7, October 2, 2013, 53p.

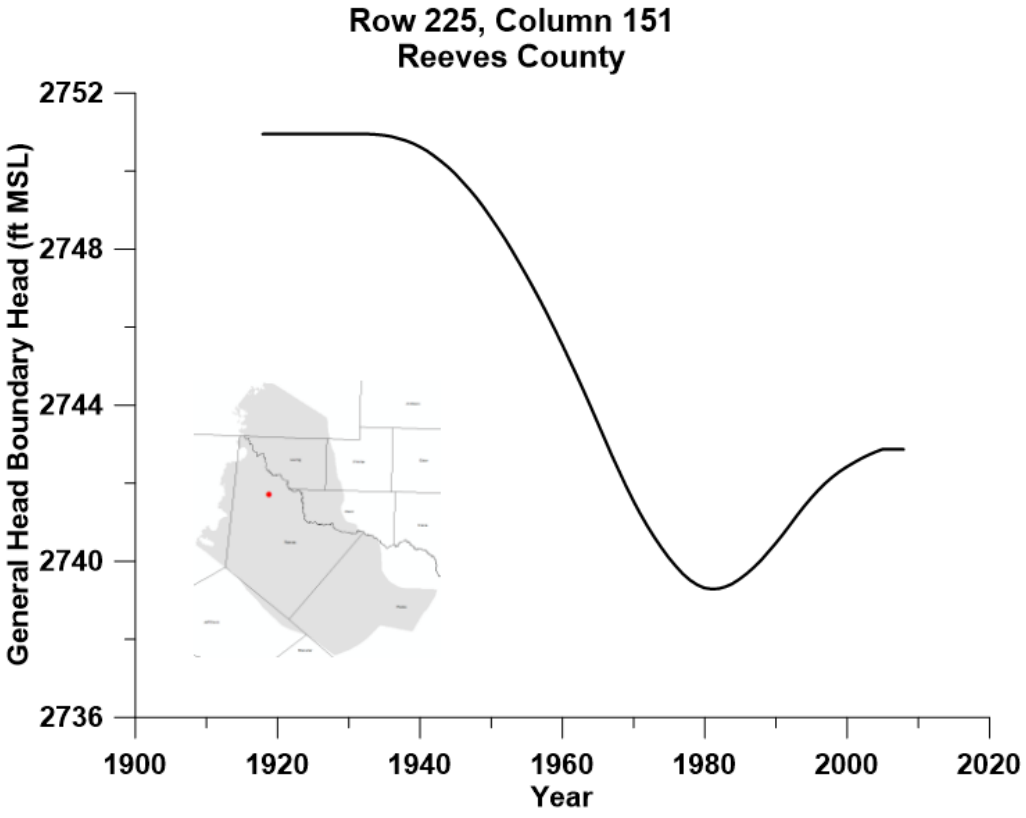
Shi, Jerry, 2015a. Email communication with Bill Hutchison, January 7, 2015.

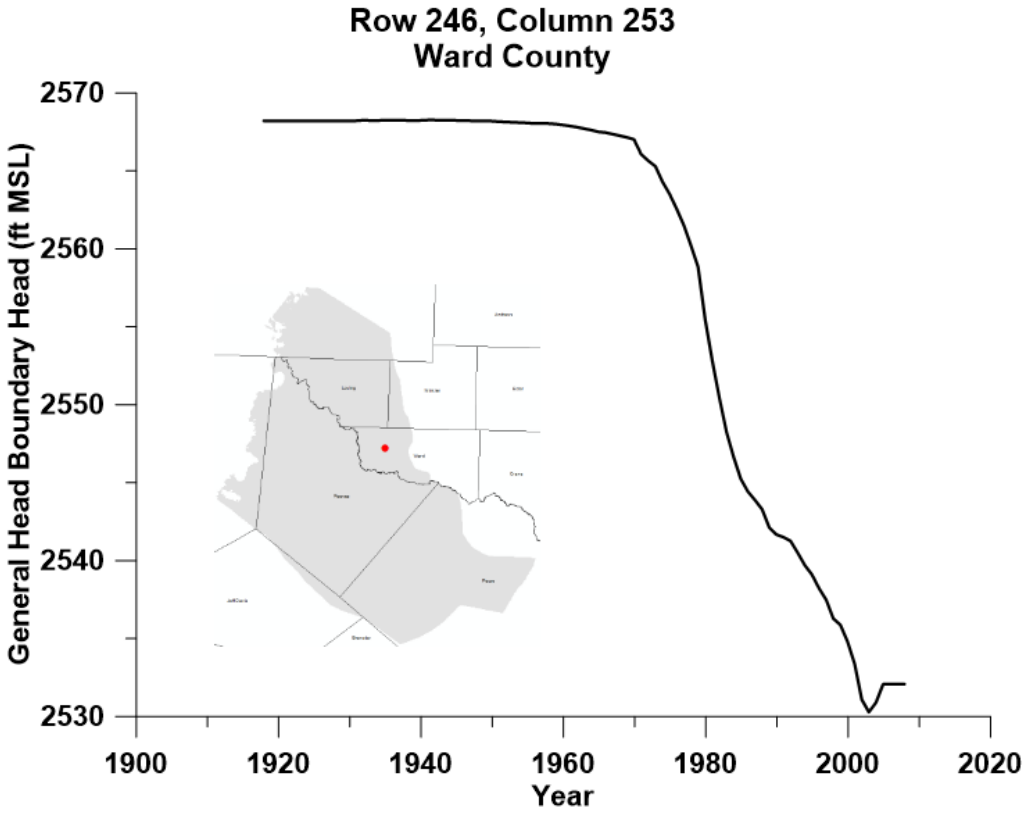
Shi, Jerry, 2015b. Email communication with Bill Hutchison, March 31, 2015.

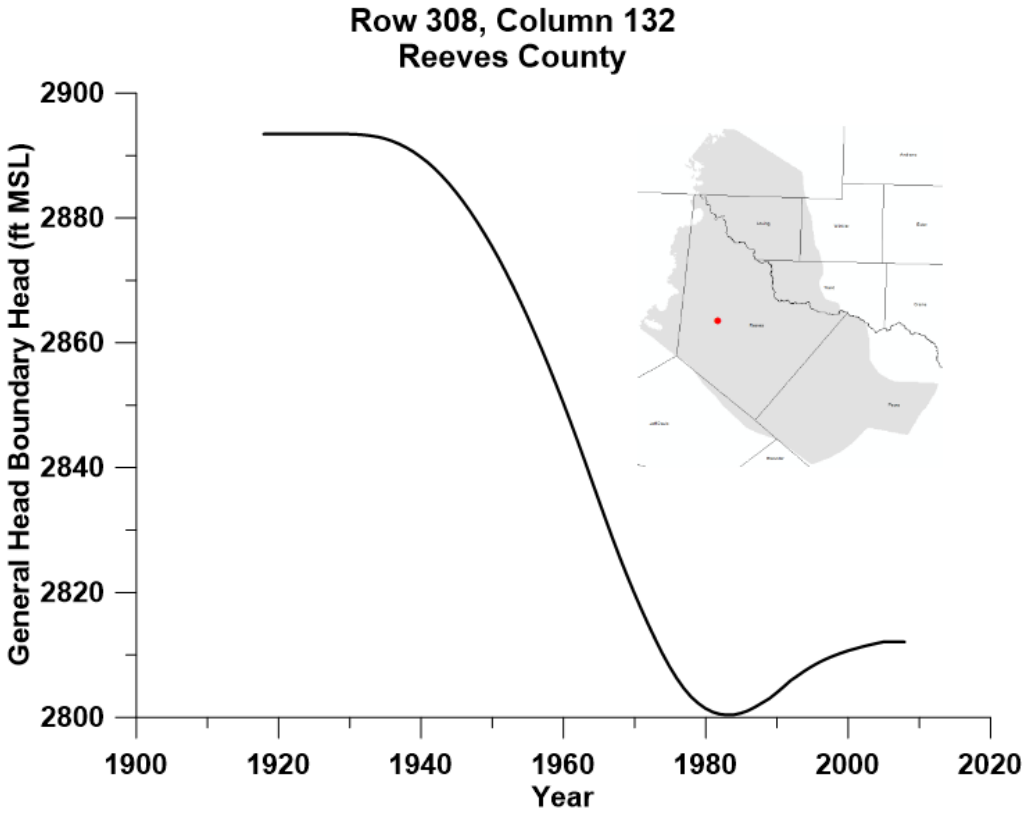
Appendix A

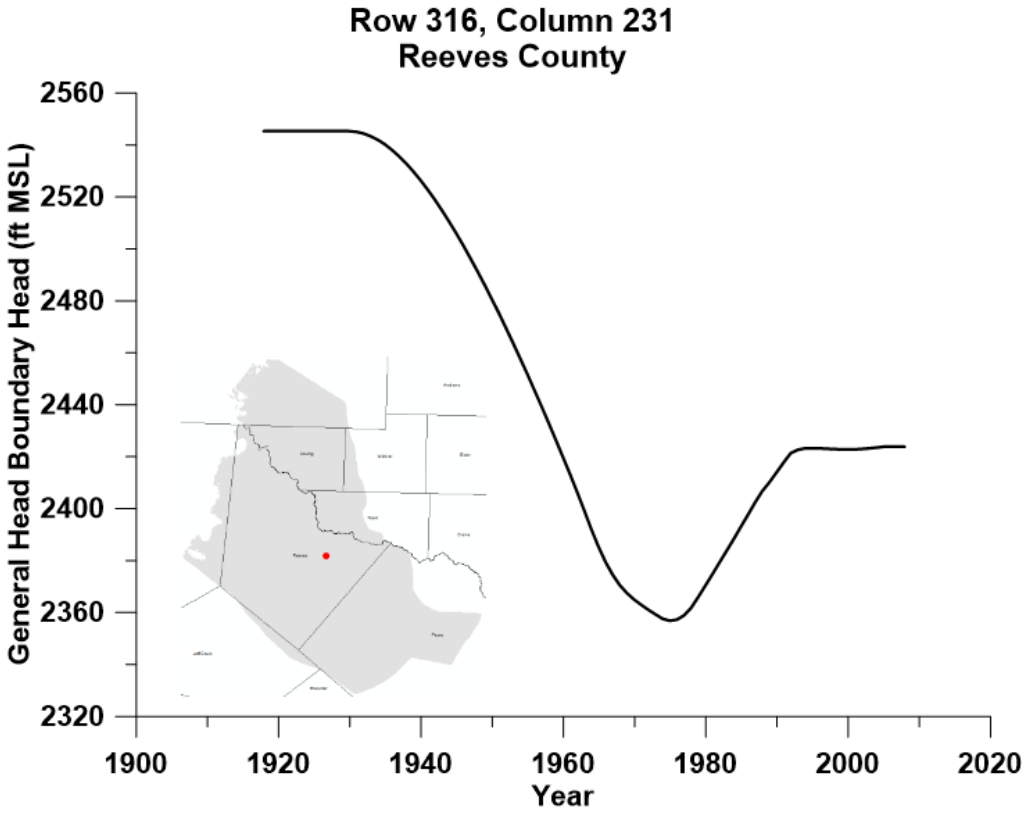
Hydrographs of Elected Points of GHB Head Variation during Model Calibration Period


Row 173, Column 209
Loving County
General Head Boundary Head (ft MSL)
2622.4
2622.3
2622.2
2622.1
2622
2621.9
1900
1920
1940
1960
1980
2000
2020
Year


Row 225, Column 151
Reeves County
General Head Boundary Head (ft MSL)
2752
2748
2744
2740
2736
1900
1920
1940
1960
1980
2000
2020
Year


Row 246, Column 253
Ward County
General Head Boundary Head (ft MSL)
2570
2560
2550
2540
2530
1900
1920
1940
1960
1980
2000
2020
Year


Row 308, Column 132
Reeves County
General Head Boundary Head (ft MSL)
2900
2880
2860
2840
2820
2800
1900
1920
1940
1960
1980
2000
2020
Year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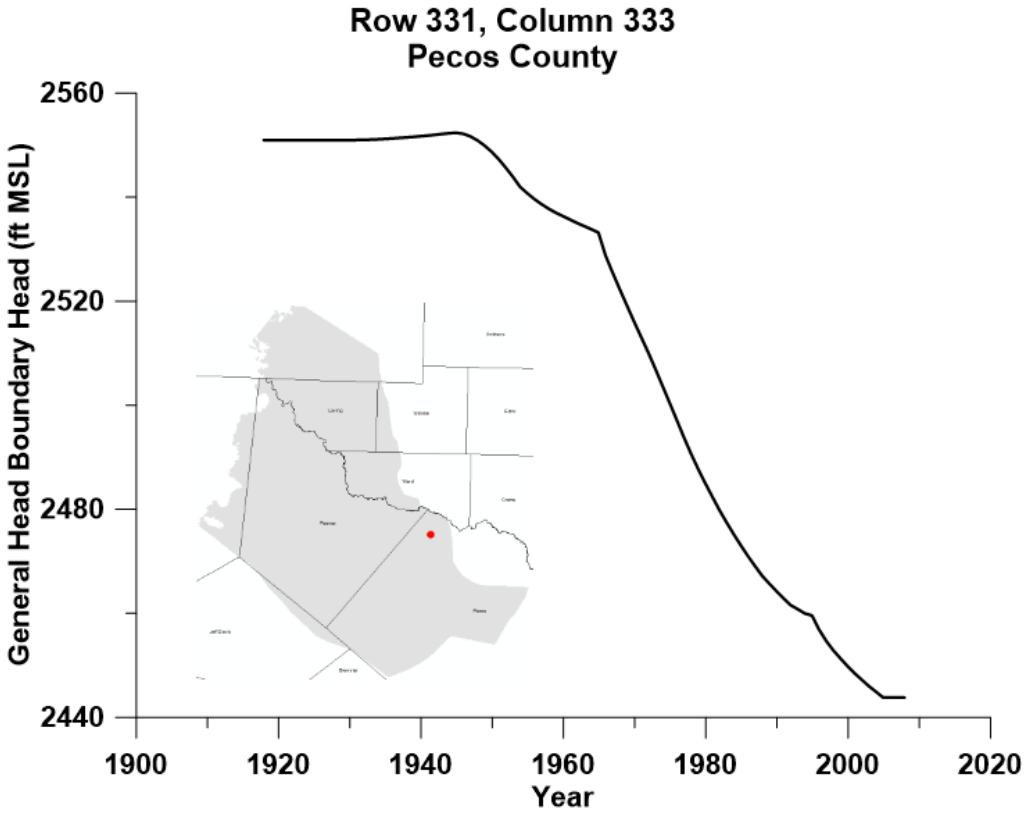
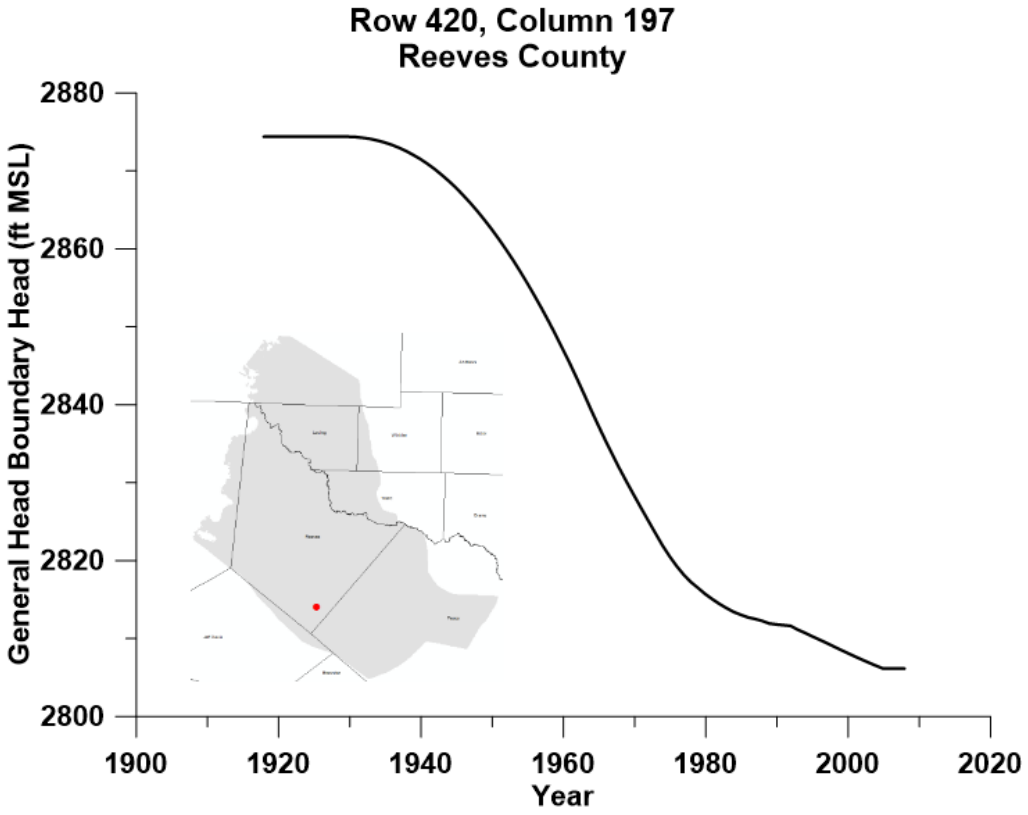
Reeves County
General Head Boundary Head (ft MSL)
2560
2520
2480
2440
2400
2360
2320
1900
1920
1940
1960
1980
2000
2020
Year


Row 331, Column 333
Pecos County
General Head Boundary Head (ft MSL)
2560
2520
2480
2440
1900
1920
1940
1960
1980
2000
2020
Year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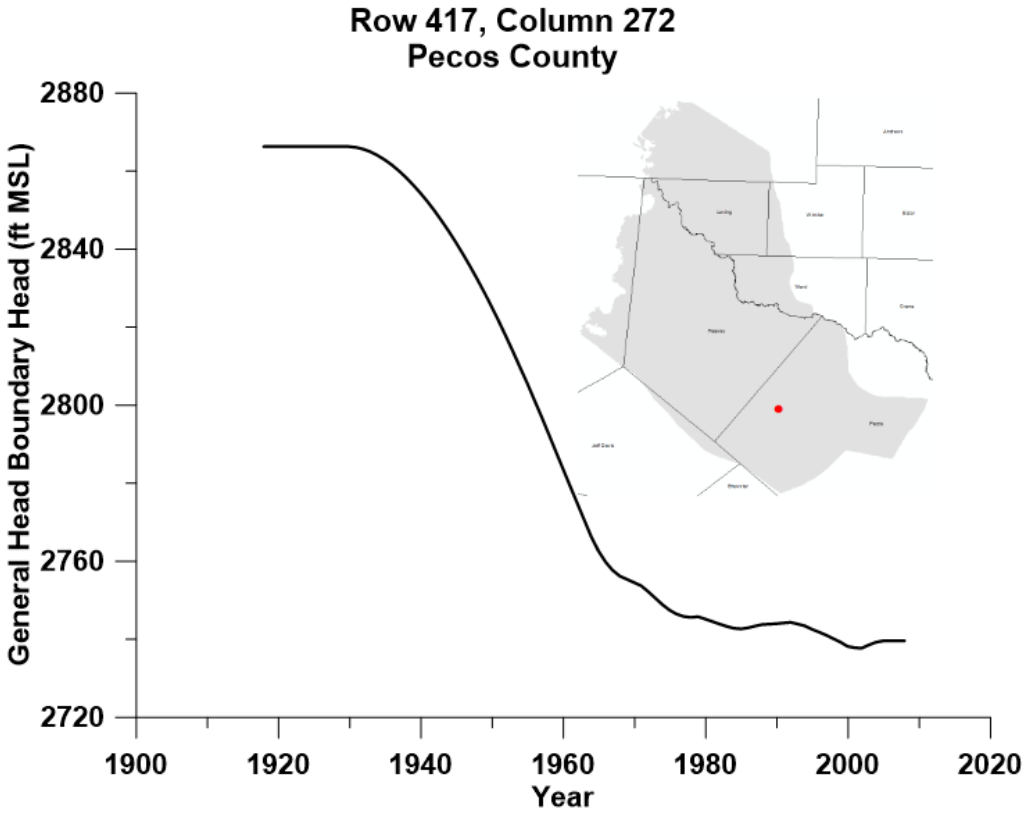
Reeves County
General Head Boundary Head (ft MSL)
2880
2860
2840
2820
2800
1900
1920
1940
1960
1980
2000
2020
Year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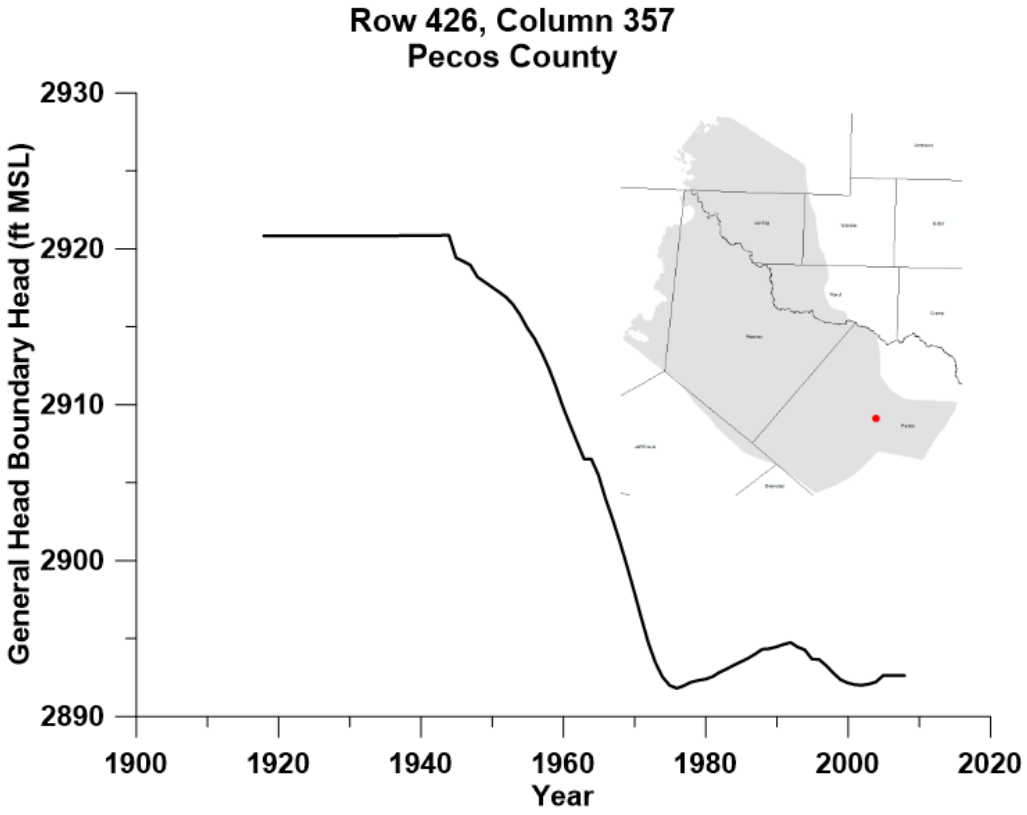
Pecos County
General Head Boundary Head (ft MSL)
2880
2840
2800
2760
2720
1900
1920
1940
1960
1980
2000
2020
Year


Row 426, Column 357
Pecos County
General Head Boundary Head (ft MSL)
2930
2920
2910
2900
2890
1900
1920
1940
1960
1980
2000
2020
Year