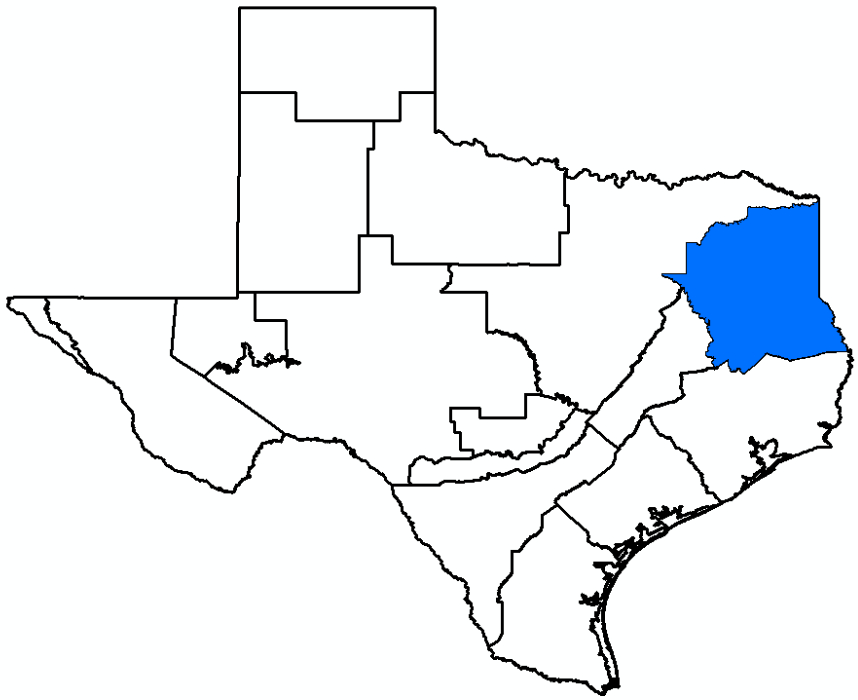
GMA 11 Technical Memorandum 16-02
Draft 2

Use of Predictive Simulation Results from Scenario 4 in Desired Future Conditions for Sparta, Queen City, and Carrizo-Wilcox Aquifers



Prepared for:
Groundwater Management Area 11

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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. Due to issues with the model and uncertainties with pumping estimates in the area, the effort to update the calibration period was not entirely successful. The effort to update the calibration period of the model is documented in Technical Memorandum 16-01.

In Technical Memorandum 15-01, it was assumed for purposes of calculating average drawdowns by county and model layer, that all areas with rising groundwater levels were attributable to the increased recharge, and that the actual drawdown could be considered zero. The basis of this assumption was that with a constant and average recharge and little or no pumping, no change in groundwater levels would be expected.

In evaluating the model results more closely during the effort to recalibrate the model, it appears that there are other factors that cause the rising groundwater levels. This apparently also contributed to the difficulties in updating the calibration period of the model. These factors are more fully discussed in Technical Memorandum 16-01.

The objective of this technical memorandum is to briefly summarize the results of Scenario 4 (the base case) in the context of developing a proposed desired future condition for the Sparta, Queen City, and Carrizo-Wilcox aquifers.

2.0 Summary of the Joint Planning Process

The joint planning process is a result of HB 1763 that was adopted by the Texas State Legislature in 2005. Every five years, groundwater conservation districts within a groundwater management area must adopt desired future conditions (DFCs) for relevant aquifers within the groundwater management area. Desired future conditions are defined as a quantified condition of groundwater at a specified time or times in the future. Once the desired future conditions are adopted, the Texas Water Development Board calculates the modeled available groundwater (MAG) for the aquifer, which is the amount of pumping that will achieve the desired future condition. The desired future condition is essentially a planning goal.

As a result of the definition of desired future condition (i.e. quantified condition), and the use of models to calculate the modeled available groundwater, groundwater availability models are an important aspect of developing desired future conditions. The Texas Water Development Board developed groundwater availability models for nearly all aquifers in the state. These are used by groundwater conservation districts and regional planning groups as tools to define groundwater availability. However, as with any model, there are limitations to their use. These limitations must be considered and understood when using the results or output from the model.

In 2010, GMA 11 adopted desired future conditions for the Sparta, Queen City, and Carrizo-Wilcox aquifers. The desired future conditions were expressed in terms of average drawdown from 2000 to 2060. The overall average drawdown for GMA 11 for all aquifers was 17 feet. A table was also included in the desired future condition resolution that listed average drawdown for each county and each model layer. This table was generated from a simulation using the groundwater availability model of the area. This approach provided a means for the Texas Water Development Board to calculate modeled available groundwater values.

The use of average drawdown for purposes of developing desired future conditions is often confusing and misunderstood. Common misunderstandings include stating that the average drawdown is the same everywhere in the entire area of interest (i.e. county). Variations in pumping locations and amounts, and the natural variation of aquifer hydraulic conductivity and thickness will always result in varying drawdowns within the area of interest. In general, a regional average positive drawdown suggests that pumping has increased during the period of interest. Zero drawdown suggests that pumping is relatively constant. Negative drawdown suggests that there has been a pumping reduction. However, as is developed further in this technical memorandum and in Technical Memorandum 16-01, the presence of "negative drawdowns", or groundwater level increases, are the result of model limitations.

In 2010, there were instances where simulated future pumping was less than historic pumping as defined in the calibrated model. This, as expected, resulted in groundwater level recoveries (i.e. negative drawdown). In other instances, (i.e. the Queen City Aquifer) pumping was significantly above historic amounts.

The development of the desired future conditions by GMA 11 in 2010 was based on evaluating a range of alternative model simulations, and understanding the impacts of different amounts of pumping. During the development of the desired future condition in 2010, there was virtually no public input, despite numerous efforts to seek input from key stakeholders in GMA 11 by groundwater conservation district representatives.

In response to specific input from various stakeholders, this round of joint planning included integration of the planned Forestar project and all the recommended and alternative water management strategies in the regional water plans from Region D and Region I. This additional pumping was included as a base case, and the effects of decreasing and increasing the base pumping was evaluated. The process also included a closer evaluation of the output of the model and addressing more fully the limitations of using the model to develop desired future conditions. A key objective of developing the base case was that all pumping was the same as or greater than historic pumping as a means to reduce or eliminate planned groundwater level recoveries. However, as developed in this technical memorandum, there continue to be instances of negative drawdown which are attributable to model limitations.

3.0 Scenario 4 Results

Scenario 4 results in the form of pumping and drawdown by county and model layer are summarized in Tables 1 and 2, respectively. Please note that the drawdown table (Table 2) is different from the one that appeared in Technical Memorandum 15-01 due to the correction for the assignment of cells (only cells in the official aquifer boundary are included in Table 2), and the average drawdown includes cells with rising groundwater levels (negative drawdown).

Table 1. Summary of Pumping for Scenario 4 (AF/yr)

County	Layer 1 (Sparta)	Layer 2 (Weches confining Unit)	Layer 3 (Queen City)	Layer 4 (Reclaw confining Unit)	Layer 5 (Carrizo)	Layer 6 (Upper Wilcox)	Layer 7 (Middle Wilcox)	Layer 8 (Lower Wilcox)	Overall
Anderson	616	0	20,853	0	9,893	9,748	9,147	281	50,538
Angelina	687	0	1,102	0	28,764	3,486	0	0	34,039
Bowie	0	0	0	0	0	1,468	7,167	358	8,993
Camp	0	0	4,202	0	1,965	1,111	969	2	8,249
Cass	0	0	39,114	0	9,162	4,285	3,350	856	56,767
Cherokee	358	0	23,058	0	6,512	9,683	4,262	0	43,873
Franklin	0	0	0	0	1,894	1,256	6,328	301	9,779
Gregg	0	0	7,568	0	4,363	2,501	1,171	0	15,603
Harrison	0	0	10,323	0	6,378	2,163	2,011	268	21,143
Henderson	0	0	15,838	0	6,303	2,774	2,053	2,444	29,412
Hopkins	0	0	0	0	478	232	3,194	2,484	6,388
Houston	1,492	0	2,321	0	9,142	8,274	9,006	0	30,235
Marion	0	0	15,456	0	1,861	556	303	4	18,180
Morris	0	0	9,355	0	1,188	403	971	5	11,922
Nacogdoches	407	0	4,994	0	12,314	11,094	771	1	29,581
Panola	0	0	0	0	660	770	5,763	869	8,062
Rains	0	0	0	0	0	449	1,000	295	1,744
Rusk	0	0	60	0	6,923	5,153	8,727	0	20,863
Sabine	295	0	0	0	4,212	1,691	469	469	7,136
SanAugustine	204	0	8	0	1,129	651	9	0	2,001
Shelby	0	0	0	0	828	3,314	4,853	104	9,099
Smith	0	0	58,866	0	16,157	14,775	4,933	0	94,731
Titus	0	0	183	0	1,591	1,904	5,938	33	9,649
Trinity	613	0	0	0	2,216	0	0	0	2,829
Upshur	0	0	27,127	0	4,189	2,324	614	0	34,254
VanZandt	0	0	4,877	0	2,203	1,549	4,128	2,084	14,841
Wood	0	0	10,105	0	13,036	5,904	2,279	3	31,327
GMA 11	**4,672**	**0**	**255,410**	**0**	**153,361**	**97,518**	**89,416**	**10,861**	**611,238**

Table 2. Summary of Average Drawdown (ft) from 2000 to 2070

County	Layer 1 (Sparta)	Layer 2 (Weches confining Unit)	Layer 3 (Queen City)	Layer 4 (Reclaw confining Unit)	Layer 5 (Carrizo)	Layer 6 (Upper Wilcox)	Layer 7 (Middle Wilcox)	Layer 8 (Lower Wilcox)	Overall
Anderson	-2	2	9	38	95	102	100	63	67
Angelina	16	18	20	56	113	60	7	14	43
Bowie						22	5		5
Camp			18	2	24	24	50		26
Cass			10	28	78	64	64		50
Cherokee	12	16	14	29	80	112	123	80	72
Franklin				-24	-3	8	23		13
Gregg			9	13	49	58	67	86	42
Harrison			1	5	36	21	10	4	15
Henderson			5	24	66	54	50	36	41
Hopkins				-27	-12	-19	-19	-215	-22
Houston	3	3	6	45	99	95	88	39	49
Marion			24	23	51	41	44		38
Morris			17	16	53	45	42		37
Nacogdoches	5	5	4	27	44	43	16	16	24
Panola				-21	6	1	0	5	2
Rains						8	-13	-6	-10
Rusk			-14	-3	8	9	34	38	20
Sabine	1	2		8	17	10	6	5	7
SanAugustine	-8	-7		10	22	13	-1	-2	4
Shelby				-23	15	-5	4	2	1
Smith		-4	17	42	119	138	116	102	87
Titus			1	-6	38	19	5		9
Trinity	9	9	10	44	97	56	32	23	32
Upshur		-6	9	21	66	78	82	115	54
VanZandt			11	15	41	18	22	15	20
Wood		-8	-3	39	119	91	62	127	66
GMA11	4	4	10	29	73	63	49	40	43

The average drawdown values in Table 2 were calculated by summing the drawdown in individual model cells in each county and in each model layer, and then dividing the sum by the number of active cells. The number of cells used accounted for cells that went dry during the simulation (i.e. groundwater level dropped below the bottom of the model layer and the cell was inactivated for the rest of the simulation). The cell count used to calculate average drawdown in 2070 is presented in Table 3.

Table 3. Number of Active Model Cells in 2070 used for Drawdown Calculation

County	Layer 1 (Sparta)	Layer 2 (Weches confining Unit)	Layer 3 (Queen City)	Layer 4 (Reclaw confining Unit)	Layer 5 (Carrizo)	Layer 6 (Upper Wilcox)	Layer 7 (Middle Wilcox)	Layer 8 (Lower Wilcox)	Overall
Anderson	89	150	853	1028	1036	1072	1075	1075	6378
Angelina	235	235	81	413	413	413	433	413	2636
Bowie	0	0	0	0	0	5	318	0	323
Camp	0	0	75	159	182	200	200	0	816
Cass	0	0	729	823	794	944	958	0	4248
Cherokee	126	208	834	1029	1061	1062	1062	1062	6444
Franklin	0	0	0	7	46	78	156	0	287
Gregg	0	0	168	266	273	273	273	14	1267
Harrison	0	0	230	369	389	554	909	20	2471
Henderson	0	0	427	485	510	630	723	794	3569
Hopkins	0	0	0	5	16	49	276	6	352
Houston	1057	1132	1103	1212	1212	1212	1221	1212	9361
Marion	0	0	233	333	339	402	422	0	1729
Morris	0	0	134	180	178	224	264	0	980
Nacogdoches	343	482	386	786	914	964	976	975	5826
Panola	0	0	0	3	5	168	822	453	1451
Rains	0	0	0	0	0	14	154	52	220
Rusk	0	0	21	282	601	943	944	663	3454
Sabine	239	244	0	186	211	303	318	303	1804
SanAugustine	322	328	0	325	383	429	441	429	2657
Shelby	0	0	0	12	5	450	833	831	2131
Smith	0	199	884	935	949	955	955	870	5747
Titus	0	0	18	51	33	148	344	0	594
Trinity	202	202	58	112	112	112	130	112	1040
Upshur	0	11	555	586	596	596	596	93	3033
VanZandt	0	0	106	139	163	341	530	610	1889
Wood	0	50	414	503	543	654	700	36	2900
GMA11	2613	3241	7309	10229	10964	13195	16038	10023	73612

4.0 Discussion of Scenario 4 Results in the Context of Desired Future Conditions

4.1 Areas with Negative Drawdown

Table 4 summarizes the 24 instances of negative drawdown in Table 2. Table 4 includes the county, model layer, the calculated drawdown, number of active cells in the model, the number of dry cells in the area in 2070, the pumping, and the percentage of the area in the GMA 11 portion of the county. The table is sorted with the smallest number of active cells at the top and the largest number of active cells at the bottom.

For example, the most dramatic groundwater rise occurs in Hopkins County in Layer 8 (215 feet). This is the average rise in six model cells (six square miles). This six square mile area represents 2.1 percent of the area of Hopkins County that is in GMA 11.

Table 4. Summary of Counties with Negative Drawdowns

County	Layer	Drawdown (ft) 2000 to 2070	Number of Active Cells	Number of Dry Cells	Pumping (AF/yr)	Percent of Active Area to Total Area of County in GMA 11
Panola	4	-21	3	0	0	0.36
Hopkins	4	-27	5	0	0	1.75
Hopkins	8	-215	6	0	2,484	2.10
Franklin	4	-24	7	0	0	4.43
Upshur	2	-6	11	0	0	1.85
Shelby	4	-23	12	0	0	1.44
Hopkins	5	-12	19	3	478	5.59
Rusk	3	-14	21	0	60	2.22
Franklin	5	-3	48	2	1,894	29.11
Hopkins	6	-19	49	0	232	17.13
Wood	2	-8	50	0	0	7.14
Titus	4	-6	51	0	0	11.97
Rains	8	-6	52	0	295	31.52
Anderson	1	-2	89	0	616	8.28
Rains	7	-13	154	0	1,000	93.33
Smith	2	-4	199	0	0	20.84
Hopkins	7	-19	282	6	3,194	96.50
Rusk	4	-3	282	0	0	29.87
SanAugustine	1	-8	322	0	204	53.76
SanAugustine	2	-7	328	0	0	54.76
Wood	3	-3	414	0	10,105	59.14
SanAugustine	8	-2	429	0	0	71.62
SanAugustine	7	-1	441	0	9	73.62
Shelby	6	-5	451	1	3,314	54.02

Note that 16 of the 24 instances of negative drawdown are in areas of less than 200 model cells (200 square miles). Due to the small size, it is unlikely that regional groundwater monitoring would include a small area such as these, and these areas should not be considered relevant for purposes of joint planning.

Of the eight entries in Table 4 that are greater than 200 square miles, one is in model layer 2 and one is in model layer 4. These are confining units, and all of layer 2 and layer 4 should be considered not relevant for purposes of joint planning (i.e. desired future conditions are only defined for aquifer units).

The remaining six entries in Table 4 include one entry for Hopkins County (layer 7), three entries for San Augustine County (layers 1, 7 and 8), one entry for Shelby County (layer 6), and one entry for Wood County (layer 3). Maps with all areas with negative drawdowns were presented in Appendix D of Technical Memorandum 15-01.

These areas were examined more closely by examining the annual change in drawdown from both the calibrated model and the results of Scenario 4. For example, Figure 1 presents the time-history of average groundwater level change in San Augustine County for layer 8 (Lower Wilcox Aquifer). Please note that the base time is the end of 1999 (the end of the calibration period). Thus, the values that are plotted represent the difference between that year and 1999, whether the particular year is from 1975 to 1999 (the calibration period) or 2000 to 2070 (the predictive simulation period).

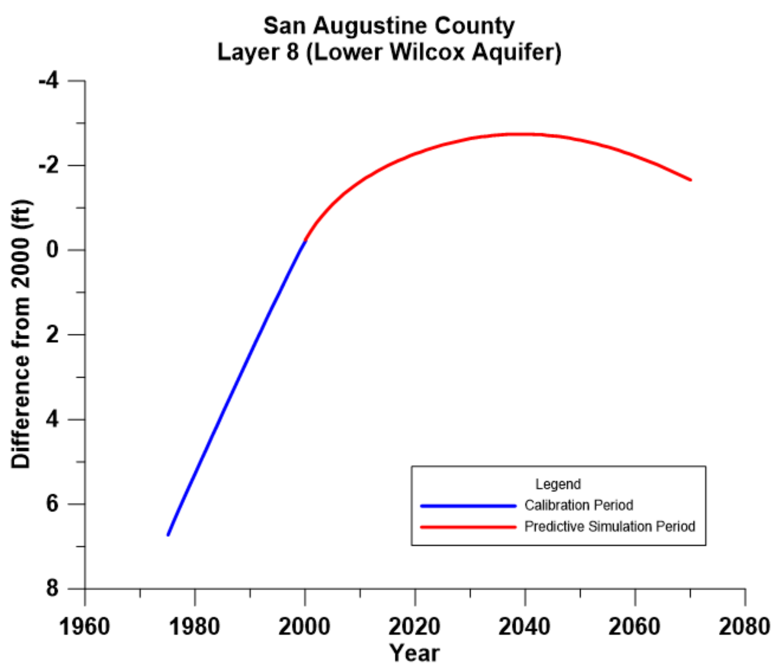

Figure 1. Change in Average Groundwater Level in San Augustine County in the Lower Wilcox Aquifer (1975-2070)

Note that during the calibration period, average groundwater levels rose about 7 feet from 1975 to 1999. This suggests that the model is not simulating actual conditions well. The model conditions that caused the rise from 1975 to 1999 continue to affect the change in average groundwater levels after 2000 (the simulation period). The rise continues until about 2030, and the model predicts a drop in average groundwater level after this peak. However, the decline from 2030 to 2070 leaves the average groundwater level higher than the average level in 2000 (the start of the simulation period). Please recall from Table 4, presented above, that there is no pumping from the Lower Wilcox Aquifer in San Augustine County, and there are no dry cells that would have affected the calculation. This is an example of a model limitation that needs to be taken into account when using the results of the model in considering desired future conditions.

If it assumed that the negative drawdown areas can be eliminated from the average drawdown calculation due to model limitations, the recalculated drawdowns can be substituted in Hopkins County (layer 7), San Augustine County (layers 1, 7 and 8), Shelby County (layer 6), and entry for Wood County (layer 3).

4.2 Aquifer-Based Desired Future Conditions

At the March 22, 2016 GMA 11 meeting, the representatives from the groundwater conservation districts requested that desired future conditions be expressed for each aquifer as defined by the Texas Water Development Board. This request was made after a discussion of the potential issues associated with monitoring groundwater levels in wells that would be compared to the desired future condition in areas where the actual completion interval is difficult to interpret (i.e. distinction between the Upper Wilcox, Middle Wilcox and Lower Wilcox).

As a result, the desired future conditions will be established as follows:

- For the Sparta Aquifer, the layer 1 drawdowns in Table 2 will be used with the exception of San Augustine County, where it is assumed that all negative drawdowns are zero, and the recalculated drawdown is substituted.
- For the Queen City Aquifer, the layer 3 drawdowns in Table 2 will be used with the exception of Wood County, where is assumed that all negative drawdowns are zero, and the recalculated drawdown is substituted.
- For the Carrizo-Wilcox Aquifer, the average drawdown is calculated as the sum of drawdowns in layers 5, 6, 7, and 8 is divided by the sum of active cells in layers 5, 6, 7, and 8.

5.0 Recommendations for Desired Future Conditions

Based on the discussion in Section 4 of this technical memorandum, Table 5 presents the drawdowns that can be considered for desired future conditions. These recommendations differ from the raw output of Scenario 4 as follows:

- Layers 2 and 4 (the confining units) are eliminated, and Table 4 includes only aquifer units. Areas that have no active cells are designated as NP (for not present).
- Layers 5, 6, 7, and 8 are combined, and a single drawdown value for the Carrizo-Wilcox Aquifer are provided
- All areas in Table 2 that are less than 200 square miles are either eliminated (noted as NRS, or not relevant for purposes of joint planning due to size of area).
- Areas with negative drawdown in Table 2 that are greater than 200 square miles have had the negative drawdown cells eliminated from the average drawdown calculation, effectively assuming that those cells have a zero drawdown, and that the negative drawdown areas are a result of model limitations, as discussed (designated in yellow).
- The desired future condition in Panola County for the Carrizo-Wilcox Aquifer is listed as 3 feet. The actual average using all data from the model is 2 feet. If the areas with negative drawdown are assumed to be zero, the revised average is 4 feet. As presented at the March 22, 2016 GMA 11 meeting, Mr. Wade Oliver (representing the Panola County GCD) evaluated the average drawdown under Scenario 4 using an alternative analytical modeling approach and concluded that the drawdown was 3 feet. Thus, Mr. Oliver's result is consistent with the midpoint between the two GAM-based drawdown approaches.

Table 6 presents the pumping amounts associated with the drawdowns in Scenario 4, and essentially represent the values that the Texas Water Development Board would calculate for modeled available groundwater using the county-aquifer split that is shown in the table.

Table 5. Recommended Drawdown for Use as Desired Future Conditions (2000 to 2070 in feet)

County	Sparta Aquifer	Queen City Aquifer	Carrizo-Wilcox Aquifer
Anderson	NRS	9	90
Angelina	16	NRS	48
Bowie	NP	NP	5
Camp	NP	NRS	33
Cass	NP	10	68
Cherokee	NRS	14	99
Franklin	NP	NP	14
Gregg	NP	NRS	58
Harrison	NP	1	18
Henderson	NP	5	50
Hopkins	NP	NP	3
Houston	3	6	80
Marion	NP	24	45
Morris	NP	NRS	46
Nacogdoches	5	4	29
Panola	NP	NP	3
Rains	NP	NP	1
Rusk	NP	NRS	23
Sabine	1	NP	9
SanAugustine	2	NP	7
Shelby	NP	NP	1
Smith	NP	17	119
Titus	NP	NRS	11
Trinity	9	NRS	51
Upshur	NP	9	77
VanZandt	NP	NRS	21
Wood	NP	5	89
GMA11	4	10	56

Notes: NP = Not present
NRS = Not Relevant due to size (less than 200 square miles)
Yellow Cells represent average drawdown calculations that assume negative drawdown is zero (model artifact and model
Green Cell represents the recommended DFC for Panola County as described in report

Table 6. Summary of Pumping to Achieve Drawdowns (AF/yr)

County	Sparta Aquifer	Queen City Aquifer	Carrizo-Wilcox Aquifer
Anderson	616	20,853	29,069
Angelina	687	1,102	32,250
Bowie		0	8,993
Camp		4,202	4,047
Cass		39,114	17,653
Cherokee	358	23,058	20,457
Franklin			9,779
Gregg		7,568	8,035
Harrison		10,323	10,820
Henderson		15,838	13,574
Hopkins			6,388
Houston	1,492	2,321	26,422
Marion		15,456	2,724
Morris		9,355	2,567
Nacogdoches	407	4,994	24,180
Panola			8,062
Rains			1,744
Rusk		60	20,803
Sabine	295		6,841
San Augustine	204		1,789
Shelby			9,099
Smith		58,866	35,865
Titus		183	9,466
Trinity	613	0	2,216
Upshur		27,127	7,127
VanZandt		4,877	9,964
Wood		10,105	21,222
GMA 11	**4,672**	**255,402**	**351,156**