Draft Technical Memorandum 3

Recharge Sensitivity

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August 26, 2022

Draft Technical Memorandum 3

Professional Engineer and Professional Geoscientist Seals

This report was prepared by William R. Hutchison, Ph.D., P.E., P.G., who is licensed in the State of Texas as follows:

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1.0 Executive Summary

This technical memorandum documents the recharge sensitivity simulations completed with the new GAM. Recharge sensitivity was evaluated by simulating variations in recharge and observing the change in average drawdown. The recharge sensitivity simulations consisted of two groups of five simulations. The first group assumed constant pumping at 2011 amounts and locations, the second group assumed constant pumping at 2017 amounts and locations. The five simulations in each group varied the baseline recharge (increased and decreased) as follows:

- Scenario 1: 80% of Baseline recharge
- Scenario 2: 90% of Baseline recharge
- Scenario 3: 100% of Baseline recharge
- Scenario 4: 110% of Baseline recharge
- Scenario 5: 120% of Baseline recharge

Results of the simulations included average drawdown and outcrop area volume remaining.

2.0 Background

One of the uses of the updated Groundwater Availability Model for the Southern Portion of the Queen City, Sparta, and Carrizo-Wilcox aquifers documented in the main report will be to support the Joint Planning Process that leads to the adoption of desired future conditions by the groundwater conservation districts in Groundwater Management Area 13 and the calculation of the modeled available groundwater by TWDB. As part of the work associated with developing the updated Groundwater Availability Model, five technical memoranda appear in the Appendix of the report:

- Technical Memorandum 1: Pumping Comparisons
- Technical Memorandum 2: Pumping Sensitivity
- Technical Memorandum 3: Recharge Sensitivity
- Technical Memorandum 4: Calculation of Drawdown from Existing Modeled Available Groundwater Using Updated Groundwater Availability Model
- Technical Memorandum 5: Calculation of Future Pumping from Existing Desired Future Conditions Using Updated Groundwater Availability Model

This technical memorandum summarizes a sensitivity analysis of recharge as measured by average drawdown in GMA 13.

3.0 Parameters and Assumptions

Recharge sensitivity was evaluated by simulating variations in recharge and observing the change in average drawdown. Section 3.1 documents the model files used in the simulations. Section 3.2 documents the pumping files used in the simulations. Section 3.3 documents the calculation of average drawdown.

3.1 Model Files

The directory on the share site named *BaseFiles* contains all model files for the simulations other than the simulated pumping files.

3.1.1 Files Unchanged from Calibrated Model

Table 1 presents the model files that were unchanged from the calibration run of the model.

Table 1. Model Files Unchanged from Calibrated Model

File Name	File Date	Description
GMA13_Historical_Period_Calibration._kx	5/10/2022	Horizontal hydraulic conductivity
GMA13_Historical_Period_Calibration._kz	5/10/2022	Vertical hydraulic conductivity
GMA13_Historical_Period_Calibration._ss	5/10/2022	Specific storage
GMA13_Historical_Period_Calibration._sy	5/10/2022	Specific yield
GMA13_Historical_Period_Calibration.dis	5/10/2022	Discretization
GMA13_Historical_Period_Calibration.hfb	5/10/2022	Horizontal fflow barrier
GMA13_Historical_Period_Calibration.ims	5/10/2022	Solver
GMA13_Historical_Period_Calibration.npf	5/10/2022	Node property flow

3.1.2 Files Modified from the Calibrated Model

Table 2 presents the model files that were modified from the calibration run of the model in order to run the sensitivity simulations. The pumping and recharge files are discussed in the next subsection.

Table 2. Model Files Modified from the Calibrated Model

File Name	File Date	Description
calsp39hds.dat	5/27/2022	Starting heads
mfsim.nam	5/27/2022	Simulation name file
pred.evt	5/25/2022	Evapotranspiration
pred.ghb	5/25/2022	General head boundary
pred.ic6	5/27/2022	Initial condition file
pred.oc6	5/26/2022	Output control
pred.riv	5/25/2022	River
pred.sto	5/25/2022	Storage
pred.tdis	5/25/2022	Time discretization
predbase.nam	5/26/2022	GWF Model name file

The modifications were generally associated with using the final stress period from the calibrated model and holding all parameters constant for the sensitivity simulation, which was run from 2018 to 2080 (63 stress periods). Modifications also included updating the file names for the simulations. Please note that no recharge and pumping file is listed above. It was not part of the general group of modified files and not included in this directory. Details of the recharge and pumping files used for these sensitivity simulations are provided below.

3.2 Pumping and Recharge Files

The recharge sensitivity simulations consisted of two groups of five simulations. The first group assumed constant pumping at 2011 amounts and locations, the second group assumed constant pumping at 2017 amounts and locations. The five simulations in each group varied the baseline recharge (increased and decreased) as follows:

- Scenario 1: 80% of Baseline recharge
- Scenario 2: 90% of Baseline recharge
- Scenario 3: 100% of Baseline recharge
- Scenario 4: 110% of Baseline recharge
- Scenario 5: 120% of Baseline recharge

It was assumed that recharge and pumping were constant from 2018 to 2080 (the full simulation).

The directory named *Rech* on the share site contains the five recharge files that were used in the sensitivity simulations (*scen1.rch* to *scen5.rch*).

Pumping files included were labeled *p2011scen3.wel* and *p2017scen3.wel*. The year after the "*p*" is the baseline year for pumping, and "scen3" designates the 100 percent of the baseline pumping as documented in Technical Memorandum 2.

3.3 Average Drawdown Calculation

3.3.1 Grid Counts and Acreage

Model output includes groundwater elevation results for each model cell. Drawdown can be calculated by subtracting the groundwater elevation in a specific cell over two different time periods. Average drawdown can be calculated by averaging the drawdown results in multiple cells. Typical average drawdown calculations involve county-aquifer units or GMA-aquifer units.

The old GAM had a regular grid where all cells were 640 acres, or one square mile. Averaging drawdowns with the old GAM was a relatively simple calculation of summing all drawdown results over a defined area and dividing the sum by the number of cells.

The new GAM has a variable grid that is refined near streams, and the cell sizes range from 10 acres to 640 acres. Thus, averaging drawdown must be weighted by the cell size. Appendix A contains summary tables of cell counts, areas, and average cell size for each county-aquifer unit for outcrop, downdip and total areas. Appendix A also presents bar graphs of the average cell size for each county-aquifer unit. Data for these tables and graphs was developed using a FORTRAN code that read the grid file of the new GAM. All data associated with the tables and graphs in Appendix A are contained in the directory named *GridFile* on the share site.

3.3.2 Average Drawdown Calculations

Average drawdown calculations were performed using a FORTRAN post-processor named *CalibDD.exe* (for the calibration period) and *PredDD.exe* (for the predictive period). The post-processor reads the simulation output file (a *hds* file) and the files with acreage totals for each unit (county-aquifer and GMA13-aquifer). Drawdowns for each cell are calculated based on a starting point of 2017 (the last stress period of the calibration period). The cell drawdown values are then multiplied by the cell acreage (drawdown-acreage product). The sum of all drawdown-acreage products for a particular unit (county-aquifer or GMA13-aquifer) are then divided by the total acreage of that unit to obtain an average drawdown.

The source code, executable and all files associated with these calculations are contained in the directory *CalibDD* (for the calibration period) and the directory *PredDD* (for the predictive period) on the share site. Please note that the directory *PredDD* also includes the results from the pumping sensitivity simulations that are the subject of Technical Memorandum 2.

The overall GMA 13 drawdown files are contained in the directory *AllAqGMA13* on the share site. A post-processor named *TotPredDD.exe* was developed to read the GMA 13 files from the predictive simulations and calculate overall average drawdowns for all aquifers (Sparta, Queen City, and Carrizo-Wilcox).

3.3.3 Volumetric/Saturated Thickness Calculations

The current DFC for GMA 13 includes a "Primary" DFC that covers the Sparta, Queen City, and Carrizo-Wilcox aquifers in GMA 13: "75 percent of the saturated thickness in the outcrop at the end of 2012 remains at the end of 2080". It was noted that this DFC could not be simulated with the old GAM. One of the key objectives of this update was to improve the GAM so that this type of calculation could be completed.

As part of this model evaluation in the context of predictive simulations that are similar to those that might be used by GMA 13 in the future, calculations using model output were completed to demonstrate that the new GAM can provide results that would be useful in the next round of joint planning. These calculations involved a volumetric analysis to provide additional context to saturated thickness calculations. The volume of groundwater in each model cell was calculated as:

Volume (Acre-feet) = Saturated Thickness (ft) * Cell Area (acres) * Specific Yield (dimensionless)

The files associated with these calculations are provided on the share site under the directory *SatThick*. A FORTRAN post-processor named *SatThick.exe* was developed to read the model grid file, read the starting heads and predictive heads, and calculate volumes for each aquifer's outcrop area for all of GMA 13. These results were then imported into an Excel file named *VolumeSummary.xlsx* that contains the volumetric calculations for each aquifer (and total) and calculates the percentage remaining volume using 2017 as the baseline for each aquifer (and total).

4.0 Methods and Results

4.1 Average Drawdown

The calculated average drawdowns for the calibration period and the predictive period are contained in files for each county-aquifer unit (or county-GMA13) are contained in files with 12 columns of results organized as follows:

- Column 1 = County Code
- Column 2 = County Name
- Column 3 = Year
- Column 4 = Sparta Aquifer drawdown from 2017 (outcrop area)
- Column 5 = Sparta Aquifer drawdown from 2017 (downdip area)
- Column 6 = Sparta Aquifer drawdown from 2017 (total area)
- Column 7 = Queen City Aquifer drawdown from 2017 (outcrop area)
- Column 8 = Queen City Aquifer drawdown from 2017 (downdip area)
- Column 9 = Queen City Aquifer drawdown from 2017 (total area)
- Column 10 = Carrizo-Wilcox Aquifer drawdown from 2017 (outcrop area)
- Column 11 = Carrizo-Wilcox Aquifer drawdown from 2017 (downdip area)
- Column 12 = Carrizo-Wilcox Aquifer drawdown from 2017 (total area)

Names of the calibration period files start with the base name *CalibDD* and are followed by the county name (or GMA13). Names of the predictive period files start with a *r* (for recharge scenarios) and the year of the base pumping (either 2011 or 2017) and the recharge scenario (*scen1* to *scen5*) followed by the county (or GMA13).

The overall predictive drawdown files for GMA 13 are named with a *r* (for recharge scenarios) and the year of the base pumping (either 2011 or 2017) and the pumping scenario (*s1* to *s5*) followed by *tot*. These files have four columns: the year followed by the outcrop area drawdown, the downdip area drawdown, and the total area drawdown. The calibration period overall drawdown file is named *bigavgcaldd.dat*. The columns of the calibration file are the same as the predictive files.

Appendix B presents the hydrographs of average drawdown for the Sparta, Queen City, and Carrizo-Wilcox aquifers for GMA 13. Included are hydrographs of the outcrop area, the downdip area, and the total area. The calibration period is presented along with the results of the five simulations using 2011 as the base pumping and with the results of the five simulations using 2017 as the base pumping.

Note that, generally, drawdown stabilizes after some initial adjustment period, either as an overall rise or decline in average groundwater level depending on the amount of pumping. This suggests that the model is suitable for use in evaluating alternative pumping scenarios related to the joint planning process, even in the outcrop area. Also, please note that the sensitivity to recharge is greater in the outcrop area than it is in the downdip area.

4.2 Remaining Volume in the Outcrop Area

As noted above, the results of the model were processed, and the Excel file named *VolumeSummary.xlsx* contains the volumetric calculations for each aquifer (and total) and calculates the percentage remaining volume using 2017 as the baseline for each aquifer (and total).

Figure 1 presents the initial (2017) outcrop area volume for the Sparta, Queen City, Carrizo-Wilcox aquifer, a total of the three aquifers, and the 75 percent of the total (the primary DFC). Please note that the Queen City Aquifer initial storage is significantly higher than the initial storage in the Sparta and Carrizo-Wilcox aquifers.

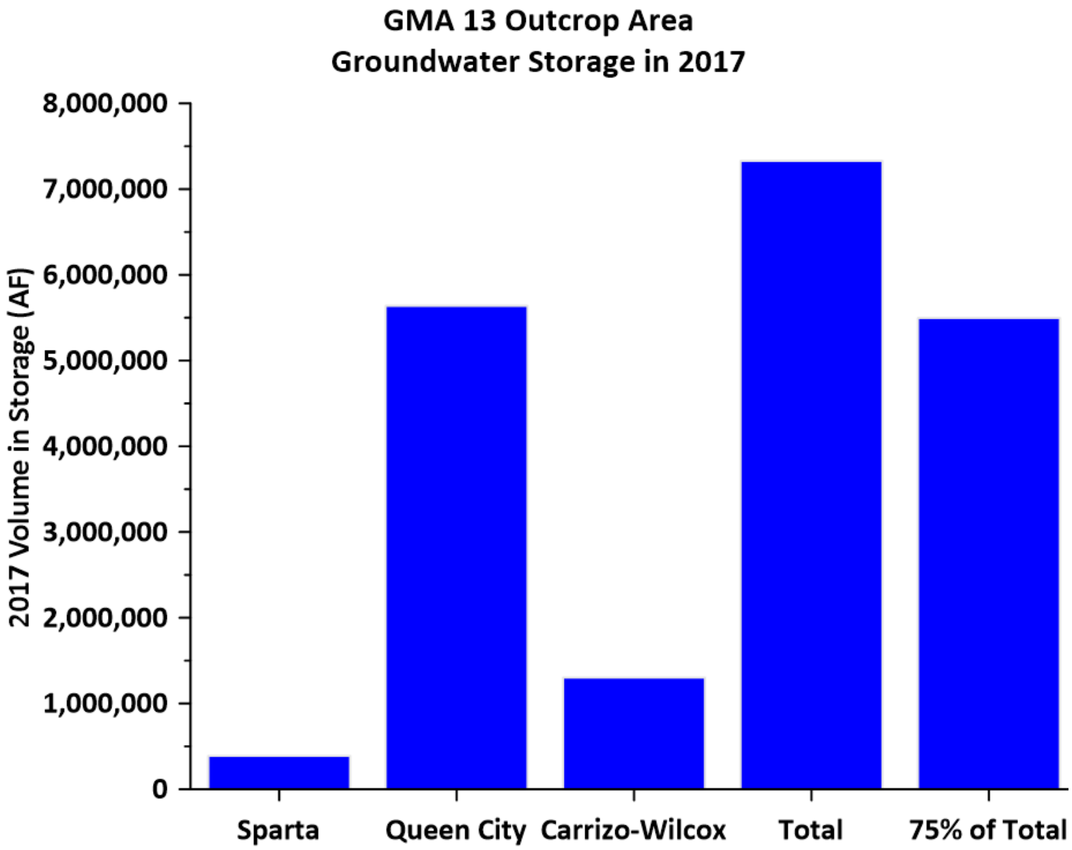


Figure 1. GMA 13 Outcrop Area Groundwater Storage in 2017

Appendix C presents the hydrographs of the volume remaining. Please note that the worst-case scenario (80 percent of average annual recharge with 2011 base pumping) in the Carrizo-Wilcox yields a volume remaining of 84 percent in 2080 as compared to 2017 in the outcrop area. At the other end of the spectrum, a 120 of average annual recharge with 2017 pumping results in about an increase in outcrop groundwater storage in the Carrizo-Wilcox (104 percent of 2017 storage) in 2080. These ranges suggest that the new GAM is a suitable tool to evaluate volume remaining in the outcrop area in the joint planning process.

5.0 Limitations

The simulations using two alternative base pumping levels and five variations in recharge are not particularly realistic. Recharge would not rise or fall and remain constant for decades. These simulations were intended to demonstrate the stability of the model under controlled conditions to assess its utility in future simulations of prolonged drought conditions, if needed by GMA 13. These simulations demonstrate that the limitations associated with the old GAM have been corrected.

Appendix A

Grid Cell County and Acreage by County and Aquifer

Outcrop Area

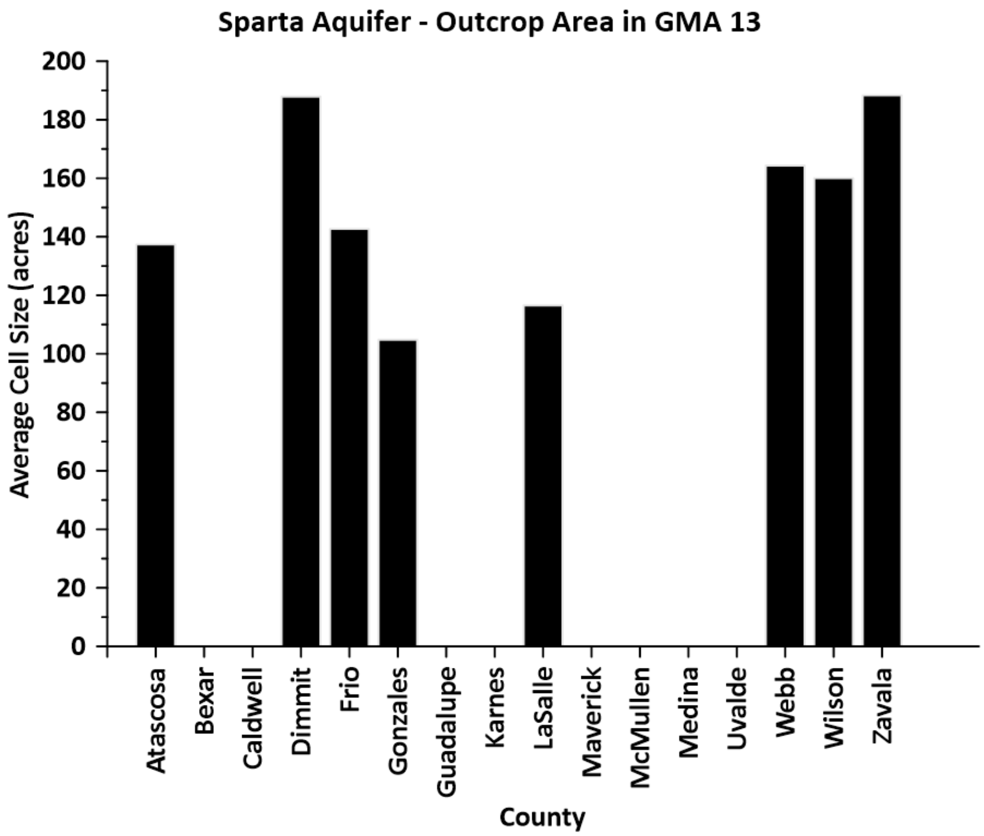
County Code	County Name	Cell Count			Area (Acres)			Average Cell Size (acres)		
		Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox
7	Atascosa	233	1,229	540	32,000	113,000	78,720	137	92	146
11	Bastrop	21	45	1,156	3,840	24,480	126,400	183	544	109
13	Bee	0	0	0	0	0	0	0	0	0
15	Bexar	0	0	2,022	0	0	207,360	0	0	103
28	Caldwell	0	90	1,615	0	10,560	205,600	0	117	127
59	DeWitt	0	0	0	0	0	0	0	0	0
64	Dimmit	417	3,759	991	78,360	477,480	157,000	188	127	158
75	Fayette	8	0	0	1,400	0	0	175	0	0
82	Frio	1,045	2,467	163	149,080	279,040	13,480	143	113	83
89	Gonzales	287	922	115	30,080	90,280	11,800	105	98	103
94	Guadalupe	0	4	1,125	0	640	218,880	0	160	195
128	Karnes	0	0	0	0	0	0	0	0	0
139	LaSalle	1,047	0	0	122,040	0	0	117	0	0
143	Lavaca	0	0	0	0	0	0	0	0	0
149	LiveOak	0	0	0	0	0	0	0	0	0
159	Maverick	0	0	1,180	0	0	130,120	0	0	110
162	McMullen	0	0	0	0	0	0	0	0	0
163	Medina	0	0	1,850	0	0	207,200	0	0	112
232	Uvalde	0	0	887	0	0	88,280	0	0	100
240	Webb	469	3,130	276	77,080	492,040	18,840	164	157	68
247	Wilson	148	967	662	23,680	140,560	85,760	160	145	130
254	Zavala	636	4,426	1,489	119,760	421,240	147,760	188	95	99
255	Mexico	237	323	890	57,720	59,960	152,720	244	186	172
999	GMA 13	4,485	17,204	13,062	686,520	2,078,480	1,629,360	153	121	125

Downdip Area

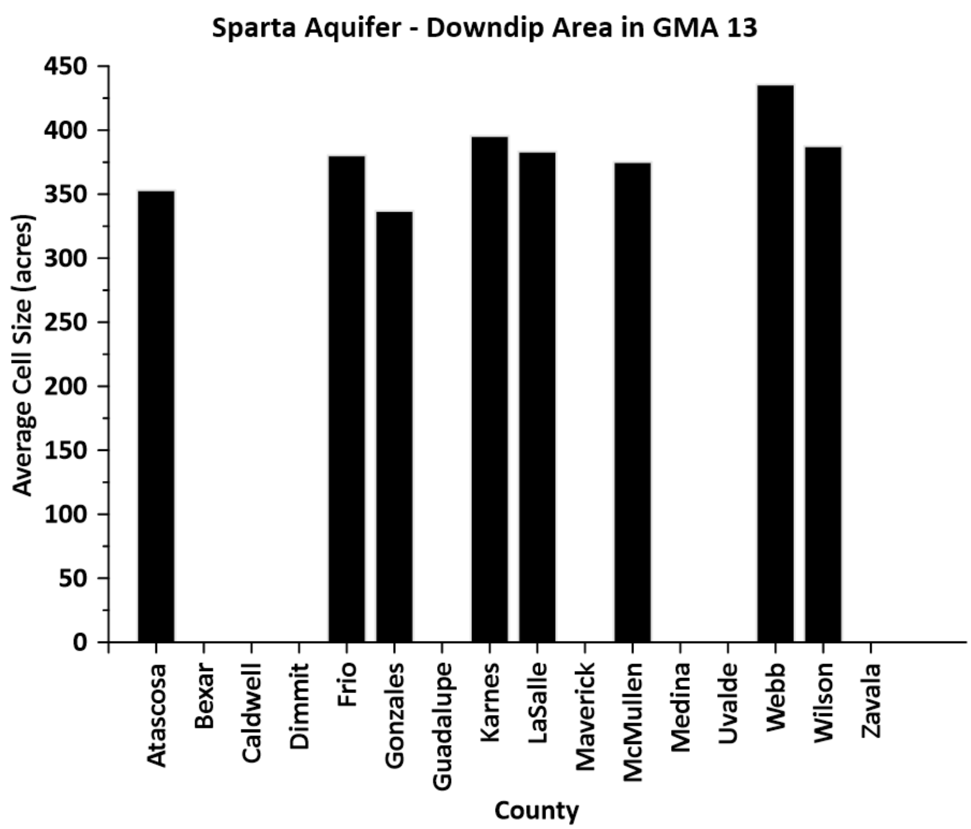
County Code	County Name	Cell Count			Area (Acres)			Average Cell Size (acres)		
		Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox
7	Atascosa	1,307	862	3,348	461,600	507,040	2,067,840	353	588	618
11	Bastrop	6	19	497	3,840	11,200	249,920	640	589	503
13	Bee	103	64	192	41,920	40,960	122,880	407	640	640
15	Bexar	0	0	239	0	0	96,320	0	0	403
28	Caldwell	0	0	537	0	0	231,840	0	0	432
59	DeWitt	883	543	1,629	350,080	347,520	1,042,560	396	640	640
64	Dimmit	0	192	3,473	0	104,640	2,091,200	0	545	602
75	Fayette	153	125	372	78,240	79,520	238,080	511	636	640
82	Frio	331	680	3,213	125,920	339,200	1,995,360	380	499	621
89	Gonzales	1,321	850	3,029	445,120	500,320	1,891,040	337	589	624
94	Guadalupe	0	0	330	0	0	160,800	0	0	487
128	Karnes	974	599	1,797	385,280	383,360	1,150,080	396	640	640
139	LaSalle	2,050	1,403	4,203	785,920	896,960	2,689,920	383	639	640
143	Lavaca	763	455	1,365	292,480	291,200	873,600	383	640	640
149	LiveOak	626	329	987	213,920	210,560	631,680	342	640	640
159	Maverick	0	0	140	0	0	41,120	0	0	294
162	McMullen	1,515	882	2,646	568,320	564,480	1,693,440	375	640	640
163	Medina	0	0	465	0	0	165,600	0	0	356
232	Uvalde	0	0	157	0	0	41,440	0	0	264
240	Webb	1,370	1,109	5,601	596,960	684,800	3,531,840	436	617	631
247	Wilson	443	394	2,201	171,680	217,600	1,322,240	388	552	601
254	Zavala	0	258	3,607	0	151,680	2,074,720	0	588	575
255	Mexico	597	664	3,130	294,720	414,400	1,890,880	494	624	604
999	GMA 13	8,770	7,071	35,498	3,338,560	4,240,800	21,479,360	381	600	605

Total Area

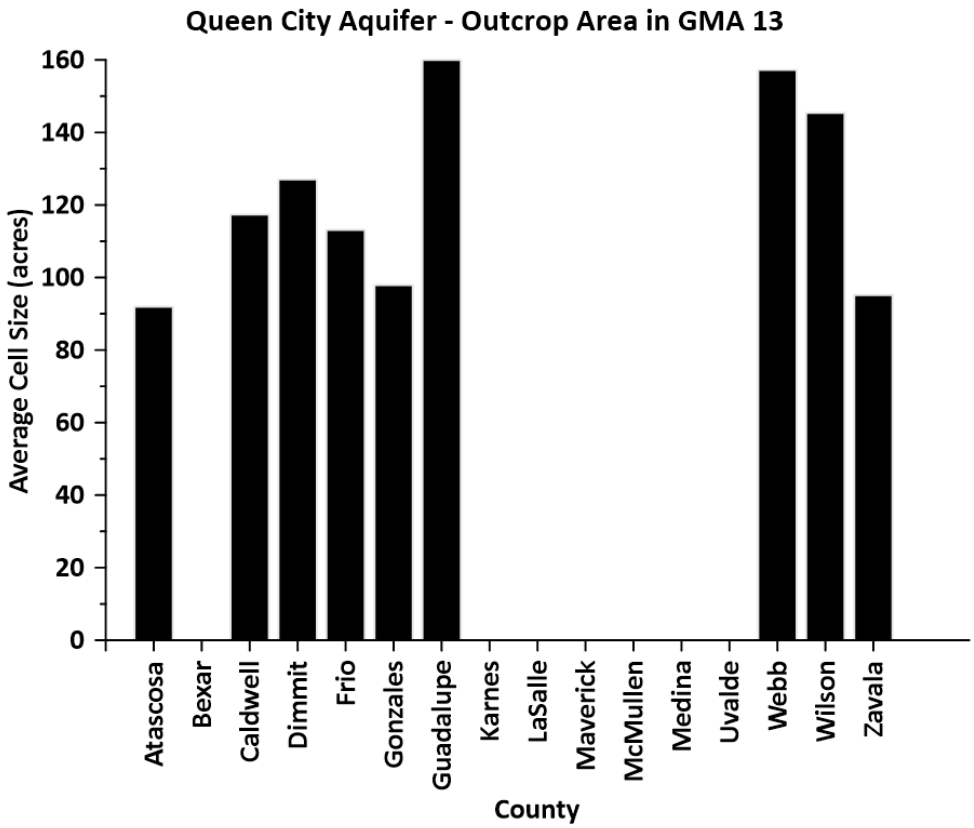
County Code	County Name	Cell Count			Area (Acres)			Average Cell Size (acres)		
		Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox	Sparta	Queen City	Carrizo-Wilcox
7	Atascosa	1,540	2,091	3,888	493,600	620,040	2,146,560	321	297	552
11	Bastrop	27	64	1,653	7,680	35,680	376,320	284	558	228
13	Bee	103	64	192	41,920	40,960	122,880	407	640	640
15	Bexar	0	0	2,261	0	0	303,680	0	0	134
28	Caldwell	0	90	2,152	0	10,560	437,440	0	117	203
59	DeWitt	883	543	1,629	350,080	347,520	1,042,560	396	640	640
64	Dimmit	417	3,951	4,464	78,360	582,120	2,248,200	188	147	504
75	Fayette	161	125	372	79,640	79,520	238,080	495	636	640
82	Frio	1,376	3,147	3,376	275,000	618,240	2,008,840	200	196	595
89	Gonzales	1,608	1,772	3,144	475,200	590,600	1,902,840	296	333	605
94	Guadalupe	0	4	1,455	0	640	379,680	0	160	261
128	Karnes	974	599	1,797	385,280	383,360	1,150,080	396	640	640
139	LaSalle	3,097	1,403	4,203	907,960	896,960	2,689,920	293	639	640
143	Lavaca	763	455	1,365	292,480	291,200	873,600	383	640	640
149	LiveOak	626	329	987	213,920	210,560	631,680	342	640	640
159	Maverick	0	0	1,320	0	0	171,240	0	0	130
162	McMullen	1,515	882	2,646	568,320	564,480	1,693,440	375	640	640
163	Medina	0	0	2,315	0	0	372,800	0	0	161
232	Uvalde	0	0	1,044	0	0	129,720	0	0	124
240	Webb	1,839	4,239	5,877	674,040	1,176,840	3,550,680	367	278	604
247	Wilson	591	1,361	2,863	195,360	358,160	1,408,000	331	263	492
254	Zavala	636	4,684	5,096	119,760	572,920	2,222,480	188	122	436
255	Mexico	834	987	4,020	352,440	474,360	2,043,600	423	481	508
999	GMA 13	13,255	24,275	48,560	4,025,080	6,319,280	23,108,720	304	260	476

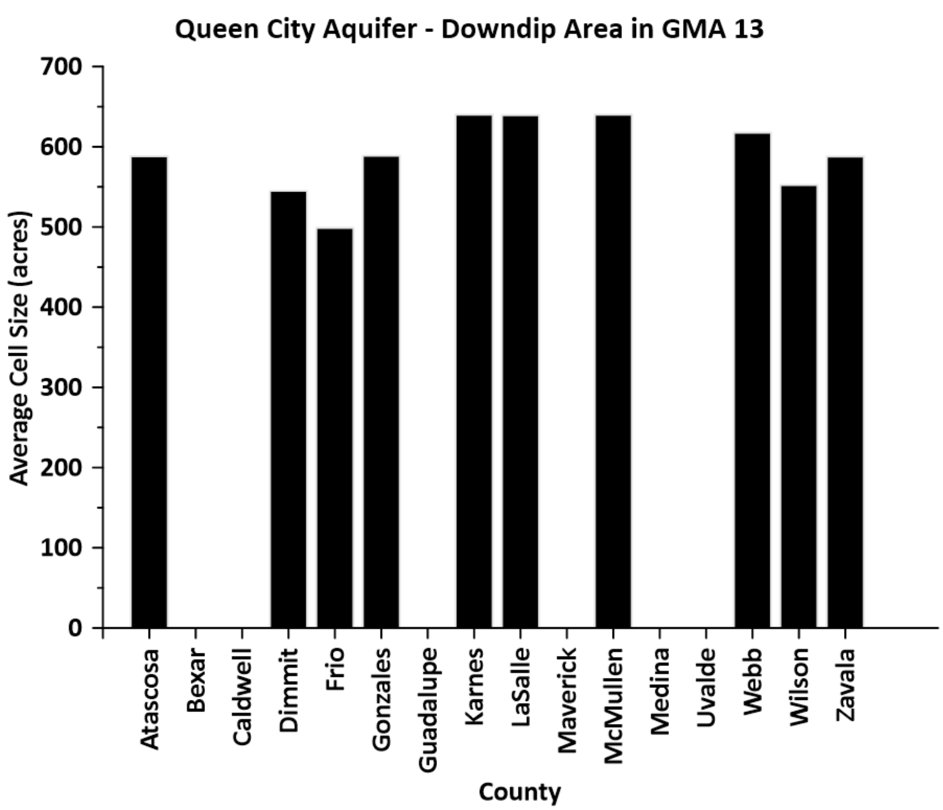


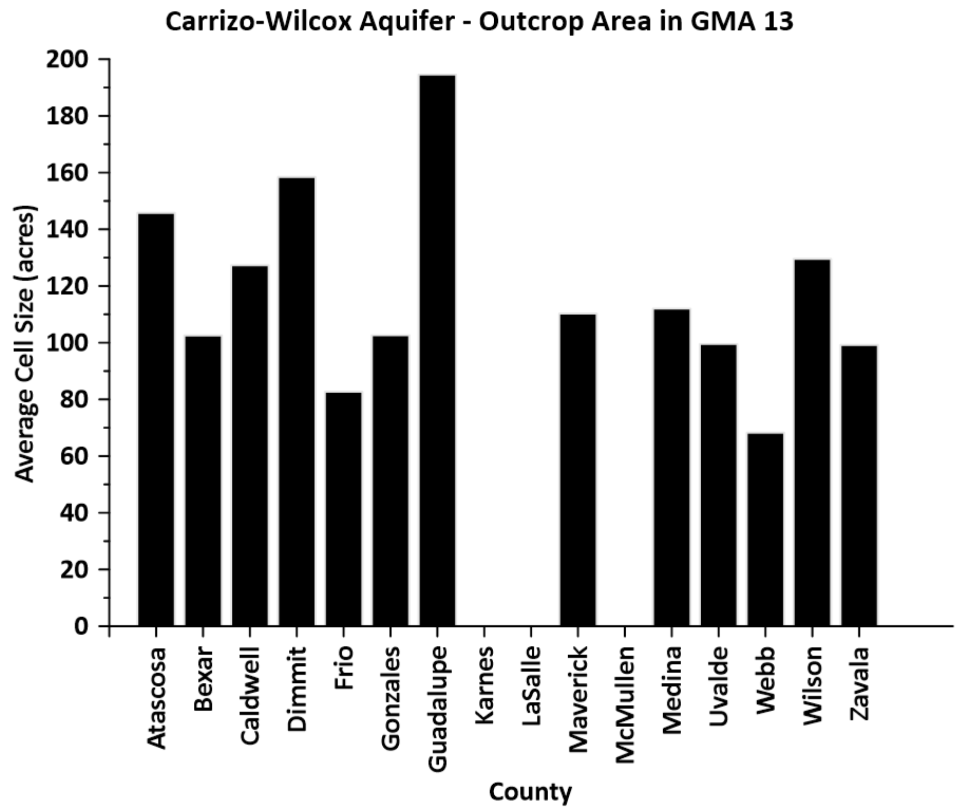
Sparta Aquifer - Outcrop Area in GMA 13
Average Cell Size (acres)
0
20
40
60
80
100
120
140
160
180
200
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County

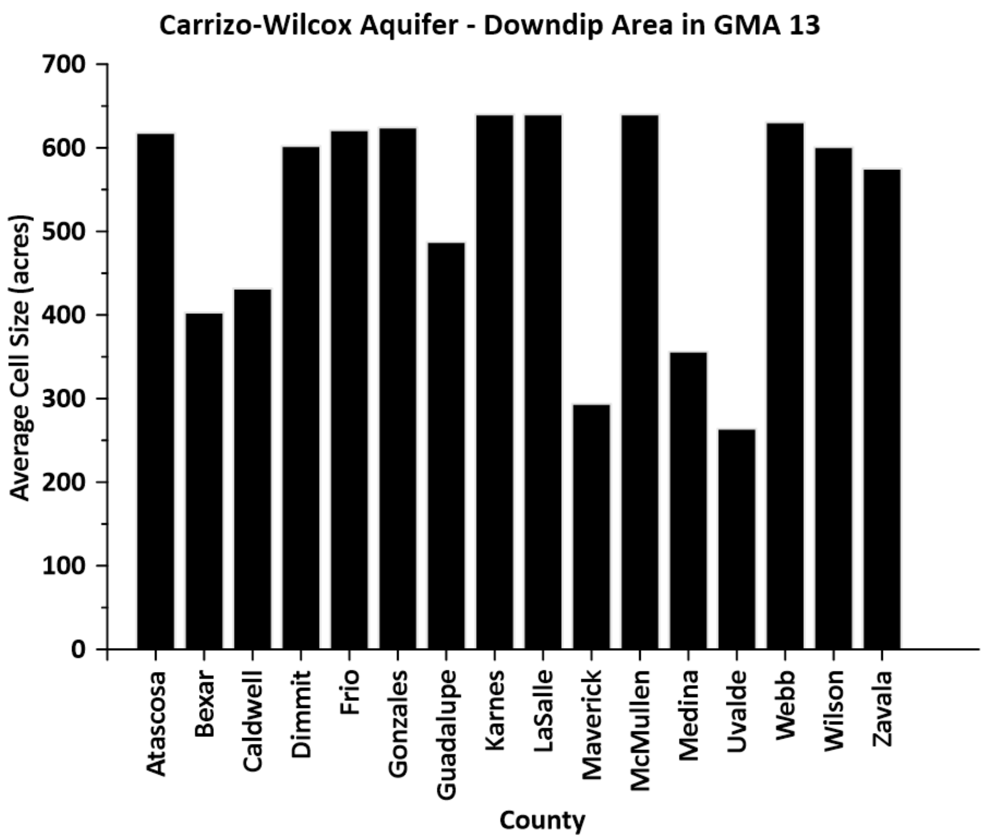


Sparta Aquifer - Downdip Area in GMA 13
Average Cell Size (acres)
0
50
100
150
200
250
300
350
400
450
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County


Queen City Aquifer - Outcrop Area in GMA 13
Average Cell Size (acres)
0
20
40
60
80
100
120
140
160
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County

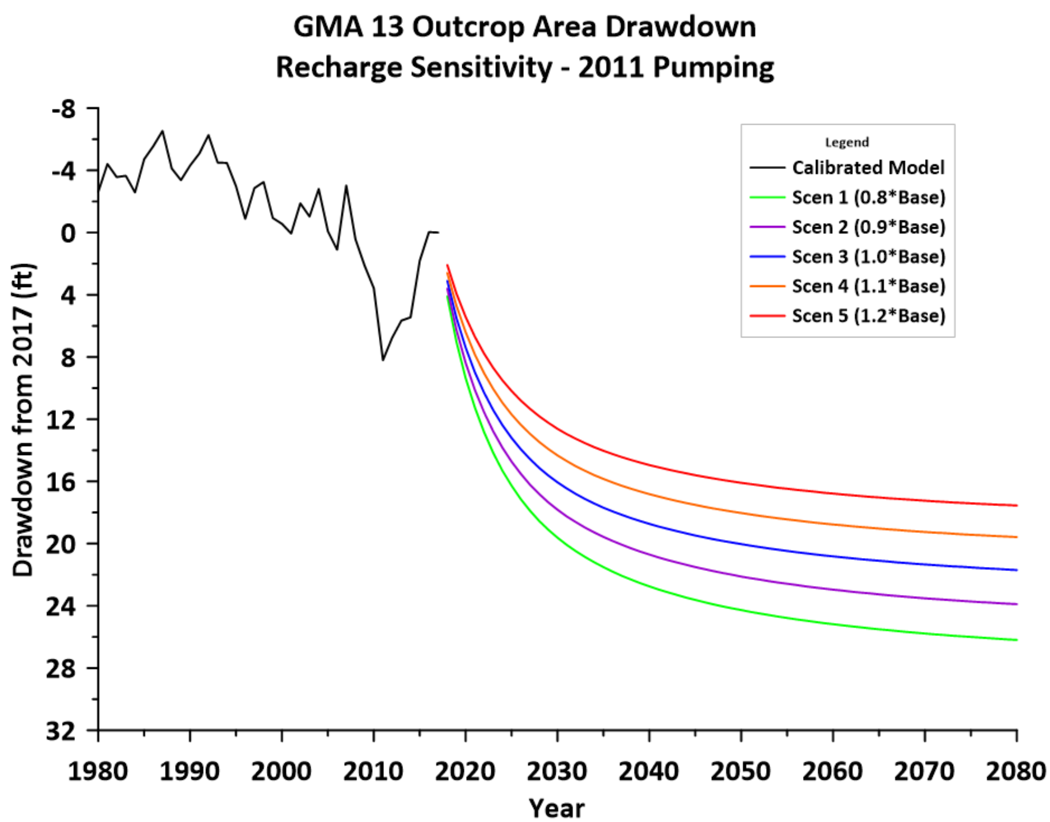

Queen City Aquifer - Downdip Area in GMA 13
Average Cell Size (acres)
0
100
200
300
400
500
600
700
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County

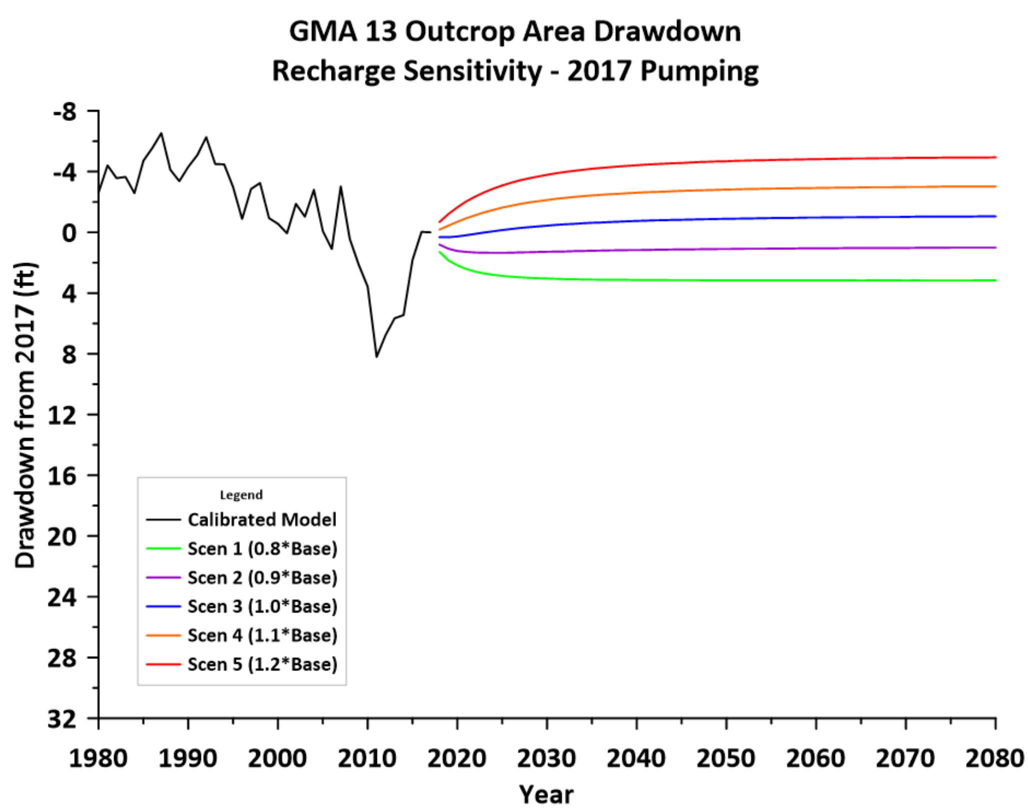

Carrizo-Wilcox Aquifer - Outcrop Area in GMA 13
Average Cell Size (acres)
0
20
40
60
80
100
120
140
160
180
200
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County

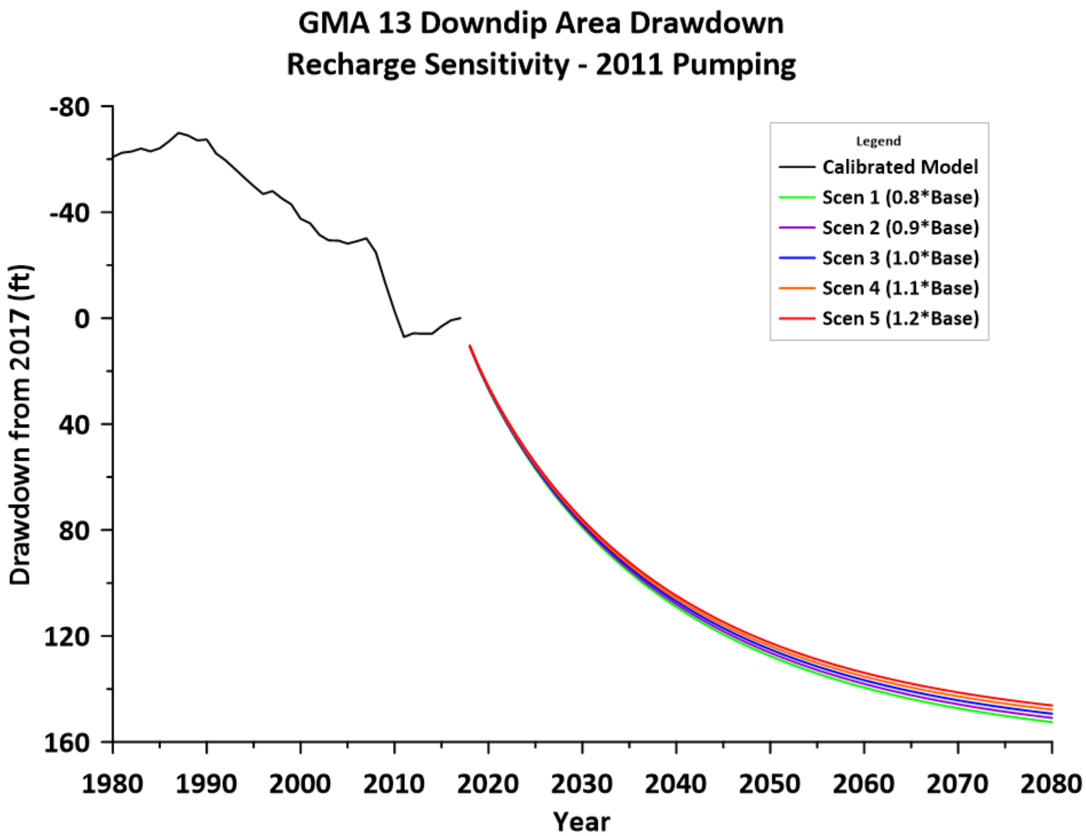

Carrizo-Wilcox Aquifer - Downdip Area in GMA 13
Average Cell Size (acres)
0
100
200
300
400
500
600
700
Atascosa
Bexar
Caldwell
Dimmit
Frio
Gonzales
Guadalupe
Karnes
LaSalle
Maverick
McMullen
Medina
Uvalde
Webb
Wilson
Zavala
County

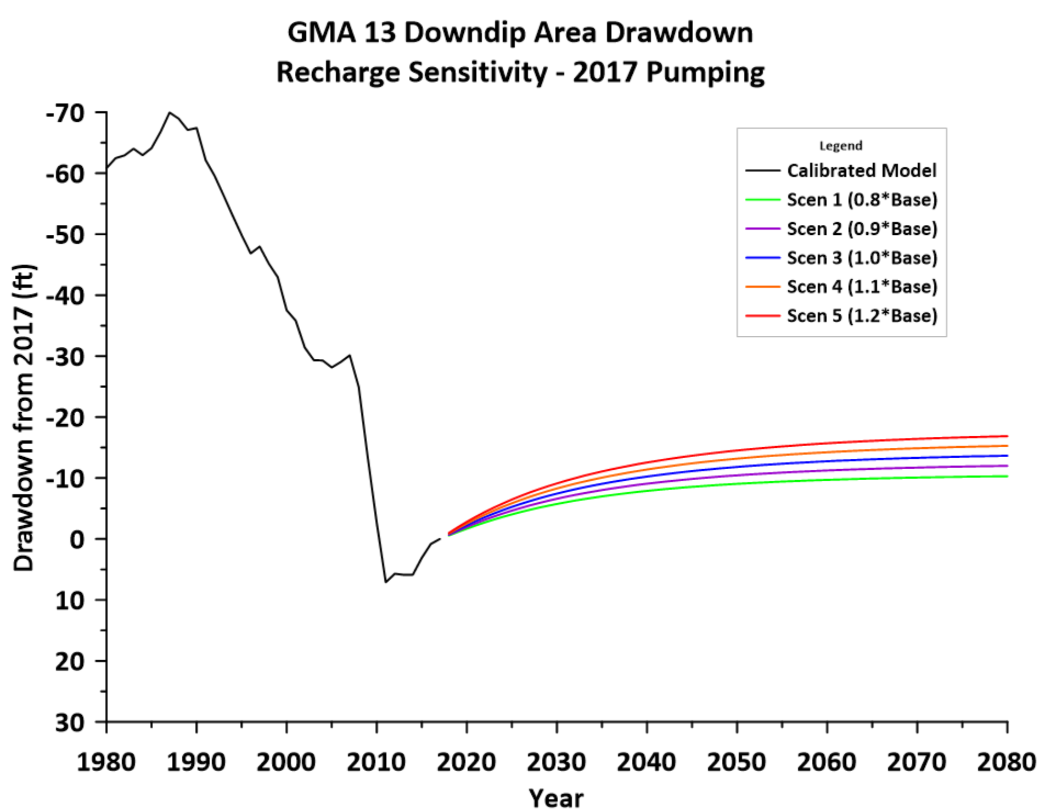
Appendix B

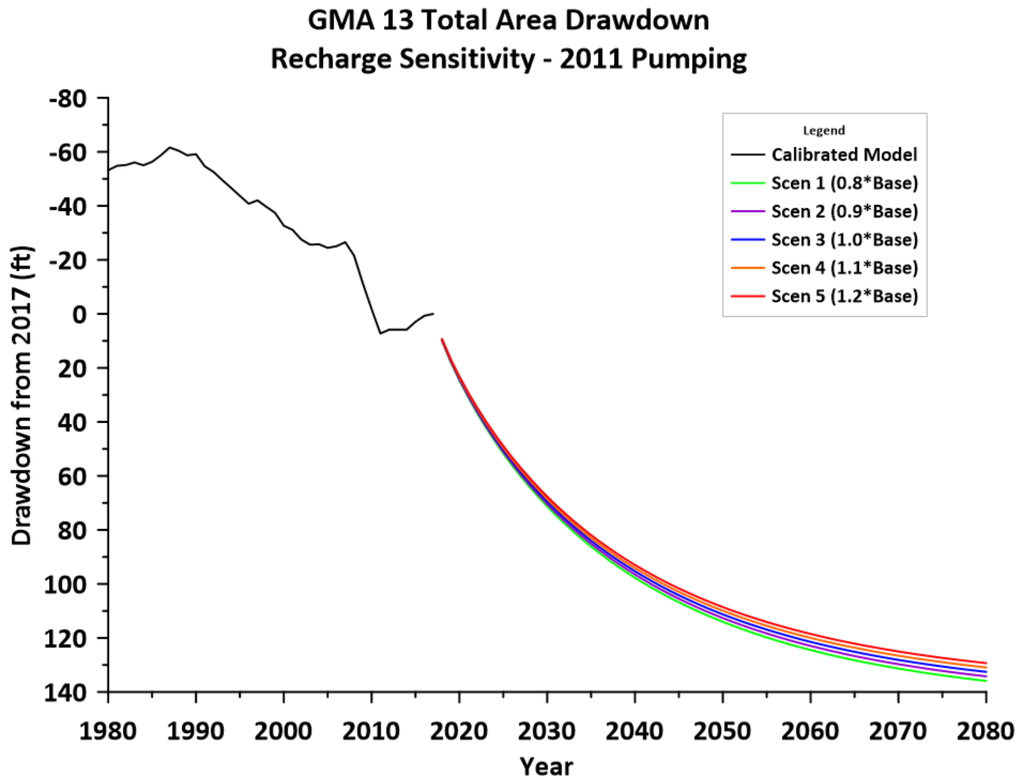
Overall Average Drawdown Hydrographs of Pumping Sensitivity Scenarios

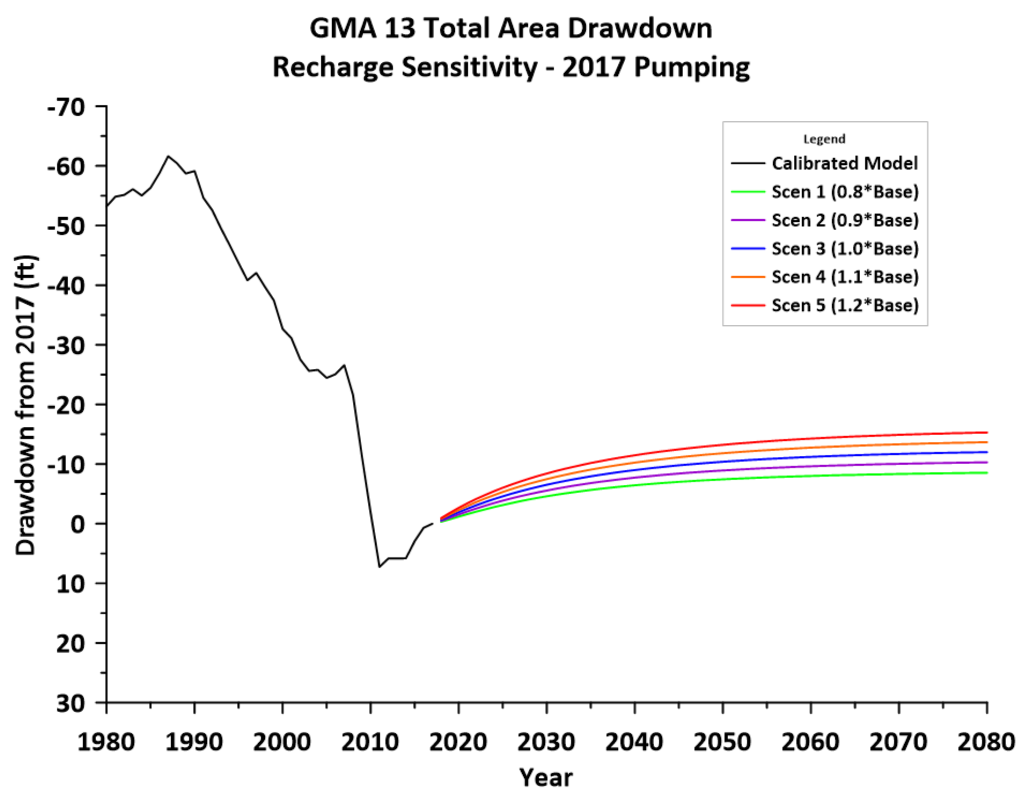

GMA 13 Outcrop Area Drawdown
Recharge Sensitivity - 2011 Pumping
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
Drawdown from 2017 (ft)
Year
-8
-4
0
4
8
12
16
20
24
28
32
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080


GMA 13 Outcrop Area Drawdown
Recharge Sensitivity - 2017 Pumping
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
Drawdown from 2017 (ft)
Year
-8
-4
0
4
8
12
16
20
24
28
32
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080


GMA 13 Downdip Area Drawdown
Recharge Sensitivity - 2011 Pumping
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
Drawdown from 2017 (ft)
-80
-40
0
40
80
120
160
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
Year

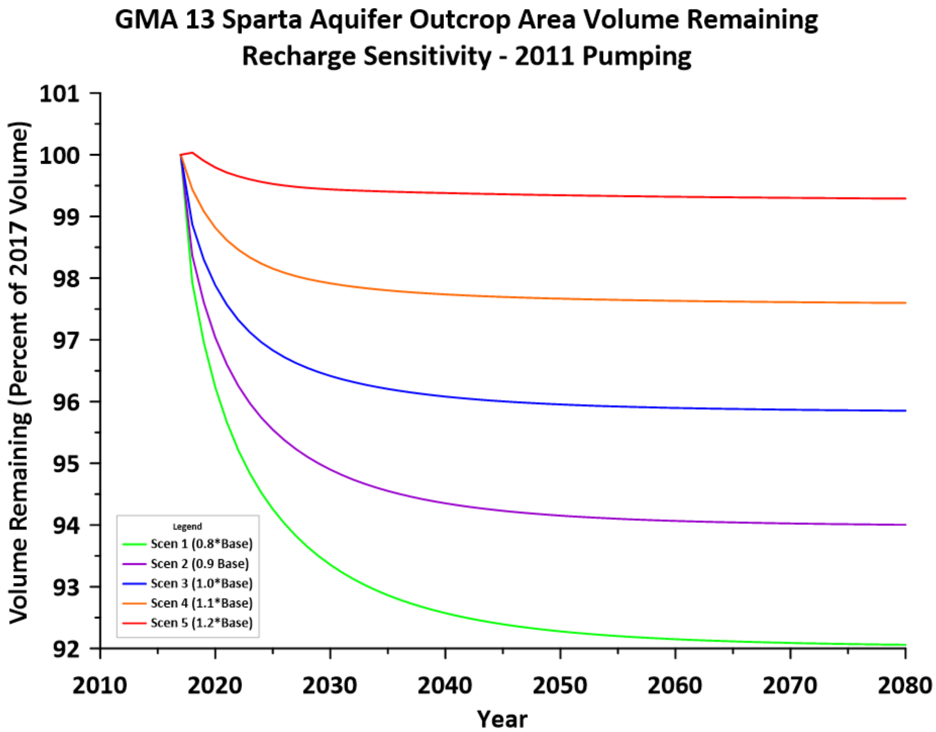

GMA 13 Downdip Area Drawdown
Recharge Sensitivity - 2017 Pumping
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
Drawdown from 2017 (ft)
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
Year

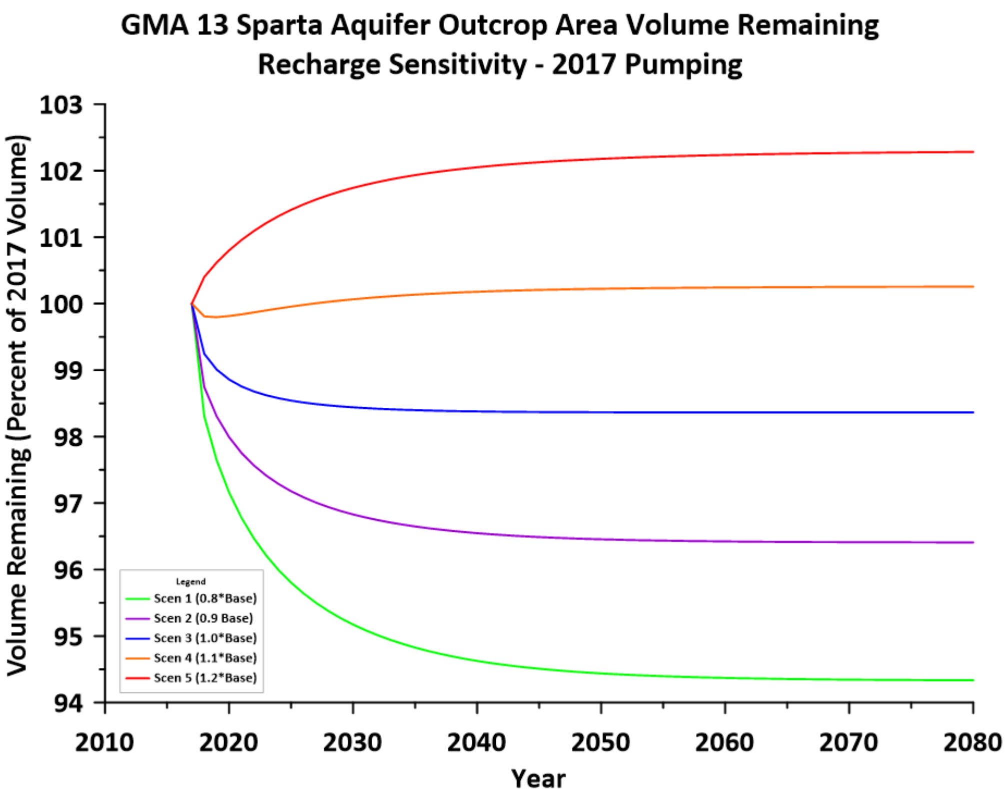

GMA 13 Total Area Drawdown
Recharge Sensitivity - 2011 Pumping
Drawdown from 2017 (ft)
Year
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)

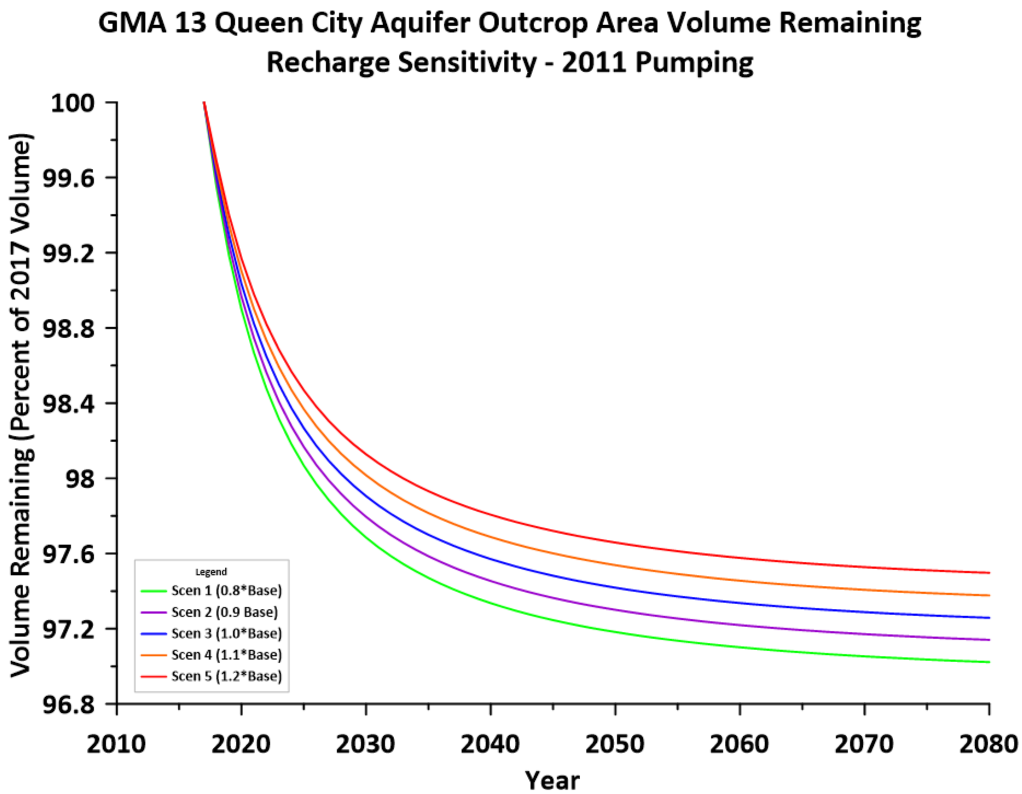

GMA 13 Total Area Drawdown
Recharge Sensitivity - 2017 Pumping
Drawdown from 2017 (ft)
Year
Legend
Calibrated Model
Scen 1 (0.8*Base)
Scen 2 (0.9*Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)

Appendix C

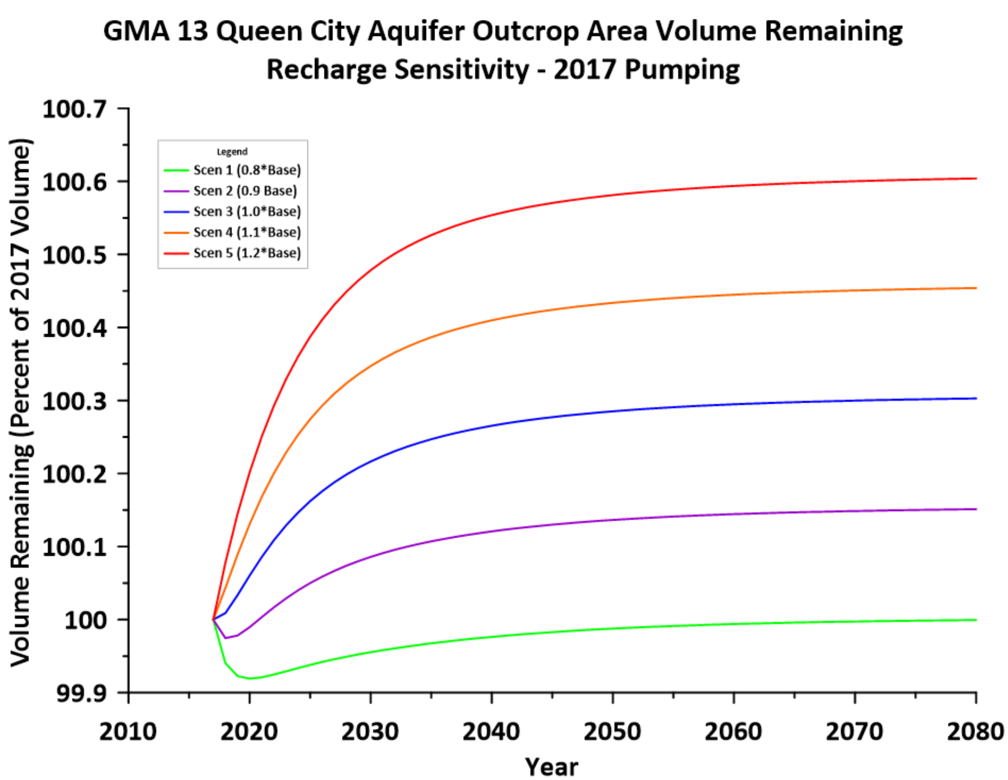
Outcrop Volume Remaining Hydrographs


GMA 13 Sparta Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2011 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
101
100
99
98
97
96
95
94
93
92
2010
2020
2030
2040
2050
2060
2070
2080

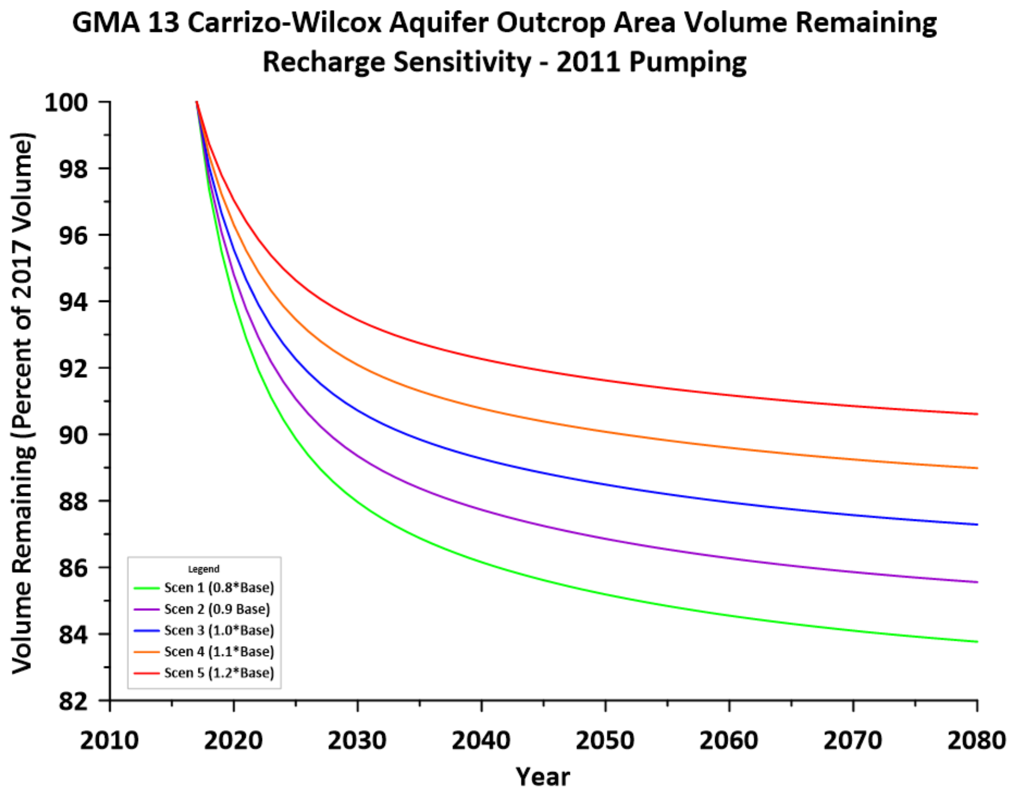

GMA 13 Sparta Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2017 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
103
102
101
100
99
98
97
96
95
94
2010
2020
2030
2040
2050
2060
2070
2080



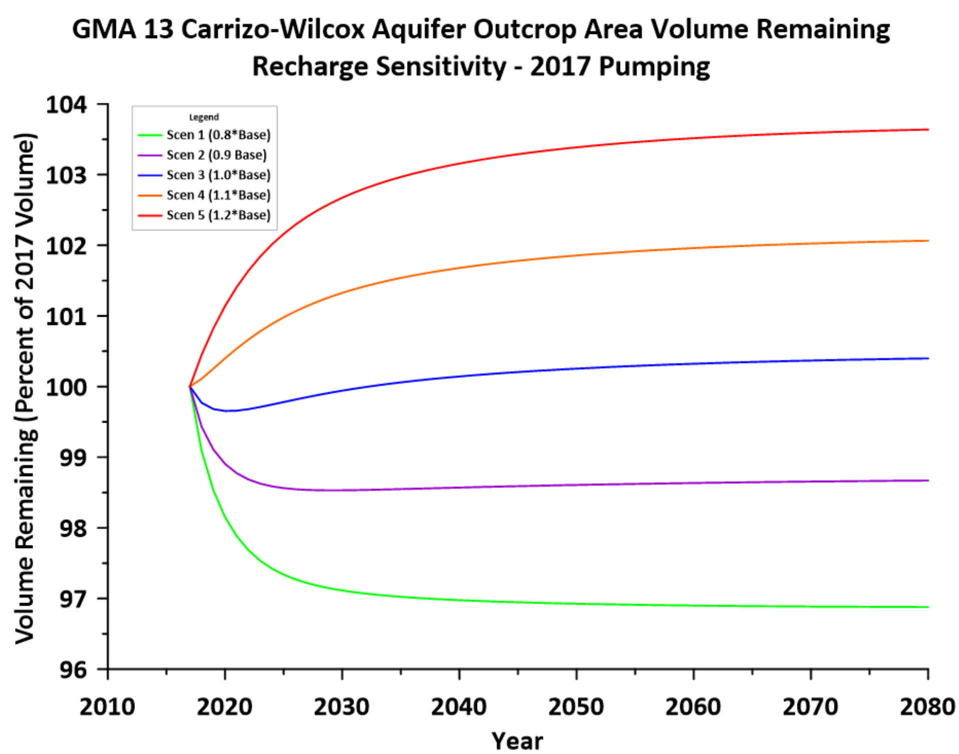
GMA 13 Queen City Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2011 Pumping
Volume Remaining (Percent of 2017 Volume)
100
99.6
99.2
98.8
98.4
98
97.6
97.2
96.8
2010
2020
2030
2040
2050
2060
2070
2080
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)



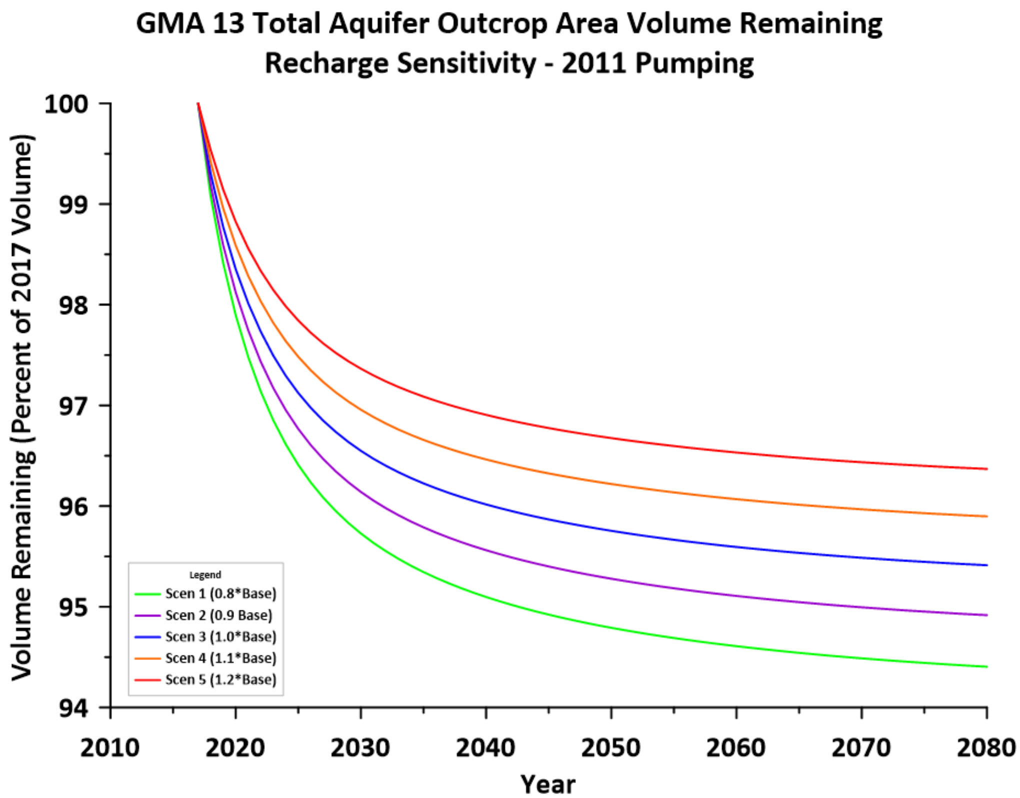
GMA 13 Queen City Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2017 Pumping
Volume Remaining (Percent of 2017 Volume)
100.7
100.6
100.5
100.4
100.3
100.2
100.1
100
99.9
2010
2020
2030
2040
2050
2060
2070
2080
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)



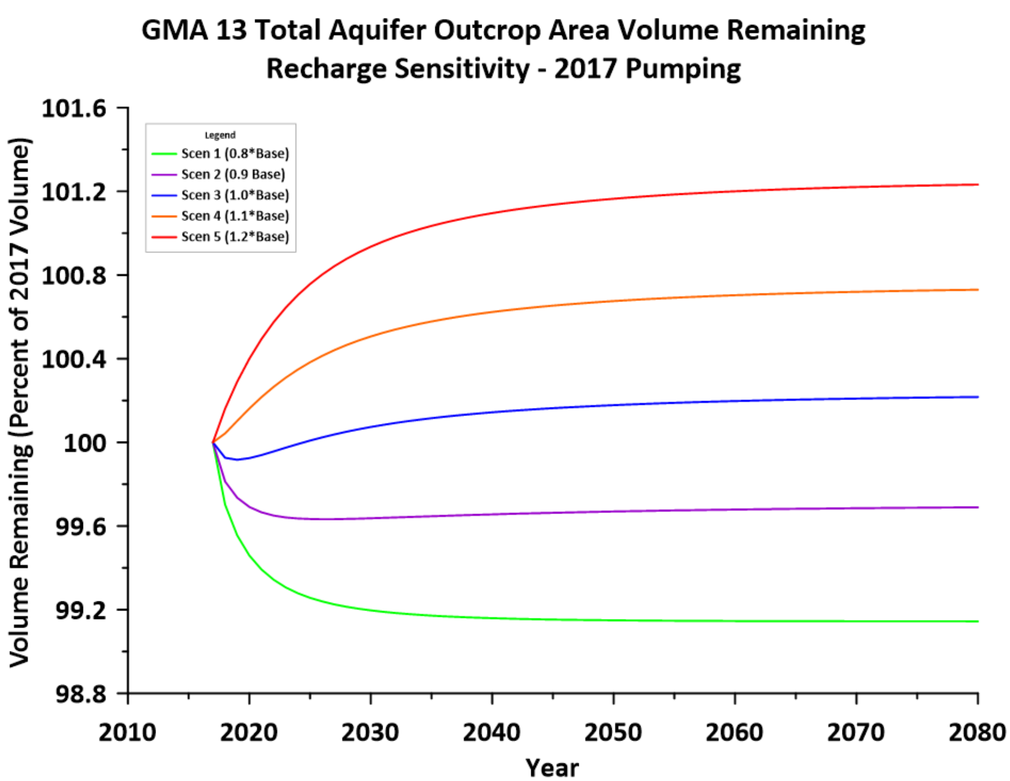
GMA 13 Carrizo-Wilcox Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2011 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)



GMA 13 Carrizo-Wilcox Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2017 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)



GMA 13 Total Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2011 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
100
99
98
97
96
95
94
2010
2020
2030
2040
2050
2060
2070
2080



GMA 13 Total Aquifer Outcrop Area Volume Remaining
Recharge Sensitivity - 2017 Pumping
Volume Remaining (Percent of 2017 Volume)
Year
Legend
Scen 1 (0.8*Base)
Scen 2 (0.9 Base)
Scen 3 (1.0*Base)
Scen 4 (1.1*Base)
Scen 5 (1.2*Base)
101.6
101.2
100.8
100.4
100
99.6
99.2
98.8
2010
2020
2030
2040
2050
2060
2070
2080