GM EXHIBIT 13

Expert Report for the General Manager of the Lost Pines Groundwater Conservation District:

Application of Lower Colorado River Authority for Operating and Transport Permits for Eight Wells in Bastrop County, Texas;
Before the State Office of Administrative Hearings;
SOAH Docket No. 952-19-0705

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July 25, 2019

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Professional Engineer and Professional Geoscientist Seals

This report documents the work of a licensed Texas Professional Geoscientist and licensed Texas Professional Engineer:

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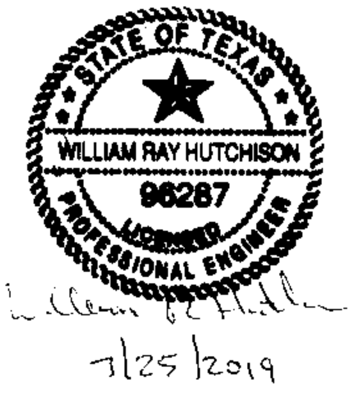
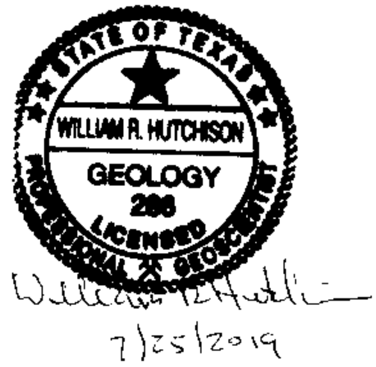
Dr. Hutchison completed the model simulations and analyses described in this report and was the author of the report.





1.0 Introduction and Summary of Conclusions

This report documents analyses related to the *Application of Lower Colorado River Authority for Operating and Transport Permits for Eight Wells in Bastrop County, Texas*; that is before the State Office of Administrative Hearings; SOAH Docket No. 952-19-0705.

The Lower Colorado River Authority (LCRA) has submitted permit applications to pump groundwater from eight wells located on the Griffith League Ranch property owned by the Capitol Area Council, Inc. Boy Scouts of America in Bastrop County.

LCRA's request is for a total combined maximum production of up to 25,000 acre-feet per year (AF/yr) and requested a phased approach to the pumping. LCRA's consultants (INTERA) provided model simulation files (model directory *dfc.braa.wel.2011.2070* and model directory *dfc.braa.wel.lcra.2011.2070*). These files represent two simulations: one that simulates a base condition (i.e. without the proposed LCRA pumping), and one that simulates the base case plus the proposed LCRA pumping. The FORTRAN program *comparewelnew.exe* was written to extract the output pumping from the cell-by-cell file of the two simulations. The results for all model layers were saved in an Excel file named *BastropPumpCompare.xlsx.* Results of that comparison yields the following phased pumping plan in the Simsboro Aquifer:

- Pumping from 2020 to 2022 (3 years): 7,995 AF/yr
- Pumping from 2023 to 2025 (3 years): 14,990 AF/yr
- Pumping from 2026 to 2070 (45 years): 24,894 AF/yr to 24,983 AF/yr

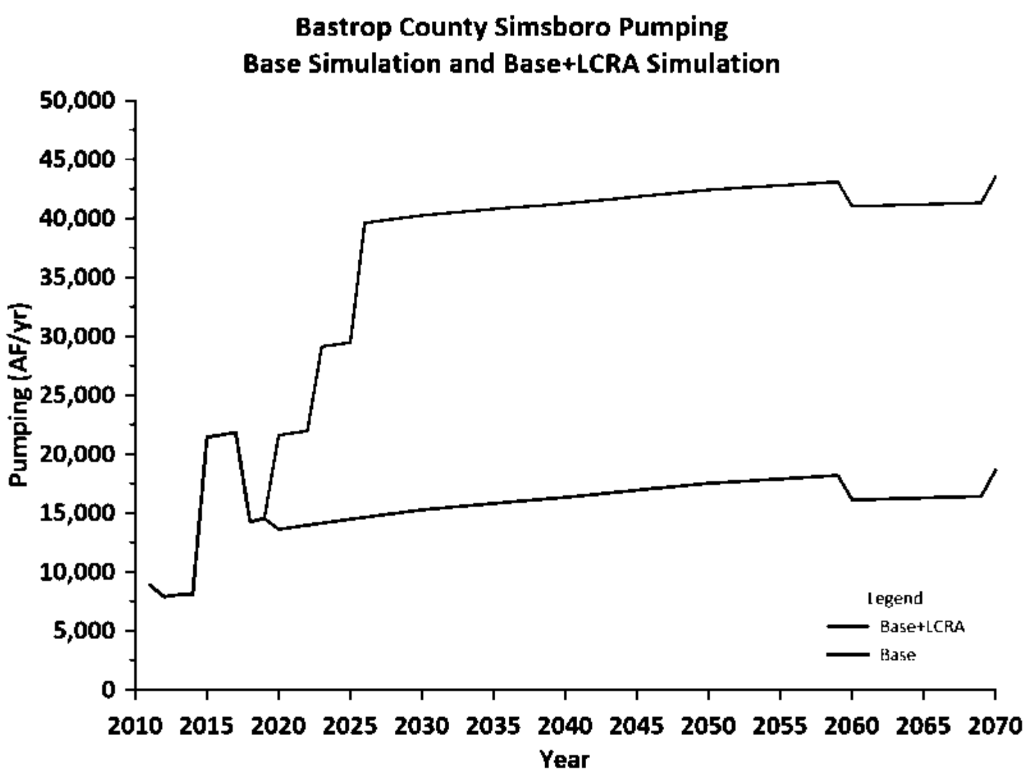


Figure 1. Bastrop County Simsboro Pumping

1.1 Objective 1: Model Comparison

The current desired future conditions for the area were adopted in 2016 and relied, in part, on model simulations using the Groundwater Availability Model that was documented in Kelley and others (2004). More recently, an updated Groundwater Availability Model of the area was completed as documented in Young and others (2018).

The initial objective was to compare these models and evaluate which one should be used to develop findings and recommendations relative to LCRA's application.

As developed in this report, the Young and others (2018) Groundwater Availability Model (also referred to as the new GAM) is based on a more updated model code, has a more refined spatial discretization approach, was calibrated over a longer time period, and achieved a better calibration fit. These were the primary reasons that the new GAM was used in all analyses contained in this report.

1.2 Objective 2: Evaluation of Groundwater Budgets

Groundwater budgets are an accounting of all inflows, outflows, and storage changes within a specified area. For this evaluation, three groundwater budgets for Bastrop County were developed:

1. The historic groundwater budget from 1930 to 2010 (the calibration period of the new GAM) for Bastrop County was developed using the calibrated model (new GAM) from files obtained from the Texas Water Development Board.
2. A groundwater budget from 2011 to 2070 was developed using the predictive model (new GAM) of the "base case" using model files obtained from INTERA as part of the disclosure from LCRA (model directory *dfc.braa.wel.2011.2070*).
3. A groundwater budget from 2011 to 2070 was developed using the predictive model (new GAM) of the "LCRA case" (i.e. base case plus LCRA pumping) using files obtained from INTERA as part of the disclosure from LCRA (model directory *dfc.braa.wel.lcra.2011.2070*).

As developed in this report, these water budgets demonstrate that about 94 percent of the variation in groundwater storage change from 1930 to 2010 is attributable to variation in recharge. The most significant finding from the comparison of the two predictive scenarios (i.e. future water budgets from 2011 to 2070) is the sources of the proposed LCRA pumping:

- About 46 percent from decreased groundwater discharge to surface water (i.e. decreased river base flow).
- About 35 percent from decreased groundwater storage (i.e. decreased groundwater levels)
- About 16 percent from decreased outflow to Lee County
- The remaining 3 percent of the groundwater pumping is sourced from decreased spring and seep flow, decreased evapotranspiration from groundwater, decreased upward flow to younger formations not explicitly simulated in the model, and decreased outflow to Caldwell and Fayette counties.

1.3 Objective 3: Groundwater Elevation Predictions in Registered Wells

Lost Pines Groundwater Conservation District provided an Excel file with 2,617 registered wells. Registered wells include permitted wells and non-exempt permitted wells (*LPGCD Well export.xlsx*). As developed in this report, the data in this file were used with the model output from the two predictive scenarios from the new GAM to develop findings and conclusions relative to the predicted drawdowns.

The results of this analysis show:

- The drawdown impacts of the LCRA impact drawdowns are highest in the Simsboro Formation (Layer 9)
- Drawdown in overlying and underlying formations is present, but the restriction in vertical movement results in smaller drawdowns than in the Simsboro Formation.
- Drawdown in the "shallow flow zone" of the model (Layer 2) and in the alluvial formations (Layer 1) are small in comparison to the drawdowns in the underlying layers, but result in gradient changes that result in reduced groundwater discharge to surface water which eventually result in a gradient reversal in the Base+LCRA scenario that result in the surface water providing recharge to groundwater.

1.4 Objective 4: Groundwater Elevation Predictions in Monitoring Wells

Lost Pines Groundwater Conservation District provided an Excel file with 37 monitoring wells (*Lost Pines GCD Water Level Monitoring Wells – 20190305.xlsx*). As developed in this report, the data in this file were used with the model output from the two predictive scenarios from the new GAM to develop findings and conclusions relative to the predicted groundwater elevations in these wells.

The analysis resulted in estimates of annual drawdown attributable to the proposed LCRA pumping in each of the 37 monitoring wells. These estimates can be used to assist in the interpretation of future monitoring data relative to decisions on moving into the next phase of pumping.

For example, the most responsive well in the network to the proposed LCRA pumping is Well 58-55-407. The model simulations predict that the drawdown due to the pumping of the LCRA wells (as simulated in the model) would be 229 ft from 2019 to 2070. However, the data also show that after the three years of the initial phase of pumping, the drawdown in this well would be about 50 feet in the first year, 52 feet in the second year, and 52 feet in the third year. Thus, if there is no other new pumping in the area of the LCRA wells at the time of their start-up and the precipitation/recharge conditions are near average during the first three years of operation of the LCRA wells, the actual monitoring data from this monitoring well should show about a 50 ft decline in the first year and remain fairly consistent for the next two years.

The possible deviation from this prediction could be the result of other pumping in the area, and/or an abnormally wet or dry period. If none of these conditions are true and the drawdown is substantially more or less than 50 feet, it should be concluded that the model is not a good predictor of drawdown and more investigation is warranted, including updating and recalibrating the model.

If, on the other hand, the actual monitoring data from this monitoring well and the other monitoring wells are substantially the same as the model predictions, then it could be concluded that the model appears to be reasonably accurate and the next phase of pumping should proceed.

2.0 Model Comparison

2.1 Overview of Models

The old GAM (Kelley and others, 2004) and the new GAM (Young and others, 2018) cover approximately the same area.

The old GAM was developed using MODFLOW-96, an earlier code in the MODFLOW series of finite difference modeling codes developed by the USGS (Harbaugh and McDonald, 1996). The old GAM has a uniform model grid consisting of one-square mile (640 acres) grid cells.

The new GAM was developed using MODFLOW-USG (Panday and others, 2013). The new GAM has a variable grid using quadtree mesh refinement that reduces the cell size in the area of selected surface water features. The largest cell size is one square mile (640 acres), the smallest cell size is 40 acres (1/16 of a square mile).

The layering of the old GAM and the new GAM are somewhat different. The old GAM has 8 layers, the new GAM has 10 layers. The new GAM included an explicit layer (Layer 1) to simulate the Brazos River Alluvium and the Colorado River Alluvium. Layer 2 of the new GAM is the "shallow flow zone", which cuts across all layers in the outcrop area. Except for the "shallow flow zone", layers 3 to 10 of the new GAM represent the same formations as Layers 1 to 8 of the old GAM.

Figure 2 (taken from Figure 3.5a on page Vol. 1-125 of Young and others, 2018) is a conceptual illustration of the layering approach of the new GAM. Please note that the illustration includes the term "overlying formations" which are not explicitly included in the model. These formations include Yegua Formation (part of the Yegua-Jackson Aquifer), and the Cook Mountain Formation.

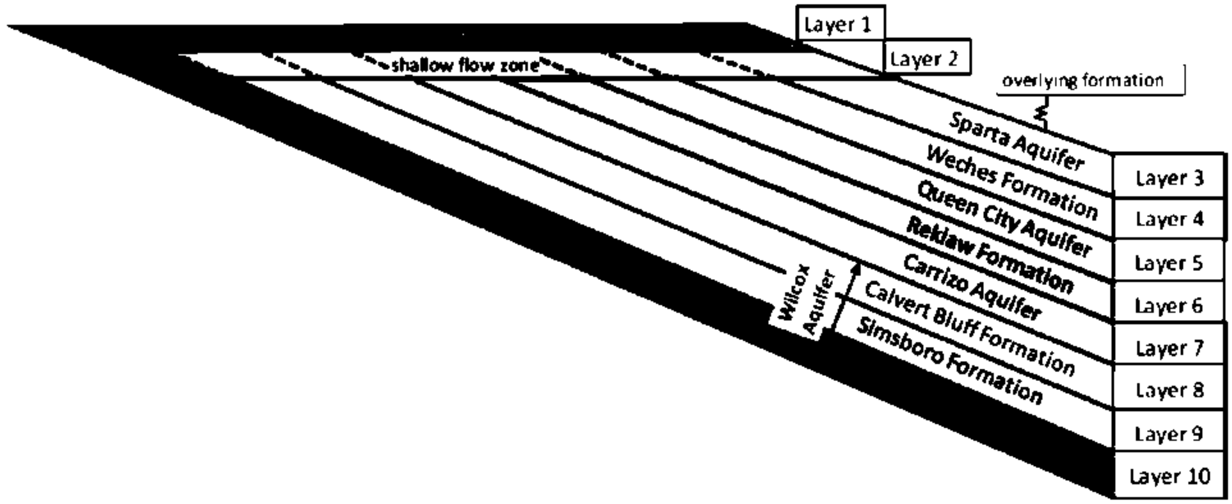


Figure 2. Conceptual Illustration of New GAM Layering (from Young and others, 2018)

2.2 TWDB Groundwater Data

The Old GAM (Kelley and others, 2004) and the new GAM (Young and others, 2018) were evaluated primarily on how well the model estimated groundwater elevations in Bastrop County matched actual groundwater elevation data obtained from the Texas Water Development Board. Actual data were obtained at the website:

http://www2.twdb.texas.gov/ReportServerExt/Pages/ReportViewer.aspx?%2fGWDB%2fWaterLevelsByCounty&rs:Command=Render

Data were obtained by entering the county (Bastrop), the aquifer (all), the observation type (all), and the coordinate format (decimal degrees). The resulting 3,445 records were saved in the file *BastropWL070919.csv*. The latitude and longitude of the well location were converted into GAM coordinates using Surfer, a commercial gridding program and the specifications of the GAM coordinate system.

The records were sorted and records with no recorded groundwater level or well depth were deleted. The remaining 3,424 records were saved in the file *BastropWL070919.xlsx*. The same file was also saved as *BastropCoWL.csv* for further use in FORTRAN programs as described below.

2.2.1 Well List and All Water Levels

The FORTRAN program *getallwl.exe* was written to obtain a listing of the 553 wells in the TWDB data, the number of data points for each well, the earliest and latest year of data for each well, the depth of the well, the surface elevation of the well, the bottom elevation of the well, and the x-and y-coordinate for each well. Output from the program is saved in the file *allwelsum.dat*.

2.2.2 End-of-Year Water Levels

The FORTRAN program *geteoywl.exe* was written to limit the data to end-of-year groundwater elevations because the groundwater models are run on annual stress periods. Thus, comparison of actual data and model estimated groundwater elevations is best made using end-of-year data. The program used the following preference in filtering the data:

- December of current year
- January of subsequent year
- November of current year
- February of subsequent year
- October of current year

All other data were discarded. Results were saved in the file *BastropEOYwl.dat*. A list of the wells for the end-of-year data along with the number of records for the well, and the earliest and latest data points are saved in the file *eoylist.dat*. The filtering resulted in 385 wells and 1,109 data points.

2.3 Locate Wells on GAM Grids

The old GAM grid file provided by the Texas Water Development Board (*qcsp_c_poly082615.csv*) was used in FORTRAN programs (*getoldgamtopbot*.exe and *getrcoldgam.exe*) to obtain the layer, row, and column for each record. These results were saved in the file *BastropELoldgrid.dat*. Please note that only 1,010 records were located on the model grid. The rest were well locations that fell outside the grid or were not completed in aquifers simulated in the model. Please recall that the model does not explicitly include the formations associated with the Yegua-Jackson Aquifer or the Cook Mountain Formation.

The new GAM grid file provided by the Texas Water Development Board (*getnodenewgam.exe*) was used in a FORTRAN program (*getnodenewgam.exe*) to find and save the closest cell or node center for each record. These results were saved in the file *BastropWLnewgrid.dat*. Please note that only 1,060 records were located on the model grid. The rest were well locations that fell outside the grid or were not completed in aquifers simulated in the model. Please recall that the model does not explicitly include the formations associated with the Yegua-Jackson Aquifer or the Cook Mountain Formation.

2.4 Model Estimated Groundwater Elevations

Calibrated model groundwater elevations were extracted from model output files (*qcsp_c_ps12.hds* for the old GAM, and *gma12.hds* for the new GAM).

Please note that the old GAM model files were obtained from TWDB for the most recent desired future condition/modeled available groundwater simulation. The first 25 stress periods of this model run covers the calibration period (1975 to 1999) and are the same as the 25 stress periods of the calibrated model.

The saved head files from the GAMs were read by FORTRAN programs (*gethednewgam.exe* for the old GAM and *gethednewgam.exe* for the new GAM). The old GAM saved file is *oldgridactsim.dat* and contains 391 comparisons of actual groundwater elevations and model estimated groundwater elevations. Please note that records that were either before or after the calibration period were not used.

The new GAM saved file is *newgridactsim.dat* and contains 968 comparisons of actual groundwater elevations and model estimated groundwater elevations. Please note that records that were either before or after the calibration period were not used.

Both comparisons were saved in a single Excel file named *actsimoldnew.xlsx*. Summary statistics of the calibrations in Bastrop County are presented in Table 1. Please note that the new GAM has more data points and a better fit as evidenced by the residual mean, the absolute residual mean, the residual standard deviation, and the root mean square error. Of note is the scaled residual standard deviation, where the value for the New GAM in Bastrop County is less than 0.1, which is considered an acceptable error.

Table 1. Comparison of Calibration Statistics for Old GAM and New GAM – Bastrop County

Statistic	Old GAM	New GAM
Residual Mean	-9.56	-8.38
Absolute Residual Mean	28.91	21.70
Residual Standard Deviation	37.37	28.11
Sum of Squared Residuals	580,290.91	832,288.53
Root Mean Square Error	38.52	29.32
Minimum Residual	-121.74	-143.77
Maximum Residual	124.72	116.16
Number of Observations	391	968
Range in Observations	317.00	354.00
Scaled Residual Standard Deviation	0.1179	0.0794
Scaled Absolute Residual Mean	0.0912	0.0613
Scaled Root Mean Square Error	0.1215	0.0828
Scaled Residual Mean	-0.0302	-0.0237

Summary graphs comparing the actual and simulated groundwater elevations in Bastrop County are presented in Figure 3 (old GAM) and Figure 4 (new GAM). The summary graphs confirm that the new GAM has a better fit to the 1:1 line than the old GAM.

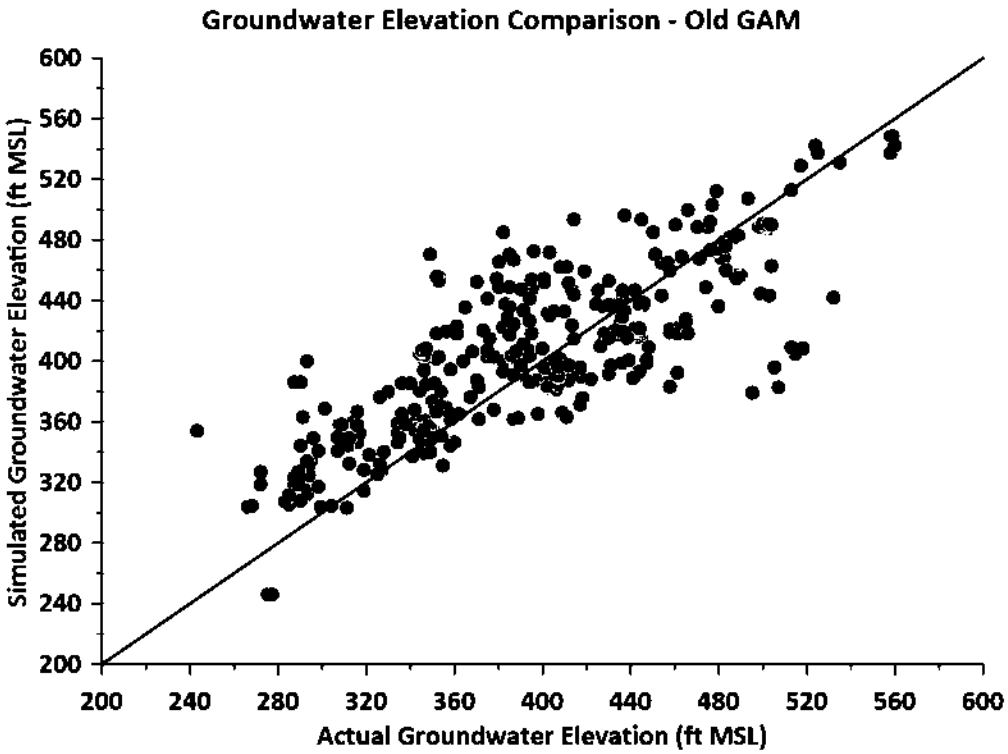


Figure 3. Groundwater Elevation Comparison - Old GAM

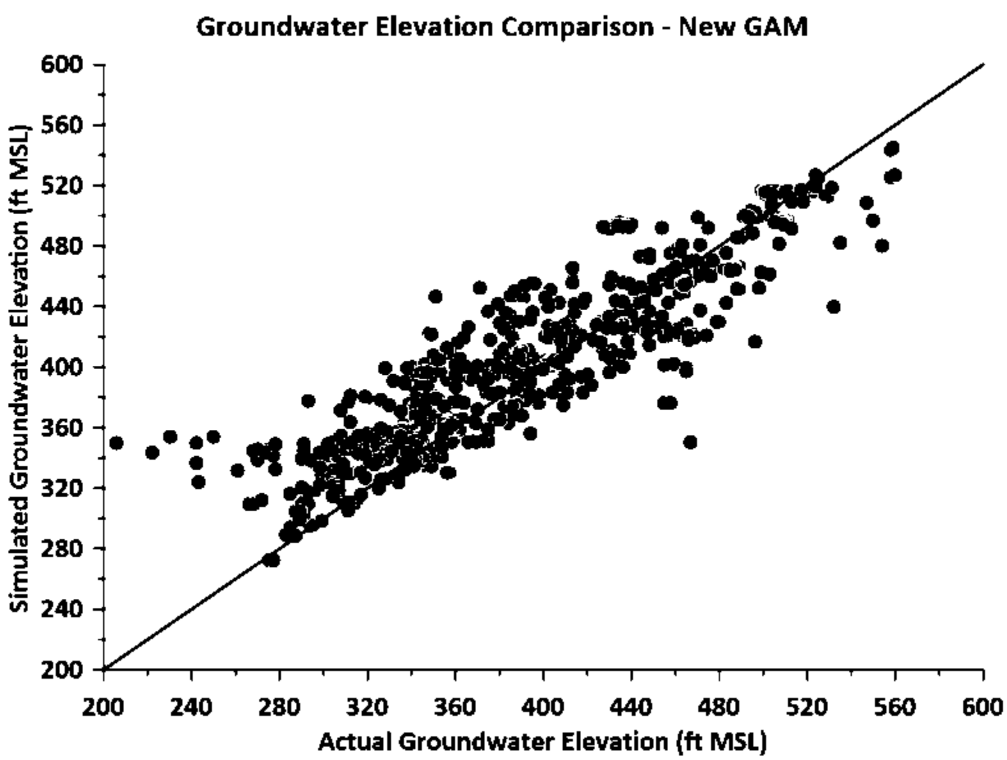


Figure 4. Groundwater Elevation Comparison - New GAM

3.0 Groundwater Budgets

3.1 Zone Budget Input and Output

Groundwater budgets for Bastrop County were extracted from model output files using the USGS program *zonbudusg.exe*. Three groundwater budgets were developed using the cell-by-cell output files from three runs of the model:

- The calibrated model cell-by-cell file was obtained from the Texas Water Development Board. The file has a date of June 8, 2018 and was renamed *gam12cal.cbb* for use in this analysis.
- The base case model run was provided by INTERA in the directory *dfc.braa.wel.2011.2070* was renamed *gma12base.cbb* for use in this analysis.
- The simulation where proposed LCRA pumping is added to the base case was provided by INTERA in the directory *dfc.braa.wel.lcra.2011.2070* was renamed *gma12lcra.cbb* for use in this analysis.

Other input files common to all three runs of *zonbudusg.exe* are the discretization file (*gma12.dis*) obtained from the Texas Water Development Board and the zone file *(sevenzone.dat)*. The zone file was developed by the FORTRAN program *makezone.exe* that uses the new GAM grid file as input (*czwx_c_v3.01_grid_point092118.csv*), which was obtained from the Texas Water Development Board. Six zones were designated to distinguish all counties that border Bastrop County, the seventh zone includes all counties that do not border Bastrop County:

1. Bastrop County (code 11 in the grid file)
2. Caldwell County (code 28 in the grid file)
3. Fayette County (code 75 in the grid file)
4. Gonzales County (code 89 in the grid file)
5. Lee County (code 144 in the grid file)
6. Williamson County (code 246 in the grid file)
7. All other counties (all other codes in the grid file)

Output was saved as follows:

- Output for the calibrated model: *cal.2.csv*
- Output for the base case: *base.2.csv*
- Output for the base+LCRA case: *lcra.2.csv*

The output files contained data for all zones. The output for Bastrop County for each instance was saved as follows:

- Calibrated model: *zbcal.xlsx*
- Base case: *zbbase.xlsx*
- Base+LCRA case: *lcra.xlsx*

For each of the Excel files with the Bastrop County results, there are five sheets:

- Full output from the *zonbudusg.exe* program (named *cal.2* for the calibrated model, named *base.2* for the base case, and named *lcra.2* for the base+LCRA case)
- *Bastrop-cfd* contains all data for Bastrop County in cubic feet per day
- *Bastrop-AFY* contains all data for Bastrop County in acre-feet per year
- *Bastrop-NetAFY* contains the net components for Bastrop County in acre-feet per year
- *WB* contains a summary water budget

3.2 Calibrated Model Groundwater Budget for Bastrop County

Table 2 presents a groundwater budget for Bastrop County from the results of the calibrated model. Two time periods are presented: 1930 to 1995 and 1996 to 2010.

Table 2. Calibrated Model Groundwater Budget for Bastrop County
All Values in AF/yr

Inflow	**1930 to 1995**	**1996 to 2010**
Recharge	61,383	54,307
Caldwell	2,401	2,445
Williamson	21	21
Total	63,805	56,773
Outflow		
Pumping	3,594	13,268
Springs	4,791	3,936
River Baseflow	52,311	41,489
Evapotranspiration	261	210
GHB (overlying)	259	1,173
Fayette	2,345	4,498
Lee	2,061	5,279
Total	65,622	69,853
Inflow-Outflow	-1,817	-13,079
Storage Change	-1,817	-13,079
Model Error	0	0

Please note that the pumping in the later period is about 10,000 AF/yr higher than in the earlier time period (about 14,000 AF/yr vs. about 4,000 AF/yr). Also, please note that the storage decline increases in the later period as compared to the earlier period by about 11,000 AF/yr (about 2,000 AF/yr vs. about 13,000 AF/yr. The recharge in the later period is about 7,000 AF/yr less than the earlier period. Finally, the discharge to river baseflow is about 11,000 AF/yr less in the later period than the earlier period (about 41,000 AF/yr vs. about 52,000 AF/yr).

As discussed by Bredehoeft and others (1982) and Bredehoeft (2002), when pumping increases, three impacts are expected to happen: 1) declining storage (manifested by declining groundwater levels), 2) induced inflow from connected surface water and/or subsurface flow from surrounding areas, and 3) decreased natural outflow to surface water, and/or decreased subsurface outflow to surrounding areas. The groundwater budgets in Table 2 above show an increase in pumping, an increase in the rate of storage decline, and a decrease in discharge to rivers. However, the lower recharge between the two time periods complicates the interpretation on the impact of pumping.

Figure 5 plots the annual recharge and the annual groundwater storage change from 1930 to 2010 in Bastrop County. Please note that the regression line is also plotted along with the regression equation and r^2 value of the regression that is a quantitative expression of how well the line fits the data (perfect fit = 1.0). The r^2 value of 0.94 can be interpreted as 94 percent of the variation in groundwater storage change can be explained by the variation in recharge. This suggests that, historically, groundwater pumping has had a relatively minor impact on changes in regional groundwater storage (i.e. groundwater levels).

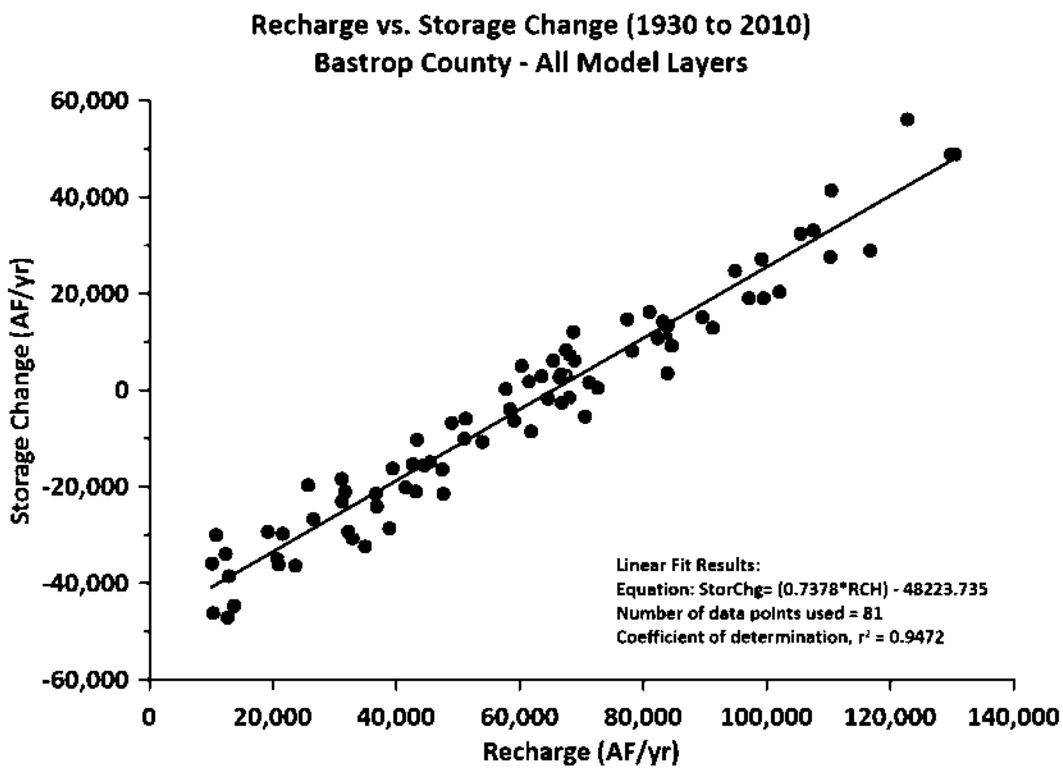


Figure 5. Recharge vs. Storage Change - Bastrop County

3.3 Groundwater Budgets of Predictive Scenarios

Table 3 presents the groundwater budgets for the two predictive scenarios (Base and Base+LCRA) from 2011 to 2070.

Table 3. Bastrop County Groundwater Budget for Two Predictive Scenarios - 2011 to 2070

Inflow	Base	Base+LCRA
Recharge	62,666	62,666
Williamson	21	21
Total	62,686	62,686

Outflow		
Pumping	29,546	49,375
Springs	2,707	2,498
River Baseflow	18,053	8,898
Evapotranspiration	172	171
GHB (overlying)	985	979
Caldwell	6,176	6,052
Fayette	13,974	13,722
Lee	9,982	6,907
Total	81,594	88,603

Inflow-Outflow	-18,908	-25,917
Storage Change	-18,908	-25,917
Model Error	0	0

Please note that the proposed LCRA pumping increases total pumping about 20,000 AF/yr (average increase from 2011 to 2070). Because the LCRA pumping is the only change to model input, the changes in output are all attributable to the LCRA pumping. River baseflow is decreased about 9,000 AF/yr (about 18,000 AF/yr to about 9,000 AF/yr). Storage declines increase by about 7,000 AF/yr (about 19,000 AF/yr to about 26,000 AF/yr). The remaining large change is the subsurface outflow to Lee County (reduced about 3,000 AF/yr from about 10,000 AF/yr to about 7,000 AF/yr). These components of the water budget represent the source of about 97 percent of the pumping.

The groundwater budget comparison suggests that about 46 percent of the pumping will be sourced from reduced baseflow to the surface water system in Bastrop County. About 35 percent of the pumping will be sourced from reduced groundwater storage, and about 16 percent will be sourced from decreased subsurface outflow to Lee County.

The results highlight the fact that groundwater pumping results in three impacts: 1) reduced storage (manifested by reduced groundwater levels), 2) induced inflow from surrounding areas and from surface water, and 3) reduced natural outflow to surface water and/or subsurface outflow to surrounding area.

Figure 6 presents the annual surface water-groundwater interaction graph and includes the calibrated model results and the two predictive scenario results. Please note that negative values represent a flow from groundwater to surface water (groundwater discharge to rivers that forms baseflow), and positive values represent a flow from surface water to groundwater (surface water providing recharge water to groundwater).

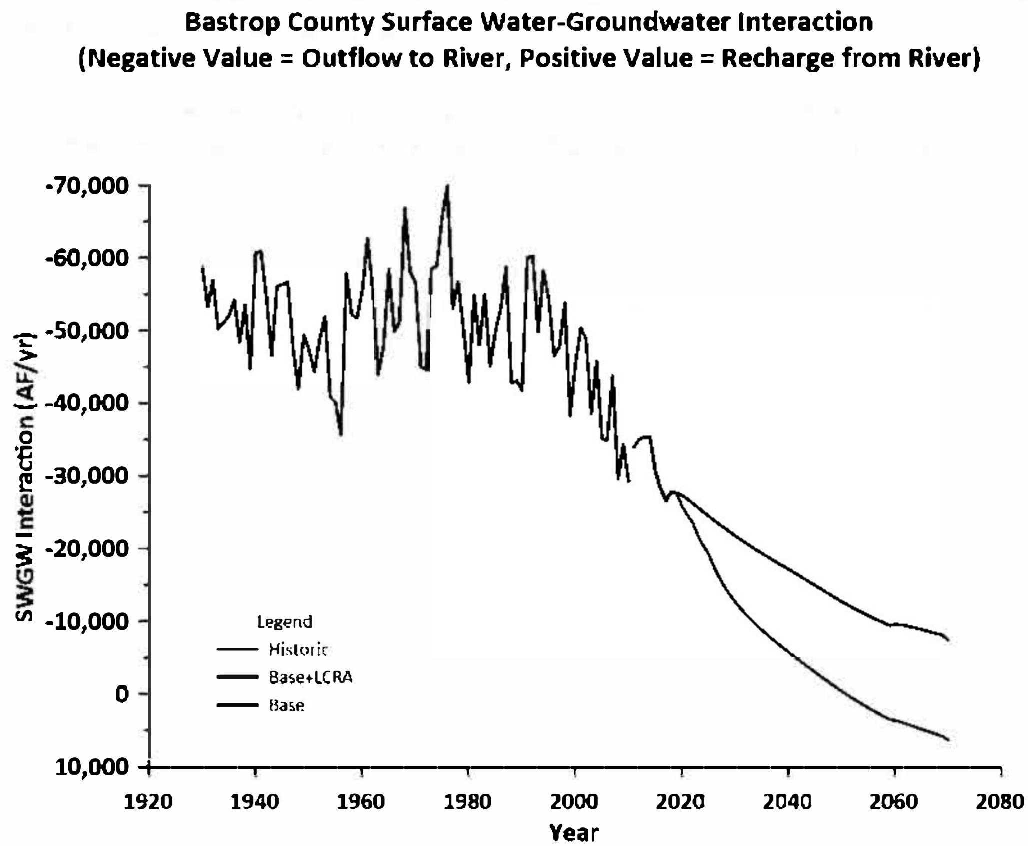


Figure 6. Bastrop County Surface Water-Groundwater Interaction

Please note that prior to about 1990, groundwater discharge to surface water varied without a discernible trend. Beginning in about 1990 a trend begins to be observed where the rate of discharge to surface water declines (from about 60,000 AF/yr to about 30,000 AF/yr in 2010).

The base case simulation shows a continued decline in the rate of discharge, but the Base+LCRA scenario shows that, in about 2040, the discharge is eliminated, and the surface water system begins to act as a recharge source to groundwater.

Based on the groundwater budget for Bastrop County, the two largest sources of the proposed pumped groundwater are reduction in baseflow to surface water and storage decline. The annual contribution to the pumping for each of these components to presented in Figure 7.

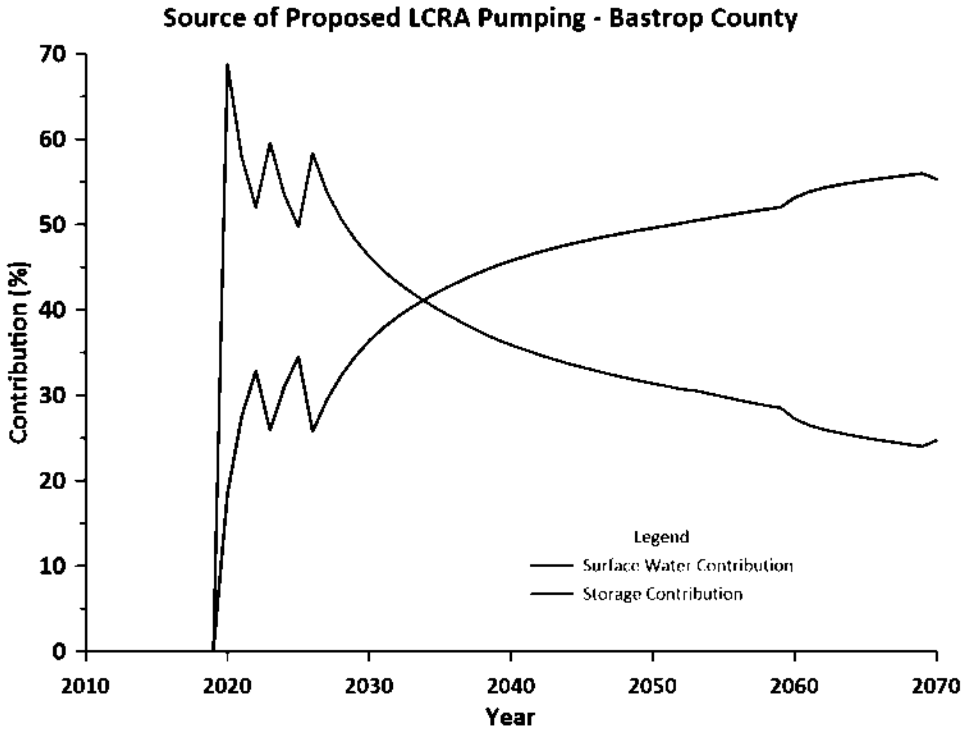


Figure 7. Source of Proposed LCRA Pumping

Please note that when the proposed LCRA pumping begins in 2020, about 70 percent of the pumped water comes from groundwater storage, and the relative contribution from reduced storage declines with time. Conversely, the relative contribution from reduced discharge to surface water/induced recharge from surface water increases with time. The steps in pumping can also be seen in Figure 6. Please note that when the simulated pumping is increased in 2023 and 2026, the initial response is to increase the relative contribution from groundwater storage increases and the relative contribution from surface water decreases. These results suggest that by 2050, over half of the proposed LCRA pumping would be sourced from surface water.

4.0 Groundwater Drawdown Predictions in Registered Wells

4.1 Initial Processing of Registered Well Data

Lost Pines Groundwater Conservation District provided an Excel file with 2,617 registered wells. Registered wells include permitted wells and non-exempt permitted wells (*LPGCD Well export.xlsx*). This file contained data on the latitude, longitude, surface elevation, and depth for each well. For purposes of this analysis, 242 wells without a recorded depth were not used. Also, 344 wells were not used that had the same latitude and longitude (30.5 and -97 respectively), which appeared to be "place-holders". These wells were not used in further analysis.

Of the remaining 2,031 wells, 510 did not have surface elevation listed. Of the wells that had a surface elevation listed, 22 wells were listed at 300 ft MSL or lower. The elevation of the Colorado River at the Bastrop-Fayette County line is about 300 ft MSL based on an online topographic map:

https://en-us.topographic-map.com/maps/sqvz/Bastrop-County/

Therefore, these surface elevations were considered erroneous and were reset to zero for further processing.

Of the wells that had a surface elevation listed, 14 wells were listed at 670 ft MSL or higher. The apparent high elevation in Bastrop County is about 731 ft MSL and is about 678 ft MSL in Lee County. These high points are close to each other near the Bastrop-Lee County line. Thus, all elevations above 670 were set equal to zero for further processing.

The final dataset, therefore, contains 2,031 wells: all of which include a well depth, 1,485 with a surface elevation, and 546 without a surface elevation.

The latitude and longitude were converted into GAM x- and y-coordinates using Surfer, a commercial gridding program.

The resulting file was saved as *RegWellLatLongSurfDepthGAMxy.csv* for further use.

4.2 Locating Registered Wells on Model Grid

The FORTRAN program *getregwellnode.exe* was written to find the cell or node center closest to each well. The program also compared the well bottom elevation to cell top and bottom elevations to place the well in the correct layer. Well bottom elevation was set based on the database value of surface elevation, where available, or the surface elevation of the surface cell in the model if the database had no surface elevation data available. Output from the program is a file named *regwel3dnode.dat*.

The results were sorted by the LPGCD ID number and saved in the Excel file *RegWellNodeLayer.xlsx*. Please note that a total of 1,833 were located on the model grid. The rest of the wells were either located outside the model grid or completed in aquifers not simulated in the model.

4.3 Model Simulated Groundwater Elevations in Registered Wells

The FORTRAN program *getrwhed.exe* was written to extract simulated groundwater elevations from three model runs of the new GAM: 1) the calibrated model, 2) the predictive simulation of the base case, and 3) the predictive simulation of the base+LCRA scenario. The output of the program is a file named *rgwelhed.dat*.

The results were saved in the Excel file *RegWellImpacts.xlsx*. The Excel file has three sheets:

- "GWE" includes the output from the program
- "DD" includes various calculated drawdowns
- "Averages" includes average drawdowns for each model layer

The GWE sheet includes the following data:

- LPGCD ID number (Column A)
- New GAM Node Number (Column B)
- Layer (Column C)
- Surface Elevation (Column D)
- Well Depth (Column E)
- Well Bottom Elevation (Column F)
- Simulated Groundwater Elevation in 2010 (Column G)
- Simulated Groundwater Elevation in 2019 (Column H)

For the Base Case:

- Simulated Groundwater Elevation in 2022 (Column I)
- Simulated Groundwater Elevation in 2025 (Column J)
- Simulated Groundwater Elevation in 2070 (Column K)

For the Base+LCRA Scenario:

- Simulated Groundwater Elevation in 2022 (Column L)
- Simulated Groundwater Elevation in 2025 (Column M)
- Simulated Groundwater Elevation in 2070 (Column N)

The DD sheet includes the same identifying data as the GWE sheet (Columns A to F). Columns G to M contain various drawdown calculations, and columns N to P contain estimates of the simulated drawdown attributable to the proposed LCRA pumping at three points in the project for each registered well located in the model grid. Each calculation is the difference between the simulated groundwater elevation from the base case and the simulated groundwater elevation from the Base+LCRA scenario. These columns represent the drawdown in each registered well located in the model grid attributable to the proposed LCRA pumping in each well.

- Column N includes the simulated drawdown attributable to the proposed LCRA pumping at the end of three years of pumping (i.e. end of the initial phase of pumping 7,995 AF/yr, or 2022).
- Column O includes the simulated drawdown attributable to the proposed LCRA pumping at the end of six years of pumping (i.e. three years of pumping 7,995 AF/yr followed by three years of pumping 14,990 AF/yr, or 2025).
- Column P includes the simulated drawdown attributable to the proposed LCRA pumping at the end of the simulation period, or 2070, and after three years of pumping 7,995 AF/yr

followed by three years of pumping 14,990 AF/yr, followed by 45 years of pumping between 24,894 AF/yr and 24,983 AF/yr.

4.5 Discussion of Simulated Drawdown in Registered Wells

The last sheet of the Excel file with the simulated groundwater elevation results and calculated drawdowns discussed in the previous section (*RegWellImpacts.xlsx*) is reproduced below as Table 4.

Table 4. Layer-Averaged Simulated Drawdowns and LCRA Impacts in LPGCD Registered Wells

Layer	Formation	Number of Wells	Drawdown (ft)							LCRA Impact (Drawdown in ft)		
			2010-2019	2019-2022 Base	2019-2025 Base	2019-2070 Base	2019-2022 LCRA	2019-2025 LCRA	2019-2070 LCRA	2022	2025	2070
1	BRAA and CRA	22	0.00	0.07	0.14	1.06	0.14	0.40	2.73	0.07	0.25	1.67
2	"Shallow Flow Zone"	127	0.22	0.25	0.52	4.49	0.38	0.84	6.65	0.13	0.32	2.16
3	Sparta Aquifer	104	11.44	1.84	3.28	14.68	1.88	3.38	15.33	0.04	0.10	0.65
4	Weches Formation	14	7.84	1.54	2.76	13.44	1.61	2.93	14.32	0.08	0.17	0.88
5	Queen City Aquifer	257	10.27	1.75	3.14	17.22	1.86	3.39	18.36	0.11	0.25	1.14
6	Reklaw Formation	94	15.84	3.65	6.39	32.30	4.27	7.69	37.14	0.62	1.30	4.84
7	Carrizo Aquifer	134	28.35	6.11	10.47	54.98	6.85	12.03	61.48	0.74	1.55	6.50
8	Calvert Bluff Formation	505	9.17	2.79	5.06	27.07	4.81	8.99	41.79	2.03	3.93	14.72
9	Simsboro Formation	173	14.48	4.19	6.62	25.78	11.73	20.58	55.29	7.54	13.96	29.52
10	Hooper Formation	301	-4.36	1.58	3.00	14.43	3.12	6.21	23.31	1.55	3.21	8.88

Please note that the new GAM layers are listed, and the names associated with those layers are also listed. The number of registered wells in each layer are included. The drawdowns for each layer and time period represent the average of all registered wells in that layer. The LCRA impact is the average drawdown in each layer attributable to the proposed LCRA pumping.

Please note that the drawdown from 2010 to 2019 is not attributable to the proposed LCRA pumping because the simulated LCRA pumping begins in 2020. Thus, the drawdown is associated with increases in pumping that were contemplated in the simulation that was used in the development of the desired future condition by GMA 12 and subsequently adopted by the Lost Pines GCD.

As noted earlier, historic pumping in Bastrop County has been relatively low. The simulation represents a large increase in pumping starting in 2015 (about 32,000 AF/yr) compared with about 20,000 AF/yr in 2010. The effect of this increase in pumping is manifested in significant drawdown from 2010 to 2019.

Drawdowns from 2019 to 2022 corresponds to the first three-year period of the proposed LCRA pumping. The Base Case 2019 to 2022 drawdown represents the case without LCRA pumping and the LCRA column for 2019 to 2022 represents the drawdown with the LCRA pumping. The LCRA impact column for 2022 represents the drawdown that is attributable to the proposed LCRA pumping and is the difference between the base case column and the LCRA column.

The columns labeled 2019 to 2025 represent the drawdowns at the end of the second phase of proposed pumping, and the columns labeled 2019 to 2070 represent the drawdown associated with the full simulation period.

Please note that the LCRA impact drawdowns are highest in the Simsboro Formation (Layer 9). However, the simulations show that the vertical connection between the layers results in drawdowns above and below the Simsboro Formation.

For example, the drawdown attributable to LCRA pumping from 2019 to 2070 in the Simsboro is about 30 feet. Immediately below the Simsboro Formation, the drawdown attributable to the LCRA pumping in the Hooper Formation is about 9 feet. Immediately above the Simsboro Formation, the drawdown attributable to the LCRA pumping in the Calvert Bluff Formation is about 15 feet.

Two layers above the Simsboro Formation is the Carrizo Aquifer. The 2019 to 2070 drawdown in the Carrizo Aquifer attributable to the proposed LCRA pumping is about 7 feet. Please note that the drawdowns decrease in layers 6, 5, 4, and 3 in each column. However, the drawdown in layer 2 (the "shallow flow zone") is higher than in layer 3. This is because there are places in the model where layer 2 directly overlies layer 8.

The drawdowns in layer 2 and layer 1 are small in comparison to the drawdowns in the underlying layers, but result in gradient changes that result in reduced groundwater discharge to surface water which eventually result in a gradient reversal in the Base+LCRA scenario that result in the surface water providing recharge to groundwater.

5.0 Groundwater Drawdown Predictions in Monitoring Wells

5.1 Initial Processing of Monitoring Well Data

Lost Pines Groundwater Conservation District provided two Excel files with 45 monitoring wells used in the District The first file (*Lost Pines Water Level Monitoring Wells- 20180305.xlsx)* included data on the latitude, longitude, and depth for each well. The second file (*2018 Water Level Measurements – 20190130-jt.xlsx*) included data on the surface elevation of the well.

The data from these two files were combined using the well number as a guide to create a single file that includes latitude, longitude, surface elevation, and well depth. When combined, the first file had two wells that were not included in the second file (58-62-208 and 58-46-510), and the second file had two wells that were not in the first file (59-33-408 and 58-46-501). In addition, there was a Queen City well that is listed as removed from the network (58-63-103). Finally, there were three wells that have no surface elevation listed (59-57-201, 59-50-401, and 5951-102) and were deleted.

This combined file with the remaining 39 wells was saved as *MonWells.xlsx*, and included the spatial coordinates converted to the GAM coordinate system using Surfer, a commercial gridding program. An abbreviated version of the file was saved as *MonWells.csv* for further processing.

5.2 Locating Monitoring Wells on Model Grid

The FORTRAN program *getrmonwellnode.exe* was written to find the cell or node center closest to each well. The program also compared the well bottom elevation to cell top and bottom elevations to place the well in the correct layer. Output from the program is a file named *monwel3dnode.dat*. Please note that all 38 wells were located on the model grid.

5.3 Model Simulated Groundwater Elevations in Monitoring Wells

The FORTRAN program *getmwhed.exe* was written to extract simulated groundwater elevations from three model runs of the new GAM: 1) the calibrated model, 2) the predictive simulation of the base case, and 3) the predictive simulation of the base+LCRA scenario.

A summary output from the program is a file named *monwelhed.dat*. This output file was combined with the identifying information from the original monitoring well file that was provided by Lost Pines GCD and saved as an Excel file named *MonWellSumHed.xlsx*. Columns A to I and Column R contain various identifying or well construction details. Of note is Column E, which is the LPGCD's designation of the aquifer and Column F which is the model layer picked by the location and well bottom elevation. Please note that there are four wells in the "shallow flow zone" (Layer 2). These are indeed shallow wells (basically 100 feet or less in depth). In several cases, the LPGCD designation of the aquifer is not consistent with the model layer.

Column J represents the simulated groundwater elevation at the end of the calibration period (2010). Please note that two of the shallow wells (58-46-301 and 58-46-503) have simulated groundwater elevations below the calculated bottom elevation of the well. As discussed further below, this highlights a limitation of the model that is useful in guiding the use of model results in the future.

Column K is the simulated groundwater elevation at the end of 2019 and is the same for both scenarios because the proposed LCRA simulated pumping does not begin until 2020. Thus, it is only presented once in this table. There is predicted drawdown in all monitoring wells between 2010 and 2019 due to the simulated pumping in the base case. Please recall that the model calibration period ended in 2010, and the proposed pumping of the LCRA wells would not begin until 2020. This complicates the future use of the model results in interpreting actual future monitoring data.

In addition, the simulations assume constant recharge each year approximately equal to the average recharge of the calibration period (1930 to 2010). The calibrated model demonstrated that variations in recharge has historically been the most important factor in explaining variations in groundwater elevations. Thus, the simulations provide an idealized case where drawdown is caused by increases in pumping.

Columns L, M. and N are the estimated groundwater elevations for the base case for 2022, 2025, and 2080, respectively. Columns O, P, and Q are the estimated groundwater elevations for the Base+LCRA scenario for 2022, 2025, and 2080, respectively. These data provide a broad overview of all the wells with the identifying and construction data.

Please note that some of the drawdowns based on 2010 groundwater elevations are negative, which means that there is a predicted groundwater level are rising from the 2010 condition. This usually means that some of the pumping that was included in the last few years of the calibrated model was not included in the predictive model. The issue is most prominent in Well 58-46-516, a Layer 10 well shown in Column AL.

The program also writes two files with more detailed estimates of groundwater elevation. The file that contains the simulated groundwater elevations for the base case is named *allhedbasemw.dat* and the file that contains the groundwater elevations for the Base+LCRA scenario is named *allhedlcramw.dat.*

These files were combined with the well number and model layer into two Excel files: *BaseGWEDDAllMonWells.xlsx* (for the base case) and *LCRAandBaseGWEDDAllMonWells.xlsx* for the Base+LCRA scenario).

Each of these Excel files have three sheets. The first is the identifying information in Rows 1 to 4 and the year in Column A, and the simulated groundwater elevations for the 37 wells in Columns B to AL. The second sheet calculates the annual drawdown in each well using 2010 as the starting point. The third sheet calculates the annual drawdown in each well using 2019 as the starting point. The 2010 calculation is consistent with the end of the calibrated model, and the 2019 calculation is consistent with the beginning of the proposed LCRA pumping.

The groundwater elevation estimates from for the two scenarios (base case and Base+LCRA) from the program were also saved in the first two sheets of an Excel file named *LCRAImpactAllMonWells.xlsx.* The third sheet of this file contain the estimated annual drawdown impact of the proposed LCRA pumping in each monitoring well. These results are the most useful to assist in the interpretation of future monitoring data, especially in the context of providing some guidance or basis related to the decision to move to the next phase of the LCRA pumping (i.e. increase pumping after three years).

For example, the most responsive well in the network to the proposed LCRA pumping is Well 58-55-407 (Column T in *LCRAImpactAllMonWells.xlsx*). The model simulations predict that the drawdown due to the pumping of the LCRA wells (as simulated in the model) will be 229 ft from 2019 to 2070. However, the data also show that after the three years of the initial phase of pumping, the drawdown in this well will be about 50 feet in the first year, 52 feet in the second year, and 52 feet in the third year. Thus, if there is no other new pumping in the area of the LCRA wells at the time of their start-up and the precipitation/recharge conditions are near average, the actual monitoring data from this well should show about a 50 ft decline in the first year and remains fairly constant for the next two years.

The possible deviation from this prediction could be the result of other pumping in the area, and/or an abnormally wet or dry period. If none of these conditions are true and the drawdown is substantially more or less than 50 feet, it should be concluded that the model is not a good predictor of drawdown and more investigation is warranted, including updating and recalibrating the model.

If, on the other hand, the actual monitoring data from this well and the other wells are substantially the same as the model predictions, then it could be concluded that the model appears to be reasonably accurate and the next phase of pumping should proceed.

6.0 References

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