GAM Runs 09-011, 09-012, and 09-24, Supplement

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EXECUTIVE SUMMARY

This supplement expands the a GAM run requested by GMA 9 (Chowdhury, 2010) by evaluating the 2007 state water plan groundwater availability numbers in relation to the requested pumping amounts, considering the frequency of drought conditions using a longer record of precipitation based on tree-ring research, and evaluating the relationships between pumping and drought versus drawdown, spring and base flow and outflow across the Balcones Fault Zone. This supplement included seven separate scenarios. Three of the scenarios assumed constant pumping (i.e. no drought reduction), and four assumed a 33% drought reduction. Each scenario included 430 seven years simulations based on tree-ring precipitation estimates from 1537 to 1972 for the Edwards Plateau (Cleaveland, 2006).

Similar to the request run (Chowdhury, 2010), results from these supplemental runs focused on drawdown impacts, impacts to spring and base flow, and impacts to outflow across the Balcones Fault Zone. Results were summarized GMA-wide and by county. Because each scenario consisted of 430 seven-year simulations, the results can also be expressed in terms of minimum, average, and maximum, as well as values that are exceeded 5% of the time and values that are exceeded 95% of the time.

Key results include:

- When pumping is about 94,000 acre-feet per year (the 75% of "base pumping"), average drawdown in the Trinity Aquifer in GMA 9 is about 24 feet, and the maximum drawdown is about 47 feet. However, drawdown would be less than 39 feet 95% of the time.

- A pumping increase of about 59,000 acre-feet per year (the range of pumping investigated in these supplemental runs) results in a decrease in spring and base flow of about 17,000 acre-feet per year over the entire GMA 9 area, and a decrease in outflow across the Balcones Fault Zone of about 17,000 acre-feet per year over the entire GMA 9 area.

- Increases in pumping over the range investigated have only a minimal impact on Upper Trinity Aquifer drawdown, presumably due to the buffering effect of surface water.

- Pumping increases result in increased drawdown in the middle and lower Trinity Aquifer. However, the increases are more dramatic in the average, 5% exceedance and maximum values than the 95% exceedance and minimum values. It is apparent that drawdown in dry years is impacted by pumping more than in wet years.

- Under reduced pumping conditions during drought and as more years are considered drought, maximum drawdown and 5% exceedance drawdown are higher than when there is no reduction or minimal reduction. However, average drawdown impacts are minimal, even when a drought is defined as occurring 20% of the years.

REQUESTOR:

Mr. Ron Fieseler, General Manager of the Blanco-Pedernales Groundwater Conservation District, on behalf of the groundwater conservation districts in Groundwater Management Area 9 has requested three runs. This supplement to the report that specifically covers the requested runs is intended to expand and complement that report.

DESCRIPTION OF REQUEST:

Mr. Ron Fieseler on behalf of the Groundwater Management Area 9 requested model runs that assessed the effects of pumping and drought on water levels and groundwater flows in the Edwards Group (Plateau) Aquifer and Upper-, Middle-, and Lower Trinity aquifers in 2060. He also requested us determine pumpage conditions that would allow water level declines of up to 45 feet in the Lower Trinity Aquifer.

This supplement expands the specific request by evaluating the 2007 state water plan groundwater availability numbers in relation to the requested pumping amounts, considering the frequency of drought conditions using a longer record of precipitation based on tree-ring research, and evaluating the relationships between pumping and drought versus drawdown, spring and base flow and outflow across the Balcones Fault Zone.

METHODS:

The original request included model runs that included predictive simulations using the Hill Country portion of the Trinity Aquifer model to assess the effects of drought and increased pumping on water levels, baseflow, and flow across the Balcones Fault Zone. The requested runs consisted of 50-year simulations, some with 50 years of average recharge, and some with 43 years of average recharge followed by 7 years of drought-of-record conditions. The runs also included various combinations of pumping at 2008 levels, one and a half times the 2008 pumping levels, and one and a half times 2008 pumping levels which were reduced to 2008 pumping levels during droughts.

This supplement included seven separate scenarios. Three of the scenarios assumed constant pumping (i.e. no drought reduction), and four scenarios assumed a 33% pumping reduction during drought years. Each scenario included 430 seven years simulations based on tree-ring precipitation estimates from 1537 to 1972 for the Edwards Plateau (Cleaveland, 2006). The first simulation assumed a repeat of precipitation from 1537 to 1543; the second simulation assumes a repeat of precipitation from 1538 to 1544.

The final simulation (430th) assumes a repeat of precipitation from 1966 to 1972. Details of the precipitation data used in the 430 simulations are presented in Appendix A.

Precipitation and Recharge

The seven-year running average of the tree-ring precipitation is presented in Figure 1. Note that the precipitation for the seven year period ending in 1956 is about 84% of average, and represents the driest seven year period in the record.

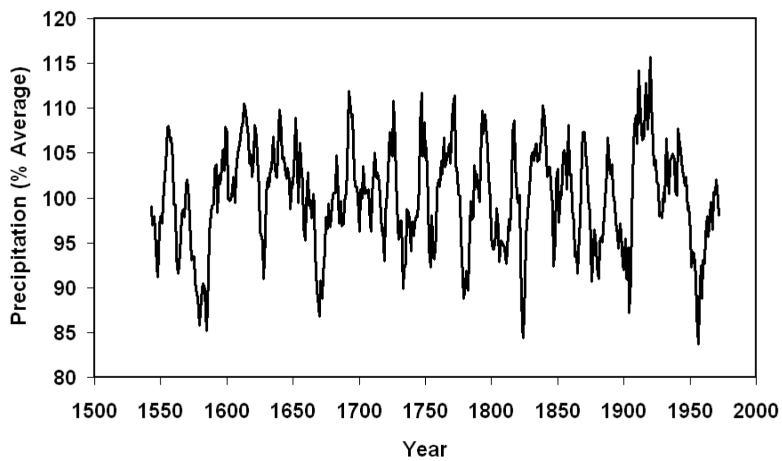

Figure 1. Seven-year running average precipitation in the Edwards Plateau region of Texas based on tree-ring data (data from Cleaveland, 2006).

These tree-ring precipitation data were used to develop 430 separate recharge input files based on the relationship between precipitation and recharge during the model calibration period as shown in Figure 2.

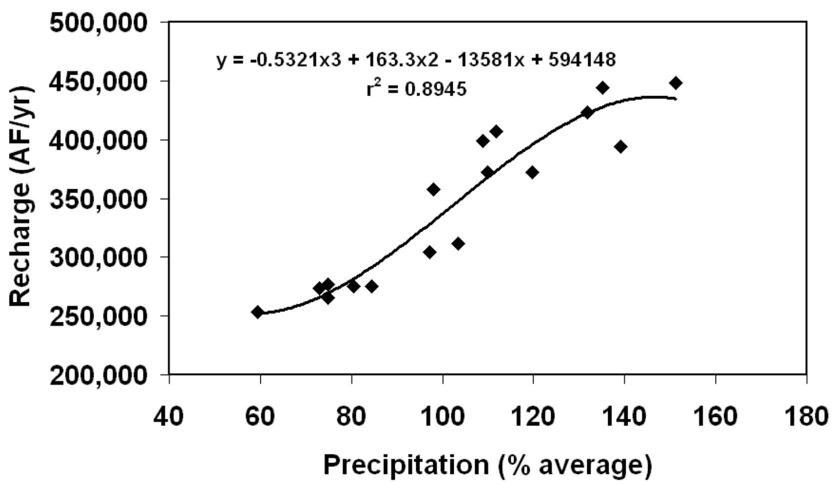

Figure 2. Precipitation vs. recharge in Hill Country model from 1981 to 1997

Pumping

Pumping in the original request was based on 2008 pumping, and in some runs, was increased to one-and-a-half times the 2008 pumping. As reported in the main report (Chowdhury, 2010) 2008 pumping totaled 61,248 acre-feet per year. One-and-a-half times 2008 pumping totaled 89,921 acre-feet per year. 2007 State Water Plan groundwater availability for 2060 is 86,112 acre-feet per year. A comparison of the requested scenarios where one-and-a-half times 2008 pumping seems reasonably close to state water plan groundwater availability numbers for 2060. However, closer inspection of the values demonstrates the differences on a county and on an aquifer basis. Figure 3 presents the comparison between state water plan groundwater availability and estimated 2008 pumping in the Edwards-Trinity (Plateau) Aquifer. Note that the groundwater availability is much higher in Bandera and Kerr counties than the 2008 estimated pumping, but the values are similar in Kendall County.

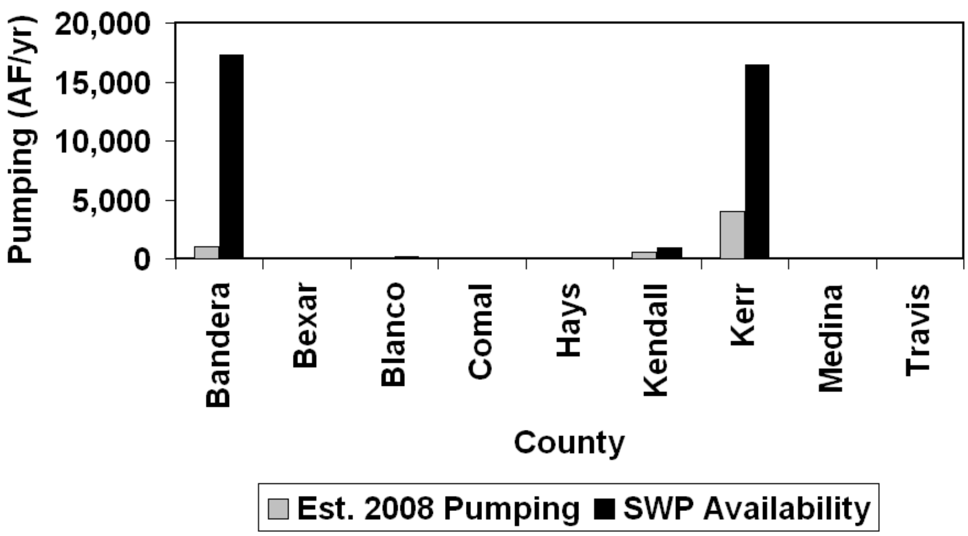

Figure 3. Comparison of 2008 Estimated Pumping and 2007 State Water Plan (SWP) Groundwater Availability in 2060 for the Edwards-Trinity (Plateau) Aquifer.

Figure 4 presents the comparison between state water plan groundwater availability and estimated 2008 pumping in the Trinity Aquifer. Note that State Water Plan groundwater availability numbers are higher in Bandera and Kerr counties. 2008 estimated pumping is much higher in Bexar County than the 2060 groundwater availability number. Estimated 2008 pumping is slightly higher than groundwater availability in Blanco, Comal, Hays, Kendall, Medina, and Travis

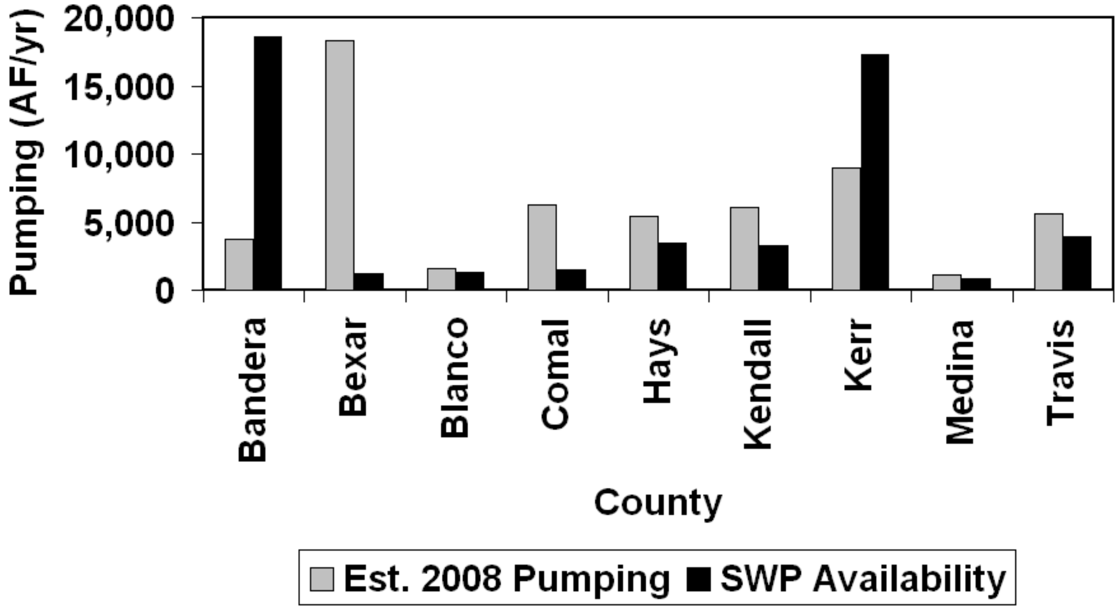

Figure 4. Comparison of 2008 Estimated Pumping and 2007 State Water Plan (SWP) Groundwater Availability in 2060 for the Trinity Aquifer.

In light of the differences, the runs completed for this supplement included developing a new set of pumping estimates using the following assumptions:

- 2008 estimated Edwards Group pumping was used.
- For all model layers other than the Edwards Group, if the one-and-a-half times 2008 estimated pumping in a county was higher than the 2060 groundwater availability, it was used.
- For all model layers other than the Edwards Group, if the 2060 groundwater availability number in a county was higher than the one-and-a-half times 2008 pumping, it was used.

The resulting input pumping estimates using this approach for the Edwards-Trinity (Plateau) Aquifer are summarized in Table 1. The resulting input pumping estimates using this approach for the Trinity Aquifer are summarized in Table 2. In each of these tables, the pumping assumptions are labeled "base" because they were subsequently varied in additional scenarios. Based on these estimated, total pumping for all of GMA 9 is about 128,000 AF/yr, which is considerably higher than the total groundwater availability in 2060 in the 2007 state water plan.

Table 1. Summary of "Base" Pumping Estimates for Supplemental Runs for the Edwards-Trinity (Plateau) Aquifer

County	Edwards Group	Trinity Group	Total
Bandera	596	11,771	12,367
Kendall	318	615	933
Kerr	1,036	11,202	12,238
Total	1,950	23,588	25,538

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Table 2. Summary of "Base" Pumping Estimates for Supplemental Runs for the Edwards-Trinity (Plateau) Aquifer

County	Upper Trinity	Middle Trinity	Lower Trinity	Trinity Aquifer Total
Bandera	1,342	14,858	2,357	3,692
Bexar	1,442	25,704	360	18,337
Blanco	116	2,229	0	1,563
Comal	701	8,676	0	6,251
Hays	642	6,849	674	5,443
Kendall	467	8,175	488	6,086
Kerr	393	6,514	10,418	8,995
Medina	66	551	1,119	1,157
Travis	828	7,575	0	5,602
Total	5,995	81,131	15,415	57,126

Seven pumping scenarios were used in these supplemental simulations. Scenarios 1 to 3 assumed constant pumping, and scenarios 4 to 7 assumed a 33% reduction in pumping during drought years (with a variation on what constitutes a drought year):

1. Base pumping (as defined in Tables 1 and 2)
2. 75% of base pumping (except for the Edwards Group)
3. 50% of base pumping (except for the Edwards Group)
4. 75% of base pumping when precipitation is above 75.5% of average, 33% reduction in pumping when precipitation is below 75.5% of average
5. 75% of base pumping when precipitation is above 79.6% of average, 33% reduction in pumping when precipitation is below 79.6% of average

6. 75% of base pumping when precipitation is above 83.3% of average, 33% reduction in pumping when precipitation is below 83.3% of average
7. 75% of base pumping when precipitation is above 87.0% of average, 33% reduction in pumping when precipitation is below 87.0% of average

The definition of a "drought year" was varied in scenarios 4 to 7 based on the tree-ring data. Scenario 4 represents a drought definition of 5% recurrence (5% of the years are defined as drought, and 95% are defined as non-drought). Scenario 5 represents a drought definition of 10% recurrence. Scenario 6 represents a drought definition of 15% recurrence. Scenario 7 represents a drought recurrence of 20% recurrence.

PARAMETERS AND ASSUMPTIONS:

- As in the requested runs, the recently updated groundwater availability model (version 2.01) for the Hill Country portion of the Trinity Aquifer developed by Jones and others (2009) was used for these simulations.

- See Mace and others (2000) and Jones and others (2009) for details on model construction, recharge, discharge, assumptions, and limitations of the model.

- The model has four layers: layer 1 represents the Edwards Group (Plateau), layer 2 represents the Upper Trinity Aquifer, layer 3 represents the Middle Trinity Aquifer, and layer 4 represents the Lower Trinity Aquifer.

- The rivers, streams, and springs were simulated in the model using MODFLOW's Drain package. MODFLOW's Drain package was also used to simulate spring discharge along bedding contacts of the Edwards Group (Plateau) and the Upper Trinity Aquifer in the northwestern parts of the model area. This resulted in the assignment of numerous drain cells along this outcrop contact.

- Seven different pumping scenarios were used as described above. Three constant pumping (a base pumping as previously summarized in Tables 1 and 2, 75% of base pumping, and 50% of base pumping), and four scenarios where pumping was reduced 33% during drought years.

- 430 recharge input files were developed based on the data previously presented in Figure 2 and Appendix A.

- Each simulation consisted of seven stress periods. Initial conditions were assumed to be equivalent to 2008 conditions.

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996)

RESULTS:

Similar to the request run (Chowdhury, 2010), results from these supplemental runs focused on drawdown impacts, impacts to spring and base flow, and impacts to outflow across the Balcones Fault Zone. Results were summarized GMA-wide and by county. Because each scenario consisted of 430 seven-year simulations, the results can also be expressed in terms of minimum, average, and maximum, as well as values that are exceeded 5% of the time and values that are exceeded 95% of the time. Summary tables of all results (for all of GMA 9 and by county) are presented in Appendix B.

Constant Pumping Scenarios (Scenarios 1 to 3)

Figure 5 summarizes the relationship between GMA 9 pumping and overall Trinity Aquifer drawdown (averaged over the entire GMA) for the three constant pumping scenarios (scenarios 1 to 3).

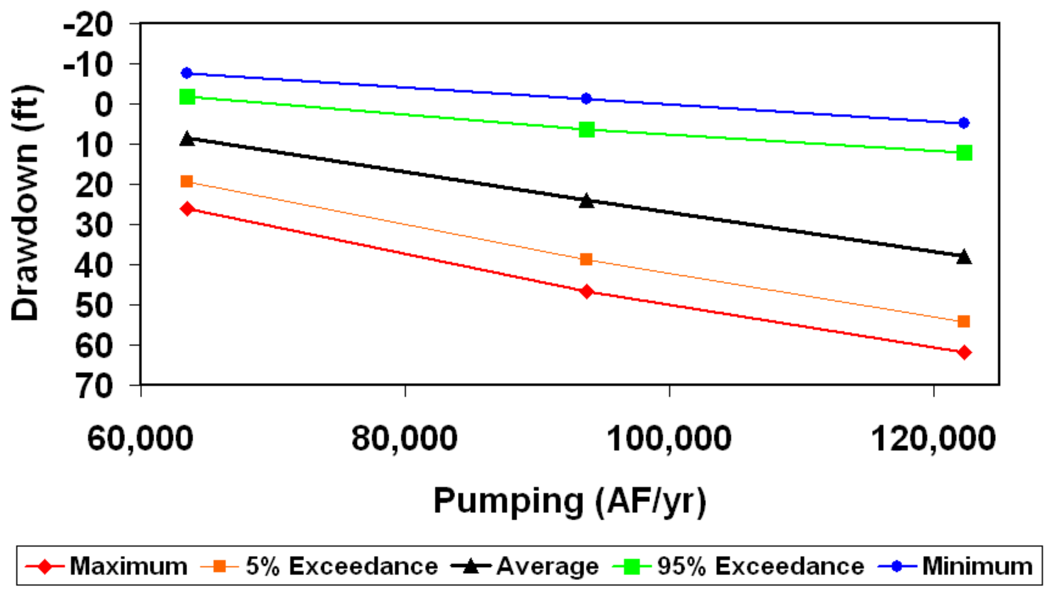

Figure 5. Pumping vs. Overall Trinity Aquifer Drawdown for Constant Pumping Scenarios for GMA 9

Note that, as expected, increases in pumping results in increases in drawdown. The nature of these simulations provides an opportunity to evaluate drawdown in terms of the minimum value (out of all 430 simulations), 95% exceedance value (drawdown that is exceeded 95% of the time based on the 430 simulations), the average drawdown (out of all 430 simulations), 5% exceedance value (drawdown that is exceeded 5% of the time based on the 430 simulations), and the maximum value (out of all 430 simulations). Note for example that when pumping is about 94,000 acre-feet per year (the 75% of "base pumping"), average drawdown is about 24 feet, and the maximum drawdown is about 47 feet. However, the summary also shows that drawdown would be less than 39 feet 95% of the time.

Figure 6 summarizes the relationship between pumping and spring and base flow (averaged over the entire GMA) for the three constant pumping scenarios (scenarios 1 to 3).

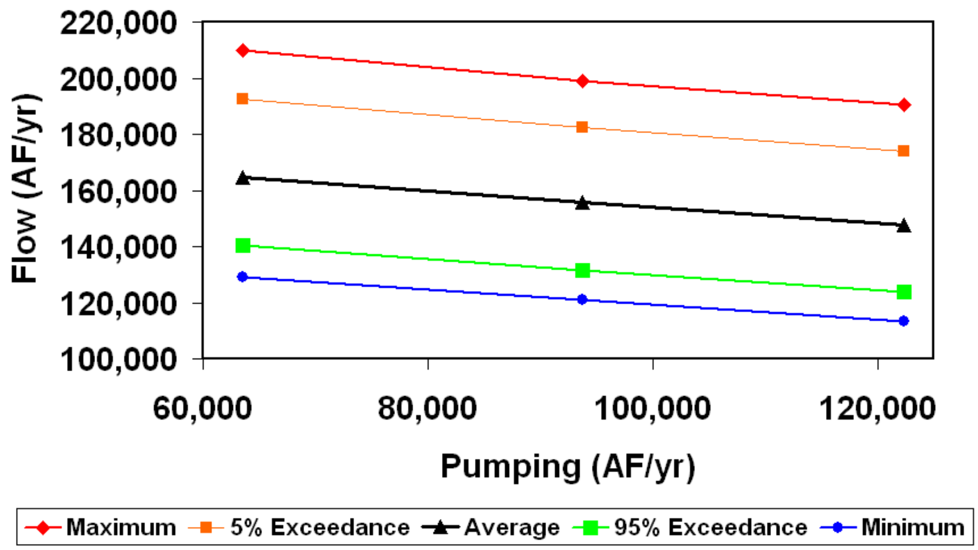

Figure 6. Pumping vs. Spring and Base Flow
for Constant Pumping Scenarios for GMA 9

As expected, pumping increases result in reductions in spring and base flow as the pumping captures this water prior to its discharge. It can be seen that, based on average values, a pumping increase of about 59,000 acre-feet per year results in a decrease in spring and base flow of about 17,000 acre-feet per year over the entire GMA 9 area.

Figure 7 summarizes the relationship between pumping and outflow across the Balcones Fault Zone (averaged over the entire GMA) for the three constant pumping scenarios (scenarios 1 to 3). As expected, pumping increases result in reductions in outflow across the Balcones Fault Zone as the pumping captures this water prior to its discharge. It can be seen that, based on average values, a pumping increase of about 59,000 acre-feet per year results in a decrease in outflow across the Balcones Fault Zone of about 17,000 acre-feet per year over the entire GMA 9 area.

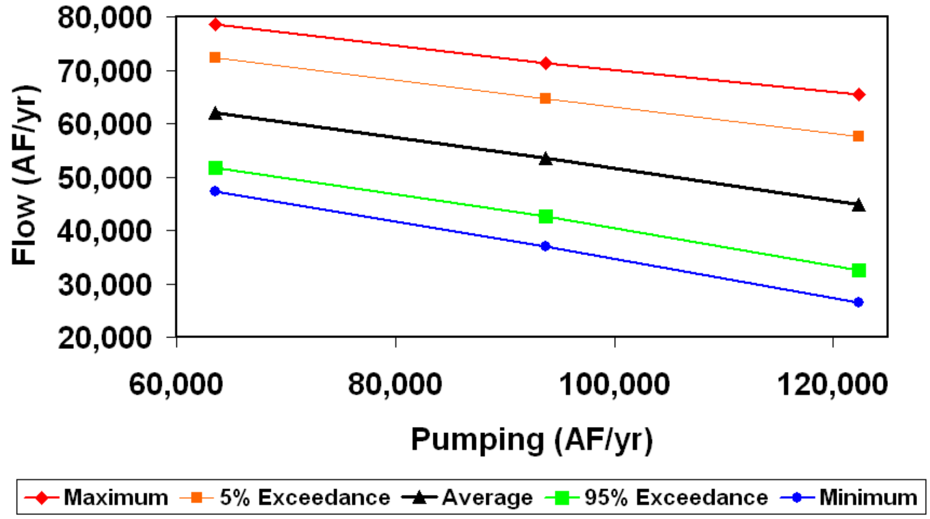

Figure 7. Pumping vs. Outflow across the Balcones Fault Zone for Constant Pumping Scenarios for GMA 9

Figures 8, 9 and 10 summarize pumping versus the average GMA 9 drawdown in the upper, middle and lower Trinity Aquifer, respectively. Note that increases in pumping have only a minimal impact on Upper Trinity Aquifer drawdown, presumably due to the buffering effect of surface water.

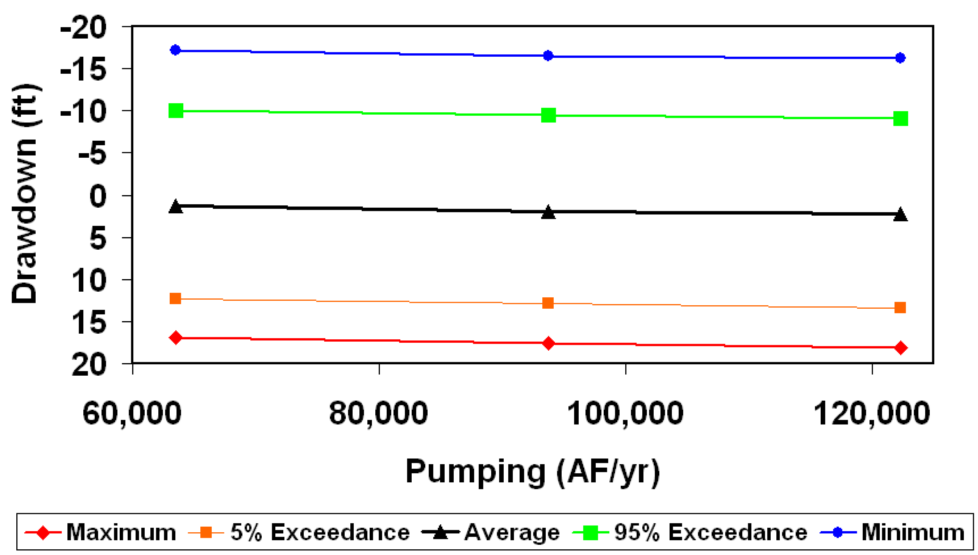

Figure 8. Pumping vs. Drawdown in the Upper Trinity Aquifer for Constant Pumping Scenarios for GMA 9

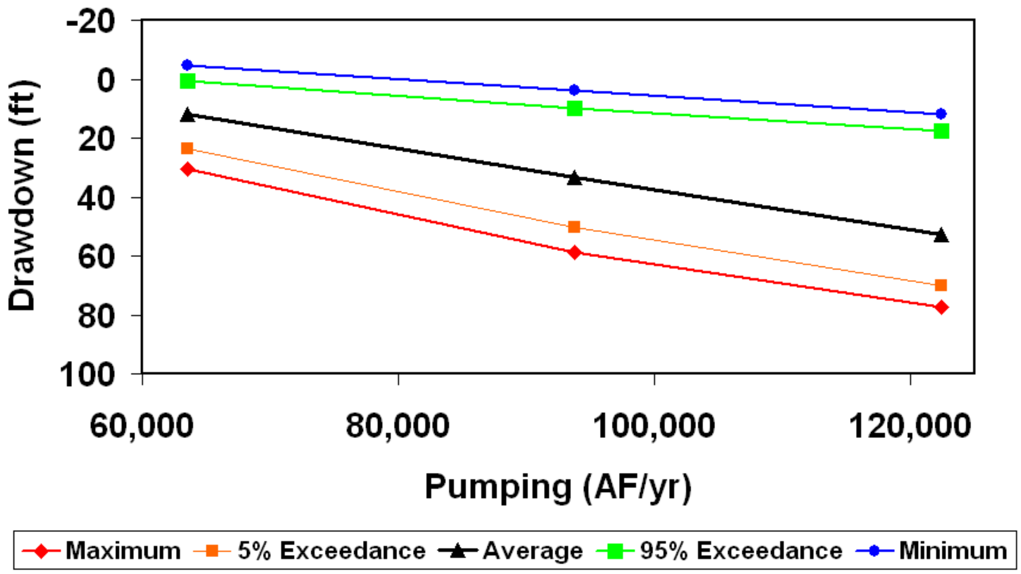

Figure 9. Pumping vs. Drawdown in the Middle Trinity Aquifer for Constant Pumping Scenarios for GMA 9

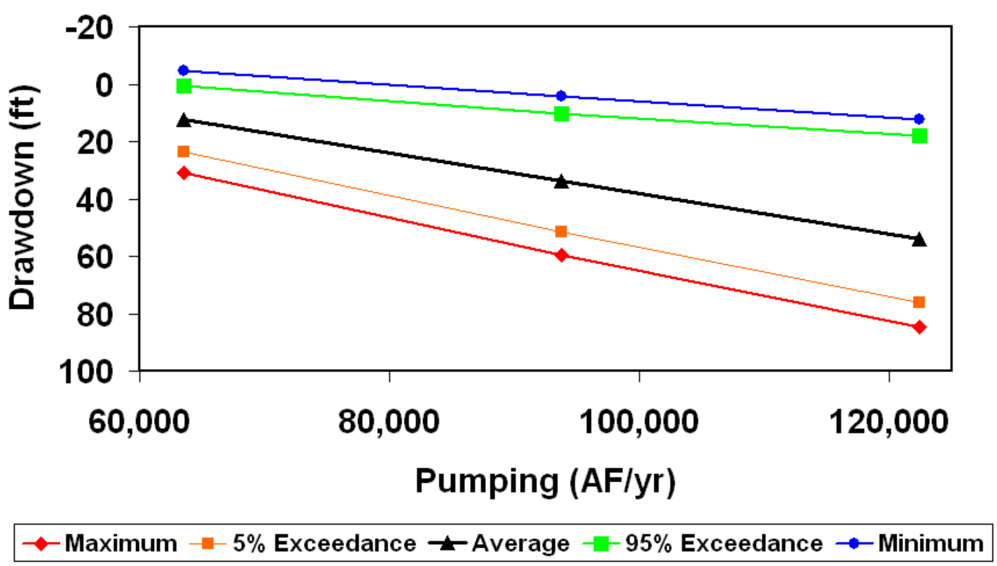

Figure 10. Pumping vs. Drawdown in the Lower Trinity Aquifer for Constant Pumping Scenarios for GMA 9

Pumping increases result in increased drawdown in the middle and lower Trinity Aquifer. However, the increases are more dramatic in the average, 5% exceedance and maximum values than the 95% exceedance and minimum values. It is apparent that drawdown in drier years is impacted by pumping more than in wet years.

The results can also be used to evaluate the relationship between overall Trinity Aquifer drawdown and spring and base flow in GMA 9 (Figure 11), and the relationship between overall Trinity Aquifer drawdown and outflow across the Balcones Fault Zone in GMA 9 (Figure 12).

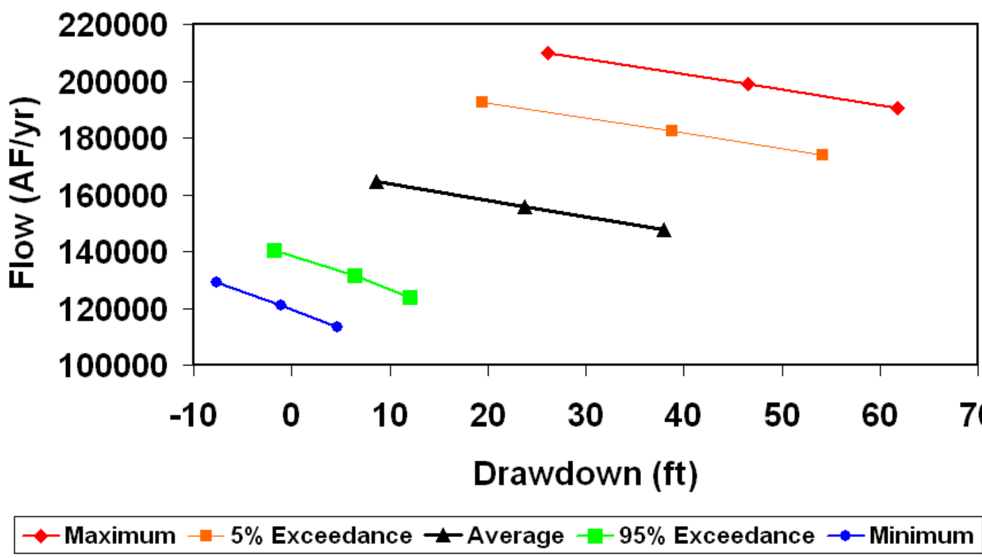

Figure 11. Overall Trinity Aquifer Drawdown in GMA 9 vs.
Spring and Base Flow in GMA 9.

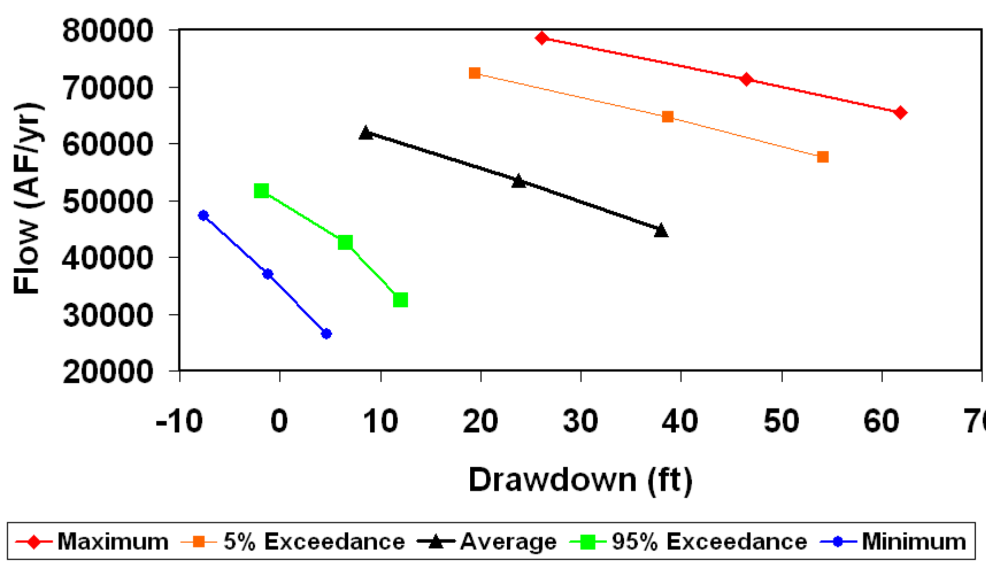

Figure 12. Overall Trinity Aquifer Drawdown in GMA 9 vs.
Outflow across the Balcones Fault Zone in GMA 9.

Note that under average conditions, an increase in drawdown of about 29 feet (associated with the increase in pumping) would result in about 17,000 acre-feet per year less spring and base flow, and about 17,000 less outflow across the Balcones Fault Zone.

Pumping Reduction Scenarios (Scenarios 4 to 7)

In order to investigate the changes that would result in pumping reductions during drought years, four scenarios were completed that varied the definition of what constitutes a drought year. As described previously, in Scenario 4, 5% of the years were considered drought (i.e. precipitation less than 75.5% of long term average as defined by the 1537 to 1972 tree-ring record). In Scenario 5, 10% of the years were considered drought (precipitation less than 79.6% of long term average), In Scenario 6, 15% of the years were considered drought years. In Scenario 7, 20% of the years were considered drought years. Pumping reductions were assumed to be 33% of pumping and the starting point for all these scenarios was the same as pumping in Scenario 2 described above (75% of the base pumping).

Figure 13 summarizes the impact of definition of drought and associated 33% pumping reductions on overall Trinity Aquifer drawdown.

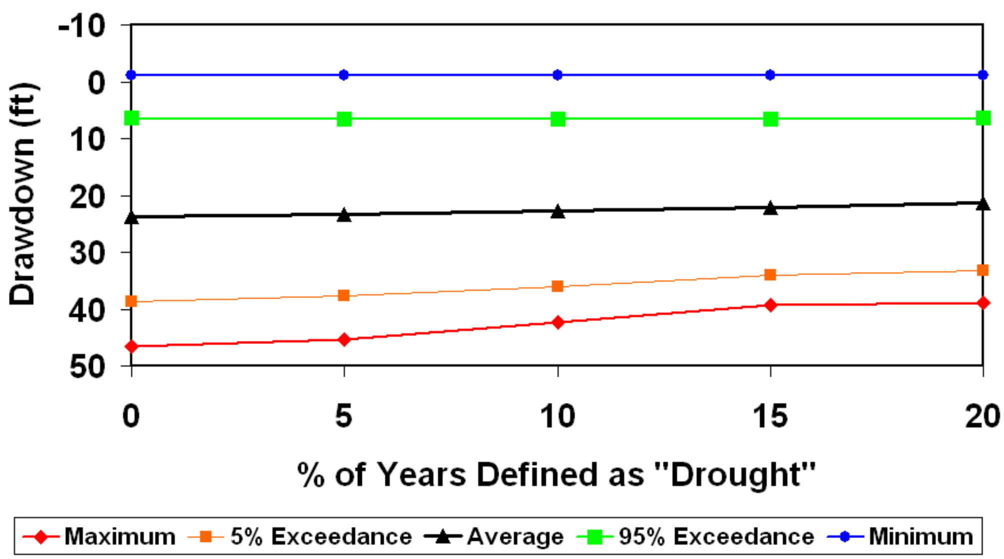

Figure 13. Impact of Definition of Drought and Associated 33% pumping reduction on overall Trinity Aquifer Drawdown in GMA 9.

Note that as more years are considered drought, and thus pumping is reduced, maximum drawdown and 5% exceedance drawdown are higher than when there is no reduction or minimal reduction. However, average drawdown impacts are minimal, even when a drought is defined as occurring 20% of the years.

Similar impacts are observed in the plots of spring and base flow (Figure 14) and outflow across the Balcones Fault Zone (Figure 15).

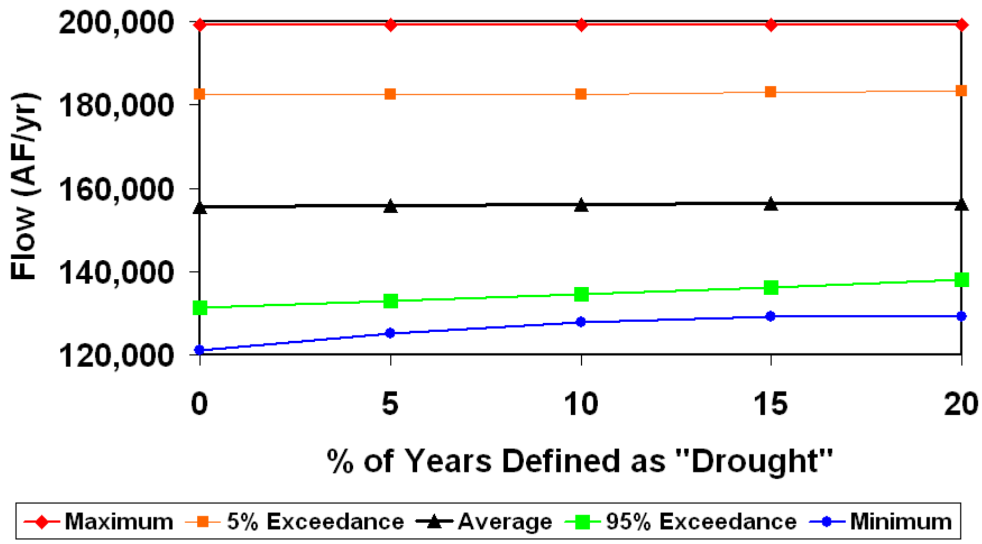

Figure 14. Impact of Definition of Drought and Associated 33% pumping reduction on Spring and Base Flow in GMA 9.

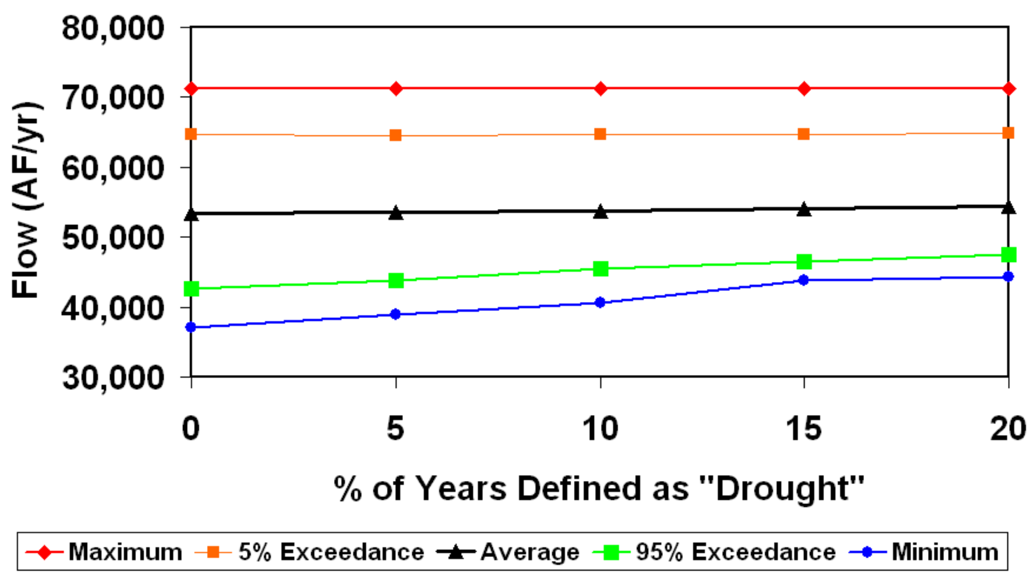

Figure 15. Impact of Definition of Drought and Associated 33% pumping reduction on Outflow across the Balcones Fault Zone in GMA 9.

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Mace, R.E., Chowdhury, A.H., Anaya, R., and Way, S-C., 2000, Groundwater availability of the Trinity Aquifer, Hill Country Area, Texas—Numerical simulations through 2050: Texas Water Development Board Report 353, 119 p.