# GTA Aquifer Assessment 07-03mag

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Texas Water Development Board
Groundwater Technical Assistance Section
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October 27, 2008

## REQUESTOR:

Cheryl Maxwell of the Clearwater Underground Water Conservation District acting on behalf of Groundwater Management Area 8.

## DESCRIPTION OF REQUEST:

In a letter dated December 26, 2007, Ms. Cheryl Maxwell provided the Texas Water Development Board (TWDB) with the desired future conditions for the Edwards (Balcones Fault Zone), Blossom, Brazos River Alluvium, Nacatoch, and Woodbine aquifers in Groundwater Management Area 8 and requested that TWDB estimate managed available groundwater values. This aquifer assessment presents the managed available groundwater for the Blossom Aquifer in Groundwater Management Area 8 (Figure 1).

## DESIRED FUTURE CONDITIONS:

- Maintain approximately 100 percent of the saturated thickness after 50 years in Lamar and Red River counties.
- Maintain approximately 100 percent of the estimated saturated thickness after 50 years in Bowie County.

## METHODS:

Williams (2007) used a spreadsheet analysis to estimate managed available groundwater for the Blossom Aquifer; however, Texas Water Development Board staff disagree with the approach. A review of the methods used by Williams (2007) and the reasons why we disagree with the approach is included in Appendix 1.

Because the desired future condition is to maintain 100 percent of the saturated thickness over the period of fifty years, the water levels within the aquifer have to remain at or near the same level throughout the fifty-year period.

Freeze and Cherry (1979, pp. 365-367) describe a methodology of determining hydraulic budgets and basis yields for groundwater basins. This is the basis for the methodology to estimate the managed available groundwater for the Blossom Aquifer.

A transient hydrologic budget for the saturated portion of an aquifer is (Freeze and Cherry, 1979, p.365):

$$Q(t) = R(t) - D(t) + \frac{dS}{dt}$$

Where: Q(t)= total rate of groundwater withdrawal
R(t)= total rate of groundwater recharge to the basin
D(t)= total rate of groundwater discharge from the basin
$\frac{dS}{dt}$ = rate of change of storage in the saturated zone of the basin

For the current desired future condition, in which no water can be taken from storage, then dS/dt can be set to zero and the budget is simplified to obtain,

$$Q(t) = R(t) - D(t)$$

Further looking at the equation, it shows that if discharge (D) leaves the aquifer, then the rate of groundwater pumping must be less than the total rate of groundwater recharge to the basin, or,

$$Q(t) < R(t)$$

Maintaining 100 percent of the saturated thickness requires that water levels remain constant. When water levels are under steady-state conditions, the estimated groundwater pumpage from the aquifer is a reasonable estimate for the managed available groundwater from the Blossom Aquifer. Additionally, data from the TWDB groundwater database (TWDB, 2008a) is used to create hydrographs to assess water-level trends in the Blossom Aquifer.

First, to assess water level trends, all wells in the Blossom Aquifer that had four or more measurements were used to create hydrographs (Figures 2 through 4). Second, the wells with the best data were used to assess periods of steady state conditions. The water-level measurements and the groundwater pumpage estimates were plotted on the same graph. For some wells, the pumpage estimates of the entity that owns the well were plotted for reference. County totals for groundwater pumpage estimates were only available up through 2003. Because of this, the discussion on pumpage is limited to this period.

Four wells with sufficient data were available in Lamar County (Figure 2). Three of the wells (17-19-901, 17-22-403, and 17-21-711) have seven or fewer measurements; however, they indicate that water levels have not declined significantly over the period of record. The remaining well (17-21-710) is located in the confined portion of the Blossom Aquifer near Paris, Texas. This well has measurements from 1942 until present. Since 1975, the total variation in water levels has been approximately 2 feet (Figure 2).

Figure 3 shows the four wells used for Red River County hydrographs. Three of these wells (16-17-701, 17-32-201, and 17-24-901) are located in the confined portion of the aquifer. This portion of the aquifer near the City of Clarksville has experienced significant water level declines.

The City of Clarksville well, 17-32-201, (Figure 3) (TWDB, 2008a) is 602 feet deep and completed in the confined portion the Blossom Aquifer. The first measurement shows that the water level in 1959 was at 285.40 feet above mean sea level (Figure 3). The maximum water-level decline occurred in 1983 when the well was measured at 85 feet above mean sea level (Figure 3). The total water level decline for this well is approximately 200 feet. Water levels in this well rebounded from the low of 370 feet below land surface in January 1983 up to 278 feet below land surface (177.00 feet above mean sea level) in January 1990.

Well 16-17-701 (Figure 3) is owned by the Red River Water Supply Corporation (WSC) and is 502 feet deep and with an elevation of 475 feet. Water levels have declined over 90 feet (Figure 3) over the measurement period. Water levels steadily declined approximately 36 feet from 1994 to 2002 and, after a small rise, water levels have remained constant since 2003. Since that time, the levels have varied approximately four feet.

Well 17-24-901 (Figure 3) has only four measurements, but it shows an overall water level decline of approximately 135 feet between 1966 and 2006. Well 17-23-903 (Figure 3) is located in the outcrop of the aquifer. The well has a total decline less than 50 feet and water levels have varied less than 20 feet total since 1972.

There are no Blossom Aquifer wells with water-level measurements in Bowie County. However, the Blossom Aquifer in western Bowie and eastern Red River County is overlain by alluvium that is interconnected with the Blossom Aquifer (McLauren, 1988, p. 4). Because of this interconnection, two wells completed in the alluvium overlying the Blossom in Bowie County, are used for this assessment (Figure 4). The assumption is that the water levels in the alluvium should reflect some of effects from pumping the Blossom Aquifer in Bowie County.

The two wells selected for Bowie County vary less than 8 feet total over the period of measurements and therefore do not show any significant influence in the overlying alluvium from pumping from Blossom Aquifer (Figure 4). Note that the water-level measurements end in 1993 for both of these wells.

Next, steady state periods were selected on the hydrographs that had sufficient data. When these periods were identified, the estimated annual groundwater pumpage amounts from the TWDB water use survey (TWDB 2008b) were used to estimate the amount of groundwater withdrawals that would allow for steady-state conditions in the aquifer. The groundwater pumpage estimates are included

on a second set of hydrographs. An average of the estimated pumpage estimates over a selected steady-state period used as the managed available groundwater. Table 1 details the periods chosen as the steady state periods, and Table 2 lists the groundwater pumpage estimates for those periods.

For Lamar County, well 17-21-710 (Figures 2 and 5) does not show significant changes over time; however, the period closest to a steady-state condition is period 1991 to 1994 (Figures 2 and 5; Table 1). The water level measurements for this period were all collected in January; therefore the previous year pumpage estimates from 1990 to 1993 were used to estimate steady-state groundwater withdrawals (Tables 1 and 2). Based on the average of the estimated pumpage estimates the managed available groundwater is 245 acre-feet per year in Lamar County.

In Red River County, two wells are used to assess the steady state conditions. The first is well 16-17-701, (Figures 3 and 6) and it shows that a near steady-state period occurs between 1994 and 2002. The reported groundwater pumpage for the Red River County Water Supply Corportation starts to increase in 1995 and levels off after 2001. Pumping does not appear to influence the water levels significantly in this area. When pumpage increased in 1995 and until it leveled off in 2001, water levels declined approximately 20 feet. Once the pumpage levels stabilized, the water-levels rebounded slightly (Figure 6).

The other well (17-32-201) in Red River County does showed considerable changes over time, and the steady-state period is difficult to ascertain. Between 1990 and 1996, water levels varied only 38 feet, and this is the period nearest steady-state conditions for this well (Figure 7; Table 1). The associated groundwater pumpage estimates (City of Clarksville) for years from 1989 to 1996 ranged from a low of 240 acre-feet in 1989 to a high i of 347 acre-feet in 1989 (Figure 7; Table 2). The water levels started rebounding in January 1990, which corresponds to a reduction in water use starting in 1987.

To determine the impact of climate on the Blossom Aquifer's water-levels in Red River County, annual precipitation amounts were used to see if the period was near normal. Data used for this analysis are from the U.S. Historical Climatology Network (Williams and others, 2007) (Figure 8), using the long-term data from a site at Clarksville (site no. 411772, Clarksville 2NE) near well 17-32-201. The six year period is a slightly above normal period with a dryer than normal 1988 (37.14 inches) before the period of interest, and a wetter than normal year in 1990 with 65.50 inches.

Based on these two wells the pumpage estimates for 1989 to 1996 are averaged to obtain an estimate of 689 acre-feet per year for the managed available groundwater.

Because no wells with water-level data exist in Bowie County in the aquifer, the managed available groundwater was estimated from the groundwater pumpage estimates from the same period (1989 to 1996) as the adjacent Red River County. This results in 95 acre-feet per year as the managed available groundwater.

## PARAMETERS AND ASSUMPTIONS:

- The Blossom Aquifer in Groundwater Management Area 8 is wholly contained within in the Region D Regional Water Planning Area boundaries.
- The Blossom Aquifer in Groundwater Management Area 8 is in both the Red River and Sulphur River basins
- Methods used assume that no change in storage occurs so that the desired future condition of 100 percent of saturated thickness in 50 years is maintained.
- Water-level measurements identified as being taken during pumping or after recent pumping within the database were removed from the data set.
- County totals for groundwater pumpage estimates are only current through 2003.
- Groundwater pumpage estimates during times of steady-state water levels are used as estimates of managed available groundwater.
- The managed available groundwater for each county was distributed to the aquifer subdivisions by percent of aerial extent.
- The areas for each subdivision were calculated from the Texas Water Development Board (TWDB) shapefile for the Blossom Aquifer, projected into the GAM projection (Anaya, 2001).
- Areas, in acres, were calculated using ArcGIS 9.2.

## RESULTS:

The managed available groundwater estimate for the Blossom Aquifer in Groundwater Management Area 8 is 1,029 acre-feet per year (Tables 3 and 4). The managed available groundwater is 95 acre-feet per year for Bowie County, 245 acre-feet per year for Lamar County, and 689 acre-feet per year for Red River County.

## STIPULATIONS:

Additional data are needed to create improved estimates; these estimates are a simplistic interpretation of the requested conditions. These solutions assume homogeneous and isotropic aquifers; however, conditions for the Blossom Aquifer may not behave in a uniform manner.

Note that estimates of managed available groundwater are based on the best available scientific tools that can be used to evaluate managed available groundwater and that these estimates can be a function of assumptions made on the magnitude and distribution of pumping in the aquifer. Therefore, it is important for groundwater conservation districts to monitor whether or not they are achieving their desired future conditions and to work with the TWDB to refine managed available groundwater given the reality of how the aquifer responds to the actual magnitude and distribution of pumping now and in the future.

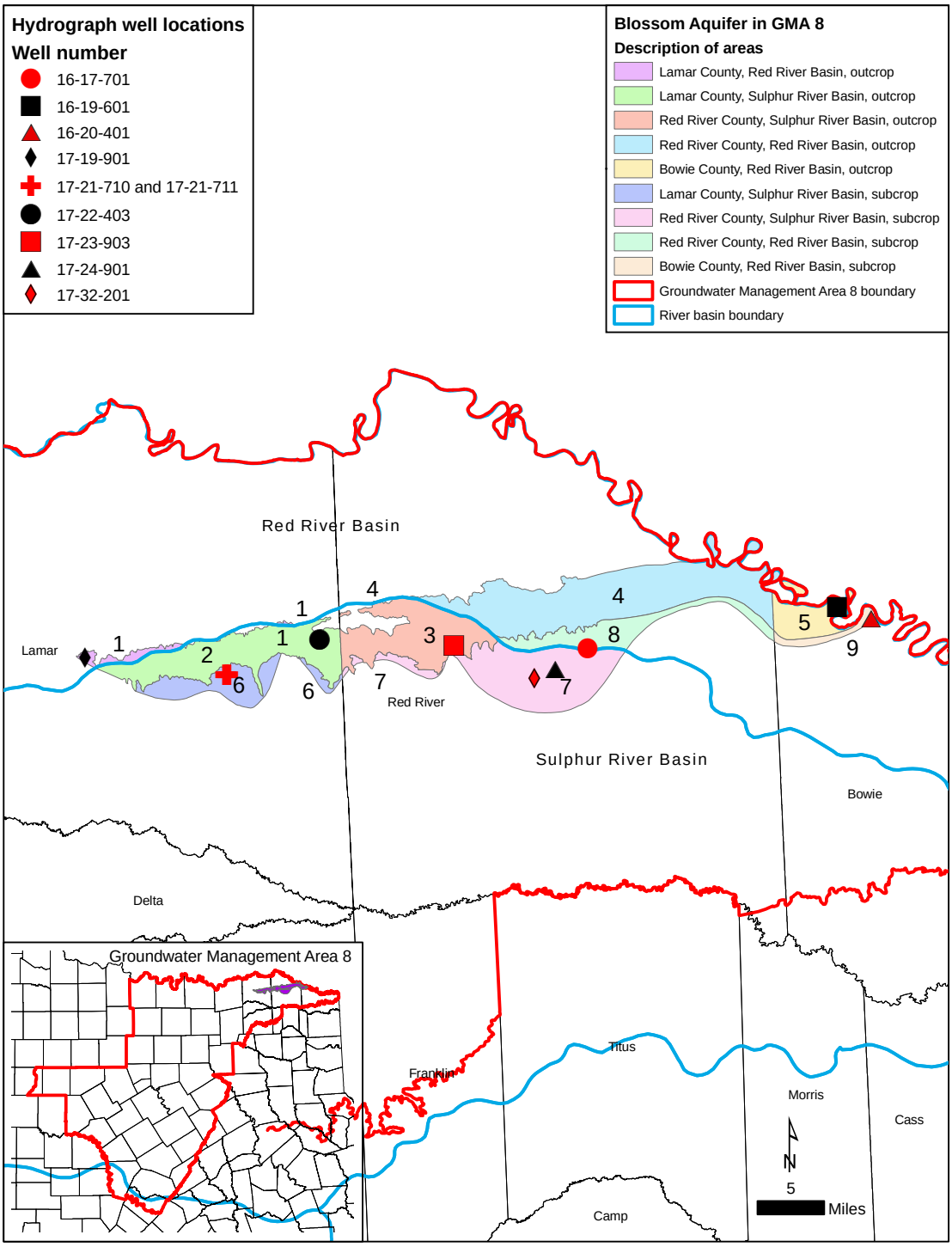



Figure 1. Location map of the Blossom Aquifer and geographic subdivision for reporting managed available groundwater.

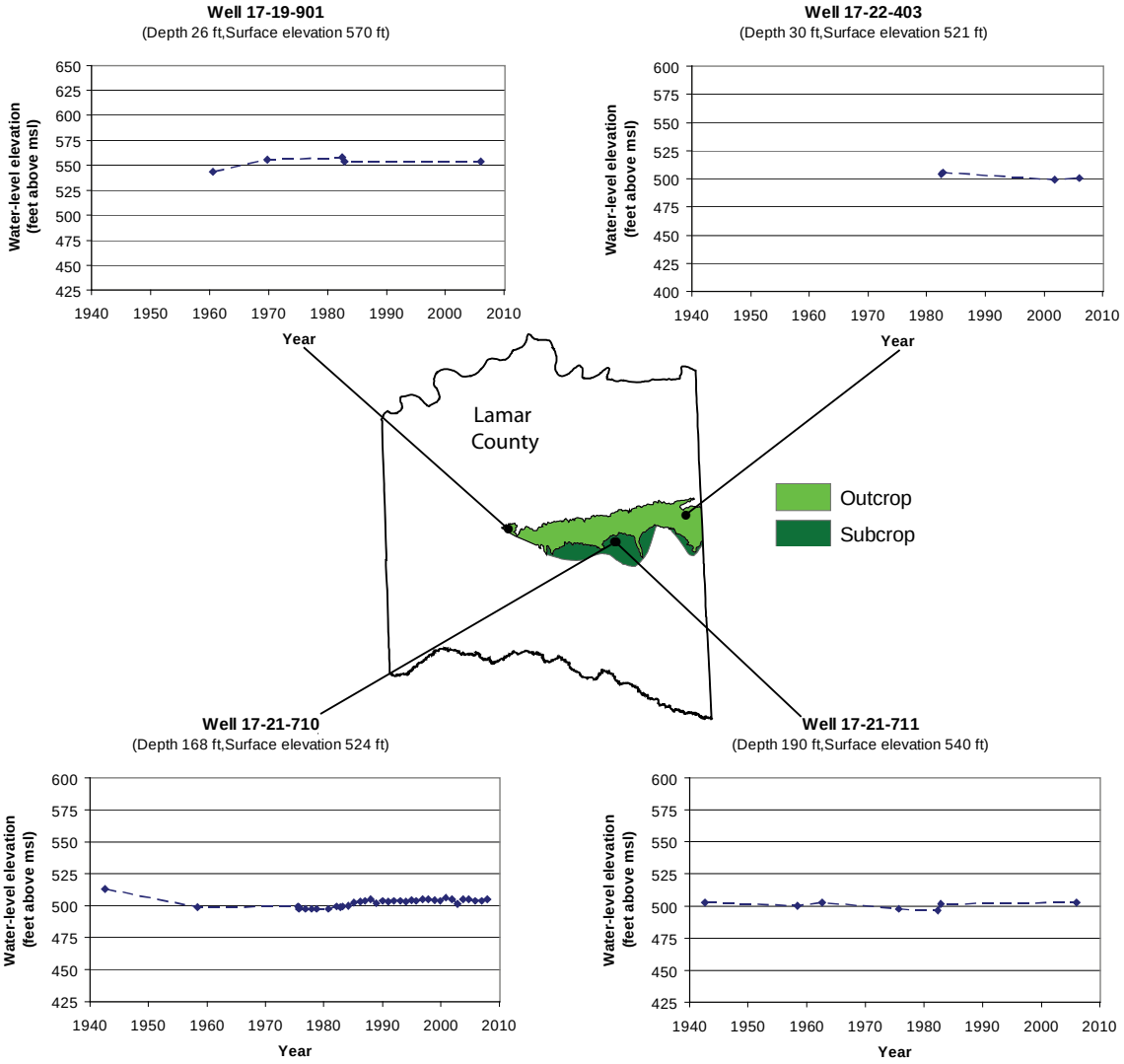



Figure 2. Hydrographs for Blossom Aquifer wells in Lamar County, Texas (TWDB, 2008a).

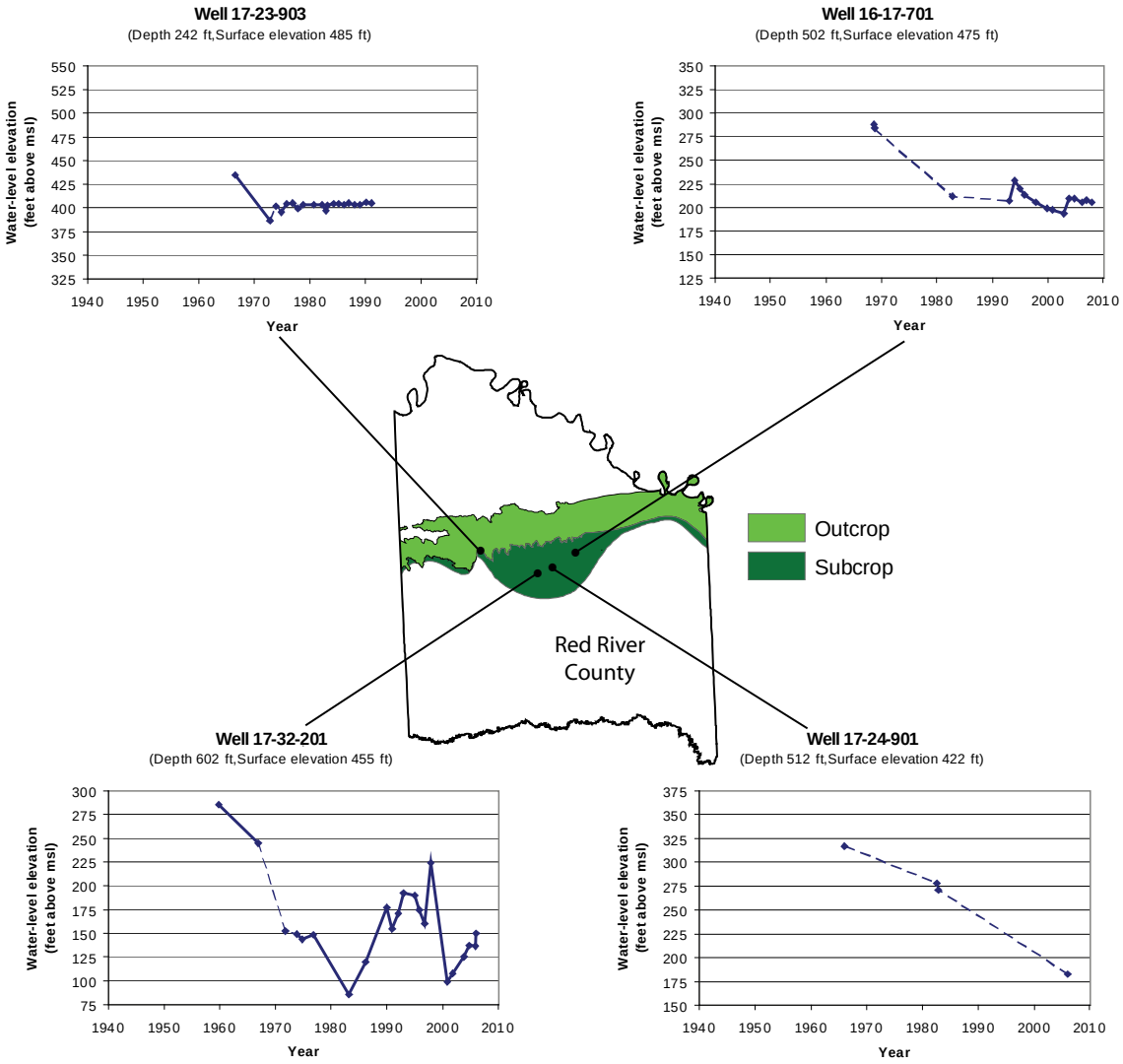



Figure 3. Hydrographs for Blossom Aquifer wells in Red River County, Texas (TWDB, 2008a).

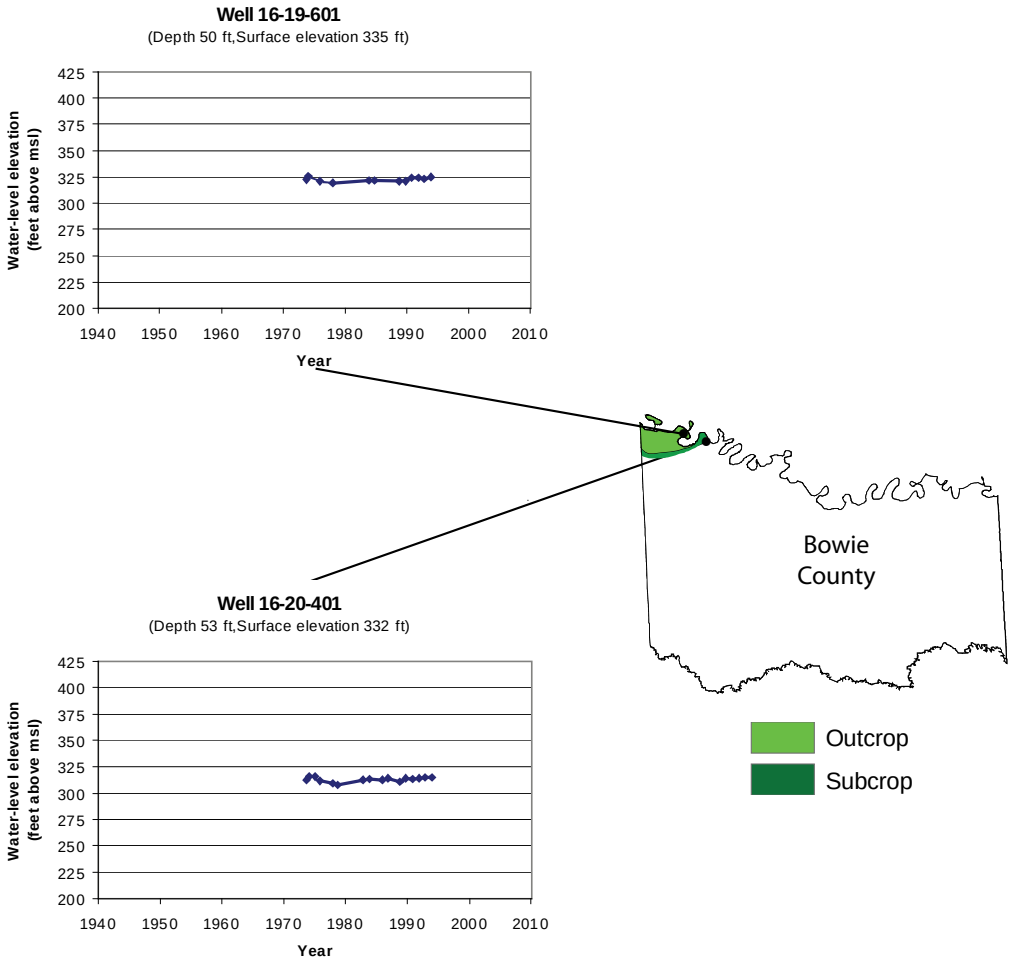



Figure 4. Hydrographs for Blossom Aquifer wells in Bowie County, Texas (TWDB, 2008a).

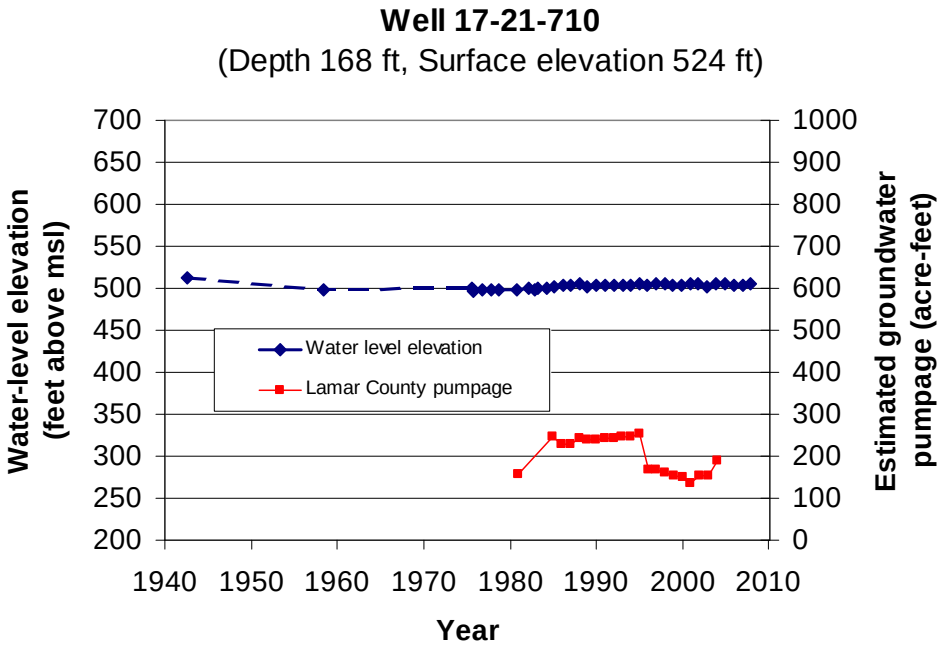



Figure 5. Water-level measurements for well 17-21-710 and the estimated groundwater pumpage for Lamar County in acre-feet.

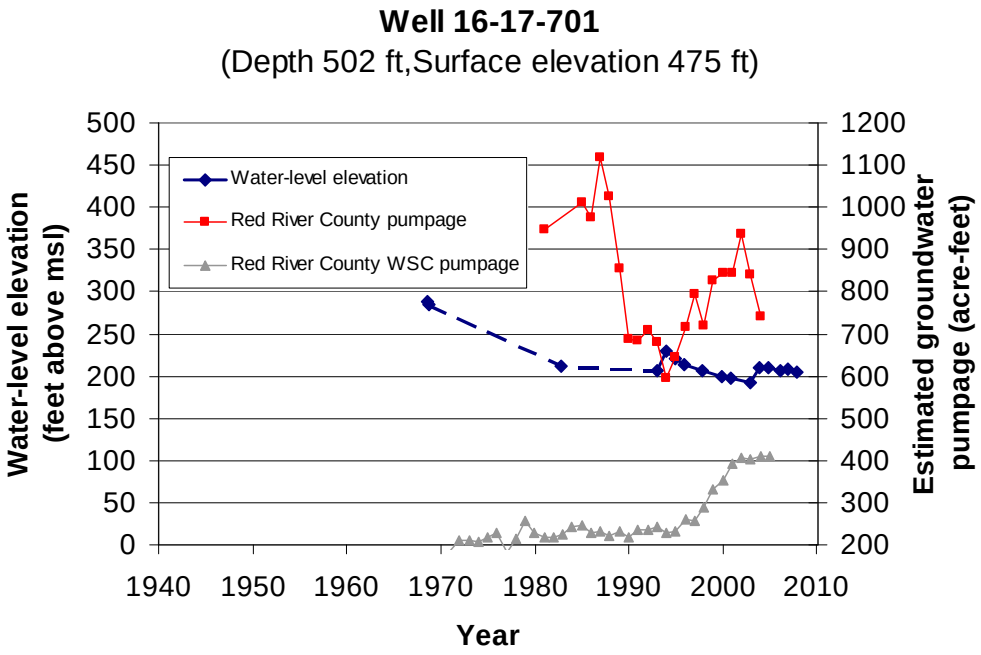



Figure 6. Water-level measurements for well 16-17-701 and the estimated groundwater pumpage for Red River County and Red River County WSC in acre-feet.

Table 1. Details of water-level data used to determine steady state periods (TWDB, 2008a).

| County | Well number | Water level data | | |
|---|---|---|---|---|
| | | Date of measurement | Elevation (feet above msl) | Difference from previous measurement (feet) |
| Lamar | 17-21-710 | 1/28/1991 | 503.40 | -0.55 |
| | | 1/8/1992 | 503.60 | 0.20 |
| | | 1/12/1993 | 503.60 | 0.00 |
| | | 1/11/1994 | 503.38 | -0.22 |
| Red River | 16-17-701 | 1/11/1994 | 229.00 | 22.00 |
| | | 1/10/1995 | 220.00 | -9.00 |
| | | 11/7/1995 | 213.50 | -6.50 |
| | | 11/20/1997 | 205.55 | -7.95 |
| | | 11/2/1999 | 199.12 | -6.43 |
| | | 11/15/2000 | 197.00 | -2.12 |
| | | 11/10/2002 | 193.00 | -4.00 |
| | 17-32-201 | 1/9/1990 | 177.00 | 57.00 |
| | | 1/8/1991 | 154.52 | -22.48 |
| | | 1/21/1992 | 171.00 | 16.48 |
| | | 1/13/1993 | 192.00 | 21.00 |
| | | 1/12/1995 | 190.00 | -2.00 |
| | | 11/8/1995 | 175.00 | -15.00 |
| | | 11/9/1996 | 160.00 | -15.00 |

Table 2. Groundwater pumpage estimates for the steady-state periods selected for assessment (TWDB, 2008b).

| County | Groundwater pumpage estimates | | |
|---|---|---|---|
| | Year | Amount (acre-feet) | Average (acre-feet) |
| Bowie | 1989 | 689 | 95 |
| | 1990 | 685 | |
| | 1991 | 709 | |
| | 1992 | 681 | |
| | 1993 | 595 | |
| | 1994 | 645 | |
| | 1995 | 717 | |
| | 1996 | 794 | |
| Lamar | 1990 | 243 | 245 |
| | 1991 | 244 | |
| | 1992 | 246 | |
| | 1993 | 246 | |
| Red River | 1989 | 689 | 689 |
| | 1990 | 685 | |
| | 1991 | 709 | |
| | 1992 | 681 | |
| | 1993 | 595 | |
| | 1994 | 645 | |
| | 1995 | 717 | |
| | 1996 | 794 | |

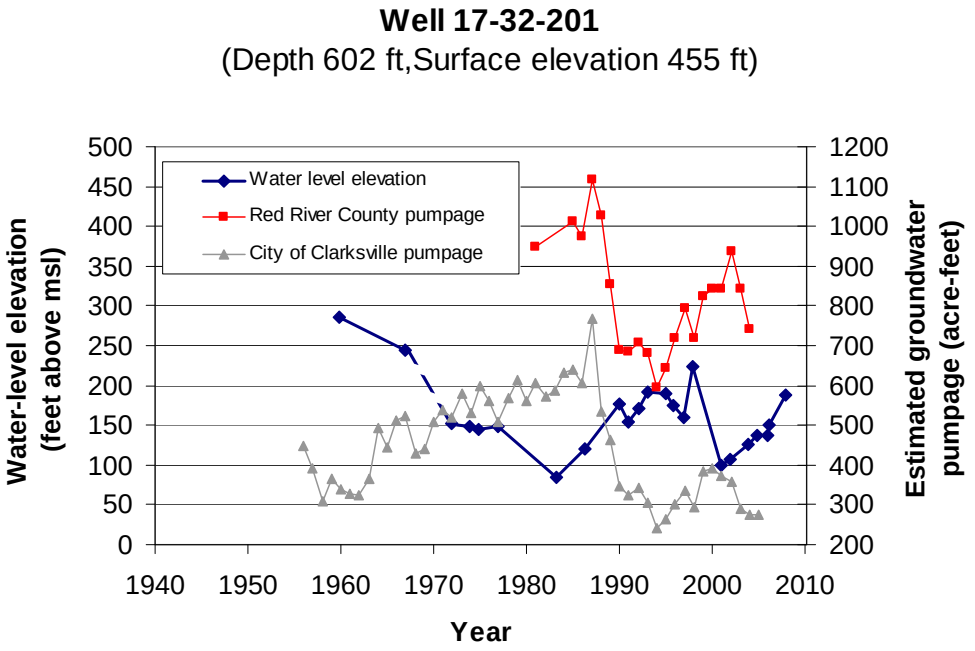



Figure 7. Water-level measurements for well 17-32-201 and the estimated Blossom Aquifer groundwater pumpage for the City of Clarksville and Red River County.

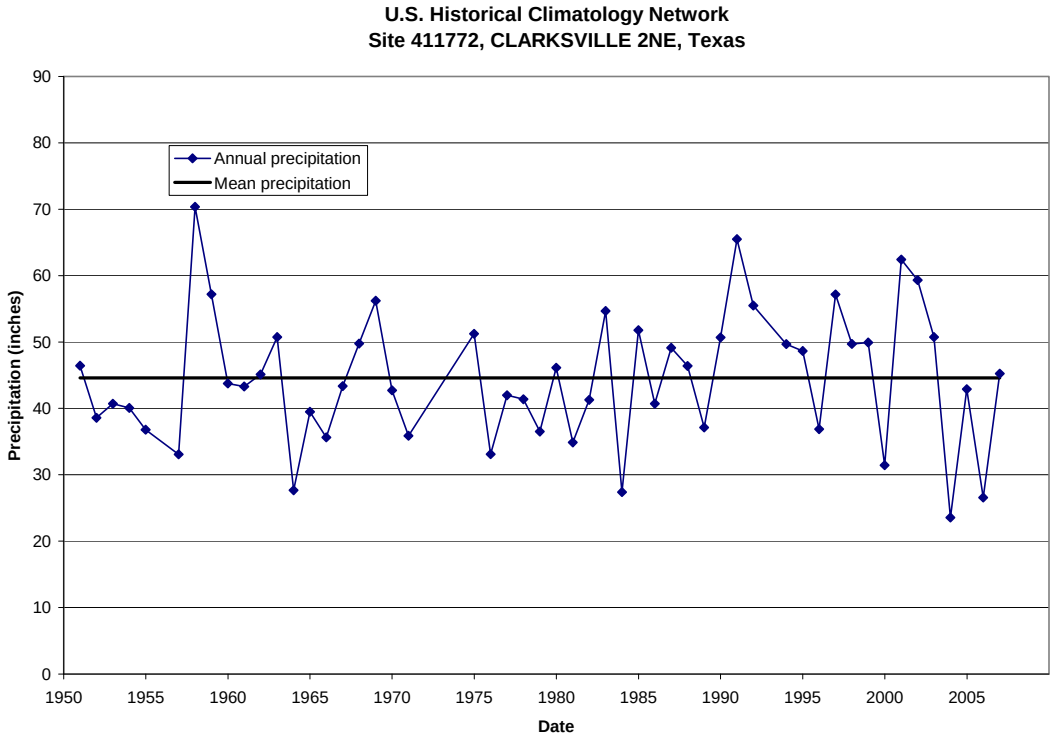



Figure 8. U.S. Historical Climatology Network precipitation for the Clarksville 2NE weather station (Williams and others, 2007).

Table 3. Assigned volume for the Blossom Aquifer by geographic subdivisions (See Figure 1).

| Aquifer | Map key | County | Map key area (acres) | Total aquifer acres in county (acres) | Percent of area | Total county pumpage (acre-feet) | Assigned volume (acre-feet) |
|---|---|---|---|---|---|---|---|
| Blossom | 1 | Lamar | 2,864 | 43,732 | 7 | 245 | 17 |
| Blossom | 2 | Lamar | 28,028 | 43,732 | 65 | 245 | 157 |
| Blossom | 3 | Red River | 23,629 | 121,043 | 20 | 689 | 138 |
| Blossom | 4 | Red River | 52,392 | 121,043 | 43 | 689 | 296 |
| Blossom | 5 | Bowie | 9,832 | 12,663 | 78 | 95 | 74 |
| Blossom | 6 | Lamar | 12,839 | 43,732 | 29 | 245 | 71 |
| Blossom | 7 | Red River | 31,477 | 121,043 | 26 | 689 | 179 |
| Blossom | 8 | Red River | 13,546 | 121,043 | 11 | 689 | 76 |
| Blossom | 9 | Bowie | 2,831 | 12,663 | 22 | 95 | 21 |
| **Total** | | | | | | | 1029 |

Groundwater pumpage estimates by county are multiplied by the percent of area to obtain the assigned volume for each

Table 4. Estimates of managed available groundwater for the Blossom Aquifer by geographic subdivisions (see Figure 1).

| Aquifer | Map Key | County | RWPA | River Basin | GCD | GMA | GeoArea | Year | MAG (acre-feet per year) |
|---|---|---|---|---|---|---|---|---|---|
| Blossom | 1 | Lamar | D | Red | None | 8 | n/a | n/a | 17 |
| Blossom | 2 | Lamar | D | Red | None | 8 | n/a | n/a | 157 |
| Blossom | 3 | Red River | D | Sulphur | None | 8 | n/a | n/a | 138 |
| Blossom | 4 | Red River | D | Red | None | 8 | n/a | n/a | 296 |
| Blossom | 5 | Bowie | D | Sulphur | None | 8 | n/a | n/a | 74 |
| Blossom | 6 | Lamar | D | Sulphur | None | 8 | n/a | n/a | 71 |
| Blossom | 7 | Red River | D | Sulphur | None | 8 | n/a | n/a | 179 |
| Blossom | 8 | Red River | D | Red | None | 8 | n/a | n/a | 76 |
| Blossom | 9 | Bowie | D | Red | None | 8 | n/a | n/a | 21 |

RWPG = regional water planning area GCD= groundwater conservation district GMA = groundwater management area

GeoArea = Geographic areas defined by unique desired future conditions as specified by a groundwater management area.

MAG = Managed available groundwater in units of acre-feet per year.

## REFERENCES:


Anaya, R., 2001, GAM technical memo 01-01(rev a): Texas Water Development Board technical memorandum, 2p.

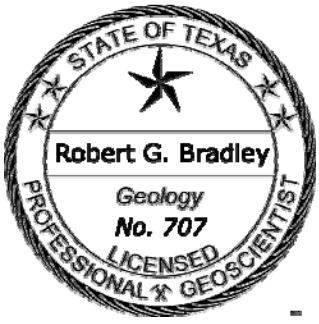
McLauren, C., 1988, Occurrence, availability, and chemical quality of the ground water in the Blossom sand aquifer: Texas Water Development Report no. 307, 32p.

Texas Water Development Board, 2008a, Groundwater database: Texas Water Development Board, Water Science and Conservation Division.

Texas Water Development Board, 2008b, Water use survey database: Texas Water Development Board, Water Resources Planning and Information Division.

Williams, C.R, 2007, Adopted desired future conditions of minor aquifers: memorandum to Cheryl Maxwell, Groundwater Management Area 8, 19p.

Williams, C.N., Jr., M.J. Menne, R.S. Vose, and D.R. Easterling. 2008. United States Historical Climatology Network Monthly Temperature and Precipitation Data. ORNL/CDIAC-118, NDP-019. Available on-line http://cdiac.ornl.gov/epubs/ndp/ushcn/usa_monthly.html] from the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee.


The seal appearing on this document was authorized by Robert G. Bradley, P.G., on October 27, 2008.

## APPENDIX 1

Williams (2007) used a two-dimensional spreadsheet model to predict pumping effects on the Blossom Aquifer. It assumes that the Blossom Aquifer is entirely unconfined. Estimates of the recharge area (outcrop), annual precipitation, recharge rate, saturated thickness, and specific yield were used to predict the saturated thickness after a specific period. Aquifer parameters used in the memorandum are from McLauren (1988). Additionally, precipitation data were from the National Oceanic and Atmospheric Administration. The outcrop area was determined from TWDB geographic information systems data.

Further, Williams (2008) split The Blossom Aquifer into two areas based on average saturated thickness; therefore, the desired future condition was split into the same areas. Lamar and Red River counties were lumped together. Bowie County was separated based on a larger estimated average saturated thickness of 65 feet.

Volumes from estimated reductions in saturated thickness and recharge volumes were calculated. Ultimately, based on this analysis, the desired future conditions were set at maintaining 100 percent of saturated thickness in the aquifer. No specific benchmark period or year was designated in the desired future condition statement or in the supporting memorandum.

In the memorandum to Groundwater Management Area 8, Williams (2007) estimated that the entire Blossom Aquifer outcrop is rechargeable material. The outcrop areal extent used for the calculations was 182 square miles. This was calculated from TWDB geographic information system (GIS) files. In TWDB report 307 (McLauren, 1988) estimated that than less than 32 percent of the outcrop defined in the report is rechargeable material (McLauren, 1988, p.4-5).

The total recharge calculated by Williams (2008) was 2,340-acre feet. In TWDB Report 307 (McLauren, 1988), the estimated total recharge to the Blossom Aquifer is 811 acre-feet per year. In comparison, the total availability for the Blossom Aquifer by North East Texas Regional Water Planning Group 2006 regional water plan is 2,270 for years 2010 through 2050, and 591 in 2060 (p.3-12)

The use of a recharge rate over the entire outcrop area may result in the overestimation of the actual recharge. This may lead to the contravention of the desired future condition, because estimated recharge exceeds the actual recharge. In addition, it is assumed that recharge by necessity needs to be greater than pumpage to maintain steady state conditions that would preserve all of the saturated thickness through the period. To add to this limitation is that the City of Paris covers a majority of the outcrop within Lamar County, which may have an effect on recharge from precipitation.