Desired Future Conditions and the Modeled Available Groundwater For
Sutton County Underground Water Conservation District

Statutory Guidance for Establishing Desired Future Conditions and Determining Modeled Available Groundwater

House Bill (HB) 1763 was passed during the 79th regular Texas Legislative Session (2005) to require that groundwater conservation districts (GCDs) conduct joint planning within their respective groundwater management areas (GMA). Joint planning is the process in which the GCDs within a GMA collectively and effectively manage the groundwater resources within the GMA. The primary goal of this planning is to define the Desired Future Conditions (DFC) of groundwater resources within their GMA. DFCs are defined in Title 31, Part 10, §356.10 (6) of the Texas Administrative Code as "the desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint planning process." The rules under which joint planning is conducted are stipulated in Chapter 36 of the Texas Water Code. GCDs, in accordance with HB 1763, must establish their respective DFC to specify how their aquifer will be managed for the next 50 years. This process was initiated in 2010 and is to be updated at least every five years. The DFCs must provide a balance between the highest practicable level of groundwater production and the conservation, preservation, protection, recharging, and prevention of waste of groundwater and control of subsidence in the management area.

The joint planning process set forth in TWC § 36.108 must be collectively conducted by all groundwater conservation districts within each GMA. In this process, the DFCs are presented by GCDs to the members of their respective GMA for approval. The DFCs must be approved by a two-thirds vote of all the district representatives for distribution to the GCDs in the management area. Once approved by the GMA, the DFCs are sent to the Texas Water Development Board (TWDB) for review and approval. After approval by the TWDB, the TWDB provides values of modeled available groundwater (MAG) to the GCDs based upon the specified DFC. TWC § 36.001 defines the MAG as the amount of water that the TWDB Executive Administrator determines may be produced on an average annual basis to achieve a DFC. Where available and when appropriate, a groundwater availability model (GAM) is used to determine the MAG. GCDs also have the option of establishing their own MAG using alternative analysis. If a GCD submits a MAG value determined using an alternative analysis, the TWDB will need to approve the calculations of the MAG submitted by the GCD. Once determined, the GCD uses its MAG to determine how and how much groundwater to allocate to its constituents.

District's Desired Future Conditions (DFC) and Modeled Available Groundwater (MAG)

The District has determined a DFC and subsequent MAG in accordance with Chapter 36 of the Texas Water Code. The DFC for the Edwards-Trinity Aquifer in Sutton County was adopted after considering the following factors specified in Texas Water Code §36.108 (d):

1. Aquifer uses or conditions within the management area, including conditions that differ substantially from one geographic area to another;

a. for each aquifer, subdivision of an aquifer, or geologic strata and
b. for each geographic area overlying an aquifer

2. The water supply needs and water management strategies included in the state water plan;
3. Hydrological conditions, including for each aquifer in the management area the total estimated recoverable storage as provided by the executive administrator, and the average annual recharge, inflows, and discharge;
4. Other environmental impacts, including impacts on spring flow and other interactions between groundwater and surface water;
5. The impact on subsidence;
6. Socioeconomic impacts reasonably expected to occur;
7. The impact on the interests and rights in private property, including ownership and the rights of management area landowners and their lessees and assigns in groundwater as recognized under Section 36.002;
8. The feasibility of achieving the Desired Future Condition; and
9. Any other information relevant to the specific Desired Future Conditions.

Following is a discussion of information used to formulate the DFC and calculation of the ensuing MAG.

Background

Sutton County covers approximately 1,453 square miles or 929,920 acres over the Edwards-Trinity Aquifer in West Central Texas. The aquifer system underlies west-central Texas nearly flat-lying Lower Cretaceous and Upper Cretaceous strata. The formation thins to the northwest and overlies generally massive pre-Cretaceous rocks that are comparatively impermeable and structurally complex. The soil in this area supports oak, juniper, mesquite, prickly pear, range grasses of the type that survive under arid to semi-arid conditions. The area contains a variety of wildlife: white-tailed deer, Rio Grande turkey, and small population of quail, dove, and a variety of migratory birds. Ranching is a major economic activity where sheep, goats, and cattle are the most common stock.

The District maintains a water-well database that currently includes 1,642 wells divided into seven categories (Table 1). Additional wells not in the database will be added when identified.

Table 1. Well Types in Sutton County

Well Type	Number of Wells
Domestic	560
Livestock	885
Permitted	65
Public Water Supply	9
Irrigation	30
Industrial	50
Miscellaneous	43
Total	**1,642**

Water Use in Sutton County

Water usage in Sutton County is discussed by category in the following sections. Unless otherwise noted, all estimates of water usage were provided by the District.

Domestic Wells

Domestic use of water in Sutton County is predicated on a household of four people using the American Water Works Association estimate for indoor use of 96 gallons per day per person. With 560 domestic wells in the database, a total of 241 acre-ft/yr is estimated for domestic water use.

Livestock Wells

Significant livestock in Sutton County includes stable populations of cattle, sheep, and goats. There are a limited number of horses that ranchers use to work their stock, but there are no horse farms or large herds. Numbers of livestock by type are listed in Table 2. Numbers represent 2014 livestock populations.

Table 2. Livestock water consumption in Sutton County (2014)

Type of Livestock	Number of Livestock	Water Consumed		
		(gal/day/head)	(gal/yr)	(acre-ft/yr)
Cows (Dry)	255	18	4590	0.014
Cows (w/ calf)	2,553	35	89,355	0.274
Bulls	102	35	3,570	0.011
Calves	2,998	5	14,990	0.046
Sheep	5,982	3	17,946	0.055
Goats	45,274	3	135,822	0.417
Total			**266,273**	**0.817**

Source: Sutton County Ag Extension Office and the Sutton County NRCS Office. Consumption numbers from the USDA Publication No. AS-954 in cooperation with North Dakota State Univ.

Irrigation Wells

There are 660 acres of land irrigated in Sutton County. A total of 1,108 acre-ft/yr was used for irrigation in 2014 (Table 3).

Table 3. 2014 irrigation water use estimates (Ag Conservation, Texas Water Development Board)

Crop	Acres	Inches/acre	Acre-ft
Cotton	0	0	0
Sorghum	0	0	0
Corn	0	0	0
Rice	0	0	0
Wheat	30	14	35
Other grain	20	22	47
Forage hay pasture	440	16	587
Peanuts	0	0	0
Soy oil	0	0	0
Vineyard	0	0	0
Orchard	70	47	274
Alfalfa	0	0	0
Sugarcane	0	0	0
Vegetables	0	0	0
Other	0	0	0
Golf courses	100	21	175
Failed	0	0	0
Total	**660**		**1,108**

Wildlife

North Llano River is the only perennial source of surface water in Sutton County. The North Llano River flows diagonally, north to south, through the eastern part of the county. This river serves as the only naturally occurring perennial source of water for wildlife. Because of the lack of surface water elsewhere in the county, wildlife rely on groundwater-fed stock tanks at selected ranches in the county. In order to account for this population and its impact, the Texas Parks and Wildlife biologist was asked to provide an estimate of the number of various species and their water requirements within the county. There are four landowners in Sutton County that raise white-tailed deer. The total water consumption for these operations is 1.12 acre-feet of water (Table 4). This water usage is included with the wildlife usage.

Table 4. Estimated population of wildlife in Sutton County

Species	Number of animals	Water use per animal (gals/animal/yr)	Total annual use by species (gal/yr)	Total annual use by species (acre-ft/yr)
White-tailed Deer	95,112	452.25	43,014,402	132.01
Axis Deer	4,000	452.25	1,809,000	5.55
Sika Deer	300	452.25	135,675	0.42
Fallow Deer	200	452.25	90,450	0.28
Elk	150	2,400	360,000	1.10
Aoudad	200	300	60,000	0.18
Blackbuck Antelope	400	300	120,000	0.37
Rio Grande turkey	40,000	73	2,920,000	8.96
Raccoon	100,000	80	8,000,000	24.55
Bobcat	1,400	90	126,000	0.39
Jackrabbit	290,000	29	8,410,000	25.81
Feral Hogs	5,000	1,460	7,300,000	22.40
Total			**72,345,527**	**222**

Oil/Gas Usage

A total of 480 acre-ft/yr of water was used by the oil/gas industry in 2008/2009. Oil/gas activity is expected to increase by no more than 30 percent in the foreseeable future. An increase of 30 percent in oil/gas activity translates to an increase in water usage to 625 acre-ft/yr.

Municipal Water Supply

The population of Sutton County was 4,270 as of the 2008 population census. 3,020 people live in the City of Sonora. City water consumption was 1,073 acre-ft/yr for the year ending 2013. (Source: City of Sonora Utility Department)

Total Water Consumption in Sutton County

The total consumption of water in Sutton County in 2013 is summarized by user group in Table 5.

Table 5. Water consumption in Sutton County

User Group	Annual Water Consumption (acre-ft/yr)
Municipal Water Supply	1,073
Domestic	241
Livestock	652
Irrigation	1,108
Wildlife	222
Mining (Oil/Gas)	625
Manufacturing	0
Total	**3,921**

Recharge

Recharge rates calculated for the western Edwards Plateau came from data and analyses compiled by Green and Bertetti (2010). The methodology they used equated recharge to calculated stream baseflow averaged over the perceived groundwater catchment area. Distributed recharge is negligible when precipitation decreases below about 16.5 inch/yr. The linear relation describing the correlation of recharge to precipitation can be written as:

$$\mathbf{R = 0.15(P - 16.5) \text{ for } P > 16.5,}$$
$$\mathbf{R = 0 \text{ for } P \leq 16.5}$$

where **R** is recharge (inch/yr) and **P** is precipitation (inch/yr). This expression provides a basis to predict recharge based on anticipated precipitation for District.

Green and Bertetti (2010) calculated that recharge in Sutton County varies from 1.30 inch/yr in the east where annual precipitation is approximately 23-25 inch/yr and recharge of 0.63 inch/yr in the Pecos River catchment area where annual precipitation is approximately 21 inch/yr. Overall, average recharge for Sutton County is approximately 1.0 inch/yr. For a total area of 929,920 acres in Sutton County, total average recharge is 77,500 acre-ft/yr. The recharge rate is marginally greater than the recharge (expressed as1.65 percent of annual precipitation, 0.37inch/yr, or 28,900 acre-ft/yr) cited in the 2004 GAM (Anaya and Jones, 2004).

The analysis by Green and Bertetti (2010) stresses that recharge in a semi-arid environment such as Sutton County is significantly variable over time. As represented in the previous equation, recharge rapidly decreases when annual precipitation approaches the threshold value of 16.5 inch/yr and is considered negligible when annual precipitation is below this threshold. In light of this critical aspect of recharge in Sutton County, the District has taken into account the variability and uncertainty of recharge to the Edwards-Trinity Aquifer. Recharge values calculated at 10, 20, and 30 percent reductions in annual precipitation are presented in Table 6. As illustrated, recharge declines from 75,000 acre-ft/yr at average precipitation to being negligible when annual precipitation decreases to 70 percent of the annual average. Recharge estimates in the 2004 GAM calculation and the 2007 Texas State Water Plan are included in Table 6 for comparison.

Table 6. Prediction of recharge based on the precipitation and recharge correlation calculated for Sutton County. Precipitation rate is relative to the long-term average of precipitation (acre-ft/yr) (Green and Bertetti, 2010).

Recharge Parameter	**(acre-ft/yr)**
Calculated recharge at average precipitation	75,500
Predicted recharge at 90 percent precipitation	48,800
Predicted recharge at 80 percent precipitation	22,100
Predicted recharge at 70 percent precipitation	0
2004 GAM recharge	28,900
2007 Texas State Water Plan	20,775

Desired Future Condition

The District is a member of GMA 7. GMA 7 encompasses most of the region served by the Edwards-Trinity Aquifer. The GCDs in GMA 7 collectively established a DFC of 7 feet of drawdown for the Edwards-Trinity (Plateau) Aquifer. The District endorsed a DFC as a balance between allowing for additional economic development, while at the same time ensuring the water resource is sustained for future generations. The DFC was adopted on July 29, 2010 (Lange, 2010).

Modeled Available Groundwater

The TWDB has several versions of a GAM of the Edwards-Trinity and Pecos Valley aquifers, including the original GAM (Anaya and Jones, 2004, 2009), a recalibrated version of the 2009 version of the GAM (Young et al., 2010), and an alternative GAM (Hutchison et al., 2011). The TWDB developed the original GAM in 2004 (Anaya and Jones, 2004) and refined it in 2009 (Anaya and Jones, 2009). The TWDB commissioned a project to recalibrate the 2009 version of the GAM using PEST, a computer program that provides the capability to semi-automatically calibrate groundwater models a and to integrate new information into the calibration process (Young et al., 2010). Separately, an alternative GAM was developed by the TWDB that converted the 2009 GAM model from a two-layer to a one-layer model and adjusted many of the input parameters including the model boundaries, model base and top elevations, recharge, hydraulic conductivity, anisotropy, and storage (Hutchison et al., 2011). The alternative GAM was calibrated for a longer period of time, 1930 through 2005, than the 2009 GAM which was calibrated for the period 1980 through 2000. PEST was also used during calibration of the alternative GAM (Hutchison et al., 2011).

The alternative GAM (Hutchison et al., 2011) was used to calculate the MAGs for the GCDs in GMA 7. GAM run 10-043 (Version 2) (Shi, 2012) documents the GAM run used to calculate the final MAG for GMA 7. Results from GAM run 10-043 (Version 2) (Shi, 2012) indicate that MAG values in GMA 7 that achieve the DFC of a maximum drawdown of no more than 7 ft is approximately 449,400 acre-ft/yr for the period from 2010 to 2060. Of this, 6,438 acre-ft/yr is determined as the MAG for Sutton County (Table 6) (Shi, 2012). 386 acre-ft/yr is assigned to the Colorado River basin and 6,052 acre-ft/yr is assigned to the Rio Grande basin. These values are constant over the period 2010 to 2060 (Table 7).

Table 7. Sutton County modeled available groundwater (MAG) by river basin for the period 2010 to 2060 (Shi, 2012) (acre-ft/yr)

River Basin	**Year**					
	2010	2020	2030	2040	2050	2060
Colorado	386	386	386	386	386	386
Rio Grande	6,052	6,052	6,052	6,052	6,052	6,052
Total	**6,438**	**6,438**	**6,438**	**6,438**	**6,438**	**6,438**

The District used an alternative analysis to increase confidence that the MAG calculated using the alternative GAM (Hutchison et al., 2011) is reasonable and defensible. The alternative analysis is predicated on a water-budget analysis of the western Edwards-Trinity Aquifer by

Green and Bertetti (2010). This decision was motivated by two basic observations. First, both the existing GAM (Anaya and Jones, 2004, 2009) and the alternative GAM (Hutchison et al., 2011) are regional in scale and neither have sufficient resolution nor local detail to provide simulations of water availability at the local level with an acceptable level of uncertainty. Second, the sensitivity of recharge to precipitation in the semi-arid environment of Sutton County is not fully accommodated in the MAG calculation. The alternative analysis used by the District to determine the MAG was predicated on estimates of regional recharge as a function of variable precipitation (Green and Bertetti, 2010). This analysis recognized that recharge varies with precipitation and that the amount of groundwater available for extraction will vary as recharge varies (Table 2).

A moderately conservative approach was assumed in this alternative analysis of the MAG. This approach is predicated on the assumption that annual precipitation will be less than the long-term average. If precipitation is 80 to 90 percent of the long-term average precipitation, recharge will be 22,100 to 48,800 acre feet/yr (Table 6). Second, if it is assumed that 20 percent of recharge will be available for pumping, then the MAG would be 4,420 to 9,760 acre-ft/yr. At the lower precipitation rate of 80 percent of the long-term average, there is sufficient groundwater to meet the current rate of consumption (i.e., 3,921 acre-ft/yr, Table 5) if recharge only is relied on to meet the water needs. Water consumption up to a rate comparable to the projected MAG (i.e., 6,438 acre-ft/yr, Table 6) could also be met at a precipitation rate of 80 percent of the long-term average, if groundwater in storage is available to make up the difference (i.e., 2,511 acre-ft/yr) without lowering the water table by more than 7 ft. The water-budget analysis by Green and Bertetti (2010) indicates that recharge will be negligible when precipitation is 70 percent or less of the long-term average of precipitation. Under these conditions, the District will need to rely totally on groundwater in storage.

This alternative analysis suggests that current consumption rates in the District (i.e., 3,921 acre-ft/yr) should be met for most anticipated recharge scenarios. A MAG of 6,438 acre-ft/yr will need to rely on groundwater in storage during periods when precipitation is more than 10 to 20 percent below the long-term average of precipitation. There remains some uncertainty in whether the District can meet the DFC under long-term drought conditions if consumption is increased to the levels calculation by the alternative GAM (Table 7) given the uncertainty in the spatial and temporal distribution of groundwater in storage in the Edwards-Trinity Aquifer in the District.

References

Anaya, R. and I. Jones. 2004. Groundwater Availability Model for the Edwards-Trinity (Plateau) and Cenozoic Pecos Alluvium Aquifer Systems, Texas. Austin, Texas: Texas Water Development Board. 208 p.

Anaya, R. and I. Jones. 2009. Groundwater Availability Model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers of Texas. Report 373. Austin, Texas: Texas Water Development Board. 103 p.

Green, R.T. and F.P. Bertetti. 2010. Investigating the Water Resources of the Western Edwards-Trinity Aquifer. Contract Report Prepared for the Sutton County Groundwater Conservation District. 79 p.

Hutchison, W.R., I.C. Jones, and R. Anaya. 2011. Update of the Groundwater Availability Model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers of Texas. Texas Water Development Board. 61 p.

Lange, A.J. 2010. GMA 7 DFC 01. Desired future conditions for the Capitan Reef Complex, Dockum, Edwards-Trinity (Plateau), Ellenburger-San Saba, Hickory, Lipan, Marble Falls, Ogallala, and Rustler aquifers.

Shi, J. 2012. GAM Run 10-043 MAG (Version 2): Modeled available groundwater for the Edwards-Trinity (Plateau), Trinity, and Pecos Valley Aquifers in Groundwater Management Area 7,11p.

Young, S.C., J. Doherty, T. Budge, and N. Deeds. 2010. Application of PEST to re-calibrate the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers. Contract report for the Texas Water Development Board.