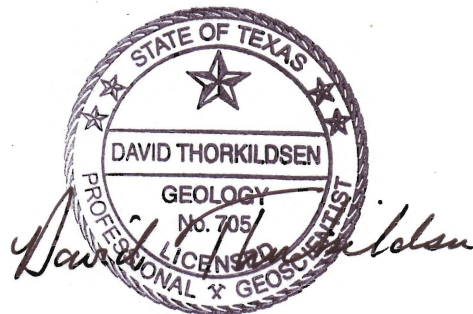


# GTA Aquifer Assessment 08-07

by David Thorkildsen, P.G. and Sarah Backhouse

Texas Water Development Board  
Groundwater Technical Assistance Section  
(512) 936-0871



August 31, 2010

## **REQUESTOR:**

Caroline Runge, of the Menard County Underground Water District acting on behalf of the member groundwater conservation districts of Groundwater Management Area 7.

## **DESCRIPTION OF REQUEST:**

In a letter dated July 8, 2008, Ms. Caroline Runge provided the Texas Water Development Board (TWDB) with draft desired future conditions for the Hickory and Ellenburger-San Saba aquifers in Groundwater Management Area 7 and requested that TWDB evaluate the draft desired future condition scenarios for each of those areas. This aquifer assessment estimates the annual total pumping to achieve the draft desired future condition scenarios for the Hickory Aquifer in Groundwater Management Area 7.

## **DRAFT DESIRED FUTURE CONDITIONS:**

- Hickory Aquifer – Four scenarios that allow water-level declines of 5, 10, 15, and 20 feet after 50 years, respectively.

## **METHODS:**

A transient hydrologic budget for the saturated portion of an aquifer is described by 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 this analysis, it is assumed that:

$$R(t) = R(r) + R(e)$$

where:  $R(r)$  = rejected recharge for the basin  
 $R(e)$  = effective recharge

Effective recharge is the amount of water that enters an aquifer and is available for development (Muller and Price, 1979, p. 5). Rejected recharge is the amount

of total (or potential) recharge that discharges from an aquifer because it is overfull and cannot accept more water (Theis, 1940, p. 1).

In addition, it is assumed that:

$$R(r) \cong D(t)$$

Therefore, the total rate of groundwater pumping equals effective recharge plus the change in storage of the aquifer, or:

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

County, regional water planning area, river basin, subcrop/outcrop, and groundwater conservation district boundaries subdivided the aquifer into map areas (Figure 1). The areal extent of each aquifer map area was calculated.

Analysis of regional water-level trends (HUWCD No.1, 2010a, TWDB, 2010a) for the Hickory Aquifer during the period 1996-2003 showed that no significant changes in water levels (storage) occurred overall (Figures 2-6). Therefore, groundwater withdrawals from wells (HUWCD No.1, 2010b, TWDB, 2010b) for that period estimated the effective recharge and the aquifer was hydrologically in a condition of steady state. The average annual withdrawal was then applied as estimated annual effective recharge to the outcrop areas within the counties where the withdrawals occurred.

To calculate change in aquifer storage based on the draft desired future conditions map areas were multiplied by the estimated aquifer storativity, and then by uniform water level declines of 5, 10, 15, and 20 feet. These volumes were then divided by 50 years to obtain a yearly volume. In cases where unconfined and confined conditions existed, those were calculated separately.

The calculations were completed in a Microsoft Excel worksheet.

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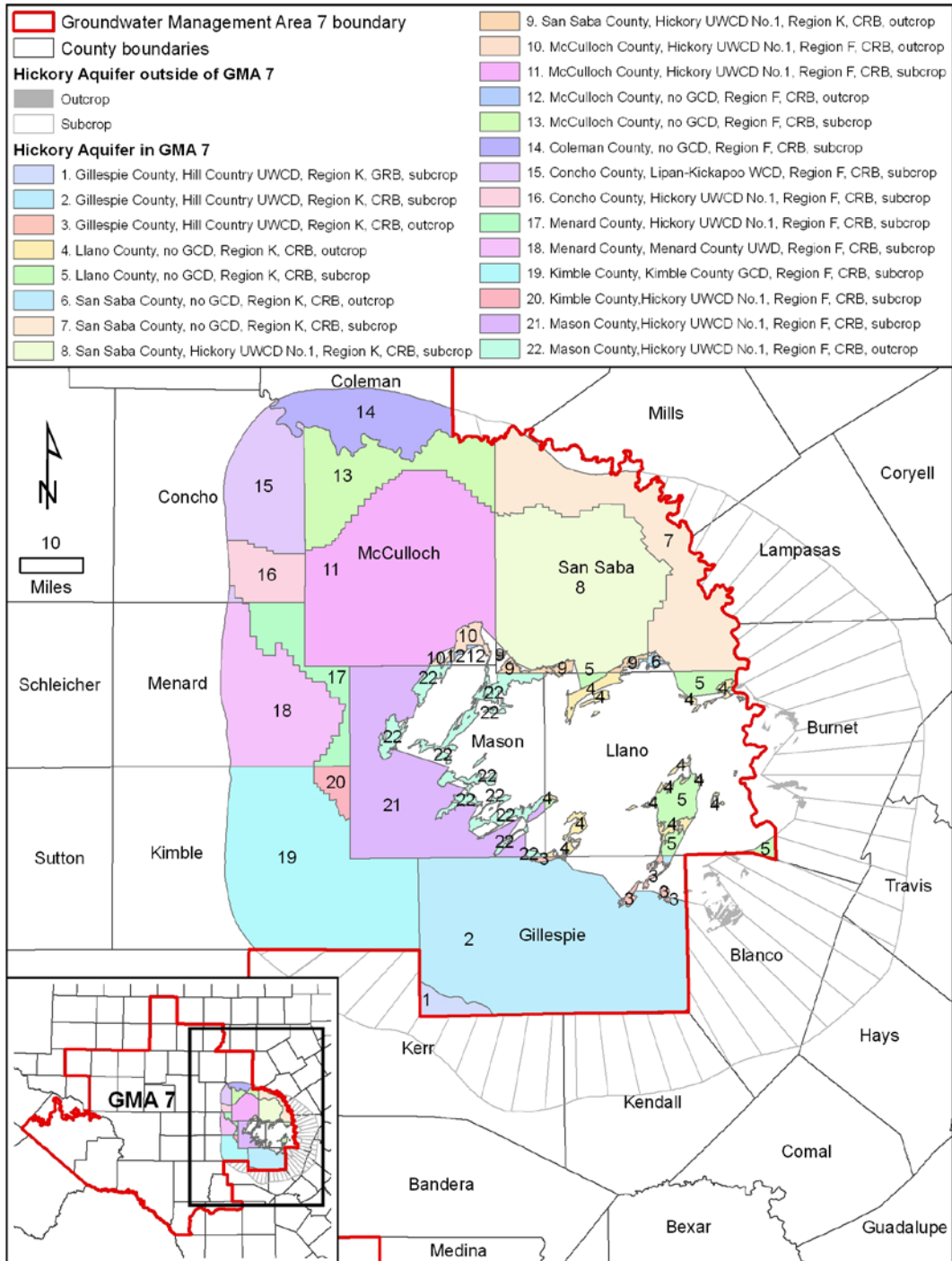


Figure 1. Geographic subdivisions for analyzing draft total pumping for the Hickory Aquifer in Groundwater Management Area 7. GMA = groundwater management area, GCD = groundwater conservation district, UWCD = underground water conservation district, UWD = underground water district, WCD = water conservation district, CRB = Colorado River Basin, GRB = Guadalupe River Basin

**PARAMETERS AND ASSUMPTIONS:**

- Water level declines of 5, 10, 15, and 20 feet, respectively, were estimated to be uniform across the aquifer.
- The areas for each area were calculated from the TWDB shapefile for the Hickory Aquifer, projected into the groundwater availability modeling (GAM) projection (Anaya, 2001).
- Areas, in acres, were calculated within ArcGIS 9.2.
- Regional water-level trends and groundwater withdrawals (pumpage) for the time period 1996 through 2003 were used to calculate annual effective recharge volumes.
- The draft annual total pumping estimates are the sum of the annual effective recharge amount and the annual volume of water depleted from the aquifer based on the draft desired future condition.
- Annual volumes are calculated by dividing the total volume by 50 years.
- Specific yield of the aquifer is estimated as 0.15 (LBG-Guyton Associates, 2003) and the storage coefficient is estimated as 0.0001 (Bluntzer, 1992; LBG-Guyton Associates, 2003).
- Outcrop areas are calculated as unconfined areas of the aquifer and subcrop areas are calculated as confined areas of the aquifer.
- Conditions were assumed to be physically possible across the groundwater management area.

Table 1. Estimated total annual effective recharge volume for the Hickory Aquifer by map areas (See Figure 1).

Aquifer	Map Key	County	Map key area (acres)	Total outcrop area (acres)	Percent of outcrop area	Total county pumpage (acre-feet)	Assigned effective recharge volume (acre-feet/year)
	3	Gillespie	9,196	9,196	100	228	228
	4	Llano	39,763	39,763	100	1,182	1,182
	6	San Saba	3,314	15,819	21	1,137	239
	9		12,505		79		898
	10	McCulloch	12,875	14,332	90	6,842	6,158
	12		1,457		10		684
	22	Mason	74,827	74,827	100	10,719	10,719
<b>Total</b>							<b>20,108</b>

Total county pumpage is multiplied by percent of outcrop area to obtain assigned effective recharge volume.

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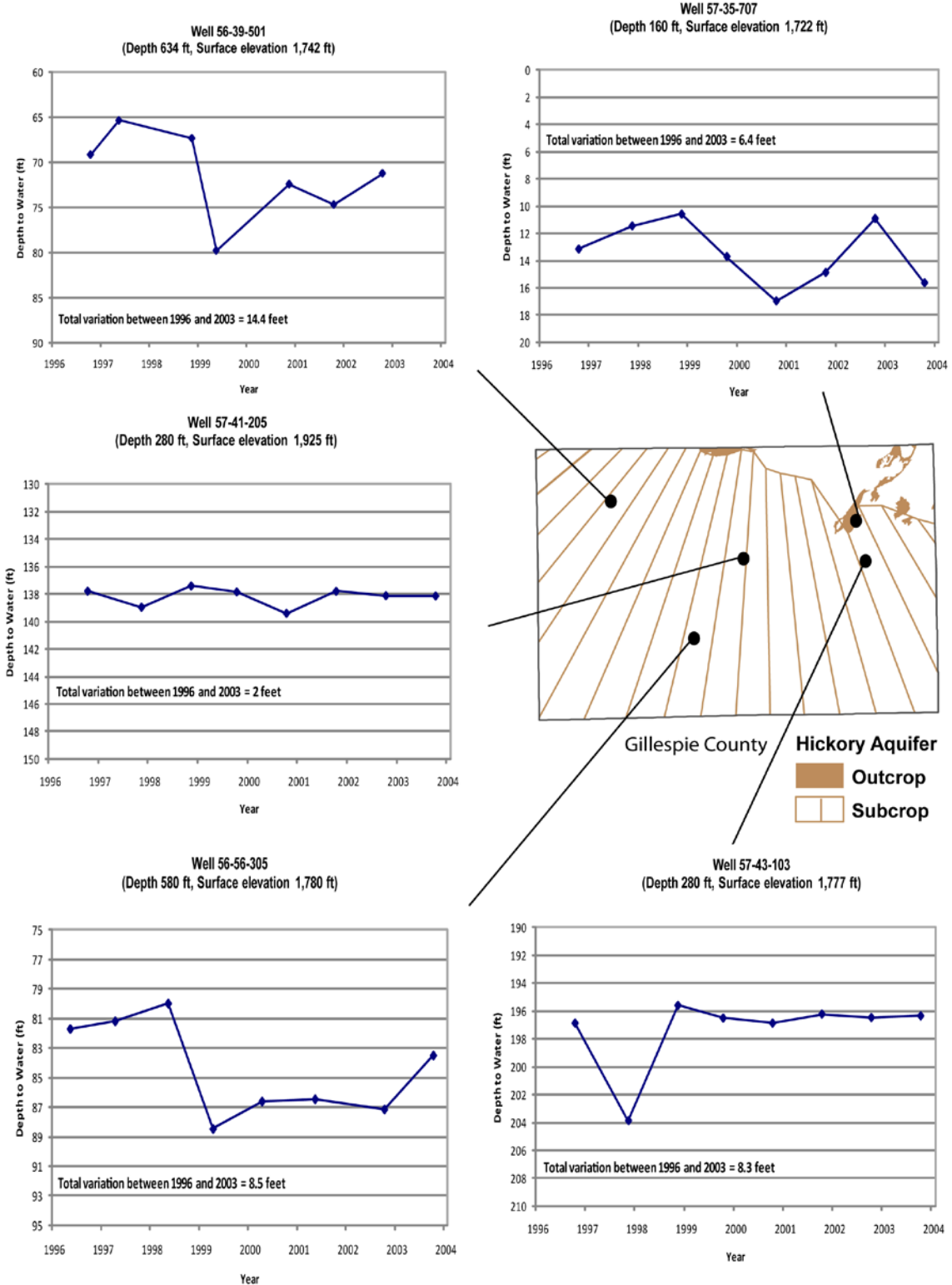


Figure 2. Water-level measurements for selected wells in Gillespie County, Texas (TWDB, 2010a)

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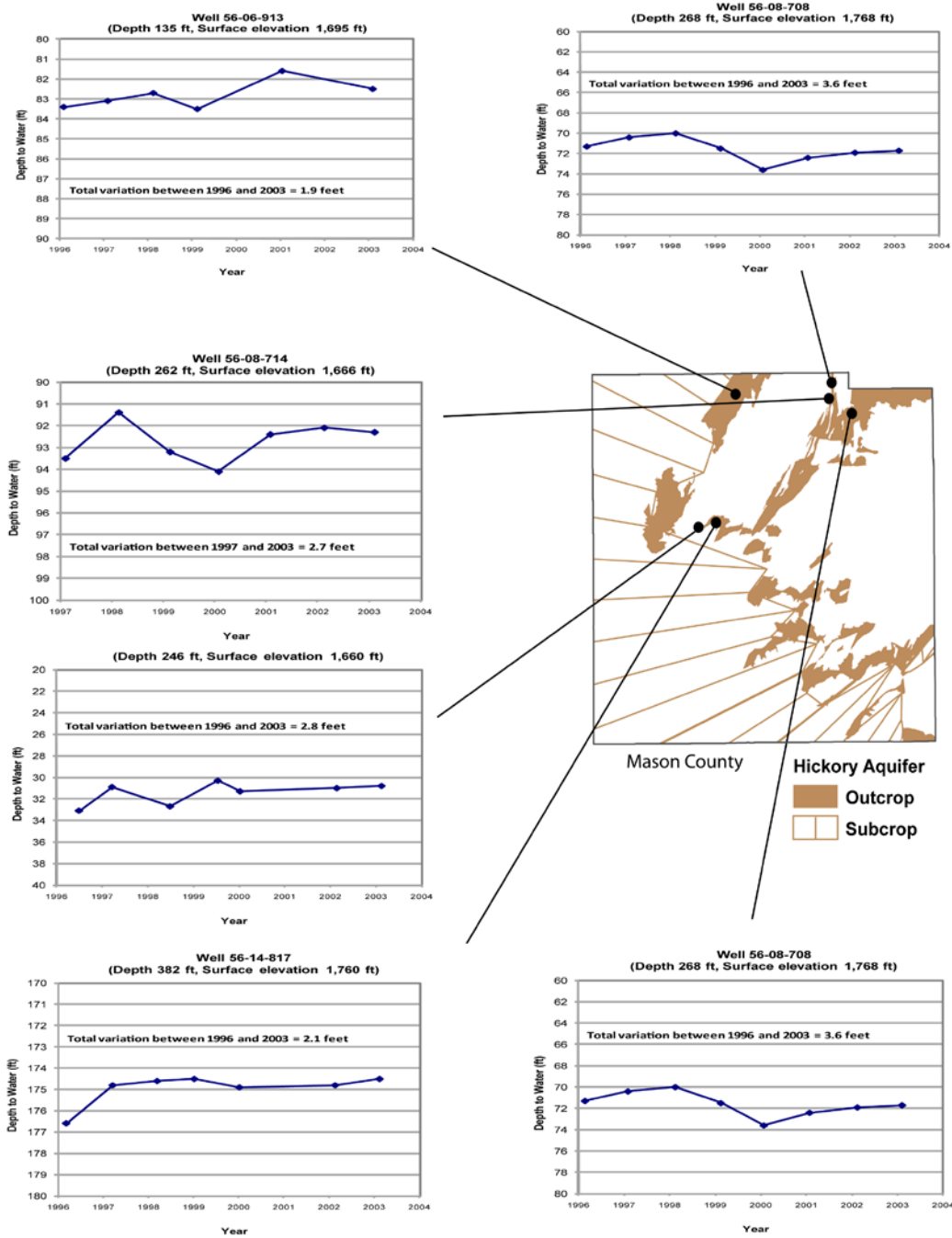


Figure 3. Water-level measurements for selected wells in Mason County, Texas (HUWCD No.1, 2010a)

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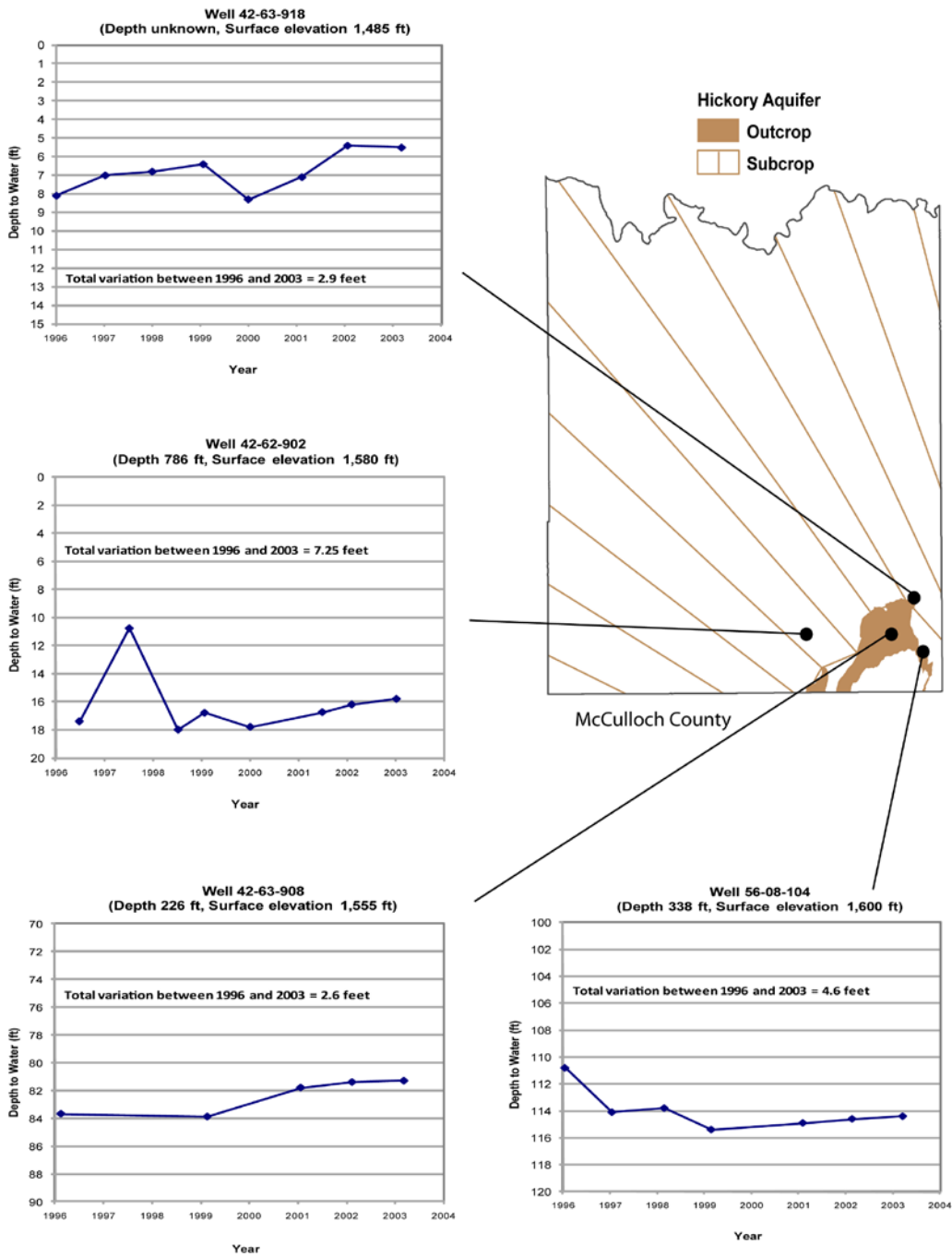


Figure 4. Water-level measurements for selected wells in McCulloch County, Texas (HUWCD No.1, 2010a)



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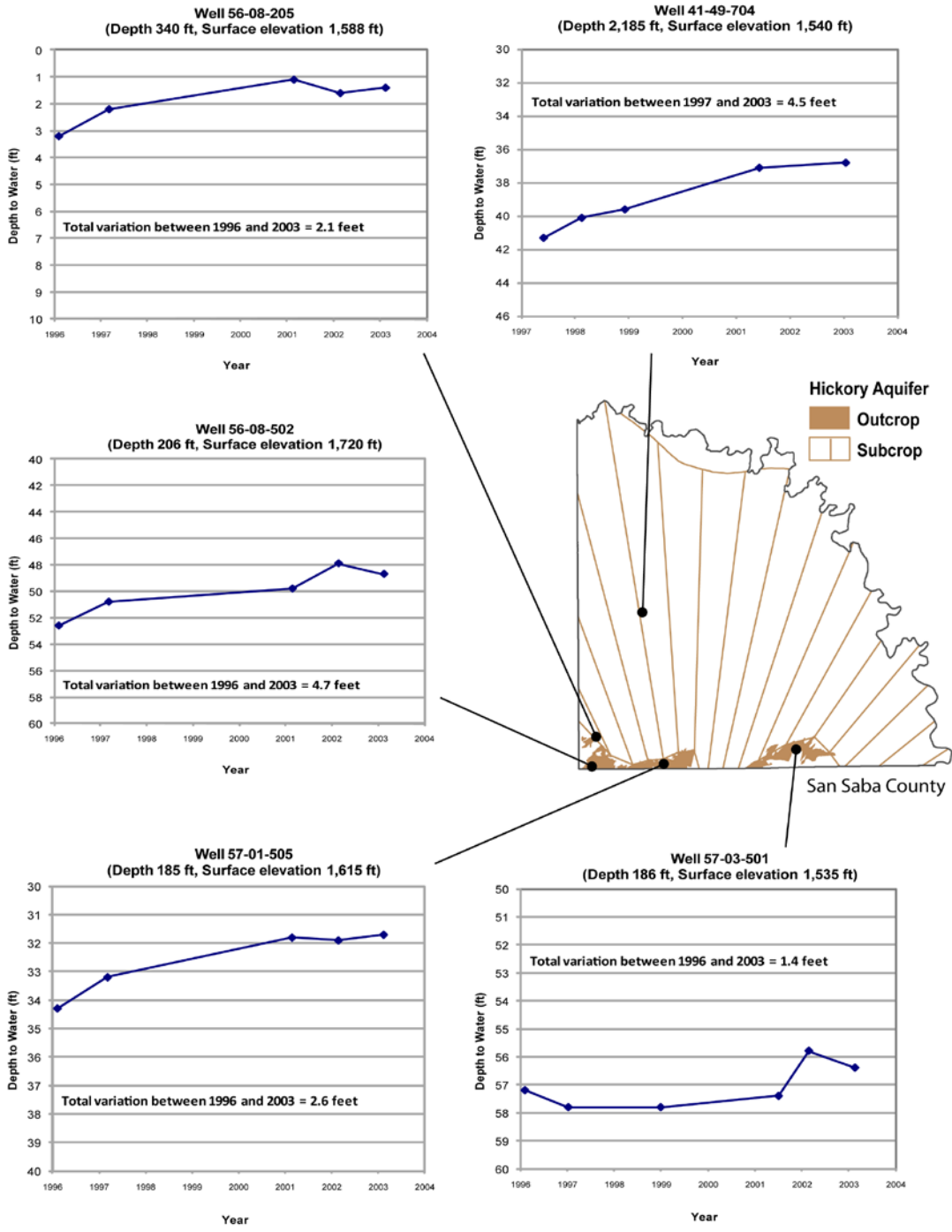


Figure 5. Water-level measurements for selected wells in San Saba County, Texas (HUWCD No.1, 2010a)

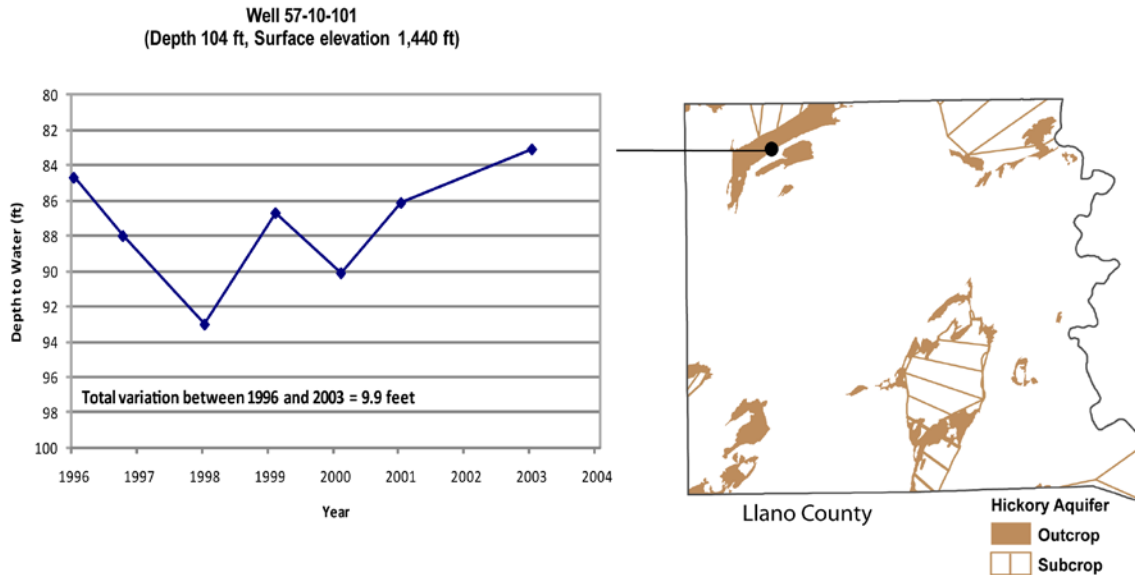


Figure 6. Water-level measurements for selected wells in Llano County, Texas (TWDB, 2010a)

## RESULTS:

The annual effective recharge estimate for the Hickory Aquifer in Groundwater Management Area 7 is 20,108 acre-feet per year.

The results (Tables 2-6) show the draft annual total pumping estimates for the Hickory Aquifer in Groundwater Management Area 7. A 5-foot decline results in an estimated annual total pumping of 22,452 acre-feet per year, a 10-foot decline results in an estimated annual total pumping of 24,795 acre-feet per year, a 15-foot decline results in an estimated annual total pumping of 27,137 acre-feet per year, and a 20-foot decline results in an estimated annual total pumping of 29,480 acre-feet per year.

The following table summarizes the draft annual total pumping for the groundwater conservation districts based on the requested conditions for the Hickory Aquifer in Groundwater Management Area 7.

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Table 2. Summary of draft annual total pumping for the Hickory Aquifer in GMA 7 by groundwater conservation district.

Groundwater Conservation District	5 ft. decline	10 ft. decline	15 ft. decline	20 ft. decline
Hickory UWCD No. 1	19,292	20,808	22,323	23,841
Hill Country UWCD	372	516	661	805
Kimble County GCD	4	9	13	17
Lipan-Kickapoo WCD	2	3	5	6
Menard County UWD	2	4	6	8
<b>Total (ac-ft/yr)</b>	<b>19,672</b>	<b>21,340</b>	<b>23,008</b>	<b>24,677</b>

UWCD = underground water conservation district  
 WCD = water conservation district

UWD = underground water district  
 ac-ft/yr = acre-feet per year

Table 3. Estimates of draft annual total pumping for the Hickory Aquifer summarized by map areas (see Figure 1 and Tables 4-7).

GMA	Aquifer	County	GCD	Map Area	Estimated storage coefficient	Areal extent (acres)	Desired total aquifer water level decline (feet)	Estimated total volume from water level decline (acre-feet)	Estimated annual volume from water level decline (acre-feet)	Estimated annual effective recharge <sup>1</sup> (ac-ft/yr)	Estimated annual total volume (ac-ft/yr)
7	Hickory	Gillespie	Hill Country UWCD	1	0.0001	22,159	5	11	0	0	0
					0.0001	22,159	10	22	0	0	
					0.0001	22,159	15	33	1	0	
					0.0001	22,159	20	44	1	0	
				2	0.0001	594,681	5	297	6	0	
					0.0001	594,681	10	595	12	0	
					0.0001	594,681	15	892	18	0	
					0.0001	594,681	20	1,189	24	0	
				3	0.15	9,196	5	6,897	138	228	
					0.15	9,196	10	13,794	276	228	
					0.15	9,196	15	20,691	414	228	
					0.15	9,196	20	27,588	552	228	
		Llano	None	4	0.15	39,763	5	29,822	596	1,182	1,778
					0.15	39,763	10	59,645	1,193	1,182	2,375
					0.15	39,763	15	89,467	1,789	1,182	2,971
					0.15	39,763	20	119,289	2,386	1,182	3,568
				5	0.0001	61,617	5	31	1	0	
					0.0001	61,617	10	62	1	0	
					0.0001	61,617	15	92	2	0	
					0.0001	61,617	20	123	2	0	
		San Saba	None	6	0.15	3,314	5	2,486	50	239	289
					0.15	3,314	10	4,971	99	239	338
					0.15	3,314	15	7,457	149	239	388
					0.15	3,314	20	9,942	199	239	438
				7	0.0001	289,284	5	145	3	0	
					0.0001	289,284	10	289	6	0	
					0.0001	289,284	15	434	9	0	
					0.0001	289,284	20	579	12	0	

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Table 3 continued.

GMA	Aquifer	County	GCD	Map Area	Estimated storage coefficient	Areal extent (acres)	Desired total aquifer water level decline (feet)	Estimated total volume from water level decline (acre-feet)	Estimated annual volume from water level decline (acre-feet)	Estimated annual effective recharge <sup>1</sup> (ac-ft/yr)	Estimated annual total volume (ac-ft/yr)		
7	Hickory	San Saba	Hickory UWCD No.1	8	0.0001	388,721	5	194	4	0	4		
					0.0001	388,721	10	389	8	0	8		
					0.0001	388,721	15	583	12	0	12		
					0.0001	388,721	20	777	16	0	16		
				9	0.15	12,505	5	9,379	188	898	1,086		
					0.15	12,505	10	18,758	375	898	1,273		
					0.15	12,505	15	28,136	563	898	1,461		
					0.15	12,505	20	37,515	750	898	1,648		
			McCulloch	Hickory UWCD No.1	10	0.15	12,875	5	9,656	193	6,158	6,351	
						0.15	12,875	10	19,313	386	6,158	6,544	
						0.15	12,875	15	28,969	579	6,158	6,737	
						0.15	12,875	20	38,625	773	6,158	6,931	
					11	0.0001	481,896	5	241	5	0	5	
						0.0001	481,896	10	482	10	0	10	
						0.0001	481,896	15	723	14	0	14	
						0.0001	481,896	20	964	19	0	19	
		None		12	0.15	1,457	5	1,093	22	684	706		
					0.15	1,457	10	2,186	44	684	728		
					0.15	1,457	15	3,278	66	684	750		
					0.15	1,457	20	4,371	87	684	771		
				13	0.0001	176,500	5	88	2	0	2		
					0.0001	176,500	10	177	4	0	4		
					0.0001	176,500	15	265	5	0	5		
					0.0001	176,500	20	353	7	0	7		
		Coleman	None	14	0.0001	131,269	5	66	1	0	1		
					0.0001	131,269	10	131	3	0	3		
					0.0001	131,269	15	197	4	0	4		
					0.0001	131,269	20	263	5	0	5		
		Concho	Lipan-Kickapoo WCD	15	0.0001	156,198	5	78	2	0	2		
					0.0001	156,198	10	156	3	0	3		
					0.0001	156,198	15	234	5	0	5		
					0.0001	156,198	20	312	6	0	6		
			Hickory UWCD No.1	16	0.0001	64,714	5	32	1	0	1		
					0.0001	64,714	10	65	1	0	1		
					0.0001	64,714	15	97	2	0	2		
					0.0001	64,714	20	129	3	0	3		
			Menard	Hickory UWCD No.1	17	0.0001	77,666	5	39	1	0	1	
						0.0001	77,666	10	78	2	0	2	
						0.0001	77,666	15	116	2	0	2	
						0.0001	77,666	20	155	3	0	3	
		Menard County UWD		18	0.0001	206,436	5	103	2	0	2		
					0.0001	206,436	10	206	4	0	4		
					0.0001	206,436	15	310	6	0	6		
					0.0001	206,436	20	413	8	0	8		
		Kimble	Kimble County GCD	19	0.0001	433,890	5	217	4	0	4		
					0.0001	433,890	10	434	9	0	9		
					0.0001	433,890	15	651	13	0	13		
					0.0001	433,890	20	868	17	0	17		
			Hickory UWCD No.1	20	0.0001	20,422	5	10	0	0	0		
					0.0001	20,422	10	20	0	0	0		
					0.0001	20,422	15	31	1	0	1		
					0.0001	20,422	20	41	1	0	1		
		Mason	Hickory UWCD No.1	21	0.0001	280,610	5	140	3	0	3		
					0.0001	280,610	10	281	6	0	6		
					0.0001	280,610	15	421	8	0	8		
					0.0001	280,610	20	561	11	0	11		
				22	0.15	74,827	5	56,120	1,122	10,719	11,841		
					0.15	74,827	10	112,241	2,245	10,719	12,964		
					0.15	74,827	15	168,361	3,367	10,719	14,086		
					0.15	74,827	20	224,481	4,490	10,719	15,209		
			<b>Total</b>					3,470,000	5	117,110	2,343	20,108	22,452
								3,470,000	10	234,225	4,685	20,108	24,795
						3,470,000	15	351,333	7,027	20,108	27,137		
						3,470,000	20	468,442	9,369	20,108	29,480		

GMA = groundwater management area      GCD = groundwater conservation district      UWCD = underground water conservation district  
 ac-ft/yr = acre-feet per year      WCD = water conservation district      UWD = underground water district  
 1 - This is the estimated total annual effective recharge volume for the Hickory Aquifer by map areas as shown in Table 1.  
 The formulas for this table are: storage coefficient \* areal extent \* desired total aquifer water level decline = estimated total volume from water level decline. Estimated total volume from water level decline/50 = estimated annual volume from water level decline. Then estimated annual volume from water level decline + estimated annual effective recharge = estimated annual total volume.

Table 4. Estimates of draft annual total pumping for water level declines of 5 feet in the Hickory Aquifer (see Figure 1).

Map Key	Aquifer	County	RWPA	River Basin	GCD	GMA	GeoArea	Year	Outcrop/ Subcrop	Total Pumping (acre-feet per year)
1	Hickory	Gillespie	K	Guadalupe	Hill Country UWCD	7	n/a	n/a	subcrop	0
2	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	subcrop	6
3	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	outcrop	366
4	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	outcrop	1,778
5	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	subcrop	1
6	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	outcrop	289
7	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	subcrop	3
8	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	4
9	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	1,086
10	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	6,351
11	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	5
12	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	outcrop	706
13	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	subcrop	2
14	Hickory	Coleman	F	Colorado	n/a	7	n/a	n/a	subcrop	1
15	Hickory	Concho	F	Colorado	Lipan-Kickapoo WCD	7	n/a	n/a	subcrop	2
16	Hickory	Concho	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	1
17	Hickory	Menard	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	1
18	Hickory	Menard	F	Colorado	Menard County UWD	7	n/a	n/a	subcrop	2
19	Hickory	Kimble	F	Colorado	Kimble County GCD	7	n/a	n/a	subcrop	4
20	Hickory	Kimble	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	0
21	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	3
22	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	11,841

RWPA = regional water planning area  
 GMA = groundwater management area  
 GeoArea = Geographic areas defined by unique desired future conditions as specified by a groundwater management area.

GCD = groundwater conservation district  
 WCD = water conservation district  
 UWD = underground water district

UWCD = underground water conservation district  
 UWD = underground water district

Table 5. Estimates of draft annual total pumping for water level declines of 10 feet in the Hickory Aquifer (see Figure 1).

Map Key	Aquifer	County	RWPA	River Basin	GCD	GMA	GeoArea	Year	Outcrop/ Subcrop	Total Pumping (acre-feet per year)
1	Hickory	Gillespie	K	Guadalupe	Hill Country UWCD	7	n/a	n/a	subcrop	0
2	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	subcrop	12
3	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	outcrop	504
4	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	outcrop	2,375
5	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	subcrop	1
6	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	outcrop	338
7	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	subcrop	6
8	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	8
9	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	1,273
10	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	6,544
11	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	10
12	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	outcrop	728
13	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	subcrop	4
14	Hickory	Coleman	F	Colorado	n/a	7	n/a	n/a	subcrop	3
15	Hickory	Concho	F	Colorado	Lipan-Kikapoo WCD	7	n/a	n/a	subcrop	3
16	Hickory	Concho	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	1
17	Hickory	Menard	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	2
18	Hickory	Menard	F	Colorado	Menard County UWD	7	n/a	n/a	subcrop	4
19	Hickory	Kimble	F	Colorado	Kimble County GCD	7	n/a	n/a	subcrop	9
20	Hickory	Kimble	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	0
21	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	6
22	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	12,964

RWPA = regional water planning area  
 GMA = groundwater management area  
 GeoArea = Geographic areas defined by unique desired future conditions as specified by a groundwater management area.

GCD = groundwater conservation district  
 WCD = water conservation district  
 UWCD = underground water conservation district  
 UWD = underground water district

Table 6. Estimates of draft annual total pumping for water level declines of 15 feet in the Hickory Aquifer (see Figure 1).

Map Key	Aquifer	County	RWPA	River Basin	GCD	GMA	GeoArea	Year	Outcrop/ Subcrop	Total Pumping (acre-feet per year)
1	Hickory	Gillespie	K	Guadalupe	Hill Country UWCD	7	n/a	n/a	subcrop	1
2	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	subcrop	18
3	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	outcrop	642
4	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	outcrop	2,971
5	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	subcrop	2
6	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	outcrop	388
7	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	subcrop	9
8	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	12
9	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	1,461
10	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	6,737
11	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	14
12	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	outcrop	750
13	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	subcrop	5
14	Hickory	Coleman	F	Colorado	n/a	7	n/a	n/a	subcrop	4
15	Hickory	Concho	F	Colorado	Lipan-Kickapoo WCD	7	n/a	n/a	subcrop	5
16	Hickory	Concho	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	2
17	Hickory	Menard	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	2
18	Hickory	Menard	F	Colorado	Menard County UWD	7	n/a	n/a	subcrop	6
19	Hickory	Kimble	F	Colorado	Kimble County GCD	7	n/a	n/a	subcrop	13
20	Hickory	Kimble	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	1
21	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	8
22	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	14,086

RWPA = regional water planning area      GCD = groundwater conservation district      UWCD = underground water conservation district  
 GMA = groundwater management area      WCD = water conservation district      UWD = underground water district  
 GeoArea = Geographic areas defined by unique desired future conditions as specified by a groundwater management area.

Table 7. Estimates of draft annual total pumping for water level declines of 20 feet in the Hickory Aquifer (see Figure 1).

Map Key	Aquifer	County	RWPA	River Basin	GCD	GMA	GeoArea	Year	Outcrop/ Subcrop	Total Pumping (acre-feet per year)
1	Hickory	Gillespie	K	Guadalupe	Hill Country UWCD	7	n/a	n/a	subcrop	1
2	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	subcrop	24
3	Hickory	Gillespie	K	Colorado	Hill Country UWCD	7	n/a	n/a	outcrop	780
4	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	outcrop	3,568
5	Hickory	Llano	K	Colorado	n/a	7	n/a	n/a	subcrop	2
6	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	outcrop	438
7	Hickory	San Saba	K	Colorado	n/a	7	n/a	n/a	subcrop	12
8	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	16
9	Hickory	San Saba	K	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	1,648
10	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	6,931
11	Hickory	McCulloch	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	19
12	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	outcrop	771
13	Hickory	McCulloch	F	Colorado	n/a	7	n/a	n/a	subcrop	7
14	Hickory	Coleman	F	Colorado	n/a	7	n/a	n/a	subcrop	5
15	Hickory	Concho	F	Colorado	Lipan-Kikapoo WCD	7	n/a	n/a	subcrop	6
16	Hickory	Concho	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	3
17	Hickory	Menard	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	3
18	Hickory	Menard	F	Colorado	Menard County UWD	7	n/a	n/a	subcrop	8
19	Hickory	Kimble	F	Colorado	Kimble County GCD	7	n/a	n/a	subcrop	17
20	Hickory	Kimble	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	1
21	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	subcrop	11
22	Hickory	Mason	F	Colorado	Hickory UWCD No. 1	7	n/a	n/a	outcrop	15,209

RWPA = regional water planning area      GCD = groundwater conservation district      UWCD = underground water conservation district  
 GMA = groundwater management area      WCD = water conservation district      UWD = underground water district  
 GeoArea = Geographic areas defined by unique desired future conditions as specified by a groundwater management area.



### **Limitations:**

Additional data are needed to create improved estimates; these estimates are a fundamental interpretation of the requested conditions. This analysis assumes homogeneous and isotropic aquifers; however, conditions for the Hickory Aquifer may not behave in a uniform manner. The analysis further assumes that the aquifer was under steady-state conditions for the time period 1996 through 2003 and that groundwater withdrawal from wells estimated the annual effective recharge, that lateral inflow to the aquifer is equal to lateral outflow from the aquifer, and that future pumping will not alter this balance.

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