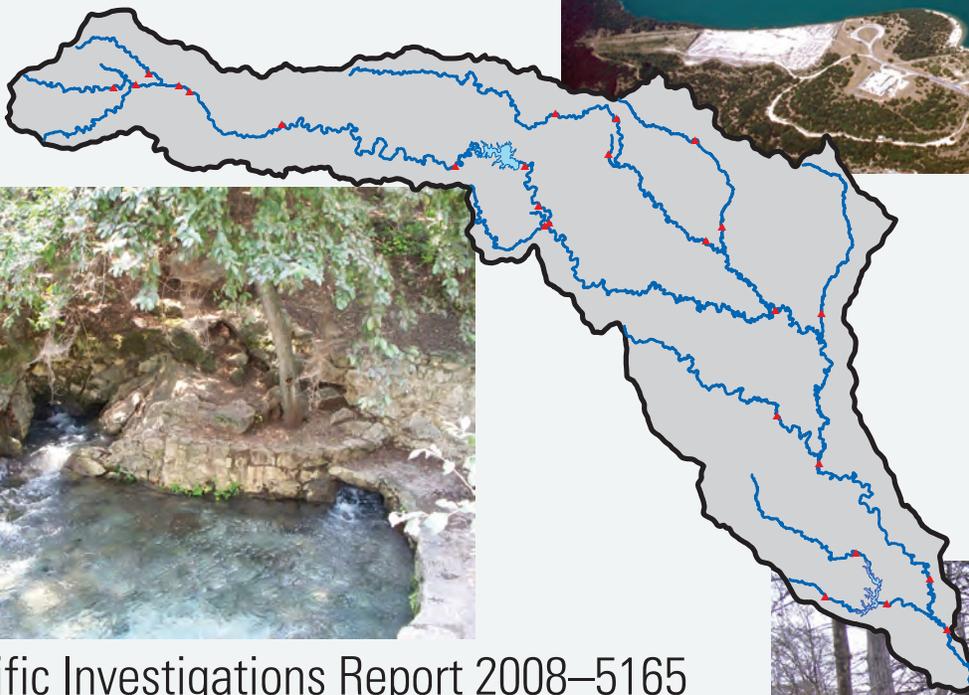


In cooperation with the Edwards Aquifer Authority

# Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006—An Assessment of Streamflow Gains and Losses and Relative Contribution of Major Springs to Streamflow



Scientific Investigations Report 2008–5165

**Cover:**

**Photographs**

**Top,** Canyon Dam and Lake near New Braunfels, Texas (photograph from U.S. Army Corps of Engineers, Fort Worth District, <http://www.swf-wc.usace.army.mil/canyon/>).

**Bottom,** Guadalupe River near Hunt, Texas December, 17, 2007 (photograph by Brian Petri, U.S. Geological Survey).

**Left,** Major spring orifices of Comal Springs in New Braunfels, Texas, January 26, 2007.

**Map,** Guadalupe River Basin, South-Central Texas, showing location of U.S. Geological Survey gaging stations.

# **Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006—An Assessment of Streamflow Gains and Losses and Relative Contribution of Major Springs to Streamflow**

By Darwin J. Ockerman and Richard N. Slattery

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**U.S. Department of the Interior**  
**U.S. Geological Survey**

**U.S. Department of the Interior**  
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## Conversion Factors and Datum

### Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
Flow rate		
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second (m <sup>3</sup> /s)
Volume		
acre-foot (acre-ft)	0.001233	cubic hectometer (hm <sup>3</sup> )

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8$$

### Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

# Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006—An Assessment of Streamflow Gains and Losses and Relative Contribution of Major Springs to Streamflow

By Darwin J. Ockerman and Richard N. Slattery

## Abstract

The U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, assessed available streamflow data in the Guadalupe River Basin to determine streamflow gains and losses and the relative contribution of flow from major springs—Comal Springs, San Marcos Springs, and Hueco Springs—to streamflow in reaches of the Guadalupe River and its tributaries. The assessment is based primarily on long-term (1987–2006) and short-term (January 1999, August 1999, August 2000, and August 2006) streamflow conditions. For each analysis period, the ratio of flow from the major springs (measured at the spring source) to the sum of inflows (measured at the source of inflow to the river system) is computed for reaches of the Comal River and San Marcos River that include springflows from major springs, and for Guadalupe River reaches downstream from Canyon Dam. The ratio of springflow to the sum of inflows to the reach is an estimate of the contribution of flows from major springs to streamflow. For 1987–2006, the ratio of springflow from the major springs to the sum of inflows for the most upstream reach that includes inflow from all three major springs, Guadalupe River—above Comal River to Gonzales, is 27 percent. At the lowermost downstream reach, Guadalupe River—Bloomington to the San Antonio River, the percentage of the sum of inflows attributed to springflow is 18 percent. At that lowermost reach, the ratio of Canyon Lake releases to the sum of inflows was 20 percent. For the short-term periods August 2000 and August 2006 (periods of relatively low flow), springflow in the reach Guadalupe River—above Comal River to Gonzales accounted for 77 and 78 percent, respectively, of the sum of inflows in that reach. At the lowermost reach Guadalupe River—Bloomington to San Antonio River, springflow was 52 and 53 percent of the sum of inflows, respectively, during August 2000 and August 2006 (compared with 18 percent during 1987–2006); and during August 2000 and August 2006, the ratios of Canyon Lake releases to the sum of inflows were less than 10 percent (compared with 20 percent during 1987–2006).

## Introduction

The Guadalupe River and its tributaries in south-central Texas are a vital source of water for Kerrville, New Braunfels, Victoria, and other towns; and the streams supply water for farms, ranches, and industry. The Guadalupe River also is a popular stream for tubing, canoeing, fishing, and other recreational activities. The Guadalupe River Basin (GRB) includes important springs that sustain streamflow and provide habitat for several endangered and threatened species.

Streamflow conditions<sup>1</sup> in the GRB are affected by springflow (spring discharge), rainfall-runoff processes, point-source discharges, withdrawals for water supply, reservoir operations, evapotranspiration, and losses to aquifer recharge. A better understanding of how these factors, or changes in these factors, affect streamflow conditions can help resource managers design watershed-management and operation strategies to optimize use of available water resources. The U.S. Geological Survey (USGS), in cooperation with the Edwards Aquifer Authority, compiled and analyzed data on streamflow conditions to assess streamflow gains and losses and the relative contribution of flow of major springs to streamflow in the GRB.

## Purpose and Scope

The purpose of this report is to describe streamflow conditions in the GRB—that is, water-budget components of stream reaches—that constitute streamflow gains and losses and the relative contribution of flow of from major springs to streamflow in selected reaches of the Guadalupe River and its tributaries. The assessment of streamflow gains and losses and the relative contribution of springflow to streamflow is based primarily on long-term (20 years) and short-term (four

<sup>1</sup> “Conditions” in the context of this report refers to water-budget components of stream reaches—upstream flow, downstream flow, and intervening gains and losses of flow including gains from major springs.

1-month base-flow periods) streamflow conditions. Streamflow and springflow data used were collected at 28 streamflow-gaging stations operated by the USGS during water years 1987–2006 (October 1986 through September 2006); the 1-month base-flow periods were January 1999, August 1999, August 2000, and August 2006. Permitted, within-reach discharge (inflow to the reach) and withdrawal (outflow from the reach) data used were reported by the Texas Commission on Environmental Quality (TCEQ).

## Description of Study Area

The headwaters of the Guadalupe River form in southwestern Kerr County. From there, the river flows easterly for about 250 river miles to Gonzales, then southeasterly for another 150 river miles to join the San Antonio River 11 river miles upstream from Guadalupe Bay, which is part of the San Antonio Bay system (fig. 1). The drainage area of the Guadalupe River is about 10,200 square miles including the San Antonio River watershed. The study area—the GRB upstream from the confluence of the Guadalupe and San Antonio Rivers—comprises 5,974 square miles and excludes the San Antonio River Basin. The Blanco River and San Marcos River are principal tributaries of the Guadalupe River. Two major reservoirs are in the GRB: Canyon Lake is on the Guadalupe River in Comal County, about 12 miles northwest of New Braunfels. The reservoir impounds runoff from 1,432 square miles of drainage area and has 382,000 acre-feet of authorized conservation storage (Guadalupe-Blanco River Authority, 2007a). Construction of the dam and reservoir began in 1958 and impoundment began in 1964. Coletto Creek Reservoir is on Coletto and Perdido Creeks, about 12 miles southwest of Victoria. The dam was completed in 1980 and impounds runoff from 507 square miles of drainage area. Conservation storage for the reservoir is 35,060 acre-feet (Guadalupe-Blanco River Authority, 2007b). The primary purpose of the reservoir is to provide cooling water for electric power generation.

Major population centers of the GRB include the cities of Kerrville, New Braunfels, San Marcos, Seguin, Lockhart, Gonzales, Cuero, Luling, and Victoria. The 2007 population of the basin was about 589,000 (U.S. Census Bureau, 2007). Land use in the basin is predominantly rural. Elevation in the study area ranges from about 25 feet (at station 08177520) to more than 2,000 feet above sea level in the upstream parts of the GRB.

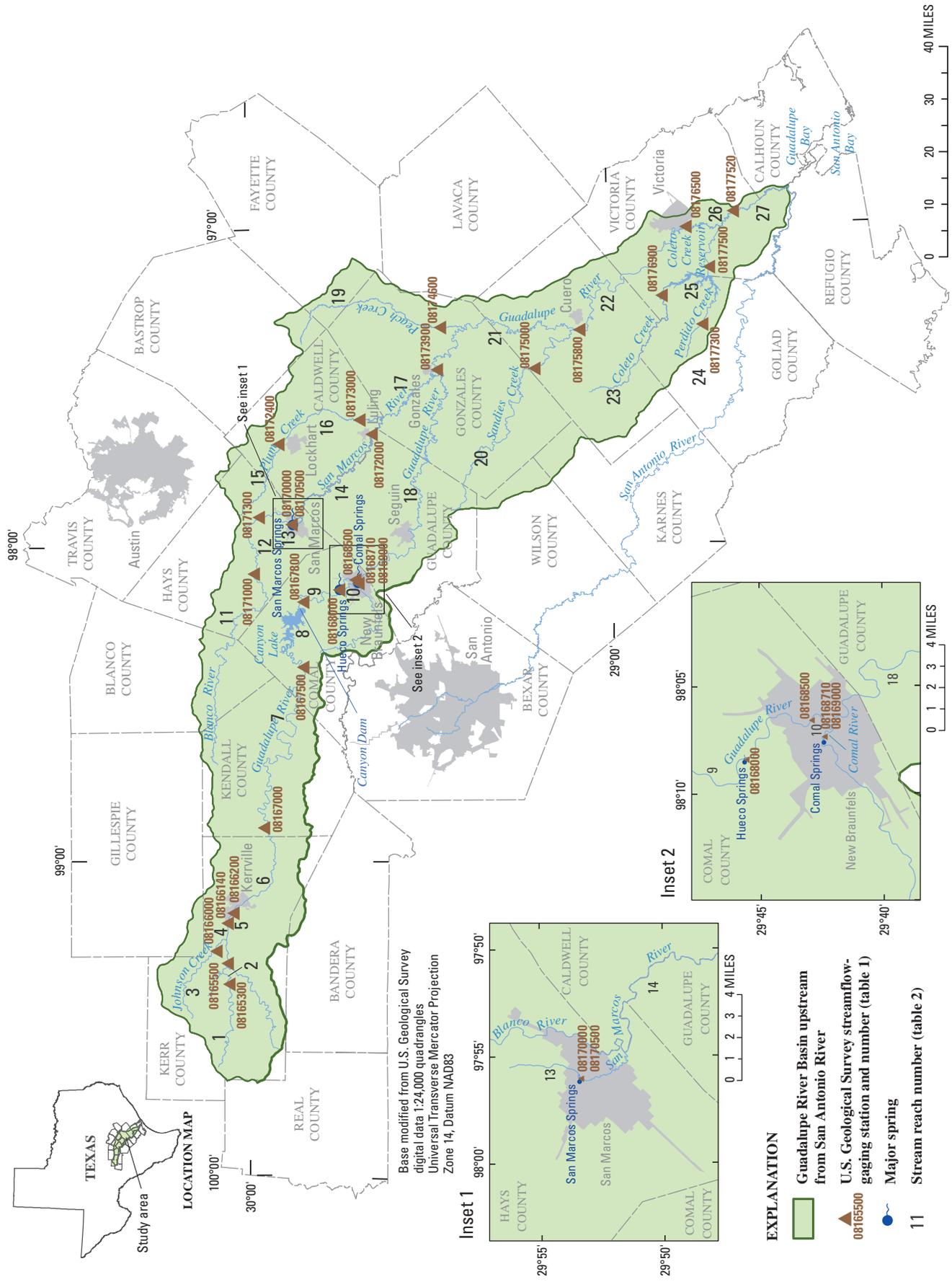
Three major springs are in the GRB: Comal Springs, San Marcos Springs, and Hueco Springs. Comal Springs provides most of the flow in the Comal River, which joins the Guadalupe River at New Braunfels. Comal Springs, which discharges from several outlets, is the largest spring in Texas and the Southwest (Brune, 1975). Long-term average Comal Springs flow (water years 1929–2006) is 290 cubic feet per second. San Marcos Springs, also with several outlets, provides most of the base flow for the San Marcos River, which joins the Guadalupe River near Gonzales. This spring is the second

largest in Texas (Brune, 1975). Long-term average flow for San Marcos Springs (water years 1957–2006) is 175 cubic feet per second. Hueco Springs is on the west side of the Guadalupe River about 3 river miles upstream from New Braunfels. Long-term average flow for Hueco Springs (water years 1944–2006) is 42 cubic feet per second. Besides these major springs east and southeast of Canyon Lake, numerous small springs in Kerr County supply much of the base flow in the headwater reaches (reaches 1–3, fig. 1) of the Guadalupe River (Heitmuller and Reece, 2003).

The climate of the study area is described as subtropical subhumid, characterized by hot summers and mild, dry winters (Larkin and Bomar, 1983). Heaviest rainfall tends to occur in spring, early summer, and fall, but can occur anytime during the year. Periods with large or small amounts of rainfall are common, resulting in recurring floods and droughts. The following meteorological statistics are from the National Weather Service station at New Braunfels (U.S. Department of Commerce, 2002): Average annual rainfall (1971–2000) is 35.74 inches per year. Rainfall greater than 0.01 inch occurs, on average, 77 days per year. The average monthly low temperatures range from 35.5 degrees Fahrenheit (°F) in January to 70.6 °F in July. Average monthly high temperatures range from 61.7 °F in January to 95.3 °F in August.

## Streamflow Conditions

Streamflow conditions in the GRB were analyzed by computing surface-water budgets for reaches of Guadalupe River and tributary streams. The GRB was divided into a network of 27 stream reaches, defined mainly by the locations of USGS streamflow-gaging stations. Table 1 lists the gaging stations from which data were compiled for this report, including station name and number, county, period of record, latitude and longitude, and drainage area upstream from the station. The data are in the USGS National Water Information System (NWISWeb) (U.S. Geological Survey, 2008). Table 2 lists each stream reach, including reach number and name, upstream and downstream station number, reach length, and cumulative drainage area at the downstream station. The locations of the gaging stations and stream reaches are shown in figure 1. Thirteen reaches (including the Canyon Lake reach) are on the main stem of the Guadalupe River. Fourteen reaches are on the tributaries Johnson Creek, Comal River, Blanco River, San Marcos River, Plum Creek, Peach Creek, Sandies Creek, Perdido Creek, and Coletto Creek. The farthest downstream gaging station used, 08177520 Guadalupe River near Bloomington, is a water-stage station, and discharge records are not available for the outlet of reach 26. Also, no gaging stations are at the outlets of reach 17 (lower San Marcos River), and reach 27 (Guadalupe River from Bloomington to the San Antonio River). Outflows from reaches 17, 26 (Guadalupe River—Victoria to Bloomington), and 27 are estimated as the sum of upstream gaging-station inflow, intervening runoff



**Figure 1.** Guadalupe River Basin, south-central Texas, locations of U.S. Geological Survey streamflow-gaging stations, and locations of stream reaches used for analysis of streamflow conditions.

#### 4 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006

**Table 1.** Selected U.S. Geological Survey streamflow-gaging stations, Guadalupe River Basin, south-central Texas.

[--, not applicable]

Station name	Station number (fig. 1)	County	Period of record <sup>1</sup> (water years)	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (square miles)
North Fork Guadalupe River near Hunt, Tex.	08165300	Kerr	1968–present	30 03 50	99 23 12	169
Guadalupe River at Hunt, Tex.	08165500	Kerr	1966–present	30 04 11	99 19 17	288
Johnson Creek near Ingram, Tex.	08166000	Kerr	1942–present	30 06 00	99 16 58	114
Guadalupe River above Bear Creek at Kerrville, Tex.	08166140	Kerr	1979–present	30 04 10	99 11 42	494
Guadalupe River at Kerrville, Tex.	08166200	Kerr	1987–present	30 03 11	99 09 47	510
Guadalupe River at Comfort, Tex.	08167000	Kendall	1940–present	29 58 10	98 53 33	839
Guadalupe River near Spring Branch, Tex.	08167500	Comal	1923–present	29 51 37	98 23 00	1,315
Guadalupe River at Sattler, Tex.	08167800	Comal	1961–present	29 51 32	98 10 47	1,436
Hueco Springs near New Braunfels, Tex.	08168000	Comal	1945–present	29 45 33	98 08 23	--
Guadalupe River above Comal River at New Braunfels, Tex.	08168500	Comal	1929–present	29 42 53	98 06 35	1,518
Comal Springs at New Braunfels, Tex.	08168710	Comal	1928–present	29 42 21	98 07 20	--
Comal River at New Braunfels, Tex.	08169000	Comal	1929–present	29 42 21	98 07 20	130
San Marcos Springs at San Marcos, Tex.	08170000	Hays	1957–present	29 53 20	97 56 02	--
San Marcos River at San Marcos, Tex.	08170500	Hays	1994–present	29 53 20	97 56 02	49
Blanco River at Wimberley, Tex.	08171000	Hays	1929–present	29 59 39	98 05 19	355
Blanco River near Kyle, Tex.	08171300	Hays	1957–present	29 58 45	97 54 35	412
San Marcos River at Luling, Tex.	08172000	Caldwell	1940–present	29 39 58	97 39 02	838
Plum Creek at Lockhart, Tex.	08172400	Caldwell	1960–present	29 55 22	97 40 44	112
Plum Creek near Luling, Tex.	08173000	Caldwell	1931–present	29 41 58	97 36 12	309
Guadalupe River at Gonzales, Tex.	08173900	Gonzales	1997–present	29 29 03	97 27 00	3,490
Peach Creek below Dilworth, Tex.	08174600	Gonzales	1960–present	29 28 26	97 18 59	460
Sandies Creek near Westhoff, Tex.	08175000	DeWitt	1960–present	29 12 54	97 26 57	549
Guadalupe River at Cuero, Tex.	08175800	DeWitt	1965–present	29 05 25	97 19 16	4,934
Guadalupe River at Victoria, Tex.	08176500	Victoria	1935–present	28 47 34	97 00 46	5,198
Coletto Creek near Schroeder, Tex.	08176900	Goliad	1979–present	28 51 41	97 13 34	357
Perdido Creek near Fannin, Tex.	08177300	Goliad	1979–present	28 45 05	97 19 01	28
Coletto Creek near Victoria, Tex.	08177500	Victoria	1979–present	28 43 51	97 08 18	514
Guadalupe River near Bloomington, Tex.	08177520	Victoria	1999–present	28 39 43	96 57 55	5,816

<sup>1</sup> Present indicates station was active in water year 2008.

(estimated from adjacent gaged reaches using a unit-runoff approach (U.S. Environmental Protection Agency, 2008)—that is, by assuming the same discharge per unit area applies in the intervening ungaged drainage area as in adjacent gaged drainage areas), and reported within-reach discharges (inflows) minus within-reach withdrawals (outflows).

For each stream reach, streamflow data from the upstream and downstream gaging stations were compiled. Reported within-reach discharges (for example, wastewater-treatment plant discharges) and withdrawals (for example, withdrawals for irrigation or water supply) were summed.

Measured (gaged) tributary inflows or measured springflows also were accounted for. Unreported or unmeasured water-budget components such as streambed leakage to or from a reach were not explicitly accounted for but are included in the overall reach gain (or loss), as determined by the difference in streamflow measured at the upstream and downstream gaging stations. Evaporation and rainfall components of the water budgets were computed only for the Canyon Lake reach (U.S. Army Corps of Engineers, 2007). The water-budget analyses were done for a long-term period, water years 1987–2006, and for four short-term, base-flow periods, January 1999, August

**Table 2.** Stream reaches for which streamflow conditions analyzed, Guadalupe River Basin, south-central Texas.

[--, not applicable]

Reach number (fig. 1) and name	Upstream gaging-station number (fig. 1)	Downstream gaging-station number (fig. 1)	Stream reach length (miles)	Cumulative drainage area at reach outlet (square miles)
1 North Fork Guadalupe River	--	08165300	23	169
2 Guadalupe River—North Fork to Hunt	08165300	08165500	5.9	288
3 Johnson Creek	--	08166000	20	114
4 Guadalupe River—Hunt to Bear Creek	08165500	08166140	8.1	494
5 Guadalupe River—Bear Creek to Kerrville	08166140	08166200	2.3	510
6 Guadalupe River—Kerrville to Comfort	08166200	08167000	24	839
7 Guadalupe River—Comfort to Spring Branch	08167000	08167500	63	1,315
8 Canyon Lake	08167500	08167800	--	1,436
9 Guadalupe River—Sattler to above Comal River	08167800	08168500	15	1,518
10 Comal River	--	08169000	--	130
11 Upper Blanco River	--	08171000	60	355
12 Blanco River—Wimberley to Kyle	08171000	08171300	17	412
13 Upper San Marcos River	--	08170500	2.6	49
14 San Marcos River—Kyle to Luling	08170500	08172000	42	838
15 Upper Plum Creek	--	08172400	22	112
16 Plum Creek—Lockhart to Luling	08172400	08173000	23	309
17 Lower San Marcos River	08172000	--	35	1,358
18 Guadalupe River—above Comal River to Gonzales	08168500	08173900	109	3,490
19 Peach Creek	--	08174600	46	460
20 Sandies Creek	--	08175000	55	549
21 Guadalupe River—Gonzales to Cuero	08173900	08175800	67	4,934
22 Guadalupe River—Cuero to Victoria	08175800	08176500	53	5,198
23 Upper Coletto Creek	--	08176900	36	357
24 Perdido Creek	--	08177300	8.4	28
25 Coletto Creek Reservoir	08176900	08177500	--	514
26 Guadalupe River—Victoria to Bloomington	08176500	08177520	24	5,816
27 Guadalupe River—Bloomington to San Antonio River	08177520	--	22	5,974

1999, August 2000, and August 2006. For each analysis period, contributions from the major springs (Comal Springs, San Marcos Springs, and Hueco Springs) to the sum of inflows are computed for various downstream locations in the Comal, San Marcos, and Guadalupe Rivers.

### Streamflow Statistics of U.S. Geological Survey Gaging-Station Data

Selected daily streamflow statistics were computed for 27 active USGS gaging stations in the GRB. Statistics include average, or mean, streamflow, 20-percent exceedance stream-

flow, 50-percent exceedance (median) streamflow, 80-percent exceedance streamflow, and 90-percent exceedance streamflow. The percentage exceedance streamflow is defined as the daily mean streamflow that was exceeded for the specified percentage of time during the analysis period. For example, 90-percent exceedance streamflow represents a (relatively low) daily mean streamflow that was exceeded 90 percent of the analysis period. For each gaging station, streamflow statistics were computed for two periods. First, statistics were computed for the available period of record (table 3A). Second, statistics were computed for water years 1987–2006 (table 3B). The period 1987–2006 provides a relatively long-term period of record for comparison common among most gages in the

## 6 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006

**Table 3.** Daily streamflow statistics for selected U.S. Geological Survey streamflow-gaging stations, Guadalupe River Basin, south-central Texas.

[ft<sup>3</sup>/s, cubic feet per second; --, not applicable]

### A. Statistics for available period of record

Station name	Station number (fig. 1)	Available record (water years)	Drainage area (square miles)	Daily mean streamflow (cubic feet per second)	20-Percent exceedance streamflow (cubic feet per second)	50-Percent exceedance streamflow (cubic feet per second)	80-Percent exceedance streamflow (cubic feet per second)	90-Percent exceedance streamflow (cubic feet per second)
North Fork Guadalupe River near Hunt, Tex.	08165300	1968–2006	169	41	37	24	18	15
Guadalupe River at Hunt, Tex.	08165500	1966–2006	288	79	74	49	35	29
Johnson Creek near Ingram, Tex.	08166000	1942–59, 1961–93, 1999–2006	114	26	28	15	8.6	6.0
Guadalupe River above Bear Creek at Kerrville, Tex.	08166140	1979–86, 1999–2006	494	113	143	92	60	45
Guadalupe River at Kerrville, Tex.	08166200	1987–2006	510	152	156	96	62	49
Guadalupe River at Comfort, Tex.	08167000	1940–2006	839	229	245	115	50	28
Guadalupe River near Spring Branch, Tex.	08167500	1923–2006	1,315	373	417	159	61	35
Guadalupe River at Sattler, Tex.	08167800	1961–2006	1,436	487	646	215	101	72
Hueco Springs near New Braunfels, Tex.	08168000	1945–2006	--	42	78	35	6.8	.7
Guadalupe River above Comal River at New Braunfels, Tex.	08168500	1929–2006	1,518	491	659	233	91	51
Comal Springs at New Braunfels, Tex.	08168710	1929–2006	--	290	356	305	226	177
Comal River at New Braunfels, Tex.	08169000	1929–2006	130	303	360	308	226	180
San Marcos Springs at San Marcos, Tex.	08170000	1957–2006	--	175	222	162	120	105
San Marcos River at San Marcos, Tex.	08170500	1995–2006	49	196	260	179	120	108
Blanco River at Wimberley, Tex.	08171000	1929–2006	355	145	165	56	21	13
Blanco River near Kyle, Tex.	08171300	1957–2006	412	167	200	52	16	2.0
San Marcos River at Luling, Tex.	08172000	1940–2006	838	415	482	212	118	93
Plum Creek at Lockhart, Tex.	08172400	1960–2006	112	49	17	.82	0	0
Plum Creek near Luling, Tex.	08173000	1931–2006	309	114	40	9.7	3.4	1.7
Guadalupe River at Gonzales, Tex.	08173900	1997–2006	3,490	2,120	2,580	1,090	591	454
Peach Creek below Dilworth, Tex.	08174600	1960–2006	460	170	39	5.7	1.0	0
Sandies Creek near Westhoff, Tex.	08175000	1960–2006	549	140	34	9.8	3.5	1.8
Guadalupe River at Cuero, Tex.	08175800	1965–2006	4,934	2,153	2,270	1,110	635	484
Guadalupe River at Victoria, Tex.	08176500	1935–2006	5,198	1,980	2,140	1,020	564	375
Coletto Creek near Schroeder, Tex.	08176900	1979–2006	357	84	37	12	3.1	.93
Perdido Creek near Fannin, Tex.	08177300	1979–2006	28	6.8	.82	.33	.11	.01
Coletto Creek near Victoria, Tex.	08177500	1979–2006	514	115	10	5.1	2.8	2.0

**Table 3.** Daily streamflow statistics for selected U.S. Geological Survey streamflow-gaging stations, Guadalupe River Basin, south-central Texas—Continued.**B.** Statistics for water years 1987–2006

Station name	Station number (fig. 1)	Available record (water years)	Drainage area (square miles)	Daily mean streamflow (cubic feet per second)	20-Percent exceedance streamflow (cubic feet per second)	50-Percent exceedance streamflow (cubic feet per second)	80-Percent exceedance streamflow (cubic feet per second)	90-Percent exceedance streamflow (cubic feet per second)
North Fork Guadalupe River near Hunt, Tex.	08165300	1987–2006	169	41	40	26	19	16
Guadalupe River at Hunt, Tex.	08165500	1987–2006	288	82	80	53	36	30
Johnson Creek near Ingram, Tex.	08166000	<sup>1</sup> 1987–93, 1999–2006	114	37	40	26	19	16
Guadalupe River above Bear Creek at Kerrville, Tex.	08166140	<sup>1</sup> 1999–2006	494	143	156	100	69	57
Guadalupe River at Kerrville, Tex.	08166200	1987–2006	510	152	156	96	62	49
Guadalupe River at Comfort, Tex.	08167000	1987–2006	839	323	340	158	86	62
Guadalupe River near Spring Branch, Tex.	08167500	1987–2006	1,315	565	599	224	109	78
Guadalupe River at Sattler, Tex.	08167800	1987–2006	1,436	612	607	216	115	99
Hueco Springs near New Braunfels, Tex.	08168000	1987–2006	--	49	83	43	14	6.8
Guadalupe River above Comal River at New Braunfels, Tex.	08168500	1987–2006	1,518	708	782	298	141	111
Comal Springs at New Braunfels, Tex.	08168710	1987–2006	--	307	382	317	229	186
Comal River at New Braunfels, Tex.	08169000	1987–2006	130	327	388	320	230	187
San Marcos Springs at San Marcos, Tex.	08170000	1987–2006	--	189	246	174	118	108
San Marcos River at San Marcos, Tex.	08170500	1995–2006	47	196	260	179	120	108
Blanco River at Wimberley, Tex.	08171000	1987–2006	355	202	216	74	32	21
Blanco River near Kyle, Tex.	08171300	1987–2006	412	197	211	52	12	0
San Marcos River at Luling, Tex.	08172000	1987–2006	838	524	597	244	125	106
Plum Creek at Lockhart, Tex.	08172400	1987–2006	112	52	17	.44	0	0
Plum Creek near Luling, Tex.	08173000	<sup>1</sup> 1987–93, 2001–06	309	170	67	13	4.8	2.8
Guadalupe River at Gonzales, Tex.	08173900	<sup>1</sup> 1997–2006	3,490	1,900	2,170	964	542	426
Peach Creek below Dilworth, Tex.	08174600	2001–06	460	167	46	6.0	1.7	1.3
Sandies Creek near Westhoff, Tex.	08175000	1987–2006	549	150	38	9.1	3.1	1.8
Guadalupe River at Cuero, Tex.	08175800	1987–2006	4,934	2,370	2,510	1,090	594	464
Guadalupe River at Victoria, Tex.	08176500	1987–2006	5,198	2,500	2,680	1,160	617	485
Coletto Creek near Schroeder, Tex.	08176900	1987–2006	357	87	34	8.3	1.8	.40
Perdido Creek near Fannin, Tex.	08177300	1987–2006	28	7.7	.56	.23	0	0
Coletto Creek near Victoria, Tex.	08177500	1987–2006	514	120	7.6	4.8	2.3	1.8

<sup>1</sup> Missing record estimated by regression to calculate statistics for 1987–2006 period.

## 8 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006

Stations with missing record during water years 1987–2006 and stations used in regressions to calculate missing record, Guadalupe River Basin, south-central Texas.

Station with missing record	Station or stations from which daily mean streamflow or sum of daily mean streamflows obtained	Coefficient of determination
08173900, Guadalupe River at Gonzales, Tex.	08168500, Guadalupe River above Comal River at New Braunfels, Tex. 08169000, Comal River at New Braunfels, Tex. 08172000, San Marcos River at Luling, Tex. 08175800, Guadalupe River at Cuero, Tex.	.96
08166000, Johnson Creek near Ingram, Tex.	08166200, Guadalupe River at Kerrville, Tex.	.76
08166140, Guadalupe River above Bear Creek at Kerrville, Tex.	08166200, Guadalupe River at Kerrville, Tex. 08165500, Guadalupe River at Hunt, Tex.	.95
08173000, Plum Creek near Luling, Tex.	08172400, Plum Creek at Lockhart, Tex.	.80

GRB. This period was used for long-term mean streamflow analyses. Statistics for the available period of record for each gaging station are provided for reference and for comparison with statistics for water years 1987–2006.

Daily values from USGS gaging stations used for analysis were obtained from the USGS National Water Information System (NWISWeb) (U.S. Geological Survey, 2008). These data were collected by the USGS in cooperation with Federal, State, and local agencies, including U.S. Army Corps of Engineers, Texas Water Development Board, Guadalupe-Blanco River Authority, Upper Guadalupe River Authority, and Edwards Aquifer Authority. Accuracy of the streamflow records varies in time and by station. Overall, the accuracy of the records is considered “good” (excluding estimated values, 95 percent of the daily streamflows are within 10 percent of their true values) (U.S. Geological Survey, 2007).

Several stations have periods of missing record because of discontinuous station operation. Statistics in table 3A were computed using only available data. For several stations with missing record during water years 1987–2006, statistics in table 3B were computed by including estimates of missing record during the 20-year period. These estimates were calculated by simple linear regression<sup>2</sup> with data from nearby stations, as indicated in the table above.

The most critical missing record was for station 08173900 Guadalupe River at Gonzales. This station was installed in 1996 and therefore had no record during water years 1987–1996. The station is the endpoint for reach 18, which is the longest reach in the study area at 109 river miles. Reach 18 also includes inflow from the San Marcos River

(reach 17). Without station 08173900, the length of reach 18 would have been increased to about 176 river miles.

For stations with periods of record beginning before approximately 1950, statistics for the water year 1987–2006 period generally indicate greater streamflow than statistics for the entire periods of record. Two major factors contribute to this: First, the historic drought of the 1950s (Bomar, 1995) resulted in several years of much-below-normal streamflow. Second, the construction of Canyon Dam and Lake in the early 1960s affected streamflow on the Guadalupe River downstream from New Braunfels. As an example of the effect of the 1950s drought, mean annual streamflow at station 08167000 Guadalupe River at Comfort (upstream from Canyon Lake) was 323 cubic feet per second during water years 1987–2006. However, during 1940–2006, the mean annual streamflow was 229 cubic feet per second (about 29 percent less). Comal Springs stopped flowing during June–October 1956. During the same period, the Guadalupe River from Comfort to New Braunfels flowed intermittently. San Marcos Springs reached a historical minimum daily mean flow of 46 cubic feet per second on August 15, 1956. Streamflow at station 08176500 Guadalupe River at Victoria was sustained by San Marcos Springs and reached a historical minimum daily mean flow of 14 cubic feet per second on August 20, 1956.

### Reported Within-Reach Discharges and Withdrawals

Reported (TCEQ permitted), within-reach discharge and withdrawal data were obtained from TCEQ. Discharge data for 1992–2006 were obtained in the form of monthly totals (Robert Organ, Texas Commission on Environmental Quality, written commun., 2007). Withdrawal data for 1991–2006 also were in the form of monthly totals (Ceasar Alvarado, Texas Commission on Environmental Quality, written

<sup>2</sup> The model for simple linear regression is  $y_i = b_0 + b_1x_i$  (Helsel and Hirsch, 1992, p. 222) where  $y_i$  is the estimate of missing streamflow on the  $i$ th day,  $b_0$  and  $b_1$  are coefficients, and  $x_i$  is observed daily mean streamflow from a nearby station on the  $i$ th day, or the sum of observed daily mean streamflows from two or more stations.

commun., 2007). For both datasets, average monthly totals for available periods were used to estimate averages for the entire 1987–2006 period. For the short-term analysis periods, the reported monthly discharge and withdrawal totals were used, if available. If totals for a particular monthly period were not available, the average monthly inflow and outflow were used for the analysis.

## Analyses of Streamflow Conditions for Water Years 1987–2006

For each stream reach listed in table 2, computations were done to obtain the following streamflow conditions, as summarized in table 4:

- Average streamflow at upstream and downstream gaging stations
- Average measured within-reach inflow from tributaries and major springs
- Average total within-reach gain or loss of streamflow, defined as the difference between average streamflow at the downstream station and average streamflow at the upstream station
- Average reported within-reach discharge inflow
- Average reported within-reach withdrawal
- Average adjusted within-reach gain/loss of streamflow, defined as the average total gain (or loss) plus average reported withdrawal minus average measured tributary and springs inflow minus average reported discharge inflow. This component also includes the sum of unmeasured or unreported streamflow components entering or exiting the reach. Such components include intervening runoff, evaporation, streamflow infiltration losses, unreported discharges and withdrawals, and streamflow-gaging measurement error.
- Cumulative average reported discharge inflow and withdrawal upstream from the reach outlet. These components represent, for each stream reach, the sum of all reported inflows and outflows upstream from, and including, those in the given reach. So, the cumulative inflows and outflows at lowermost reach 27 (Guadalupe River—Bloomington to San Antonio River) would represent the sum of reported discharge inflows and withdrawals for the entire study area.
- Cumulative average springflow from major springs upstream from, and including, those in the given reach.
- Average sum of inflows to each reach. The sum of inflows to the reach is an estimate of the total flow entering the river system within, and upstream from, the given reach. Inflows are quantified (measured or estimated) as they enter the river system. For example, measured releases from Canyon Lake enter the Guadalupe River in reach 9 and are considered inflows to all reaches of the river including and downstream from reach 9 (18, 21, 22, 26, and 27). Other inflows

include springflows, gaged tributary inflows, reported discharges, and intervening runoff and base flow. Intervening runoff and base flow were estimated as the adjusted gain/loss in the reach.

- Ratio of springflow from major springs (Comal, San Marcos, and Hueco) to the sum of inflows to the reach, expressed as a percentage (for reaches of the Comal River and San Marcos River that include springflows from major springs, and the Guadalupe River reaches downstream from Canyon Dam). The ratio of springflow to the sum of inflows to the reach is an estimate of the contribution of flow from major springs to streamflow:

$$\text{Contribution of springs to streamflow} = \frac{\text{Discharge}_{\text{springs}}}{\sum \text{Inflows}_{\text{source}}}, \quad (1)$$

where

$\text{Discharge}_{\text{springs}}$  = total springflow of major springs, measured at the spring source, and

$\text{Inflows}_{\text{source}}$  = sum of all inflows (measured at the source of inflow to the river system) entering the reach of interest.

The contribution of springs to streamflow can be computed in other ways. Another way to estimate the contribution of springflow from major springs to streamflow is to compare springflow, after adjusting for losses (from withdrawals, evaporation, seepage) during travel downstream, to streamflow measured at the downstream point of interest:

$$\text{Contribution of springs to streamflow} = \frac{\text{Discharge}_{\text{springs}} - \text{Losses}_{\text{springflow}}}{Q_{\text{reach}}}, \quad (2)$$

where

$\text{Discharge}_{\text{springs}}$  = total springflow of major springs, measured at the spring source;

$\text{Losses}_{\text{springflow}}$  = losses to springflow (from evaporation, seepage, or withdrawals) as springflow travels downstream to the reach of interest; and

$Q_{\text{reach}}$  = measured streamflow in the reach of interest.

Equation 1 involves values of streamflow components measured or estimated at the point where they enter the river system. Equation 2 involves values of streamflow components measured or estimated at the reach of interest. The advantage of equation 2 is that the denominator is obtained from measured streamflow. The difficulty with equation 2 is determining, or estimating, losses from springflow as it travels downstream. Also, springflows from the major springs originate from three locations and are subject to varying losses under different conditions. Given the difficulties associated with computing losses to springflow, estimates of the contribution of springflow to streamflow were computed using equation 1.

## 10 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006

**Table 4.** Summary of average streamflow conditions for 1987–2006 by stream reach, Guadalupe River Basin, south-central Texas.

[In cubic feet per second except as indicated; --, not applicable;]

Reach number (fig. 1) and name	Stream length (miles)	Average streamflow at upstream gage, or reach inlet <sup>1</sup>	Average measured within-reach tributary and major spring inflow <sup>2</sup>	Average streamflow at downstream gage, or reach outlet <sup>3</sup>	Average total within-reach gain/loss <sup>4</sup>
1 North Fork Guadalupe River	23	--	--	41	41
2 Guadalupe River—North Fork to Hunt	5.9	41	--	82	41
3 Johnson Creek	20	--	--	37	37
4 Guadalupe River—Hunt to Bear Creek	8.1	82	37	143	61
5 Guadalupe River—Bear Creek to Kerrville	2.3	143	--	152	9
6 Guadalupe River—Kerrville to Comfort	24	152	--	323	171
7 Guadalupe River—Comfort to Spring Branch	63	323	--	565	242
8 Canyon Lake	--	565	21	612	47
9 Guadalupe River—Sattler to above Comal River	15	612	49	708	96
10 Comal River	--	--	307	327	327
11 Upper Blanco River	60	--	--	202	202
12 Blanco River—Wimberley to Kyle	17	202	--	197	-5
13 Upper San Marcos River	2.6	--	189	196	196
14 San Marcos River—Kyle to Luling	42	196	197	524	328
15 Upper Plum Creek	22	--	--	52	52
16 Plum Creek—Lockhart to Luling	23	52	--	170	118
17 Lower San Marcos River	35	524	170	817	293
18 Guadalupe River—above Comal River to Gonzales	109	708	1,140	1,900	1,190
19 Peach Creek	46	--	--	167	167
20 Sandies Creek	55	--	--	150	150
21 Guadalupe River—Gonzales to Cuero	67	1,900	317	2,370	470
22 Guadalupe River—Cuero to Victoria	53	2,370	--	2,500	130
23 Upper Coletto Creek	36	--	--	87	87
24 Perdido Creek	8.4	--	--	10	10
25 Coletto Creek Reservoir	--	87	10	120	33
26 Guadalupe River—Victoria to Bloomington	24	2,500	120	2,680	180
27 Guadalupe River—Bloomington to San Antonio River	22	2,680	--	2,780	100

<sup>1</sup> Upstream streamflow for reach 27 estimated as (streamflow at downstream outlet of reach 26) + (estimated adjusted within-reach gain/loss) + (reported discharges) – (reported withdrawals).

<sup>2</sup> Average within-reach tributary inflows to reach 8, Canyon Lake, also include estimates of ungaged runoff, direct rainfall on lake surface, and evaporative losses; average within-reach tributary inflow to reach 8 computed as (estimated ungaged runoff) + (direct rainfall) – (evaporative losses).

<sup>3</sup> Downstream streamflows for reaches 17, 26, and 27 estimated as (streamflow at upstream gaging station) + (within-reach tributary inflow) + (estimated adjusted gain/loss) + (reported discharges) – (reported withdrawals).

Reach number (fig. 1)	Average reported within-reach discharge inflow	Average reported within-reach withdrawal	Average adjusted within-reach gain/loss <sup>5</sup>	Cumulative average reported discharge upstream from reach outlet	Cumulative average reported withdrawal upstream from reach outlet	Cumulative average springflow from major springs	Average sum of inflows to reach <sup>6</sup>	Ratio of springflow to sum of inflows to reach (percent)
1	0	0.4	41	0	0.4	--	41	--
2	0	.9	42	0	1.3	--	83	--
3	0	.7	38	0	.7	--	38	--
4	0	.05	24	0	2	--	145	--
5	0	8.6	18	0	11	--	163	--
6	0	3.7	175	0	14	--	338	--
7	0	3.6	246	0	18	--	584	--
8	.1	21	68	.1	39	--	652	--
9	.4	.2	47	.5	39	49	708	6.9
10	0	0	20	0	0	307	327	94
11	.2	.5	202	.2	.5	--	202	--
12	0	0	-5	.2	0	--	202	--
13	0	0	7	0	0	189	196	96
14	5.2	13	139	5.4	13	189	542	35
15	.5	.02	52	.5	.02	--	52	--
16	1.9	.1	116	2.4	.1	--	170	--
17	0	.7	124	7.8	14	189	836	23
18	11	39	78	19	92	545	2,000	27
19	.2	.2	167	.2	.2	--	167	--
20	.3	0	150	.3	0	--	150	--
21	1.5	1.5	153	21	94	545	2,470	22
22	43	53	140	64	147	545	2,660	20
23	0	0	87	0	0	--	87	--
24	0	0	10	0	0	--	10	--
25	0	19	42	0	19	--	149	--
26	65	83	74	129	249	545	2,940	19
27	0	14	112	129	263	545	3,060	18

<sup>4</sup> Total within-reach gain/loss = (average downstream streamflow) – (average upstream streamflow).

<sup>5</sup> Adjusted gain/loss = (total gain/loss) + (reported within-reach withdrawals) – (tributary and major spring inflows) – (within-reach discharges).

<sup>6</sup> Average sum of inflows to reach = (sum of inflows from entering upstream and tributary reaches, except for reach 9 which only includes streamflow entering from upstream reach 8) + (springflow originating within reach, for reaches 9, 10, and 13 only) + (average adjusted within-reach gain/loss) + (reported within-reach discharges).

For 1987–2006, total and adjusted within-reach gain/loss in 26 of 27 reaches is positive—the reaches gained streamflow (table 4). Most of the 26 gaining reaches incurred substantial gains, likely because of intervening runoff and base flow. Reach 12 (Blanco River—Wimberley to Kyle) lost streamflow, about 2.5 percent of inflow at the upstream reach boundary. Losses in this reach are attributed to infiltration to the Edwards aquifer recharge zone (outcrop) (Puente, 1978). Results of gain/loss studies by Slade and others (2002) also indicate losses to streamflow in reach 12.

The ratio of springflow from the major springs to the sum of inflows for the first reach that includes inflow from all three major springs, reach 18 (Guadalupe River—above Comal River to Gonzales) is 27 percent. At the lowermost downstream reach, 27 (Guadalupe River—Bloomington to San Antonio River), the percentage of streamflow attributed to springflow is reduced to 18 percent because of the effects of tributary inflows (intervening reaches 19, 20, and 25) and reported discharges (intervening reaches 22 and 26).

Flow from Comal Springs into reach 10 (Comal River) accounted for about 94 percent of the total inflow to that reach during 1987–2006. Flow from San Marcos Springs into reach 13 (upper San Marcos River) accounted for 96 percent of the inflow to reach 13. San Marcos Springs flow was reduced to 35 percent of the inflow to reach 14 (San Marcos River—Kyle to Luling) because of intervening inflow from the Blanco River. The contribution of San Marcos Springs to the inflow to reach 17 (lower San Marcos River) was further reduced to about 23 percent because of the intervening inflow from Plum Creek in that reach. Hueco Springs flows into reach 9 (Guadalupe River—Sattler to above Comal River) and contributed about 6.9 percent of the inflow to that reach.

For reach 27, the most downstream reach, cumulative average reported discharges accounted for 129 cubic feet

per second, compared with average sum of inflows of 3,060 cubic feet per second during 1987–2006; cumulative average reported withdrawals were 263 cubic feet per second. Most of the reported discharges and withdrawals occur in reach 22 (Guadalupe River—Cuero to Victoria) and reach 26 (Guadalupe River—Victoria to Bloomington). Additional major withdrawals from the Guadalupe River occur downstream from reach 27, outside the study area.

Releases from Canyon Lake (reach 8) averaged 612 cubic feet per second during 1987–2006. Compared with cumulative average springflow from major springs (545 cubic feet per second) in reach 18 (Guadalupe River—above Comal River to Gonzales), Canyon Lake releases (streamflow at outlet of reach 8) accounted for a slightly higher percentage of streamflow at downstream reaches. At reach 27, the ratio of Canyon Lake releases to average sum of inflows was 20 percent, compared with the ratio of springflow to average sum of inflows of 18 percent.

### Analyses of Streamflow Conditions for Selected Short-Term Periods

Analyses similar to those done for 1987–2006 were done for four short-term periods: January 1999, August 1999, August 2000, and August 2006. These periods were selected to represent a variety of relatively steady-state flow conditions, including low-flow periods. These analyses provide additional understanding of streamflow gains and losses and contributions of springflows to streamflows in the GRB during steady-state and low-flow periods.

Table 5 shows average springflows at the three major springs for the four monthly base-flow periods compared with long-term springflow statistics. January 1999 represents a

**Table 5.** Average springflows at major springs for selected short-term periods compared with long-term flow statistics, Guadalupe River Basin, south-central Texas.

[In cubic feet per second; --, not applicable]

Analysis period	Comal Springs	San Marcos Springs	Hueco Springs	Total springs
Short-term analysis period				
January 1999	415	312	79	806
August 1999	318	147	25	490
August 2000	177	124	7.7	309
August 2006	213	99	6.0	318
Long-term statistical period				
Mean	1929–2006 290	1957–2006 175	1944–2006 42	--
20-percent exceedance	356	222	78	--
50-percent exceedance (median)	305	162	35	--
80-percent exceedance	226	120	6.8	--
90-percent exceedance	177	105	.7	--

period when flows from all springs were greater than long-term median springflows. Streamflows upstream from Canyon Lake generally were near or greater than median streamflows. Streamflows downstream from Canyon Lake, including those of tributaries, generally were greater than median streamflows.

During August 1999 springflow at Comal Springs was slightly greater than the long-term median, and flows at San Marcos and Hueco Springs were less than their respective medians. In August 1999, most streamflows throughout the GRB were less than median 1987–2006 streamflows. During August 2000 springflows at all springs were low—at or near the long-term 90-percent exceedance values. Streamflows throughout the GRB also were relatively low. As an example, average streamflow at station 08176500 Guadalupe River at Victoria was 290 cubic feet per second compared with the 90-percent exceedance flow of 485 cubic feet per second. During August 2006, total springflow was about the same as in August 2000, although the distribution of springflow among the springs was different. Comal Springs flow was higher in August 2006 than in August 2000, whereas Hueco and San Marcos Springs flows were lower in August 2006 than in August 2000. During August 2006, streamflows throughout the GRB were similar to those of August 2000, generally near or below 90-percent exceedance values.

Similar to the 1987–2006 analyses, computations were done for each of the short-term periods to obtain the following streamflow conditions, as summarized in table 6:

- Average streamflow at upstream and downstream gaging stations
- Average measured within-reach inflow from tributaries and major springs
- Total within-reach gain or loss of streamflow, defined as the difference between average streamflow at the downstream station and average streamflow at the upstream station
- Reported within-reach discharge inflow
- Reported within-reach withdrawal
- Adjusted within-reach gain or loss of streamflow, defined as the total gain (or loss) plus reported withdrawal minus measured tributary and springs inflow minus reported discharge inflow
- Cumulative reported discharge inflow and withdrawal upstream from the reach outlet. These components represent, for each stream reach, the sum of all reported inflows and outflows upstream from, and including, those in the given reach
- Cumulative average springflow from major springs upstream from, and including, the given reach
- Sum of inflows to each reach.
- Ratio of springflow from major springs (Comal, San Marcos, and Hueco) to the sum of inflows to the reach,

expressed as a percentage (for reaches of the Comal River and San Marcos River that include springflows from major springs, and the Guadalupe River reaches downstream from Canyon Dam).

During January 1999, streamflow increased for most reaches for which gain/loss computations could be made (table 6); streamflow decreased in reaches 12 and 25 (indicated either by negative values of average within-reach gain/loss or by negative values of adjusted within-reach gain/loss). During August 1999, streamflow decreased in four reaches (5, 9, 12, and 15). During the short-term period with the lowest streamflows, August 2000, streamflow decreased in nine reaches (4, 5, 6, 7, 9, 12, 14, 15, and 18). Streamflow in 11 reaches decreased during one or more of the four short-term periods. Only in reach 12 did streamflow decrease in all four periods. Gains and losses for reach 8, Canyon Lake, and reach 25, Coleta Creek Reservoir, are affected by reservoir operations and do not take into account storage conditions in the reservoir; gain/loss computations only reflect the difference between inflows and outflows measured at gaging stations. Although inflow exceeded outflow for the Canyon Lake reach during each short-term period, storage in the reservoir might actually have decreased.

During the four short-term periods, springflow from Hueco Springs accounted for 11–16 percent of the sum of inflows in reach 9 (Guadalupe River—Sattler to above Comal River). Flow from Comal Springs accounted for all inflows in reach 10 (Comal River). In reach 13 (upper San Marcos River), flow from San Marcos Springs accounted for all inflows during the short-term periods. Downstream in reach 14 (San Marcos River—Kyle to Luling), springflow was 60–87 percent of inflows. In the next downstream reach, reach 17 (lower San Marcos River), springflow was 52–85 percent of inflows during the four periods.

Reach 18 (Guadalupe River—above Comal River to Gonzales) is the most upstream reach that includes flows from all three major springs. During August 2000 and August 2006 (periods of relatively low flow), springflow accounted for 77 and 78 percent, respectively, of inflows in that reach. These percentages are considerably greater than the 27 percent that springflow accounted for during 1987–2006 (table 4). Farther downstream, the contribution of springflow during August 2000 and August 2006, as during 1987–2006, decreased because of tributary inflow and reported discharge inflows. At reach 26 (Guadalupe River—Victoria to Bloomington), springflow accounted for 57 and 56 percent of inflows, respectively, in August 2000 and August 2006 (table 6). At reach 27 (Guadalupe River—Bloomington to San Antonio River), springflow was 52 and 53 percent of inflows, respectively, during August 2000 and August 2006. The comparable percentage at reach 27 during 1987–2006 was 18 percent (table 4).

During the short-term periods, reported discharge inflows and withdrawals (table 6) were similar to average reported discharge inflows and withdrawals for 1987–2006 (table 4). However, during low-flow periods, discharge inflows and withdrawals account for substantially larger percentages of the sum

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**Table 6.** Summary of streamflow conditions for selected short-term periods by stream reach, Guadalupe River Basin, south-central

[In cubic feet per second except as indicated; --, not applicable or not available]

Reach number (fig. 1) and name	Analysis period	Average streamflow at upstream gage, or reach inlet <sup>1</sup>	Average measured within-reach tributary and major spring inflow <sup>2</sup>	Average streamflow at downstream gage, or reach outlet <sup>3</sup>	Average total within-reach gain/loss <sup>4</sup>
1 North Fork Guadalupe River	January 1999	--	--	24	24
	August 1999	--	--	23	23
	August 2000	--	--	13	13
	August 2006	--	--	13	13
2 Guadalupe River—North Fork to Hunt	January 1999	24	--	55	31
	August 1999	23	--	39	16
	August 2000	13	--	20	7
	August 2006	13	--	19	6
3 Johnson Creek	January 1999	--	--	33	33
	August 1999	--	--	26	26
	August 2000	--	--	13	13
	August 2006	--	--	11	11
4 Guadalupe River—Hunt to Bear Creek	January 1999	55	33	--	--
	August 1999	39	26	69	30
	August 2000	20	13	32	12
	August 2006	19	11	38	19
5 Guadalupe River—Bear Creek to Kerrville	January 1999	118	--	121	3
	August 1999	69	--	63	-6
	August 2000	32	--	30	-2
	August 2006	38	--	24	-14
6 Guadalupe River—Kerrville to Comfort	January 1999	121	--	192	71
	August 1999	63	--	71	8
	August 2000	30	--	23	-7
	August 2006	24	--	25	1
7 Guadalupe River—Comfort to Spring Branch	January 1999	192	--	280	88
	August 1999	71	--	90	19
	August 2000	23	--	13	-10
	August 2006	25	--	17	-8
8 Canyon Lake	January 1999	280	-12	427	147
	August 1999	90	-106	142	52
	August 2000	13	-117	56	43
	August 2006	17	-108	54	37
9 Guadalupe River—Sattler to above Comal River	January 1999	427	79	564	137
	August 1999	142	25	160	18
	August 2000	56	7.7	47	-9
	August 2006	54	6.0	54	0

See footnotes at end of table.

Texas.

Reach number (fig. 1)	Reported within-reach discharge inflow	Reported within-reach withdrawal	Adjusted within-reach gain/loss <sup>5</sup>	Cumulative reported discharge upstream from reach outlet	Cumulative reported withdrawal upstream from reach outlet	Cumulative average springflow from major springs	Sum of inflows to reach <sup>6</sup>	Ratio of springflow to sum of inflows to reach (percent)
1	0	0.4	24	0	0.4	--	24	--
	0	.5	24	0	.5	--	24	--
	0	.5	14	0	.5	--	14	--
	0	.4	13	0	.4	--	13	--
2	0	.9	32	0	1.3	--	56	--
	0	1	17	0	1.5	--	41	--
	0	.9	8	0	1.4	--	22	--
	0	.9	7	0	1.3	--	20	--
3	0	.6	34	0	.6	--	34	--
	0	1	27	0	1	--	27	--
	0	.7	14	0	.7	--	14	--
	0	.7	12	0	.7	--	12	--
4	0	.04	--	0	1.9	--	92	--
	0	.05	4	0	2.6	--	72	--
	0	.05	-1	0	2.2	--	35	--
	0	.05	8	0	2.1	--	40	--
5	0	5.4	8	0	7	--	100	--
	0	6.3	0	0	9	--	72	--
	0	8.6	7	0	11	--	42	--
	0	4.1	-10	0	6	--	40	--
6	0	3.4	74	0	11	--	174	--
	0	5.2	13	0	14	--	85	--
	0	4.4	-3	0	15	--	42	--
	0	3.9	5	0	10	--	45	--
7	0	3.4	91	0	14	--	266	--
	0	3.6	23	0	18	--	108	--
	0	3.4	-7	0	19	--	42	--
	0	3.2	-5	0	13	--	45	--
8	.05	5.8	165	.05	20	--	431	--
	.09	24	182	.09	42	--	290	--
	.09	21	181	.09	40	--	222	--
	.09	70	215	.09	83	--	260	--
9	.3	.3	58	.4	20	79	564	14
	.3	.3	-7	.4	42	25	160	16
	.3	.3	-17	.4	39	7.7	47	16
	.3	.3	-6	.4	83	6.0	54	11

See footnotes at end of table.

**16 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006**

**Table 6.** Summary of streamflow conditions for selected short-term periods by stream reach, Guadalupe River Basin, south-central

Reach number (fig. 1) and name	Analysis period	Average streamflow at upstream gage, or reach inlet <sup>1</sup>	Average measured within-reach tributary and major spring inflow <sup>2</sup>	Average streamflow at downstream gage, or reach outlet <sup>3</sup>	Average total within-reach gain/loss <sup>4</sup>
10 Comal River	January 1999	--	415	415	415
	August 1999	--	318	318	318
	August 2000	--	179	179	179
	August 2006	--	213	213	213
11 Upper Blanco River	January 1999	--	--	133	133
	August 1999	--	--	25	25
	August 2000	--	--	12	12
	August 2006	--	--	7.5	7.5
12 Blanco River—Wimberley to Kyle	January 1999	133	--	125	-8
	August 1999	25	--	3.2	-22
	August 2000	12	--	0	-12
	August 2006	7.5	--	0	-7.5
13 Upper San Marcos River	January 1999	--	312	312	312
	August 1999	--	147	147	147
	August 2000	--	124	124	124
	August 2006	--	99	99	99
14 San Marcos River—Kyle to Luling	January 1999	125	312	496	371
	August 1999	3.2	147	151	148
	August 2000	0	124	104	104
	August 2006	0	99	96	96
15 Upper Plum Creek	January 1999	--	0	12	12
	August 1999	--	0	0	0
	August 2000	--	0	0	0
	August 2006	--	0	0	0
16 Plum Creek—Lockhart to Luling	January 1999	12	0	47	35
	August 1999	0	0	1.8	1.8
	August 2000	0	0	1.8	1.8
	August 2006	0	0	1.8	1.8
17 Lower San Marcos River	January 1999	496	47	577	82
	August 1999	151	1.8	152	1
	August 2000	104	1.8	104	0
	August 2006	96	1.8	94	-2
18 Guadalupe River—above Comal River to Gonzales	January 1999	564	993	1,950	1,390
	August 1999	160	470	612	452
	August 2000	47	283	242	195
	August 2006	54	307	277	223

See footnotes at end of table.

Texas—Continued.

Reach number (fig. 1)	Reported within-reach discharge inflow	Reported within-reach withdrawal	Adjusted within-reach gain/loss <sup>5</sup>	Cumulative reported discharge upstream from reach outlet	Cumulative reported withdrawal upstream from reach outlet	Cumulative average springflow from major springs	Sum of inflows to reach <sup>6</sup>	Ratio of springflow to sum of inflows to reach (percent)
10	0	0	0	0	0	415	415	100
	0	0	0	0	0	318	318	100
	0	0	0	0	0	177	179	100
	0	0	0	0	0	213	213	100
11	.2	.4	133	.2	.4	--	133	--
	.2	.5	25	.2	.5	--	26	--
	.2	.5	12	.2	.5	--	113	--
	.2	.5	8	.2	.5	--	8.0	--
12	0	0	-8	.2	.4	--	133	--
	0	0	-22	.2	.5	--	26	--
	0	0	-12	.2	.5	--	113	--
	0	0	-8	.2	.5	--	8.0	--
13	0	0	0	0	0	312	312	100
	0	0	0	0	0	147	147	100
	0	0	0	0	0	124	124	100
	0	0	0	0	0	99	99	100
14	6.6	12	64	6.8	12	312	516	60
	5.6	14	9	5.8	14	147	187	78
	5.6	13	-13	5.8	14	124	142	87
	5.9	13	4	6.1	14	99	99	85
15	.4	.02	12	.4	.02	--	12	--
	1.0	0	-1	1.0	0	--	1.0	--
	1.3	0	-1	1.3	0	--	1.3	--
	1.4	0	-1	1.4	0	--	1.4	--
16	2.3	.1	33	2.7	.1	--	48	--
	1.2	.1	1	2.2	.1	--	3.2	--
	1.9	.1	0	3.2	.1	--	3.2	--
	1.9	.1	0	3.3	.1	--	3.3	--
17	.8	1.6	35	10	14	312	600	52
	.6	2.4	1	9	17	147	192	77
	.7	2.2	0	10	16	124	146	85
	.7	4.8	0	10	19	99	121	82
18	11	13	399	22	47	806	1,990	41
	11	44	15	20	103	490	703	70
	11	43	-56	21	98	309	400	77
	11	39	-56	21	141	318	406	78

See footnotes at end of table.

**18 Streamflow Conditions in the Guadalupe River Basin, South-Central Texas, Water Years 1987–2006**

**Table 6.** Summary of streamflow conditions for selected short-term periods by stream reach, Guadalupe River Basin, south-central

Reach number (fig. 1) and name	Analysis period	Average streamflow at upstream gage, or reach inlet <sup>1</sup>	Average measured within-reach tributary and major spring inflow <sup>2</sup>	Average streamflow at downstream gage, or reach outlet <sup>3</sup>	Average total within-reach gain/loss <sup>4</sup>
19 Peach Creek	January 1999	--	--	--	--
	August 1999	--	--	--	--
	August 2000	--	--	--	--
	August 2006	--	--	1.1	1.1
20 Sandies Creek	January 1999	--	--	43	43
	August 1999	--	--	4.2	4.2
	August 2000	--	--	1.5	1.5
	August 2006	--	--	.2	.2
21 Guadalupe River—Gonzales to Cuero	January 1999	1,950	43	2,180	230
	August 1999	612	4.2	672	60
	August 2000	242	1.5	282	40
	August 2006	277	.2	288	11
22 Guadalupe River—Cuero to Victoria	January 1999	2,180	--	2,210	30
	August 1999	672	--	714	42
	August 2000	282	--	290	8
	August 2006	288	--	296	8
23 Upper Coleto Creek	January 1999	--	0	31	31
	August 1999	--	0	3.4	3.4
	August 2000	--	0	0	0
	August 2006	--	0	1.1	1.1
24 Perdido Creek	January 1999	--	--	--	--
	August 1999	--	--	--	--
	August 2000	--	--	--	--
	August 2006	--	--	--	--
25 Coleto Creek Reservoir	January 1999	31	2.9	24	-7.0
	August 1999	3.4	.3	4.6	1.2
	August 2000	0	0	3.9	3.9
	August 2006	1.1	0	4.5	3.4
26 Guadalupe River—Victoria to Bloomington	January 1999	2,210	24	2,230	20
	August 1999	714	4.6	723	9
	August 2000	290	3.9	310	20
	August 2006	296	4.5	308	12
27 Guadalupe River—Bloomington to San Antonio River	January 1999	2,230	--	2,240	10
	August 1999	723	--	743	20
	August 2000	310	--	347	37
	August 2006	308	--	333	25

<sup>1</sup> Upstream streamflow for reach 27 estimated as (streamflow at downstream outlet of reach 26) + (estimated adjusted within-reach gain/loss) + (reported discharges) – (reported withdrawals).

<sup>2</sup> Average within-reach tributary inflows to reach 8, Canyon Lake, also include estimates of ungaged runoff, direct rainfall on lake surface, and evaporative losses; average within-reach tributary inflow to reach 8 computed as (estimated ungaged runoff) + (direct rainfall) – (evaporative losses).

<sup>3</sup> Downstream streamflows for reaches 17, 26, and 27 estimated as (streamflow at upstream gaging station) + (within-reach tributary inflow) + (estimated adjusted gain/loss) + (reported discharges) – (reported withdrawals).

Texas—Continued.

Reach number (fig. 1)	Reported within-reach discharge inflow	Reported within-reach withdrawal	Adjusted within-reach gain/loss <sup>5</sup>	Cumulative re-reported discharge upstream from reach outlet	Cumulative reported withdrawals upstream from reach outlet	Cumulative average springflow from major springs	Sum of inflows to reach <sup>6</sup>	Ratio of springflow to sum of inflows to reach (percent)
19	0.1	0.2	--	0.1	0.2	--	--	--
	.1	.2	--	.1	.2	--	--	--
	.1	.2	--	.1	.2	--	--	--
	.2	.2	1	.2	.2	--	1.2	--
20	.3	0	43	.3	0	--	43	--
	.3	0	4	.3	0	--	4.3	--
	.3	0	1	.3	0	--	1.3	--
	.3	0	0	.3	0	--	0.3	--
21	2.3	.4	185	24	47	806	2,220	36
	2.3	4.1	58	23	107	490	768	64
	2.3	2.6	39	24	101	309	442	70
	2.3	4.5	13	24	145	318	422	75
22	43	44	31	67	91	806	2,290	35
	55	76	42	78	183	490	879	56
	38	45	15	62	146	309	422	73
	43	83	48	67	228	318	451	70
23	0	0	31	0	0	--	31	--
	0	0	3	0	0	--	3.0	--
	0	0	0	0	0	--	0	--
	0	0	1	0	0	--	1.0	--
24	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
25	0	19	9	0	19	--	40	--
	0	19	20	0	19	--	23	--
	0	19	23	0	19	--	23	--
	0	19	22	0	19	--	23	--
26	65	83	14	132	193	806	2,410	33
	65	83	22	143	285	490	989	50
	65	83	34	127	248	309	544	57
	65	83	26	132	330	318	565	56
27	0	14	24	132	207	806	2,430	33
	0	14	34	143	299	490	1,020	48
	0	14	51	127	262	309	595	52
	0	14	39	132	344	318	604	53

<sup>4</sup> Total within-reach gain/loss = (average downstream streamflow) – (average upstream streamflow).<sup>5</sup> Adjusted gain/loss = (total gain/loss) + (reported within-reach withdrawals) – (tributary and major spring inflows) – (within-reach discharges).<sup>6</sup> Sum of inflows to reach = (sum of inflows from entering upstream and tributary reaches, except for reach 9 which only includes streamflow entering from upstream reach 8) + (springflow originating within reach, for reaches 9, 10, and 13 only) + (adjusted within-reach gain/loss) + (reported within-reach discharges).

**Table 7.** Comparison of contributions of Canyon Lake releases and flow from major springs to streamflow in selected stream reaches for selected short-term periods, Guadalupe River Basin, south-central Texas.

Reach number and name	Analysis period	Average streamflow from Canyon Lake (cubic feet per second)	Cumulative springflow from major springs (cubic feet per second)	Sum of inflows to reach (cubic feet per second)	Ratio of streamflow from Canyon Lake to sum of inflows to reach (percent)	Ratio of springflow to sum of inflows to reach (percent)
18 Guadalupe River—above Comal River to Gonzales	January 1999	427	806	1,990	21	41
	August 1999	142	490	703	20	70
	August 2000	56	309	400	14	77
	August 2006	54	318	406	13	78
22 Guadalupe River—Cuero to Victoria	January 1999	427	806	2,290	19	35
	August 1999	142	490	879	16	56
	August 2000	56	309	422	13	73
	August 2006	54	318	451	12	70
26 Guadalupe River—Victoria to Bloomington	January 1999	427	806	2,410	18	33
	August 1999	142	490	989	14	50
	August 2000	56	309	544	10	57
	August 2006	54	318	565	9.6	56
27 Guadalupe River—Bloomington to San Antonio River	January 1999	427	806	2,430	18	33
	August 1999	142	490	1,020	14	48
	August 2000	56	309	595	9.4	52
	August 2006	54	318	604	8.9	53

of inflows than those during 1987–2006. For example, during August 2006 (a low-flow period) combined reaches 22 and 26 reported discharge inflows accounted for 24 percent of the sum of inflows to reach 22. During the same period, withdrawals from reaches 22 and 26 accounted for about 37 percent of the sum of inflows to reach 22. During 1987–2006 (table 4), combined reach 22 and 26 reported discharge inflows accounted for 4.0 percent of sum of inflows, and withdrawals accounted for 5.0 percent of sum of inflows to reach 22.

Similar to the computations indicating the contributions of springflow to the sum of inflows for selected short-term periods (table 6), contributions of releases from Canyon Lake (reach 8) to the sum of inflows were computed for selected reaches and are shown in table 7. Also shown for comparison are the ratios of springflow to the sum of inflows.

In contrast to Canyon Lake releases during 1987–2006 (table 4), Canyon Lake releases during the short-term periods accounted for smaller percentages of the sum of inflows at downstream reaches than springflows (table 6). During the relatively low-flow periods August 2000 and August 2006 for reach 27, the ratios of Canyon Lake releases to the sum of inflows were less than 10 percent. During those same periods, flow from major springs accounted for more than 50 percent of the sum of inflows for reach 27. During 1987–2006 for reach 27 (table 4), the ratio of Canyon Lake releases to the

sum of inflows was 20 percent, and the ratio of springflow to the sum of inflows was 18 percent.

## Summary

The U.S. Geological Survey, in cooperation with the Edwards Aquifer Authority, assessed available streamflow data in the Guadalupe River Basin (GRB) to determine streamflow gains and losses and the relative contribution of flow from major springs—Comal Springs, San Marcos Springs, and Hueco Springs—to streamflow in reaches of the Guadalupe River and its tributaries. The assessment is based primarily on long-term (20 years) and short-term (four 1-month base-flow periods) streamflow conditions.

The GRB was divided into a network of 27 stream reaches (13 Guadalupe River and 14 tributary), defined mainly by the locations of USGS streamflow-gaging stations. For each reach, streamflow data from the upstream and downstream gaging stations and intervening discharges (inflows) and withdrawals (outflows) were compiled. Water-budget analyses were done for water years 1987–2006 and for four short-term, base-flow periods, January 1999, August 1999, August 2000, and August 2006. For each analysis period, the ratio of flow from the major springs (measured at the

spring source) to the sum of inflows (measured at the source of inflow to the river system) is computed for reaches of the Comal River and San Marcos River that include springflows from major springs, and for the Guadalupe River reaches downstream from Canyon Dam. The ratio of springflow to the sum of inflows to the reach is an estimate of the contribution of flow from major springs to streamflow.

For 1987–2006, 26 of the 27 reaches gained streamflow. Most of the 26 gaining reaches incurred substantial gains, likely because of intervening runoff and base flow. The ratio of springflow from the major springs to the sum of inflows for the most upstream reach that includes inflow from all three major springs, reach 18 (Guadalupe River—above Comal River to Gonzales) is 27 percent. At the lowermost downstream reach, 27 (Guadalupe River—Bloomington to San Antonio River), the percentage of the sum of inflows attributed to springflow is reduced to 18 percent because of the effects of tributary inflows (intervening reaches 19, 20, and 25) and reported (Texas Commission on Environmental Quality permitted), discharges (intervening reaches 22 and 26).

Compared with cumulative average springflow from major springs in reach 18, Canyon Lake releases (streamflow at outlet of reach 8) accounted for a slightly higher percentage of the sum of inflows at downstream reaches. At reach 27, the ratio of Canyon Lake releases to the sum of inflows was 20 percent, compared with the ratio of springflow to the sum of inflows of 18 percent.

The four short-term periods were selected to represent a variety of relatively steady-state flow conditions, including low-flow periods. During August 2000 and August 2006 (periods of relatively low flow), springflow in reach 18 (Guadalupe River—above Comal River to Gonzales), the most upstream reach that includes inflow from all three major springs, accounted for 77 and 78 percent, respectively, of the sum of inflows in that reach. These percentages are considerably greater than the 27 percent that springflow accounted for during 1987–2006. Farther downstream, the contribution of springflow to the sum of inflows during August 2000 and August 2006, as during 1987–2006, decreased because of tributary inflow and reported discharge inflows. At the most downstream reach, 27 (Guadalupe River—Bloomington to San Antonio River), springflow was 52 and 53 percent of the sum of inflows, respectively, during August 2000 and August 2006 (compared with 18 percent during 1987–2006).

In contrast to Canyon Lake releases during 1987–2006, Canyon Lake releases during the short-term periods accounted for smaller percentages of the sum of inflows at downstream reaches than springflows. During the relatively low-flow periods August 2000 and August 2006 for reach 27, the ratios of Canyon Lake releases to the sum of inflows were less than 10 percent (compared with 20 percent during 1987–2006). During those same periods, flow from major springs accounted for more than 50 percent of the sum of inflows for reach 27 (compared with 18 percent during 1987–2006).

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