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Estimation of Streamflow Gains and Losses in the Lower San Antonio River Watershed, South-Central Texas, 2006–10

Scientific Investigations Report 2012–5073

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

Cover: Photograph of U.S. Geological Survey hydrologist (Darwin Ockerman) kayaking upstream from U.S. Geological Survey streamflow-gaging station 08181500 Medina River at San Antonio, Texas, November 10, 2009 (photograph by Brian Petri, U.S. Geological Survey).

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

Altitude, as used in this report, refers to distance above the vertical datum.

Estimation of Streamflow Gains and Losses in the Lower San Antonio River Watershed, South-Central, Texas 2006–10

By Joy S. Lizárraga and Loren L. Wehmeyer

Abstract

The U.S. Geological Survey (USGS), in cooperation with the San Antonio River Authority, the Evergreen Underground Water Conservation District, and the Goliad County Groundwater Conservation District, investigated streamflow gains and losses during 2006–10 in the lower San Antonio River watershed in south-central Texas. Streamflow gains and losses were estimated using 2006–10 continuous streamflow records from 11 continuous streamflow-gaging stations, and discrete streamflow measurements made at as many as 20 locations on the San Antonio River and selected tributaries during four synoptic surveys during 2006–7. From the continuous streamflow records, the greatest streamflow gain on the lower San Antonio River occurred in the reach from Falls City, Tex., to Goliad, Tex. The greatest streamflow gain on Cibolo Creek during 2006–10 occurred in the reach from near Saint Hedwig, Tex., to Sutherland Springs, Tex. The San Antonio River between Floresville, Tex., and Falls City was the only reach that had an estimated streamflow loss during 2006–10. During all four synoptic streamflow measurement surveys, the only substantially flowing tributary reach to the main stem of the lower San Antonio River was Cibolo Creek. Along the main stem of the lower San Antonio River, verifiable gains larger than the potential measurement error were estimated in two of the four synoptic streamflow measurement surveys. These gaining reaches occurred in the two most downstream reaches of the San Antonio River between Goliad and Farm Road (FM) 2506 near Fannin, Tex., and between FM 2506 near Fannin to near McFaddin. There were verifiable gains in streamflow in Cibolo Creek, between La Vernia, Tex., and the town of Sutherland Springs during all four surveys, estimated at between 4.8 and 14 ft^3/s.

Introduction

The lower San Antonio River is a vital water resource supporting human and ecological communities in south-central Texas. Understanding the spatial distribution and magnitude of streamflow gains and losses in the lower San Antonio River (fig. 1) is important to water-resource managers in the region.

Water usage in the San Antonio River watershed has undergone a rapid transformation during the past 50 years because of development, particularly in Bexar County, Tex. (Texas Instream Flow Program and San Antonio River Authority, 2009). The San Antonio River's streamflow has been increasingly augmented by return flows from municipal use within the City of San Antonio, Tex., and surrounding municipalities. The river has changed from a system driven predominantly by groundwater discharge to a system highly influenced by year-round treated wastewater discharges, intermittent discharges and withdrawals, and a variety of urban and rural land uses (Texas Instream Flow Program and San Antonio River Authority, 2009).

There is scant information available regarding streamflow gains and losses in the lower San Antonio River watershed. Although three streamflow gain-loss studies (1958, 1963, 1968) were completed on Cibolo Creek (Slade and others, 2002), streamflow gain-loss studies for the total length of the lower San Antonio River have not been done. Accordingly, the U.S. Geological Survey (USGS), in cooperation with the San Antonio River Authority, the Evergreen Underground Water Conservation District, and the Goliad County Groundwater Conservation District, evaluated streamflow gains and losses during 2006–10 in the lower San Antonio River watershed.

Purpose and Scope

The purpose of this report is to document estimated streamflow gains and losses in the lower San Antonio River watershed during 2006–10. Streamflow gains and losses were estimated using 2006–10 continuous streamflow records from 11 continuous USGS streamflow-gaging stations, and discrete streamflow measurements made at as many as 20 locations on the San Antonio River and selected tributaries during four synoptic streamflow measurement surveys during 2006–7 (19 and 20 measurement sites during April and August 2006, respectively, and 20 and 15 measurement sites during February and October 2007, respectively).

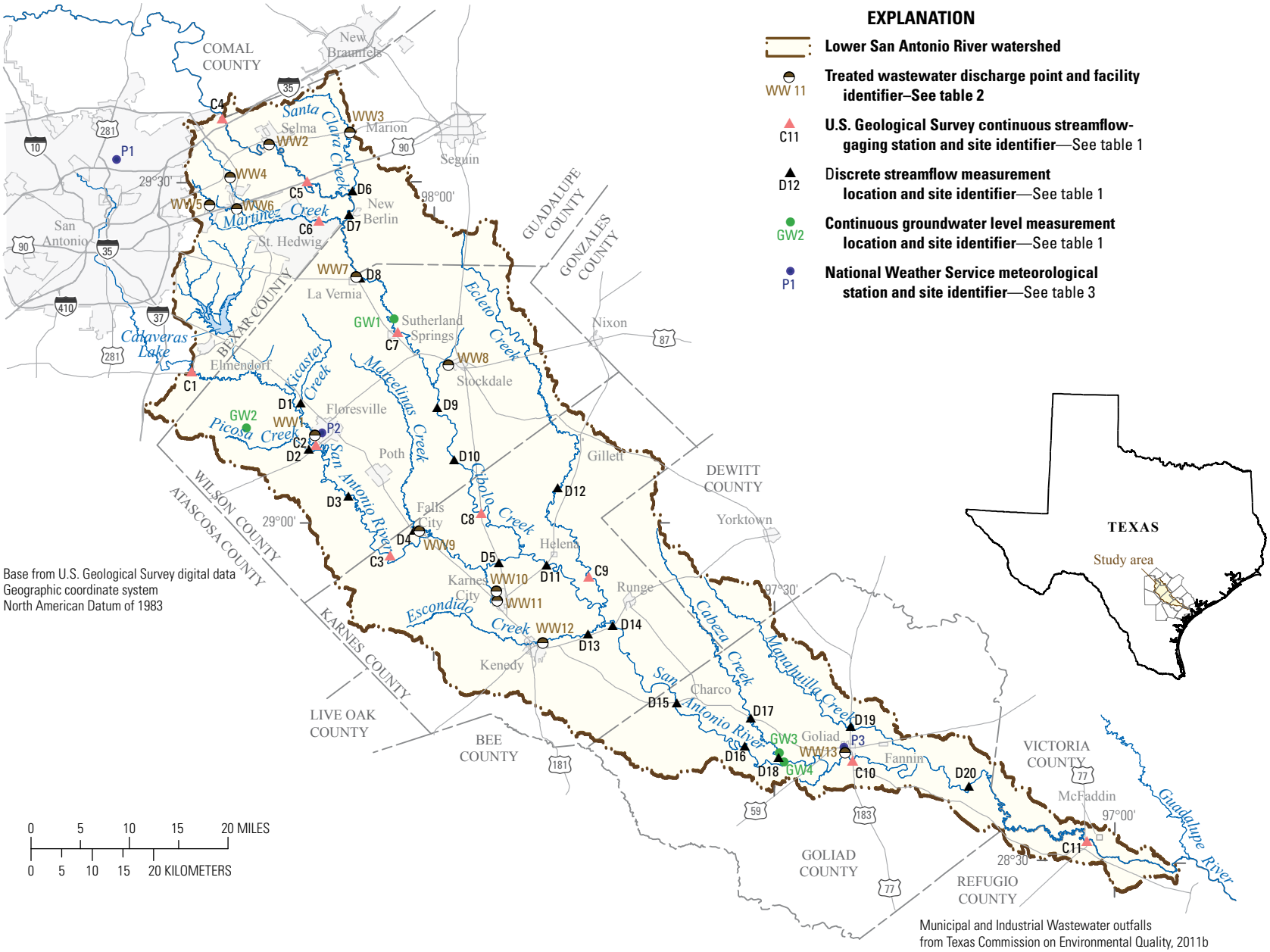

Figure 1. Lower San Antonio River watershed in south-central Texas.

Description of Study Area

The study area (fig. 1) is defined as the 2,120 square mile (mi^2) contributing area to the San Antonio River downstream from USGS streamflow-gaging station 08181800 San Antonio River near Elmendorf, Tex. (site C1, fig. 1, table 1 at end of report), and downstream from USGS streamflow-gaging station 08185000 Cibolo Creek at Selma, Tex. (site C4, fig. 1, table 1). The San Antonio River extends about 206 miles (mi) from site C1 to its confluence with the Guadalupe River. Major tributaries to the San Antonio River in the study area include Cibolo Creek, Ecleto Creek, Escondido Creek, Cabeza Creek, and Manahuilla Creek. Cibolo Creek begins in the study area as an ephemeral stream; streamflow at site C4 on Cibolo Creek occurs only in response to large runoff-producing storms north of the study area.

Six USGS streamflow-gaging stations with more than 40 years of continuous streamflow record are in the lower San Antonio River watershed (fig. 1, table 1):

1. 08181800 San Antonio River near Elmendorf, Tex. (site C1, table 1)
2. 08183500 San Antonio River near Falls City, Tex. (site C3, table 1)
3. 08188500 San Antonio River at Goliad, Tex. (site C10, table 1)
4. 08185000 Cibolo Creek at Selma, Tex. (site C4, table 1)
5. 08186000 Cibolo Creek near Falls City, Tex. (site C8, table 1)
6. 08186500 Ecleto Creek near Runge, Tex. (site C9, table 1).

To better understand streamflow gains losses in the study area, five additional continuous USGS streamflow-gaging stations were established in late 2005 and early 2006 (fig. 1):

1. 08183200 San Antonio River near Floresville, Tex. (site C2, table 1)
2. 08188570 San Antonio River near McFaddin, Tex. (site C11, table 1)
3. 08185065 Cibolo Creek near Saint Hedwig, Tex. (site C5, table 1)
4. 08185500 Cibolo Creek at Sutherland Springs (site C7, table 1)
5. 08185100 Martinez Creek near Saint Hedwig, Tex. (site C6, table 1).

The study area is less than 5 percent urbanized (Lizárraga and Ockerman, 2010), but the hydrology of the study area is affected by the rapidly growing San Antonio metropolitan area (fig. 1), which is mostly upstream. Groundwater discharge from springs has historically contributed to the base flow in the lower San Antonio River (Texas Instream Flow Program and San Antonio River Authority, 2009). The groundwater discharge from springs largely originates upstream from the study area, and from springs near Sutherland Springs, Tex., between sites D7 and C7 of Cibolo Creek (discrete measurements of streamflow were measured at sites D1 through D20 [fig. 1, table 1]). In recent years, flow in the river has been increasingly augmented by the discharge of treated wastewater.

The streamflow at site C1 (upstream drainage area of 1,740 mi^2) consists primarily of stormwater runoff, treated wastewater discharges, and groundwater discharge (Ockerman and McNamara, 2003). Streamflow into the study area at site C4 (upstream drainage area of 274 mi^2) only occurs after heavy rainfall north of the study area. Treated wastewater from the San Antonio metropolitan area discharges primarily to the San Antonio River upstream from Elmendorf, Tex., but some of the treated wastewater from the San Antonio metropolitan area is discharged into Cibolo Creek and its tributary, Martinez Creek. Cibolo Creek is a perennially flowing stream at site C7 because of treated wastewater discharges and springflow near the town of Sutherland Spring. Cibolo Creek flows into the lower San Antonio River near Helena, Tex. Treated wastewater discharges from smaller urban areas within the study area also affect the streamflow at various locations downstream from Saint Hedwig and Elmendorf. Permitted discharges of treated wastewater in the study area that were used in the assessment of streamflow gains and losses are listed in table 2, at end of report.

Lizárraga and Ockerman (2010, p. 4) noted "The northern tip of the lower San Antonio River watershed overlies Cretaceous rocks of the Edwards-Trinity aquifer system. The remainder of the watershed overlies the Texas Coastal Uplands and Coastal Lowlands aquifer systems (Ryder, 1996)" (fig. 2). The Texas Coastal Uplands aquifer system is composed of formations of Paleocene and Oligocene age, and the Texas Coastal Lowlands aquifer system is composed of younger formations from Oligocene through Holocene age. Lizárraga and Ockerman (2010) grouped the formations composing the aquifer systems in the study area into nine surficial geology zones (fig. 2). The surficial geology is shown in figure 2. These zones provide a common frame of reference for analysis in this report and comparison to modeling results in Lizárraga and Ockerman (2010). Formations gently dip and thicken toward the southeastern part of the study area (Young and others, 2010; Ryder, 1996).

The San Antonio River channel has become increasingly incised since the 1950s from site C1 to C10 and there are few active flood plains in this area (Cawthon, 2008; Engel, 2008). The San Antonio River downstream from site C10 crosses the outcrop of the Lissie Formation (fig. 2) and is wider and more prone to channel migration than upstream from site C10. Approaching the southeastern part of the study area (zone 9), there is a wider, more active flood plain. With an increasingly active flood plain and sandy soils, bank and alluvial water storage increases downstream from site C10.

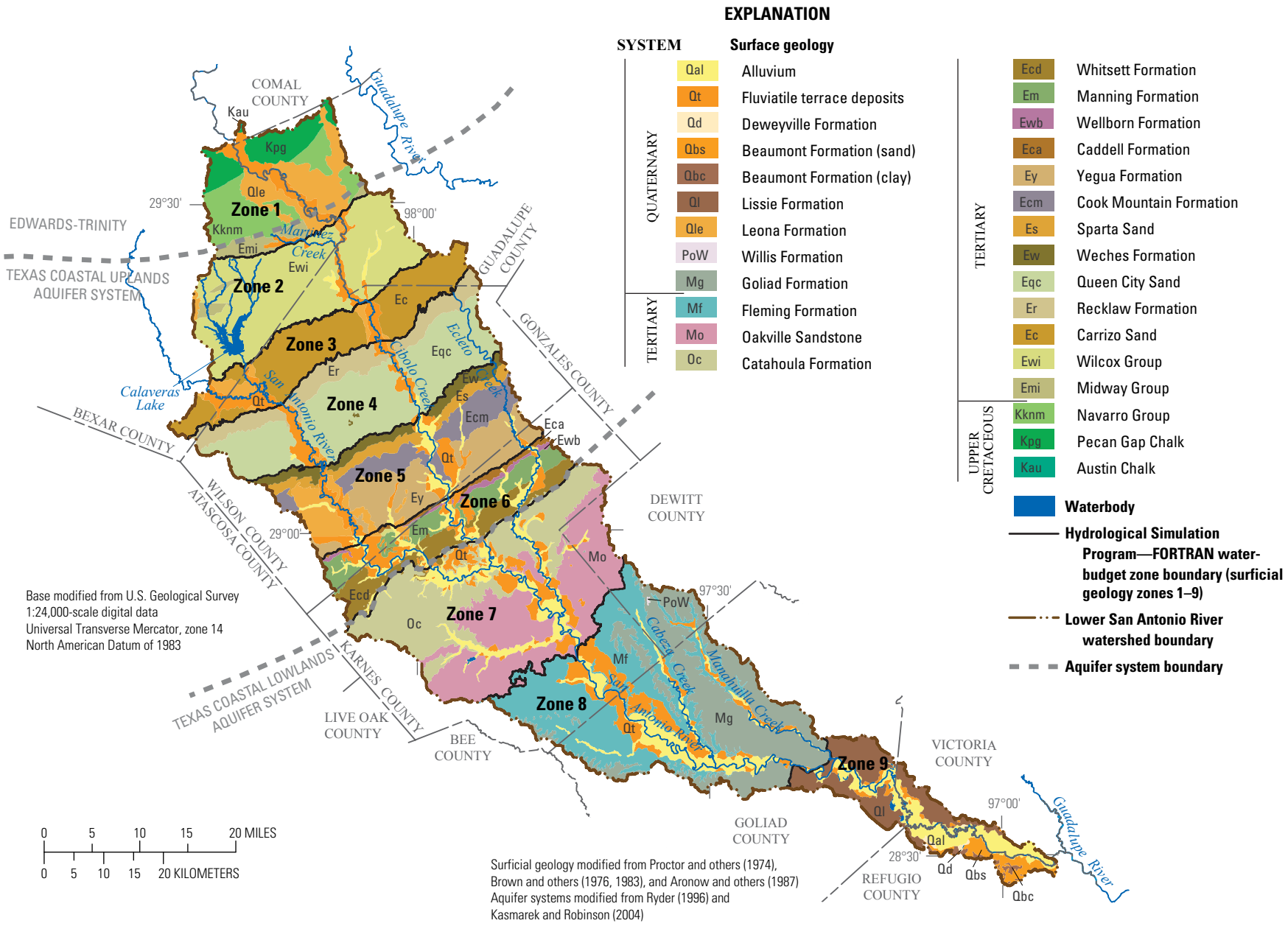

Figure 2. Aquifer systems, surficial geology, and delineation of water-budget zones of the lower San Antonio River watershed, south-central Texas.

Meteorological Conditions

The climate of the northwestern part of the study area is subtropical subhumid transitioning into subtropical humid in the southeastern part of the study area (Larkin and Bomar, 1983). Heavy rainfall in the study area is common and can occur any time throughout the year. The 24-hour rainfall total corresponding to the 50-percent annual exceedance probability in Karnes County, Tex., is 4.2 inches (in.) (Natural Resources Conservation Service, 2009); Karnes County is at about the midpoint of the study area. Over a long period of record, a bimodal pattern in rainfall has been observed with wet periods in the late spring and mid-fall (Engel, 2008). During 2006–10, rainfall recorded at three rainfall stations shows generally increasing amounts from northwest to southeast in the study area, in the downstream direction (table 3 at end of report). During 2006–10, a wide range of annual rainfall amounts was measured, representing almost the entire range of annual rainfall variability recorded since 1960 at these stations.

Methods

Continuous streamflow records and discrete streamflow measurements were used to evaluate streamflow gains and losses in the lower San Antonio River watershed from Comal County, Tex., downstream to Refugio County, Tex. The discussion of methods pertaining to discrete measurements of streamflow is modified from Turco and others (2007, p. 5–7).

Computation of Streamflow Statistics

To determine whether the lower San Antonio River and lower Cibolo Creek generally gain or lose streamflow in the downstream direction, streamflow statistics were calculated for each of the 11 continuous USGS streamflow-gaging stations in the study area (table 1; sites C1 through C11). Daily streamflow statistics (average streamflow, 80-percent exceedance probability streamflow, 50-percent exceedance probability streamflow, 20-percent exceedance probability streamflow, and 10-percent exceedance probability streamflow) were computed for period of record at each station and for January 1, 2006, through December 31, 2010, using data obtained from the USGS National Water Information System (U.S. Geological Survey, 2011a).

Computation of Streamflow Gains and Losses from Continuous Streamflow Records

Streamflow gains and losses were first computed from records of continuous streamflow measured at 11 USGS streamflow-gaging stations (table 1; sites C1 through C11) in the study area. Streamflow gains and losses over the length of a stream reach were computed indirectly by calculating the differences in streamflow between continuous streamflow-gaging stations along the stream. Sources of gains or losses between two sites (which define a reach), in addition to groundwater inflow or outflow through the streambed, include tributary inflow, diversions, return flows, and evaporation. Using these factors, streamflow gain or loss in the reach using continuous streamflow measurements was computed as

$$G = Q_D - Q_U - I + D_{wr} - R + E, \quad (1)$$

where

G is streamflow gain or loss (groundwater inflow or outflow);
Q_D is measured streamflow at the downstream boundary of the reach;
Q_U is measured streamflow at the upstream boundary of the reach;
I is measured inflows from tributaries;
D_{wr} is active surface-water rights (diversions) from the reach;
R is return flows to the reach; and
E is evaporation.

During this study, numerous tributary inflows were measured directly and annual active surface-water rights diversions (table 4 at end of report) were acquired from the Texas Commission on Environmental Quality (2010). Active surface-water rights are not measured diversions. Over the 5-year period from 2006–10, actual diversions were approximated by 2010 active surface-water rights because on an annual basis, water rights in Texas generally are exercised so they are not lost (Townsend, 1986). However, return flows and evaporation were not measured during 2006–10. Return flows for 2006–10 were estimated as the 2008 annual withdrawal amount reported to the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 2010). Evaporation was excluded from equation 1 for the gain and loss computation using continuous streamflow measurements in the lower San Antonio River watershed 2006–10. The magnitude of error associated with the exclusion of evaporation is believed to be minor when compared to potential errors associated with the flow measurements (Turco and others, 2007).

Computation of Streamflow Gains and Losses from Discrete Measurements of Streamflow

In addition to computing streamflow gains and losses from records of continuous streamflow measured at USGS streamflow-gaging stations during 2006–10, streamflow data for computation of gains and losses were collected from the San Antonio River and nine tributaries to the San Antonio River during four synoptic streamflow measurement surveys: April 18–19, 2006, August 23–24, 2006, February 13–15, 2007, and October 9–11, 2007 (table 5 at end of report). The four surveys were representative of various hydrologic conditions. During 2006 and 2007, discrete measurements

of streamflow were made at sites D1 through D20 (fig. 1, table 5). During the April 18–19, 2006, survey, streamflow was measured at 19 sites, 7 on the San Antonio River and 12 on tributaries (fig. 1; table 1). During the August 23–24, 2006, and October 9–11, 2007, surveys, streamflow measurements were made at 20 sites, 7 on the San Antonio River and 13 on tributaries. During the February 13–15, 2007, survey, streamflow measurements were made at 15 sites, 3 on the San Antonio River and 12 on tributaries. When it was possible, average daily discharges of treated wastewater in the study area were obtained for the days of synoptic streamflow measurement surveys (table 6 at end of report).

Discrete measurements of streamflow were made in accordance with USGS methods (Rantz and others, 1982; Turnipseed and Sauer, 2010). Where conditions allowed (that is, when water depths were generally less than 3 feet), streams were waded and velocity measurements were made using rod-mounted acoustic meters (Xylem Analytics, 2012). In all other instances, boat-mounted acoustic Doppler current profilers were used to measure streamflow (Oberg and others, 2005). Streamflow measurements were made during relatively stable base-flow conditions. By conducting the surveys in this manner, any streamflow gain or loss was unlikely to be attributed to rainfall.

Streamflow gains and losses over the length of a stream reach using discrete measurements were computed indirectly by calculating the differences in streamflow between sites along the stream. Sources of gains or losses between two sites, which define a reach, in addition to groundwater inflow or outflow through the streambed, include tributary inflow, diversions, return flows, and evaporation. Using these factors, streamflow gain or loss in the reach was computed as

$$G = Q_D - Q_U - I + D - R + E, \quad (2)$$

where

G is streamflow gain or loss (groundwater inflow or outflow);
Q_D is measured streamflow at the downstream boundary of the reach;
Q_U is measured streamflow at the upstream boundary of the reach;
I is measured inflows from tributaries;
D is measured outflows (diversions) from the reach;
R is return flows to the reach; and
E is evaporation.

During this study, numerous tributary inflows and return flows were measured directly. However, diversions and evaporation were not measured, and those components were excluded from equation 2 for the gain and loss computation using discrete measurements. The magnitude of error associated with the exclusions of diversions and evaporation is believed to be minor when compared to potential errors associated with the flow measurements. Diversion amounts were not used in the gain and loss equation used for the computation using discrete measurements because information concerning actual diversions at the temporal scale of the synoptic streamflow measurement surveys cannot be approximated by active surface-water rights. Reaches were defined using the locations of the continuous stations as well as the locations of streamflow measurements made during four synoptic streamflow measurement surveys in April 2006, August 2006, February 2007, and October 2007.

Classification of Stream Reaches as Verifiably Gaining or Losing

For this report, a stream reach was classified as verifiably gaining or losing only when the streamflow gain or loss in a reach was greater than the sum of the potential errors associated with the upstream and downstream flow measurements. Streamflows used in gain-loss estimations included computed streamflows measured at continuously-recording USGS streamflow-gaging stations (fig. 1, table 1, sites C1 through C11) and discrete measurements of streamflow made at additional locations (fig. 1, table 1, sites D1 through D20) during the synoptic streamflow measurement surveys. Computed streamflows at continuously-recording streamflow-gaging stations were based on river stage and an established rating curve that relates stage to streamflow. The rating curve was evaluated regularly using field measurements in accordance with U.S. Geological Survey protocols (Kennedy, 1984; Turnipseed and Sauer, 2010). For continuously-recording streamflow-gaging stations, the potential error was defined by the corresponding annual accuracy rating by water year (U.S. Geological Survey, 2011b). An annual accuracy rating of "excellent" for a station indicates that 95 percent of the daily discharges in that water year were considered to be within 5 percent of the true value. An accuracy rating of "good" indicates that 95 percent of the daily discharges in that water year were considered to be within 10 percent of the true value, "fair" indicates that 95 percent of the daily discharges in that water year were considered to be within 15 percent of the true value, and records that are considered to be less accurate are rated "poor" (Novak, 1985).

Discrete streamflow measurement error was based on the rating of the streamflow measurement (excellent, good, fair, or poor) by the streamgager (Sauer and Meyer, 1992; Turnipseed and Sauer, 2010). The rating is based on factors such as cross-section uniformity, velocity homogeneity, streambed conditions, and other factors that affect the accuracy of the measurement. Measurements rated excellent are believed to be within 2 percent of the true value, good are believed to be within 5 percent of the true value, fair are believed to be within 8 percent of the true value, and poor are believed to differ from the true value by more than 8 percent.

Diurnal variation in streamflow was defined as the highest and lowest hourly streamflow values during the synoptic streamflow-measurement surveys. Diurnal variation was not accounted for in the computations of streamflow gains or losses. Streamflow gains and losses computed for each reach

were normalized by the contributing drainage area. The contributing drainage area to a reach was defined as the difference between the drainage area at the upstream and downstream sites. The gain or loss normalized by drainage area was computed as the gain or loss divided by the total contributing drainage area to the reach.

Water-Level-Altitude Measurements

Understanding surface-water/groundwater interactions is useful in gain-loss studies. Groundwater often adds to streamflow; conversely, formations composing the recharges zones of aquifers can remove water from streams. The importance of groundwater varies with local differences in geology and the degree of connection between the stream and the underlying formations (U.S. Geological Survey, 1999). Groundwater water-level altitudes were monitored continuously in four wells in the study area during 2006–8 (two completed in the Texas coastal uplands aquifer system and two in the Texas coastal lowlands aquifer system) to help determine if groundwater contributions to streamflow or streamflow contributions to recharge occurred in the study area. Four State wells, two in the Texas coastal uplands aquifer system and two in the Texas coastal lowlands aquifer system, were monitored from 2006 through 2008. The four groundwater stations instrumented to record continuous groundwater-level altitudes were State wells 68-48-502, 68-54-901, 79-21-705, and 79-21-706 (sites GW1 through GW4, fig. 1, table 1). The well depths are 243, 56.27, 983, and 150 feet below land surface, respectively.

Continuous water-level altitudes were measured with a pressure transducer using methods described by Cunningham and Schalk (2011). The pressure transducers measure the depth to the water surface below a land-surface datum and are reported as the depth below the land-surface datum or water-surface elevation above the National Geodetic Vertical Datum of 1929 (NGVD 29). The continuous water-level altitudes were recorded every 15 minutes and transmitted hourly by way of satellite to the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2011a). Continuous daily water-level altitudes were periodically verified during field visits using methods described by Cunningham and Schalk (2011). Depth to groundwater was measured at each well with a steel tape or an electronic water-level contact tape (e-line) at least 15 separate times between July 20, 2006, and November 13, 2008. USGS station numbers corresponding to all State well numbers used in this report are shown in table 1.

Streamflow Gain and Loss Using Continuous Streamflow Measurements, 2006–10

Streamflow statistics at 11 U.S. Geological Survey continuous streamflow-gaging stations (tables 7a and 7b at end of report) indicate that the lower San Antonio River and lower Cibolo Creek (fig. 1) generally gain streamflow in the downstream direction. The x-percent exceedance streamflow is defined as the daily average streamflow that was exceeded x-percent of the days during the analysis period. For example, the 50-percent exceedance streamflow represents the daily average streamflow that was exceeded 50 percent of the days during the period of analysis—either the period of record for the station (table 7a) or during 2006–10 (table 7b).

From the continuous streamflow records, the greatest streamflow gain on the lower San Antonio River occurred in the reach from site C3 to site C10 (it also was the longest reach, and has several tributary inflows). The greatest streamflow gain on Cibolo Creek during 2006–10 occurred in the reach from site C5 to site C7 (table 8 at end of report). When normalized by drainage area, the reaches in the study area with the greatest estimated streamflow gains per unit area were Martinez Creek from the headwaters to site C6, and the San Antonio River between site C10 and site C11. The San Antonio River between site C2 and site C3 was the only reach that had an estimated streamflow loss during 2006–10.

Streamflow Gain and Loss Using Discrete Measurements, 2006–7

During both 2006 synoptic streamflow measurement surveys, streamflow measurements were made more than 2 weeks after measured rainfall occurred within the study area. During the 2007 surveys, small amounts of rainfall in the 2 weeks prior to streamflow measurements could not be avoided. Rainfall of 0.3 in. was measured on February 12, 2007, at the National Weather Service station in Goliad (site P3, fig. 1, table 3), approximately 12 days prior to the February 2007 sampling, and rainfall of 0.5 in. was measured at the National Weather Service station in Goliad on the first day of the October 2007 survey, following 29 days of no measurable rainfall. Streamflow and groundwater changes in response to the rainfall preceding the 2007 surveys were minimal; stream height above an arbitrary datum (stream stage) did not rise substantially at the continuous streamflow-gaging stations (sites C1–C11; fig. 1, table 1) and groundwater water-level altitudes at sites GW1 through GW4 (fig. 1, table 1) remained relatively stable during the 2007 survey periods (fig. 3). For example, water-level altitudes at site GW1 (fig. 3) declined about 0.02 percent, and streamflows at site C10 and site C11 (fig. 3) fell about 6.6 and 3.1 percent, respectively, from October 7–12, 2007, indicating a minimal groundwater and surface-water response to rainfall during the week prior to the October survey.

During all four synoptic streamflow measurement surveys, the only substantially flowing tributary reach to the main stem of the lower San Antonio River was Cibolo Creek. Tributaries of the main channel of the San Antonio River, with the exception of Cibolo Creek, were not flowing

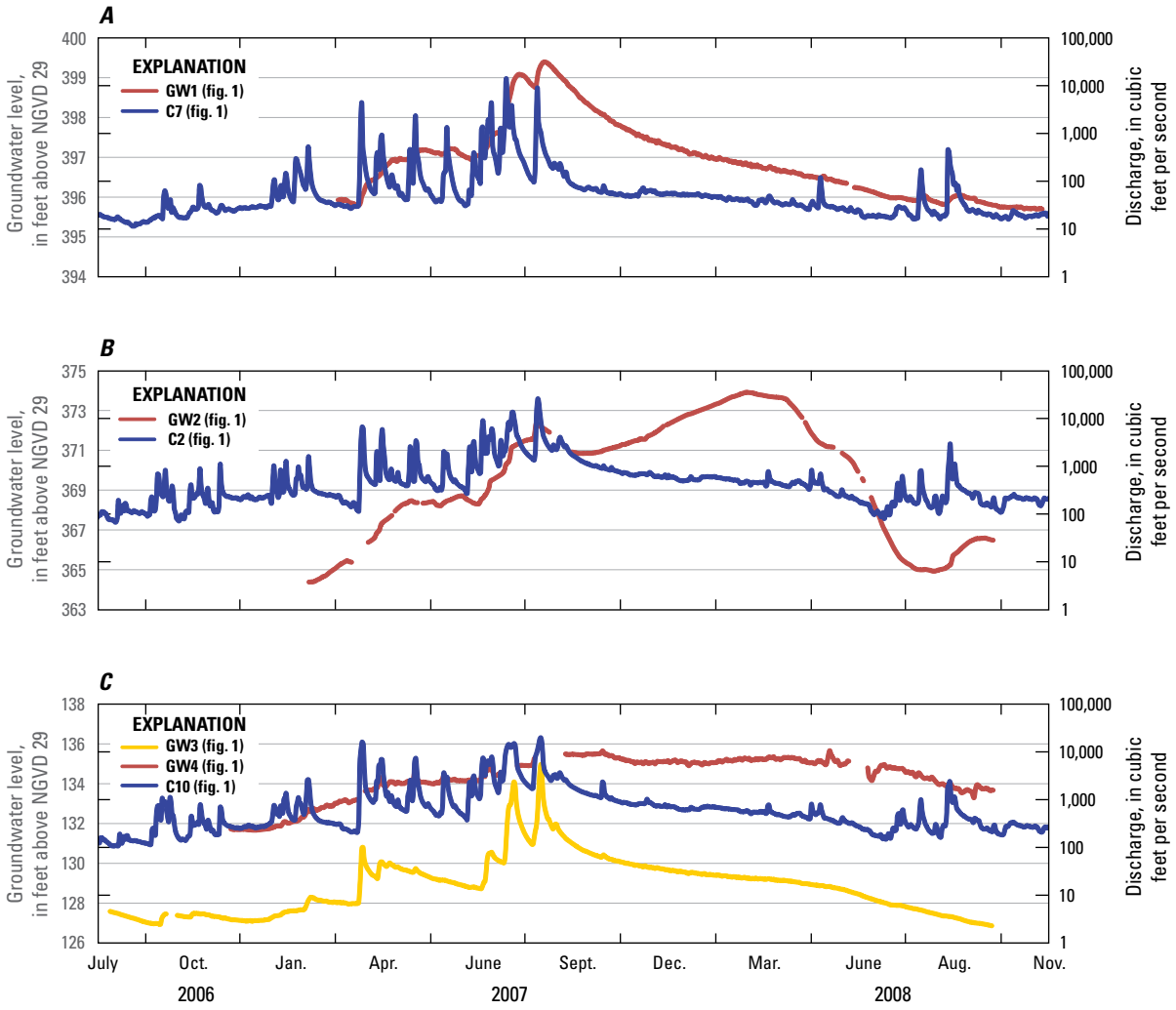

Figure 3. Water-level altitudes measured in state wells and streamflow measured at the nearest downstream U.S. Geological Survey streamflow-gaging stations during 2006–8: *A*, State well 68-48-502 (site GW1) and U.S. Geological Survey streamflow-gaging station 08185500 Cibolo Creek at Sutherland Springs, Texas (site C7), *B*, State well 68-54-901 (site GW2) and U.S. Geological Survey streamflow-gaging station 08183200 San Antonio River near Floresville, Tex. (site C2), and *C*, State wells 79-21-705 and 79-21-706 (site identifier GW3 and GW4, respectively) and U.S. Geological Survey streamflow-gaging station 08188500 San Antonio River at Goliad, Tex. (site C10).

or only minimally flowing during the 2006 and 2007 synoptic streamflow measurement surveys. The three tributaries to the San Antonio River overlying the Texas coastal uplands and Texas coastal lowlands aquifer system (Cabeza Creek, Escondida Creek, and Manahuilla Creek) were flowing during the October 2007 survey but each contributed only 3.0 to 4.5 ft^3/s (table 5), a small percentage of the overall flow in the San Antonio River. Although there was rainfall in the study area prior to the October 2007 survey, streamflow declined slowly at the San Antonio River streamflow-gaging stations throughout the October sampling period (fig. 3). This declining streamflow could be an indication that the river was still adjusting from heavier rains earlier in the year; large amounts of rain fell on the study area during May–August 2007 (National Climatic Data Center, 2011).

During the synoptic streamflow measurement survey periods, there was a diurnal fluctuation in streamflow in the San Antonio River and Cibolo Creek. It was unknown whether discrete measurements were made on the high end or low end of a diurnal fluctuation. Therefore, ranges of hourly streamflows at the continuous measurement stations during the four synoptic surveys are presented (fig. 4; fig. 5). Most of the gain in the main channel of the lower San Antonio River (fig. 4) occurred gradually except for an abrupt increase at the

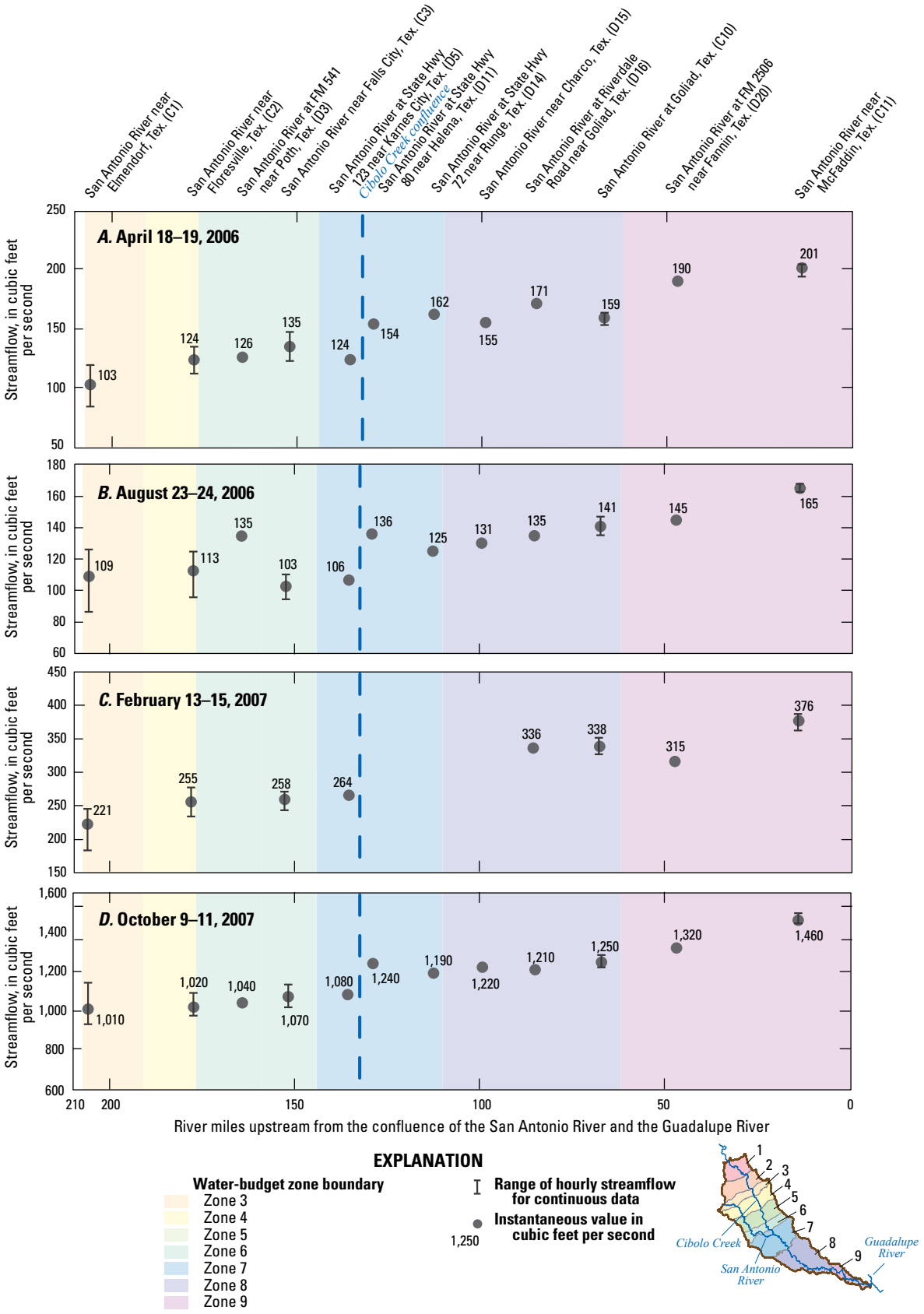

Figure 4. Discrete streamflow measurements made along the main channel of the lower San Antonio River during four synoptic surveys: *A*, April 18–19, 2006, *B*, August 23–24, 2006, *C*, February 13–15, 2007, and *D*, October 9–11, 2007.

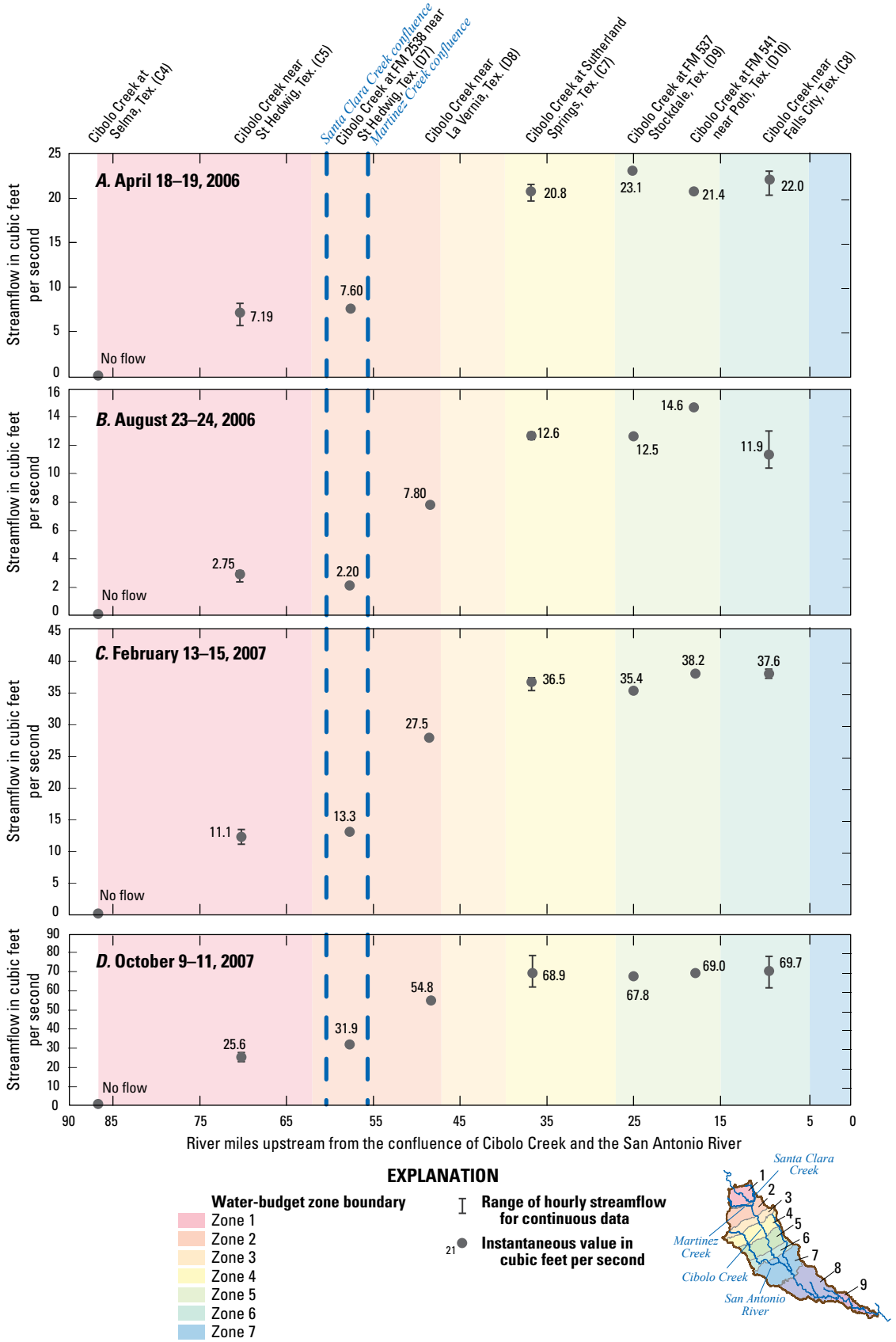

Figure 5. Discrete streamflow measurements made along the main channel of the Cibolo Creek during four synoptic surveys: *A*, April 18–19, 2006, *B*, August 23–24, 2006, *C*, February 13–15, 2007, and *D*, October 9–11, 2007.

confluence of the San Antonio River with Cibolo Creek, and an increase across zone 9 (fig. 2), which includes the outcrop of the Lissie Formation.

Most of the gain in Cibolo Creek occurred in the reaches overlying zones 2, 3, and 4 (fig. 5), which includes the outcrops of the Wilcox Group, Carrizo Sand, and Queen City Sand (fig. 2).

For the 11 reaches of the San Antonio River and 7 reaches of Cibolo Creek, streamflow gains or losses were computed for the four synoptic streamflow measurement survey periods (tables 9–11). It is not known whether or not there were actual diversions based on the active surface-water rights (table 4) during the short periods of the synoptic streamflow measurement surveys. Therefore, permitted diversion amounts from active surface-water rights were not included in the analysis of streamflow gains and losses during the synoptic streamflow measurement surveys.

On the main stem of the lower San Antonio River, the synoptic streamflow measurement survey data showed generally increasing streamflow in the downstream direction from site C1 to site C11 (table 9). Measured tributary inflows from Cibolo Creek and smaller tributaries composed at least 24 percent of the gain in San Antonio River streamflow in the first three synoptic streamflow measurement surveys. In the October 2007 synoptic streamflow measurement survey, only 19 percent of the overall gain was from measured tributary inflow.

Along the main stem of the lower San Antonio River, verifiable gains larger than the potential measurement error were estimated in two of the four synoptic streamflow measurement surveys (fig. 6, *A* and *C*). These gaining reaches occurred in the two most downstream reaches of the San Antonio River between sites C10 at Goliad and D20 near Fannin and between sites D20 near Fannin and C11 near McFaddin. During the April survey, there was a verifiable gain estimated as 30.9 ft^3/s between site C10 and site D20. During the February 2007 synoptic streamflow measurement survey, there was a verifiable gain estimated as 61.0 ft^3/s between sites D20 and C11.

Except for the February synoptic streamflow measurement survey, most of the overall gain in the main stem of the lower San Antonio River that was not accounted for by measured tributary inflow or discharges was measured in the reach between site C10 and site C11 (table 10). During February 2007 (the wetter year), the water-level altitudes in wells were just beginning to rise near site C10, and there was a gain of 38.0 ft^3/s in streamflow between site C10 and site C11 (table 10); however, this was not larger than the range of potential measurement error. By October 2007, after substantial rainfall across the study area, water-level altitudes had responded and there was an estimated gain of 207 ft^3/s between site C10 and site C11 measured during the synoptic streamflow measurement survey (table 10). While also not verifiable, this gain represented 46 percent of the overall gain in streamflow for the reach between sites C1 and C11.

At the most upstream site on Cibolo Creek (site C4), no flow was observed during any of the synoptic streamflow measurement surveys (fig. 5). The Cibolo Creek Municipal Authority plant (site WW3; table 2) discharges to Cibolo Creek upstream from site C5 near St. Hedwig on Cibolo Creek (fig. 1, table 1), where streamflow ranged from 2.37–26.3 ft^3/s during the four synoptic streamflow measurement surveys (fig. 5, table 11). Martinez Creek was the only tributary to Cibolo Creek that was flowing during the synoptic streamflow measurement surveys. During base-flow conditions, streamflow measured at site C6 on Martinez Creek was composed mostly of discharge from the Salitrillo, Upper Martinez I, and Martinez II wastewater-treatment facilities (fig. 4, table 2). Computed discharge at site C6 ranged from 5.73–14.0 ft^3/s during the synoptic streamflow measurement surveys (no data were collected during the February 13–15, 2007 survey). Martinez Creek discharges into Cibolo Creek downstream from site C5 (fig. 1, table 1).

There were verifiable gains in streamflow in Cibolo Creek, between La Vernia, Tex. (site D8) and the town of Sutherland Springs, Tex. (site C7), during all four surveys, estimated at between 4.8–14 ft^3/s (fig. 6, table 11). Added to this gain would be any diversions that might have been made to satisfy permitted amounts. During the April 2006, February 2007, and October 2007 synoptic streamflow measurement surveys, there were also verifiable gains in reaches upstream from site D8 (fig. 6) where Cibolo Creek crosses over the outcrop of the Wilcox Group (fig. 2). Much of the rainfall prior to the October 2007 survey occurred south of these gaining reaches (National Climatic Data Center, 2011). In August 2006, after a long period of minimal rainfall, while Cibolo Creek was still gaining streamflow between La Vernia and Sutherland Springs (smallest amount of streamflow gain during the four surveys), there were verifiable losses in streamflow on Cibolo Creek from sites C4 to C6 and sites D10 to C8.

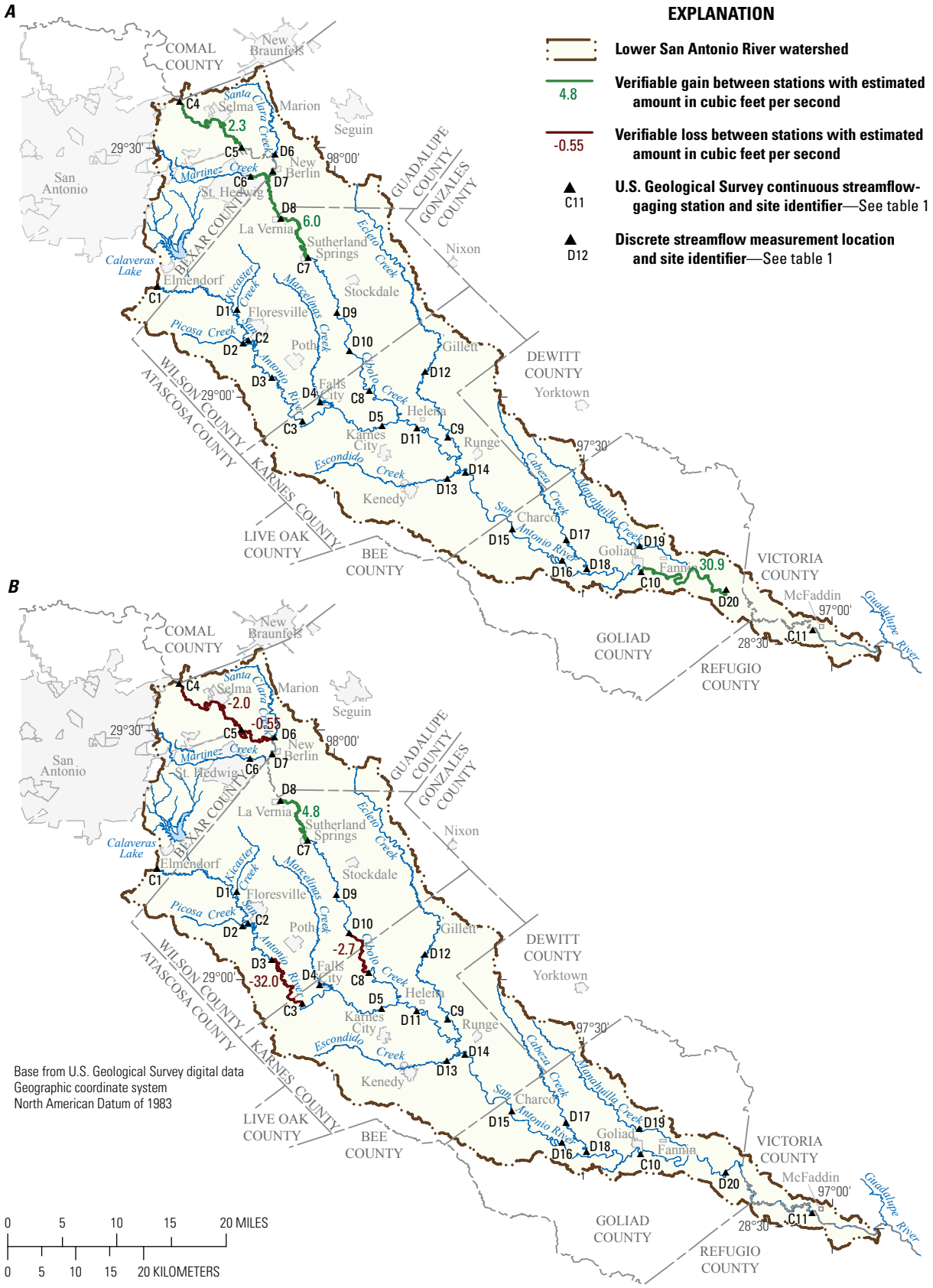

Figure 6. Verifiable streamflow gains and losses during four synoptic surveys in lower San Antonio River watershed: *A*, April 18–19, 2006; *B*, August 23–24, 2006; *C*, February 13–15, 2007; and *D*, October 9–11, 2007, south-central Texas.

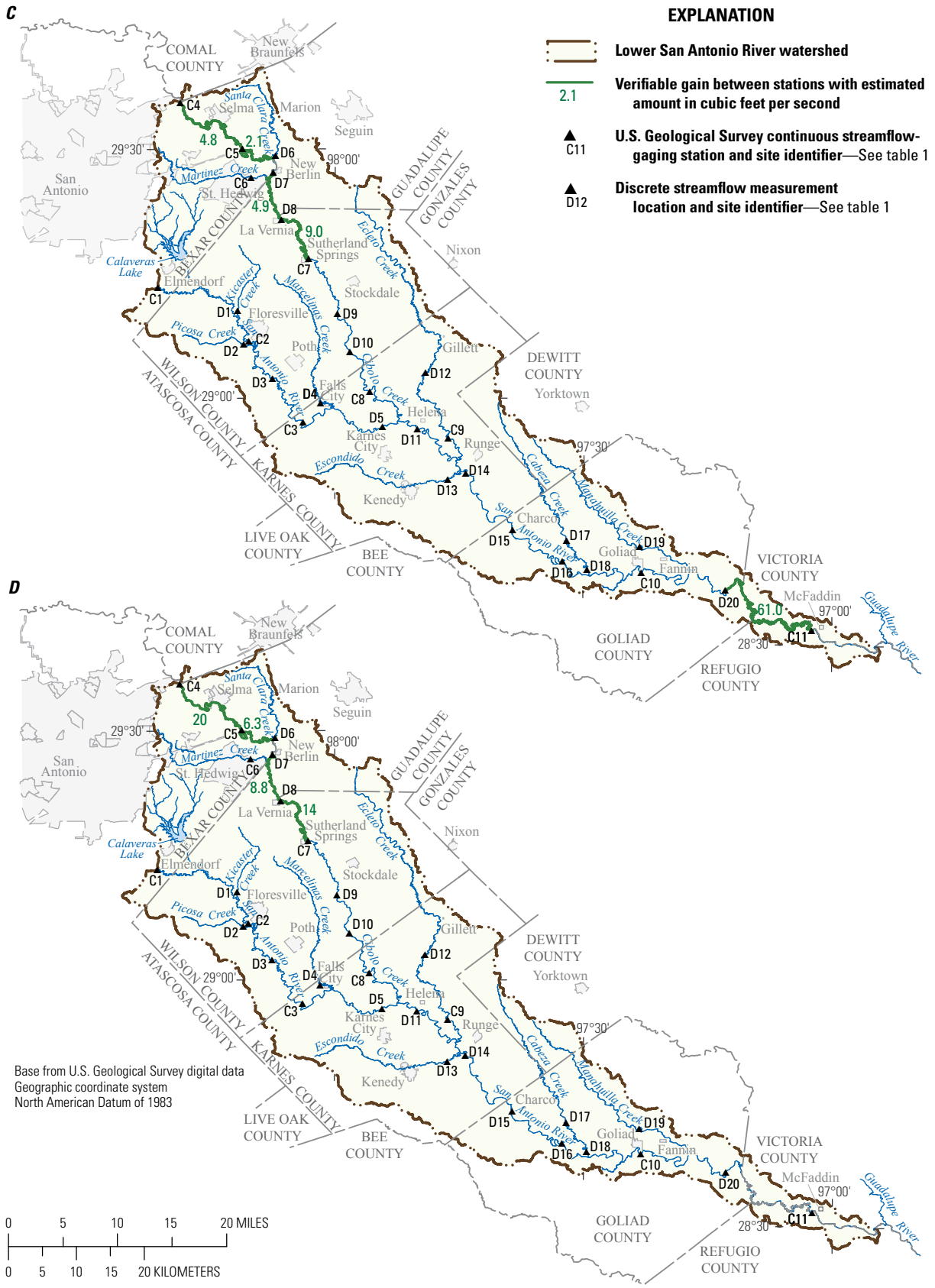

Figure 6.—Continued

Summary

The U.S. Geological Survey (USGS), in cooperation with the San Antonio River Authority, the Evergreen Underground Water Conservation District, and the Goliad County Groundwater Conservation District, investigated streamflow gains and losses during 2006–10 in the lower San Antonio River watershed in south-central Texas. Streamflow gains and losses were estimated using 2006–10 continuous streamflow records from 11 continuous streamflow-gaging stations, and discrete streamflow measurements made at as many as 20 locations on the San Antonio River and selected tributaries during four synoptic surveys during 2006–7 (19 and 20 measurement sites during April and August 2006, respectively, and 15 and 20 measurement sites during February and October 2007, respectively). The lower San Antonio River and lower Cibolo Creek generally gain streamflow in the downstream direction. From the continuous streamflow records, the greatest streamflow gain on the lower San Antonio River occurred in the reach from Falls City to Goliad, Tex. The greatest streamflow gain on Cibolo Creek during 2006–10 occurred in the reach from near Saint Hedwig, Tex., to Sutherland Springs, Tex. The San Antonio River between Floresville, Tex., and Falls City, Tex., was the only reach that had an estimated streamflow loss during 2006–10.

During all four synoptic streamflow measurement surveys, the only substantially flowing tributary reach to the main stem of the lower San Antonio River was Cibolo Creek. Tributaries of the main channel of the San Antonio River, with the exception of Cibolo Creek, were not flowing or only minimally flowing during the 2006 and 2007 synoptic streamflow measurement surveys. Most of the gain in the main channel of the lower San Antonio River occurred gradually except for an abrupt increase at the confluence of the San Antonio River with Cibolo Creek. Most of the gain in Cibolo Creek flow occurred in the reaches overlying the outcrops of the Wilcox group, Carrizo Sand, and Queen City Sand.

On the main stem of the lower San Antonio River, the synoptic streamflow measurement survey data showed generally increasing streamflow in the downstream direction from near Falls City and to near McFaddin. Measured tributary inflows from Cibolo Creek and smaller tributaries composed at least 24 percent of the gain in San Antonio River streamflow in the first three synoptic streamflow measurement surveys. In the October 2007 synoptic streamflow measurement survey, only 19 percent of the overall gain was from measured tributary inflow.

Along the main stem of the lower San Antonio River, verifiable gains larger than the potential measurement error were estimated in two of the four synoptic streamflow measurement surveys. These gaining reaches occurred in the two most downstream reaches of the San Antonio River between Goliad and Farm Road (FM) 2506 near Fannin, Tex., and between FM 2506 near Fannin to near McFaddin. During the April 2006 survey, there was a verifiable gain estimated as 30.9 ft^3/s between Goliad and FM 2506 near Fannin. During the February 2007 synoptic streamflow measurement survey, there was a verifiable gain estimated as 61.0 ft^3/s between FM 2506 near Fannin to near McFaddin.

There were verifiable gains in streamflow in Cibolo Creek, between La Vernia, Tex., and the town of Sutherland Springs during all four surveys, estimated at between 4.8 and 14 ft^3/s. Added to this gain would be any diversions that might have been made to satisfy permitted amounts. During the April 2006, February 2007, and October 2007 synoptic streamflow measurement surveys, there were also verifiable gains in reaches upstream from measurement site on Cibolo Creek at FM 775 near La Vernia where Cibolo Creek crosses over the outcrop of the Wilcox Group. In August 2006, after a long period of minimal rainfall, while Cibolo Creek was still gaining streamflow between La Vernia and Sutherland Springs, there were verifiable losses in streamflow on Cibolo Creek between Cibolo Creek at Selma, Tex., and Martinez Creek near Saint Hedwig, Tex., and between FM 541 near Poth, Tex., and near Falls City, Tex.

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Table 1. U.S. Geological Survey continuous and discrete measurement locations in the lower San Antonio River watershed, south-central Texas, 2006–10.

[USGS, U.S. Geological Survey; mi², square miles; FM, Farm Road; Hwy, Highway; --, not applicable; Tex., Texas]

Site number (fig. 1)	Station name	USGS station number	County	Period of record[1]	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (mi²)
			Continuous groundwater-level measurement locations				
GW1	[2]68-48-502	291756098033101	Wilson	2007–8	29 17 55.86	98 03 30.71	--
GW2	[2]68-54-901	290818098163201	Wilson	2007–8	29 08 18.1	98 16 31.6	--
GW3	[2]79-21-705	283939097293201	Goliad	2006–8	28 39 39	97 29 32	--
GW4	[2]79-21-706	283853097290701	Goliad	2006–8	28 38 53	97 29 07	--
			Continuous streamflow measurement locations				
C1	San Antonio River near Elmendorf, Tex.	08181800	Bexar	1962–present	29 13 19	98 21 20	1,743
C2	San Antonio River near Floresville, Tex.	08183200	Wilson	2006–present	29 06 36	98 10 28	1,964
C3	San Antonio River near Falls City, Tex.	08183500	Karnes	1925–present	28 57 05	98 03 50	2,113
C4	Cibolo Creek at Selma, Tex.	08185000	Bexar	1946–present	29 35 38	98 18 39	274
C5	Cibolo Creek near Saint Hedwig, Tex.	08185065	Guadalupe	2005–present	29 30 05	98 11 10	306
C6	Martinez Creek near Saint Hedwig, Tex.	08185100	Bexar	2005–present	29 26 38	98 10 08	81.1
C7	Cibolo Creek at Sutherland Springs, Tex.	08185500	Wilson	1924–1929, 2005–present	29 16 47	98 03 12	665
C8	Cibolo Creek near Falls City, Tex.	08186000	Karnes	1930–present	29 00 50	97 55 48	827
C9	Ecleto Creek near Runge, Tex.	08186500	Karnes	1962–89, 2002–present	28 55 12	97 46 19	239
C10	San Antonio River at Goliad, Tex.	08188500	Goliad	1924–1929, 1939–present	28 38 58	97 23 04	3,921
C11	San Antonio River near McFaddin, Tex.	08188570	Refugio	2005–present	28 31 52	97 02 34	4,134
			Discrete streamflow measurement locations				
D1	Kicaster Creek at U.S. Hwy 181 near Floresville, Tex.	08183100	Wilson	--	29 10 35	98 11 45	29.8
D2	Picosa Creek at State Hwy 97 near Floresville, Tex.	08183280	Wilson	--	29 06 16	98 10 49	47.2
D3	San Antonio River at FM 541 near Poth, Tex.	08183300	Wilson	--	29 02 22	98 07 32	2,047
D4	Marcelinas Creek at FM 887 near Falls City, Tex.	08183600	Karnes	--	28 59 24	98 01 45	71.3
D5	San Antonio River at State Hwy 123 near Karnes City, Tex.	08183700	Karnes	--	28 56 32	97 54 17	2,284
D6	Santa Clara Creek near New Berlin, Tex.	08185080	Guadalupe	--	29 29 16	98 07 11	63.2
D7	Cibolo Creek at FM 2538 near Saint Hedwig, Tex.	08185085	Guadalupe	--	29 27 12	98 07 28	384
D8	Cibolo Creek at FM 775 near La Vernia, Tex.	08185200	Wilson	--	29 21 34	98 06 29	539
D9	Cibolo Creek at FM 537 near Stockdale, Tex.	08185800	Wilson	--	29 10 13	97 59 42	728
D10	Cibolo Creek at FM 541 near Poth, Tex.	08185900	Wilson	--	29 05 37	97 58 12	755
D11	San Antonio River at State Hwy 80 near Helena, Tex.	08186100	Karnes	--	28 56 16	97 50 05	3,157

Table 1. U.S. Geological Survey continuous and discrete measurement locations in the lower San Antonio River watershed, south-central Texas, 2006–10.—Continued

[USGS, U.S. Geological Survey; mi², square miles; FM, Farm Road; Hwy, Highway; --, not applicable; Tex., Texas]

Site number (fig. 1)	Station name	USGS station number	County	Period of record[1]	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (mi²)
Discrete streamflow measurement locations—Continued							
D12	Ecleto Creek at FM 627 near Gillett, Tex.	08186450	Karnes	--	29 03 04	97 49 06	134
D13	Escondido Creek at County Road 331 near Kenedy, Tex.	08188050	Karnes	--	28 50 11	97 46 26	109
D14	San Antonio River at State Highway 72 near Runge, Tex.	08188060	Karnes	--	28 50 55	97 44 14	3,570
D15	San Antonio River near Charco, Tex.	08188200	Goliad	--	98 44 07	97 38 35	3,688
D16	San Antonio River at Riverdale Road near Goliad, Tex.	08188300	Goliad	--	28 40 19	97 32 35	3,774
D17	Cabeza Creek at State Highway 239 near Goliad, Tex.	08188325	Goliad	--	28 42 48	97 32 04	63.6
D18	Cabeza Creek at FM 2043 near Goliad, Tex.	08188350	Goliad	--	28 39 18	97 29 36	76.0
D19	Manahuilla Creek at U.S. Hwy 183 near Goliad, Tex.	08188525	Goliad	--	28 42 04	97 23 16	89.4
D20	San Antonio River at FM 2506 near Fannin, Tex.	08188550	Goliad	--	28 36 47	97 12 51	4,060

[a]Present indicates station was active in water year 2011.

[b]State well number.

Table 2. Permitted wastewater discharges included in gain and loss estimations during 2006–10 in the lower San Antonio River watershed, south-central Texas.

[Mgal/d, million gallons per day; ft^3/sec, cubic feet per second; WW, wastewater]

Facility identifier (fig. 4)	Facility name	Permitted discharge (Mgal/d[1])	Permitted discharge (ft^3/s^1)	Receiving stream	Reach (fig. 1)
WW1	City of Floresville	0.71	1.1	San Antonio River	C1–C2
WW2	Cibolo Creek Municipal Authority	6.2	9.6	Cibolo Creek	C4–C5
WW3	City of Marion	0.20	0.31	Santa Clara Creek	headwaters to D6
WW4	Salitrillo	4.3	6.7	Salitrillo Creek	headwaters to C6
WW5	Upper Martinez I	2.2	3.4	Martinez Creek	headwaters to C6
WW6	Martinez II	2.0	3.1	Escondido Creek in Bexar County	headwaters to C6
WW7	City of La Vernia	0.11	0.17	Cibolo Creek	D7–D8
WW8	City of Stockdale	0.30	0.46	Clifton Branch	C7–D9
WW9	City of Falls City	0.07	0.10	Marcelinas Creek	C3–D5
WW10	Karnes City - Milam	0.42	0.65	San Antonio River	C3–D5
WW11	Karnes City - Main Street	0.09	0.14	San Antonio River	C3–D5
WW12	City of Kenedy	1.1	1.7	Escondido Creek in Karnes County	headwaters to D13
WW13	City of Goliad	0.35	0.54	San Antonio River	D16–C10

[1]Permitted discharge amount for the Cibolo Creek Municipal Authority from Clint Ellis, Cibolo Creek Municipal Authority, oral comm. (2012) and from U.S. Environmental Protection Agency (2010) for all other facilities.

Table 3. Annual rainfall, in inches, measured at three National Weather Service stations in or near the lower San Antonio River watershed, south-central Texas, 1960–2010.

	National Weather Service station name and number[1]		
	San Antonio Airport (417945) (site P1, fig. 1)	Floresville (413201) (site P2, fig. 1)	Goliad (413618) (site P3, fig. 1)
1960–2005 minimum	16.4	[2]15.5	[3]22.7
1960–2005 maximum	52.3	[2]54.4	[3]59.5
1960–2005 mean	31.8	[2]30.4	[3]38.3
2006	21.3	26.0	32.8
2007	47.3	48.9	51.8
2008	13.8	13.4	22.6
2009	30.7	29.7	36.0
2010	37.4	35.8	41.4
2006–10 mean	30.1	30.8	36.9

[1]Station data accessed from National Climatic Data Center (2011).

[2]Annual precipitation unavailable 1982, 1984, 1986–91, and 2003.

[3]Annual precipitation unavailable 1986–88.

Table 4. Active surface-water rights (2010) with diversion amounts used for gain or loss estimates during 2006–10 in lower San Antonio River watershed, south-central Texas.

[ft^3/s, cubic feet per second]

Surface-water right number[1]	Description of location[2] (fig. 1)	Reach (fig. 1)	Diversion amount (ft^3/s)[1]	Use[1]
		Lower Cibolo Creek		
[3]1146	Between site C4 and site C5	C4–C5	0.14	irrigation
1170	Martinez Creek watershed	headwaters to C6	0.02	irrigation
[3]3811	Martinez Creek watershed	headwaters to C6	0.21	irrigation
4031	Martinez Creek watershed	headwaters to C6	0.03	irrigation
4032	Martinez Creek watershed	headwaters to C6	0.03	irrigation
4191	Martinez Creek watershed	headwaters to C6	0.04	irrigation
[3]4195	Martinez Creek watershed	headwaters to C6	0.28	irrigation
4196	Martinez Creek watershed	headwaters to C6	0.11	irrigation
4197	Martinez Creek watershed	headwaters to C6	0.07	irrigation
5265	Martinez Creek watershed	headwaters to C6	0.05	irrigation
[3]5634	Martinez Creek watershed	headwaters to C6	1.10	irrigation and industrial
5917	Martinez Creek watershed	headwaters to C6	1.17	municipal
1148	Between site D7 and site C7	C5–C7	0.02	irrigation
1149	Between site D7 and site C7	C5–C7	0.09	irrigation
1150	Between site D7 and site C7	C5–C7	0.28	irrigation
1171	Between site D7 and site D8	C5–C7	0.99	irrigation
5182	Between site D7 and site C7	C5–C7	0.14	irrigation
5224	Between site D7 and site D8	C5–C7	0.08	irrigation
5693	Upstream from D6 on Santa Clara Creek	C5–C7	0.14	irrigation
1151	Between site C7 and site D9	C7–C8	0.12	irrigation and municipal
1152	Between site C7 and site D9	C7–C8	0.05	irrigation
1153	Between site C7 and site D9	C7–C8	0.14	irrigation
1154	Between site C7 and site D9	C7–C8	0.10	irrigation
1155	Between site C7 and site D9	C7–C8	0.06	irrigation and municipal
1156	Between site C7 and site D9	C7–C8	0.05	irrigation
1157	Between site C7 and site D9	C7–C8	0.16	irrigation and municipal
1158	Between site C7 and site D9	C7–C8	0.04	irrigation
1159	Between site C7 and site D9	C7–C8	0.06	irrigation
1160	Between site C7 and site D9	C7–C8	0.19	irrigation
1161	Between site D9 and site D10	C7–C8	0.02	irrigation
1162	Between site D9 and site D10	C7–C8	0.11	irrigation
1163	Between site D9 and site D10	C7–C8	0.11	irrigation
[3]1164	Between site D10 and site C8	C7–C8	0.01	irrigation
1165	Between site D10 and site C8	C7–C8	0.01	irrigation
1166	Between site D10 and site C8	C7–C8	0.03	irrigation
1167	Between site D10 and site C8	C7–C8	0.01	irrigation
3710	Between site D10 and site C8	C7–C8	0.11	irrigation
5218	Between site C7 and site D9	C7–C8	0.50	irrigation
5308	Between site D10 and site C8	C7–C8	0.14	irrigation

Table 4. Active surface-water rights (2010) with diversion amounts used for gain or loss estimates during 2006–10 in lower San Antonio River watershed, south-central Texas.—Continued

[ft^3/s, cubic feet per second]

Surface-water right number[1]	Description of location[2] (fig. 1)	Reach (fig. 1)	Diversion amount (ft^3/s)[1]	Use[1]
	Lower Cibolo Creek—Continued			
5559	Between site C7 and site D9	C7–C8	0.14	irrigation
5611	Between site D9 and site D10	C7–C8	0.24	irrigation
1168	Downstream from site C8 and upstream from the confluence with the San Antonio River	C3–C10	0.04	irrigation
3162	Downstream from site C8 and upstream from the confluence with the San Antonio River	C3–C10	0.08	irrigation
4240	Downstream from site C8 and upstream from the confluence with the San Antonio River	C3–C10	0.72	irrigation
[3]5635	Downstream from site C8 and upstream from the confluence with the San Antonio River	C3–C10	0.48	irrigation
	Lower San Antonio River			
[3]2163	Between site C1 and site C2	C1–C2	0.41	irrigation
[3]2164	Between site C1 and site C2	C1–C2	0.11	irrigation
[3]2165	Between site C1 and site C2	C1–C2	0.17	irrigation
[3]2166	Between site C1 and site C2	C1–C2	0.28	irrigation
2167	Between site C1 and site C2	C1–C2	0.02	irrigation
[3]2169	Between site C1 and site C2	C1–C2	0.06	irrigation
3553	Between site C1 and site C2	C1–C2	0.07	irrigation
3595	Between site C1 and site C2	C1–C2	0.07	irrigation
3613	Between site C1 and site C2	C1–C2	0.99	irrigation
3825	Between site C1 and site C2	C1–C2	0.05	irrigation
[3]3852	Between site C1 and site C2	C1–C2	0.29	irrigation
4190	Between site C1 and site C2	C1–C2	0.07	irrigation
5126	Between site C1 and site C2	C1–C2	0.21	irrigation
5194	Between site C1 and site C2	C1–C2	0.29	irrigation
5243	Between site C1 and site C2	C1–C2	0.07	irrigation
5264	Between site C1 and site C2	C1–C2	0.18	irrigation
5307	Between site C1 and site C2	C1–C2	0.41	irrigation
5727	Between site C1 and site C2	C1–C2	0.17	irrigation
[3]5395	Between site C2 and site D3	C2–C3	0.62	irrigation
5171	Between site C2 and site D3	C2–C3	0.28	irrigation
5320	Between site C2 and site D3	C2–C3	0.28	irrigation
5633	Between site C2 and site D3	C2–C3	0.18	irrigation
2173	Between site C2 and site D3	C2–C3	0.11	irrigation
2171	Between site C2 and site D3	C2–C3	0.09	irrigation
[3]2175	Between site C2 and site D3	C2–C3	0.14	irrigation
5499	Between site C2 and site D3	C2–C3	0.07	irrigation
2172	Between site C2 and site D3	C2–C3	0.02	irrigation
2174	Between site C2 and site D3	C2–C3	0.02	irrigation
3704	Between site D3 and site C3	C2–C3	1.46	irrigation

Table 4. Active surface-water rights (2010) with diversion amounts used for gain or loss estimates during 2006–10 in lower San Antonio River watershed, south-central Texas.—Continued

[ft^3/s, cubic feet per second]

Surface-water right number[1]	Description of location[2] (fig. 1)	Reach (fig. 1)	Diversion amount (ft^3/s)[1]	Use[1]
	Lower San Antonio River—Continued			
[3]2182	Between site D3 and site C3	C2–C3	1.20	irrigation
[3]2178	Between site D3 and site C3	C2–C3	1.03	irrigation
2180	Between site D3 and site C3	C2–C3	0.69	irrigation
2179	Between site D3 and site C3	C2–C3	0.66	irrigation
5587	Between site D3 and site C3	C2–C3	0.41	irrigation
3526	Between site D3 and site C3	C2–C3	0.32	irrigation
3568	Between site D3 and site C3	C2–C3	0.28	irrigation
[3]2181	Between site D3 and site C3	C2–C3	0.52	irrigation
[3]2176	Between site D3 and site C3	C2–C3	0.35	irrigation
4161	Between site D3 and site C3	C2–C3	0.12	irrigation
2177	Between site D3 and site C3	C2–C3	0.11	irrigation
5202	Between site D3 and site C3	C2–C3	0.10	irrigation
[3]2184	Between site D3 and site C3	C2–C3	0.28	irrigation
4174	Between site D3 and site C3	C2–C3	0.08	irrigation
2183	Between site D3 and site C3	C2–C3	0.14	irrigation
4176	Between site D3 and site D15	C2–C3	0.41	irrigation
[3]5333	Between site C3 and site D5	C3–C10	0.54	irrigation
[3]4224	Between site C3 and site D5	C3–C10	0.41	irrigation
5306	Between site C3 and site D5	C3–C10	0.28	irrigation
4230	Between site C3 and site D5	C3–C10	0.21	irrigation
5002	Between site C3 and site D5	C3–C10	0.21	irrigation
5062	Between site C3 and site D5	C3–C10	0.14	irrigation
5323	Between site C3 and site D5	C3–C10	0.14	irrigation
5751	Between site C3 and site D5	C3–C10	0.14	irrigation
2185	Between site C3 and site D5	C3–C10	0.12	irrigation
5296	Between site C3 and site D5	C3–C10	0.10	irrigation
2186	Between site C3 and site D5	C3–C10	0.10	irrigation
[3]3558	Between site C3 and site D5	C3–C10	0.10	irrigation
4072	Between site C3 and site D5	C3–C10	0.07	irrigation
[3]3557	Between site C3 and site D5	C3–C10	0.07	irrigation
2188	Between site C3 and site D5	C3–C10	0.06	irrigation
5239	Between site C3 and site D5	C3–C10	0.01	irrigation
5455	Between site C3 and site D5	C3–C10	0.00	irrigation
5532	Between site C3 and site D5	C3–C10	0.00	irrigation
2189	Between site D5 and site D11	C3–C10	0.48	irrigation
5367	Between site D5 and site D11	C3–C10	0.41	irrigation
5368	Between site D5 and site D11	C3–C10	0.41	irrigation
4175	Between site D11 and site D14	C3–C10	0.22	irrigation
5044	Between site D11 and site D14	C3–C10	0.21	irrigation

Table 4. Active surface-water rights (2010) with diversion amounts used for gain or loss estimates during 2006–10 in lower San Antonio River watershed, south-central Texas.—Continued

[ft^3/s, cubic feet per second]

Surface-water right number[1]	Description of location[2] (fig. 1)	Reach (fig. 1)	Diversion amount (ft^3/s)[1]	Use[1]
		Lower San Antonio River—Continued		
2190	Between site D11 and site D14	C3–C10	0.14	irrigation
3517	Between site D11 and site D14	C3–C10	0.11	irrigation
5622	Between site D14 and site D15	C3–C10	0.33	irrigation
5043	Between site D14 and site D15	C3–C10	0.21	irrigation
2192	Between site D14 and site D15	C3–C10	0.19	irrigation
2194	Between site D15 and site D16	C3–C10	1.41	irrigation
2195	Between site D15 and site D16	C3–C10	0.57	irrigation
2196	Between site D15 and site D16	C3–C10	0.46	irrigation
2193	Between site D15 and site D16	C3–C10	0.39	irrigation
5313	Between site D15 and site D16	C3–C10	0.14	irrigation
3820	Between site D16 and site C10	C3–C10	1.31	irrigation
2198	Between site D16 and site C10	C3–C10	0.46	irrigation
5220	Between site D16 and site C10	C3–C10	0.46	irrigation
2199	Between site D16 and site C10	C3–C10	0.45	irrigation
5478	Between site D16 and site C10	C3–C10	0.41	irrigation
5079	Between site D16 and site C10	C3–C10	0.16	irrigation
2197	Between site D16 and site C10	C3–C10	0.12	irrigation
5489	Between site C1 and site C2	downstream from C10	1.04	other

[1]Surface-water right numbers, diversion amounts, and use were obtained from the Texas Commission on Environmental Quality (2010).

[2]Location obtained from the Texas Commission on Environmental Quality (2011a).

[3]More than one diversion amount listed for the same surface-water-permit number. The diversion amounts were summed.

Table 5. Discrete streamflow measurements at 20 locations in the lower San Antonio River watershed, south-central Texas, 2006–7.

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; *italics* indicate that the station is on a tributary; FM, Farm Road; Hwy, Highway; nm, not measured]

Site identifier (fig. 1)	USGS streamflow-gaging station name	USGS station number	April 2006		
			Day	Time of measurement	Streamflow (ft^3/s)
	Lower Cibolo Creek watershed				
D6	*Santa Clara Creek near New Berlin, Tex.*	*08185080*	*18*	*8:00:00 a.m.*	*no flow*
D7	Cibolo Creek at FM 2538 near St. Hedwig, Tex.	08185085	18	10:44:00 a.m.	[1]7.64
D8	Cibolo Creek at FM 775 near La Vernia, Tex.	08185200	nm[2]	nm[2]	nm[2]
D9	Cibolo Creek at FM 537 near Stockdale, Tex.	08185800	18	1:36:30 p.m.	23.1
D10	Cibolo Creek at FM 541 near Poth, Tex.	08185900	18	1:56:00 p.m.	[1]21.4
	Lower San Antonio River watershed, not including Cibolo Creek watershed				
D1	*Kicaster Creek at U.S. Hwy 181 near Floresville, Tex.*	*08183100*	*18*	*8:10:00 a.m.*	*no flow*
D2	*Picosa Creek at State Hwy 97 near Floresville, Tex.*	*08183250*	*18*	*8:35:00 a.m.*	*no flow*
D3	San Antonio River at FM 541 near Poth, Tex.	08183300	18	10:13:30 a.m.	126
D4	*Marcelinas Creek at FM 887 near Falls City, Tex.*	*08183600*	*18*	*10:52:00 a.m.*	*no flow*
D5	San Antonio River at State Hwy 123 near Karnes City, Tex.	08183700	18	1:05:30 p.m.	124
D11	San Antonio River at State Hwy 80 near Helena, Tex.	08186100	18	2:22:30 p.m.	154
D12	*Ecleto Creek at FM 627 near Gillett, Tex.*	*08186450*	*18*	*8:30:00 a.m.*	*no flow*
D13	*Escondido Creek at County Road 331 near Kenedy, Tex.*	*08188050*	*18*	*6:17:30 p.m.*	*1.46*
D14	San Antonio River at State Highway 72 near Runge, Tex.	08188060	18	5:02:00 p.m.	162
D15	San Antonio River near Charco, Tex.	08188200	19	9:03:30 a.m.	155
D16	San Antonio River at Riverdale Road near Goliad, Tex.	08188300	19	9:39:30 a.m.	171
D17	*Cabeza Creek at State Highway 239 near Goliad, Tex.*	*08188325*	*19*	*8:35:00 a.m.*	*no flow*
D18	*Cabeza Creek at FM 2043 near Goliad, Tex.*	*08188350*	*19*	*9:06:00 a.m.*	*[1]0.15*
D19	*Manahuilla Creek at US Hwy 183 near Goliad, Tex.*	*08188525*	*19*	*10:15:30 a.m.*	*0.11*
D20	San Antonio River at FM 2506 near Fannin, Tex.	08188550	19	11:46:30 a.m.	190

[1]Based on site conditions, two measurements were made and averaged within the hour of the listed time of measurement.

[2]Not measured because of bridge construction.

[3]Time is estimated. Visually inspected as dry (Brian Petri, U.S. Geological Survey, oral commun., 2011).

[4]Time is estimated (Brian Petri, U.S. Geological Survey, oral commun., 2011).

Table 5. Discrete streamflow measurements at 20 locations in the lower San Antonio River watershed, south-central Texas, 2006–7.—Continued

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; *italics* indicate that the station is on a tributary; FM, Farm Road; Hwy, Highway; nm, not measured]

Site identifier (fig. 1)	August 2006			February 2007			October 2007		
	Day	Time of measurement	Streamflow (ft^3/s)	Day	Time of measurement	Streamflow (ft^3/s)	Day	Time of measurement	Streamflow (ft^3/s)
Lower Cibolo Creek watershed									
D6	*23*	*11:00:00 a.m.*	*no flow*	*13*	*1:00:00 p.m.*	*0.10*	*11*	*3:33:00 p.m.*	*0.50*
D7	23	1:26:30 p.m.	[1]2.16	13	2:10:10 p.m.	13.3	11	4:00:00 p.m.	31.9
D8	23	3:20:00 p.m.	7.78	13	5:00:00 p.m.	[1]27.5	9	2:50:00 p.m.	54.8
D9	23	5:52:30 p.m.	[1]12.5	14	10:23:00 a.m.	[1]35.4	9	5:05:00 p.m.	67.8
D10	23	3:38:00 p.m.	[1]14.6	14	11:43:00 a.m.	[1]38.2	9	5:40:30 p.m.	69.0
Lower San Antonio River watershed, not including Cibolo Creek watershed									
D1	*[3]23*	*8:00:00 a.m.[3]*	*no flow[3]*	*14*	*8:00:00 a.m.[3]*	*no flow[3]*	*9*	*11:37:30 a.m.*	*0.33*
D2	*[3]23*	*9:00:00 a.m.[3]*	*no flow[3]*	*14*	*9:00:00 a.m.[3]*	*no flow[3]*	*9*	*12:36:00 p.m.*	*no flow*
D3	23	1:50:00 p.m.	135	nm	nm	nm	9	1:08:30 p.m.	1,040
D4	*24*	*8:00:00 a.m.*	*no flow*	*nm*	*nm*	*no flow*	*9*	*7:44:00 p.m.*	*0.25*
D5	23	7:56:15 p.m.	[1]106	14	3:45:00 p.m.	264	9	4:21:00 p.m.	1,080
D11	23	7:47:30 p.m.	136	nm	nm	nm	9	6:37:30 p.m.	1,240
D12	*nm*	*nm*	*no flow*	*nm*	*nm*	*no flow*	*9*	*6:45:00 p.m.*	*no flow*
D13	*24*	*8:23:45 a.m.*	*[1]2.05*	*14*	*5:59:00 p.m.*	*[1]2.54*	*10*	*8:57:30 a.m.*	*3.54*
D14	24	8:44:30 a.m.	125	nm	nm	nm	10	8:41:30 a.m.	1,190
D15	24	10:08:30 a.m.	[1]131	nm	nm	nm	10	9:50:00 a.m.	1,220
D16	24	10:22:30 a.m.	135	15	1:38:00 p.m.	336	10	11:56:00 a.m.	1,210
D17	*24*	*11:03:00 a.m.*	*no flow*	*15*	*12:50:00 p.m.*	*0.000*	*10*	*9:54:30 a.m.*	*2.96*
D18	*24*	*11:30:00 a.m.[4]*	*0.05*	*15*	*12:31:00 p.m.*	*0.10*	*10*	*10:45:00 a.m.*	*4.48*
D19	*24*	*11:30:00 a.m.*	*0.10*	*nm*	*nm*	*nm*	*10*	*1:20:00 p.m.*	*3.50*
D20	24	12:31:00 p.m.	145	15	11:00:00 a.m.	315	10	2:41:30 p.m.	1,320

Table 6. Average daily discharge of treated wastewater, in cubic feet per second, during synoptic streamflow measurement surveys, lower San Antonio River watershed, south Texas, 2006–10.

[--, not available]

Facility identifier (fig. 4)	Facility name (table 2)	4/18/2006	4/19/2006	8/23/2006	8/24/2006	2/13/2007	2/14/2007	2/15/2007	10/9/2007	10/10/2007	10/11/2007
WW1	City of Floresville[1]	0.853	0.853	0.890	0.889	0.878	0.879	0.876	0.933	0.933	0.93
WW2	Cibolo Creek Municipal Authority[2]	3.54	6.16	4.35	5.09	6.41	6.33	6.24	5.17	6.42	6.56
WW3	City of Marion[3]	0.036	0.036	0.048	0.048	0.046	0.063	0.063	0.067	0.056	0.051
WW4	Salitrillo[4]	4.82	5.13	4.71	4.67	5.56	5.45	3.17	5.49	5.46	5.38
WW5	Upper Martinez I[4]	2.30	2.15	2.21	2.09	2.42	2.49	2.21	2.70	2.59	2.52
WW6	Martinez II[4]	1.84	1.89	1.80	1.94	1.92	1.73	2.11	1.85	1.67	1.72
WW7	City of La Vernia[4]	0.125	0.129	0.133	0.139	0.148	0.125	0.146	0.156	0.154	0.16
WW8	City of Stockdale[5]	0.152	0.152	0.152	0.152	0.183	0.152	0.152	0.152	0.141	0.152
WW9	City of Falls City[6]	no flow	no flow	no flow	no flow	no flow	no flow	no flow	no flow	no flow	no flow
WW10	Karnes City - Milam[7]	--	--	--	--	--	--	--	--	--	--
WW11	Karnes City - Main Street[7]	--	--	--	--	--	--	--	--	--	--
WW12	City of Kenedy[8]	1.51	1.47	1.66	1.68	1.57	1.40	1.45	1.80	1.71	1.72
WW13	City of Goliad[9]	0.232	0.211	0.236	0.232	0.341	0.402	0.378	0.513	0.461	0.487

[1]Sherry Pollock, City of Floresville, written commun., March 13, 2012.

[2]Christine Budnik, Cibolo Creek Municipal Authority, written commun., March 9, 2012.

[3]Randy Schwenn, City of Marion, written commun., March 19, 2012.

[4]Melissa Bryant, San Antonio River Authority, written commun., March 14, 2012.

[5]David Tillery, City of Stockdale, written commun., March 15, 2012.

[6]Lauren Sturm, City of Falls City, written commun., March 12, 2012.

[7]Information unavailable, Scott Barrientez, City of Karnes City, oral commun., April 4, 2012.

[8]Raymond Borroum, Veolia Water North America, written commun., March 16, 2012.

[9]Cindy Shilinga, City of Goliad, written commun., March 15, 2012.

Table 7. Streamflow statistics for A, the period of record, and B, 2006–10, at U.S. Geological Survey streamflow-gaging stations in the lower San Antonio River, south-central Texas.

[USGS, U.S. Geological Survey; mi^2, square miles; ft^3/s, cubic feet per second]

A. Statistics for available period of record

Station name	Site number (fig. 1)	Period of analysis	Drainage area (mi^2)	Average daily streamflow (ft^3/s)	80-percent exceedance streamflow (ft^3/s)	50-percent exceedance streamflow (ft^3/s)	20-percent exceedance streamflow (ft^3/s)	10-percent exceedance streamflow (ft^3/s)
San Antonio River near Elmendorf, Tex.	C1	10/1962–12/2010	1,743	599	189	325	631	1,040
San Antonio River near Floresville, Tex.	C2	01/2006–12/2010	1,964	639	170	292	613	1,080
San Antonio River near Falls City, Tex.	C3	05/1925–12/2010	2,113	498	131	263	532	901
Cibolo Creek at Selma, Tex.	C4	04/1946–12/2010	274	26.7	no flow	no flow	no flow	no flow
Cibolo Creek near St. Hedwig, Tex.	C5	12/2005–12/2010	306	34.4	5.51	11.1	25.5	34.0
Martinez Creek near St. Hedwig, Tex.	C6	11/2005–12/2010	81.1	39.7	7.32	9.85	24.4	56.3
Cibolo Creek at Sutherland Springs, Tex.	C7	07/1924–12/2010	665	96.6	12.0	20.5	53.3	87.0
Cibolo Creek near Falls City, Tex.	C8	10/1930–12/2010	877	143	14.7	29.0	70.0	145
Ecleto Creek near Runge, Tex.	C9	04/1962–12/2010	239	36.9	no flow	.480	6.00	21.4
San Antonio River at Goliad, Tex.	C10	07/1924–12/2010	3,921	784	182	356	769	1,340
San Antonio River near McFaddin, Tex.	C11	11/2005–12/2010	4,134	941	250	445	945	1,700

B. Statistics for 01/2006–12/2010

Station name	Site number (fig. 1)	Period of analysis	Drainage area (mi^2)	Average daily streamflow (ft^3/s)	80-percent exceedance streamflow (ft^3/s)	50-percent exceedance streamflow (ft^3/s)	20-percent exceedance streamflow (ft^3/s)	10-percent exceedance streamflow (ft^3/s)
San Antonio River near Elmendorf, Tex.	C1	01/01/2006–12/31/2010	1,743	599	164	302	635	1,030
San Antonio River near Floresville, Tex.	C2	01/04/2006–12/31/2010	1,964	639	170	292	613	1,080
San Antonio River near Falls City, Tex.	C3	01/01/2006–12//312010	2,113	591	184	305	658	1,090
Cibolo Creek at Selma, Tex.	C4	01/01/2006–12/31/2010	274	23.1	no flow	no flow	no flow	no flow
Cibolo Creek near St. Hedwig, Tex.	C5	01/01/2006–12/31/2010	306	34.4	5.51	11.1	25.5	34.0
Martinez Creek near St. Hedwig, Tex.	C6	01/01/2006–12/31/2010	81.1	39.7	7.32	9.85	24.4	56.3
Cibolo Creek at Sutherland Springs, Tex.	C7	01/01/2006–12/31/2010	665	130	22.4	35.6	71.0	150
Cibolo Creek near Falls City, Tex.	C8	01/01/2006–12/31/2010	877	158	26.4	48.0	95.4	191
Ecleto Creek near Runge, Tex.	C9	01/01/2006–12/31/2010	239	34.4	.043	.573	7.94	23.6
San Antonio River at Goliad, Tex.	C10	01/01/2006–12/31/2010	3,921	879	256	424	931	1,490
San Antonio River near McFaddin, Tex.	C11	01/01/2006–12/31/2010	4,134	941	250	445	945	1,700

Table 8. Estimation of streamflow gain or loss during 2006–10 using continuous streamflow-gaging stations in the lower San Antonio River watershed, south-central Texas.

[mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; $ft^3/s/mi^2$; cubic feet per second per square mile; --, not applicable]

Reach	Stream length (mi)	Contributing drainage area to reach (mi^2)	Average daily streamflow at reach inlet (ft^3/s)	Average daily streamflow of measured tributary inflows (ft^3/s)	Permitted return flows[1] (ft^3/s)	Permitted diversions[2] (ft^3/s)	Average streamflow at reach outlet (ft^3/s)	Estimated streamflow gain (+) or loss (-) (ft^3/s)
San Antonio River—Elmendorf to Floresville (site C1 to C2, fig. 1)	27.9	221	599	no flow	1.1	3.9	639	43
San Antonio River—Floresville to Falls City (site C2 to C3, fig. 1)	25.3	149	639	no flow	no flow	10	591	-38
Cibolo Creek—Selma to St Hedwig (site C4 to C5, fig. 1)	16.7	32.0	23.1	no flow	9.9	0.14	34.4	1.5
Martinez Creek (headwaters to site C6)	--	81.1	no flow	no flow	13	3.1	39.7	30
Cibolo Creek—St Hedwig to Sutherland Springs (site C5 to C7, fig. 1)	33.7	359 (81.1 gaged)[3]	34.4	[3]39.7	0.17	1.7	130	57
Cibolo Creek—Sutherland Springs to Falls City (site C7 to C8, fig. 1)	27.1	212	130	no flow	0.46	2.4	158	30
Ecleto Creek (headwaters to site C9)	--	239	no flow	no flow	no flow	no flow	34.4	34
San Antonio River—Falls City to Goliad (site C3 to C10, fig. 1)	85.2	1,808 (1,066 gaged)[4]	591	[4]192	27	19	879	88
San Antonio River—Goliad to McFaddin (site C10 to C11, fig. 1)	54.2	213	879	no flow	no flow	no flow	941	62

[1]Permitted discharge amounts and locations from U.S. Environmental Protection Agency (2010).

[2]Surface-water right diversion amounts and locations from Texas Commision on Environmental Quality (2010; 2011a).

[3]Measured inflows are gaged at Martinez Creek near Saint Hedwig, Tex.

[4]Measured inflows are gaged at Ecleto Creek near Runge, Texas, and Cibolo Creek near Falls City, Tex.

Table 9. Estimated streamflow gains and losses for the main stem of the lower San Antonio River, south-central Texas, 2006–7.

[**Bold** font indicates gain or loss greater than the potential measurement error and discrete measurements outside the range of the hourly continuous measurements at the upstream station; mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; na, not available; --, not applicable]

Reach (fig. 2)	Site identifier (fig. 1, table 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow[2] (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[3] (ft^3/s)	Potential measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
April 18–19, 2006							
	C1	103	84.4 to 121			15.5	
1				no flow	0.85	25.4	20.1
	C2	124	112 to 136			9.92	
2				no flow	no flow	20.0	2.00
	D3	126	--			10.1	
3				no flow	no flow	23.6	9.00
	C3	135	123 to 145			13.5	
4				no flow	no flow	23.4	-11.0
	D5	124	--			9.92	
5				22	no flow	22.2	7.96
	D11	154	--			12.3	
6				1.5	no flow	25.3	6.50
	D14	162	--			13.0	
7				no flow	no flow	25.4	-7.00
	D15	155	--			12.4	
8				no flow	no flow	26.1	16.0
	D16	171	--			13.7	
9				0.15	0.22	26.4	-12.4
	C10	159	153 to 165			12.7	
10				0.11	no flow	27.9	**30.9**
	D20	190	--			15.2	
11				no flow	no flow	31.3	11.0
	C11	201	194 to 203			16.1	
August 23–24, 2006							
	C1	109	86.7 to 127			16.4	
1				no flow	0.89	27.7	3.11
	C2	113	95.7 to 126			11.3	
2				no flow	no flow	22.1	22.0
	D3	135	--			10.8	
3				no flow	no flow	21.1	**-32.0**
	C3	103	95.0 to 111			10.3	
4				no flow	no flow	18.8	3.00
	D5	106	--			8.48	
5				12	no flow	21.2	18.1
	D11	136	--			10.9	
6				2.1	no flow	20.9	-13.1
	D14	125	--			10.0	
7				no flow	no flow	20.5	6.00
	D15	131	--			10.5	
8				no flow	no flow	21.3	4.00

Table 9. Estimated streamflow gains and losses for the main stem of the lower San Antonio River, south-central Texas, 2006–7.—Continued

[**Bold** font indicates gain or loss greater than the potential measurement error and discrete measurements outside the range of the hourly continuous measurements at the upstream station; mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; na, not available; --, not applicable]

Reach (fig. 2)	Site identifier (fig. 1, table 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow[2] (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[3] (ft^3/s)	Potential measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
			August 23–24, 2006—Continued				
	D16	135	--			10.8	
9				0.05	0.23	22.1	5.77
	C10	141	135 to 147			11.3	
10				0.10	no flow	22.9	3.90
	D20	145	--			11.6	
11				no flow	no flow	24.8	20.0
	C11	165	163 to 167			13.2	
			February 13–15, 2007				
	C1	221	185 to 244			33.2	
1				no flow	0.88	58.7	33.1
	C2	255	235 to 275			25.5	
2				no flow	no flow	--	--
	D3	na	--			--	--
3				no flow	no flow	--	--
	C3	258	244 to 271			38.7	
4				no flow	no flow	59.8	6.00
	D5	264	--			21.1	
5				38	no flow	--	--
	D11	na	--			--	--
6				3.5	no flow	--	--
	D14	na	--			--	--
7				no flow	no flow	--	--
	D15	na	--			--	--
8				no flow	no flow	--	--
	D16	336	--			26.9	
9				0.10	0.37	53.9	1.53
	C10	338	329 to 351			27.0	
10				no flow	no flow	52.2	-23.0
	D20	315	--			25.2	
11				no flow	no flow	55.3	**61.0**
	C11	376	366 to 387			30.1	
			October 9–11, 2007				
	C1	1,010	933 to 1,140			80.8	
1				0.33	0.93	132	8.74
	C2	1,020	975 to 1,090			51.0	
2				no flow	no flow	134	20.0
	D3	1,040	--			83.2	
3				no flow	no flow	137	30.0
	C3	1,070	1,020 to 1,130			53.5	
4				0.25	no flow	140	9.75

Table 9. Estimated streamflow gains and losses for the main stem of the lower San Antonio River, south-central Texas, 2006–7.—Continued

[**Bold** font indicates gain or loss greater than the potential measurement error and discrete measurements outside the range of the hourly continuous measurements at the upstream station; mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; na, not available; --, not applicable]

Reach (fig. 2)	Site identifier (fig. 1, table 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow[2] (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[3] (ft^3/s)	Potential measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
October 9–11, 2007—Continued							
	D5	1,080	--			86.4	
5				70	no flow	186	90.3
	D11	1,240	--			99.2	
6				6.9	no flow	194	-56.9
	D14	1,190	--			95.2	
7				no flow	no flow	193	30.0
	D15	1,220	--			97.6	
8				no flow	no flow	194	-10.0
	D16	1,210	--			96.8	
9				4.5	0.49	222	35.0
	C10	1,250	1,230 to 1,280			125	
10				3.5	no flow	231	66.5
	D20	1,320	--			106	
11				no flow	no flow	222	140
	C11	1,460	1,450 to 1,490			117	

[1]Streamflow at continuous record streamflow-gaging stations computed as the average of the daily values over the synoptic periodor the result of the flow measurement at the discrete measurement locations (table 1).

[2]Ranges of hourly streamflows measured at the U.S. Geological Survey continuous streamflow-measurement stations (table 1).

[3]Wastewater discharges computed as the average of the daily values over the synoptic period.

Table 10. Estimated streamflow gains on the main stem of the lower San Antonio River, from Elemendorf, Texas, to Goliad, Tex., and from Goliad Tex., to McFaddin, Tex., south-central Texas, 2006–7.

[**Bold** font indicates gain or loss greater than the potential measurement error; mi, miles; mi^2, square miles; ft^3/s,cubic feet per second; nm, not measured]

Site identifier (fig. 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[2] (ft^3/s)	Potential measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
			April 18–19, 2006			
C1	103	84.4 to 121			15.5	
			23.7	16.8	28.2	15.5
C10	159	153 to 165			12.7	
			0.110	no flow	28.8	**41.9**
C11	201	194 to 203			16.1	
			August 23–24, 2006			
C1	109	86.7 to 127			16.4	
			14.0	16.6	27.6	1.43
C10	141	135 to 147			11.3	
			0.100	no flow	24.5	23.9
C11	165	163 to 167			13.2	
			February 13–15, 2007			
C1	221	185 to 244			33.2	
			41.1	18.4	60.2	57.4
C10	338	329 to 351			27.0	
			no flow	no flow	57.1	38.0
C11	376	366 to 387			30.1	
			October 9–11, 2007			
C1	1,010	933 to 1,140			80.8	
			81.7	19.4	206	139
C10	1,250	1,230 to 1,280			125	
			3.50	no flow	242	207
C11	1,460	1,450 to 1,490			117	

[1]Streamflow at continuous record streamflow-gaging stations computed as the average of the daily values over the synoptic period.

[2]Wastewater discharges computed as the average of the daily values over the synoptic period.

Table 11. Estimated streamflow gains and losses on the main stem of lower Cibolo Creek, Texas, 2006–7.

[**Bold** font indicates gain or loss greater than the potential measurement error and discrete measurements outside the range of the hourly continuous measurements at the upstream station; mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; nm, not measured; --, not applicable]

Reach (fig. 2)	Site identifier (table 1, fig. 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow[2] (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[3] (ft^3/s)	Measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
April 18–19, 2006							
	C4	no flow	no flow			no flow	
1				no flow	4.8	0.58	**2.3**
	C5	7.19	5.85 to 7.75			0.58	
2				no flow	no flow	1.2	**0.41**
	D7	7.60	--			0.61	
3				7.0	0.13	--	--
	D8	nm	--			--	
4				no flow	no flow	1.6	[4]**6.0**
	C7	20.8	20.2 to 21.3			1.0	
5				no flow	0.15	2.9	2.2
	D9	23.1	--			1.8	
6				no flow	no flow	3.6	-1.7
	D10	21.4	--			1.7	
7				no flow	no flow	3.5	0.64
	C8	22.0	20.8 to 22.6			1.8	
August 23–24, 2006							
	C4	no flow	no flow			no flow	
1				no flow	4.7	0.22	**-2.0**
	C5	2.75	2.37 to 3.10			0.22	
2				no flow	no flow	0.40	**-0.55**
	D7	2.20	--			0.18	
3				4.9	0.14	0.80	0.56
	D8	7.80	--			0.62	
4				no flow	no flow	1.6	**4.8**
	C7	12.6	11.8 to 19.2			1.0	
5				no flow	0.15	2.0	-0.26
	D9	12.5	--			1.0	
6				no flow	no flow	2.2	2.1
	D10	14.6	--			1.2	
7				no flow	no flow	2.1	**-2.7**
	C8	11.9	10.4 to 13.6			0.95	
February 13–15, 2007							
	C4	no flow	no flow			no flow	
1				no flow	6.3	0.89	**4.8**
	C5	11.1	9.76 to 12.6			0.89	
2				0.10	no flow	2.0	**2.1**
	D7	13.3	--			1.1	
3				9.11	0.14	3.3	**4.9**
	D8	27.5	--			2.2	
4				no flow	no flow	5.1	**9.0**

Table 11. Estimated streamflow gains and losses on the main stem of lower Cibolo Creek, Texas, 2006–7.—Continued

[**Bold** font indicates gain or loss greater than the potential measurement error and discrete measurements outside the range of the hourly continuous measurements at the upstream station; mi, miles; mi^2, square miles; ft^3/s, cubic feet per second; nm, not measured; --, not applicable]

Reach (fig. 2)	Site identifier (table 1, fig. 1)	Streamflow[1] (ft^3/s)	Range of hourly streamflow[2] (ft^3/s)	Average streamflow of measured tributary inflows (ft^3/s)	Return flows[3] (ft^3/s)	Measurement error (ft^3/s)	Estimated streamflow gain (+) or loss (-)
			February 13–15, 2007—Continued				
	C7	36.5	34.5 to 38.0			2.9	
5				no flow	0.17	5.8	-1.3
	D9	35.4	--			2.8	
6				no flow	no flow	5.9	2.8
	D10	38.2	--			3.1	
7				no flow	no flow	6.1	-0.64
	C8	37.6	35.6 to 39.1			3.0	
			October 9–11, 2007				
	C4	no flow	no flow			no flow	
1				no flow	6.0	2.0	**20**
	C5	25.6	24.7 to 26.3			2.0	
2				0.50	no flow	3.6	**6.3**
	D7	31.9	--			1.6	
3				14	0.16	4.3	**8.8**
	D8	54.8	--			2.7	
4				no flow	no flow	8.3	**14**
	C7	68.9	62.5 to 78.3			5.5	
5				no flow	0.15	8.9	-1.2
	D9	67.8	--			3.4	
6				no flow	no flow	6.8	1.2
	D10	69.0	--			3.5	
7				no flow	no flow	10	0.69
	C8	69.7	65.4 to 73.5			7.0	

[1]Streamflow at continuous record streamflow-gaging stations computed as the average of the daily values over the synoptic period or the result of the flow measurement at the discrete measurement locations (table 1).

[2]Ranges of hourly streamflows measured at the U.S. Geological Survey continuous streamflow-measurement stations (table1).

[3]Wastewater discharges computed as the average of the daily values over the synoptic period.

[4]Results compiled for reaches 3 and 4, D7 to C7.

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