science for a changing world

In cooperation with the U.S. Army Corps of Engineers, Fort Worth District

Rainfall and Evapotranspiration Data for Southwest Medina County, Texas, August 2006–December 2009

Data Series 554

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

Front cover:

Top right, U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D’Hanis, Texas, July 6, 2007.

Bottom right, Study area viewing southwest from the tower at U.S. Geological Survey meteorological station 298010099212100 in southwest Medina County near D’Hanis, Texas, February 19, 2010.

Top left, CSAT3 and CS–7500 instruments on tower at U.S. Geological Survey meteorological station 298010099212100 in southwest Medina County near D’Hanis, Texas, August 17, 2006.

Bottom left, Study area viewing southwest from the tower at U.S. Geological Survey meteorological station 298010099212100 in southwest Medina County near D’Hanis, Texas, July 6, 2007.

Rainfall and Evapotranspiration Data for Southwest Medina County, Texas, August 2006–December 2009

By Richard N. Slattery, William H. Asquith, and Darwin J. Ockerman

In cooperation with the U.S. Army Corps of Engineers, Fort Worth District

Data Series 554

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011

This and other USGS information products are available at http://store.usgs.gov/
U.S. Geological Survey
Box 25286, Denver Federal Center
Denver, CO 80225

To learn about the USGS and its information products visit http://www.usgs.gov/
1-888-ASK-USGS

Suggested citation:
Slattery, R.N., Asquith, W.H., and Ockerman, D.J., 2011, Rainfall and evapotranspiration data for southwest Medina County, Texas, August 2006–December 2009: U.S. Geological Survey Data Series 554, 28 p. (Appendix available online at http://pubs.usgs.gov/ds/554/.)

Acknowledgments

The authors thank Mrs. Charissa Ann Wells and Dr. John Calhoun Wells for allowing installation of the southwest Medina meteorological station on their ranch and for providing ongoing access to the site for operation and maintenance of the equipment.

Blank Page

Contents

Figures

Tables

Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
	Flow rate	
inch per hour (in/h)	.0254	meter per hour (m/h)
	Energy	
watt	1	joules per second (J/s)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
	Pressure	
kilopascal (kPa)	0.1450	pound per square inch (lb/ft^2)
	Density	
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot (lb/ft^3)
	Energy	
joule (J)	0.0000002	kilowatthour (kWh)

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

$$°F=(1.8\times°C)+3$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Rainfall and Evapotranspiration Data for Southwest Medina County, Texas, August 2006–December 2009

By Richard N. Slattery, William H. Asquith, and Darwin J. Ockerman

Abstract

During August 2006–December 2009, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, Fort Worth District, collected rainfall and evapotranspiration data to help characterize the hydrology of the Nueces River Basin, Texas. The USGS installed and operated a station to collect continuous (30-minute interval) rainfall and evapotranspiration data in southwest Medina County approximately 14 miles southwest of D’Hanis, Texas, and 23 miles northwest of Pearsall, Texas. Rainfall data were collected by using an 8-inch tipping bucket raingage. Meteorological and surface-energy flux data used to calculate evapotranspiration were collected by using an extended Open Path Eddy Covariance system from Campbell Scientific, Inc. Data recorded by the system were used to calculate evapotranspiration by using the eddy covariance and Bowen ratio closure methods and to analyze the surface energy budget closure.

During August 2006–December 2009 (excluding days of missing record), measured rainfall totaled 86.85 inches. In 2007, 2008, and 2009, annual rainfall totaled 40.98, 12.35, and 27.15 inches, respectively. The largest monthly rainfall total, 12.30 inches, occurred in July 2007. During August 2006–December 2009, evapotranspiration calculated by using the eddy covariance method totaled 69.91 inches. Annual evapotranspiration calculated by using the eddy covariance method totaled 34.62 inches in 2007, 15.24 inches in 2008, and 15.57 inches in 2009. During August 2006–December 2009, evapotranspiration calculated by using the Bowen ratio closure method (the more refined of the two datasets) totaled 68.33 inches. Annual evapotranspiration calculated by using the Bowen ratio closure method totaled 32.49, 15.54, and 15.80 inches in 2007, 2008, and 2009, respectively (excluding days of missing record).

Introduction

During August 2006–December 2009, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, Fort Worth District, collected rainfall and evapotranspiration data to help characterize the hydrology of the Nueces River Basin, Texas (U.S. Army Corps of Engineers, 2009). The USGS installed and operated a meteorological station to collect rainfall and evapotranspiration data in southwest Medina County on a privately owned ranch on the Carrizo-Wilcox aquifer outcrop (fig. 1). Quantifying rainfall is important because rainfall provides most of the freshwater in the hydrologic cycle; quantifying evapotranspiration, the coupled processes of evaporation and transpiration, is equally important because evapotranspiration is a dominant part of the hydrologic cycle (Water Encyclopedia, 2010).

Purpose and Scope

The purpose of this report is to document rainfall and evapotranspiration (ET) data collected at USGS meteorological station 290810099212100 in southwest Medina County near D’Hanis, Tex. (hereinafter, the SW Medina County meteorological station), during August 2006–December 2009. Methods of calculating ET by the eddy covariance and Bowen ratio closure methods are described, as well as methods of evaluating the eddy covariance data and analyzing the surface energy budget. Tables of daily rainfall and ET (with monthly and annual totals and summary statistics) during August 2006–December 2009 are provided, and hourly values of rainfall and ET are included as appendixes 1.1–1.4.

Description of Study Area

The SW Medina County meteorological station is approximately 14 miles (mi) southwest of D’Hanis, Tex., and 23 mi northwest of Pearsall, Tex., and near the intersection of the Frio, Medina, Uvalde, and Zavala County lines (fig. 1). The climate of the study area is transitional between subtropical subhumid to the east, characterized by hot summers and dry winters, and subtropical steppe to the west, characterized by arid to semiarid conditions throughout the year (Larkin and Bomar, 1983). Annual rainfall measured at the National Weather Service meteorological station 416879 in Pearsall, Tex. (fig. 1), from 1971 through 2000, averages about 26 inches (in.) per year but varies greatly, ranging from 15 to 39 in. per year (National Oceanic and Atmospheric Administration, 2004).

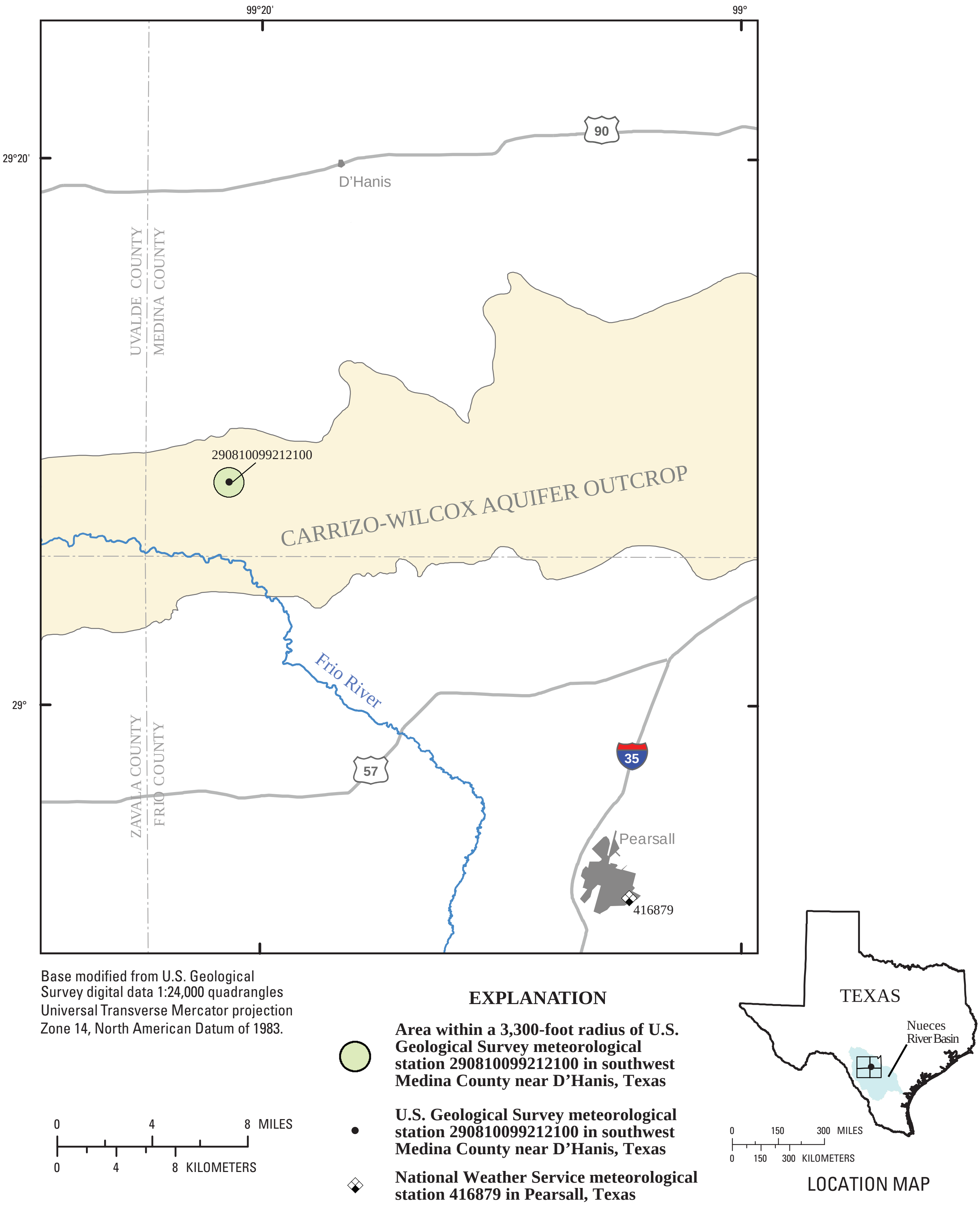


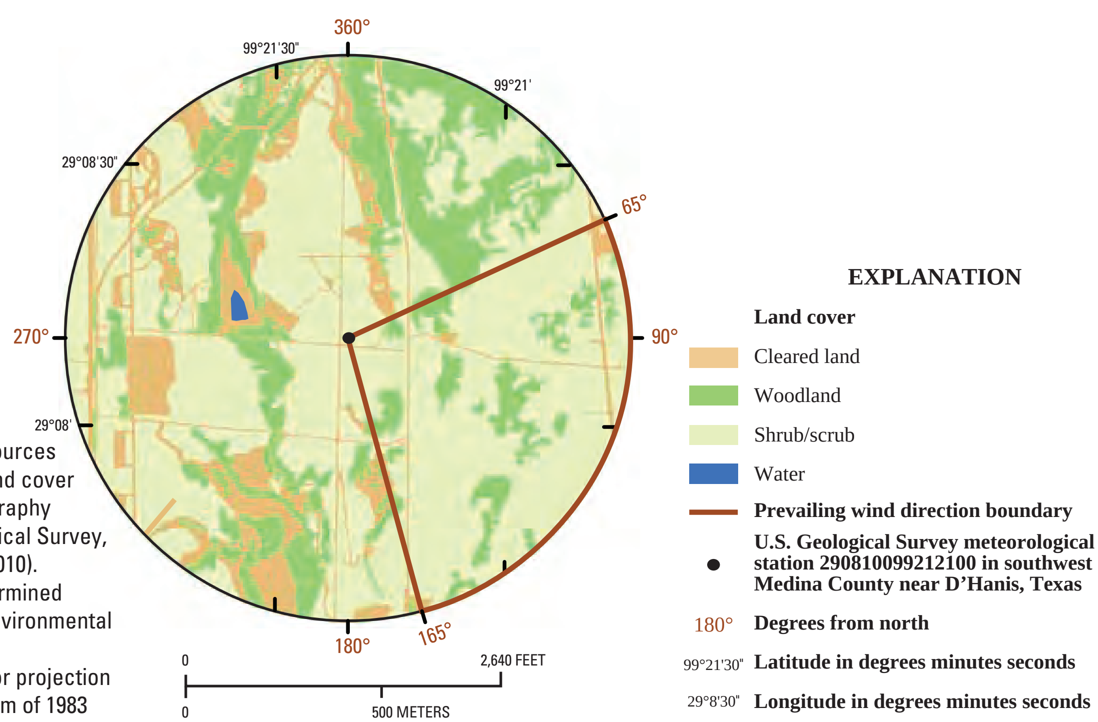
Figure 1. Location of U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, and National Weather Service meteorological station 416879 in Pearsall, Texas.

The area around the site that influences the measured ET is described by the fetch and footprint of the site. The fetch describes the land features within a distance upwind from the measurement site that influence airflow patterns and affect the quality of the measured data. These features might be natural or humanmade and include vegetation, terrain, and buildings. The footprint, coinciding with the area of fetch, describes the area upwind of the measurement site that influences the measured fluxes and includes ground cover, vegetation types, and open bodies of water. The footprint of the site can affect the representative quality of the measured data relative to the larger area (Burba and Anderson, 2006).

The fetch for the site can be estimated on the basis of the general assumption that the local surface layer increases at a rate of 1 vertical unit per 100 horizontal units (Burba and Anderson, 2006). Therefore, measurements of ET made by the instruments placed at a height of 33 feet (ft) might be influenced by features within an area 3,300 ft upwind of the site. The height to distance ratio could be as large as 1:500 (representing an area about 16,500 ft upwind of the site) during both calm wind and stable conditions that often occur at night (Burba and Anderson, 2006).

Within a 3,300-ft radius of the SW Medina County meteorological station, the terrain is gently sloping (1–3 percent). From north to south, elevations range from about 780 to 720 ft above the North American Vertical Datum of 1988 (NAVD 88), respectively, and from west to east, elevations range from about 750 to 780 ft above NAVD 88, respectively. Shrubs approximately 3–10 ft tall compose most of the vegetation, with some scattered mesquite (*Prosopis glandulosa*) trees growing up to 25 ft tall. Shrubs include blackbrush (*Acacia rigidula*), guajillo (*Acacia berlandieri*), and senisa (*Leucophyllum frutescens*), and trees are predominantly mesquite (Griffith and others, 2004; U.S. Department of Agriculture, Natural Resources Conservation Service, 2010; Phillip N. Wright, U.S. Department of Agriculture, Natural Resources Conservation Service, written commun., 2006) (figs. 2, 3). Soils in the footprint of the site are mostly weakly consolidated, noncalcareous sandstone and sandy loams with moderate permeability and water capacity; small areas of fine sandy and clay loam soils of low permeability and water capacity are also found near the site (Dittmar and others, 1977; U.S. Department of Agriculture Natural Resources Conservation Service, 2010). A small lake with a surface area of about 2 acres when it is full is about 1,200 ft west of the site; the lake likely had minimal effect on flux measurements made at the site because winds from the direction of the lake occurred less than 2 percent of the time, and the lake was observed to be empty or near empty during the study. Between 3,300 and 16,500 ft in all directions from the site, the terrain and vegetation are also similar with the exception of the riparian vegetation along the banks of the Frio River, which is closest at about 14,000 ft south of the site.

Through standard azimuth definitions of north as 0 or 360 degrees and south as 180 degrees (Federal Geographic Data Committee, 2010), the prevailing wind direction was



Base from Texas Natural Resources Information System (2010). Land cover interpreted from aerial photography (Robert R. Morris, U.S. Geological Survey, volunteer, written commun., 2010). Prevailing wind direction determined with Wind Rose Plot (Lakes Environmental [2010] Software 1998–2008). Universal Transverse Mercator projection Zone 14, North American Datum of 1983

Figure 2. Land cover and prevailing wind direction for the area within a 3,300-foot radius of U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

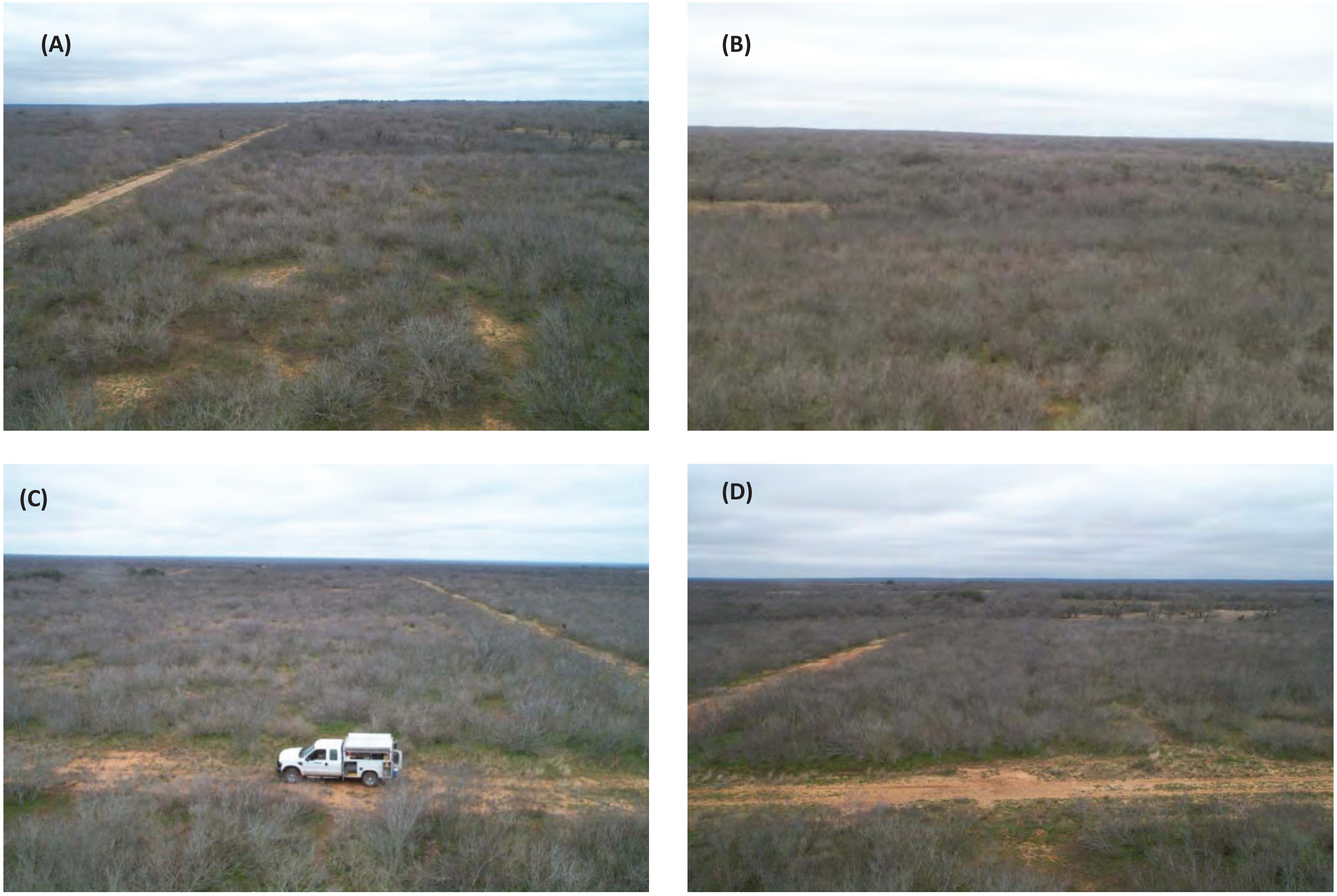


Figure 3. Study area as viewed from the tower, (A) north, (B) east, (C) south, (D) west, at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, on February 19, 2010.

found to be from 65 to 165 degrees from north (fig. 2); between 7 a.m. and 7 p.m., when surface-energy fluxes are generally largest, winds from 65 to 165 degrees from north (that is, from an east-northeast to south-southeast direction) occur about 61 percent of the time. The prevailing wind direction was determined by using WRPLOT View version 5.9 (Lakes Environmental, 2010) from wind directions measured between 7 a.m. and 7 p.m. for the entire period of record. Given the uniform characteristics of the terrain and vegetation within 3,300 ft of the site in all directions, the fetch and footprint of the site are conducive to making reliable ET measurements. Land cover for the area within 3,300 ft of the SW Medina County meteorological station, the area for which the measured ET and prevailing wind direction are representative, is shown in figure 2.

Methods

Rainfall, meteorological, and surface-energy flux data were recorded at 30-minute intervals and transmitted hourly to the USGS National Water Information System (NWIS) database by way of a Geostationary Operational Environmental Satellite (GOES) satellite. ET was calculated from the surface-energy flux data retrieved from NWIS; the rainfall and ET data are stored in NWIS (U.S. Geological Survey, 2010).

Rainfall Measurements

Rainfall was measured with a NovaLynx 8-in. tipping bucket raingage mounted 6 ft above the land surface (NovaLynx Corporation, 2009) (fig. 4). Measurements made by the raingage can be affected by environmental conditions, which can cause recorded rainfall values to differ from the actual rainfall amounts. These conditions can include high winds, which can result in the undercatch of rainfall (Duchon and Essenberg, 2001). During low-intensity rainfall, the measurement accuracy might be affected by losses to evaporation, and during high-intensity rainfall, the accuracy might be affected by the ability of the instrument to register rainfall at the rate of input (Legates and Deliberty, 1993; Duchon and Essenberg, 2001). Raindrop splash can add to or subtract from the amount of measured rainfall, depending on whether

Figure 4. Raingage during a calibration check at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, February 19, 2010.

raindrops splash in or out of the gage (Gold, 1931; Ashmore, 1934; Golubev, 1985), as can errors associated with the shape and diameter of the gage orifice (Gordon, 2003).

Evapotranspiration Measurements

The Process of Evapotranspiration

ET refers to the combined processes of evaporation and transpiration. Through these coupled processes, water is converted from a liquid to a vapor and is transferred from Earth's surface to the atmosphere. Sources of water available for evaporation include open bodies of water, soil moisture, and water condensate on surfaces. In the process of transpiration, water is transpired by plants, changing from a liquid to a vapor and passing through the stomata.

The process of ET utilizes energy from the environment, and measuring this transfer of energy is the basis for measuring ET (Brutsaert, 1982; Laczniak and others, 1999). The energy at Earth's surface can be described by the surface energy budget (hereinafter the energy budget). The energy budget balances the incoming and outgoing energy fluxes at Earth's surface and will occur in equilibrium once all sources of energy in their different states of transformation are taken into account. Assuming that energy fluxes from other sources and sinks are negligible, the simplified form of the energy budget can be expressed as follows (Brutsaert, 1982; Wilson and others, 2002):

$$Rn - G = H + \lambda E, \tag{1}$$

where

Rn is the net radiation, the difference between incoming and reflected radiation, in watts per square meter;

G is the soil-heat flux, the rate of change of heat flow in soil plus the combined heat storage in the soil and soil moisture, in watts per square meter;

H is the sensible-heat flux, energy transferred between the surface and the air, in watts per square meter; and

λE is the latent-heat flux, energy utilized in the process of ET, in watts per square meter.

ET can be described as the mass flux of water dependent on the latent-heat flux (λ) and can be calculated as follows (Laczniak and others, 1999):

$$\mathrm{ET} = 1{,}000 \ \frac{\lambda E}{\lambda \rho_w}, \tag{2}$$

where

ET is the rate of evapotranspiration, in millimeters per second;

λE is the latent-heat flux, in watts per square meter (λ is the latent heat of vaporization of water, in joules per kilogram, and E is the rate of water evaporation, in kilograms per square meter per second);

λ is the latent heat of vaporization of water, in joules per kilogram; and

ρ_w is the density of water, in kilograms per cubic meter.

Methods of Measuring Evapotranspiration

To calculate ET, the latent-heat flux was measured or estimated by using three different methods: the eddy covariance method, the Bowen ratio closure method, and the residual latent energy closure method. The eddy covariance method makes direct measurements of sensible- and latent-heat fluxes (eq. 1), from which ET is calculated (eq. 2). The Bowen ratio closure method balances the terms of equation 1 by adjusting the measurements of sensible- and latent-heat from the eddy covariance method; ET is then calculated from the adjusted latent energy term (eq. 2). The eddy covariance and Bowen ratio closure methods both resulted in comprehensive ET datasets for the period of study; of these, ET calculated by using the Bowen ratio closure method is considered the most refined. The residual latent energy closure method calculates latent energy as the residual of the energy balance by rearranging equation 1 (as $\lambda E = Rn - G + H$). ET calculated by using the residual latent energy closure method was used only for comparison with the ET calculated by using the eddy covariance and Bowen ratio closure methods.

To obtain the meteorological and surface-energy flux data needed for the calculation of ET by the three methods (eddy covariance, Bowen ratio closure, and residual latent energy closure), as well as for analysis of the energy budget, the site was equipped with an extended Open Path Eddy Covariance (OPEC) system from Campbell Scientific, Inc. The system included a data logger (Campbell Scientific CR3000), a three-dimensional sonic anemometer (Campbell Scientific CSAT3), an open path infrared gas analyzer (Campbell Scientific CS–7500), a net radiometer (Kipp and Zonen NR-Lite), a pyranometer (Campbell Scientific CS300), soil-heat flux plates (Campbell Scientific HFT3), soil temperature sensors (Campbell Scientific TCAV), and soil moisture sensors (Campbell Scientific CS616) (Campbell Scientific, Inc., 2006a, b). The CSAT3, CS–7500, net radiometer, and pyranometer were installed on a tower 33 ft above the land surface. The soil temperature and moisture sensors were placed near the tower, 4 to 8 in. below the land surface, and the soil-heat flux plates were placed at 6 in. below the land surface.

Eddy Covariance Method

The eddy covariance (EC) method measures the vertical movement of vapor and energy to and away from Earth's surface and provides the most direct method for measuring sensible and latent heat. The EC method depends on the turbulent transport of vapor and energy occurring within rotating eddies at Earth's surface layer. These rotating eddies transport vapor and energy, which can be measured in regard to their concentration and velocity of movement. The EC method is statistically based; sensible heat is calculated from the covariance between vertical windspeed and temperature (Burba and Anderson, 2006; Campbell, 2006b):

$$H_{EC} = \rho_a C_p \overline{T' U'_z}, \tag{3}$$

where

H_{EC} is the sensible-heat flux, energy transferred between the surface and the air (calculated by the EC method), in watts per square meter;

ρ_a is the density of air, in kilograms per cubic meter;

C_p is the heat capacity of air at a constant pressure, in joules per kilogram per degree Celsius;

T' is the instantaneous deviation of air temperature from the mean, in degrees Celsius; and

U'_z is the instantaneous deviation of vertical windspeed from the mean, in meters per second (the quantity $\overline{T' U'_z}$ is the covariance between the vertical windspeed and temperature [Campbell Scientific, 2006b]).

The latent energy is calculated from the covariance between vertical windspeed and vapor density (Burba and Anderson, 2006; Campbell Scientific, Inc., 2006b):

$$\lambda E_{EC} = \lambda \overline{\rho'_v U'_z}, \tag{4}$$

where

λE_{EC} is the latent-heat flux, energy utilized in the process of ET (calculated by the EC method), in watts per square meter;

λ is the latent heat of vaporization of water, in joules per kilogram;

ρ'_v is the instantaneous deviation of the water vapor density from the mean, in kilograms per cubic meter; and

U'_z is the instantaneous deviation of vertical windspeed from the mean, in meters per second (the quantity $\overline{\rho'_v U'_z}$ is the covariance between the vertical windspeed and vapor density [Campbell Scientific, 2006b])

The measurements are made at 10 hertz (10 samples per second) and averaged over a 30-minute period.

ET by the EC method was calculated from λE_{EC} using equation 2 and the data reviewed and edited under selected conditions. During periods of rainfall, measurements of sensible and latent heat made by the CSAT3 and LI–7500 can be unreliable; during these periods, when available energy was zero or less [$(Rn - G) \leq 0$)], ET by the EC method was assumed to be zero; if available energy was greater than zero [$(Rn - G) > 0$)], ET by the EC method was assumed to be zero or substituted with an ET value calculated by using the Bowen ratio closure method. In cases when the value exceeded the theoretically possible range of energy fluxes, the ET by EC value was edited as a spike (a sudden large increase or decrease in value not corroborated by preceding or subsequent values), and either the anomalous value was removed and assumed to be zero if no energy was available, or the value was substituted with an ET value calculated by using the Bowen ratio closure method. About 6 percent of the 30-minute ET by EC values were edited by one of these methods.

Measurements of ET by the EC method also can be influenced by the tower structure when the wind directions are between approximately 350 and 10 degrees from north. On the basis of wind direction, the tower structure might have affected as much as 5 percent of ET measurements. ET calculated by using the EC method and coinciding with periods when the wind direction was between approximately 350 and 10 degrees from north were reviewed and found not to deviate from preceding and subsequent ET values when the wind direction was between 11 and 349 degrees, and no revisions were made to the data.

Bowen Ratio Closure Method

When using the EC method to calculate ET, several investigators recommend methods of forcing closure of the energy budget to adjust the latent energy calculated from the EC method (Twine and others, 2000; Wilson and others, 2002; Brotzge and Crawford, 2003; Wohlfahrt and others, 2009). In this study, a variation of the energy budget Bowen ratio method, referred to as the Bowen ratio closure method, was used to force closure of the energy budget and calculate ET from the latent energy value derived from this method (Twine and others, 2000; Wohlfahrt and others, 2009). This method attributes the energy budget imbalance to errors associated with measurements of sensible- and latent-heat fluxes (Twine and others, 2000; Wilson and others, 2002; Brotzge and Crawford, 2003; Foken, 2008; Wohlfahrt and others, 2009).

The energy budget Bowen ratio method is based on the conservation of energy and mass and the closure of the energy budget (eq. 1). The method relies on direct measurements of *Rn* and *G* and on estimates of the sensible- and latent-heat fluxes derived from the Bowen ratio. The Bowen ratio (β) assumes vertical gradients of temperature and vapor pressure to be proportional to the ratio of sensible- and latent-heat fluxes. The gradients can be calculated from direct measurements of temperature and vapor pressure at two different heights above the land surface (Bowen, 1926; Brutsaert, 1982):

$$\beta = \frac{H}{\lambda E} = \gamma \frac{\Delta T}{\Delta e}, \tag{5}$$

where

β is the Bowen ratio, dimensionless;

H is the sensible-heat flux, energy transferred between the surface and the air, in watts per square meter;

λE is the latent-heat flux, energy utilized in the process of ET, in watts per square meter;

γ is the psychrometric constant, in kilopascals per degree Celsius;

ΔT is the difference between air temperature at two different heights, in degrees Celsius; and

Δe is the difference between vapor pressure at two different heights, in kilopascals.

The Bowen ratio (β) is substituted into equation 1 and the latent-heat flux calculated by algebraic rearrangement:

$$\lambda E = \frac{Rn - G}{1 + \beta}, \tag{6}$$

where

λE is the latent-heat flux, energy utilized in the process of ET, in watts per square meter;

Rn is the net radiation, the difference between incoming and reflected radiation, in watts per square meter;

G is the soil-heat flux, the rate of change of heat flow in soil plus the combined heat storage in the soil and soil moisture, in watts per square meter; and

β is the Bowen ratio, dimensionless (eq. 5).

The ratio of H_{EC} and λE_{EC} was used to estimate the bowen ratio using equation 5. From equation 6, the latent-heat flux was then calculated as follows (Twine and others, 2000; Wohlfahrt and others, 2009):

$$\lambda E_{\beta C} = \frac{Rn - G}{1 + \frac{H_{EC}}{\lambda E_{EC}}}, \tag{7}$$

where

$\lambda E_{\beta C}$ is the latent-heat flux, energy utilized in the process of ET (calculated by the Bowen ratio closure method), in watts per square meter;

Rn is the net radiation, the difference between incoming and reflected radiation, in watts per square meter;

G is the soil-heat flux, the rate of change of heat flow in soil plus the combined heat storage in the soil and soil moisture, in watts per square meter;

H_{EC} is the sensible-heat flux, energy transferred between the surface and the air (calculated by the EC method) (eq. 3), in watts per square meter; and

λE_{EC} is the latent-heat flux, energy utilized in the process of ET (calculated by the EC method) (eq. 4), in watts per square meter.

ET by the Bowen ratio closure method calculated from $\lambda E_{\beta C}$ was reviewed and the data edited under these conditions: As the Bowen ratio approaches -1, the denominator of equation 6 approaches or becomes zero, making the method unreliable for the calculation of ET. This condition is occasionally found in the early morning, in the late evening, or during calm, high-humidity conditions when flux values are normally small (Ohmura, 1982). To edit these periods, the Bowen ratio was substituted with -1.5 when the Bowen ratio was between -1.5 and -1.0, and substituted with -0.5 when the Bowen ratio was less than or equal to -0.5 or greater than -1.0. ET calculated by the Bowen ratio closure method with substitutions compare well with preceding and subsequent (unsubstituted) ET values and with ET calculated by the EC method. In the Bowen ratio closure method, spike ET values were either substituted with an interpolated value or set to zero during periods of rainfall and during periods when no energy was available [($Rn - G$) < 0]. About 7 percent of the ET values calculated by the Bowen ratio closure method were revised by one of these methods.

Quality Assurance

Rainfall Data

To maintain the accuracy of the raingage at the SW Medina County meteorological station, the instrument was periodically inspected and cleaned and calibration checks performed as described by the manufacturer (NovaLynx Corporation, 2009). Eight calibration checks were performed during August 2006–December 2009. The amount of rainfall recorded when calibration check volumes simulating a rainfall rate of 2 inches per hour (in/h)were applied was, on average, 2.3 percent larger than the applied volume. At an applied rainfall rate of 6 in/h, the amount of rainfall recorded averaged 0.2 percent larger than the applied volume. These checks compare well with the manufacturer's reported accuracy of 2 percent of total rainfall for rainfall rates of as much as 2 in/h (NovaLynx Corporation, 2009).

Other than removing spike values, no further corrections were made to the rainfall data. On the basis of calibration checks and taking possible environmental effects into account, the rainfall data are likely accurate to within 5 percent of actual rainfall.

Evapotranspiration Data

ET calculated by the EC method can be evaluated by assessing the degree of closure of the energy budget. Closure of the energy budget occurs when the available energy from *Rn* and *G* equals the vertical energy fluxes, *H* and λE (eq. 1). Although a balance of these terms is expected, previous investigations indicate that measurements of sensible- and latent-heat fluxes ($H_{EC} + \lambda E_{EC}$) can be 10–30 percent less relative to the available energy ($Rn - G$) (Twine and others, 2000; Wilson and others, 2002; Brotzge and Crawford, 2003). Possible causes of this imbalance include inconsistent sources of measured energy-flux measurements, H_{EC} and λE_{EC}, representative of the area within the flux footprint that are not comparable to sensor measurements, *Rn* and *G*, made at the measurement site; biases and errors associated with the individual sensors; possible sources of energy not accounted for; and frequency response of the flux measuring instruments, which might include errors associated with sensor separation and high and low pass filtering (Twine and others, 2000; Wilson and others, 2002; Brotzge and Crawford, 2003; Burba and Anderson, 2006). More recent studies during 2007–09 emphasize the importance of the selected measurement site, quality data-collection methods, and proper postprocessing techniques to minimize possible measurement biases and energy imbalances (Foken, 2008; Wolf and others, 2008; Wohlfahrt and others, 2009). Although good closure of the energy budget is not necessarily a conclusive validation of the data, poor closure is an indication of possible biases and errors (Burba and Anderson, 2006). In this study, closure of the energy budget was evaluated by using simple linear regression[1] models and by calculation of the energy budget ratio (Wilson and others, 2002; Burba and Anderson, 2006). ET values calculated by using the EC method also were evaluated by comparing them with ET values calculated by using the residual latent energy (λE_{RL}) closure method (Wohlfahrt and others, 2009).

[1] The model for simple linear regression is $y_i = b_o + b_1x_i$, where y_i is the estimate of the sum of the latent- and sensible-heat flux at the *ith* interval; b_o is the intercept; b_1 is the slope; and x_i is the net radiation minus the soil-heat flux at the *ith* interval. R-squared is the coefficient of determination, or the fraction of the variance explained by the linear regression model (Helsel and Hirsch, 2002).

Simple Linear Regression Analysis To Evaluate Evapotranspiration Data

Simple linear regression analyses were used to evaluate the relation between the sum of sensible- and latent-heat fluxes ($H_{EC} + \lambda E_{EC}$) and the sum of available energy ($Rn - G$). The regression model provides the linear regression coefficients for the slope and intercept of the regression line (Helsel and Hirsch, 2002): a slope of 1 and intercept of 0 representing an ideal closure of the energy budget (Twine and others, 2000; Wilson and others, 2002). The closure of the energy budget was evaluated for each month by using the regression model. The results of the analysis are summarized in table 1 (at end of report).

The resulting intercepts of the regression line ranged from -14.05 to 10.25 watts per square meter (W/m^2) and averaged 1.06 W/m^2; slopes ranged from 0.89 to 1.15 and averaged 1.00; and the coefficient of determination (R-squared) ranged from 0.73 to 0.95 and averaged 0.90 (table 1).

Energy Budget Ratio To Evaluate Evapotranspiration Data

A second method was used to examine closure of the energy budget by summing the latent- and sensible-heat fluxes and dividing by the available energy (eq. 8) to obtain the energy budget ratio (EBR) for selected periods; an EBR of 1 indicates complete closure of the energy balance (Wilson and others, 2002; Brotzge and Crawford, 2003):

$$\mathrm{EBR} = \sum \left(\frac{\lambda E_{EC} + H_{EC}}{Rn - G} \right), \tag{8}$$

where

λE_{EC} is the latent-heat flux, energy utilized in the process of ET (calculated by the EC method) (eq. 4), in watts per square meter;

H_{EC} is the sensible-heat flux, energy transferred between the surface and the air (calculated by the EC method) (eq. 3), in watts per square meter;

Rn is the net radiation, the difference between incoming and reflected radiation, in watts per square meter; and

G is the soil-heat flux, the rate of change of heat flow in soil plus the combined heat storage in the soil and soil moisture, in watts per square meter.

These analyses were done on a monthly time step by using corresponding 30-minute values; the results of these analyses are summarized in table 1. EBR ranged from 0.85 to 1.41 and averaged 1.04 for all months. EBR greater than 1 (indicating measured sensible- and latent-heat fluxes to be greater than measured net radiation and soil-heat flux) typically occurred in November, December, and January.

EBR less than 1 (indicating measured sensible- and latent-heat fluxes to be less than measured net radiation and soil-heat flux) typically occurred in May, June, July, and August (table 1).

Residual Latent Energy Closure Method To Evaluate Evapotranspiration Data

The residual latent energy closure method of calculating ET is based on equation 1. The method assumes that net radiation, soil-heat flux, and sensible-heat flux were measured correctly and that imbalances in the energy budget are associated with the measurements of the latent-heat flux (Twine and others, 2000; Wilson and others, 2002; Brotzge and Crawford, 2003; Foken, 2008; Wohlfahrt and others, 2009). By rearranging equation 1 and discarding λE, the latent-heat flux is recalculated as follows:

$$\lambda E_{RL} = Rn - G - H_{EC} \,, \tag{9}$$

where

λE_{RL} is the latent-heat flux, energy utilized in the process of ET (calculated by residual latent energy method), in watts per square meter;

Rn is the net radiation, the difference between incoming and reflected radiation, in watts per square meter;

G is the soil-heat flux, the rate of change of heat flow in soil plus the combined heat storage in the soil and soil moisture, in watts per square meter; and

H_{EC} is the sensible-heat flux, energy transferred between the surface and the air (calculated by the EC method) (eq. 3), in watts per square meter.

Though not provided in this report, ET calculated by using the residual latent energy closure method were used in the data review process for comparison with the ET calculated by the EC method and by the Bowen ratio closure method.

Rainfall Data

Monthly rainfall totals during August 2006–December 2009 at the SW Medina County meteorological station are summarized in table 1; daily rainfall totals are listed in tables 2–5 (at end of report) and shown in figure 5. Daily total rainfall amounts are not reported for days missing 20 percent or more of the 30-minute values; days with 20 percent or more missing values were January 14–19 and 24–25, 2007, and December 12–17, 2007. Cumulative rainfall amounts derived from daily totals are shown in figure 6. Hourly rainfall data are provided in appendixes 1.1–1.4.

During August 2006–December 2009 (excluding days of missing record), the total amount of rainfall was 86.85 in. (fig. 6, table 1). Annual rainfall in 2007, 2008, and 2009 was 40.98, 12.35, and 27.15 in., respectively (tables 3–5). In July 2007, the largest monthly rainfall amount (12.30 in.) was recorded. Of the 1,233 days of record, there were 256 days with measurable rainfall of a least 0.01 in.; for these days, the daily rainfall averaged 0.34 in., and the largest daily rainfall total was 3.15 in. on June 16, 2007 (fig. 5, table 3). The largest hourly rainfall rate was 1.92 in. between 7 and 8 p.m. on June 16, 2007 (appendix 1.2).

Evapotranspiration Data

Daily and monthly ET calculated for August 2006–December 2009 by using the EC method are listed in tables 6–9 (at end of report); daily and monthly ET calculated for August 2006–December 2009 by using the Bowen ratio closure method are listed in tables 10–13 (at end of report). Cumulative and daily ET calculated for August 2006–December 2009 by the EC method and by the Bowen ratio closure method are shown in figures 6 and 7, respectively. Hourly ET calculated by using the EC method and by using the Bowen ratio closure method are listed in appendixes 1.1–1.4.

Daily ET values were not calculated when more than 20 percent of the day's 30-minute meteorological and surface-energy flux data were missing; these days include December 20, 2006–January 11, 2007; January 14–18 and 24–25, 2007; December 6–18, 2007; and October 4–November 4, 2009. Daily estimates of ET calculated by the EC method and by the Bowen ratio closure method were made when the CS–7500 was removed for calibration. During these periods, daily ET calculated by the EC method and by the Bowen ratio closure method were estimated on the basis of a correlation between available energy ($Rn - G$) and corresponding ET data for both methods from the weeks before and after the period of calibration. Hourly ET values are not reported for these periods, and daily values are reported as estimated; these days include March 12–14, 2008, and March 23–27, 2009.

During August 2006–December 2009 (excluding days of missing record), the total ET calculated by using the EC method was 69.91 in. (fig. 6, table 1); annual ET by the EC method totaled 34.62, 15.24, and 15.57 in. for 2007, 2008, and 2009, respectively (excluding days of missing record) (tables 7–9). During August 2006–December 2009, the largest monthly ET total calculated by using the EC method was 6.17 in. (August 2007) (table 7), and the largest daily total ET by the EC method was 0.26 in. on April 25 and August 1 and 14, 2007 (fig. 7, table 7).

During August 2006–December 2009, ET calculated by using the Bowen ratio closure method totaled 68.33 in. (fig. 6, table 1), and measured annual ET by the Bowen ratio closure method totaled 32.49 in., 15.54 in., and 15.80 in. for 2007, 2008, and 2009, respectively (tables 11–13). During August 2006–December 2009, the largest monthly ET total

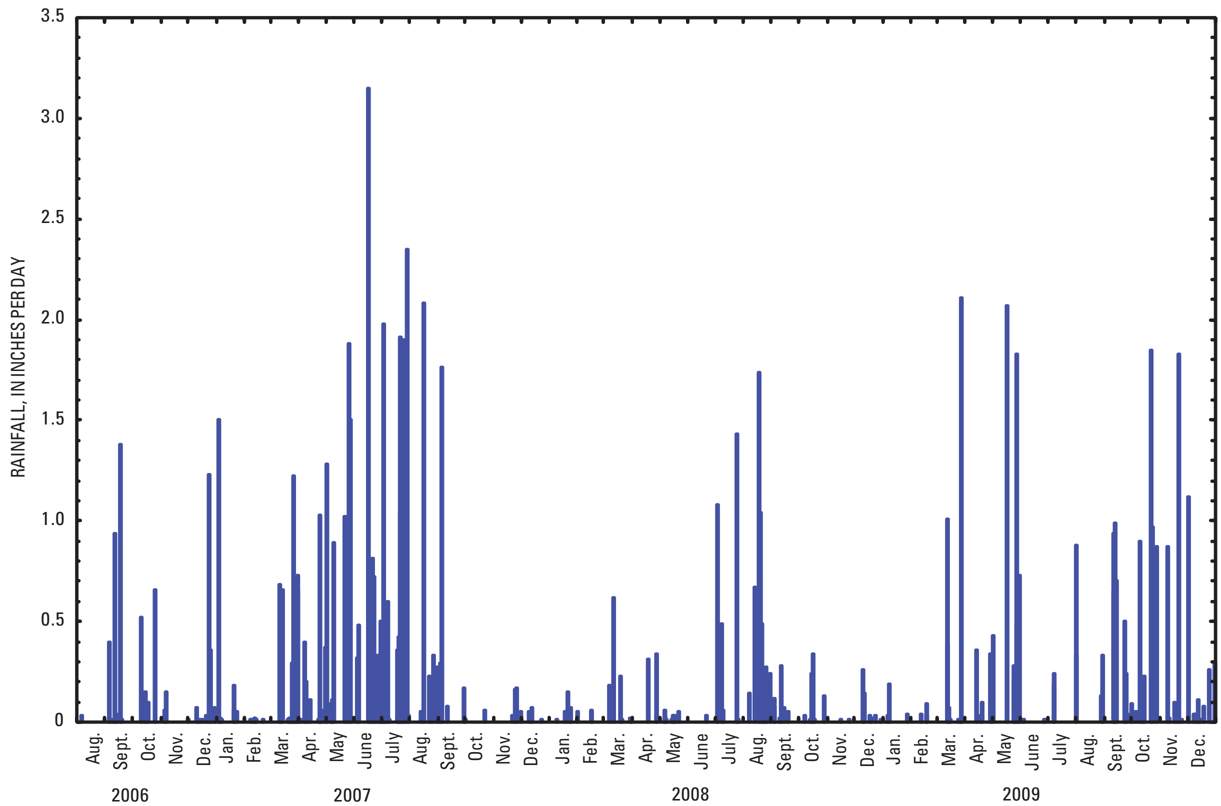


Figure 5. Rainfall at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, August 2006–December 2009.

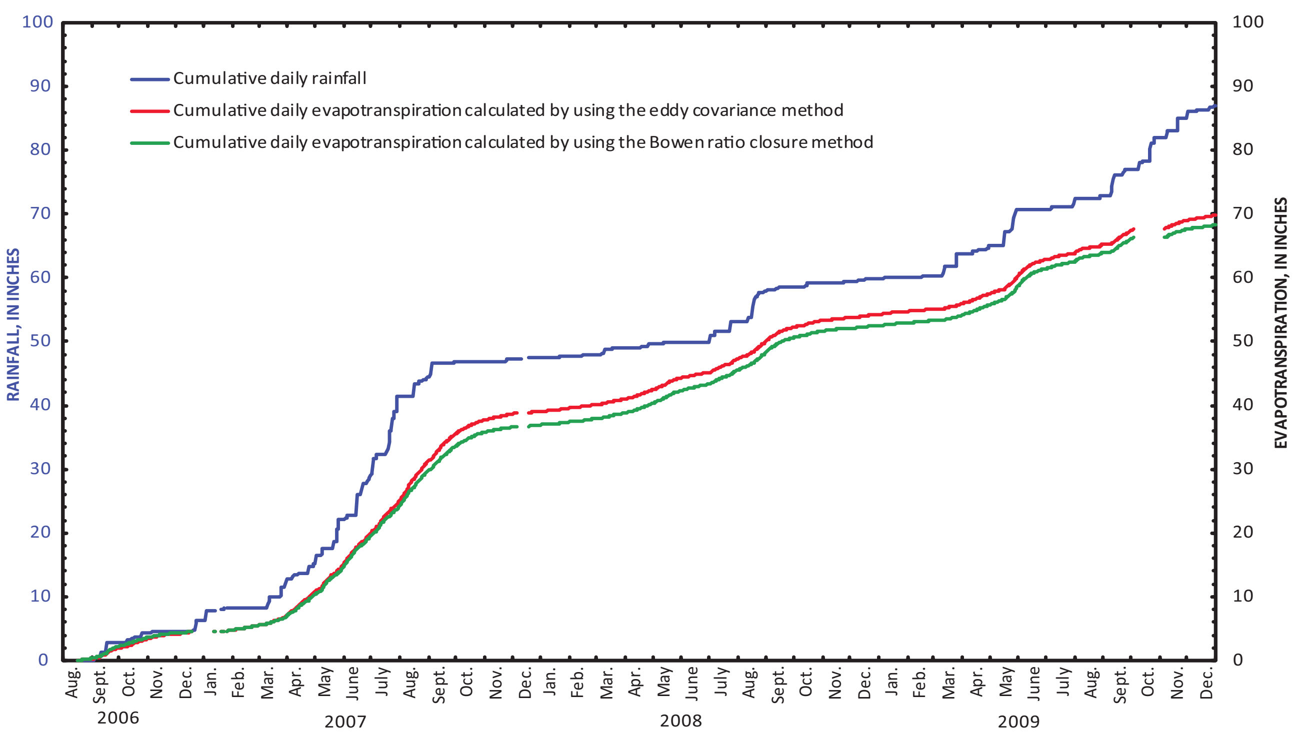


Figure 6. Cumulative rainfall and evapotranspiration calculated by using the eddy covariance method and the Bowen ratio closure method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, August 2006–December 2009.

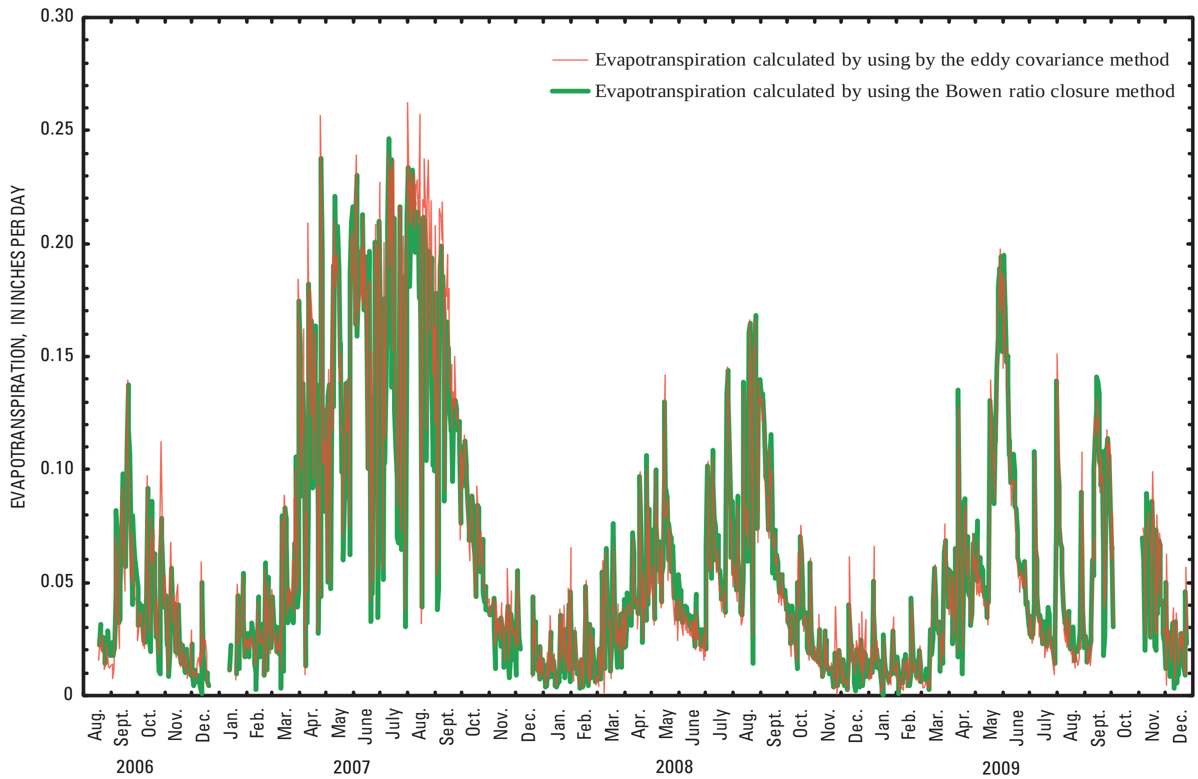


Figure 7. Daily evapotranspiration calculated by using the eddy covariance method and the Bowen ratio closure method at U.S. Geological Survey meteorological station 29081009212100 in southwest Medina County near D'Hanis, Texas, August 2006–December 2009.

was 5.57 in. (August 2007), and the largest daily ET total was 0.25 in. (July 10, 2007) (fig. 7, table 11).

ET calculated by using the EC method and the Bowen ratio closure method were largely dependent on the amount of available energy and moisture. In 2007 when annual rainfall was greatest (40.98 in.), annual ET by the EC method and by the Bowen ratio closure method also were high, 34.62 and 32.49 in., respectively. In 2008, when annual rainfall was the least (12.35 in.), annual ET by the EC method and by the Bowen ratio closure method also were low, 15.24 and 15.54 in., respectively. On average, most ET occurred during the late spring and early summer, approximately coinciding with the annual peak of daily insolation (Bendta and others, 1981) and high monthly rainfall totals. Conversely, less ET occurred in winter months when daily insolation and rainfall were low.

Summary

During August 2006–December 2009, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers, Fort Worth District, collected rainfall and evapotranspiration data to help characterize the hydrology of the Nueces River Basin, Texas. The USGS installed and operated a station to collect continuous (30-minute interval) rainfall and evapotranspiration data. The station, identified as the USGS meteorological station 290810099212100 in southwest Medina County (hereinafter the SW Medina County meteorological station) is located in southwest Medina County approximately 14 mi southwest of D'Hanis, Texas, and 23 mi northwest of Pearsall, Texas, on a private ranch overlying part of the Carrizo-Wilcox aquifer outcrop. Rainfall data were collected by using an 8-in. tipping bucket raingage. To maintain the accuracy of the raingage, the instrument was periodically inspected and cleaned and calibration checks performed as described by the manufacturer. Meteorological and surface-energy flux data used for the calculation of ET were collected by using an extended Open Path Eddy Covariance system from Campbell Scientific, Inc. Data recorded by the system were used to calculate ET by using the eddy covariance and Bowen ratio closure methods and to analyze the surface energy budget closure.

Simple linear regression analyses were used to evaluate the relation between the sum of sensible- and latent-heat fluxes and the sum of available energy. The regression model provides the linear regression coefficients for the slope and intercept of the regression line—a slope of 1 and intercept of 0 representing an ideal closure of the energy budget. The closure of the energy budget was evaluated for each month by using the regression model. The resulting intercepts of the regression line ranged from -14.05 to 10.25 W/m^2 and averaged 1.06 W/m^2; slopes ranged from 0.89 to 1.15 and averaged 1.00; and the coefficient of determination ranged from 0.73 to 0.95 and averaged 0.90.

A second method was used to examine closure of the energy budget by summing the latent- and sensible-heat fluxes and dividing by the sum of available energy to obtain the energy budget ratio; an energy budget ratio of 1 indicates complete closure of the energy balance. These analyses were done on a monthly time step by using corresponding 30-minute values. Energy budget ratios ranged from 0.85 to 1.41 and averaged 1.04 for all months. Energy budget ratios greater than 1 (indicating measured sensible- and latent-heat fluxes to be greater than measured net radiation and soil-heat flux) typically occurred in November, December, and January. Energy budget ratios less than 1 (indicating measured sensible- and latent-heat fluxes to be less than measured net radiation and soil-heat flux) typically occurred in May, June, July, and August.

During August 2006–December 2009 (excluding days of missing record), measured rainfall totaled 86.85 in. During 2007, 2008, and 2009, annual rainfall totaled 40.98, 12.35, and 27.15 in., respectively. The largest monthly rainfall total during August 2006–December 2009 was 12.30 in. (July 2007), and the largest daily rainfall total was 3.15 in. on June 16, 2007. The largest hourly rainfall rate was 1.92 in. between 7 and 8 p.m. on June 16, 2007.

During August 2006–December 2009 (excluding days of missing record), evapotranspiration calculated by using the eddy covariance method totaled 69.91 in. Annual evapotranspiration calculated by using the eddy covariance method totaled 34.62 in. during 2007, 15.24 in. during 2008, and 15.57 in. during 2009. During August 2006–December 2009, the largest monthly evapotranspiration total by the eddy covariance method was 6.17 in. (August 2007), and the largest daily total was 0.26 in. on April 25 and August 1 and 14, 2007.

During August 2006–December 2009, evapotranspiration calculated by using the Bowen ratio closure method totaled 68.33 in. Annual evapotranspiration calculated by using the Bowen ratio closure method totaled 32.49 in. during 2007, 15.54 in. during 2008, and 15.80 in. during 2009. During August 2006–December 2009, the largest monthly evapotranspiration total by the Bowen ratio method was 5.57 in. (August 2007), and the largest daily total was 0.25 in. on July 10, 2007.

References Cited

Ashmore, S.E., 1934, The splashing of rain: London, Quarterly Journal of the Royal Meteorological Society, v. 60, no. 257, p. 517–522.

Bendta, P., Collares-Pereirab, M., and Rabla, A., 1981, The frequency distribution of daily insolation values: Solar Energy, v. 27, no. 1, p. 1–5.

Bowen, I.S., 1926, The ratio of heat losses by conduction and by evaporation from any water surface: Physics Review, v. 27, p. 779–787.

Brotzge, J.A., and Crawford, K.C., 2003, Examination of the surface energy budget—A comparison of eddy correlation and Bowen ratio measurement systems: Journal of Hydrometeorology, v. 4, no. 2, p. 160–178.

Brutsaert, W.H., 1982, Evaporation in the atmosphere—Theory, history, applications: Dordrecht-Boston, D. Reidel Publishing Company, 299 p.

Burba, G., and Anderson, D., 2006, Introduction to the eddy covariance method—General guidelines and conventional workflow: accessed December 2006, at *http://www.licor.com/env/PDF/EddyCovariance_readonly.pdf*.

Campbell Scientific, Inc., 2006a, Instruction manual—CSAT3 three dimensional sonic anemometer: Logan, Utah, Campbell Scientific, Inc., 44 p., accessed October 13, 2010, at *http://www.campbellsci.com/documents/manuals/csat3.pdf*.

Campbell Scientific, Inc., 2006b, Instruction manual—Open Path Eddy Covariance system operator's manual CSAT3, LI–7500, and KH20: Logan, Utah, Campbell Scientific, Inc., 40 p., accessed October 13, 2010, at *http://www.campbellsci.com/documents/manuals/opecsystem.pdf*.

Dittmar, G.W., Deike, M.L., and Richmond, D.L., 1977, Soil survey of Medina County, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service, variously paged.

Duchon, C.E., and Essenberg, G.R., 2001, Comparative rainfall observations from pit and above ground rain gauges with and without wind shields: Water Resources Research, v. 37, no. 12, p. 3,253–3,263, accessed October 13, 2010, at *http://www.agu.org/journals/ABS/2001/2001WR000541.shtml*.

Federal Geographic Data Committee, 2010, Spatial reference information: accessed October 13, 2010, at *http://www.fgdc.gov/*.

Foken, Thomas, 2008, The energy balance closure problem—An overview: Ecological Applications, v. 18, no. 6, p. 1,351–1,367.

Gold, E., 1931, The splashing of rain: London, The Meteorological Magazine, v. 66, no. 787, p. 153–160.

Golubev, V.S., 1985, On the problem of stand conditions for precipitation gage installation, *in* Sevruk, B., ed., Correction of precipitation measurements: World Meteorological Organization/IAHS/ETH Workshop on Precipitation Measurement, St. Moritz, Switzerland, December 2–5, 1993, p. 181–182.

Gordon, J.D., 2003, Evaluation of candidate rain gages for upgrading precipitation measurement tools for the National Atmospheric Deposition Program: U.S. Geological Survey Water-Resources Investigations Report 02–4302, 30 p.

Griffith, G.E., Bryce, S.A., Omernik, J.M., Comstock, J.A., Rogers, A.C., Harrison, B., Hatch, S.L., and Bezanson, D., 2004, Ecoregions of Texas: Reston, Va., U.S. Geological Survey (map scale 1:2,500,000), accessed April 9, 2010, at: *http://www.epa.gov/wed/pages/ecoregions/tx_eco.htm*.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 510 p., available online at *http://pubs.usgs.gov/twri/twri4a3/*.

Laczniak, R.J., DeMeo, G.A., Reiner, S.R., Smith, J.L., and Nylund, W.E., 1999, Estimates of ground-water discharge as determined from measurements of evapotranspiration, Ash Meadows Area, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 99–4079, 70 p.

Lakes Environmental, 2010, WRPLOT View Freeware (version 5.9): Waterloo, Ontario, Canada, Lakes Environmental, accessed April 15, 2010, at *http://www.weblakes.com/products/wrplot/index.html*.

Larkin, T.J., and Bomar, G.W., 1983, Climatic map of Texas: Texas Department of Water Resources, LP–192, p. 157.

Legates, D.R., and Deliberty, T.L., 1993, Precipitation bias in the United States: Water Resources Bulletin, American Water Resources Association, v. 29, no. 5, p. 855–861.

Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., 1982, Hydrology for engineers (3d ed.): New York, McGraw-Hill, 512 p.

National Oceanic and Atmospheric Administration, 2004, Monthly climate summaries, 1971–2000: Asheville, N.C., National Environmental Satellite, Data, and Information Service, National Climatic Data Center, no. 20, p. 222A–222E.

NovaLynx Corporation, 2009, Model 260–2501–A and 260–2501M–A tipping bucket rain gauge user's manual: Auburn, Calif., NovaLynx Corporation, 15 p., accessed October 13, 2010, at *http://www.novalynx.com/manuals/260-2501-manual.pdf*.

Ohmura, Atsumu, 1982, Objective criteria for rejecting data for Bowen ratio flux calculations: Journal of Applied Meteorology, v. 21, no. 4, p. 595–598.

Texas Natural Resources Information System, 2010, The Strategic Mapping Program (StratMap): Texas Water Development Board, accessed October 13, 2010, at *http://www.tnris.state.tx.us/Programs/Stratmap/Index.aspx*.

Twine, T.E., Kustas, W.P., Norman, J.M., Cook, D.R., Houser, P.R., Meyers, T.P., Prueger, J.H., Starks, J.H., and Wesely, M.L., 2000, Correcting eddy-covariance flux underestimates over a grassland: Agricultural and Forest Meteorology, v. 103, no. 3, p. 279–300.

U.S. Army Corps of Engineers, 2009, Nueces River Basin reconnaissance study: U.S. Army Corps of Engineers, Fort Worth District, accessed May 23, 2009, at *http://www.swf.usace.army.mil/pubdata/notices/nueces_river_study.asp*.

U.S. Department of Agriculture, Natural Resources Conservation Service, 2010, Web soil survey (WSS): U.S. Department of Agriculture, Natural Resources Conservation Service, accessed April 26, 2010, at *http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx*.

U.S. Geological Survey, 2010, National Water Information System, Web interface—USGS water data for Texas: U.S. Geological Survey, accessed October 13, 2010, at *http://waterdata.usgs.gov/tx/nwis/*.

Water Encyclopedia, 2010, The hydrologic cycle: Advameg, Inc., accessed October 13, 2010, at *http://www.waterencyclopedia.com/Hy-La/Hydrologic-Cycle.html*.

Wilson, K., Goldstein, A., Falge, E., Aubinet, M., Baldocchi, D., Berbigier, P., Bernofer, C., Ceulemans, R., Dolman, H., Field, C., Grelle, A., Ibrom, A., Law, B., Kowalski, A., Meyers, T., Moncrieff, J., Monson, R., Oechel, W., Tenhunen, J., Valentini, R., and Verma, S., 2002, Energy balance closure at FLUXNET sites: Agricultural and Forest Meteorology, v. 113, p. 223–243.

Wohlfahrt, G., Haslwanter, A., Hortnagl, L., Jasoni, R., Fenstermaker, L., Arnone, J., and Hammerle, A., 2009, On the consequences of the energy imbalance for calculating surface conductance to water vapour: Agricultural and Forest Meteorology, v. 149, p. 1,556–1,559.

Wolf, A., Saliendra, N., Akshalov, K., Johnson, D., and Laca, E., 2008, Effects of different eddy covariance correction schemes on energy balance closure and comparisons with the modified Bowen ratio system: Agricultural and Forest Meteorology, v. 148, p. 942–952.

Table 1. Monthly rainfall, evapotranspiration, linear regression analysis of available energy and surface-energy flux, and energy budget ratios measured at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, August 2006–December 2009.

[ET_{EC}, evapotranspiration by eddy covariance method; $ET_{\beta c}$, evapotranspiration by Bowen ratio closure method; EBR, energy budget ratio; n, number of 30-minute observations; R-squared, coefficient of determination]

Year	Month	Rainfall (inches)	ET_{EC} (inches)	$ET_{\beta c}$ (inches)	Summary of regression and EBR analysis				
					n	Intercept[a] (watts per square meter)	Slope[a]	R-squared[a]	EBR
2006	Aug	[b]0.03	[b]0.25	[b]0.31	696	-8.65	0.95	0.95	0.88
	Sep	2.79	1.71	1.93	1,372	-.70	.94	.91	.94
	Oct	1.53	1.45	1.36	1,444	3.40	1.00	.88	1.04
	Nov	.22	.77	.71	1,433	2.70	1.04	.89	1.08
	Dec	1.80	[b].31	[b].19	901	8.92	1.08	.73	1.41
2007	Jan	[b]1.76	[b].30	[b].30	668	5.56	.93	.81	1.07
	Feb	.07	.72	.70	1,344	3.55	.99	.84	1.04
	Mar	4.66	1.56	1.44	1,395	6.36	.98	.88	1.07
	Apr	2.30	3.59	3.30	1,287	9.11	1.04	.91	1.12
	May	6.88	4.35	4.37	1,398	1.86	.96	.94	.98
	Jun	6.97	5.00	4.87	1,369	1.82	1.00	.94	1.02
	Jul	12.30	5.01	4.63	1,332	7.30	1.03	.92	1.09
	Aug	3.20	6.17	5.57	1,439	-2.36	1.11	.93	1.10
	Sep	2.31	4.38	3.93	1,310	1.57	1.09	.93	1.11
	Oct	.06	2.19	2.18	1,484	-2.79	1.02	.93	.99
	Nov	.41	.97	.80	1,366	4.74	1.08	.83	1.17
	Dec	[b].06	[b].40	[b].40	847	9.17	1.15	.87	1.34
2008	Jan	.34	.57	.45	1,443	3.48	1.15	.88	1.23
	Feb	.11	.46	.46	1,325	-4.83	1.07	.90	1.02
	Mar	1.08	.90	.90	1,372	-3.92	1.01	.91	.97
	Apr	.68	1.44	1.50	1,406	-7.23	.99	.94	.93
	May	.24	1.85	2.00	1,466	-14.05	.96	.92	.87
	Jun	.03	.89	1.01	1,434	-10.97	.92	.95	.85
	Jul	3.10	2.14	2.23	1,445	.41	.94	.94	.95
	Aug	4.88	2.74	2.76	1,398	-.69	.97	.93	.97
	Sep	.62	2.23	2.35	1,425	-3.18	.98	.93	.96
	Oct	.76	1.02	1.02	1,471	-2.29	1.01	.93	.98
	Nov	.02	.45	.44	1,436	4.07	1.03	.91	1.10
	Dec	.49	.55	.42	1,455	6.66	1.01	.86	1.17

Table 1. Monthly rainfall, evapotranspiration, linear regression analysis of available energy and surface-energy flux, and energy budget ratios measured at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas, August 2006–December 2009—Continued.

Year	Month	Rainfall (inches)	ET_{EC} (inches)	$ET_{\beta c}$ (inches)	Summary of regression and EBR analysis				
					n	Intercept[a] (watts per square meter)	Slope[a]	R-squared[a]	EBR
2009	Jan	0.26	0.46	0.44	1,476	4.66	1.03	0.88	1.12
	Feb	.16	.33	.35	1,337	2.09	.99	.92	.96
	Mar	3.62	.87	.83	1,274	-2.59	.97	.90	.94
	Apr	1.26	1.55	1.61	1,418	-.37	.96	.93	.94
	May	5.61	2.84	2.95	1,460	-2.42	.95	.94	.93
	Jun	.02	2.55	2.75	1,439	-1.28	.91	.94	.91
	Jul	1.63	1.01	1.09	1,464	-1.01	.94	.93	.93
	Aug	.46	1.34	1.36	1,481	-3.06	.95	.94	.93
	Sep	4.20	2.20	2.20	1,360	4.24	.96	.92	1.00
	Oct	5.03	[b].17	[b].16	145	7.23	.89	.83	1.00
	Nov	2.90	[b]1.46	[b]1.39	1,230	6.68	1.03	.85	1.16
	Dec	2.00	.80	.67	1,434	10.25	1.05	.81	1.33
Summary, 2006–09	Total[c]	86.85	69.91	68.33	53,679	--	--	--	--
	Mean	2.12	1.71	1.67	--	1.06	1.00	.90	1.04
	Maximum	12.30	6.17	5.57	--	10.25	1.15	.95	1.41
	Minimum	.02	.17	.16	--	-14.05	.89	.73	.85

[a] Intercept and slope are from the model for simple linear regression, $y_i = b_o + b_1x_i$, where y_i is estimate of sum of latent- and sensible-heat flux at the *ith* interval; b_o is intercept; b_1 is slope; and x_i is net radiation minus soil-heat flux at the *ith* interval. R-squared is the coefficient of determination, or the fraction of the variance explained by the linear regression model (Helsel and Hirsch, 2002).

[b] Value based on incomplete month of record.

[c] Total might not equal sum of monthly values because of rounding.

Table 2. Rainfall during August–December 2006 at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Rainfall (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	---	---	---	---	---	---	---	---	0	0	0	0	---
2	---	---	---	---	---	---	---	---	0	0	0	0	---
3	---	---	---	---	---	---	---	0	0	0	0	0	---
4	---	---	---	---	---	---	---	0	0	0	0	0	---
5	---	---	---	---	---	---	---	0	.40	0	.06	0	---
6	---	---	---	---	---	---	---	.03	.01	0	.15	0	---
7	---	---	---	---	---	---	---	0	0	0	0	0	---
8	---	---	---	---	---	---	---	0	0	0	0	0	---
9	---	---	---	---	---	---	---	0	.01	0	0	0	---
10	---	---	---	---	---	---	---	0	0	.52	0	.07	---
11	---	---	---	---	---	---	---	0	.94	0	0	.01	---
12	---	---	---	---	---	---	---	0	.04	0	0	.01	---
13	---	---	---	---	---	---	---	0	0	0	0	0	---
14	---	---	---	---	---	---	---	0	0	.15	0	0	---
15	---	---	---	---	---	---	---	0	0	.10	0	0	---
16	---	---	---	---	---	---	---	0	0	0	0	.01	---
17	---	---	---	---	---	---	---	0	1.38	0	0	0	---
18	---	---	---	---	---	---	---	0	.01	.10	0	0	---
19	---	---	---	---	---	---	---	0	0	0	0	0	---
20	---	---	---	---	---	---	---	0	0	0	0	.03	---
21	---	---	---	---	---	---	---	0	0	0	0	0	---
22	---	---	---	---	---	---	---	0	0	0	0	0	---
23	---	---	---	---	---	---	---	0	0	0	0	1.23	---
24	---	---	---	---	---	---	---	0	0	0	0	.36	---
25	---	---	---	---	---	---	---	0	0	.66	0	0	---
26	---	---	---	---	---	---	---	0	0	0	0	0	---
27	---	---	---	---	---	---	---	0	0	0	0	0	---
28	---	---	---	---	---	---	---	0	0	0	0	0	---
29	---	---	---	---	---	---	---	0	0	0	0	.07	---
30	---	---	---	---	---	---	---	0	0	0	.01	.01	---
31	---	---	---	---	---	---	---	0	---	0	---	0	---
Total	---	---	---	---	---	---	---	.03	2.79	1.53	.22	1.80	6.37
Mean	---	---	---	---	---	---	---	0	.09	.05	.01	.06	.04
Maximum	---	---	---	---	---	---	---	.03	1.38	.66	.15	1.23	1.38
Minimum	---	---	---	---	---	---	---	0	0	0	0	0	0

Table 3. Rainfall during January–December 2007 at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Rainfall (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0	0	0	0	0	0	0.32	0	0	0	0	0	---
2	0	0	0	0	1.28	0	.10	0	0	0	0	0	---
3	1.50	0	0	.01	0	.32	1.98	0	.29	0	0	0	---
4	.02	0	0	0	0	0	.25	0	1.76	0	0	0	---
5	0	0	0	0	0	.48	0	0	0	0	0	0	---
6	.01	0	0	0	.09	0	.04	0	0	0	0	0	---
7	0	.01	0	.40	.01	0	.60	0	0	0	0	0	---
8	0	.01	0	.20	.11	0	.01	0	0	0	0	0	---
9	0	0	0	.03	.89	0	0	0	0	0	0	.05	---
10	0	0	0	.02	0	0	0	0	0	0	0	0	---
11	0	.01	.68	0	0	0	0	0	.08	0	0	0	---
12	0	.02	.35	0	0	0	0	0	0	0	0	---	---
13	0	.01	.66	.11	0	0	0	.05	0	0	0	---	---
14	---	0	0	0	0	0	0	0	0	0	0	---	---
15	---	0	0	0	0	0	0	0	0	0	0	---	---
16	---	0	0	0	0	3.15	0	2.08	0	0	0	---	---
17	---	0	0	0	0	.08	.36	0	0	0	0	---	---
18	---	0	0	0	0	0	.02	0	0	0	0	0	---
19	---	0	0	0	0	0	.42	0	0	0	0	0	---
20	.18	.01	.01	0	0	.81	1.05	0	0	0	.03	0	---
21	0	0	.01	0	1.02	.08	1.91	0	0	0	0	0	---
22	0	0	.02	.01	0	.72	0	.23	0	.06	0	.01	---
23	.05	0	.01	.06	0	0	.03	.04	0	0	0	0	---
24	---	0	.01	1.03	.10	.07	1.90	0	0	0	.16	0	---
25	---	0	.29	.06	1.88	0	.02	0	0	0	.17	0	---
26	0	0	1.22	0	0	0	.91	.33	0	0	0	0	---
27	0	0	.01	0	1.50	.33	0	0	0	0	0	0	---
28	0	0	0	0	0	.32	0	0	0	0	0	0	---
29	0	---	.01	0	0	.11	2.35	0	.17	0	0	0	---
30	0	---	.65	.37	0	.50	.03	.20	.01	0	.05	0	---
31	0	---	.73	---	0	---	0	.27	---	0	---	0	---
Total	1.76	.07	4.66	2.30	6.88	6.97	12.30	3.20	2.31	.06	.41	.06	40.98
Mean	.07	0	.15	.08	.22	.23	.40	.10	.08	0	.01	0	.11
Maximum	1.50	.02	1.22	1.03	1.88	3.15	2.35	2.08	1.76	.06	.17	.07	3.15
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. Rainfall during January–December 2008 at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Rainfall (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0	0	0	0	0	0	0	0	0	0	0	0	---
2	0	0	0	0	0	0	1.08	0	.12	0	0	0	---
3	0	0	0	0	0	0	.01	0	.08	0	0	0	---
4	0	0	0	0	0	0	0	0	0	0	0	0	---
5	0	0	0	0	.06	0	0	0	0	0	0	0	---
6	0	0	.18	0	.03	0	0	.14	0	.03	0	0	---
7	0	0	0	0	.01	0	.49	0	0	0	0	0	---
8	.01	0	0	0	0	0	.06	0	0	0	0	0	---
9	0	0	0	0	0	0	0	0	.02	0	0	.26	---
10	0	0	.62	0	0	0	0	0	0	0	0	.14	---
11	0	0	0	0	0	0	0	0	.28	0	0	0	---
12	0	0	0	0	0	0	0	.67	0	.01	0	0	---
13	0	0	0	0	.01	0	0	0	0	.24	0	0	---
14	0	0	0	0	.01	0	0	0	.07	0	.01	0	---
15	0	.05	0	0	.03	0	0	0	0	.34	0	0	---
16	0	.06	0	0	.03	0	0	0	0	.01	0	0	---
17	0	0	0	0	.01	0	0	1.74	0	0	0	.03	---
18	.05	0	.23	.31	0	0	0	1.04	.05	0	0	.02	---
19	0	0	.01	0	0	0	0	0	0	0	0	0	---
20	0	0	0	0	0	.03	0	.49	0	0	0	0	---
21	.15	0	0	0	.05	0	0	0	0	0	0	0	---
22	0	0	0	0	0	0	0	.22	0	0	0	0	---
23	.01	0	0	0	0	0	.02	.06	0	0	0	.03	---
24	.07	0	0	0	0	0	1.43	.27	0	0	.01	0	---
25	0	0	0	0	0	0	.01	.01	0	0	0	0	---
26	0	0	0	.34	0	0	0	0	0	0	0	0	---
27	0	0	0	.03	0	0	0	0	0	.13	0	0	---
28	0	0	0	0	0	0	0	0	0	0	0	.01	---
29	0	0	.02	0	0	0	0	.24	0	0	0	0	---
30	0	---	.02	0	0	0	0	0	0	0	0	0	---
31	.05	---	0	---	0	---	0	0	---	0	---	0	---
Total	.34	.11	1.08	.68	.24	.03	3.10	4.88	.62	.76	.02	.49	12.35
Mean	.01	0	.03	.02	.01	0	.10	.16	.02	.02	0	.02	.03
Maximum	.15	.06	.62	.34	.06	.03	1.43	1.74	.28	.34	.01	.26	1.74
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5. Rainfall during January–December 2009 at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Rainfall (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0	0	0	0	0	0	0	0	0	0	0	1.12	---
2	0	0	0	0	0	0	0	0	0	0	0	0	---
3	0	0	0	0	0	.01	0	0	0	0	0	0	---
4	0	0	0	0	0	0	0	0	0	.05	0	0	---
5	.03	0	0	0	0	0	0	0	0	0	0	0	---
6	.19	0	0	0	0	0	.24	0	0	0	0	0	---
7	0	0	0	0	0	0	.18	0	0	0	0	.04	---
8	0	0	0	0	0	0	0	0	0	0	.87	.04	---
9	0	0	0	0	0	0	0	0	.65	.90	.02	0	---
10	0	0	0	0	0	0	0	0	.94	0	0	0	---
11	0	.04	.39	0	0	0	0	0	.99	.13	0	.11	---
12	0	0	1.01	.36	0	0	0	0	.70	.03	0	.01	---
13	0	0	.07	0	0	0	0	0	0	.23	0	.01	---
14	0	0	0	0	0	0	0	0	0	0	0	.01	---
15	0	0	.01	0	0	0	0	0	0	0	0	.01	---
16	0	.03	0	0	2.07	0	0	0	0	0	.10	0	---
17	0	.09	0	.03	0	0	0	0	0	0	0	.08	---
18	0	0	0	.10	0	0	0	0	0	0	0	0	---
19	0	0	0	0	0	0	0	0	0	0	.04	0	---
20	0	0	0	0	0	0	0	0	0	0	1.83	0	---
21	0	0	0	0	0	0	0	0	0	1.85	0	0	---
22	0	0	0	0	0	0	0	0	.50	.97	0	0	---
23	0	0	0	0	.20	0	0	0	.24	0	.01	0	---
24	0	0	.01	0	.28	0	0	0	.05	0	0	.26	---
25	0	0	0	0	.01	0	0	0	0	0	0	0	---
26	0	0	2.11	0	1.83	.01	0	0	0	.87	0	0	---
27	.04	0	.02	.34	.48	0	0	.13	0	0	0	0	---
28	0	0	0	0	0	0	0	.33	.04	0	0	0	---
29	0	---	0	0	.73	0	0	0	.09	0	0	.29	---
30	0	---	0	.43	.01	0	.33	0	0	0	.03	.01	---
31	0	---	0	---	0	---	.88	0	---	0	---	.01	---
Total	.26	.16	3.62	1.26	5.61	.02	1.63	.46	4.20	5.03	2.90	2.00	27.15
Mean	.01	.01	.12	.04	.18	0	.05	.01	.14	.16	.10	.06	.07
Maximum	.19	.09	2.11	.43	2.07	.01	.88	.33	.99	1.85	1.83	1.12	2.11
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6. Evapotranspiration during August–December 2006 calculated by using the eddy covariance method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	---	---	---	---	---	---	---	---	0.01	0.02	0.05	0.01	---
2	---	---	---	---	---	---	---	---	.01	.03	.02	.01	---
3	---	---	---	---	---	---	---	---	.01	.04	.04	.01	---
4	---	---	---	---	---	---	---	---	.01	.03	.01	.01	---
5	---	---	---	---	---	---	---	---	.04	.04	.02	.01	---
6	---	---	---	---	---	---	---	---	.07	.03	.04	.01	---
7	---	---	---	---	---	---	---	---	.06	.02	.07	.01	---
8	---	---	---	---	---	---	---	---	.04	.03	.04	.02	---
9	---	---	---	---	---	---	---	---	.03	.02	.03	.01	---
10	---	---	---	---	---	---	---	---	.02	.04	.04	.02	---
11	---	---	---	---	---	---	---	---	.05	.10	.04	.01	---
12	---	---	---	---	---	---	---	---	.08	.06	.02	.06	---
13	---	---	---	---	---	---	---	---	.09	.04	.02	.02	---
14	---	---	---	---	---	---	---	---	.08	.03	.04	.03	---
15	---	---	---	---	---	---	---	---	.06	.06	.05	.02	---
16	---	---	---	---	---	---	---	---	.05	.08	.02	.02	---
17	---	---	---	---	---	---	---	0.01	.06	.06	.02	.02	---
18	---	---	---	---	---	---	---	.02	.11	.06	.01	0	---
19	---	---	---	---	---	---	---	.03	.14	.07	.02	.01	---
20	---	---	---	---	---	---	---	.02	.11	.06	.02	---	---
21	---	---	---	---	---	---	---	.02	.09	.03	.01	---	---
22	---	---	---	---	---	---	---	.03	.08	.04	.01	---	---
23	---	---	---	---	---	---	---	.02	.06	.03	.01	---	---
24	---	---	---	---	---	---	---	.02	.05	.02	.02	---	---
25	---	---	---	---	---	---	---	.01	.07	.02	.01	---	---
26	---	---	---	---	---	---	---	.01	.05	.07	.01	---	---
27	---	---	---	---	---	---	---	.02	.05	.11	.01	---	---
28	---	---	---	---	---	---	---	.02	.04	.07	.01	---	---
29	---	---	---	---	---	---	---	.01	.04	.06	.01	---	---
30	---	---	---	---	---	---	---	.01	.04	.04	.03	---	---
31	---	---	---	---	---	---	---	.01	---	.04	---	---	---
Total[a]	---	---	---	---	---	---	---	.25	1.71	1.45	.77	.31	4.48
Mean	---	---	---	---	---	---	---	.02	.06	.05	.03	.02	.03
Maximum	---	---	---	---	---	---	---	.03	.14	.11	.07	.06	.14
Minimum	---	---	---	---	---	---	---	.01	.01	.02	.01	0	0

[a] Totals might not equal sum of respective values because of rounding.

Table 7. Evapotranspiration during January–December 2007 calculated by using the eddy covariance method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	---	0.02	0.05	0.16	0.13	0.19	0.18	0.26	0.21	0.11	0.04	0.02	---
2	---	.02	.04	.11	.05	.16	.16	.22	.13	.09	.04	.05	---
3	---	.03	.03	.10	.14	.21	.10	.21	.05	.11	.04	.05	---
4	---	.02	.02	.12	.13	.24	.06	.23	.06	.11	.04	.03	---
5	---	.03	.03	.16	.09	.16	.20	.21	.16	.10	.04	e.02	---
6	---	.03	.02	.12	.05	.17	.11	.23	.22	.09	.04	---	---
7	---	.02	.02	.01	.14	.17	.15	.21	.21	.08	.02	---	---
8	---	.02	.02	.08	.19	.18	.17	.23	.20	.07	.03	---	---
9	---	.02	.02	.05	.12	.20	.21	.21	.22	.06	.04	---	---
10	---	.01	.03	.10	.21	.17	.24	.23	.19	.07	.03	---	---
11	---	.02	.01	.21	.19	.21	.22	.23	.09	.08	.03	---	---
12	0.01	.03	.08	.15	.18	.17	.19	.22	.18	.09	.03	---	---
13	.01	.04	.03	.12	.20	.19	.23	.21	.18	.07	.02	---	---
14	---	.03	.06	.18	.19	.20	.15	.26	.20	.06	.04	---	---
15	---	.02	.09	.17	.18	.18	.23	.18	.17	.06	.04	---	---
16	---	.02	.07	.10	.14	.10	.24	.03	.18	.04	.03	---	---
17	---	.03	.07	.11	.15	.18	.14	.19	.14	.07	.01	---	---
18	---	.02	.03	.16	.12	.18	.15	.22	.13	.09	.02	---	---
19	---	.02	.05	.12	.12	.18	.12	.22	.15	.08	.04	.01	---
20	.01	.01	.04	.13	.07	.04	.08	.24	.12	.06	.03	.04	---
21	.05	.06	.05	.08	.10	.15	.09	.21	.13	.06	.06	.02	---
22	.03	.03	.04	.03	.10	.05	.22	.12	.13	.07	.03	.03	---
23	.02	.01	.04	.09	.14	.13	.22	.22	.15	.06	.02	.01	---
24	---	.05	.06	.04	.12	.15	.07	.24	.13	.07	.03	.01	---
25	---	.03	.04	.26	.12	.21	.12	.19	.12	.05	.05	.01	---
26	.03	.03	.09	.21	.14	.19	.17	.16	.13	.05	.04	.02	---
27	.05	.02	.06	.12	.07	.20	.20	.22	.12	.05	.03	.01	---
28	.03	.02	.10	.10	.19	.06	.17	.16	.12	.04	.03	.02	---
29	.02	---	.04	.11	.20	.14	.04	.14	.07	.04	.03	.01	---
30	.02	---	.05	.08	.20	.23	.17	.16	.11	.04	.02	.01	---
31	.02	---	.18	---	.18	---	.22	.12	---	.04	---	.02	---
Total[a]	.30	.72	1.56	3.59	4.35	5.00	5.01	6.17	4.38	2.19	.97	.40	34.62
Mean	.02	.03	.05	.12	.14	.17	.16	.20	.15	.07	.03	.02	.10
Maximum	.05	.06	.18	.26	.21	.24	.24	.26	.22	.11	.06	.05	.26
Minimum	.01	.01	.01	.01	.05	.04	.04	.03	.05	.04	.01	.01	.01

[a] Totals might not equal sum of respective values because of rounding.

Table 8. Evapotranspiration during January–December 2008 calculated by using the eddy covariance method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0.01	0.02	0.01	0.04	0.05	0.04	0.02	0.05	0.13	0.04	0.02	0.01	---
2	.01	.01	0	.02	.06	.04	.04	.06	.13	.03	.02	0	---
3	0	.01	.02	.03	.05	.04	.10	.06	.12	.03	.02	.02	---
4	0	.02	.02	.04	.03	.03	.09	.05	.13	.03	.01	.01	---
5	.02	.03	.01	.04	.06	.03	.07	.04	.11	.02	.01	.01	---
6	.01	.02	.03	.04	.10	.04	.06	.08	.10	.04	.04	.01	---
7	.01	.01	.06	.04	.08	.03	.05	.06	.09	.04	.02	0	---
8	.04	.01	.03	.04	.07	.04	.06	.05	.09	.03	.02	0	---
9	.01	.01	0	.03	.05	.03	.11	.04	.07	.02	.01	.02	---
10	.02	0	.05	.07	.05	.04	.09	.03	.07	.02	.01	.06	---
11	.01	.01	.06	.06	.07	.03	.07	.03	.11	.01	.01	.03	---
12	.02	.02	e.04	.04	.04	.03	.07	.06	.09	.02	.03	.03	---
13	.01	.02	e.04	.04	.04	.03	.05	.13	.10	.06	.01	.01	---
14	.01	0	e.03	.04	.06	.03	.06	.09	.08	.04	.02	.02	---
15	0	.01	.03	.04	.10	.03	.06	.07	.07	.05	.02	.02	---
16	.01	.04	.01	.03	.14	.03	.05	.07	.07	.08	.01	.01	---
17	.01	.05	.01	.05	.08	.02	.05	.08	.07	.06	.01	.02	---
18	.01	.02	.04	.10	.08	.03	.04	.06	.06	.04	.01	.02	---
19	.04	.01	.07	.08	.09	.02	.04	.15	.06	.04	.01	.02	---
20	.02	.01	.04	.04	.05	.04	.04	.17	.05	.03	.01	.02	---
21	.03	.01	.03	.02	.07	.03	.04	.14	.05	.04	.01	.03	---
22	.04	.03	.02	.05	.07	.02	.05	.08	.04	.03	.01	.01	---
23	.01	.01	.02	.04	.06	.03	.03	.03	.05	.03	0	.02	---
24	.04	.03	.04	.04	.04	.02	.06	.15	.04	.02	.04	.04	---
25	.02	.02	.02	.03	.05	.02	.14	.15	.05	.02	.02	.01	---
26	.02	.01	.03	.10	.04	.02	.15	.17	.05	.02	0	.01	---
27	.02	.01	.03	.04	.03	.02	.12	.12	.04	.06	.01	.02	---
28	.01	0	.01	.08	.04	.03	.11	.12	.04	.03	.01	.03	---
29	.05	.01	.04	.06	.04	.02	.08	.07	.04	.02	.02	.01	---
30	.01	---	.03	.04	.03	.03	.06	.14	.03	.02	.01	.01	---
31	.07	---	.02	---	.02	---	.08	.14	---	.02	---	.01	---
Total[a]	.57	.46	.90	1.44	1.85	.89	2.14	2.74	2.23	1.02	.45	.55	15.24
Mean	.02	.02	.03	.05	.06	.03	.07	.09	.07	.03	.02	.02	.04
Maximum	.07	.05	.07	.10	.14	.04	.15	.17	.13	.08	.04	.06	.17
Minimum	0	0	0	.02	.02	.02	.02	.03	.03	.01	0	0	0

[a] Totals might not equal sum of respective values because of rounding.

Table 9. Evapotranspiration during January–December 2009 calculated by using the eddy covariance method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0.01	0.02	0.01	0.04	0.06	0.14	0.03	0.15	0.02	0.06	---	0	---
2	.01	.01	.01	.06	.04	.19	.04	.12	.02	.08	---	.06	---
3	.02	.01	0	.04	.07	.17	.02	.10	.02	.03	---	.02	---
4	.01	0	0	.04	.05	.15	.02	.08	.01	---	---	.03	---
5	.02	.01	.01	.05	.04	.15	.02	.07	.02	---	0.07	.03	---
6	.07	0	.01	.03	.05	.14	.03	.06	.02	---	.07	.02	---
7	.03	0	0	.04	.05	.13	.11	.05	.01	---	.06	.01	---
8	.02	0	.01	.04	.05	.10	.06	.04	.02	---	.03	.02	---
9	.01	.02	0	.07	.05	.11	.06	.03	.03	---	.06	.04	---
10	.02	.01	0	.04	.04	.08	.04	.02	.07	---	.07	.03	---
11	.01	.01	.03	.02	.04	.09	.03	.04	.06	---	.08	.01	---
12	.01	0	.03	.13	.04	.09	.03	.02	.12	---	.07	.03	---
13	.01	.02	.04	.07	.04	.10	.03	.03	.12	---	.07	.04	---
14	.01	.02	.04	.06	.03	.09	.03	.03	.12	---	.06	.03	---
15	0	.01	.04	.05	.03	.07	.02	.02	.13	---	.03	.02	---
16	0	.01	.06	.02	.04	.07	.03	.02	.12	---	.10	.01	---
17	0	.02	.04	.04	.12	.06	.02	.02	.12	---	.07	.03	---
18	.03	.04	.03	.08	.14	.05	.02	.01	.09	---	.07	.02	---
19	.01	.03	.03	.08	.12	.05	.02	.02	.11	---	.03	.03	---
20	.01	.01	.03	.06	.11	.05	.02	.01	.09	---	.03	.03	---
21	.01	.01	.03	.05	.11	.06	.02	.02	.10	---	.08	.02	---
22	.01	.01	.02	.07	.09	.05	.03	.02	.06	---	.06	.01	---
23	0	.01	e.01	.04	.10	.05	.03	.02	.04	---	.04	.01	---
24	.01	.01	e.03	.04	.12	.05	.02	.01	.05	---	.07	.06	---
25	0	.01	e.02	.04	.14	.05	.02	.02	.12	---	.06	.03	---
26	.01	.01	e.03	.03	.17	.06	.02	.02	.11	---	.04	.02	---
27	.02	.02	e.08	.04	.18	.04	.01	.02	.11	---	.04	.03	---
28	.03	.01	.07	.07	.20	.04	.01	.11	.10	---	.04	.03	---
29	.01	---	.06	.06	.17	.04	.01	.09	.11	---	.03	.01	---
30	.01	---	.05	.05	.19	.03	.03	.05	.08	---	.03	.03	---
31	.01	---	.05	---	.18	---	.09	.03	---	---	---	.06	---
Total[a]	.46	.33	.87	1.55	2.84	2.55	1.01	1.34	2.20	.17	1.46	.80	15.57
Mean	.01	.01	.03	.05	.09	.08	.03	.04	.07	.06	.06	.03	.05
Maximum	.07	.04	.08	.13	.20	.19	.11	.15	.13	.08	.10	.06	.20
Minimum	0	0	0	.02	.03	.03	.01	.01	.01	.03	.03	0	0

[a] Totals might not equal sum of respective values because of rounding.

Table 10. Evapotranspiration during August–December 2006 calculated by using the Bowen ratio closure method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	---	---	---	---	---	---	---	---	0.02	0.03	0.04	0.01	---
2	---	---	---	---	---	---	---	---	.02	.04	.02	0	---
3	---	---	---	---	---	---	---	---	.02	.04	.04	.01	---
4	---	---	---	---	---	---	---	---	.02	.04	.01	.01	---
5	---	---	---	---	---	---	---	---	.05	.04	.02	.01	---
6	---	---	---	---	---	---	---	---	.08	.03	.03	.01	---
7	---	---	---	---	---	---	---	---	.07	.02	.06	.01	---
8	---	---	---	---	---	---	---	---	.03	.03	.04	.01	---
9	---	---	---	---	---	---	---	---	.03	.02	.04	.01	---
10	---	---	---	---	---	---	---	---	.03	.04	.04	0	---
									0	0	0	0	
11	---	---	---	---	---	---	---	---	.05	.09	.04	0	---
12	---	---	---	---	---	---	---	---	.07	.06	.02	.05	---
13	---	---	---	---	---	---	---	---	.10	.02	.02	.02	---
14	---	---	---	---	---	---	---	---	.09	.02	.03	.01	---
15	---	---	---	---	---	---	---	---	.07	.05	.04	.01	---
16	---	---	---	---	---	---	---	---	.06	.09	.02	.01	---
17	---	---	---	---	---	---	---	---	.06	.06	.02	.01	---
18	---	---	---	---	---	---	---	0.02	.11	.05	.01	.01	---
19	---	---	---	---	---	---	---	.03	.14	.06	.02	0	---
20	---	---	---	---	---	---	---	.02	.12	.05	.02	---	---
21	---	---	---	---	---	---	---	.02	.11	.03	.01	---	---
22	---	---	---	---	---	---	---	.03	.11	.04	.01	---	---
23	---	---	---	---	---	---	---	.02	.07	.03	.01	---	---
24	---	---	---	---	---	---	---	.02	.04	.01	.02	---	---
25	---	---	---	---	---	---	---	.01	.08	.01	.01	---	---
26	---	---	---	---	---	---	---	.03	.07	.06	.01	---	---
27	---	---	---	---	---	---	---	.02	.06	.08	.01	---	---
28	---	---	---	---	---	---	---	.03	.06	.07	.01	---	---
29	---	---	---	---	---	---	---	.02	.05	.05	.01	---	---
30	---	---	---	---	---	---	---	.02	.05	.04	.02	---	---
31	---	---	---	---	---	---	---	.02	---	.04	---	---	---
Total[a]	---	---	---	---	---	---	---	.31	1.93	1.36	.71	.19	4.49
Mean	---	---	---	---	---	---	---	.02	.06	.04	.02	.01	.03
Maximum	---	---	---	---	---	---	---	.03	.14	.09	.06	.05	.14
Minimum	---	---	---	---	---	---	---	.01	.02	.01	.01	0	0

[a] Totals might not equal sum of respective values because of rounding.

Table 11. Evapotranspiration during January–December 2007 calculated by using the Bowen ratio closure method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	---	0.03	0.04	0.16	0.13	0.20	0.16	0.23	0.18	0.10	0.04	0.02	---
2	---	.02	.03	.10	.05	.16	.16	.20	.12	.09	.04	.06	---
3	---	.02	.03	.09	.13	.21	.09	.18	.04	.11	.04	.05	---
4	---	.03	.03	.12	.14	.23	.05	.21	.05	.11	.04	.03	---
5	---	.03	.03	.14	.09	.16	.18	.20	.13	.10	.04	e.02	---
6	---	.03	.02	.11	.05	.18	.10	.23	.19	.10	.03	---	---
7	---	.03	.02	.01	.14	.18	.14	.22	.20	.08	.01	---	---
8	---	.02	.02	.05	.19	.18	.17	.22	.18	.07	.02	---	---
9	---	.01	.02	.03	.13	.20	.21	.20	.19	.07	.03	---	---
10	---	.01	.03	.08	.22	.19	.25	.21	.17	.08	.03	---	---
11	---	0	0	.18	.22	.21	.22	.21	.09	.08	.03	---	---
12	0.01	.02	.08	.15	.19	.17	.18	.21	.16	.09	.03	---	---
13	.02	.04	.01	.14	.21	.19	.24	.18	.15	.08	.02	---	---
14	---	.02	.06	.17	.21	.19	.14	.21	.17	.07	.03	---	---
15	---	.02	.08	.14	.19	.17	.21	.16	.15	.06	.03	---	---
16	---	.03	.08	.09	.14	.10	.21	.04	.15	.04	.03	---	---
17	---	.03	.07	.10	.16	.16	.13	.16	.13	.08	.01	---	---
18	---	.02	.03	.16	.10	.20	.11	.21	.12	.08	.02	---	---
19	---	.02	.05	.12	.11	.18	.10	.20	.13	.08	.03	.01	---
20	.01	.01	.04	.14	.06	.03	.07	.21	.09	.07	.02	.04	---
21	.04	.06	.04	.08	.09	.13	.07	.19	.13	.05	.04	.02	---
22	.02	.03	.03	.03	.09	.04	.22	.10	.13	.06	.02	.03	---
23	.01	.01	.03	.06	.14	.12	.21	.18	.13	.06	.01	.01	---
24	---	.05	.04	.04	.10	.12	.06	.20	.13	.07	.02	.01	---
25	---	.03	.03	.24	.12	.20	.09	.17	.12	.05	.04	.01	---
26	.03	.03	.07	.19	.14	.19	.14	.15	.12	.04	.03	.02	---
27	.05	.03	.05	.10	.06	.19	.19	.19	.12	.05	.02	.01	---
28	.03	.02	.11	.09	.19	.03	.16	.14	.11	.04	.02	.02	---
29	.02	---	.04	.11	.21	.13	.03	.10	.08	.04	.03	.01	---
30	.02	---	.05	.08	.22	.21	.15	.16	.11	.04	.01	.01	---
31	.02	---	.17	---	.19	---	.21	.10	---	.04	---	.02	---
Total[a]	.30	.70	1.44	3.30	4.37	4.87	4.63	5.57	3.93	2.18	.80	.40	32.49
Mean	.03	.02	.05	.11	.14	.16	.15	.18	.13	.07	.03	.02	.09
Maximum	.05	.06	.17	.24	.22	.23	.25	.23	.20	.11	.04	.06	.25
Minimum	.01	0	0	.01	.05	.03	.03	.04	.04	.04	.01	.01	0

[a] Totals might not equal sum of respective values because of rounding.

Table 12. Evapotranspiration during January–December 2008 calculated by using the Bowen ratio closure method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0.01	0.02	0.01	0.04	0.05	0.05	0.02	0.05	0.14	0.04	0.02	0.01	---
2	.01	.01	.01	.02	.07	.05	.07	.06	.13	.03	.02	.01	---
3	0	.01	.02	.03	.06	.05	.10	.06	.13	.03	.02	.02	---
4	0	.02	.02	.05	.03	.04	.09	.06	.13	.03	.02	.01	---
5	.01	.03	.01	.04	.07	.03	.07	.05	.12	.02	.01	0	---
6	.01	.02	.03	.04	.10	.04	.06	.09	.10	.03	.03	.01	---
7	.01	.01	.05	.04	.07	.04	.05	.06	.10	.04	.02	0	---
8	.03	.01	.03	.04	.06	.04	.05	.05	.09	.03	.02	0	---
9	.01	.01	.01	.03	.06	.03	.11	.05	.07	.02	.01	.02	---
10	.02	0	.04	.07	.06	.04	.09	.04	.07	.02	.01	.04	---
11	.01	.01	.06	.06	.07	.03	.08	.04	.10	.02	.01	.03	---
12	.02	.02	e.03	.04	.04	.04	.07	.05	.11	.01	.03	.02	---
13	.01	.01	e.03	.04	.05	.03	.06	.14	.12	.05	.02	.02	---
14	0	0	e.03	.04	.06	.04	.07	.09	.08	.03	.02	.02	---
15	0	.01	.03	.04	.10	.03	.07	.08	.05	.04	.01	.02	---
16	.01	.03	.01	.04	.13	.03	.06	.06	.07	.07	.01	.01	---
17	.01	.05	.02	.05	.08	.03	.06	.06	.07	.06	.01	0	---
18	.01	.02	.04	.10	.09	.04	.05	.07	.05	.04	.01	.01	---
19	.04	.01	.08	.08	.09	.02	.04	.16	.06	.04	.01	.02	---
20	.01	0	.04	.05	.06	.04	.04	.16	.06	.03	.01	.02	---
21	.01	.01	.03	.02	.08	.04	.05	.14	.05	.04	.01	.02	---
22	.03	.03	.03	.06	.07	.03	.04	.07	.05	.04	0	0	---
23	.01	.01	.01	.04	.07	.03	.04	.01	.05	.03	0	.01	---
24	.03	.03	.03	.05	.05	.03	.05	.14	.05	.02	.02	.02	---
25	.01	.02	.02	.03	.07	.03	.13	.15	.05	.02	.01	0	---
26	.03	.02	.04	.11	.05	.02	.14	.17	.05	.02	0	.01	---
27	.02	.01	.03	.04	.04	.03	.13	.13	.04	.06	.02	.02	---
28	.01	.01	.01	.08	.05	.03	.11	.11	.05	.03	.01	.02	---
29	.04	.01	.04	.07	.05	.02	.08	.07	.05	.02	.02	.01	---
30	.01	---	.03	.05	.03	.03	.06	.14	.04	.02	.01	.01	---
31	.05	---	.02	---	.03	---	.09	.14	---	.02	---	.01	---
Total[a]	.45	.46	.90	1.50	2.00	1.01	2.23	2.76	2.35	1.02	.44	.42	15.54
Mean	.01	.02	.03	.05	.06	.03	.07	.09	.08	.03	.01	.01	.04
Maximum	.05	.05	.08	.11	.13	.05	.14	.17	.14	.07	.03	.04	.17
Minimum	0	0	.01	.02	.03	.02	.02	.01	.04	.01	0	0	0

[a] Totals might not equal sum of respective values because of rounding.

Table 13. Evapotranspiration during January–December 2009 calculated by using the Bowen ratio closure method at U.S. Geological Survey meteorological station 290810099212100 in southwest Medina County near D'Hanis, Texas.

[---, not collected or calculated or not applicable; e, estimated]

Day	Evapotranspiration (inches)												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual summary
1	0.01	0.02	0.01	0.04	0.07	0.15	0.03	0.14	0.02	0.06	---	0.01	---
2	.01	.02	.01	.06	.05	.19	.04	.10	.03	.07	---	.05	---
3	.02	.01	.01	.05	.08	.17	.03	.09	.02	.03	---	.01	---
4	.01	0	.01	.05	.05	.17	.03	.08	.01	---	---	.03	---
5	.01	.01	.01	.05	.05	.15	.03	.07	.02	---	0.07	.03	---
6	.05	.01	.01	.02	.06	.15	.04	.07	.02	---	.06	.01	---
7	.04	.01	.01	.04	.05	.14	.11	.05	.02	---	.06	.01	---
8	.02	.01	.01	.05	.06	.11	.06	.04	.02	---	.02	.02	---
9	.01	.02	.01	.07	.06	.11	.06	.03	.03	---	.06	.03	---
10	.02	.01	0	.04	.05	.09	.04	.03	.06	---	.09	.03	---
11	.02	.02	.03	.02	.04	.10	.04	.04	.05	---	.08	0	---
12	.01	.01	.02	.14	.05	.10	.03	.03	.10	---	.06	.01	---
13	.02	.01	.02	.08	.05	.11	.04	.03	.11	---	.07	.03	---
14	.01	.01	.03	.06	.03	.10	.03	.04	.13	---	.06	.01	---
15	0	0	.04	.05	.04	.08	.02	.03	.14	---	.03	.02	---
16	0	0	.06	.01	.04	.08	.03	.02	.14	---	.09	.01	---
17	0	.01	.04	.05	.13	.07	.03	.02	.13	---	.07	.02	---
18	.03	.04	.03	.09	.13	.06	.02	.02	.10	---	.06	.02	---
19	.02	.03	.03	.09	.12	.06	.03	.03	.10	---	.02	.03	---
20	.01	.01	.03	.07	.11	.05	.03	.02	.09	---	.02	.02	---
21	.01	.02	.03	.06	.10	.06	.02	.02	.11	---	.07	.02	---
22	.01	.01	.03	.07	.09	.06	.04	.02	.06	---	.05	.01	---
23	.01	.01	e.01	.05	.12	.06	.04	.02	.02	---	.04	.01	---
24	.01	.01	e.03	.04	.11	.06	.03	.02	.03	---	.07	.05	---
25	.01	.01	e.01	.05	.14	.05	.03	.02	.11	---	.07	.02	---
26	.01	.01	e.02	.03	.16	.06	.02	.02	.11	---	.04	.02	---
27	.01	.02	e.06	.04	.18	.04	.02	.03	.11	---	.04	.03	---
28	.03	.01	.07	.07	.19	.04	.02	.09	.10	---	.04	.03	---
29	.01	---	.06	.06	.16	.04	.01	.08	.11	---	.03	.01	---
30	.01	---	.05	.05	.19	.03	.03	.04	.08	---	.02	.02	---
31	.01	---	.06	---	.18	---	.08	.02	---	---	---	.05	---
Total[a]	.44	.35	.83	1.61	2.95	2.75	1.09	1.36	2.20	.16	1.39	.67	15.80
Mean	.01	.01	.03	.05	.10	.09	.04	.04	.07	.05	.05	.02	.05
Maximum	.05	.04	.07	.14	.19	.19	.11	.14	.14	.07	.09	.05	.19
Minimum	0	0	0	.01	.03	.03	.01	.02	.01	.03	.02	0	0

[a] Totals might not equal sum of respective values because of rounding.

Publishing support provided by
Lafayette Publishing Service Center

Information regarding water resources in Texas is available at
http://tx.usgs.gov/

Slattery, Asquith, and Ockerman—Rainfall and Evapotranspiration Data for Southwest Medina County, Texas, August 2006–December 2009—DS 554