Prepared in collaboration with the University of Oklahoma, Oklahoma State University, and the U.S. Environmental Protection Agency

Stable-Isotope Ratios of Hydrogen and Oxygen in Precipitation at Norman, Oklahoma, 1996–2008

Scientific Investigations Report 2011–5262

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By Jeanne B. Jaeschke, Martha A. Scholl, Isabelle M. Cozzarelli, Jason R. Masoner, Scott Christenson, and Haiping Qi

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Conversion Factors and Abbreviations

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
Volume		
liter (L)	33.82	ounce, fluid (fl. oz)
milliliter (mL)	0.0338	ounce, fluid (fl. oz)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m ³)	264.2	gallon (gal)
cubic decimeter (dm ³)	0.2642	gallon (gal)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)

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

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

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

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

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Vertical Datum of 1988 (NAVD 88).”

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Datum of 1983 (NAD 83).”

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

Per mil: A unit expressing the ratio of stable-isotopic abundances of an element in a sample to those of a standard material.

Additional Abbreviations Used in this Report

$\delta^2\text{H}$	relative difference of hydrogen isotope ratios
$\delta^{18}\text{O}$	relative difference of oxygen isotope ratio
GMWL	Global Meteoric Water Line
LMWL	Local Meteoric Water Line
NWIS	National Water Information System
P	precipitation sample volume
per mil, ‰	1/1,000
SLAP	Standard Light Antarctic Precipitation
USGS	U.S. Geological Survey
VWA	volume-weighted average
VSMOW	Vienna Standard Mean Ocean Water

Stable-Isotope Ratios of Hydrogen and Oxygen in Precipitation at Norman, Oklahoma, 1996–2008

By Jeanne B. Jaeschke, Martha A. Scholl, Isabelle M. Cozzarelli, Jason R. Masoner, Scott Christenson, and Haiping Qi

Abstract

Precipitation samples for measurement of stable-isotope ratios of hydrogen ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$) were collected at the Norman Landfill Research Site in Norman, Oklahoma, from May 1996 to October 2008. Rainfall amounts also were measured at the site (U.S. Geological Survey gaging station 07229053) during the collection period. The $\delta^2\text{H}$ of precipitation samples ranged from -121.9 to $+8.3$ per mil, and the $\delta^{18}\text{O}$ of precipitation ranged from -16.96 to $+0.50$ per mil. The volume-weighted average values for $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of precipitation over the 12-year measurement period were -31.13 per mil for $\delta^2\text{H}$ and -5.57 per mil for $\delta^{18}\text{O}$. Average summer-season $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of precipitation usually were more positive (enriched in the heavier isotopes) than winter values.

Introduction

The U.S. Geological Survey (USGS) began multidisciplinary investigations in 1994 at the Norman Landfill (fig. 1), as part of the Toxic Substances Hydrology Program (<http://toxics.usgs.gov>), in collaboration with scientists at the University of Oklahoma, Oklahoma State University, and the U.S. Environmental Protection Agency. The Norman Landfill is a closed municipal solid waste landfill on the Canadian River alluvial plain in the southern part of Norman, Okla.; the landfill does not have a liner or leachate-collection system. The landfill accepted solid waste from about 1922 to 1985 then was closed and capped with a clayey soil (Christenson and Cozzarelli, 2003). Cumulative precipitation samples were collected at intervals from 1 to 4 weeks, but usually biweekly (every 2 weeks), at the landfill from May 1996 through October 2008. These samples were analyzed for relative isotope ratios of hydrogen ($^2\text{H}/^1\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$), abbreviated hereafter as $\delta^2\text{H}$ and $\delta^{18}\text{O}$. Some of these data have been previously reported in Scholl and others (1999), Schlottman and others (1999), Scholl and others (2005), and Masoner and others (2008).

Stable-isotope ratios of hydrogen and oxygen in precipitation were measured at the Norman Landfill Research Site. These data can be useful for investigations involving (1) regional average precipitation isotope values, (2) distinguishing variations in local climate patterns, (3) hydrologic tracers of recharge and groundwater-surface water interactions and (4) water-balance calculations.

This report provides $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of precipitation collected at the Norman Landfill Research Site from May 1996 through October 2008, as well as rainfall amounts for that period from gaging station 07229053 Canadian River tributary at Norman. Volume-weighted average $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of precipitation collected during the entire monitoring period and by season during that period also are presented.

Methods

Precipitation Sample Collection

Precipitation samples for stable-isotope analysis were collected from May 1996 through October 2008 on top of the east landfill mound (east cell), which rises approximately 13 meters (m) above the surrounding land surface at the Norman Landfill Research Site (fig. 1). Precipitation samples were collected at intervals from 1 to 4 weeks, but usually biweekly (every 2 weeks). Snow was infrequent at the site, and any snow falling on the precipitation collector was added to each precipitation sample when the snow melted. Snow catch was affected by wind; thus, snow contribution to a cumulative sample may have been underrepresented. The collector location was $35^\circ 09' 57'' \text{ N}$; $97^\circ 26' 36'' \text{ W}$ (Universal Transverse Mercator Zone 14; 641765 East, 3892536 North). Rainfall amounts were measured by a tipping-bucket rain gage at the USGS streamflow-gaging station 07229053 Canadian River tributary at Norman, Okla. (fig. 1), which was approximately 386 m from the precipitation sample collector. Daily

Figure 1. Location of the Norman Landfill, Oklahoma.

precipitation amounts measured at this and other sites are available online from the USGS National Water Information system (NWIS) at <http://waterdata.usgs.gov/nwis/rt>.

Precipitation samples for stable-isotope analysis were collected in a funnel/bottle collector. The bottle contained a 2-centimeter (cm) layer of mineral oil to prevent sample evaporation. The funnel was about 20 cm in diameter, with tubing from the funnel stem inserted into the top of a 2-liter (L) collection bottle. The top of the funnel was 2.2 m above the ground. At the end of each sampling period, mineral oil was separated from water samples by using one of three methods: (1) a separatory funnel, (2) a valve cap placed on the collection bottle so that the bottle functioned as a separatory funnel, or (3) sample water was pumped slowly from underneath the oil layer. Samples were filtered by using a small funnel holding two qualitative paper filters to remove residual oil and debris into 30- or 60-milliliter (mL) glass bottles with cone shaped Poly-Seal™ caps. In the sampling process, the total volume of water from the collection bottle was measured with a graduated cylinder and recorded. For 14 of the 290 samples, the collection bottle overfilled during the sampling period so either no analysis was done or the analysis that was done represented only part of the precipitation for those sampling periods (appendix 1).

Measurement and Analysis of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of Precipitation Samples

Measurement of $\delta^2\text{H}$ in the precipitation samples was done by the Pt-Hokko-bead equilibration technique with a VG Micromass 602 dual inlet isotope-ratio mass spectrometer (DI-IRMS) (Révész and Coplen, 2008a), with each analysis requiring 1.5 mL of sample. Measurement of $\delta^{18}\text{O}$ in the samples was done by the carbon dioxide (CO_2)-water equilibration technique by using a DuPont dual inlet double-focusing mass spectrometer, which measured, alternatively, the isotope-number ratios of the unknown CO_2 gas derived from the sample and of the “working reference” CO_2 gas (Révész and Coplen, 2008b), with each analysis requiring 2 mL of water. The stable-isotope ratio of a sample is expressed as a delta value, and is defined for hydrogen as

$$\delta^2\text{H} = \frac{\left(\frac{{}^2\text{H}}{{}^1\text{H}}\right)_s - \left(\frac{{}^2\text{H}}{{}^1\text{H}}\right)_{std}}{\left(\frac{{}^2\text{H}}{{}^1\text{H}}\right)_{std}} \quad (1)$$

where s is the sample and std is the laboratory standard. Oxygen isotope delta values are calculated in the same way, except the isotopes are $^{18}\text{O}/^{16}\text{O}$. Stable isotope values are reported in parts per thousand, or per mil (‰), so the value is multiplied by 1,000.

Volume-weighted average (VWA) isotopic compositions of water samples were calculated for both $\delta^2\text{H}$ and $\delta^{18}\text{O}$ by the equation

$$VWA = \frac{\sum_{i=1}^n (P_i * \delta_i)}{\sum_{i=1}^n P_i} \quad (2)$$

where

δ_i is the $\delta^{18}\text{O}$ or $\delta^2\text{H}$ value of the sample (per mil),

P_i is the measured sample volume, in milliliters, and

n is the total number of samples over which the summation ($i = 1$ to n) was performed.

Quality Assurance

Laboratory reference waters, deionized water, and Antarctic water (highly depleted in $\delta^2\text{H}$), were analyzed with the precipitation samples. The precision goal was standard deviation of sample groups of less than ± 1.55 per mil (‰). The local laboratory reference waters were calibrated with the international measurement standards Vienna Standard Mean Ocean Water (VSMOW) and Standard Light Antarctic Precipitation (SLAP) (Coplen, 1988; Coplen, 1994), having international consensus $\delta^2\text{H}$ values of 0‰ and -428 ‰, and $\delta^{18}\text{O}$ values of 0‰ and -55.5 ‰, respectively.

Duplicates of all samples were analyzed on different days. Different Pt-Hokko-bead rods and ports typically were used for analysis of duplicates, minimizing errors caused by misidentification and any other analytical problems. If hydrogen-isotope values of the duplicates did not agree within acceptable tolerances (± 1 ‰), the samples were reanalyzed until acceptable tolerances were met. For each batch of samples, a graph was made of $\delta^2\text{H}$ plotted in relation to $\delta^{18}\text{O}$. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of naturally occurring waters normally have high correlations.

Stable-Isotope Ratios of Hydrogen and Oxygen in Precipitation at Norman, Oklahoma, 1996–2008

The climate of Oklahoma is continental, with warm moist air periodically moving northward from the Gulf of Mexico. Summers are long and hot; winters are shorter, with infrequent periods of extreme cold. Maximum precipitation typically falls in late spring in most of the State east of the panhandle (Arndt, 2002). On average, more precipitation falls in May than in any other month across 90 percent of Oklahoma (Arndt, 2002).

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There typically is a secondary maximum of precipitation in September in most of the State (Arndt, 2002).

On average, more precipitation falls during the nighttime hours, whereas the greatest rainfall intensities occur during late afternoon in Oklahoma (Carr, 1999). The character of precipitation also varies by season. Precipitation in winter (November through March) tends to be widespread stratiform precipitation and is usually associated with synoptic or large-scale storm systems (Carr, 1999). Precipitation in the summer (April through October) is almost entirely convective in nature, produced by mesoscale complexes and thunderstorms (Carr, 1999). The transition seasons of spring and autumn have both convective and stratiform precipitation (Loehrer and Johnson, 1995). Much of the precipitation during the transition seasons is associated with systems of moderate to severe thunderstorms.

From October 1996 through September 2008, the annual average precipitation at the Norman Landfill Research Site was 851 mm/yr, and the average number of days with precipitation in each year was 75. Variation in daily precipitation amount is shown in figure 2, and monthly precipitation amounts are shown in figure 3 and table 1.

For the precipitation samples collected from May 1996 through October 2008 the $\delta^2\text{H}$ ranged from -121.9 to $+8.3$ ‰

and $\delta^{18}\text{O}$ ranged from -16.96 to $+0.50$ ‰ (appendix 1). The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for the sampling period are shown in figure 4 with the Global Meteoric Water Line (GMWL) ($\delta^2\text{H} = 8.2 \delta^{18}\text{O} + 11.3$; Rozanski and others, 1993) and Local Meteoric Water Line (LMWL) ($\delta^2\text{H} = 7.32 \delta^{18}\text{O} + 9.5$, best-fit line to the data). The volume-weighted average isotope values of precipitation at the Norman Landfill Research Site for the sampling period were -31.13 ‰ for $\delta^2\text{H}$ and -5.57 ‰ for $\delta^{18}\text{O}$ (appendix 1). Figures 5 and 6 illustrate the range of values of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ observed at the Norman Landfill Research Site during each sample period.

Because of high transpiration rates, summer precipitation in some areas at the landfill site does not recharge the groundwater system (Scholl and others, 2005; Scholl and others, 2006). For use in future groundwater studies involving isotopes, seasonal volume-weighted average values of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of precipitation for each year of the sampling period were calculated and are listed in appendix 2 and shown in figures 7 and 8. Seasonal values are volume-weighted averages for the summer growing season (April–October) and for the winter (November–March). Both $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values in precipitation were greater in summer than in winter samples, with the exception of one year, 1998.

Figure 2. Frequency distribution of daily precipitation amounts in millimeters at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008.

Figure 3. Monthly precipitation at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008.

Figure 4. Precipitation isotope data collected at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008, and the global and local meteoric water lines.

Figure 5. Ratio of hydrogen isotopes ($\delta^2\text{H}$) measured in precipitation samples collected at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008.

Figure 6. Ratio of oxygen isotopes ($\delta^{18}\text{O}$) measured in precipitation samples collected at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008.

Figure 7. Annual seasonal average ratio of hydrogen isotopes ($\delta^2\text{H}$) of precipitation samples collected at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, in summer and winter seasons, 1996–2008.

Figure 8. Annual seasonal average ratio of oxygen isotopes ($\delta^{18}\text{O}$) of precipitation samples collected at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, in summer and winter seasons, 1996–2008.

Table 1. Monthly precipitation at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, April 1996 through October 2008.

[mm, millimeters]

Month and year	Monthly precipitation (mm)	Month and year	Monthly precipitation (mm)
May 1996	31	November 1999	0.4
June 1996	9	December 1999	80
July 1996	17	January 2000	21
August 1996	93	February 2000	45
September 1996	41	March 2000	90
October 1996	26		
		April 2000	89
November 1996	132	May 2000	57
December 1996	2	June 2000	199
January 1997	6	July 2000	46
February 1997	89	August 2000	0
March 1997	27	September 2000	2
		October 2000	218
April 1997	145		
May 1997	138	November 2000	110
June 1997	140	December 2000	54
July 1997	18	January 2001	71
August 1997	68	February 2001	35
September 1997	0	March 2001	20
October 1997	101		
		April 2001	44
November 1997	80	May 2001	211
December 1997	115	June 2001	10
January 1998	116	July 2001	12
February 1998	20	August 2001	77
March 1998	175	September 2001	90
		October 2001	66
April 1998	84		
May 1998	31	November 2001	12
June 1998	33	December 2001	54
July 1998	6	January 2002	52
August 1998	13	February 2002	53
September 1998	137	March 2002	48
October 1998	67		
		April 2002	118
November 1998	43	May 2002	50
December 1998	36	June 2002	97
January 1999	41	July 2002	92
February 1999	38	August 2002	52
March 1999	89	September 2002	86
		October 2002	88
April 1999	191		
May 1999	90	November 2002	20
June 1999	159	December 2002	60
July 1999	22	January 2003	2
August 1999	11	February 2003	40
September 1999	73	March 2003	76
October 1999	66		

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Table 1. Monthly precipitation at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, April 1996 through October 2008—Continued.

[mm, millimeters]

Month and year	Monthly precipitation (mm)	Month and year	Monthly precipitation (mm)
April 2003	58	April 2006	97
May 2003	41	May 2006	54
June 2003	159	June 2006	33
July 2003	14	July 2006	40
August 2003	120	August 2006	74
September 2003	71	September 2006	58
October 2003	23	October 2006	81
November 2003	27	November 2006	46
December 2003	21	December 2006	94
January 2004	48	January 2007	138
February 2004	47	February 2007	44
March 2004	86	March 2007	196
April 2004	52	April 2007	57
May 2004	10	May 2007	250
June 2004	199	June 2007	293
July 2004	113	July 2007	184
August 2004	81	August 2007	156
September 2004	26	September 2007	51
October 2004	150	October 2007	0
November 2004	139	November 2007	20
December 2004	20	December 2007	27
January 2005	52	January 2008	4
February 2005	52	February 2008	16
March 2005	18	March 2008	76
April 2005	7	April 2008	112
May 2005	62	May 2008	138
June 2005	86	June 2008	194
July 2005	60	July 2008	13
August 2005	108	August 2008	218
September 2005	50	September 2008	44
October 2005	60	October 2008	38
November 2005	0		
December 2005	7		
January 2006	8		
February 2006	9		
March 2006	66		

¹ This precipitation is the total from May 11–31, the period of sample collection.

Summary

Precipitation samples were collected systematically from May 1996 through October 2008 at the Norman Landfill Research Site in Norman, Oklahoma, for determination of stable-isotope ratios of hydrogen ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$). The $\delta^2\text{H}$ of the precipitation samples ranged from -121.9 to $+8.3\text{‰}$, and the $\delta^{18}\text{O}$ ranged from -16.96 to $+0.50\text{‰}$. Volume-weighted average values of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ of precipitation at the site for the 12-year collection period were -31.13‰ for $\delta^2\text{H}$ and -5.57‰ for $\delta^{18}\text{O}$. The local meteoric water line, calculated from those data, is $\delta^2\text{H} = 7.32 \delta^{18}\text{O} + 9.5$. Isotopic composition of the precipitation samples varied with season. With few exceptions, average summer (April through October) $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of precipitation were greater than winter values (November through March).

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Appendixes 1–2

14 Stable-Isotope Ratios of Hydrogen and Oxygen in Precipitation at Norman, Oklahoma, 1996–2008

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008.

[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-01	91	-13.7	-2.9	05/10/96	05/22/96	12
NLFP-02	1,400	-31.3	-5.26	05/22/96	06/03/96	22
NLFP-03	900	-15.3	-3.39	06/03/96	06/19/96	6
NLFP-04	149	-2.2	-.82	06/19/96	07/03/96	7
NLFP-05	890	-30.3	-5.42	07/03/96	07/12/96	10
NLFP-06	1,670	-20.9	-4.22	07/12/96	07/31/96	ND
NLFP-07	2,340	-13.5	-3.59	07/31/96	08/15/96	60
NLFP-09	498	-36.7	-5.92	08/15/96	08/29/96	33
NLFP-11	--	--	--	08/29/96	09/10/96	0
NLFP-12	570	-54.6	-8.43	09/10/96	09/18/96	28
NLFP-13	950	-25.9	-5.03	09/18/96	09/25/96	11
NLFP-14	900	-45.9	-7.44	09/25/96	10/11/96	ND
NLFP-15	250	-52.2	-8.74	10/11/96	10/25/96	ND
NLFP-16	2,000	-21.4	-4.77	10/25/96	11/08/96	102
NLFP-17	303	-17.4	-4.46	11/08/96	11/22/96	20
NLFP-18	530	-59.9	-9.87	11/22/96	12/05/96	36
NLFP-19	--	--	--	12/05/96	12/20/96	0
NLFP-20	--	--	--	12/20/96	01/03/97	.5
NLFP-21	74	-76.9	-11.67	01/03/97	01/16/97	5
NLFP-22	--	--	--	01/16/97	01/30/97	0
NLFP-23	310	-121.9	-16.96	01/30/97	02/14/97	24
NLFP-24	900	-34.8	-5.94	02/14/97	03/05/97	66
NLFP-25	59	+6.4	-1.44	03/05/97	03/13/97	6
NLFP-26	410	-27.3	-5.34	03/13/97	03/27/97	19
NLFP-27	1,200	-35.7	-6.46	03/27/97	04/10/97	51
NLFP-28	1,002	-55.5	-8.43	04/10/97	04/23/97	45
NLFP-29	1,595	-54.4	-8.44	04/23/97	05/07/97	73
NLFP-30	1,384	-33.8	-5.76	05/07/97	05/22/97	59
NLFP-32	1,220	-31.2	-5.21	05/22/97	06/05/97	54
² NLFP-34	2,500	-25.8	-4.95	06/05/97	06/16/97	124
NLFP-36	435	-33.2	-5.59	06/16/97	07/02/97	16
NLFP-37	150	-14.9	-3.17	07/02/97	07/17/97	6
NLFP-38	288	-16.4	-3.69	07/17/97	07/31/97	13
NLFP-39	1,469	-9.2	-2.9	07/31/97	08/14/97	68
NLFP-40	1,380	-19.8	-4.06	08/14/97	08/28/97	ND
NLFP-41	50	+5.1	-.61	08/28/97	09/11/97	ND
NLFP-42	1,861	-17.6	-3.74	09/11/97	09/25/97	ND
NLFP-43	216	+3	-2.52	09/25/97	10/09/97	11
NLFP-44	1,580	-8.6	-3.06	10/09/97	10/23/97	89
NLFP-45	372	-31.8	-6.51	10/23/97	11/06/97	ND

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008—Continued.

[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-46	892	-73.8	-11.87	11/06/97	11/20/97	40
NLFP-47	1,240	-26.4	-5.66	11/20/97	12/03/97	58
NLFP-48	290	-51.5	-9.48	12/03/97	12/18/97	12
NLFP-49	2,150	-61.8	-10.06	12/18/97	01/02/98	84
² NLFP-50	2,225	-43.2	-7.53	01/02/98	01/13/98	87
NLFP-51	164	-61.4	-9.94	01/13/98	01/29/98	7
NLFP-52	791	-25.7	-5.8	01/29/98	02/12/98	29
NLFP-53	360	-83.5	-12.16	02/12/98	02/26/98	12
NLFP-54	1,034	-54.8	-8.39	02/26/98	03/12/98	40
NLFP-55	2,338	-23.6	-5.6	03/12/98	03/17/98	109
NLFP-56	461	--	-8.86	03/17/98	03/26/98	21
¹ NLFP-57	--	--	--	03/26/98	04/09/98	10
NLFP-58	238	-56.1	-8.93	04/09/98	04/23/98	9
NLFP-59	1,647	-30.5	-6.18	04/23/98	04/27/98	70
NLFP-60	44	-105.0	-14.14	04/27/98	05/07/98	.3
NLFP-61	1,330	-8.8	-3.01	05/07/98	05/21/98	9
NLFP-62	592	-10.5	-2.89	05/21/98	06/04/98	22
NLFP-63	735	-20.9	-3.6	06/04/98	06/18/98	33
NLFP-64	--	--	--	06/18/98	07/02/98	0
NLFP-65	--	--	--	07/02/98	07/16/98	6
NLFP-66	175	-8.9	-1.78	07/16/98	07/30/98	ND
NLFP-67	215	-7.3	-1.5	07/30/98	08/17/98	10
NLFP-68	--	--	--	08/17/98	08/27/98	0
NLFP-69	195	-12.0	-2.19	08/27/98	09/10/98	3
NLFP-70	1,870	-98.6	-13.7	09/10/98	09/15/98	85
NLFP-71	1,265	-34.8	-5.73	09/15/98	09/25/98	52
NLFP-72	1,195	-31.4	-5.72	09/25/98	10/07/98	34
NLFP-73	815	-30.3	-5.09	10/07/98	10/28/98	32
NLFP-74	1,488	-28.4	-5.94	10/28/98	11/03/98	ND
NLFP-75	324	-24.9	-5.84	11/03/98	11/24/98	23
NLFP-76	1,078	-27.7	-5.44	11/24/98	12/16/98	49
NLFP-77	212	-21.5	-5.53	12/16/98	01/05/99	6
NLFP-78	--	--	--	01/05/99	01/20/99	0
NLFP-79	1,104	-62.7	-9.64	01/20/99	02/04/99	41
NLFP-80	112	-21.3	-4.25	02/04/99	02/10/99	34
NLFP-81	679	-20.3	-4.61	02/10/99	02/25/99	4
NLFP-82	670	-9.9	-3.61	02/25/99	03/11/99	28
NLFP-83	1,240	-24.1	-5.10	03/11/99	03/18/99	55
NLFP-84	363	-11.9	-2.99	03/18/99	04/01/99	5
NLFP-85	2,370	-13.3	-3.44	04/01/99	04/28/99	191

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008—Continued.

[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-86	1,035	-22.0	-4.02	04/28/99	05/12/99	43
NLFP-87	1,387	-3.2	.00	05/12/99	06/14/99	69
NLFP-88	1,738	-15.0	-3.74	06/14/99	06/23/99	125
NLFP-89	735	-25.7	-4.66	06/23/99	07/19/99	34
NLFP-90	441	-13.0	-3.98	07/19/99	08/10/99	11
NLFP-91	--	--	--	08/10/99	08/30/99	0
NLFP-92	2,377	-38.5	-6.73	08/30/99	09/14/99	ND
NLFP-93	375	-4.4	-1.98	09/14/99	10/05/99	83
NLFP-94	67	-14.7	-2.75	10/05/99	10/18/99	3
NLFP-95	1,165	-39.3	-7.69	10/18/99	11/02/99	54
NLFP-96	--	--	--	11/02/99	12/02/99	9
NLFP-97	1,375	-28.5	-6.07	12/02/99	12/09/99	70
NLFP-98	413	-49.3	-8.45	12/09/99	01/05/00	4
NLFP-99	511	-91.9	-13.06	01/05/00	01/31/00	17
NLFP-100	--	--	--	01/31/00	02/10/00	0
NLFP-101	753	-26.7	-4.78	02/10/00	02/24/00	33
NLFP-102	1,104	-8.6	-2.77	02/24/00	03/14/00	50
NLFP-103	825	-20.5	-4.42	03/14/00	03/27/00	41
NLFP-104	499	-12.9	-3.44	03/27/00	04/06/00	28
NLFP-105	748	-22.8	-4.99	04/06/00	04/19/00	33
NLFP-106	1,005	-11.8	-2.82	04/19/00	05/03/00	42
NLFP-107	22	-27.5	-4.35	05/03/00	05/24/00	.3
NLFP-108	1,758	-29.9	-5.07	05/24/00	06/08/00	79
NLFP-109	1,098	-30.6	-5.63	06/08/00	06/19/00	90
NLFP-110	2,380	-25.6	-4.77	06/19/00	06/29/00	84
NLFP-111	1,703	-35.2	-5.3	06/29/00	07/05/00	ND
NLFP-112	787	-31.8	-5.9	07/05/00	07/25/00	ND
NLFP-113	200	+8.3	+4.7	07/25/00	08/09/00	10
NLFP-114	--	--	--	08/09/00	08/31/00	0
NLFP-115	1,172	-58.8	-9.02	08/31/00	09/26/00	ND
NLFP-116	28	-27.4	-5.48	09/26/00	10/12/00	3
NLFP-117	990	-33.6	-6.49	10/12/00	10/17/00	44
NLFP-118	1,463	-22.2	-5.26	10/17/00	10/23/00	68
NLFP-119	1,610	-14.4	-4.04	10/23/00	10/26/00	63
NLFP-120	1,970	-33.8	-6.16	10/26/00	11/07/00	100
NLFP-121	1,200	-61.5	-10.25	11/07/00	11/27/00	51
NLFP-122	745	-59.5	-9.86	11/27/00	12/20/00	28
NLFP-123	610	-64.2	-10.42	12/20/00	01/04/01	39
NLFP-124	1,182	-44.9	-7.97	01/04/01	01/31/01	57
NLFP-125	1,674	-20.3	-4.16	01/31/01	02/26/01	33

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008—Continued.

[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-126	275	-43.7	-6.86	02/26/01	03/21/01	17
NLFP-127	55	-47.0	-8.54	03/21/01	04/06/01	5
NLFP-128	1,205	-5.9	-2.20	04/06/01	04/26/01	44
NLFP-129	1,015	-40.4	-6.05	04/26/01	05/10/01	48
NLFP-130	2,025	-24.9	-4.51	05/10/01	05/29/01	97
NLFP-131	1,455	-14.9	-3.32	05/29/01	06/27/01	66
NLFP-132	206	+2	-1.04	06/27/01	06/28/01	2
NLFP-133	40	-9.2	-2.85	06/28/01	07/02/01	8
NLFP-134	1,085	-9.4	-2.53	07/02/01	08/15/01	47
NLFP-135	211	-28.5	-3.35	08/15/01	08/25/01	34
NLFP-136	655	-20.4	-3.26	08/25/01	08/27/01	8
NLFP-137	2,225	-27.7	-5.07	08/27/01	09/17/01	53
NLFP-138	2,067	-24.8	-5.27	09/17/01	09/21/01	31
NLFP-139	1,405	-34.6	-6.21	09/21/01	10/22/01	66
NLFP-140	355	-9.1	-3.68	10/22/01	11/07/01	5
NLFP-141	336	-27.9	-5.91	11/07/01	12/12/01	17
NLFP-142	1,019	-79.2	-11.05	12/12/01	01/03/02	44
NLFP-143	689	-41.7	-6.79	01/03/02	01/28/02	24
NLFP-144	896	-50.3	-7.86	01/28/02	02/11/02	66
NLFP-145	90	-26.7	-4.85	02/11/02	02/21/02	15
NLFP-146	40	-26.3	-5.72	02/21/02	03/07/02	.3
NLFP-147	959	-47.1	-6.60	03/07/02	03/25/02	45
NLFP-148	1,525	-18.3	-4.27	03/25/02	04/10/02	70
NLFP-149	670	-42.7	-6.35	04/10/02	04/15/02	31
NLFP-150	425	-12.7	-2.25	04/15/02	05/02/02	20
NLFP-151	70	+5.9	-.58	05/02/02	05/13/02	5
² NLFP-152	>2,390	-24.2	-4.73	05/13/02	06/17/02	142
NLFP-153	740	-23.8	-4.50	06/17/02	07/02/02	37
NLFP-154	555	-12.8	-2.45	07/02/02	07/23/02	21
NLFP-155	655	-16.0	-3.40	07/23/02	08/11/02	33
NLFP-156	1,071	-7.2	-2.10	08/11/02	08/29/02	52
NLFP-157	990	-23.0	-5.41	08/29/02	09/17/02	41
NLFP-158	985	-43.1	-7.40	09/17/02	09/23/02	45
NLFP-159	940	-68.4	-9.90	09/23/02	10/10/02	ND
NLFP-160	2,375	-66.0	-10.39	10/10/02	11/04/02	104
NLFP-161	18	-65.0	-8.97	11/04/02	11/26/02	4
NLFP-162	1,365	-73.1	-11.21	11/26/02	12/23/02	59
NLFP-163	32	-36.8	-6.52	12/23/02	01/09/03	1
NLFP-164	--	--	--	01/09/03	01/15/03	2
NLFP-165	25	-48.6	-8.72	01/15/03	01/28/03	.3

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008—Continued.

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Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-166	380	-89.3	-13.34	01/28/03	02/13/03	21
NLFP-167	480	-68.8	-10.29	02/13/03	03/06/03	19
NLFP-168	900	-31.8	-5.12	03/06/03	03/18/03	36
NLFP-169	815	-60.4	-8.98	03/18/03	03/13/03	ND
NLFP-170	620	-11.8	-3.31	03/13/03	04/05/03	68
NLFP-171	535	-21.9	-4.68	04/05/03	04/22/03	53
NLFP-172	38	-2.9	-1.82	04/22/03	04/30/03	4
NLFP-173	575	-18.5	-3.78	04/30/03	05/22/03	41
NLFP-174	310	-27.3	-4.90	05/22/03	06/03/03	15
NLFP-175	790	-47.6	-7.32	06/03/03	06/05/03	47
NLFP-176	705	-71.4	-10.14	06/05/03	06/10/03	61
NLFP-177	937	-28.8	-5.34	06/10/03	06/11/03	12
NLFP-178	406	-5.8	-1.25	06/11/03	06/25/03	18
NLFP-179	255	-18.7	-3.48	06/25/03	07/15/03	9
NLFP-180	1,166	-12.0	-2.88	07/15/03	08/11/03	31
NLFP-181	280	-16.2	-3.09	08/11/03	08/28/03	15
NLFP-182	1,500	-34.0	-6.22	08/28/03	09/02/03	ND
NLFP-183	480	-25.3	-4.13	09/02/03	10/08/03	81
NLFP-184	162	-19.5	-3.84	10/08/03	10/23/03	12
NLFP-185	182	-1.9	-2.88	10/23/03	11/10/03	13
NLFP-186	218	-24.2	-4.97	11/10/03	11/20/03	16
NLFP-187	470	-29.2	-7.55	11/20/03	12/15/03	18
NLFP-188	31	-5.9	-2.36	12/15/03	01/08/04	2
NLFP-189	112	-21.2	-3.94	01/08/04	01/15/04	6
NLFP-190	937	-72.7	-10.57	01/15/04	01/20/04	37
NLFP-191	112	-34.0	-6.28	01/20/04	01/26/04	5
NLFP-192	420	-46.0	-8.74	01/26/04	02/03/04	19
NLFP-193	172	-37.1	-7.39	02/03/04	02/10/04	8
NLFP-194	495	-38.9	-6.92	02/10/04	03/01/04	20
NLFP-195	1,509	-9.9	-3.40	03/01/04	03/04/04	68
NLFP-196	160	-21.0	-3.57	03/04/04	03/11/04	3
NLFP-197	42	+1.6	-1.18	03/11/04	03/24/04	3
NLFP-198	370	-21.4	-4.5	03/24/04	04/08/04	18
NLFP-199	277	-45.1	-7.21	04/08/04	04/14/04	14
NLFP-200	186	-4.1	-1.68	04/14/04	04/22/04	9
NLFP-201	430	-24.1	-3.85	04/22/04	05/04/04	22
NLFP-202	1,520	-31.6	-4.81	05/04/04	06/14/04	122
NLFP-203	1,255	-31.4	-5.56	06/14/04	06/21/04	58
NLFP-204	1,802	-23.5	-3.88	06/21/04	07/07/04	77
NLFP-205	1,860	-25.6	-4.84	07/07/04	07/29/04	64

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[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-206	216	-1.3	-0.50	07/29/04	08/04/04	11
NLFP-207	920	-19.5	-4.51	08/04/04	08/11/04	42
NLFP-208	338	-21.1	-4.58	08/11/04	08/16/04	17
NLFP-209	56	-24	-4.75	08/16/04	08/25/04	4
³ NLFP-210	1,001	-7.0	-2.19	08/25/04	09/22/04	32
³ NLFP-211	1,508	-19.2	-4.41	09/22/04	10/06/04	48
NLFP-212	1,315	-95.8	-13.35	10/06/04	10/12/04	57
NLFP-213	104	-51.3	-7.13	10/12/04	10/28/04	24
NLFP-214	258	-8.6	-2.07	10/28/04	11/08/04	44
NLFP-215	--	--	--	11/08/04	11/18/04	65
NLFP-216	640	-56.6	-9.29	11/18/04	12/01/04	52
NLFP-217	--	--	--	12/01/04	12/20/04	40
NLFP-218	168	-24.9	-5.14	12/20/04	01/10/05	17
NLFP-219	328	-112.3	-15.92	01/10/05	02/04/05	20
NLFP-220	280	-45.9	-8.22	02/04/05	02/08/05	6
NLFP-221	340	-6.3	-3.76	02/08/05	02/16/05	12
NLFP-222	310	-24.1	-4.80	02/16/05	02/25/05	9
NLFP-223	1,125	-95.8	-13.74	02/25/05	03/01/05	86
NLFP-224	870	-40.1	-6.78	03/01/05	06/01/05	60
NLFP-225	460	-11.2	-3.48	06/01/05	07/11/05	49
NLFP-226	--	--	--	07/11/05	10/04/05	214
NLFP-227	480	-11.6	-2.97	10/04/05	10/11/05	30
NLFP-228	220	-24.7	-6.08	10/11/05	12/06/05	12
NLFP-229	450	-38.4	-6.8	12/06/05	03/13/06	29
NLFP-230	1,410	-44.1	-7.34	03/13/06	03/21/06	59
NLFP-231	--	--	--	03/21/06	04/19/06	18
^{1,2} NLFP-232	--	--	--	04/19/06	05/03/06	86
NLFP-233	1,106	-21.6	-4.28	05/03/06	05/11/06	40
NLFP-234	360	-38.5	-5.72	05/11/06	06/01/06	14
NLFP-235	830	-25.1	-4.34	06/01/06	07/06/06	33
NLFP-236	1,060	-14.1	-2.98	07/06/06	07/17/06	34
NLFP-237	700	-11.0	-1.81	07/17/06	08/14/06	29
NLFP-238	700	+1.3	-.26	08/14/06	08/24/06	18
NLFP-239	900	-18.5	-3.76	08/24/06	08/28/06	29
NLFP-240	750	-35.2	-6.31	08/28/06	09/05/06	27
NLFP-241	640	-85.7	-11.82	09/05/06	09/18/06	22
NLFP-242	286	-27.4	-4.42	09/18/06	09/27/06	9
² NLFP-243	>2,200	-46.8	-7.76	09/27/06	10/18/06	81
NLFP-244	840	-24.0	-5.38	10/18/06	11/07/06	28
NLFP-245	490	-24.8	-5.11	11/07/06	11/29/06	18

Appendix 1. Measurements of sample volume, ratios of hydrogen and oxygen isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$), collection dates, and precipitation amounts from the precipitation-isotope collector and from the tipping bucket gage at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, May 10, 1996 through October 28, 2008—Continued.

[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
³ NLFP-246	2,147	-31.6	-6.07	11/29/06	12/21/06	68
³ NLFP-247	826	-32.5	-5.55	12/21/06	01/05/07	26
^{3,2} NLFP-248	>2200	-41.6	-7.16	01/05/07	01/23/07	129
³ NLFP-249	1,508	-65.2	-9.64	01/23/07	02/21/07	48
³ NLFP-250	1,373	-19.6	-4.02	02/21/07	03/20/07	44
NLFP-251	--	--	--	03/20/07	03/30/07	156
³ NLFP-252	1,365	-38.3	-5.92	03/30/07	04/02/07	ND
NLFP-253	118	-2.2	-3.07	04/02/07	04/18/07	43
² NLFP-254	>2,200	-24.1	-4.28	04/18/07	05/08/07	175
NLFP-255	405	-15.0	-3.1	05/08/07	05/15/07	11
NLFP-256	2,100	-20.5	-4.02	05/15/07	05/29/07	66
NLFP-257	1,210	-26.6	-4.18	05/29/07	06/11/07	41
² NLFP-258	>2,200	-19.3	-3.74	06/11/07	06/26/07	179
² NLFP-259	>2,200	-40.0	-6.33	06/26/07	07/09/07	126
² NLFP-260	>2,200	-24.4	-4.18	07/09/07	07/10/07	74
NLFP-261	2,100	-28.8	-4.87	07/10/07	08/01/07	69
² NLFP-262	>2,200	-56.6	-8.52	08/01/07	08/02/07	ND
NLFP-263	1,200	-36.6	-6.20	08/21/07	09/12/07	37
NLFP-264	310	-14.6	+5.0	09/12/07	09/26/07	13
NLFP-265	2,100	-19.7	-4.38	09/26/07	10/16/07	ND
NLFP-266	500	-47.9	-8.25	10/16/07	10/26/07	ND
NLFP-267	475	-72.4	-11.07	10/26/07	12/05/07	23
NLFP-268	2,150	-21.4	-4.64	12/05/07	12/18/07	19
NLFP-269	200	-49.9	-9.15	12/18/07	01/23/08	9
NLFP-270	240	-29.1	-5.59	01/23/08	02/08/08	11
NLFP-271	1,005	-35.5	-6.43	02/08/08	02/19/08	6
NLFP-272	900	-41.2	-7.03	02/19/08	03/04/08	22
NLFP-273	1,480	-29.4	-5.02	03/04/08	03/19/08	43
² NLFP-274	>2,200	-16.4	-3.82	03/19/08	04/11/08	110
NLFP-275	1,790	-10.1	-2.99	04/11/08	05/07/08	88
NLFP-276	1,600	-43.8	-7.20	05/07/08	05/19/08	23
NLFP-277	1,295	-28.9	-4.82	05/19/08	05/27/08	40
² NLFP-278	>2,200	-47.7	-7.77	05/27/08	06/09/08	98
² NLFP-279	>2,200	-30.6	-5.55	06/09/08	06/25/08	79
NLFP-280	600	-12.2	-2.40	06/25/08	07/11/08	20
NLFP-281	300	-6.6	-1.12	07/11/08	08/01/08	10
² NLFP-282	>2,200	-32.8	-5.44	08/01/08	08/11/08	91
NLFP-283	500	-45.1	-7.71	08/11/08	08/15/08	16
² NLFP-284	>2,200	-31.5	-5.85	08/15/08	08/19/08	104
NLFP-285	400	-28.3	-5.04	08/19/08	09/04/08	8

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[mL, milliliters; $\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil; ND, no data; mm, millimeters; --, collection periods with no sample; >, greater than]

Sample identifier	Sample volume (mL)	$\delta^2\text{H}$ (‰)	$\delta^{18}\text{O}$ (‰)	Start date	End date	Precipitation amount (mm)
NLFP-286	1,100	-22.0	-4.68	09/04/08	09/10/08	33
NLFP-287	400	-32.1	-5.42	09/10/08	09/15/08	10
NLFP-288	500	-13.2	-3.85	09/15/08	10/14/08	20
NLFP-289	560	-13.6	-3.71	10/14/08	10/23/08	18
NLFP-290	1,800	-24.2	-5.02	10/23/08	10/28/08	ND
Volume-weighted average (VWA)		-31.1	-5.57			

¹ Data not used because sample was a duplicate, a control, or evaporated due to lack of oil layer.

² Collector overflowed.

³ Volume not measured, estimated from rainfall.

22 Stable-Isotope Ratios of Hydrogen and Oxygen in Precipitation at Norman, Oklahoma, 1996–2008

Appendix 2. Annual volume-weighted average deuterium and oxygen-18 ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) values during summer and winter seasons from the precipitation isotope collector at U.S. Geological Survey streamflow-gaging station 07229053 Canadian River tributary at Norman, Oklahoma, 1996–2008.

[$\delta^2\text{H}$ ‰, ratio of hydrogen isotopes, in per mil; $\delta^{18}\text{O}$ ‰, ratio of oxygen isotopes, in per mil]

Collection year(s)	$\delta^2\text{H}$ (o/oo)	$\delta^{18}\text{O}$ (o/oo)
Summer season (April through October)		
1996	-26.49	-4.95
1997	-27.12	-5.06
1998	-38.54	-6.42
1999	-19.09	-3.86
2000	-27.48	-5.16
2001	-23.02	-4.40
2002	-26.49	-4.92
2003	-27.99	-5.00
2004	-30.62	-5.25
2005	-25.20	-4.93
2006	-30.32	-5.14
2007	-29.89	-5.07
2008	-28.07	-5.20
Winter season (November through March)		
1996–97	-36.07	-6.51
1997–98	-42.76	-7.92
1998–99	-29.92	-5.90
1999–2000	-32.35	-6.15
2000–01	-42.18	-7.37
2001–02	-49.21	-7.59
2002–03	-63.36	-9.78
2003–04	-32.31	-6.25
2004–05	-60.80	-9.59
2005–06	-40.81	-7.09
2006–07	-36.63	-6.44
2007–08	-33.12	-5.99