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Dry Season Mean Monthly Flow and Harmonic Mean Flow Regression Equations for Selected Ungaged Basins in Arkansas

Scientific Investigations Report 2015–5031
Version 1.1, July 2015

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U.S. Geological Survey

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meters per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Datum

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).

Abbreviations

ADEQ	Arkansas Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
MLR	multiple-linear-regression
NPDES	National Pollutant Discharge Elimination System
NRMSE	normalized root mean square error
NWIS	National Water Information System
OLS	ordinary-least-squares
PBIAS	percent bias
QAH	harmonic mean flow
R^2	coefficient of determination
RSE	residual standard error
USGS	U.S. Geological Survey
WLS	weighted-least-squares

Dry Season Mean Monthly Flow and Harmonic Mean Flow Regression Equations for Selected Ungaged Basins in Arkansas

By Brian K. Breaker

Abstract

The U.S. Geological Survey, in cooperation with the Arkansas Department of Environmental Quality, Southwestern Energy, the Arkansas Natural Resources Commission, and the Arkansas Game and Fish Commission, developed regression equations for estimation of dry season mean monthly flows and harmonic mean flows that are representative of natural streamflow conditions at selected ungaged basins in Arkansas. Observed values of dry season mean monthly flow and harmonic mean flow computed from daily-mean flow data were used with basin characteristics to identify significant explanatory variables for multiple-linear-regression equations to estimate predicted values of dry season mean monthly flow and harmonic mean flow. Five dry season mean monthly flow regression equations and two harmonic mean flow regression equations were developed using dry season mean monthly flows and harmonic mean flows established for 91 and 93 U.S. Geological Survey continuous-record streamflow-gaging stations, respectively. The dry season in Arkansas is defined as the months of July through November for this study. For harmonic mean flow calculations and regression equations, the study area is composed of the Springfield-Salem Plateaus (Arkansas and Missouri), Boston Mountains, Arkansas Valley, Ouachita Mountains (Arkansas and Oklahoma), and West Gulf Coastal Plain (Arkansas) physiographic sections. All continuous-record streamflow-gaging stations used to compute dry season mean monthly flows were located within Arkansas.

Equations for two regions were found to be statistically significant for developing regression equations for estimating harmonic mean flows at ungaged basins; thus, equations are applicable only to streams in those respective regions in Arkansas. Regression equations for dry season mean monthly flows are applicable only to streams located throughout Arkansas. All regression equations are applicable only to unaltered streams where flows were not significantly affected by regulation, diversion, or urbanization. The median number of years used for dry season mean monthly flow calculation was 43, and the median number of years used for harmonic mean flow calculations was 34 for region 1 and 43 for region 2.

Introduction

Water use in the State of Arkansas was estimated to be about 11,500 million gallons per day in 2010 (A.L. Pugh and Terrance W. Holland, U.S. Geological Survey, written commun., 2014). Groundwater and surface-water sources comprised 69 percent and 31 percent, respectively, of total water use. Total water use increased in Arkansas by 435 percent between 1965 and 2010 (A.L. Pugh and Terrance W. Holland, U.S. Geological Survey, written commun., 2014). As population and agriculture in Arkansas continue to increase, more stress is placed on streams in the State. The Arkansas Department of Environmental Quality (ADEQ) protects and regulates water resources of Arkansas through various programs (*http://www.adeq.state.ar.us/Default.htm*) involving permitting. Through issuance of National Pollutant Discharge Elimination System (NPDES) permits, the ADEQ is responsible for ensuring waters of the State of Arkansas are suitable for sustaining diverse biological communities and do not simultaneously pose threats to human health. The NPDES permits are required for industrial, municipal, or other facilities that discharge treated wastewater directly to surface waters. The U.S. Environmental Protection Agency (EPA) recommends that the long-term harmonic mean flow be used for assessing potential human health effects because it provides a more conservative estimate than the arithmetic mean flow. The harmonic mean flow is determined by taking the reciprocal of the mean value of the reciprocal of individual values.

The U.S. Geological Survey (USGS), in cooperation with the ADEQ, Southwestern Energy, the Arkansas Natural Resources Commission, and the Arkansas Game and Fish Commission, developed regional regression equations for estimation of dry season mean monthly flows and harmonic mean flows that are representative of natural streamflow conditions, defined as streamflows that are not affected by regulation, diversion, or urbanization (referred to hereinafter as unaltered) at ungaged basins in Arkansas. A continuous-record streamflow-gaging station (referred to hereinafter as a streamflow gage) is a location on a stream where gage height is recorded continuously and for which daily-mean streamflow is computed (Funkhouser and others, 2008).

Dry season mean monthly flows and harmonic mean flows are routinely needed for ungaged streams for water-quality regulation, stream-related structural design, wastewater management, and stream-hazard identification. These two streamflow statistics, in particular, are useful for setting criteria for wastewater-treatment plant effluent and allowable pollutant loads to meet water-quality standards for human health criteria, irrigation, recreation, and wildlife conservation. For the estimation of these two statistics at ungaged streams, regional regression equations were developed using statistical relations that exist between streamflow data collected at streamflow gages and geologic, climatic, physical, and statistical variables for watersheds that contribute flow to a streamflow gage (Eash and Barnes, 2012).

Purpose and Scope

The purpose of this report is to present regression equations for estimation of dry season mean monthly flows and harmonic mean flows (QAH) at ungaged basins in Arkansas. Dry season mean monthly flows and QAH computed from USGS streamflow gages are also presented. Equations developed during this study also are intended for delivery in the USGS StreamStats program (U.S. Geological Survey, 2012a,b). The StreamStats program allows users to select a point on a stream in an interactive map and then automatically delineates the watershed for that point and computes selected statistics for the watershed (Eash and Barnes, 2012). The StreamStats program will provide users the ability to estimate dry season mean monthly flow, QAH, and associated 90 percent prediction intervals for ungaged streams in Arkansas.

Previous Studies

Six studies have been conducted for estimation of low-flow characteristics in Arkansas beginning with Hines (1965). The most recent study by Funkhouser and others (2008) used data collected through the 2005 water year, defined as the period from October 1 of a given year to September 30 of the following year designated by the calendar year in which it ends. Previous reports for low-flow statistics in Arkansas have focused primarily on development of regional regression equations for low-flow frequencies, such as the 7-day, 2-year low flow ($Q_{7,2}$) and the 7-day,10-year low flow ($Q_{7,10}$). No previous studies in Arkansas have developed regional regression equations to estimate dry season mean monthly flow or QAH.

Methods of Analysis for Data from U.S. Geological Survey Continuous-Record Streamflow Gages

Data used for this report are from 113 streamflow gages in Arkansas, Oklahoma, and Missouri (fig. 1); however, streamflow gages from neighboring States were used only for QAH because explanatory variables used in regression equations for dry season mean monthly flow were spatially limited to within Arkansas. Streamflow gages from neighboring States were used to improve the representativeness of QAH and basin characteristics found in the Arkansas border areas and to provide better estimates of the error of the regression equations for ungaged sites near the Arkansas border. Streamflow gages located on unaltered streams (fig. 1; app. 1) with a minimum of 15 water years of daily-mean flows were initially selected for evaluation in the study. However, some gages with 12 water years of daily-mean flow data were added to enhance the spatial distribution of streamflow gages used to develop regression equations. Daily-mean flow data collected through the 2013 water year were retrieved for the 113 streamflow gages from the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2001).

Basin Characteristics

For this study, 47 basin characteristics (app. 2) were evaluated as potential explanatory variables for use in regression equations for estimating dry season mean monthly flow and QAH. The geographic information system (GIS) derived characteristics were selected to represent the varying geologic, climatic, physical, and statistical properties of the watersheds for the 113 streamflow gages.

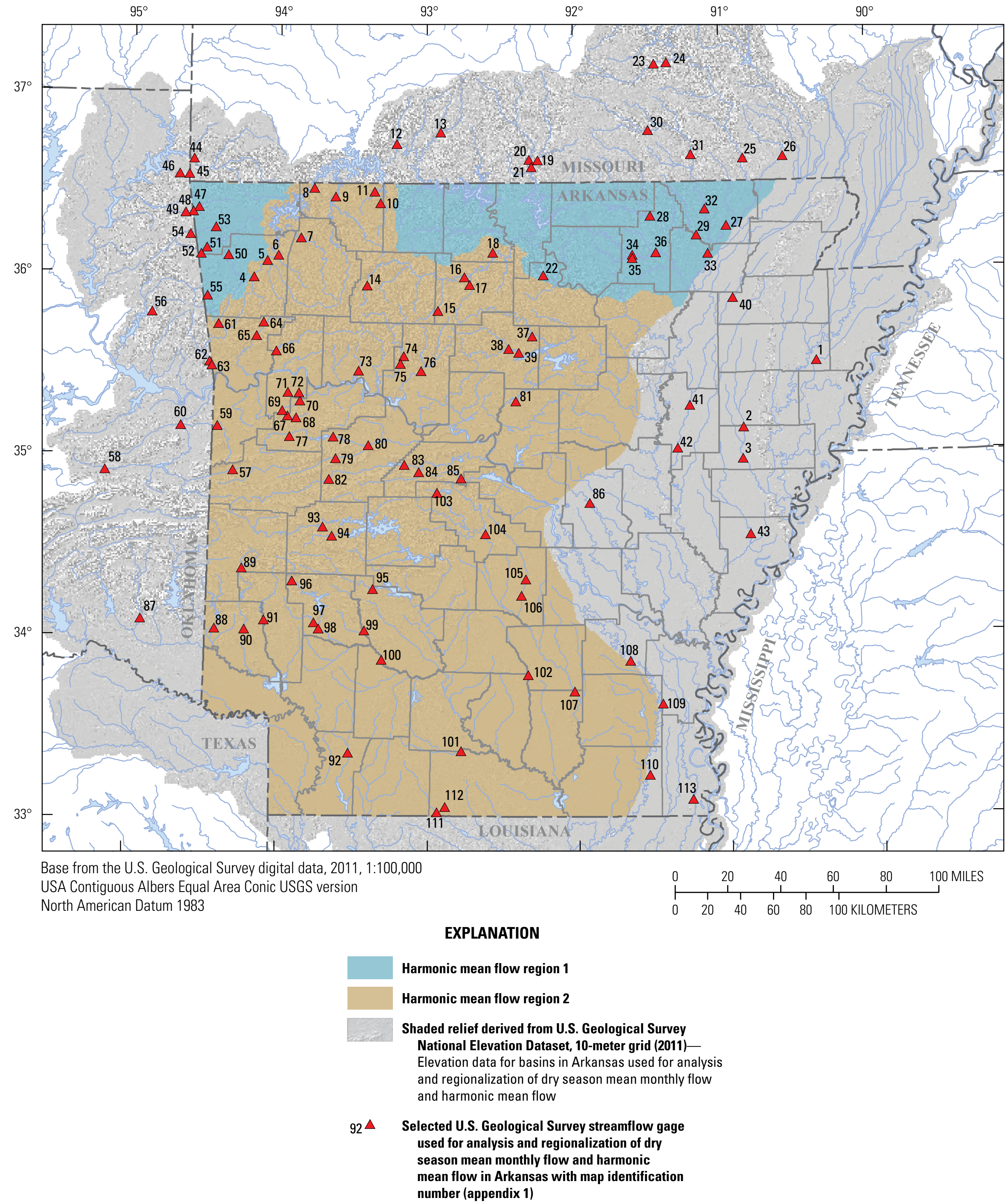

Figure 1. U.S. Geological Survey streamflow gages used for dry season mean monthly flow and harmonic mean flow regressions.

Regression Techniques

Ordinary-least-squares (OLS) regressions were used to develop initial multiple-linear-regression (MLR) equations that were used for the initial analysis of streamflow data. Final equations for regional regressions were developed using weighted-least-squares (WLS) regressions. Logarithmic transformations (base 10) were used on all response variables (mean monthly flow and QAH) and tested for select explanatory variables (table 1) for the final regression equations. Logarithmic transformations were applied based on graphical comparisons of response variables and explanatory variables. Only drainage area was log transformed for the final regression equations. Other transformations were used for select explanatory variables (percent Ordovician and Mississippian) as necessary to increase linearity between the response variable and explanatory variables. The response variable was assumed to be a linear function of the explanatory variables.

MLR equations followed the general form

$$Y_i = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n + e_i \tag{1}$$

where

Y_i is the response variable for site i,
X_1 to X_n are the n explanatory variables for site i,
b_0 to b_n are the n + 1 regression model coefficients, and
e_i is the residual error for site i.

A base-10 logarithmic transformation of the MLR has the form of

$$logY_i = b_0 + b_1logX_1 + b_2logX_2 + \cdots + b_nlogX_n + e_i \tag{2}$$

where

log is the base-10 logarithmic transformation of the variable.

The algebraic equivalence of equation 2 after transformation back to its original units is

$$Y_i = 10^{b0} X_1^{b1} X_2^{b2} \ldots X_n^{bn} 10^{ei} \tag{3}$$

Tasker (1980) reported that OLS regression assumes that the time-sampling variance in the response-variable estimates is the same for each streamflow gage used in the analysis. As a result, this would imply that all observations of the response variable are equally reliable. This assumption is not always satisfied in hydrologic regressions because of the reliability of the record available for computation of the response variable based on the length of the observed streamflow record (Tasker, 1980; Eash and Barnes, 2012). The WLS regression adjusts for the variation in the reliability of the response-variable estimates by using a weight for each streamflow gage to account for differences in the period of record available for computation of the response variable (Eng and others, 2009; Eash and Barnes, 2012).

Table 1. Range of basin characteristic values used to develop dry season mean monthly flow and harmonic mean flow regression equations for unregulated streams in Arkansas.

[Slope1085, slope of channel in feet per mile between points at 10 and 85 percent of the longest flow path from the outlet]

Dry season mean monthly streamflow											
Drainage area						Mean dry season total runoff					
Minimum	First quartile	Median	Mean	Third quartile	Maximum	Minimum	First quartile	Median	Mean	Third quartile	Maximum
4.1	89.0	241	464	528	7,350	3.6	4.0	4.3	4.3	4.6	5.6

Harmonic mean flow region 1																	
Drainage area						Base-flow index						Slope1085					
Minimum	First quartile	Median	Mean	Third quartile	Maximum	Minimum	First quartile	Median	Mean	Third quartile	Maximum	Minimum	First quartile	Median	Mean	Third quartile	Maximum
8.0	99.8	304	779	784	7,350	0.3	0.4	0.5	0.5	0.5	0.7	2.0	7.2	9.2	15.1	17.2	95.8

Harmonic mean flow region 2																	
Drainage area						Base-flow index						Percent Ordovician and Mississippian					
Minimum	First quartile	Median	Mean	Third quartile	Maximum	Minimum	First quartile	Median	Mean	Third quartile	Maximum	Minimum	First quartile	Median	Mean	Third quartile	Maximum
4.1	83.0	210	341	410	2,090	0.1	0.2	0.2	0.3	0.3	0.4	0.0	0.0	6.0	24.8	47.0	100

Candidate regressions were selected for WLS by testing all possible combinations of the 42 explanatory variables (app. 2) using the *allReg()* function contained within the "USGSwsStats" package (Lorenz, 2013b) for R, an integrated suite of software facilities for data manipulation, calculation, and graphical display (R Core Team, 2014). The best candidate regression equations were selected based on the lowest values of Mallow's C_p and analysis of multicollinearity using the variance inflation factor (Helsel and Hirsch, 2002). The WLS regressions were repeatedly performed in R (R Core Team, 2014) to reduce the number of explanatory variables to those significant at the 95-percent confidence interval. Regression diagnostics, including residual standard error, coefficient of determination (R^2), multicollinearity, Cook's D, leverage, and graphical relations (Helsel and Hirsch, 2002), were used to evaluate the performance of WLS regressions.

Dry Season Mean Monthly Flow Data

Daily-mean streamflow data for 91 USGS streamflow gages were used to compute monthly-mean flows. A mean monthly flow is computed as the arithmetic mean of all monthly-mean flows for a given month of the year for a selected period of record for a streamflow gage. A monthly-mean flow is computed as the arithmetic mean of the daily-mean flows for a given month of the year. Regression analysis was performed with ensembles for five critical, dry season months, July through November.

Five regression equations were developed for the calculation of dry season mean monthly flows during the months of July through November. All five equations contain at least one significant explanatory variable (table 1) derived from a previous runoff study in Arkansas (Pugh and Westerman, 2014). The median number of years of record used for calculation of dry season mean monthly flow at the 91 streamflow gages was 43 (app. 1). Equations for estimation of dry season mean monthly flow are applicable only at ungaged, unaltered stream locations in Arkansas.

Harmonic Mean Flow Data

Equations for two regions were found to be statistically significant for developing regression equations for estimating harmonic mean flow at selected ungaged basins in Arkansas. Of the 93 streamflow gages used for QAH (fig. 1; app. 1), 33 and 60 streamflow gages were used for the first and second regions, respectively. The median number of years of data used for QAH calculations in the WLS regression analysis was 34 for region 1 and 43 for region 2 (app. 1). The WLS regression equations used to estimate QAH are applicable only to ungaged, unaltered streams in region 1 and region 2.

For QAH calculations (app. 3), the study area is composed of the Springfield-Salem Plateaus (Arkansas and Missouri), Boston Mountains, Arkansas Valley, Ouachita Mountains (Arkansas and Oklahoma), and West Gulf Coastal Plain (Arkansas) physiographic sections (fig. 2). A QAH value was calculated for all streamflow gages used in the regression equations using the USGS "DVstats" package (Lorenz, 2013a) in R software (R Core Team, 2014), which is based on the EPA's computer program for estimating design flows for use in water-quality studies (DFLOW) (Rossman, 1990b). The QAH statistic generally is smaller than the arithmetic mean statistic, gives more weight to lower flows, and is corrected for daily flow values of zero (Rossman, 1990a). The QAH is calculated as

$$QAH = \left(\frac{N_{nz}}{N_t}\right)\left(\frac{N_{nz}}{\sum_{i=1}^{N_{nz}}\left(\frac{1}{Q_i}\right)}\right) \quad (4)$$

where

Q_i is the daily mean streamflow, in cubic feet per second,

N_{nz} is the number of nonzero days, and

N_t is the total number of Q_i values.

If N_{nz} equals N_t, QAH is equal to the reciprocal of the mean of the reciprocals of all Q_i.

Regionalization of Harmonic Mean Flow Data

Regionalization is a statistical framework used to estimate statistics at ungaged stream locations from statistics calculated at USGS streamflow gages (Ries, 2007). Regionalization techniques are used because streamflow statistics can vary substantially between regions because of differences in geology, climate, and physical characteristics. Regionalization of low-flow statistics in Arkansas was first attempted by Hines (1965). Subsequently, Ludwig and Tasker (1993) divided the western two-thirds of Arkansas into three low-flow regions of well sustained and poorly sustained low flow. Minor changes were made to the existing low-flow statistical regions by Funkhouser and others (2008) attributable to enhanced GIS capabilities for spatial data processing. No regional methods for mean flow estimation have been developed for Arkansas prior to this study.

Streamflow gages used for QAH were located on streams in Arkansas, Oklahoma, or Missouri. An initial OLS regression was performed on all gages selected for inclusion in a statewide regression analysis. Residuals from the statewide OLS regression were spatially analyzed and indicated the need for equations in two regions.

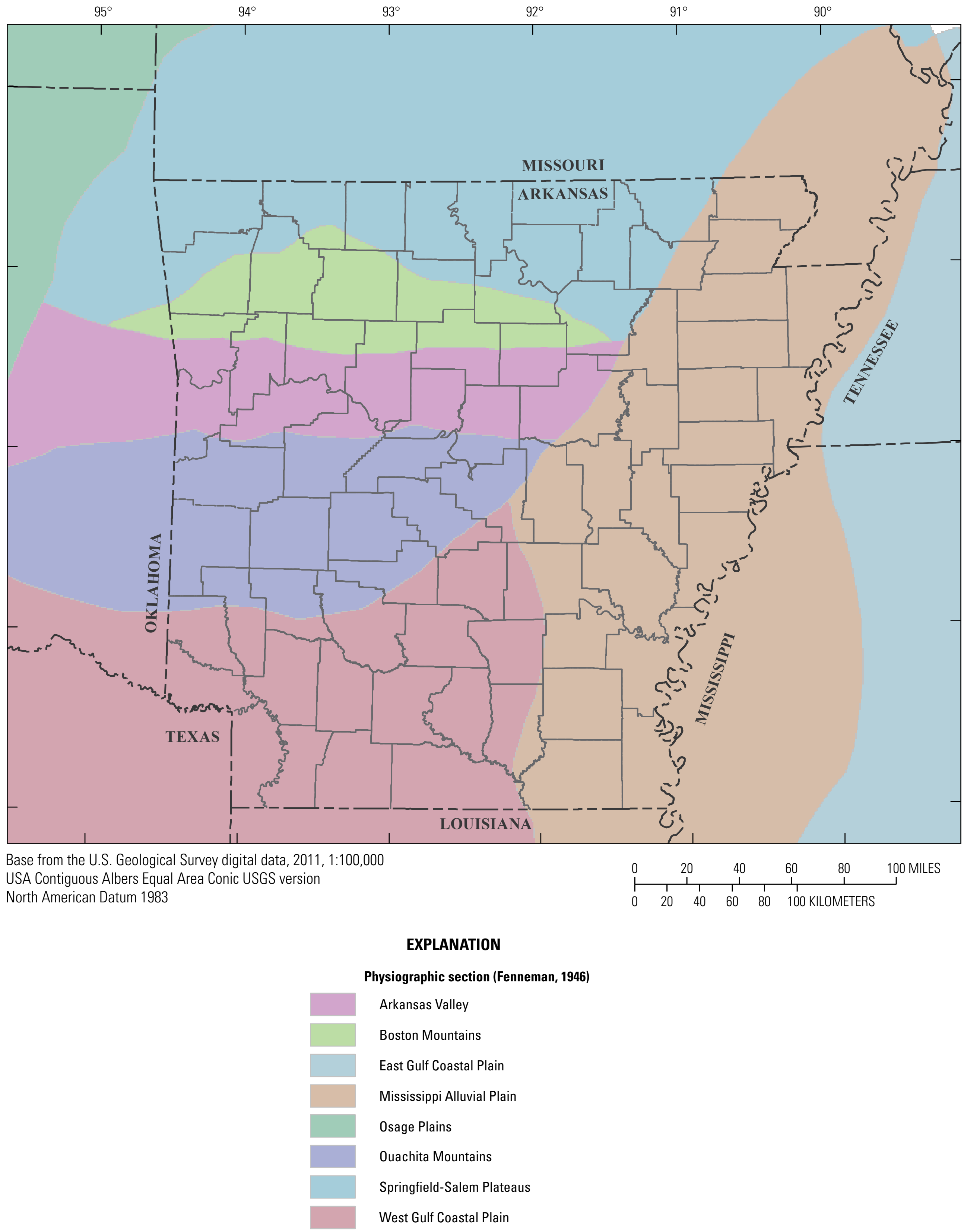

Figure 2. Physiographic sections of Arkansas.

Region 1 includes a small part of Arkansas that is located exclusively in the northern part of the State (fig. 1), mostly in the Springfield-Salem Plateaus (figs. 1 and 2). The region is underlain by a series of limestone and dolomite units and therefore exhibits numerous karst features that affect regional hydrology and groundwater/surface-water interaction (Ludwig and Tasker, 1993). Streams in region 1 often are sustained by numerous springs. The well-sustained flows from numerous springs are indicative of a regional source of water that is supplemented during extended periods of precipitation by a local component of groundwater recharge (Ludwig and Tasker, 1993).

Region 2 includes the rest of the State excluding the Mississippi Alluvial Plain. The northern part of region 2 (fig. 1) includes the Boston Mountains, Arkansas Valley, Ouachita Mountains, and parts of the Springfield Plateau physiographic sections (fig. 2; Fenneman, 1946). Region 2 is underlain or mantled by consolidated rocks consisting primarily of sandstones and shales. The primary porosity and permeability of these sandstones and shales have been greatly reduced by compaction and deep burial; therefore, only limited amounts of groundwater are available from secondary openings including joints and fractures. The fractures, however, do not supply the base flows of streams to the extent that numerous springs do in region 1 (Ludwig and Tasker, 1993).

The southern part of region 2 is located in the West Gulf Coastal Plain physiographic section, which is underlain by unconsolidated deposits composed of sand, silt, and clay. The streams in the southern part of region 2 generally do not have sustained base flow because (1) the stream channels are not incised deeply enough to intercept the water table, and (2) the surficial deposits typically have low permeability and porosity (Ludwig and Tasker, 1993).

Dry Season Mean Monthly Flow and Harmonic Mean Flow Regression Equations

Observed values of dry season mean monthly flows and QAH (app. 3) computed from daily-mean flow data were used with basin characteristics (app. 2) to identify significant explanatory variables (table 1) for multiple-linear-regression equations (tables 2 and 3) to estimate predicted values of dry season mean monthly flows and QAH. Predicted values were compared to observed values to evaluate the performance of the WLS regression equations. The widely used residual standard error (RSE) and adjusted correlation coefficient (Helsel and Hirsch, 2002) diagnostics of the regression analysis are provided for their respective regression equations (tables 2 and 3). Normalized root mean square error (NRMSE) and percent bias (PBIAS) were additional metrics computed for all of the regression equations. Values for normalized root mean square error ranged from 33.6 to 38.4 percent for dry season mean monthly flow (table 2) and from 29.2 to 45.8 percent for QAH (table 3). The NRMSE is computed as

$$NRMSE = 100\frac{\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(predicted_i - observed_i\right)^2}}{sd\left(observed_i\right)} \quad (5)$$

where

sd	is standard deviation,
N	is the total number of comparisons, and
i	is the individual value.

and PBIAS as

$$PBIAS = 100\frac{\sum_{i=1}^{N}\left(predicted_i - observed_i\right)}{\sum_{i=1}^{N}observed_i} \quad (6)$$

Of the 47 basin characteristics (app. 2), 5 were found to be significant explanatory variables for dry season mean monthly flow and QAH regressions for regions 1 and 2: (1) drainage area; (2) base-flow index; (3) slope 1085; the stream slope computed as the change in elevation in feet between points at 10 and 85 percent of the length in miles of the longest flow path from the outlet, divided by length between the points; (4) mean dry season total runoff; and (5) percent Mississippian and Ordovician surficial geology (app. 3). An example regression equation for QAH for region 2 is:

$$logQAH = A + blogDA + cOM + dBFI \quad (7)$$

where

log	is the base-10 logarithmic transformation of the variable,
QAH	is the harmonic mean flow,
A	is the intercept,
DA	is the drainage area, in square miles,
OM	is the percent Ordovician and Mississippian surficial geology divided by 100 + 1,
BFI	is the base-flow index, and
b, *c*, and *d*	are the coefficients of regression for the basin characteristics used as explanatory variables,

Or, in the algebraic equivalence of equation 7, the regression equation can be transformed back to the original units

$$QAH = 10^{A}(DA)^{b}10^{c(OM)}\ 10^{d(BFI)} \quad (8)$$

Table 2. Regression equations and ancillary regression diagnostics for dry season mean monthly flow estimation in Arkansas.

[DRNAREA, drainage area; DryTotRun, mean dry season total runoff; RSE, residual standard error; R^2, correlation coefficient; NRMSE, normalized root mean square error; PBIAS, percent bias]

Regression equation	Number of streamflow gages used to develop equation	RSE	Adjusted R^2	NRMSE (percent)	PBIAS (percent)
Weighted-least-squares regression equation for July mean monthly streamflow					
$July=10^{-1.441}DRNAREA^{1.022}10^{0.229(DryTotRun)}$	91	0.198	0.89	34.1	-1.1
Weighted-least-squares regression equation for August mean monthly streamflow					
$August=10^{-1.921}DRNAREA^{1.092}10^{0.250(DryTotRun)}$	91	0.262	0.84	38.4	-1.2
Weighted-least-squares regression equation for September mean monthly streamflow					
$September=10^{-1.556}DRNAREA^{0.975}10^{0.274(DryTotRun)}$	91	0.197	0.88	33.6	-0.2
Weighted-least-squares regression equation for October mean monthly streamflow					
$October=10^{-0.902}DRNAREA^{0.929}10^{0.174(DryTotRun)}$	91	0.193	0.87	35.6	0.3
Weighted-least-squares regression equation for November mean monthly streamflow					
$November=10^{-0.446}DRNAREA^{0.865}10^{0.179(DryTotfRun)}$	91	0.180	0.87	35.0	1.0

Table 3. Regression equations and ancillary regression diagnostics for harmonic mean flow estimation in two regions identified in Arkansas.

[QAH, harmonic mean flow; DRNAREA, drainage area; BFI, base flow index; Slope1085, slope of channel in feet per mile between points at 10 and 85 percent of the longest flow path from the outlet; ORDOMISS, percent surficial geology Ordovician and Mississippian rocks divided by 100 plus 1; RSE, residual standard error; R^2, correlation coefficient; NRMSE, normalized root mean square error; PBIAS, percent bias]

Regression equation	Number of streamflow gages used to develop equation	RSE	Adjusted R^2	NRMSE (percent)	PBIAS (percent)
Weighted-least-squares regression equation for region 1					
$QAH=10^{-2.733}DRNAREA^{1.320}10^{2.690(BFI)}10^{0.0150(Slope1085)}$	33	0.233	0.93	29.2	-0.8
Weighted-least-squares regression equation for region 2					
$QAH=10^{-3.654}DRNAREA^{1.022}10^{1.132(ORDOMISS)}10^{2.431(BFI)}$	60	0.295	0.82	45.8	-4.6

Limitations

The final regression equations are applicable only to streams in Arkansas that are unaltered. The range of values for explanatory variables used to develop the final regression equations for this report is listed in table 1. A measure of the uncertainty associated with the regression of dry season mean monthly flows and QAH is the prediction interval. A prediction interval is the probability that the actual value of the estimated statistic will be within a specific margin of error (Helsel and Hirsch, 2002). For a 90-percent prediction interval, the true streamflow statistic has a 90-percent probability of being within the margin of error. The following equation described by Eash and Barnes (2012), which is modified from Tasker and Driver (1988), can be used to compute the 90-percent prediction interval for the true value of a streamflow statistic for an ungaged site:

$$\frac{Q}{T} < Q < QT \quad (9)$$

where

Q is the dry season mean monthly flow or QAH predicted for the ungaged site from the regression equation, and T is computed as

$$T = 10^{\left[t_{(\alpha/2,n-p)}S_i\right]} \quad (10)$$

where

$t_{(\alpha/2,n-t)}$ is the critical value from the student's t-distribution at alpha level α (α=0.10 for the 90-percent prediction intervals; critical values may be obtained in many statistics textbooks (Iman and Conover, 1983),

$n-p$ is the degree of freedom with n streamflow gages included in the regression analysis and p parameters in the equation (the number of explanatory variables plus one), and

S_i is the standard error of prediction for site i and is computed as

$$S_i = [\text{MEV} + X_i U X'_i]^{0.5} \quad (11)$$

where

MEV is the mean squared error from WLS regression equations developed for this study using a user-defined weighting matrix;

X_i is the row vector for the streamflow gage i, starting with the number 1, followed by the logarithmic values of the basin characteristics used in the regression;

U is the covariance matrix for the annual or seasonal regression coefficients; and

X'_i is the matrix algebra transpose of the Xi (Ludwig and Tasker, 1993; Ries and Friesz, 2000).

The $X_i U X'_i$ in equation 11 also is referred to as the sampling error variance. The values of $t_{(\alpha/2,n-p)}$ and U needed to determine prediction intervals for estimates obtained by the regression equations in tables 2 and 3 are listed in table 4.

Table 4. Values needed to determine the 90-percent prediction intervals for estimates obtained from regression equations using covariance matrices in A rkansas.

[$t_{(\alpha/2,n-p)}$, the critical value from Students t-distribution for the 90-percent probability used in equation 10; MEV, regression model error variance used in equation 11; U, covariance matrix as used in equation 10; logDA, log 10 transformed drainage area; DryTotRun, mean dry season total runoff; BFI, base-flow index; Slope1085, slope of channel in feet per mile between points at 10 and 85 percent of the longest flow path from the outlet; OM, percent surficial geology Ordovician and Mississippian divided by 100 plus 1]

Response variable	$t_{(\alpha/2,n-p)}$	MEV	U				
July mean monthly streamflow	1.8467	0.0452		(Intercept)	logDA	DryTotRun	
			(Intercept)	0.04535396	-0.00365853	-0.00820081	
			logDA	-0.00365853	0.00151157	-0.00001740	
			DryTotRun	-0.00820081	-0.00001740	0.00188411	
August mean monthly streamflow	1.6063	0.0700		(Intercept)	logDA	DryTotRun	
			(Intercept)	0.07906513	-0.00637789	-0.01429639	
			logDA	-0.00637789	0.00263511	-0.00003034	
			DryTotRun	-0.01429639	-0.00003034	0.00328455	
September mean monthly streamflow	1.7944	0.0457		(Intercept)	logDA	DryTotRun	
			(Intercept)	0.04486505	-0.00361909	-0.00811240	
			logDA	-0.00361909	0.00149528	-0.00001722	
			DryTotRun	-0.00811240	-0.00001722	0.00186380	
October mean monthly streamflow	1.9042	0.0474		(Intercept)	logDA	DryTotRun	
			(Intercept)	0.04288050	-0.00345901	-0.00775356	
			logDA	-0.00345901	0.00142914	-0.00001645	
			DryTotRun	-0.00775356	-0.00001645	0.00178136	
November mean monthly streamflow	2.2257	0.0381		(Intercept)	logDA	DryTotRun	
			(Intercept)	0.03741506	-0.00301813	-0.00676531	
			logDA	-0.00301813	0.00124698	-0.00001436	
			DryTotRun	-0.00676531	-0.00001436	0.00155431	
Harmonic mean flow region 1	1.6937	0.0641		(Intercept)	logDA	BFI	Slope 1085
			(Intercept)	0.14021140	-0.01779832	-0.16399111	-0.00097720
			logDA	-0.01779832	0.00820252	-0.01328758	0.00021931
			BFI	-0.16399111	-0.01328758	0.39735529	0.00047734
			Slope1085	-0.00097720	0.00021931	0.00047734	0.00001313
Harmonic mean flow region 2	0.6311	0.0966		(Intercept)	logDA	OM	BFI
			(Intercept)	0.08792426	-0.02244803	-0.01608324	-0.04605076
			logDA	-0.02244803	0.01227426	-0.00007389	-0.03009622
			OM	-0.01608324	-0.00007389	0.01884845	-0.02850505
			BFI	-0.04605076	-0.03009622	-0.02850505	0.62346886

Summary

The U.S. Geological Survey (USGS), in cooperation with the Arkansas Department of Environmental Quality (ADEQ), Southwestern Energy, the Arkansas Natural Resources Commission, and the Arkansas Game and Fish Commission, developed regression equations for estimation of dry season mean monthly flows and harmonic mean flows (QAH) that are representative of natural streamflow conditions at selected ungaged basins in Arkansas. Observed values of dry season mean monthly flow and QAH computed from daily-mean flow data were used with basin characteristics to identify significant explanatory variables for multiple-linear-regression equations to estimate predicted values of dry season mean monthly flow and QAH. These two streamflow statistics are routinely needed for ungaged streams for water-quality regulation, stream-related structural design, wastewater management, and stream-hazard identification. Dry season mean monthly flow and QAH are useful for setting criteria for wastewater-treatment plant effluent and allowable pollutant loads to meet water-quality standards for human health criteria, irrigation, recreation, and wildlife conservation.

Five dry season mean monthly flow regression equations and two QAH regression equations were developed using dry season mean monthly flow and QAH established for 91 and 93 USGS continuous-record streamflow gaging stations, respectively. The dry season in Arkansas is defined as the months of July through November. For QAH calculations and regression equations, the study area is composed of the Springfield-Salem Plateaus (Arkansas and Missouri), Boston Mountains, Arkansas Valley, Ouachita Mountains (Arkansas and Oklahoma), and West Gulf Coastal Plain (Arkansas) physiographic sections. All streamflow-gaging stations used to compute dry season mean monthly flows were located within Arkansas. Continuous-record streamflow-gaging stations used for this study had a minimum of 12 water years of daily-mean flow data. Basin characteristics that included geologic, climatic, physical, and statistical variables were computed for each basin.

The median number of years used for dry season mean monthly flow calculation was 43. Regression equations for mean monthly flow were applicable only to stream sites located throughout Arkansas. The regression equations for dry season mean monthly flow and QAH are applicable only to unaltered streams where flows were not significantly affected by regulation, diversion, or urbanization.

Equations for two regions were found to be statistically significant for developing regression equations for estimating QAH at ungaged basins in Arkansas. Of the 93 continuous-record streamflow-gaging stations used for QAH, 33 and 60 streamflow-gaging stations were used for the first and second regions, respectively. The median number of years of data used for QAH calculations in the weighted-least-squares regression analysis was 34 for region 1 and 43 for region 2. The weighted-least-squares regression equations used to estimate QAH were applicable only to streams in their respective regions, region 1 and region 2.

Residual standard error, adjusted correlation coefficient, normalized root mean square error, and percent bias were used to evaluate the performance of the regression equations developed for this study. Values for normalized root mean square error ranged from 33.6 to 38.4 percent for dry season mean monthly flow and from 29.2 to 45.8 percent for QAH. Equations developed during this study also are intended for delivery in the USGS StreamStats program. StreamStats will provide users the ability to estimate dry season mean monthly flow, QAH, and 90 percent prediction intervals for ungaged streams in Arkansas.

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Appendixes 1–3

Appendix 1

Table 1–1. U.S. Geological Survey streamflow gages used for regression analysis for dry season mean monthly flow and harmonic mean flow.

[ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma; --, gage was not used for the regression in the column heading for that station]

Map identification number	Dry season mean monthly streamflow (ft^3/s)	Harmonic mean flow region 1 (ft^3/s)	Harmonic mean flow region 2 (ft^3/s)	USGS site number	USGS station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Begin date	End date	Period of record (years)
1	✓	--	--	07047600	Tyronza River near Tyronza, Ark.	35.505082	-90.380101	10/01/1949	09/30/1974	25
2	✓	--	--	07047942	L'Anguille River near Colt, Ark.	35.144722	-90.878056	10/01/1970	09/30/2013	33
3	✓	--	--	07047950	L'Anguille River at Palestine, Ark.	34.972778	-90.885556	10/01/1949	09/30/2013	64
4	✓	--	✓	07048000	West Fork White River at Greenland, Ark.	35.982906	-94.172622	10/01/1945	09/30/1983	38
5	✓	--	✓	07048600	White River near Fayetteville, Ark.	36.073056	-94.081111	10/01/1963	09/30/2013	50
6	✓	--	✓	07048800	Richland Creek at Goshen, Ark.	36.104167	-94.007500	10/01/1998	09/30/2013	15
7	✓	--	✓	07049000	War Eagle Creek near Hindsville, Ark.	36.200000	-93.855000	10/01/1952	09/30/2013	61
8	✓	--	✓	07050000	White River at Beaver, Ark.	36.472293	-93.765472	10/01/1909	09/30/1958	49
9	✓	--	✓	07050500	Kings River near Berryville, Ark.	36.427222	-93.620833	10/01/1939	09/30/2013	74
10	✓	--	✓	07053207	Long Creek at Denver, Ark.	36.389444	-93.315833	10/01/1996	09/30/2012	16
11	✓	--	✓	07053250	Yocum Creek near Oak Grove, Ark.	36.454444	-93.356111	10/01/1993	09/30/2013	20
12	--	✓	--	07053810	Bull Creek near Walnut Shade, Mo.	36.717750	-93.206806	10/01/1997	09/30/2013	16
13	--	✓	--	07054080	Beaver Creek at Bradleyville, Mo.	36.779639	-92.907278	10/01/1994	09/30/2013	19
14	✓	--	✓	07055646	Buffalo River near Boxley, Ark.	35.938889	-93.405000	10/01/1993	09/30/2013	20
15	✓	--	✓	07055875	Richland Creek near Witts Spring, Ark.	35.797222	-92.928889	10/01/1995	09/30/2013	18
16	✓	--	✓	07056000	Buffalo River near St. Joe, Ark.	35.983056	-92.747222	10/01/1939	09/30/2013	74
17	✓	--	✓	07056515	Bear Creek near Silver Hill, Ark.	35.940000	-92.713333	01/22/1999	09/30/2013	14
18	✓	--	✓	07057000	Buffalo River near Rush, Ark.	36.117294	-92.554607	10/01/1928	09/30/1970	42
19	--	✓	--	07057500	North Fork River near Tecumseh, Mo.	36.623028	-92.248139	10/01/1944	09/30/2013	69
20	--	✓	--	07058000	Bryant Creek near Tecumseh, Mo.	36.627222	-92.306056	10/01/1944	09/30/2013	69
21	--	✓	--	07058500	North Fork River at Tecumseh, Mo.	36.587611	-92.288856	10/01/1921	09/30/1944	23
22	✓	✓	--	07060710	North Sylamore Creek near Fifty Six, Ark.	35.991667	-92.213889	10/01/1966	09/30/2013	47
23	--	✓	--	07065495	Jacks Fork at Alley Spring, Mo.	37.148167	-91.443083	10/01/1993	09/30/2013	20
24	--	✓	--	07066000	Jacks Fork at Eminence, Mo.	37.154083	-91.358167	10/01/1922	09/30/2013	91
25	--	✓	--	07068000	Current River at Doniphan, Mo.	36.622003	-90.847623	10/01/1921	09/30/2013	92
26	--	✓	--	07068510	Little Black River below Fairdealing, Mo.	36.631724	-90.575393	10/01/1980	09/30/2013	33
27	✓	✓	--	07069000	Black River at Pocahontas, Ark.	36.254167	-90.970278	10/01/1980	09/30/2013	33
28	✓	✓	--	07069305	Spring River at Town Branch Bridge at Hardy, Ark.	36.313611	-91.482778	10/01/2001	09/30/2013	12
29	✓	✓	--	07069500	Spring River at Imboden, Ark.	36.205556	-91.171667	10/01/1936	09/30/2013	77
30	--	✓	--	07070500	Eleven Point River near Thomasville, Mo.	36.784780	-91.492084	10/01/1950	09/30/1976	26

Table 1–1. U.S. Geological Survey streamflow gages used for regression analysis for dry season mean monthly flow and harmonic mean flow.—Continued

[ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma; --, gage was not used for the regression in the column heading for that station]

Map identification number	Dry season mean monthly streamflow (ft^3/s)	Harmonic mean flow region 1 (ft^3/s)	Harmonic mean flow region 2 (ft^3/s)	USGS site number	USGS station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Begin date	End date	Period of record (years)
31	--	✓	--	07071500	Eleven Point River near Bardley, Mo.	36.648694	-91.200833	10/01/1921	09/30/2013	92
32	✓	✓	--	07072000	Eleven Point River near Ravenden Springs, Ark.	36.346389	-91.114167	10/01/1929	09/30/2013	84
33	✓	✓	--	07072500	Black River at Black Rock, Ark.	36.102500	-91.097778	10/01/1929	09/30/2013	84
34	✓	✓	--	07073000	Strawberry River near Evening Shade, Ark.	36.098959	-91.608474	10/01/1939	09/30/1979	40
35	✓	✓	--	07073500	Piney Fork at Evening Shade, Ark.	36.080626	-91.610974	10/01/1939	09/30/1984	45
36	✓	✓	--	07074000	Strawberry River near Poughkeepsie, Ark.	36.111111	-91.449444	10/01/1936	09/30/1987	51
37	✓	--	✓	07075000	Middle Fork of Little Red River at Shirley, Ark.	35.656667	-92.292778	10/01/1939	09/30/2013	74
38	✓	--	✓	07075300	South Fork of Little Red River at Clinton, Ark.	35.586944	-92.451389	10/01/1961	09/30/2012	51
39	✓	--	✓	07075500	South Fork Little Red River near Clinton, Ark.	35.566744	-92.383490	10/01/1939	09/30/1961	22
40	✓	--	--	07077380	Cache River at Egypt, Ark.	35.857500	-90.933056	10/01/1964	09/30/2013	49
41	✓	--	--	07077500	Cache River at Patterson, Ark.	35.269722	-91.236389	10/01/1927	09/30/2010	83
42	✓	--	--	07077555	Cache River near Cotton Plant, Ark.	35.035556	-91.322500	10/01/1987	09/30/2013	26
43	✓	--	--	07077950	Big Creek at Poplar Grove, Ark.	34.555656	-90.845669	10/01/1970	09/30/1993	23
44	--	✓	--	07189000	Elk River near Tiff City, Mo.	36.631461	-94.586889	10/01/1939	09/30/2013	74
45	--	✓	--	07189540	Cave Springs Branch near South West City, Mo.	36.547297	-94.618000	10/01/1997	09/30/2013	16
46	--	✓	--	07189542	Honey Creek near South West City, Mo.	36.548889	-94.683611	10/01/1997	09/30/2013	16
47	✓	✓	--	07191160	Spavinaw Creek near Maysville, Ark.	36.364523	-94.551330	10/01/2001	09/30/2013	12
48	✓	✓	--	07191179	Spavinaw Creek near Cherokee City, Ark.	36.342024	-94.587720	10/01/2001	09/30/2013	12
49	--	✓	--	07191220	Spavinaw Creek near Sycamore, Okla.	36.334722	-94.641389	10/01/1961	09/30/2013	52
50	✓	✓	--	07194800	Illinois River at Savoy, Ark.	36.103056	-94.344444	10/01/1979	09/30/2013	34
51	✓	✓	--	07195400	Illinois River at Highway 16 near Siloam Springs Ark.	36.144722	-94.494722	10/01/1979	09/30/2013	34
52	✓	✓	--	07195430	Illinois River South of Siloam Springs, Ark.	36.108611	-94.533333	10/01/1995	09/30/2013	18
53	✓	✓	--	07195800	Flint Creek at Springtown, Ark.	36.256111	-94.433611	10/01/1961	09/30/2013	52
54	--	✓	--	07195855	Flint Creek near West Siloam Springs, Okla.	36.216111	-94.605278	10/01/1979	09/30/2013	34
55	✓	✓	--	07196900	Baron Fork at Dutch Mills, Ark.	35.880000	-94.486389	10/01/1958	09/30/2013	55
56	--	✓	--	07197360	Caney Creek near Barber, Okla.	35.785091	-94.856340	10/01/1997	09/30/2013	16
57	✓	--	✓	07247000	Poteau River at Cauthron, Ark.	34.918889	-94.299444	10/01/1939	09/30/2013	74
58	--	--	✓	07247500	Fourche Maline near Red Oak, Okla.	34.912599	-95.155799	10/01/1938	09/30/2013	75
59	✓	--	✓	07249400	James Fork near Hackett, Ark.	35.162500	-94.406944	10/01/1958	09/30/2013	55
60	--	--	✓	07249413	Poteau River near Pama, Okla.	35.165653	-94.653002	10/01/1989	09/30/2013	24
61	✓	--	✓	07249500	Cove Creek near Lee Creek, Ark.	35.722306	-94.407992	10/01/1950	09/30/1970	20
62	--	--	✓	07249985	Lee Creek near Short, Okla.	35.517222	-94.464167	10/01/1930	09/30/2013	83

Table 1–1. U.S. Geological Survey streamflow gages used for regression analysis for dry season mean monthly flow and harmonic mean flow.—Continued

[ft^3/s, cubic feet per second; USGS, U.S. Geological Survey; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma; --, gage was not used for the regression in the column heading for that station]

Map identi-fication number	Dry season mean monthly streamflow (ft^3/s)	Harmonic mean flow region 1 (ft^3/s)	Harmonic mean flow region 2 (ft^3/s)	USGS site number	USGS station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Begin date	End date	Period of record (years)
63	✓	--	✓	07250000	Lee Creek near Van Buren, Ark.	35.494533	-94.449659	10/01/1930	09/30/1992	62
64	--	--	✓	07250935	Jones Creek at Winfrey, Ark.	35.735833	-94.103056	10/01/2000	09/30/2013	13
65	✓	--	✓	07251000	Frog Bayou near Mountainburg, Ark.	35.660361	-94.149094	10/01/1936	09/30/1961	25
66	✓	--	✓	07252000	Mulberry River near Mulberry, Ark.	35.576944	-94.015278	10/01/1938	09/30/2013	75
67	✓	--	--	07252500	Sixmile Creek subwatershed 6 near Chismville, Ark.	35.208989	-93.878247	10/01/1955	09/30/1970	15
68	✓	--	--	07253000	Sixmile Creek at Chismville, Ark.	35.220925	-93.939091	10/01/1954	09/30/1969	15
69	✓	--	--	07253500	Sixmile Creek near Branch, Ark.	35.248703	-93.974647	10/01/1954	09/30/1969	15
70	✓	--	--	07255000	Sixmile Creek at Caulksville, Ark.	35.301478	-93.854366	10/01/1954	09/30/1969	15
71	✓	--	--	07255500	Hurricane Creek near Branch, Ark.	35.350572	-93.934392	10/01/1954	09/30/1969	15
72	✓	--	✓	07256000	Hurricane Creek near Caulksville, Ark.	35.346889	-93.863058	10/01/1954	09/30/1969	15
73	✓	--	✓	07256500	Spadra Creek at Clarksville, Ark.	35.468333	-93.463056	10/01/1952	09/30/1970	18
74	✓	--	✓	07257000	Big Piney Creek near Dover, Ark.	35.549525	-93.158508	10/01/1950	09/30/1992	42
75	✓	--	✓	07257006	Big Piney Creek at Highway 164 near Dover, Ark.	35.505833	-93.181389	10/01/1992	09/30/2013	21
76	✓	--	✓	07257500	Illinois Bayou near Scottsville, Ark.	35.466389	-93.041111	10/01/1947	09/30/2013	66
77	✓	--	✓	07258500	Petit Jean River near Booneville, Ark.	35.106944	-93.923611	10/01/1939	09/30/2013	74
78	✓	--	✓	07259500	Petit Jean River near Waveland, Ark.	35.104813	-93.631582	10/01/1939	09/30/1986	47
79	✓	--	✓	07260000	Dutch Creek at Waltreak, Ark.	34.986944	-93.613056	10/01/1945	09/30/2013	68
80	✓	--	✓	07260500	Petit Jean River at Danville, Ark.	35.058611	-93.395556	10/01/1916	09/30/2013	97
81	✓	--	✓	07261000	Cadron Creek near Guy, Ark.	35.298611	-92.403889	10/01/1954	09/30/2013	59
82	✓	--	✓	07261500	Fourche LaFave River near Gravelly, Ark.	34.872500	-93.657222	10/01/1939	09/30/2013	74
83	✓	--	✓	07262500	Fourche LaFave River near Nimrod, Ark.	34.950646	-93.154623	10/01/1936	09/30/1980	44
84	✓	--	✓	07263000	South Fourche LaFave River near Hollis, Ark.	34.911944	-93.056111	10/01/1941	09/30/1987	46
85	✓	--	✓	07263295	Maumelle River at Williams Junction, Ark.	34.876111	-92.774444	10/01/1989	09/30/2013	24
86	✓	--	--	07264000	Bayou Meto near Lonoke, Ark.	34.736667	-91.915833	10/01/1954	09/30/2013	59
87	--	--	✓	07337900	Glover River near Glover, Okla.	34.097607	-94.902167	10/01/1961	09/30/2013	52
88	✓	--	✓	07339500	Rolling Fork near DeQueen, Ark.	34.047500	-94.412778	10/01/1948	09/30/2011	63
89	✓	--	✓	07340300	Cossatot River near Vandervoort, Ark.	34.380000	-94.236389	10/01/1967	09/30/2013	46
90	✓	--	✓	07340500	Cossatot River near DeQueen, Ark.	34.045000	-94.212500	10/01/1948	09/30/2011	63
91	✓	--	--	07341000	Saline River near Dierks, Ark.	34.096111	-94.085000	10/01/1967	09/30/2013	46
92	✓	--	--	07349430	Bodcau Creek at Stamps, Ark.	33.366791	-93.522399	10/01/1938	09/30/1980	42
93	✓	--	✓	07356000	Ouachita River near Mount Ida, Ark.	34.610000	-93.697500	10/01/1941	09/30/2013	72
94	✓	--	✓	07356500	South Fork Ouachita River at Mount Ida, Ark.	34.560375	-93.636026	10/01/1949	09/30/1970	21

Table 1–1. U.S. Geological Survey streamflow gages used for regression analysis for dry season mean monthly flow and harmonic mean flow.—Continued

[ft³/s, cubic feet per second; USGS, U.S. Geological Survey; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma; --, gage was not used for the regression in the column heading for that station]

Map identification number	Dry season mean monthly streamflow (ft³/s)	Harmonic mean flow region 1 (ft³/s)	Harmonic mean flow region 2 (ft³/s)	USGS site number	USGS station name	Latitude (decimal degrees)	Longitude (decimal degrees)	Begin date	End date	Period of record (years)
95	✓	--	--	07359800	Caddo River near Alpine, Ark.	34.266763	-93.362681	10/01/1938	09/30/1970	32
96	✓	--	✓	07360200	Little Missouri River near Langley, Ark.	34.311667	-93.899722	10/01/1998	09/30/2013	15
97	✓	--	✓	07360800	Muddy Fork Creek near Murfreesboro, Ark.	34.083443	-93.752128	10/01/1940	09/30/1959	19
98	✓	--	✓	07361000	Little Missouri River near Murfreesboro, Ark.	34.048721	-93.720183	10/01/1928	09/30/1977	49
99	✓	--	✓	07361500	Antoine River at Antoine, Ark.	34.038889	-93.418056	10/01/1954	09/30/2013	59
100	✓	--	✓	07361600	Little Missouri River near Boughton, Ark.	33.878163	-93.304616	10/01/1937	09/30/1977	40
101	✓	--	✓	07362100	Smackover Creek near Smackover, Ark.	33.375278	-92.776667	10/01/1961	09/30/2013	52
102	✓	--	✓	07362500	Moro Creek near Fordyce, Ark.	33.792222	-92.333333	10/01/1951	09/30/2013	62
103	✓	--	✓	07362587	Alum Fork Saline River near Reform, Ark.	34.797500	-92.933889	10/01/1989	09/30/2013	24
104	✓	--	✓	07363000	Saline River at Benton, Ark.	34.567778	-92.610278	10/01/1950	09/30/2013	63
105	✓	--	✓	07363300	Hurricane Creek near Sheridan, Ark.	34.319541	-92.344597	10/01/1961	09/30/1995	34
106	✓	--	✓	07363400	Hurricane Creek below Sheridan, Ark.	34.228611	-92.372500	10/01/2001	09/30/2013	12
107	✓	--	✓	07363500	Saline River near Rye, Ark.	33.700833	-92.025833	10/01/1937	09/30/2013	76
108	✓	--	--	07364133	Bayou Bartholomew at Garrett Bridge, Ark.	33.866389	-91.656111	10/01/1987	09/30/2013	26
109	✓	--	--	07364150	Bayou Bartholomew near McGehee, Ark.	33.627778	-91.445833	10/01/1938	09/30/2013	75
110	✓	--	--	07364185	Bayou Bartholomew near Portland, Ark.	33.235556	-91.535556	10/01/1998	09/30/2013	15
111	✓	--	✓	07365800	Cornie Bayou near Three Creeks, Ark.	33.038056	-92.940556	10/01/1956	09/30/1987	31
112	✓	--	✓	07365900	Three Creeks near Three Creeks, Ark.	33.067082	-92.884050	10/01/1956	09/30/1971	15
113	✓	--	--	07369680	Bayou Macon at Eudora, Ark.	33.100278	-91.254444	10/01/1988	09/30/2013	25

Appendix 2. Definitions of Basin Characteristics Evaluated as Response Variables for Inclusion in the Regression Analysis

Annual precipitation, in inches, is the average annual precipitation for the drainage basin as computed from PRISM (Prism Climate Group, 2012) data for 1951–2011.

August average precipitation, in inches, is the basin average for the month of August averaged from PRISM (Prism Climate Group, 2012) data for 1981–2010.

Average basin elevation, in feet, is the average elevation of the basin as determined from the National Elevation Dataset (U.S. Geological Survey, 2011) 10 meter grid.

Base flow Index (BFI), dimensionless, is the mean ratio of base flow to annual streamflow from the USGS kriged BFI grid (Falcone and others, 2010) as an averaged value for the basin.

Basin perimeter distance, in miles, is the distance around the boundary of the basin.

Basin shape factor, dimensionless, is the ratio of the total drainage area to the basin length.

Drainage area, in square miles, is the area measured in a horizontal plane that is enclosed by a drainage divide.

Forest, in percent, calculated from the National Land Cover Database as the percentage of the basin that is mixed forested (Jin and others, 2013).

July average precipitation, in inches, as a basin average for the month of July averaged from PRISM (Prism Climate Group, 2012) data for 1981–2010.

Longest flow path length, in miles, is the maximum flow distance within a basin from the start of overland flow to the outlet.

Maximum basin elevation, in feet, is the maximum elevation of the basin computed from the National Elevation Dataset (U.S. Geological Survey, 2011) 10 meter grid.

Mean annual groundwater runoff, in inches, is the portion of the total runoff at the outlet from seepage of water from the ground into a stream channel as computed from geographic information system (GIS) grid from Pugh and Westerman (2014).

Mean annual precipitation 1951–2011, in inches, at the basin outlet is the average annual precipitation as determined from PRISM (Prism Climate Group, 2012) data for 1951–2011.

Mean annual precipitation 1971–2000, in inches, at the basin centroid and averaged for the basin is the average annual precipitation as determined from PRISM (Prism Climate Group, 2012) data for 1971–2000.

Mean annual surface runoff, in inches, is the portion of the total runoff at the outlet that travels over the land surface into the stream channel as computed from GIS grid data from Pugh and Westerman (2014).

Mean annual total runoff, in inches, is the total runoff at the outlet that travels over the land surface and from seepage of water from the ground into the stream channel as computed from GIS grid data from Pugh and Westerman (2014).

Mean dry season groundwater runoff, in inches, is the portion of the total runoff at the outlet from seepage of water from the ground into a stream channel for the months of June through November as computed from GIS grid data from Pugh and Westerman (2014).

Mean dry season precipitation, in inches, is the average precipitation for the months of July through November averaged over the drainage basin as computed from PRISM (Prism Climate Group, 2012) data for 1951–2011.

Mean dry season surface runoff, in inches, is the portion of the total runoff at the outlet that travels over the land surface into the stream channel for the months of June through November as computed from GIS grid data from Pugh and Westerman (2014).

Mean dry season total runoff, in inches, is the total runoff at the outlet that travels over the land surface and from seepage of water from the ground into the stream channel for the months of June through November as computed from GIS grid data from Pugh and Westerman (2014).

Mean wet season groundwater runoff, in inches, is the portion of the total runoff at the outlet from seepage of water from the ground into a stream channel for the months of December through May as computed from GIS grid data from Pugh and Westerman (2014).

Mean wet season precipitation, in inches, is the average precipitation for the months of December through June averaged over the drainage basin as computed from PRISM (Prism Climate Group, 2012) data 1951–2011.

Mean wet season surface runoff, in inches, is the portion of the total runoff at the outlet that travels over the land surface into the stream channel for the months of December through May as computed from GIS grid data from Pugh and Westerman (2014).

Mean wet season total runoff, in inches, is the total runoff at the outlet that travels over the land surface and from seepage of water from the ground into the stream channel for the months of December through May as computed from GIS grid data from Pugh and Westerman (2014).

Minimum basin elevation, in feet, is the maximum elevation of the basin computed from the National Elevation Dataset (U.S. Geological Survey, 2011) 10 meter grid.

November average precipitation, in inches, as a basin average for the month of November averaged from PRISM (Prism Climate Group, 2012) data for 1981–2010.

October average precipitation, in inches, as a basin average for the month of October averaged from PRISM (Prism Climate Group, 2012) data for 1981–2010.

Outlet elevation, in feet, is the elevation at the gage location computed from the National Elevation Dataset (U.S. Geological Survey, 2011) 10 meter grid.

Percent Cretaceous (K), is the percentage of the basin in which Cretaceous sedimentary rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Paleozoic (lPz), is the percentage of the basin in which lower Paleozoic sedimentary rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Mississippian, is the percentage of the basin in which Mississippian-age rocks dominate the surface of the basin as computed from GIS grid data from Haley and others (1993).

Percent Middle Paleozoic (mPz), is the percentage of the basin in which Middle Paleozoic sedimentary rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Ordovician, is the percentage of the basin in which Ordovician-age rocks dominate the surface of the basin as computed from GIS grid data from Haley and others (1993).

Percent Ordovician and Mississippian, is the percentage of the basin in which Mississippian and Ordovician-age rocks dominate the surface of the basin as computed from GIS grid data from Haley and others (1993).

Percent Paleogene (pgT), is the percentage of the basin in which Paleogene sedimentary rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Quaternary (Q), is the percentage of the basin in which Quaternary deposits dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Upper Paleozoic (uPz), is the percentage of the basin in which Upper Paleozoic sedimentary rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Percent Middle Proterozoic (Yv), is the percentage of the basin in which Middle Proterozoic volcanic rocks dominate the surface of the basin as computed from GIS grid data created by Reed and Bush (2005).

Relief, in feet, is the maximum basin elevation minus the minimum basin elevation computed from the National Elevation Dataset (U.S. Geological Survey, 2011) 10 meter grids.

September average precipitation, in inches, as a basin average for the month of September averaged from PRISM (Prism Climate Group, 2012) data for 1981–2010.

Slope, in feet per mile, of the longest flow path through the basin.

Slope 1085, in feet per mile, is the stream slope computed as the change in elevation between points at 10 and 85 percent of length along the longest flow path from the outlet, determined by GIS, divided by length between the points.

Soil Permeability, in inches per hour, is the rate at which water flows through soil as computed from STATe Soil GeOgraphic (STATSGO) grid data (Schwarz and Alexander, 1995; U.S. Department of Agriculture, 2001).

Soil hydrologic group, dimensionless, percentage of drainage basin in hydrologic soil group as computed from STATe Soil GeOgraphic (STATSGO) grid data (Schwarz and Alexander, 1995; U.S. Department of Agriculture, 2001).

Streamflow-variability Index, dimensionless, is a measure of the steepness of the slope of a streamflow duration curve as computed at the outlet.

Sum of stream lengths for basin, in miles, is the total length of all streams in the basin combined.

Urban, percent, calculated from the National Land Cover Database as the percentage of the basin that is urban (Jin and others, 2013).

Appendix 3

Table 3–1. Dry season mean monthly flow, harmonic mean flow, and explanatory variable values for final regression equations.

[USGS, U.S. Geological Survey; ft³/s, cubic feet per second; Slope1085, slope of channel between points at 10 and 85 percent of the longest flow path from the outlet; mi², square mile; ft/mi, foot per mile; in., inches; --, gage was not used for the regression in the column heading for that station; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma]

USGS site number	USGS station name	Mean monthly streamflow for July (ft³/s)	Mean monthly streamflow for August (ft³/s)	Mean monthly streamflow for September (ft³/s)	Mean monthly streamflow for October (ft³/s)	Mean monthly streamflow for November (ft³/s)	Harmonic mean flow (ft³/s)	Base-flow index	Drainage area (mi²)	Ordovician and Mississippian (percent)	Slope1085 (ft/mi)	Mean dry season total runoff (in.)
07047600	Tyronza River near Tyronza, Ark.	244	174	165	148	368	--	0.25	332	0	0.5	4.7
07047942	L'Anguille River near Colt, Ark.	265	284	440	332	625	--	0.30	534	0	0.7	4.8
07047950	L'Anguille River at Palestine, Ark.	412	442	587	374	671	--	0.31	788	0	0.7	4.8
07048000	West Fork White River at Greenland, Ark.	28	26	22	37	100	1.44	0.30	83.0	10	26.5	4.3
07048600	White River near Fayetteville, Ark.	114	52	148	255	579	11.5	0.31	399	21	13.5	4.3
07048800	Richland Creek at Goshen, Ark.	69	20	44	55	99	4.22	0.34	140	28	16.6	4.3
07049000	War Eagle Creek near Hindsville, Ark.	129	68	70	130	199	25.0	0.33	265	36	8.3	4.2
07050000	White River at Beaver, Ark.	660	508	408	649	976	143	0.43	1,250	48	3.9	4.3
07050500	Kings River near Berryville, Ark.	213	116	154	209	534	39.1	0.34	529	70	6.2	4.3
07053207	Long Creek at Denver, Ark.	37	14	30	95	74	6.52	0.38	103	79	16.5	4.3
07053250	Yocum Creek near Oak Grove, Ark.	29	21	31	24	45	14.4	0.36	52.6	100	22.5	4.3
07053810	Bull Creek near Walnut Shade, Mo.	--	--	--	--	--	11.9	0.38	196	0	17.2	--
07054080	Beaver Creek at Bradleyville, Mo.	--	--	--	--	--	69.9	0.38	298	0	9.9	--
07055646	Buffalo River near Boxley, Ark.	14	10	26	38	93	1.28	0.26	58.8	7	40.9	4
07055875	Richland Creek near Witts Spring, Ark.	25	12	31	42	120	1.18	0.29	67.3	1	40	3.9
07056000	Buffalo River near St. Joe, Ark.	238	164	226	340	960	118	0.34	828	50	9.8	4.1
07056515	Bear Creek near Silver Hill, Ark.	26	18	42	38	73	11.1	0.34	78.5	47	36.1	4.3
07057000	Buffalo River near Rush, Ark.	405	230	243	354	729	179	0.35	1,020	58	6.8	4.3
07057500	North Fork River near Tecumseh, Mo.	--	--	--	--	--	484	0.58	562	100	7.6	--
07058000	Bryant Creek near Tecumseh, Mo.	--	--	--	--	--	255	0.53	569	100	8.2	--
07058500	North Fork River at Tecumseh, Mo.	--	--	--	--	--	752	0.50	1,160	0	7.6	--
07060710	North Sylamore Creek near Fifty Six, Ark.	11	10	16	21	47	8.82	0.33	8.4	100	95.8	4.3
07065495	Jacks Fork at Alley Spring, Mo.	--	--	--	--	--	101	0.47	304	0	10.1	--
07066000	Jacks Fork at Eminence, Mo.	--	--	--	--	--	232	0.50	404	0	9.2	--
07068000	Current River at Doniphan, Mo.	--	--	--	--	--	1,920	0.55	2,050	0	4.6	--
07068510	Little Black River below Fairdealing, Mo.	--	--	--	--	--	75.4	0.51	194	0	8.6	--
07069000	Black River at Pocahontas, Ark.	3,410	2,620	2,470	2,580	3,700	3,180	0.51	4,860	66	2.3	4.2

Table 3–1. Dry season mean monthly flow, harmonic mean flow, and explanatory variable values for final regression equations.—Continued

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; Slope1085, slope of channel between points at 10 and 85 percent of the longest flow path from the outlet; mi^2, square mile; ft/mi, foot per mile; in., inches; --, gage was not used for the regression in the column heading for that station; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma]

USGS site number	USGS station name	Mean monthly streamflow for July (ft^3/s)	Mean monthly streamflow for August (ft^3/s)	Mean monthly streamflow for September (ft^3/s)	Mean monthly streamflow for October (ft^3/s)	Mean monthly streamflow for November (ft^3/s)	Harmonic mean flow (ft^3/s)	Base-flow index	Drainage area (mi^2)	Ordovician and Mississippian (percent)	Slope1085 (ft/mi)	Mean dry season total runoff (in.)
07069305	Spring River at Town Branch Bridge at Hardy, Ark.	598	500	578	754	814	575	0.49	845	100	7.5	4.7
07069500	Spring River at Imboden, Ark.	766	579	618	686	1,170	718	0.50	1,160	100	6.1	4.6
07070500	Eleven Point River near Thomasville, Mo.	--	--	--	--	--	19.3	0.51	358	100	12.9	--
07071500	Eleven Point River near Bardley, Mo.	--	--	--	--	--	491	0.65	784	100	9.7	--
07072000	Eleven Point River near Ravenden Springs, Ark.	834	685	634	625	875	734	0.52	1,120	100	7.3	4.4
07072500	Black River at Black Rock, Ark.	5,150	4,080	3,940	4,130	6,730	4,990	0.47	7,350	76	2	4.5
07073000	Strawberry River near Evening Shade, Ark.	82	43	61	58	181	32	0.47	215	99	5.6	4.6
07073500	Piney Fork at Evening Shade, Ark.	29	19	29	27	74	7.55	0.37	99.8	100	7.2	4.6
07074000	Strawberry River near Poughkeepsie, Ark.	186	123	168	193	407	138	0.42	472	100	5.7	4.6
07075000	Middle Fork of Little Red River at Shirley, Ark.	64	83	103	201	423	5.21	0.28	302	15	13.3	4.2
07075300	South Fork of Little Red River at Clinton, Ark.	28	19	60	102	242	3.05	0.28	148	0	18.6	4.1
07075500	South Fork Little Red River near Clinton, Ark.	112	153	90	213	467	2.92	0.27	317	0	14.7	4.2
07077380	Cache River at Egypt, Ark.	472	457	490	422	800	--	0.32	691	2	1	4.6
07077500	Cache River at Patterson, Ark.	528	448	493	481	911	--	0.29	1,030	1	0.8	4.6
07077555	Cache River near Cotton Plant, Ark.	670	776	633	655	1,100	--	0.30	1,160	1	0.7	4.6
07077950	Big Creek at Poplar Grove, Mo.	150	203	198	186	491	--	0.32	374	0	0.7	4.9
07189000	Elk River near Tiff City, Mo.	--	--	--	--	--	199	0.46	853	100	6.8	--
07189540	Cave Springs Branch near South West City, Mo.	--	--	--	--	--	3.12	0.46	8.0	100	27.6	4
07189542	Honey Creek near South West City, Mo.	--	--	--	--	--	16.0	0.46	48.7	100	23.8	4
07191160	Spaviw Creek near Maysville, Ark.	53	36	33	43	38	29.3	0.46	88.8	100	18.7	4.3
07191179	Spaviw Creek near Cherokee City, Ark.	77	33	77	79	164	35.4	0.46	103	100	16.4	4.3
07191220	Spaviw Creek near Sycamore, Okla.	--	--	--	--	--	33.1	0.48	132	100	14.2	3.8
07194800	Illinois River at Savoy, Ark.	77	33	77	79	164	30.5	0.41	167	74	13	4.3
07195400	Illinois River at Highway 16 near Siloam Springs Ark.	377	268	386	307	409	258	0.43	509	89	7.8	4.3
07195430	Illinois River South of Siloam Springs, Ark.	460	271	350	368	507	282	0.43	568	90	7.2	4.3
07195800	Flint Creek at Springtown, Ark.	9.7	7.5	8.5	11	17	6.01	0.48	14.9	100	36.4	4.3
07195855	Flint Creek near West Siloam Springs, Okla.	--	--	--	--	--	14.6	0.48	56.8	0	20.5	3.8
07196900	Baron Fork at Dutch Mills, Ark.	17	7.9	21	28	54	2.26	0.31	41.1	58	38.4	4.2

Table 3–1. Dry season mean monthly flow, harmonic mean flow, and explanatory variable values for final regression equations.—Continued

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; Slope1085, slope of channel between points at 10 and 85 percent of the longest flow path from the outlet; mi^2, square mile; ft/mi, foot per mile; in., inches; --, gage was not used for the regression in the column heading for that station; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma]

USGS site number	USGS station name	Mean monthly streamflow for July (ft^3/s)	Mean monthly streamflow for August (ft^3/s)	Mean monthly streamflow for September (ft^3/s)	Mean monthly streamflow for October (ft^3/s)	Mean monthly streamflow for November (ft^3/s)	Harmonic mean flow (ft^3/s)	Base-flow index	Drainage area (mi^2)	Ordovician and Mississippian (percent)	Slope1085 (ft/mi)	Mean dry season total runoff (in.)
07197360	Caney Creek near Barber, Okla.	--	--	--	--	--	23.8	0.38	90.2	100	20.9	4.1
07247000	Poteau River at Cauthron, Ark.	61	25	53	112	269	3.27	0.18	204	0	8.8	4.6
07247500	Fourche Maline near Red Oak, Okla.	--	--	--	--	--	1.17	0.14	120	0	14.6	4.3
07249400	James Fork near Hackett, Ark.	49	11	31	74	149	2.55	0.20	147	0	16.1	4.2
07249413	Poteau River near Pama, Okla.	--	--	--	--	--	70.5	0.20	1,780	0	2.6	4.3
07249500	Cove Creek near Lee Creek, Ark.	22	10	11	13	24	0.85	0.25	34.8	11	32.3	4.1
07249985	Lee Creek near Short, Okla.	--	--	--	--	--	3.16	0.24	434	0	15.6	4.5
07250000	Lee Creek near Van Buren, Ark.	127	55	139	250	495	3.09	0.24	438	6	15.1	4.1
07250935	Jones Creek at Winfrey, Ark.	--	--	--	--	--	0.74	0.23	20.5	0	91.3	4.1
07251000	Frog Bayou near Mountainburg, Ark.	27	15	8.1	16	54	5.78	0.23	75.0	0	41.5	4.1
07252000	Mulberry River near Mulberry, Ark.	125	73	102	190	501	4.68	0.25	374	0	15.4	4
07252500	Sixmile Creek subwatershed 6 near Chismville, Ark.	1.6	0.7	0.82	0.51	3.7	--	0.21	4.1	0	34.2	4
07253000	Sixmile Creek at Chismville, Ark.	10	3.3	3.1	3.7	14	--	0.20	23.8	0	24.1	3.8
07253500	Sixmile Creek near Branch, Ark.	15	5.6	5.3	7.9	22	--	0.20	36.3	0	17.5	3.8
07255000	Sixmile Creek at Caulksville, Ark.	40	14	15	27	64	--	0.19	103	0	11.7	3.8
07255500	Hurricane Creek near Branch, Ark.	7.7	3.9	2.1	7.1	15	--	0.21	17.7	0	37.8	3.9
07256000	Hurricane Creek near Caulksville, Ark.	22	9.1	6.9	24	44	0.97	0.20	53.0	0	20.9	3.9
07256500	Spadra Creek at Clarksville, Ark.	21	12	21	27	48	3.45	0.25	61.3	0	48.8	3.9
07257000	Big Piney Creek near Dover, Ark.	69	40	51	134	393	3.97	0.27	273	3	16.3	3.8
07257006	Big Piney Creek at Highway 164 near Dover, Ark.	101	57	119	166	422	2.28	0.25	297	3	15.6	3.8
07257500	Illinois Bayou near Scottsville, Ark.	94	63	89	113	258	2.71	0.26	242	0	25.1	3.8
07258500	Petit Jean River near Booneville, Ark.	62	30	57	80	194	1.21	0.18	241	0	8.9	4.2
07259500	Petit Jean River near Waveland, Ark.	323	206	122	82	251	10.9	0.22	516	0	4	4.1
07260000	Dutch Creek at Waltreak, Ark.	26	12	33	28	81	0.62	0.20	81.8	0	18	4.4
07260500	Petit Jean River at Danville, Ark.	345	211	208	190	495	18.9	0.27	762	0	2.9	4.2
07261000	Cadron Creek near Guy, Ark.	36	40	66	89	257	1.96	0.27	172	0	6.7	4.1
07261500	Fourche LaFave River near Gravelly, Ark.	120	49	130	210	467	1.71	0.22	410	2	10.4	4.5
07262500	Fourche LaFave River near Nimrod, Ark.	394	170	184	148	468	10.4	0.19	684	1	6	4.3
07263000	South Fourche LaFave River near Hollis, Ark.	45	37	60	110	219	2.51	0.19	210	5	10.6	4.2
07263295	Maumelle River at Williams Junction, Ark.	6.2	4.4	27	35	63	0.70	0.21	115	1	17.8	3.9

Table 3–1. Dry season mean monthly flow, harmonic mean flow, and explanatory variable values for final regression equations.—Continued

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; Slope1085, slope of channel between points at 10 and 85 percent of the longest flow path from the outlet; mi^2, square mile; ft/mi, foot per mile; in., inches; --, gage was not used for the regression in the column heading for that station; Ark., Arkansas; Mo., Missouri; Okla., Oklahoma]

USGS site number	USGS station name	Mean monthly streamflow for July (ft^3/s)	Mean monthly streamflow for August (ft^3/s)	Mean monthly streamflow for September (ft^3/s)	Mean monthly streamflow for October (ft^3/s)	Mean monthly streamflow for November (ft^3/s)	Harmonic mean flow (ft^3/s)	Base-flow index	Drainage area (mi^2)	Ordovician and Mississippian (percent)	Slope1085 (ft/mi)	Mean dry season total runoff (in.)
07264000	Bayou Meto near Lonoke, Ark.	55	50	81	76	253	--	0.28	207	1	4.8	4.2
07337900	Glover River near Glover, Okla.	--	--	--	--	--	3.69	0.18	320	0	13.5	4.4
07339500	Rolling Fork near DeQueen, Ark.	87	56	108	114	256	4.71	0.18	183	88	17.4	5.6
07340300	Cossatot River near Vandervoort, Ark.	80	28	72	123	206	34.8	0.23	89.1	80	26.1	5.4
07340500	Cossatot River near DeQueen, Ark.	174	125	214	200	493	38.5	0.21	361	90	15.2	5.6
07341000	Saline River near Dierks, Ark.	53	22	56	54	162	--	0.21	120	90	20.6	5.6
07349430	Bodcau Creek at Stamps, Ark.	78	19	31	50	69	--	0.29	236	69	2.5	4.5
07356000	Ouachita River near Mount Ida, Ark.	235	100	243	374	721	81.9	0.25	414	76	8.2	4.9
07356500	South Fork Ouachita River at Mount Ida, Ark.	38	14	29	28	70	7.57	0.22	61.1	100	14.7	4.9
07359800	Caddo River near Alpine, Ark.	159	92	127	146	401	--	0.24	35.2	99	5	5.1
07360200	Little Missouri River near Langley, Ark.	54	38	88	89	133	34.0	0.22	67.9	77	36	5.4
07360800	Muddy Fork Creek near Murfreesboro, Ark.	50	12	72	60	133	1.88	0.19	120	50	15.9	5.6
07361000	Little Missouri River near Murfreesboro, Ark.	486	453	425	311	460	36.6	0.21	382	57	16.2	5.6
07361500	Antoine River at Antoine, Ark.	90	37	54	118	266	2.26	0.22	179	44	7.5	5.2
07361600	Little Missouri River near Boughton, Ark.	652	487	628	489	1,180	84.7	0.23	1,070	41	7.8	4.6
07362100	Smackover Creek near Smackover, Ark.	117	42	85	200	229	9.33	0.25	539	0	2.5	3.7
07362500	Moro Creek near Fordyce, Ark.	48	22	55	97	104	1.14	0.23	241	7	2.7	3.6
07362587	Alum Fork Saline River near Reform, Ark.	3.4	4.1	25	26	49	0.61	0.18	26.6	23	42.1	4.2
07363000	Saline River at Benton, Ark.	150	130	307	281	677	52.1	0.23	549	83	10.4	4.1
07363300	Hurricane Creek near Sheridan, Ark.	46	24	34	43	142	5.58	0.25	204	33	5.7	3.9
07363400	Hurricane Creek below Sheridan, Ark.	58	58	110	270	217	4.80	0.27	262	25	4.7	3.9
07363500	Saline River near Rye, Ark.	590	308	500	643	1,290	165	0.31	2,090	35	2.7	3.6
07364133	Bayou Bartholomew at Garrett Bridge, Ark.	264	159	136	197	296	--	0.35	401	0	0.5	3.8
07364150	Bayou Bartholomew near McGehee, Ark.	225	169	174	213	369	--	0.42	608	0	0.4	4
07364185	Bayou Bartholomew near Portland, Ark.	495	281	424	644	682	--	0.32	1,140	0	0.4	3.7
07365800	Cornie Bayou near Three Creeks, Ark.	46	15	40	44	131	2.74	0.24	180	0	2.8	3.7
07365900	Three Creeks near Three Creeks, Ark.	25	7.7	11	6.9	23	1.32	0.21	50.4	0	4.4	3.7
07369680	Bayou Macon at Eudora, Ark.	235	136	127	149	141	--	0.35	528	0	0.8	3.9

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