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Streamflow Alteration at Selected Sites in Kansas

Scientific Investigations Report 2017–5046

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

Cover photograph: Chapman Creek near Chapman, Kansas (photograph taken by Dirk Hargadine, U.S. Geological Survey, on January 7, 2014).

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RYAN K. ZINKE, Secretary

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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Abstract

An understanding of streamflow alteration in response to various disturbances is necessary for the effective management of stream habitat for a variety of species in Kansas. Streamflow alteration can have negative ecological effects. Using a modeling approach, streamflow alteration was assessed for 129 selected U.S. Geological Survey streamgages in the State for which requisite streamflow and basin-characteristic information was available. The assessment involved a comparison of the observed condition from 1980 to 2015 with the predicted expected (least-disturbed) condition for 29 streamflow metrics. The metrics represent various characteristics of streamflow including average flow (annual, monthly) and low and high flow (frequency, duration, magnitude).

Streamflow alteration in Kansas was indicated locally, regionally, and statewide. Given the absence of a pronounced trend in annual precipitation in Kansas, a precipitation-related explanation for streamflow alteration was not supported. Thus, the likely explanation for streamflow alteration was human activity. Locally, a flashier flow regime (typified by shorter lag times and more frequent and higher peak discharges) was indicated for three streamgages with urbanized basins that had higher percentages of impervious surfaces than other basins in the State. The combination of localized reservoir effects and regional groundwater pumping from the High Plains aquifer likely was responsible, in part, for diminished conditions indicated for multiple streamflow metrics in western and central Kansas. Statewide, the implementation of agricultural land-management practices to reduce runoff may have been responsible, in part, for a diminished duration and magnitude of high flows. In central and eastern Kansas, implemented agricultural land-management practices may have been partly responsible for an inflated magnitude of low flows at several sites.

Introduction

The physical habitat of streams and the type, distribution, and abundance of resident aquatic organisms are fundamentally determined by streamflow (Poff and others, 1997; Bunn and Arthington, 2002). The ecological integrity of streams can be adversely affected if the natural flow regime is altered (Poff and Zimmerman, 2010; Carlisle and others, 2011). The flow regime of a stream is determined by the magnitude, frequency, duration, timing, and rate of change of flows (Poff and others, 1997). Effective management to protect aquatic organism populations and habitats in Kansas requires an understanding of streamflow conditions and how those conditions may have changed in response to various disturbances. Throughout the State, the use and management of water resources to satisfy human needs have directly or indirectly affected streamflow. Examples of human activity that affect streamflow include surface-water diversions, reservoir construction and operation, groundwater pumping from aquifers, agricultural land-management practices, and urbanization.

A 1.5-year study by the U.S. Geological Survey (USGS), in cooperation with the Kansas Department of Wildlife, Parks and Tourism (KDWPT) and the U.S. Fish and Wildlife Service (FWS), was begun in 2016 to assess streamflow alteration at USGS streamgage sites throughout Kansas. The assessment, which provides an indication of where and how streamflow conditions have changed, can aid in management decisions for stream habitat prioritization, conservation, and restoration.

Purpose and Scope

The purpose of this report is to present the results of the USGS study to assess streamflow alteration at 129 selected USGS streamgage sites throughout Kansas. For each site, streamflow alteration was assessed by comparing the observed condition from 1980 to 2015 with the predicted expected (least-disturbed) condition for 29 metrics that account for various aspects of streamflow.

Results presented in this report are intended to provide some of the information needed by the KDWPT and FWS to support more effective management of stream habitats for various aquatic organisms. Nationally, the methods and results presented in this report can provide guidance and perspective for future studies concerned with streamflow alteration and the habitat implications thereof.

Description of Kansas

The study covered the entire State of Kansas, an area of about 82,000 square miles. Within the State, major rivers include the Arkansas, Cimarron, Kansas, Marais des Cygnes, Neosho, Republican, Saline, Smoky Hill, Solomon, Verdigris, and Walnut (fig. 1). Terrain varies across the State and includes flat plains, rolling hills, sandhills, and steep slopes (Moody and others, 1986). Land use is predominantly cropland and grassland (fig. 1; Jin and others, 2013).

The climate in Kansas is characterized by well-defined seasons and variable precipitation. On average, annual precipitation ranges from about 15 inches (in.) in extreme western Kansas to about 45 in. in the southeast (National Oceanic and Atmospheric Administration, 2016). From 1950 to 2000, there was not a pronounced trend in annual precipitation for Kansas (Brunsell and others, 2010). Moreover, from 1951 to 2013, a pronounced trend in annual precipitation was not evident for southwestern and south-central Kansas (Juracek, 2015). During the 21st century, global warming is projected to result in minimal change in average annual precipitation in the State, although the amount of precipitation in individual storm events may increase (Walsh and others, 2014). Increased temperatures may result in increased evapotranspiration.

The High Plains aquifer underlies much of western and central Kansas (fig. 2). The aquifer is characterized as a water-table aquifer that primarily consists of near-surface sand and gravel deposits (Weeks and others, 1988). Extensive use of groundwater from the aquifer, primarily for irrigated agriculture, began in the 1950s and continues to the present (Kansas Water Resources Board, 1958, 1960; Gutentag and others, 1984; Kenny and Juracek, 2013). Groundwater withdrawals for irrigation far in excess of natural recharge are the primary cause of groundwater-level declines in the aquifer (Gutentag and others, 1984; Young and others, 2005; Whittemore and others, 2016). In some locations, groundwater-level declines of 50 to 150 feet or more have occurred (fig. 2; McGuire, 2014).

Methods

Streamflow alteration was assessed using the reference condition approach (Bailey and others, 2004; Carlisle and others, 2010), which is based on the principle that expected reference conditions for basins influenced by hydrologic modifications (for example, groundwater withdrawals or land-use change) can be predicted using statistical models developed for a population of reference (least-disturbed) basins. With this approach, streamflow alteration at selected streamgages was quantified as the difference between the observed flow conditions and the predicted expected reference conditions. In this study, the period from 1980 to 2015 was examined to provide an assessment of flow alteration for recent conditions in Kansas.

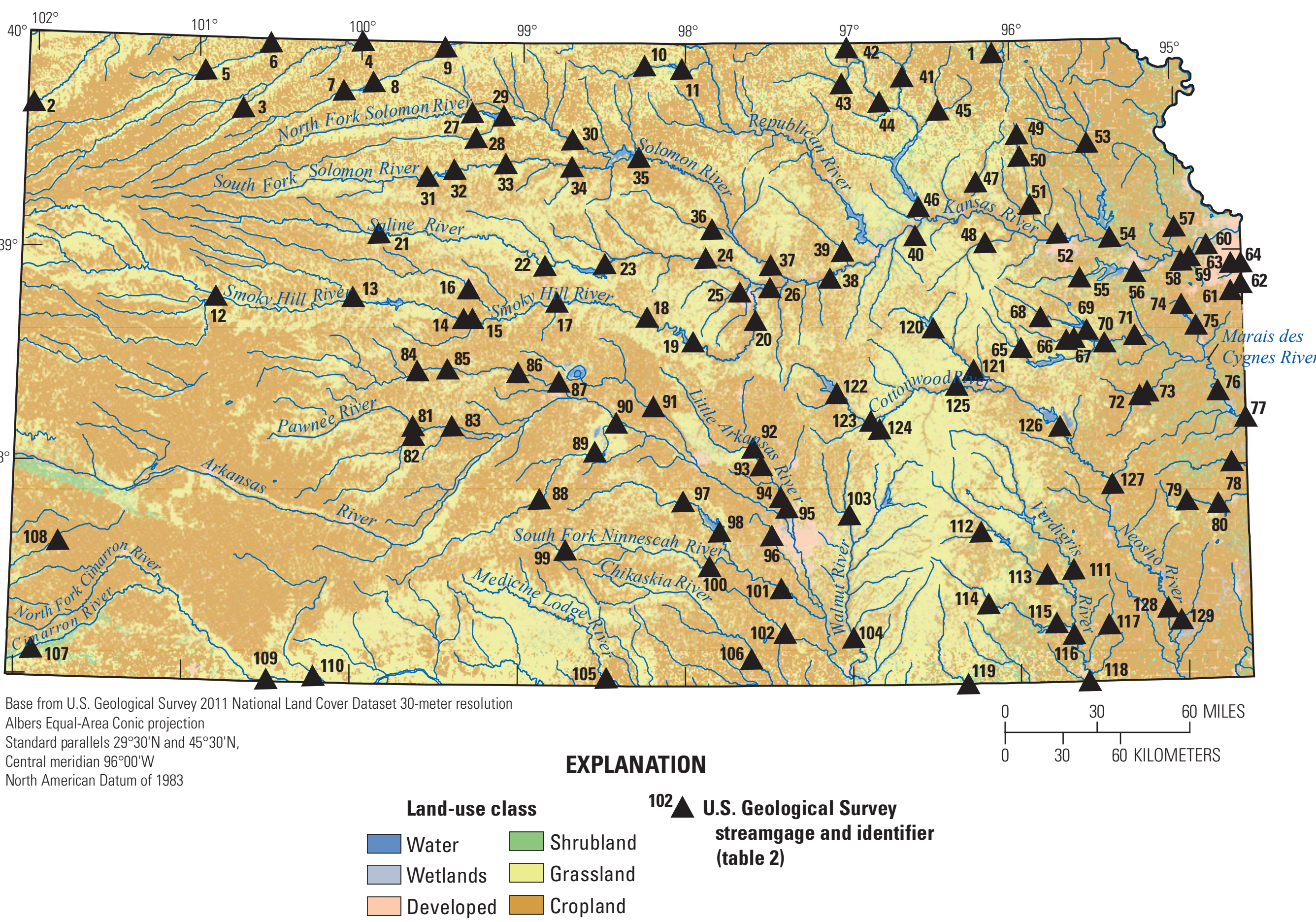

Figure 1. Land use (2011) and selected U.S. Geological Survey streamgages in Kansas.

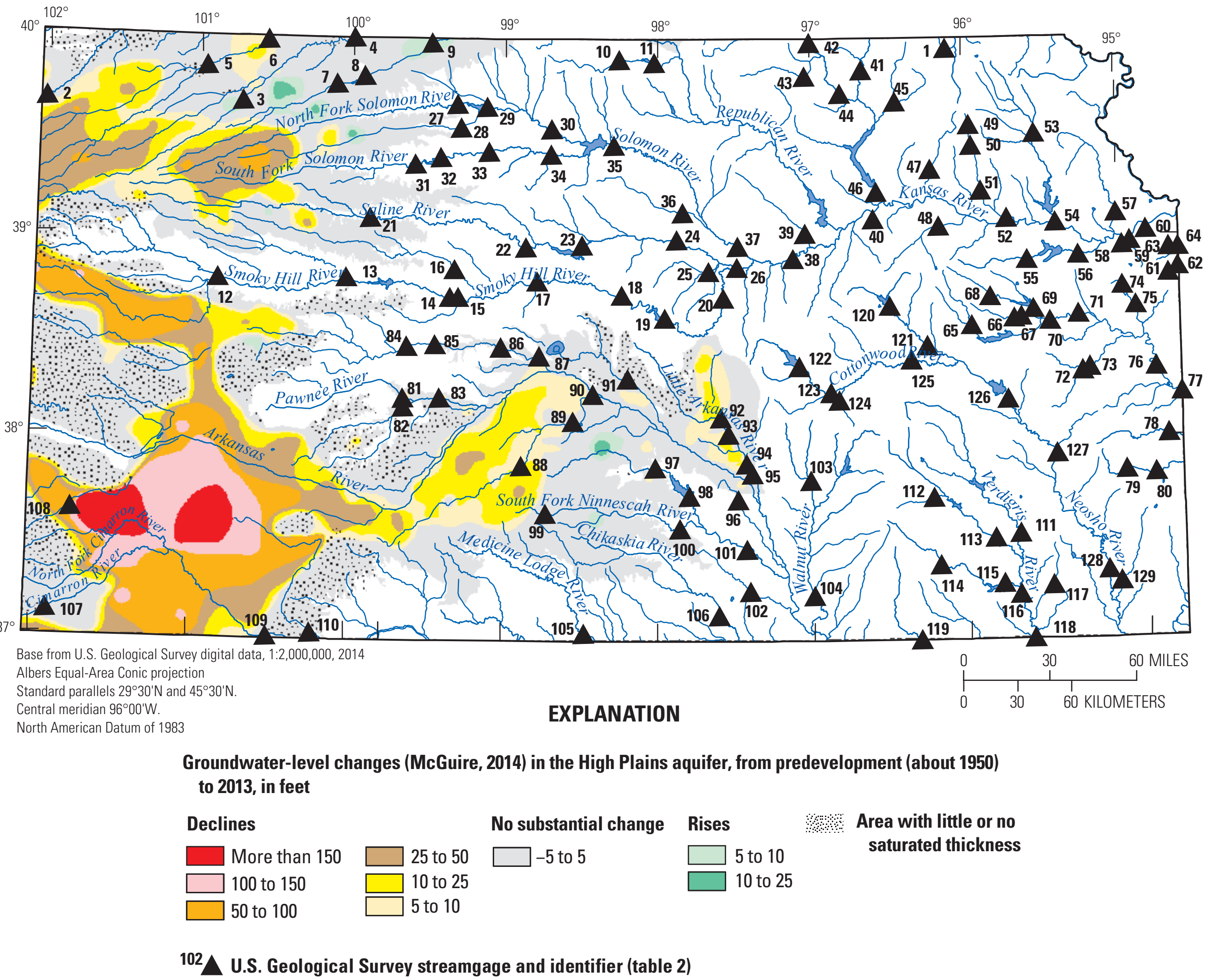

Figure 2. Groundwater-level changes in the High Plains aquifer from predevelopment to 2013 (Source: McGuire, 2014).

To assess streamflow alteration various flow metrics were used that were computed from daily-flow time series and are indicative of key aspects of the flow regime (Carlisle and others, 2010). Twenty-nine metrics that represent various characteristics of flow, including median or mean flow (annual, monthly), daily flow variability, low and high flow (frequency, duration, magnitude), and base flow, were selected (table 1).

Two criteria were used in the selection of USGS streamgages to be included in the assessment of streamflow alteration in Kansas. First, the streamgages were required to have a minimum of 12 years of complete daily streamflow record from 1980 to 2015. This minimum was used instead of the 15 years recommended by Kennard and others (2010) because of the additional number and spatial coverage of streamgages that could be included in the analysis by lowering the threshold. Moreover, the differences in bias, precision, and accuracy for 12 years as compared to 15 years were minimal (Kennard and others, 2010). Second, the streamgages also needed to be listed in the Geospatial Attributes of Gages for Evaluating Streamflow, version 2 (GAGES–II) database (Falcone, 2011) so that the associated basin characteristics required for the analysis could be used. The GAGES–II database provides more than 300 basin characteristics for streamgages with a basin size of 50,000 square kilometers (about 19,300 square miles) or less. Use of the two criteria resulted in the selection of 129 streamgages (fig. 1; table 2). Each of the streamgages provides long-term daily flow data that were collected as part of the USGS national streamgaging network using standard USGS methods (Turnipseed and Sauer, 2010). The flow data are available from the USGS National Water Information System (NWIS; U.S. Geological Survey, 2016). The observed values of the 29 flow metrics for each streamgage were calculated using daily flow data downloaded from NWIS using a program by Granato (2009).

Estimates of the expected reference value for each flow metric for each streamgage were predicted with statistical models that used basin characteristics, such as climate, topography, and soils, as explanatory variables (Carlisle and others,

Table 1. Streamflow metrics used in this study.

Metric	Description
P50	Median annual flow normalized by drainage area.
CV_FLOW	Coefficient of variation of daily flows.
AVG_JAN	Mean January flow normalized by drainage area.
AVG_FEB	Mean February flow normalized by drainage area.
AVG_MAR	Mean March flow normalized by drainage area.
AVG_APR	Mean April flow normalized by drainage area.
AVG_MAY	Mean May flow normalized by drainage area.
AVG_JUN	Mean June flow normalized by drainage area.
AVG_JUL	Mean July flow normalized by drainage area.
AVG_AUG	Mean August flow normalized by drainage area.
AVG_SEP	Mean September flow normalized by drainage area.
AVG_OCT	Mean October flow normalized by drainage area.
AVG_NOV	Mean November flow normalized by drainage area.
AVG_DEC	Mean December flow normalized by drainage area.
PUL_NO_P90	Average annual number of flow pulses greater than the 90th percentile.
PUL_NO_P75	Average annual number of flow pulses greater than the 75th percentile.
PUL_NO_P25	Average annual number of flow pulses less than the 25th percentile.
PUL_NO_P10	Average annual number of flow pulses less than the 10th percentile.
P10	10th percentile flow normalized by drainage area.
P90	90th percentile flow normalized by drainage area.
PER_BSFL[a]	Percentage of flow that is base flow.
PUL_LEN_P10	Average duration of flow pulses less than the 10th percentile.
PUL_LEN_P25	Average duration of flow pulses less than the 25th percentile.
PUL_LEN_P75	Average duration of flow pulses greater than the 75th percentile.
PUL_LEN_P90	Average duration of flow pulses greater than the 90th percentile.
PUL_FLOW_P10	Average magnitude of flow pulses less than the 10th percentile, normalized by drainage area.
PUL_FLOW_P25	Average magnitude of flow pulses less than the 25th percentile, normalized by drainage area.
PUL_FLOW_P75	Average magnitude of flow pulses greater than the 75th percentile, normalized by drainage area.
PUL_FLOW_P90	Average magnitude of flow pulses greater than the 90th percentile, normalized by drainage area.

[a]Renamed from metric M_L20 in Olden and Poff (2003).

2010). Statistical models were developed using 1,443 previously identified streamgages (Falcone and others, 2010) with least-disturbed basins (that is, reference quality) on perennial, intermittent, and ephemeral streams across the contiguous United States. For each reference site, 176 geospatial characteristics representing natural (that is, excluding land cover and other anthropogenic activities) physical attributes of the contributing basin were computed (Falcone, 2011).

Separate random forest (Cutler and others, 2007) models were developed for each flow metric using the 1,443 reference sites, with the observed metric as the dependent variable and the natural geospatial characteristics as predictors. The random forest models were implemented in Matlab using a script by Jaiantilal (2009). Modeling proceeded as follows: First, 30 random forest models, each with 1,000 trees, were fit using all 176 basin characteristics and a randomly selected subset of 90 percent of the reference sites. Then, for each random forest model, the importance of each predictor variable was computed by measuring the decrease in model performance as that variable was randomly permuted (Cutler and others, 2007). The 20 predictors with the highest average importance among the 30 initial models were selected for the final model (Eng and others, in press). For each flow metric, the final model included 100 random forest fits, each with 1,000 trees, trained on a randomly selected subset of 90 percent of the reference sites. For each random forest model fit, 10 percent of the sites were set aside for validation of model performance and were selected in equal numbers from nine aggregated ecoregions of the contiguous United States (Falcone, 2011) to ensure even geographic distribution.

Model performance was evaluated using four independent (Pearson $r < 0.3$) criteria. These were Nash-Sutcliffe

Table 2. U.S. Geological Survey streamgages used in this study to examine streamflow alteration in Kansas.

[USGS, U.S. Geological Survey; km^2, square kilometer]

Site identifier (fig. 1)	USGS streamgage number	USGS streamgage name	Drainage area[a] (km^2)	Complete years of record (since 1980)
1	06814000	Turkey Creek near Seneca, Kansas	713.8	36
2	06827000	South Fork Republican River near Colorado-Kansas State line, Kansas	5,313.8	13
3	06844900	South Fork Sappa Creek near Achilles, Kansas	1,153.5	29
4	06845110	Sappa Creek near Lyle, Kansas	3,782.1	20
5	06846000	Beaver Creek at Ludell, Kansas	3,729	14
6	06846500	Beaver Creek at Cedar Bluffs, Kansas	4,357.8	36
7	06847900	Prairie Dog Creek above Keith Sebelius Lake, Kansas	1,536.2	36
8	06848000	Prairie Dog Creek at Norton, Kansas	1,808.4	22
9	06848500	Prairie Dog Creek near Woodruff, Kansas	2,575.4	36
10	06853800	White Rock Creek near Burr Oak, Kansas	589.4	36
11	06854000	White Rock Creek at Lovewell, Kansas	895.6	22
12	06860000	Smoky Hill River at Elkader, Kansas	9,033.4	36
13	06861000	Smoky Hill River near Arnold, Kansas	12,897.8	36
14	06862700	Smoky Hill River near Schoenchen, Kansas	14,327.7	36
15	06862850	Smoky Hill River below Schoenchen, Kansas	14,460.8	34
16	06863500	Big Creek near Hays, Kansas	1,417.3	36
17	06864050	Smoky Hill River near Bunker Hill, Kansas	18,025.1	31
18	06864500	Smoky Hill River at Ellsworth, Kansas	19,334.8	36
19	06865500	Smoky Hill River near Langley, Kansas	20,074.1	36
20	06866500	Smoky Hill River near Mentor, Kansas	20,903.3	36
21	06866900	Saline River near WaKeeney, Kansas	1,801.6	34
22	06867000	Saline River near Russell, Kansas	3,857	36
23	06868200	Saline River at Wilson Dam, Kansas	4,995.3	36
24	06869500	Saline River at Tescott, Kansas	7,215.1	36
25	06869950	Mulberry Creek near Salina, Kansas	671.7	13
26	06870200	Smoky Hill River at New Cambria, Kansas	29,925.4	27
27	06871000	North Fork Solomon River at Glade, Kansas	2,424.4	36
28	06871500	Bow Creek near Stockton, Kansas	903.7	36
29	06871800	North Fork Solomon River at Kirwin, Kansas	3,609.5	22
30	06872500	North Fork Solomon River at Portis, Kansas	6,217.1	34
31	06873000	South Fork Solomon River above Webster Reservoir, Kansas	2,698.8	36
32	06873200	South Fork Solomon River below Webster Reservoir, Kansas	3,014.5	22
33	06873460	South Fork Solomon River at Woodston, Kansas	4,080.1	36
34	06874000	South Fork Solomon River at Osborne, Kansas	5,102.3	36
35	06875900	Solomon River near Glen Elder, Kansas	13,705.5	36
36	06876700	Salt Creek near Ada, Kansas	1,056.4	36
37	06876900	Solomon River at Niles, Kansas	17,487.5	36
38	06877600	Smoky Hill River at Enterprise, Kansas	49,592.2	36
39	06878000	Chapman Creek near Chapman, Kansas	776.4	36
40	06879650	Kings Creek near Manhattan, Kansas	11.5	36
41	06882510	Big Blue River at Marysville, Kansas	12,371.3	31
42	06884025	Little Blue River at Hollenberg, Kansas	7,172	35
43	06884200	Mill Creek at Washington, Kansas	908.4	36

Table 2. U.S. Geological Survey streamgages used in this study to examine streamflow alteration in Kansas.—Continued

[USGS, U.S. Geological Survey; km², square kilometer]

Site identifier (fig. 1)	USGS streamgage number	USGS streamgage name	Drainage area[a] (km²)	Complete years of record (since 1980)
44	06884400	Little Blue River near Barnes, Kansas	8,656	36
45	06885500	Black Vermillion River near Frankfort, Kansas	1,062.9	36
46	06887000	Big Blue River near Manhattan, Kansas	24,991.8	36
47	06888000	Vermillion Creek near Wamego, Kansas	609.7	13
48	06888500	Mill Creek near Paxico, Kansas	842.3	36
49	06889140	Soldier Creek near Soldier, Kansas	44.1	18
50	06889160	Soldier Creek near Circleville, Kansas	129	21
51	06889200	Soldier Creek near Delia, Kansas	385.7	36
52	06889500	Soldier Creek near Topeka, Kansas	748.6	36
53	06890100	Delaware River near Muscotah, Kansas	1,132	36
54	06890900	Delaware River at Perry, Kansas	2,923.2	27
55	06891260	Wakarusa River near Richland, Kansas	426.1	13
56	06891500	Wakarusa River near Lawrence, Kansas	1,103.7	36
57	06892000	Stranger Creek near Tonganoxie, Kansas	1,092.7	36
58	06892360	Kill Creek at 95th Street near DeSoto, Kansas	124.1	12
59	06892495	Cedar Creek near DeSoto, Kansas	151.1	13
60	06892513	Mill Creek at Johnson Drive, Shawnee, Kansas	150.5	13
61	06893080	Blue River near Stanley, Kansas	117.8	36
62	06893100	Blue River at Kenneth Road, Overland Park, Kansas	170.8	12
63	06893300	Indian Creek at Overland Park, Kansas	68.7	36
64	06893390	Indian Creek at State Line Road, Leawood, Kansas	167.5	12
65	06910800	Marais des Cygnes River near Reading, Kansas	444.6	36
66	06911490	Salt Creek at Lyndon, Kansas	248.1	16
67	06911500	Salt Creek near Lyndon, Kansas	282.2	19
68	06911900	Dragoon Creek near Burlingame, Kansas	293.1	36
69	06912500	Hundred and Ten Mile Creek near Quenemo, Kansas	836.9	36
70	06913000	Marais des Cygnes River near Pomona, Kansas	2,727.1	36
71	06913500	Marais des Cygnes River near Ottawa, Kansas	3,242.4	36
72	06914000	Pottawatomie Creek near Garnett, Kansas	862.2	21
73	06914100	Pottawatomie Creek near Scipio, Kansas	892	14
74	06914950	Big Bull Creek near Edgerton, Kansas	74.9	22
75	06915000	Big Bull Creek near Hillsdale, Kansas	378.9	36
76	06915800	Marais des Cygnes River at La Cygne, Kansas	7,026.9	31
77	06916600	Marais des Cygnes River near Kansas-Missouri State Line, Kansas	8,387	36
78	06917000	Little Osage River at Fulton, Kansas	765.8	36
79	06917240	Marmaton River near Uniontown, Kansas	213.4	14
80	06917380	Marmaton River near Marmaton, Kansas	761	28
81	07140850	Pawnee River near Burdett, Kansas	2,971	34
82	07141175	Buckner Creek near Burdett, Kansas	2,045.6	17
83	07141200	Pawnee River at Rozel, Kansas	5,767.9	36
84	07141770	Walnut Creek near Alexander, Kansas	2,892.8	18
85	07141780	Walnut Creek at Nekoma, Kansas	3,320	36
86	07141900	Walnut Creek at Albert, Kansas	4,169.3	36
87	07142020	Walnut Creek below Cheyenne Bottoms Diversion near Great Bend, Kansas	4,393.5	15

Table 2. U.S. Geological Survey streamgages used in this study to examine streamflow alteration in Kansas.—Continued

[USGS, U.S. Geological Survey; km², square kilometer]

Site identifier (fig. 1)	USGS streamgage number	USGS streamgage name	Drainage area[a] (km²)	Complete years of record (since 1980)
88	07142300	Rattlesnake Creek near Macksville, Kansas	1,819.9	36
89	07142575	Rattlesnake Creek near Zenith, Kansas	2,685.8	36
90	07142620	Rattlesnake Creek near Raymond, Kansas	3,166.1	18
91	07143300	Cow Creek near Lyons, Kansas	1,872.9	36
92	07143665	Little Arkansas River at Alta Mills, Kansas	1,923.9	36
93	07143672	Little Arkansas River at Highway 50 near Halstead, Kansas	2,003.4	20
94	07144100	Little Arkansas River near Sedgwick, Kansas	3,200.4	22
95	07144200	Little Arkansas River at Valley Center, Kansas	3,377.3	36
96	07144480	Cowskin Creek at 119th Street at Wichita, Kansas	221.8	14
97	07144780	North Fork Ninnescah River above Cheney Reservoir, Kansas	2,078.9	36
98	07144795	North Fork Ninnescah River at Cheney Dam, Kansas	2,575.9	35
99	07144910	South Fork Ninnescah River near Pratt, Kansas	321.5	35
100	07145200	South Fork Ninnescah River near Murdock, Kansas	1,555.2	36
101	07145500	Ninnescah River near Peck, Kansas	5,527.6	36
102	07145700	Slate Creek at Wellington, Kansas	399.8	36
103	07147070	Whitewater River at Towanda, Kansas	1,096.5	36
104	07147800	Walnut River at Winfield, Kansas	4,864.7	36
105	07149000	Medicine Lodge River near Kiowa, Kansas	2,291.2	36
106	07151500	Chikaskia River near Corbin, Kansas	2,109	36
107	07155590	Cimarron River near Elkhart, Kansas	7,554.3	33
108	07156220	Bear Creek near Johnson, Kansas	2,132.4	18
109	07156900	Cimarron River near Forgan, Oklahoma	17,944.5	35
110	07157500	Crooked Creek near Englewood, Kansas	3,515.7	36
111	07166500	Verdigris River near Altoona, Kansas	2,874.2	36
112	07167500	Otter Creek at Climax, Kansas	319.6	36
113	07169500	Fall River at Fredonia, Kansas	2,097.5	36
114	07169800	Elk River at Elk Falls, Kansas	565	36
115	07170060	Elk River below Elk City Lake, Kansas	1,650.2	22
116	07170500	Verdigris River at Independence, Kansas	7,358.4	36
117	07170700	Big Hill Creek near Cherryvale, Kansas	94.8	33
118	07170990	Verdigris River at Coffeyville, Kansas	8,548.4	13
119	07172000	Caney River near Elgin, Kansas	1,110.2	36
120	07179500	Neosho River at Council Grove, Kansas	686	36
121	07179730	Neosho River near Americus, Kansas	1,600.3	36
122	07179795	North Cottonwood River below Marion Lake, Kansas	534.6	36
123	07180400	Cottonwood River near Florence, Kansas	1,935.7	36
124	07180500	Cedar Creek near Cedar Point, Kansas	275.5	36
125	07182250	Cottonwood River near Plymouth, Kansas	4,477	36
126	07182510	Neosho River at Burlington, Kansas	7,882.4	36
127	07183000	Neosho River near Iola, Kansas	9,917.6	36
128	07183500	Neosho River near Parsons, Kansas	12,544.2	36
129	07184000	Lightning Creek near McCune, Kansas	510.8	36

[a]Drainage areas from Falcone (2011).

efficiency (NSE, Nash and Sutcliffe, 1970), percent bias (Moriasi and others, 2007), mean observed-to-expected (O/E) values (Carlisle and others, 2011), and the standard deviation (SD) of O/E values. These criteria were calculated on each randomly chosen set of 100 validation sites and then averaged for each flow metric. For simplicity, a single composite performance measure also was calculated by standardizing the four criteria to a 0-to-1 scale and computing their sum, with the highest scores indicating superior performance. All NSE negative values were set to zero so that the range was bound between 0 and 1. Values for percent bias were bound between ±100, divided by 100, and their absolute values were subtracted from 1. The bounds for mean O/E were 0 and 2. Values between 0 and 1 were unscaled, and values from 1 to 2 were subtracted from 2. The bounds for the SD of O/E were set at 0 and 0.5 and scaled from 0 to 1, where a value of 1 corresponds to a SD of 0 and a value of 0 corresponds to a SD of 0.5 or greater.

For the majority of the models (21 of 29) for the flow metrics, performance was either good or very good (table 3) and these were the most predictable metrics (as defined by Eng and others, in press). Model performance was fair for 7 metrics (table 3). The model for the baseflow metric (PER_BSFL) performed poorly. Poor model performance for low flow estimation has been reported elsewhere by Eng and Milly (2007) and Newman and others (2015). Based on an assessment of regional variability in hydrologic model performance for the contiguous United States, Newman and others (2015) concluded that the main factors affecting the variation in model performance were aridity, precipitation intermittency, snowmelt contribution, and runoff seasonality. In addition, other factors that contribute to poor model performance for low and base flow estimation include the inherent measurement error for low flows and a lack of good subsurface metrics that describe aquifer hydraulic properties.

Flow alteration at the streamgages for each of the 29 flow metrics (table 1) was quantified by the ratio of the observed value to the predicted expected value (O/E). The error bounds of each model were determined by taking the 10th and 90th percentile values from histograms of all validation O/E values. These bounds represent thresholds beyond which anthropogenic alteration could be reliably distinguished from model error. Thus, for this study, a flow metric was considered anthropogenically altered only if the O/E value was equal to or greater than the 90th percentile threshold (considered to be inflated) or equal to or less than the 10th percentile threshold (considered to be diminished).

Streamflow Alteration in Kansas

Results of the analysis that used 29 flow metrics to assess streamflow alteration at 129 selected streamgages in Kansas are presented in this section. The order of presentation is mean monthly flows, annual low-flow metrics, annual high-flow metrics, and other annual flow metrics. In the results presented, a minimally altered condition indicates that the O/E value for the flow metric is within the model error and is considered least disturbed. A diminished condition indicates that the O/E value for the flow metric is less than what would be expected for a least-disturbed condition. An inflated condition indicates that the O/E value for the flow metric is greater than what would be expected for a least-disturbed condition. Complete O/E results for all streamgages are provided in tables 1–1 to 1–8 in the appendix at the back of this report.

Mean Monthly Flows

In Kansas, a minimally altered condition for mean monthly flow was indicated for every month for the majority of the streamgages. The percentage of streamgages with a minimally altered condition ranged from 59 percent for March and December to 81 percent for July, with an all-month average of 66 percent (table 4). A diminished condition for mean monthly flow was indicated for a substantial number of streamgages, ranging from 14 percent for August to 39 percent for March, with an all-month average of 28 percent. With one exception, streamgages with an inflated condition for mean monthly flow were uncommon. The exception was August for which 24 percent of the streamgages had an inflated condition. For most months, the percentage of streamgages with an inflated condition was 5 percent or less.

Geographically, a pronounced pattern was evident for the distribution of streamgages with a diminished condition for mean monthly flows. In general, such streamgages were in the western half of Kansas (figs. 3–14, at the back of this report). Twelve streamgages in western Kansas (sites 4, 6, 9, 12–15, 29, 88, 90, 107, and 110) had a diminished condition for all 12 months (figs. 3–14; tables 1–1 to 1–3 in the appendix). Major river basins in western Kansas with diminished flows for multiple months and multiple streamgages were the Arkansas, Cimarron, Republican, Saline, Smoky Hill, and Solomon (figs. 3–14).

Annual Low-Flow Metrics

Annual low-flow metrics assessed were the average number, duration, and magnitude of flow pulses less than the 10th and 25th percentiles. For average duration and magnitude, the assessment was limited for western Kansas because it was not possible to compute those two metrics for several streamgages given an absence of flow.

Alteration of flow pulses less than the 10th percentile was evident across the State. For the average annual number of such pulses, the indicated conditions were minimally altered for 41 percent, diminished for 22 percent, and inflated for 36 percent of the streamgages (table 5). Reductions in the number of such pulses typically were for streamgages in the western half of Kansas, whereas increases typically were for streamgages in central and eastern Kansas (fig. 15, at the back

Table 3. Model performance criteria.

[Bias, percent bias (unstandardized values); O/E, observed (O) divided by expected (E) values (that is, O/E ratio; unstandardized values); SD, standard deviation; NSE, Nash-Sutcliffe efficiency (unstandardized values); Comp, composite performance criterion (0 to 4, higher score indicates superior performance); ModelPerf, model performance (very good [comp≥3.40], good [3.10≤comp<3.40], fair [2.70≤comp<3.10], and poor [comp<2.70])]

Metric (table 1)	Bias[a]	Mean O/E[b]	SD O/E	NSE[c]	Comp	ModelPerf[d]
P50	0.37	0.92	0.43	0.93	3.419	Very good.
CV_FLOW	-0.58	0.99	0.23	0.78	3.531	Very good.
AVG_JAN	-1.06	0.95	0.48	0.96	3.413	Very good.
AVG_FEB	-0.53	0.96	0.45	0.95	3.46	Very good.
AVG_MAR	-0.6	0.97	0.56	0.94	3.356	Good.
AVG_APR	-1.31	0.95	0.35	0.93	3.512	Very good.
AVG_MAY	-1.49	0.95	0.39	0.87	3.409	Very good.
AVG_JUN	-1.26	0.95	0.44	0.88	3.385	Good.
AVG_JUL	1.51	0.96	0.47	0.87	3.355	Good.
AVG_AUG	3.45	0.97	0.53	0.8	3.202	Good.
AVG_SEP	2.52	0.97	0.55	0.79	3.18	Good.
AVG_OCT	0.93	0.97	0.48	0.88	3.362	Good.
AVG_NOV	-0.42	0.94	0.43	0.95	3.459	Very good.
AVG_DEC	-1.37	0.94	0.46	0.95	3.417	Very good.
PUL_NO_P90	0.25	0.98	0.26	0.82	3.54	Very good.
PUL_NO_P75	0.43	0.98	0.26	0.81	3.529	Very good.
PUL_NO_P25	2.22	1.01	0.55	0.57	2.985	Fair.
PUL_NO_P10	0.77	1.01	0.8	0.54	2.712	Fair.
P10	2.15	0.87	0.63	0.77	2.997	Fair.
P90	-1.59	0.94	0.32	0.94	3.55	Very good.
PER_BSFL	-5.96	0.89	0.85	0.07	2.051	Poor.
PUL_LEN_P10	-3.03	0.96	0.38	0.45	3	Fair.
PUL_LEN_P25	-4.85	0.95	0.35	0.49	3.049	Fair.
PUL_LEN_P75	-3.04	0.96	0.36	0.69	3.269	Good.
PUL_LEN_P90	-2.79	0.96	0.36	0.72	3.293	Good.
PUL_FLOW_P10	2.04	0.85	0.63	0.76	2.964	Fair.
PUL_FLOW_P25	2.39	0.89	0.58	0.8	3.09	Fair.
PUL_FLOW_P75	-1.17	0.97	0.33	0.94	3.572	Very good.
PUL_FLOW_P90	-1.22	0.97	0.33	0.94	3.573	Very good.

[a]Moriasi and others (2007).

[b]Carlisle and others (2011).

[c]Nash and Sutcliffe (1970).

[d]Eng and others (in press, table 1).

of this report). For the average duration of such pulses, the indicated conditions were minimally altered for 47 percent, diminished for 26 percent, inflated for 5 percent, and not computed for 22 percent of the streamgages (table 5). For the average magnitude of such pulses, the indicated conditions were minimally altered for 43 percent, diminished for 16 percent, inflated for 19 percent, and not computed for 22 percent of the streamgages. A pronounced statewide pattern for the distribution of streamgages with a diminished or inflated condition for the average duration and magnitude of flow pulses less than the 10th percentile was not apparent (figs. 16 and 17, at the back of this report). Although, a diminished condition for average duration was indicated for a cluster of 13 streamgages in extreme east-central Kansas (fig. 16).

Table 4. Summary of alteration of mean monthly flows for 129 streamgages in Kansas.

[%, percent rounded to nearest whole number. As a result of rounding error, the percentages for a given month may not sum to 100]

Month	Number of streamgages		
	Diminished condition	Minimally altered condition	Inflated condition
January	44 (34%)	80 (62%)	5 (4%)
February	37 (29%)	89 (69%)	3 (2%)
March	50 (39%)	76 (59%)	3 (2%)
April	37 (29%)	83 (64%)	9 (7%)
May	35 (27%)	88 (68%)	6 (5%)
June	39 (30%)	83 (64%)	7 (5%)
July	19 (15%)	104 (81%)	6 (5%)
August	18 (14%)	80 (62%)	31 (24%)
September	39 (30%)	84 (65%)	6 (5%)
October	38 (29%)	88 (68%)	3 (2%)
November	39 (30%)	86 (67%)	4 (3%)
December	40 (31%)	76 (59%)	13 (10%)
12-month mean	36 (28%)	85 (66%)	8 (6%)

Alteration of flow pulses less than the 25th percentile was less evident. For the average annual number of such pulses, a minimally altered condition was indicated for 74 percent of the streamgages. The remaining 26 percent was split equally between streamgages with a diminished and an inflated condition (table 5). Streamgages with a decreased number of such pulses typically were in the western half of Kansas (fig. 18, at the back of this report). For the average duration and average magnitude of pulses less than the 25th percentile, similar conditions were indicated, as follows: minimally altered, mean of 61.5 percent; diminished, mean of 13 percent; inflated, mean of 12.5 percent; and not computed, 13 percent (table 5). The locations of streamgages with a diminished, inflated, or minimally altered condition for the duration and magnitude of flow pulses less than the 25th percentile are provided in figures 19 and 20, at the back of this report.

Annual High-Flow Metrics

Annual high-flow metrics assessed were the average number, duration, and magnitude of flow pulses greater than the 75th and 90th percentiles. In Kansas, there was considerable alteration of flow pulses greater than both percentiles.

For the average annual number of pulses greater than the 75th percentile, a diminished condition was indicated for 26 percent of the streamgages, most of which were in the western half of Kansas. Conversely, an inflated condition was indicated for 25 percent of the streamgages, most of which were in the eastern half of Kansas (fig. 21, at the back of this report; table 6). For the remaining streamgages, a minimally altered condition was indicated.

The average duration of flow pulses greater than the 75th percentile was minimally altered for 71 percent of the streamgages. An inflated and diminished condition was indicated for 23 percent and 6 percent of the streamgages, respectively (table 6). Frequently, especially in western Kansas, streamgages with an inflated condition for average duration also had a diminished condition for the average annual number of flow pulses greater than the 75th percentile (figs. 21 and 22, at the back of this report). Thus, at those sites, such flow pulses occurred less often but lasted longer compared with what would be expected for a least-disturbed condition.

Table 5. Summary of alteration of annual low-flow metrics for 129 streamgages in Kansas.

[%, percent rounded to nearest whole number. As a result of rounding error, the percentages for a given flow metric may not sum to 100. na, not applicable]

Metric (table 1)	Number of streamgages			
	Diminished condition	Minimally altered condition	Inflated condition	Not computed
PUL_NO_P10[a]	29 (22%)	53 (41%)	47 (36%)	na
PUL_LEN_P10[b]	33 (26%)	60 (47%)	7 (5%)	29 (22%)
PUL_FLOW_P10[c]	20 (16%)	56 (43%)	24 (19%)	29 (22%)
PUL_NO_P25[d]	17 (13%)	95 (74%)	17 (13%)	na
PUL_LEN_P25[e]	18 (14%)	79 (61%)	15 (12%)	17 (13%)
PUL_FLOW_P25[f]	15 (12%)	80 (62%)	17 (13%)	17 (13%)

[a]Average annual number of flow pulses less than the 10th percentile.

[b]Average duration of flow pulses less than the 10th percentile.

[c]Average magnitude of flow pulses less than the 10th percentile, normalized by drainage area.

[d]Average annual number of flow pulses less than the 25th percentile.

[e]Average duration of flow pulses less than the 25th percentile.

[f]Average magnitude of flow pulses less than the 25th percentile, normalized by drainage area.

Table 6. Summary of alteration of annual high-flow metrics for 129 streamgages in Kansas.

[%, percent rounded to nearest whole number. As a result of rounding error, the percentages for a given flow metric may not sum to 100]

Metric (table 1)	Number of streamgages		
	Diminished condition	Minimally altered condition	Inflated condition
PUL_NO_P75[a]	33 (26%)	64 (50%)	32 (25%)
PUL_LEN_P75[b]	8 (6%)	91 (71%)	30 (23%)
PUL_FLOW_P75[c]	48 (37%)	79 (61%)	2 (2%)
PUL_NO_P90[d]	45 (35%)	62 (48%)	22 (17%)
PUL_LEN_P90[e]	75 (58%)	46 (36%)	8 (6%)
PUL_FLOW_P90[f]	52 (40%)	75 (58%)	2 (2%)

[a]Average annual number of flow pulses greater than the 75th percentile.

[b]Average duration of flow pulses greater than the 75th percentile.

[c]Average magnitude of flow pulses greater than the 75th percentile, normalized by drainage area.

[d]Average annual number of flow pulses greater than the 90th percentile.

[e]Average duration of flow pulses greater than the 90th percentile.

[f]Average magnitude of flow pulses greater than the 90th percentile, normalized by drainage area.

The average magnitude of flow pulses greater than the 75th percentile was minimally altered for 61 percent of the streamgages. A diminished condition was indicated for 37 percent of the streamgages (table 6). Most of the streamgages with a diminished condition were in the western half of Kansas (fig. 23, at the back of this report). An inflated condition was indicated for the remaining 2 percent of the streamgages (table 6).

Considerable alteration also was evident for flow pulses greater than the 90th percentile. For the average annual number of such pulses, streamgages with a minimally altered, diminished, and inflated condition accounted for 48, 35, and 17 percent, respectively (fig. 24, at the back of this report; table 6). For the average duration of such pulses, streamgages with a minimally altered, diminished, and inflated condition accounted for 36, 58, and 6 percent, respectively (fig. 25, at the back of this report; table 6). For the average magnitude of such pulses, the indicated conditions were minimally altered, 58 percent; diminished, 40 percent; and inflated, 2 percent (table 6). Most of the streamgages with a diminished condition for average magnitude were in the western half of Kansas (fig. 26, at the back of this report).

Other Annual Flow Metrics

Five additional annual flow metrics that were assessed were percentage of flow that is base flow, 10th percentile flow normalized by drainage area, median flow normalized by drainage area, 90th percentile flow normalized by drainage area, and coefficient of variation of daily flows. For the percentage of flow that is base flow, a minimally altered condition was indicated for 81 percent of the streamgages (fig. 27, at the back of this report; table 7). Indicated conditions for the 10th percentile flow were minimally altered, 72 percent of streamgages; diminished, 12 percent; and inflated, 16 percent (table 7). For median flow, the indicated conditions were minimally altered, 73 percent; diminished, 20 percent; and inflated, 7 percent. Streamgages with a diminished condition for 10th percentile and median flow typically were in the western half of Kansas (figs. 28 and 29, at the back of this report). Throughout the State, 90th percentile flow typically was decreased as evidenced by a diminished condition that was indicated for 81 percent of the streamgages (fig. 30, at the back of this report; table 7). For the coefficient of variation of daily flows, a minimally altered condition was indicated for 73 percent of the streamgages (fig. 31, at the back of this report; table 7).

Table 7. Summary of alteration of other annual flow metrics for 129 streamgages in Kansas.

[%, percent rounded to nearest whole number. As a result of rounding error, the percentages for a given flow metric may not sum to 100]

Metric (table 1)	Number of streamgages		
	Diminished condition	Minimally altered condition	Inflated condition
PER_BSFL[a]	11 (9%)	105 (81%)	13 (10%)
P10[b]	15 (12%)	93 (72%)	21 (16%)
P50[c]	26 (20%)	94 (73%)	9 (7%)
P90[d]	104 (81%)	25 (19%)	0 (0%)
CV_FLOW[e]	20 (16%)	94 (73%)	15 (12%)

[a]Percentage of flow that is base flow.

[b]Tenth percentile flow normalized by drainage area.

[c]Median annual flow normalized by drainage area.

[d]Ninetieth percentile flow normalized by drainage area.

[e]Coefficient of variation of daily flows.

Effects of Human Disturbances on Streamflow and Habitat Implications

Human disturbances that have altered streamflow in Kansas can be categorized as regional and local. Regional disturbances include groundwater pumping from the High Plains aquifer and agricultural land-management practices. Local disturbances include reservoirs and urbanization. In the following sections, streamflow alteration in response to each of these disturbances is discussed and the possible habitat implications are briefly described.

Groundwater Pumping from the High Plains Aquifer

Groundwater withdrawals can cause groundwater-level declines and decreased groundwater contributions to streams, which can result in a reduction of streamflow (Winter, 2007; Barlow and Leake, 2012). Long-term and extensive pumping from the High Plains aquifer for irrigation is the primary cause of substantial groundwater-level declines in parts of western and central Kansas (Gutentag and others, 1984; Young and others, 2005; Whittemore and others, 2016) (fig. 2).

Groundwater pumping from the High Plains aquifer likely was responsible, in part, for the regional pattern of diminished streamflow conditions indicated for western and central Kansas. Support for this statement is twofold. First, the geographic distribution of streamgages with a diminished condition for multiple flow metrics generally corresponded with the area underlain by the High Plains aquifer and adjacent downstream areas (for example, see figs. 3, 7, 20, and 29). Second, there was no pronounced decreasing trend in annual precipitation (see the "Description of Kansas" section) that could account for the regional pattern of diminished streamflow conditions in western and central Kansas. A decreasing streamflow trend for several western Kansas streams has been documented (Rasmussen and Perry, 2001; Dodds and others, 2004; Gido and others, 2010; Juracek, 2015).

Agricultural Land-Management Practices

Historically, agricultural land-management practices have had a pronounced effect on streamflow. In response to the initial conversion of grassland and forest to cropland, infiltration decreased and surface runoff increased, resulting in an increased magnitude of high flows (Knox, 2001). Subsequently, as land-management practices improved in response to the need to decrease soil erosion and loss, infiltration increased and surface runoff decreased, resulting in increased base flow and a decreased magnitude of high flows (Potter, 1991; Gebert and Krug, 1996; Kramer and others, 1999; Knox, 2001). Included among the practices implemented to decrease runoff and increase infiltration were terraces, contour plowing, and conservation tillage (Zhang and Schilling, 2006; Juckem and others, 2008).

In Kansas, agricultural land-management practices likely have affected streamflows. In a study of rainfall-runoff relations, Jordan (1982) cited farm ponds, terraces, and changes in tillage methods as likely contributing factors for decreases in streamflow in several western Kansas streams. More recently, Putnam and others (2008) cited practices such as contour plowing and terraces as possible contributing factors for a progressive decrease in the runoff-to-precipitation ratio during historical droughts in the State. The effect of changing land-management practices possibly was indicated by several flow metrics. Case in point, for a number of streamgages in central and eastern Kansas, an inflated condition was indicated for the average magnitude of flow pulses less than the 10th percentile (fig. 17). The inflated condition for this metric may, in part, be attributable to increased base flow. A diminished condition for the average duration of flow pulses greater than the 90th percentile (fig. 25) and the magnitude of 90th percentile flow (fig. 30) was indicated for the majority of streamgages statewide. The diminished condition for these two metrics may, in part, be attributable to increased infiltration and decreased surface runoff associated with the implementation of improved land-management practices.

Reservoirs

A large reservoir can substantially alter the natural flow regime downstream from the dam. Typically, the magnitude of peak flows is reduced (Graf, 2006). Other possible downstream changes include an increase or decrease in the magnitude of low flows, an artificial flow regime characterized by abrupt increases and decreases in flow, a change in the temporal distribution of flows, and extended periods of no flow (Williams and Wolman, 1984; Kondolf, 1997; Magilligan and Nislow, 2005).

In this study, streamflow alteration downstream from 20 large reservoirs in Kansas was assessed using the first streamgage downstream from each dam (fig. 32). The assessment revealed pronounced differences in downstream flow alteration between reservoirs in western and eastern Kansas. Thus, for the purpose of discussion, the reservoirs were split into a western group (consisting of 8 reservoirs) and an eastern group (consisting of 12 reservoirs) (fig. 32).

In general, mean monthly flows downstream from the 8 western reservoirs were diminished, whereas such flows were minimally altered downstream from the 12 eastern reservoirs. For the western reservoirs, the percentage of downstream streamgages with a diminished condition ranged from 37 percent for July and August to 100 percent for March, with an all-month average of 68 percent. Conversely, for the eastern reservoirs, the percentage of downstream streamgages that were minimally altered ranged from 58 percent for September to 100 percent for four different months, with an all-month average of 86 percent (table 8).

Comparison of the western and eastern reservoirs using the annual low-flow metrics was constrained as the average duration and magnitude of low-flow pulses could not be computed downstream from several western reservoirs because of an absence of flow. For the eastern reservoirs, a minimally altered condition typically was indicated for the downstream streamgages for the average magnitude of pulses less than the 10th percentile (67 percent of streamgages). Likewise, for flow pulses less than the 25th percentile, a minimally altered condition typically was indicated for the average number (83 percent), average duration (67 percent), and average magnitude (75 percent). For the average duration of flow pulses less than the 10th percentile, a diminished condition typically (67 percent) was indicated for the eastern reservoirs (table 8).

Table 8. Summary of streamflow alteration downstream from 20 large reservoirs in Kansas.

[%, percent rounded to nearest whole number. As a result of rounding error, the percentages for a given flow metric may not sum to 100]

Metric (table 1)	Streamgages downstream from eight western Kansas reservoirs (fig. 32)			Streamgages downstream from twelve eastern Kansas reservoirs (fig. 32)		
	Diminished condition	Minimally altered condition	Inflated condition	Diminished condition	Minimally altered condition	Inflated condition
AVG_JAN	6 (75%)	2 (25%)	0 (0%)	1 (8%)	10 (83%)	1 (8%)
AVG_FEB	7 (88%)	1 (12%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)
AVG_MAR	8 (100%)	0 (0%)	0 (0%)	3 (25%)	9 (75%)	0 (0%)
AVG_APR	6 (75%)	2 (25%)	0 (0%)	1 (8%)	11 (92%)	0 (0%)
AVG_MAY	7 (88%)	1 (12%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)
AVG_JUN	7 (88%)	1 (12%)	0 (0%)	0 (0%)	11 (92%)	1 (8%)
AVG_JUL	3 (37%)	5 (63%)	0 (0%)	0 (0%)	11 (92%)	1 (8%)
AVG_AUG	3 (37%)	3 (37%)	2 (25%)	0 (0%)	8 (67%)	4 (33%)
AVG_SEP	4 (50%)	4 (50%)	0 (0%)	5 (42%)	7 (58%)	0 (0%)
AVG_OCT	5 (63%)	3 (37%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)
AVG_NOV	5 (63%)	3 (37%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)
AVG_DEC	4 (50%)	4 (50%)	0 (0%)	1 (8%)	8 (67%)	3 (25%)
PUL_NO_P10	4 (50%)	1 (12%)	3 (37%)	1 (8%)	4 (33%)	7 (58%)
PUL_LEN_P10[a]	1 (12%)	2 (25%)	1 (12%)	8 (67%)	3 (25%)	0 (0%)
PUL_FLOW_P10[a]	1 (12%)	3 (37%)	0 (0%)	1 (8%)	8 (67%)	2 (17%)
PUL_NO_P25	2 (25%)	5 (63%)	1 (12%)	0 (0%)	10 (83%)	2 (17%)
PUL_LEN_P25[a]	1 (12%)	3 (37%)	2 (25%)	3 (25%)	8 (67%)	1 (8%)
PUL_FLOW_P25[a]	3 (37%)	2 (25%)	1 (12%)	2 (17%)	9 (75%)	1 (8%)
PUL_NO_P75	6 (75%)	1 (12%)	1 (12%)	3 (25%)	8 (67%)	1 (8%)
PUL_LEN_P75	2 (25%)	1 (12%)	5 (63%)	0 (0%)	5 (42%)	7 (58%)
PUL_FLOW_P75	7 (88%)	1 (12%)	0 (0%)	0 (0%)	12 (100%)	0 (0%)
PUL_NO_P90	7 (88%)	1 (12%)	0 (0%)	8 (67%)	4 (33%)	0 (0%)
PUL_LEN_P90	1 (12%)	4 (50%)	3 (37%)	0 (0%)	9 (75%)	3 (25%)
PUL_FLOW_P90	7 (88%)	1 (12%)	0 (0%)	1 (8%)	11 (92%)	0 (0%)
PER_BSFL	0 (0%)	8 (100%)	0 (0%)	0 (0%)	10 (83%)	2 (17%)
P10	4 (50%)	3 (37%)	1 (12%)	2 (17%)	9 (75%)	1 (8%)
P50	5 (63%)	3 (37%)	0 (0%)	1 (8%)	11 (92%)	0 (0%)
P90	8 (100%)	0 (0%)	0 (0%)	3 (25%)	9 (75%)	0 (0%)
CV_FLOW	0 (0%)	4 (50%)	4 (50%)	0 (0%)	11 (92%)	1 (8%)

[a]Metric not computed for some streamgages because of an absence of flow.

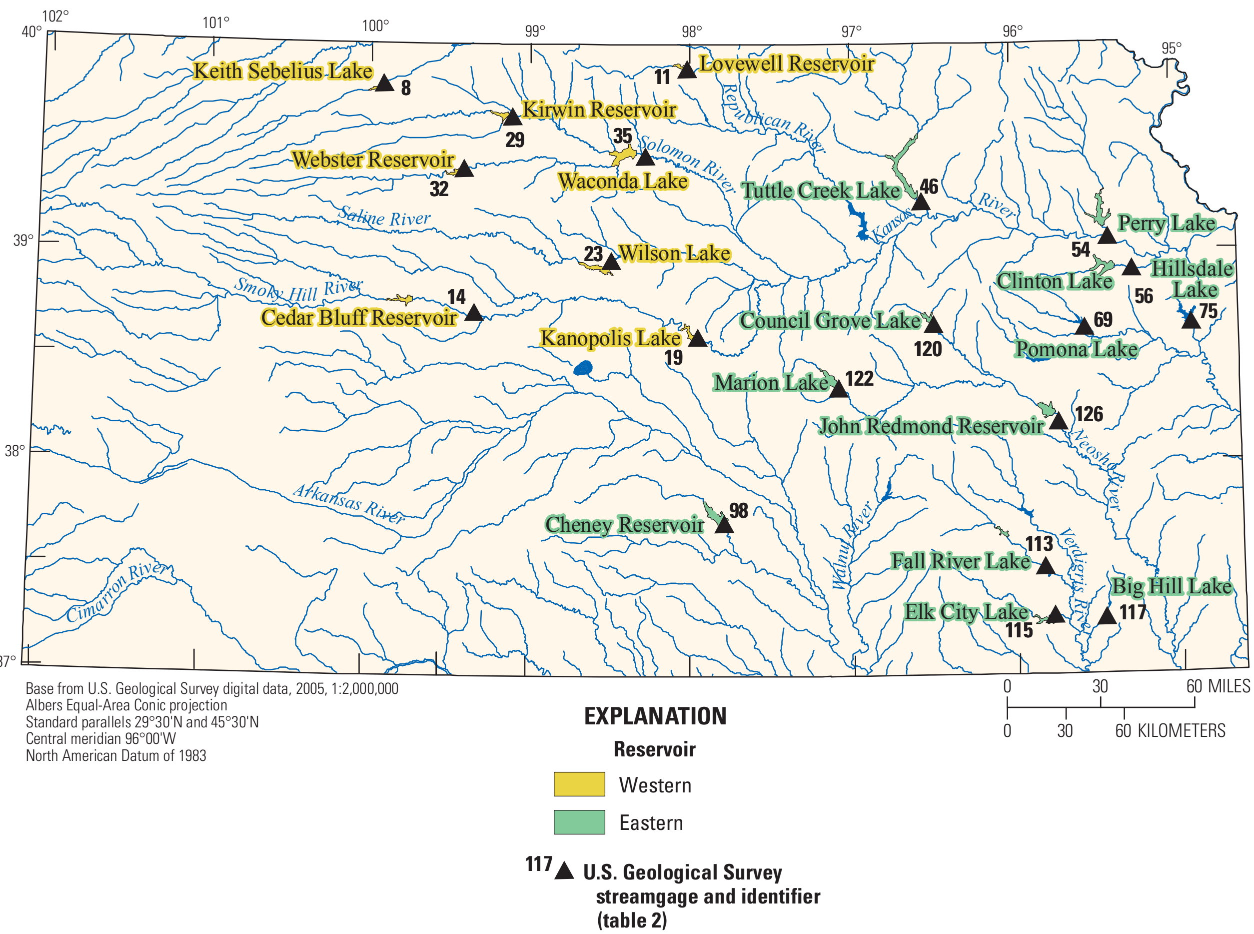

Figure 32. Large reservoirs and selected U.S. Geological Survey streamgages in Kansas.

For the annual high-flow metrics, a comparison of the western and eastern reservoirs revealed similarities and differences. In terms of the average number of flow pulses greater than the 75th percentile, a diminished condition typically (75 percent) was indicated for streamgages downstream from the western reservoirs, whereas a minimally altered condition typically (67 percent) was indicated for streamgages downstream from the eastern reservoirs. For the average duration of such pulses, an inflated condition was indicated for the majority of streamgages downstream from the western and eastern reservoirs (63 percent and 58 percent, respectively). The increased duration may be reflective of reservoir operational practices intended to manage downstream flood risk by releasing high flows over an extended period of time. The average magnitude of flow pulses greater than the 75th percentile was minimally altered for the eastern reservoirs (100 percent of downstream streamgages) and typically diminished for the western reservoirs (88 percent of downstream streamgages) (table 8).

Flow pulses greater than the 90th percentile were similar for the western and eastern reservoirs in terms of the average number and duration of pulses but divergent for the average magnitude. For the average number of such pulses, a diminished condition typically (88 and 67 percent, respectively) was indicated for streamgages downstream from the western and eastern reservoirs. For the average duration, the indicated condition for both the western and eastern reservoirs typically was either minimally altered (largest percentage of downstream streamgages) or inflated. The average magnitude of flow pulses greater than the 90th percentile typically was minimally altered (92 percent) for streamgages downstream from the eastern reservoirs and typically diminished (88 percent) for streamgages downstream from the western reservoirs (table 8).

A minimally altered condition typically was indicated for the streamgages downstream from the eastern reservoirs for the base flow, 10th percentile flow, median flow, 90th percentile flow, and coefficient of variation annual metrics (table 8). For the western reservoirs, streamflow alteration was apparent. Of particular note was the diminished condition indicated for annual median flow (63 percent of downstream streamgages) and annual 90th percentile flow (100 percent) (table 8).

Overall, the assessment of streamflow alteration downstream from the 20 large reservoirs indicated a diminished condition for the 8 western reservoirs and a minimally altered condition for the 12 eastern reservoirs. At least two factors may, in part, account for the diminished condition downstream from the western reservoirs. One factor is diversion of water for irrigation and (or) municipal use at and (or) upstream from the reservoirs. A second factor is reservoir operational practices (for example, suppression of high flows by controlled releases).

Urbanization

The effects of urbanization on streamflow can be pronounced. In general, the increased percentage of impervious surfaces and more efficient drainage systems characteristic of urban areas result in an increased volume of runoff for a given rainfall and a flashier flow regime typified by shorter lag times and more frequent and higher peak discharges (Knighton, 1998; Rose and Peters, 2001). Heterogeneity in hydrologic response to urbanization also has been documented. For example, in a study of hydrological changes associated with urbanization in nine major cities in the United States, Hopkins and others (2015) determined that hydrologic response in similarly urbanized areas varied in relation to basin physical characteristics. Specifically, they found that urbanized basins with level slopes and high soil permeability, compared to similarly urbanized basins with steep slopes and low soil permeability, had fewer high-flow events, lower peak magnitudes, longer high-flow durations, and a less flashy flow regime.

Of all the streamgages included in this streamflow alteration study, only three were within basins that were predominantly urbanized. The three streamgages, all in the Kansas City metropolitan area in Johnson County, Kansas, were site 60 (about 70 percent urban) and sites 63 and 64 (both nearly 100 percent urban; fig. 1; Peterson and others, 2010). Site 60 is on Mill Creek and sites 63 and 64 are along Indian Creek.

Streamflow alteration, when indicated, was consistent among the three urbanized sites. The alteration included an inflated condition for mean monthly flows, especially for sites 63 and 64 (tables 1–1 to 1–3). For these two sites, an inflated condition was indicated for at least one and typically both of the sites for all 12 months. The inflated condition at these two sites may, in part, be attributable to discharges from municipal wastewater treatment facilities (Rasmussen and Gatotho, 2014) as well as other possible factors, including leaky infrastructure (for example, water-supply and sewage pipes; Bhaskar and others, 2016).

Flow pulses were substantially altered. For flow pulses less than the 10th and 25th percentiles, an inflated condition was indicated for the average number and average magnitude and a diminished condition was indicated for the average duration for all three sites (tables 1–4 and 1–5). Likewise, for flow pulses greater than the 75th and 90th percentiles, an inflated condition was indicated for the average number and a diminished condition was indicated for the average duration for all three sites (tables 1–6 and 1–7). However, an inflated condition for the average magnitude was only indicated for sites 63 and 64. Overall, a flashier flow regime was indicated for the three urbanized sites compared with what would be expected for a least-disturbed condition. Other changes indicated for all three sites were an inflated condition for the 10th percentile flow and median flow and a diminished condition for the coefficient of variation of daily flows (table 1–8).

Habitat Implications

A natural flow regime is essential to provide the diversity of habitat conditions necessary to maintain the ecological integrity of streams (Poff and others, 1997; Bunn and Arthington, 2002). Alteration of the natural flow regime can have adverse consequences for resident aquatic organisms. For example, in an extensive review of flow alteration and ecological response, Poff and Zimmerman (2010) determined that fish abundance and diversity consistently decreased in response to flow alteration (both increased and decreased flow magnitude) and the risk of ecological change increased as the magnitude of flow alteration increased. In a study of about 250 sites throughout the conterminous United States, Carlisle and others (2011) concluded that the likelihood of impairment for fish and macroinvertebrate communities doubled with increasing severity of reduced minimum and maximum flows.

For Kansas, the evidence provided by this study indicated that multiple human disturbances, singly and in combination, have caused widespread streamflow alteration. In general, streamflow alteration has negative ecological effects, including a loss of habitat and (or) a decline in the quality of available habitat. Possible consequences of lost and degraded habitat include a loss of native species, an increase in nonnative species, and a less diverse assemblage of aquatic biota dominated by disturbance-tolerant species (Walsh and others, 2005; Gido and others, 2010; Hoagstrom and others, 2011; Perkin and others, 2015). For the State-listed threatened Arkansas darter (*Etheostoma cragini*) (Haslouer and others, 2005), streamflow alteration, in particular flow depletion, likely has adversely affected the availability and quality of habitat in the State (Juracek and others, 2017).

Summary and Conclusions

A 1.5-year modeling study by the U.S. Geological Survey, in cooperation with the Kansas Department of Wildlife, Parks and Tourism and the U.S. Fish and Wildlife Service, was begun in 2016 to assess streamflow alteration at 129 selected U.S. Geological Survey streamgage sites in Kansas for which requisite streamflow and basin-characteristic information was available. The purpose of the assessment was to quantify and explain streamflow alteration through a comparison of the observed condition (1980 to 2015) with the predicted expected (least-disturbed) condition using 29 metrics that accounted for various aspects of streamflow. For each metric at each streamgage, the determined condition was characterized as diminished, minimally altered, or inflated. Results of the assessment are summarized below:

- For mean monthly streamflow, a minimally altered condition was indicated for an average of 66 percent of the streamgages for every month. On average, a diminished condition was indicated for 28 percent of the streamgages each month. Typically, streamgages with a diminished condition for mean monthly flow were in the western half of Kansas.
- Alteration of the average annual number, duration, and magnitude of flow pulses less than the 10th percentile was evident statewide. For the average annual number of such pulses, streamgages with a diminished condition typically were in the western half of Kansas and streamgages with an inflated condition typically were in central and eastern Kansas.
- For the average annual number, duration, and magnitude of flow pulses less than the 25th percentile, a minimally altered condition typically was indicated. Streamgages with a diminished condition for the average annual number of such pulses typically were in the western half of Kansas.
- Pronounced alteration was indicated for flow pulses greater than the 75th percentile. For the average annual number of such pulses, streamgages with a diminished condition typically were in the western half of Kansas and streamgages with an inflated condition typically were in the eastern half of Kansas. A diminished condition for the average magnitude of such pulses typically was indicated for streamgages in the western half of Kansas.
- Pronounced alteration was indicated for flow pulses greater than the 90th percentile. For the average duration of such pulses, streamgages with a diminished condition were throughout the State. For the average magnitude of such pulses, streamgages with a diminished condition mostly were in the western half of Kansas.
- A minimally altered condition typically was indicated for the following annual flow metrics: percentage of flow that is base flow, 10th percentile flow normalized by drainage area, median flow normalized by drainage area, and coefficient of variation of daily flows. Although, for median flow, a diminished condition was indicated for multiple streamgages in western Kansas.
- For 90th percentile flow normalized by drainage area, a diminished condition was indicated for the majority (81 percent) of streamgages throughout the State.
- Given the absence of a pronounced trend in annual precipitation in Kansas, a precipitation-related explanation for streamflow alteration was not supported.
- Groundwater pumping from the High Plains aquifer likely was responsible, in part, for diminished flow conditions in western and central Kansas.
- The implementation of agricultural land-management practices to reduce runoff may have been responsible, in part, for the diminished duration and magnitude of high flows indicated for many streamgages throughout the State. In addition, such practices may have been partly responsible for an inflated magnitude of low flows at several streamgages in central and eastern Kansas.
- In general, for streamgages downstream from 20 large reservoirs, a diminished flow condition was indicated for the 8 western reservoirs and a minimally altered flow condition was indicated for the 12 eastern reservoirs.
- For the three streamgages within a predominantly urban basin, a flashier flow regime was indicated compared with what would be expected for a least-disturbed condition.

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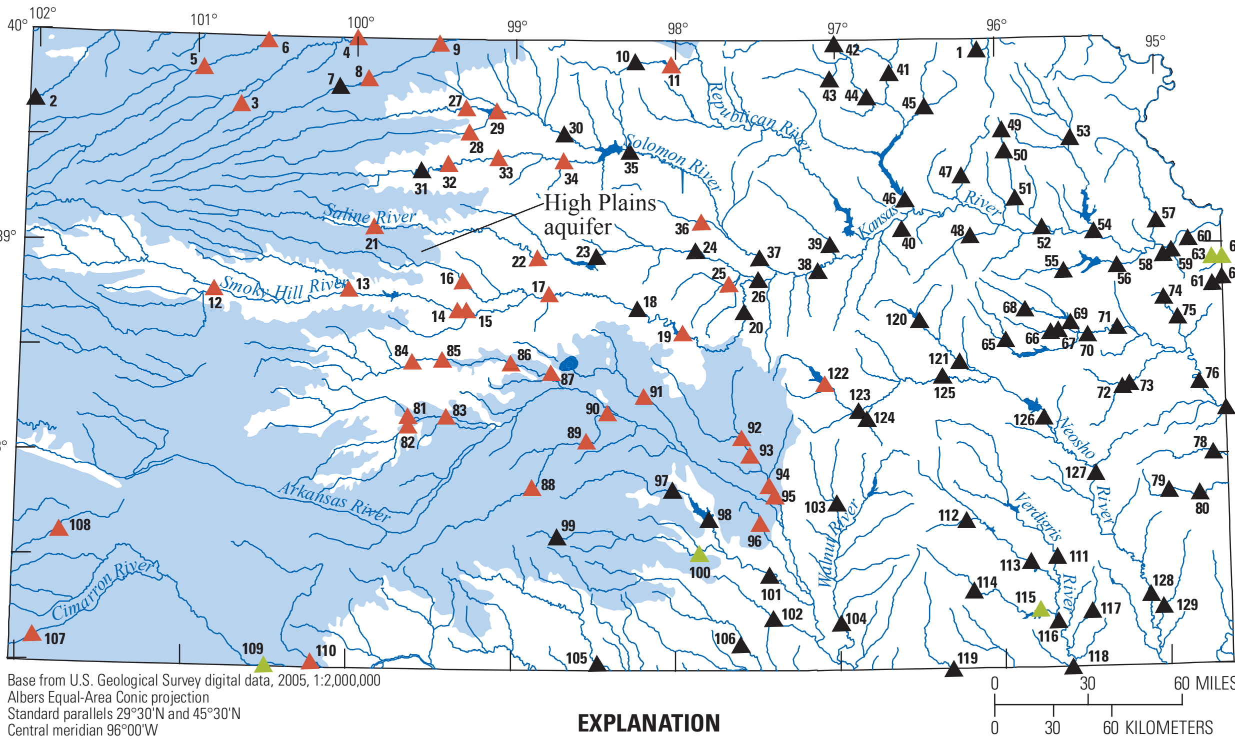
Figures 3–31



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Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

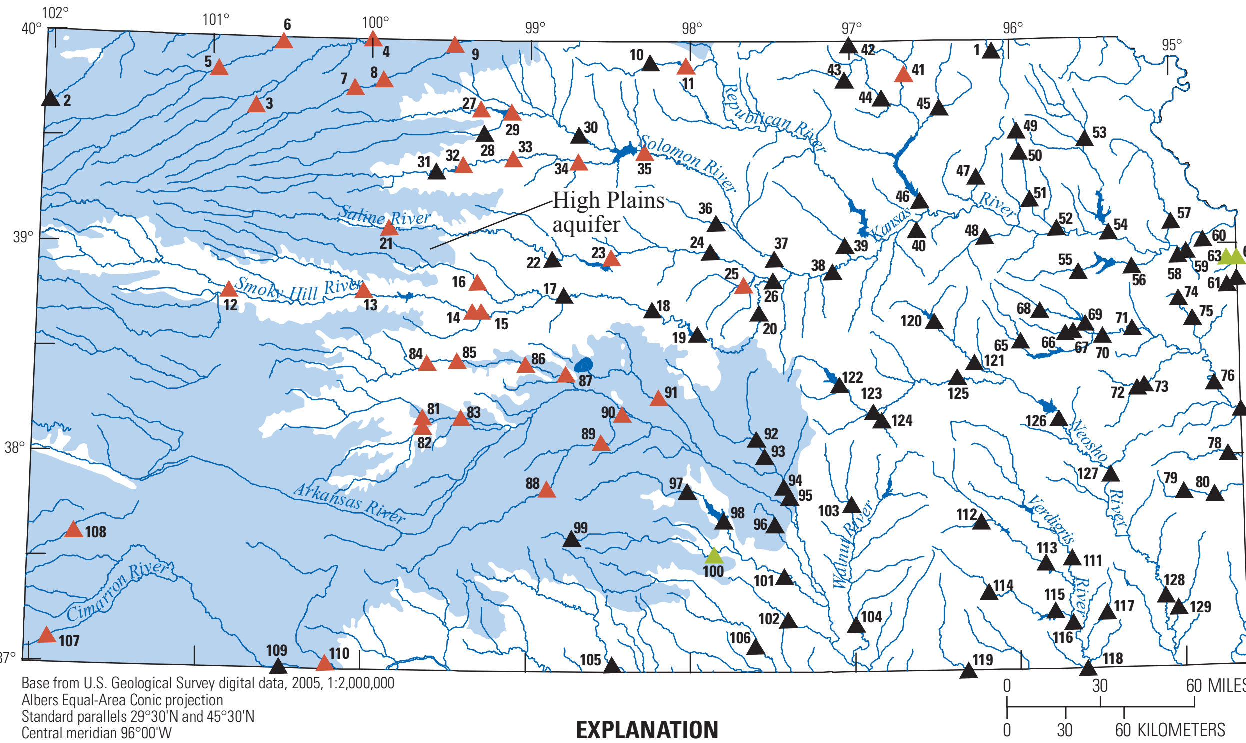
U.S. Geological Survey streamgage and identifier (table 2)—Mean January flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

106 ▲ Minimally altered flow condition

Figure 3. Condition of mean January flow normalized by drainage area for 129 streamgages in Kansas.



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Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Mean February flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

109 ▲ Minimally altered flow condition

Figure 4. Condition of mean February flow normalized by drainage area for 129 streamgages in Kansas.

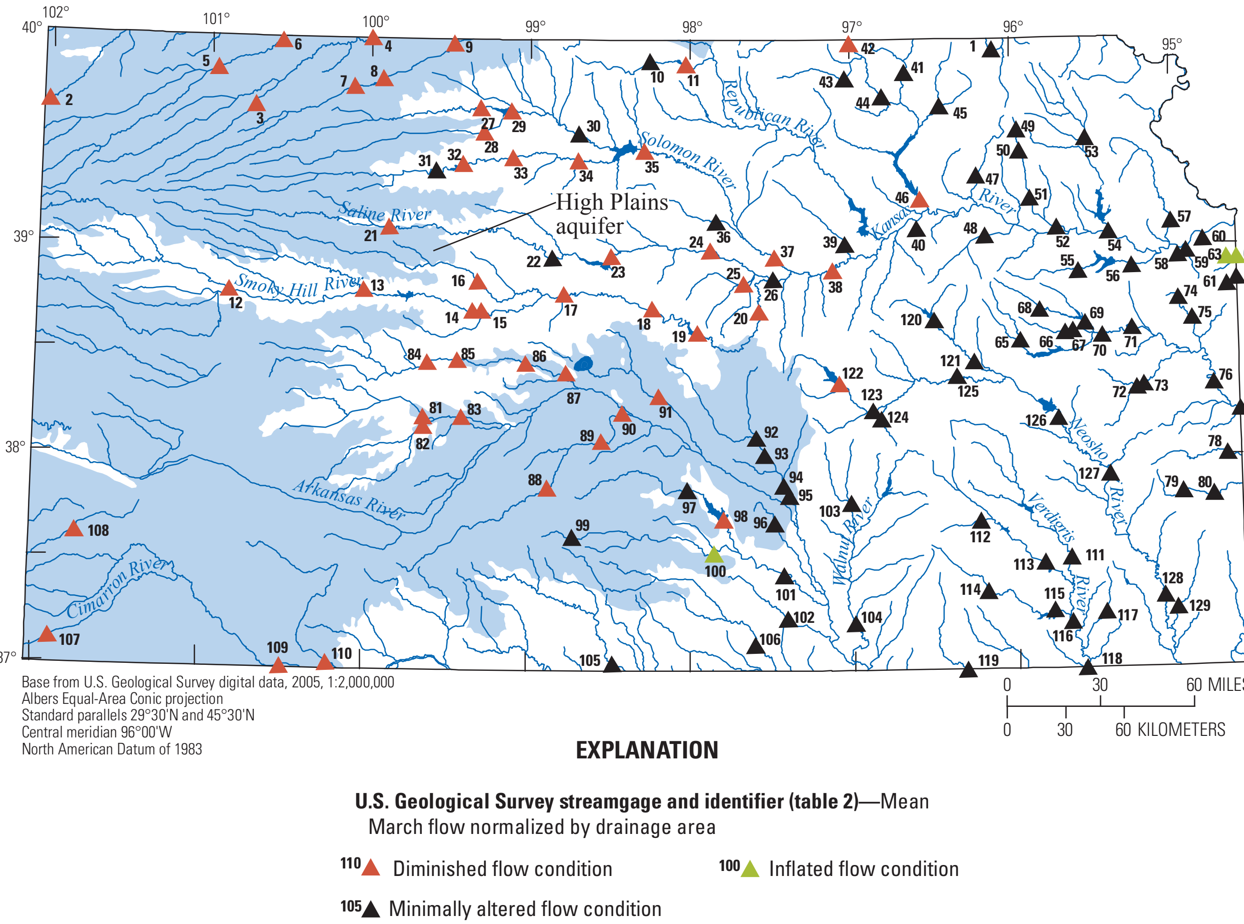
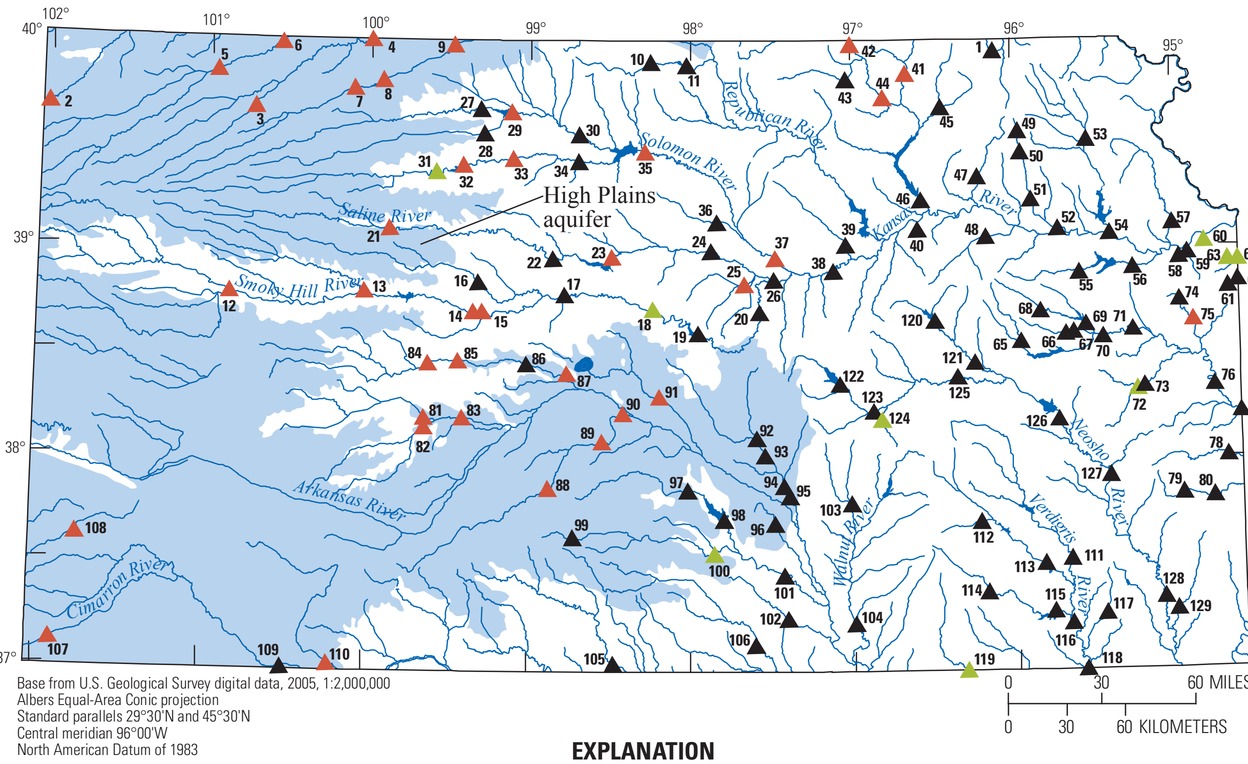


Figure 5. Condition of mean March flow normalized by drainage area for 129 streamgages in Kansas.



EXPLANATION

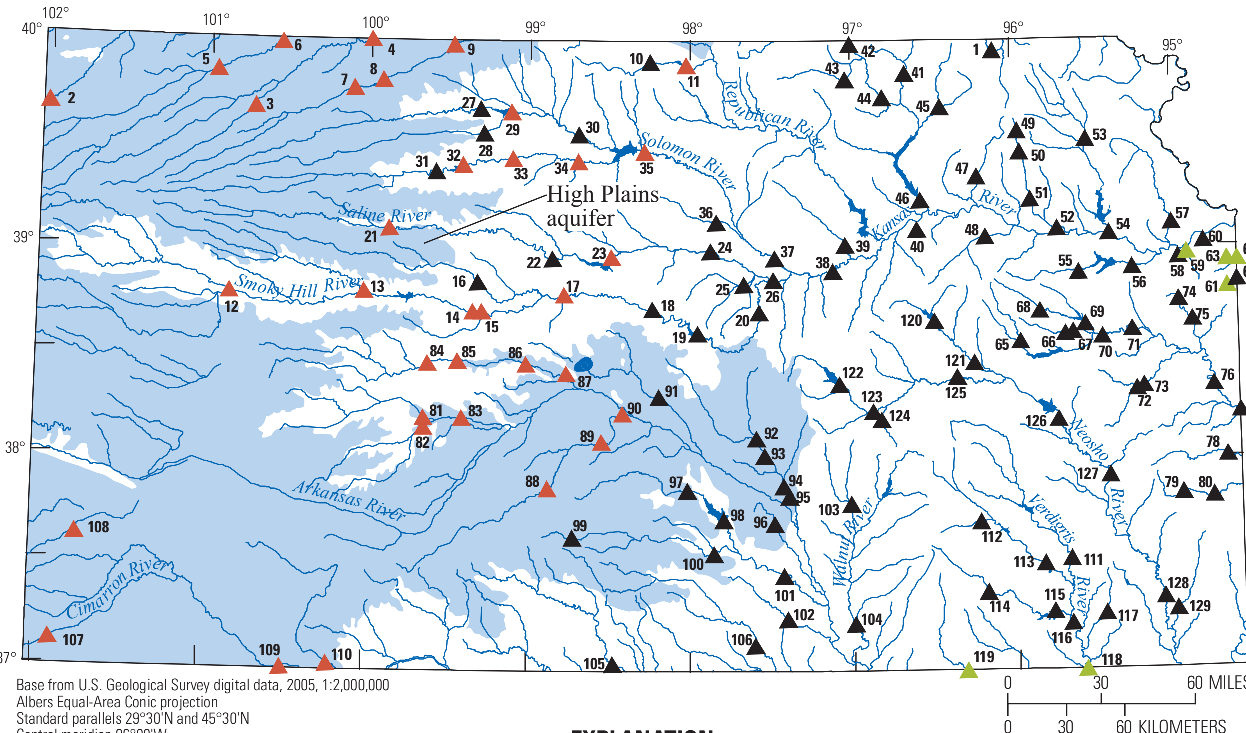
U.S. Geological Survey streamgage and identifier (table 2)—Mean April flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

109 ▲ Minimally altered flow condition

Figure 6. Condition of mean April flow normalized by drainage area for 129 streamgages in Kansas.



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Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Mean May flow normalized by drainage area

110 ▲ Diminished flow condition

119 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 7. Condition of mean May flow normalized by drainage area for 129 streamgages in Kansas.

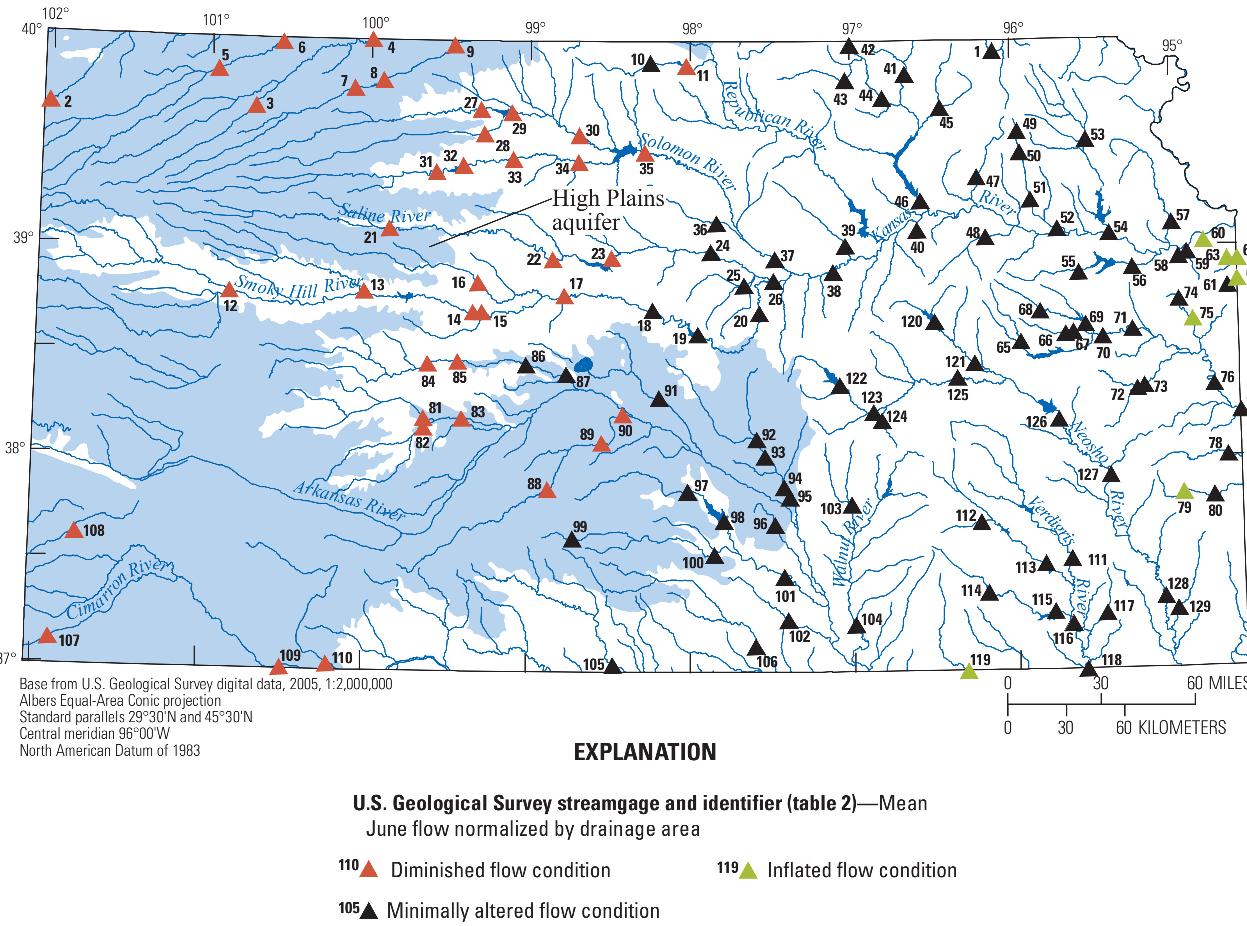


Figure 8. Condition of mean June flow normalized by drainage area for 129 streamgages in Kansas.

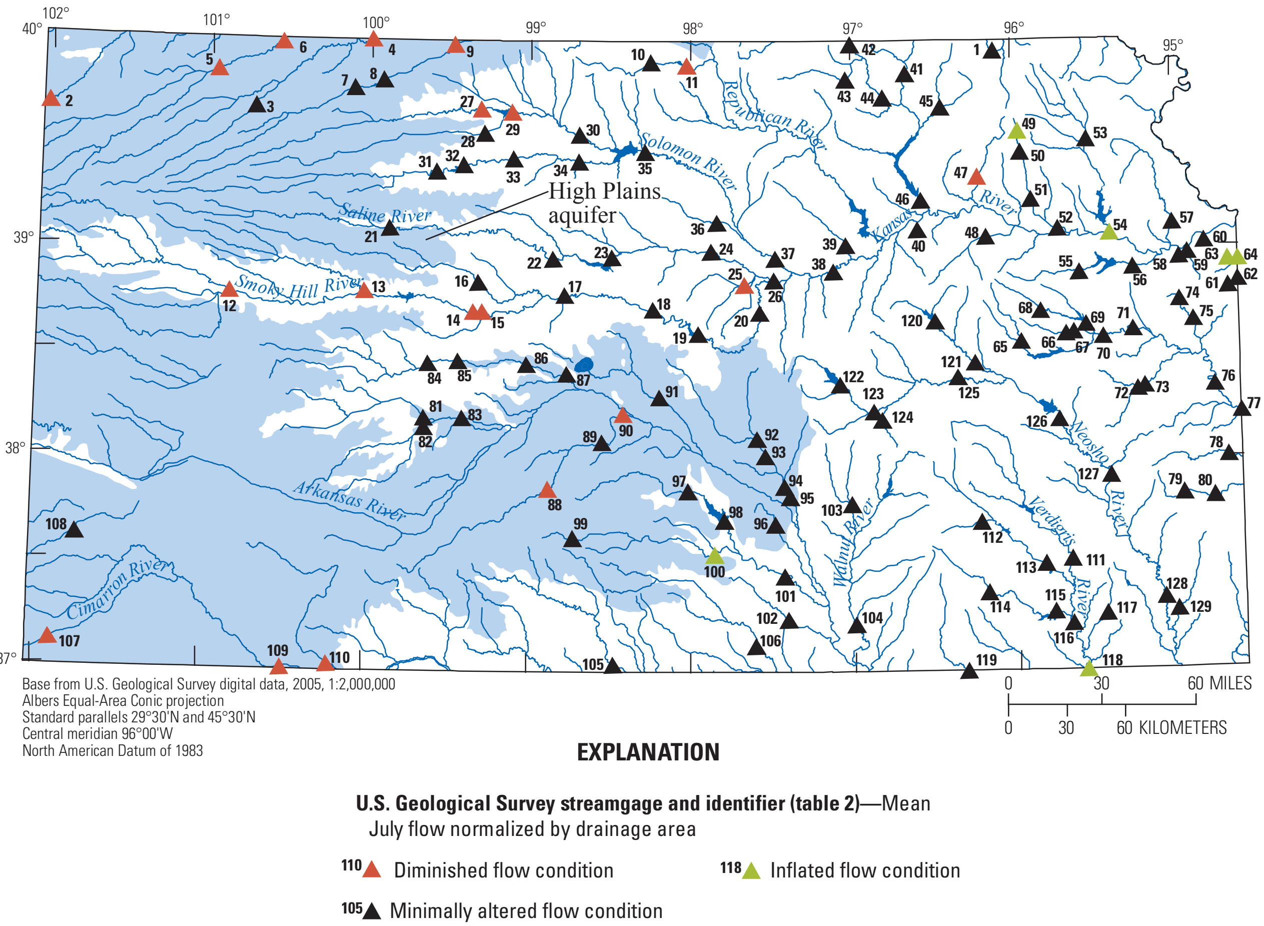


Figure 9. Condition of mean July flow normalized by drainage area for 129 streamgages in Kansas.

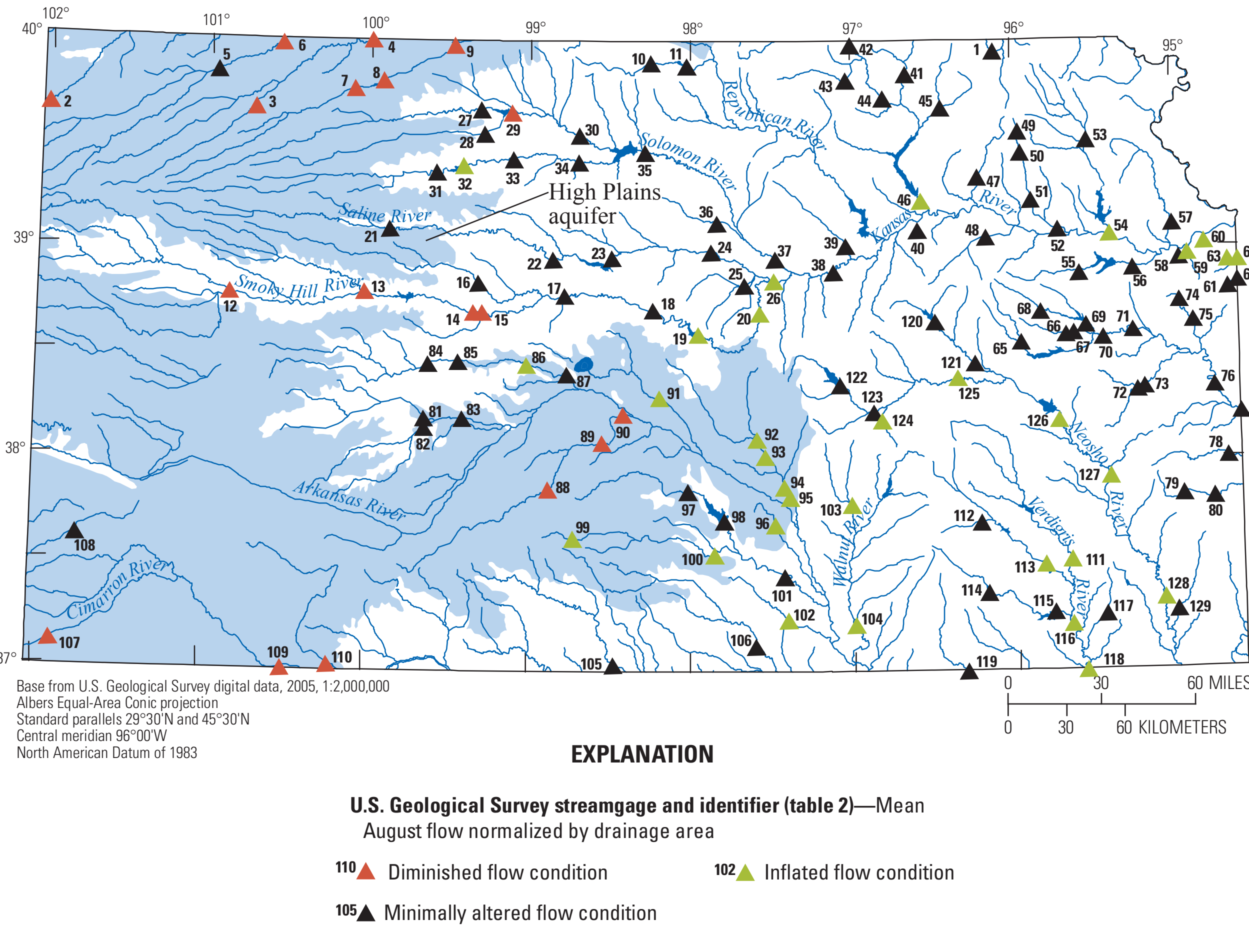


Figure 10. Condition of mean August flow normalized by drainage area for 129 streamgages in Kansas.

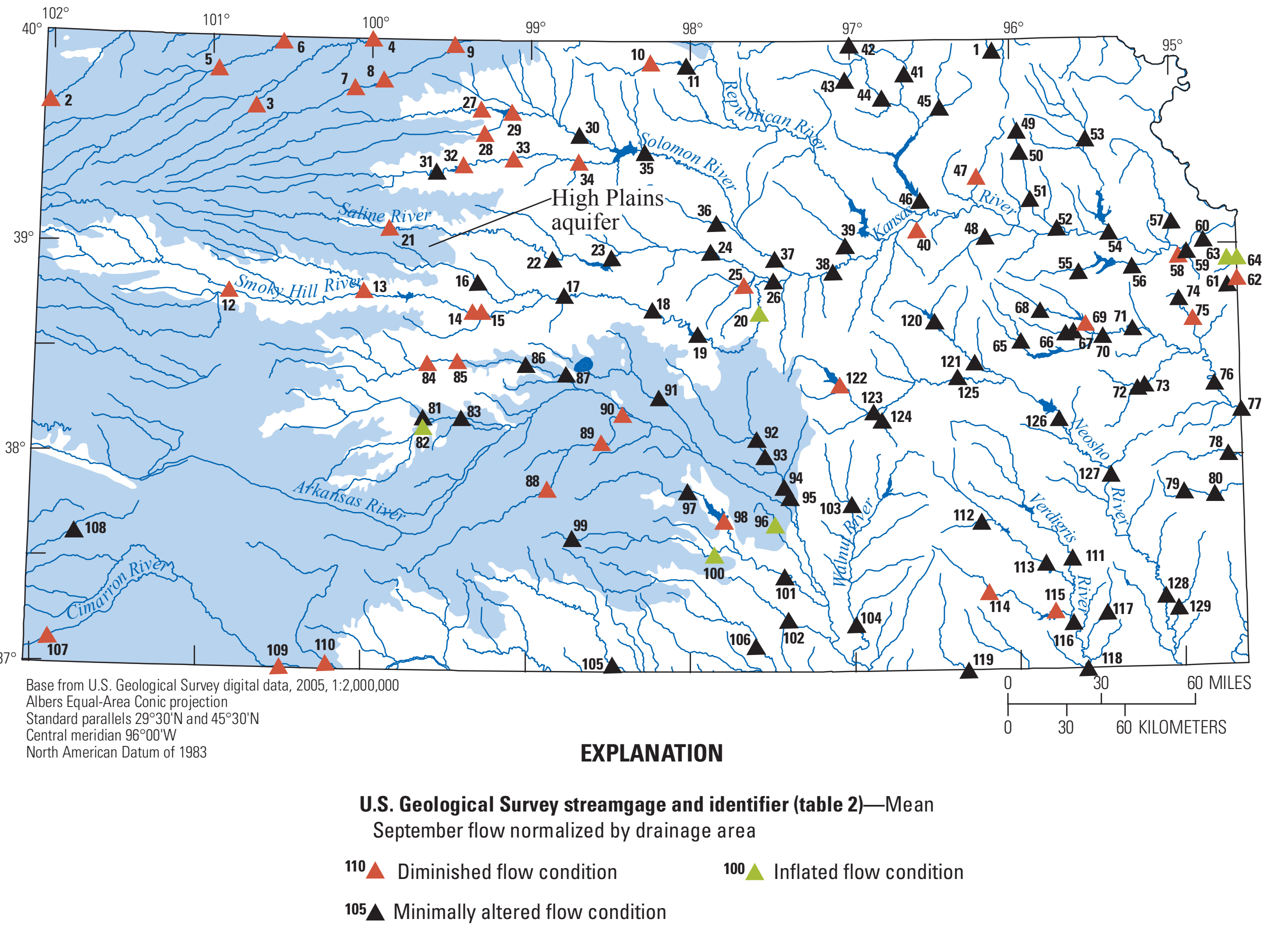
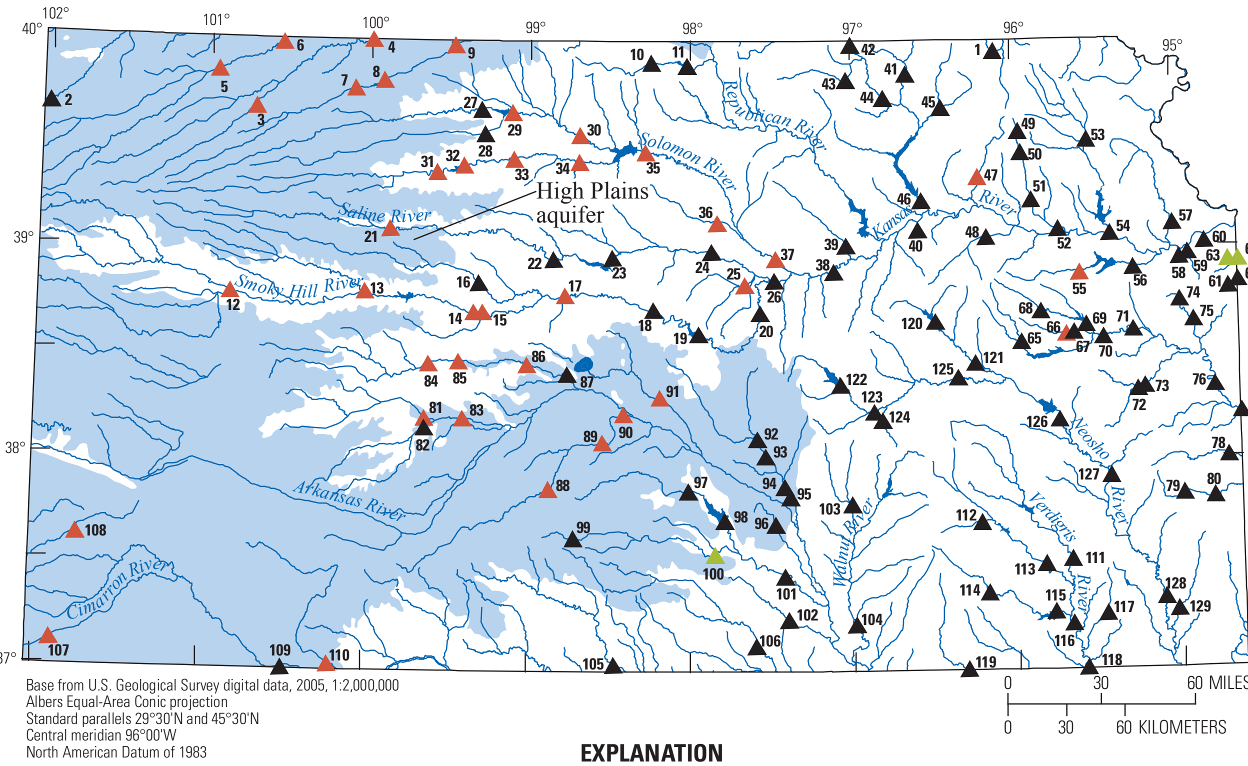


Figure 11. Condition of mean September flow normalized by drainage area for 129 streamgages in Kansas.



EXPLANATION

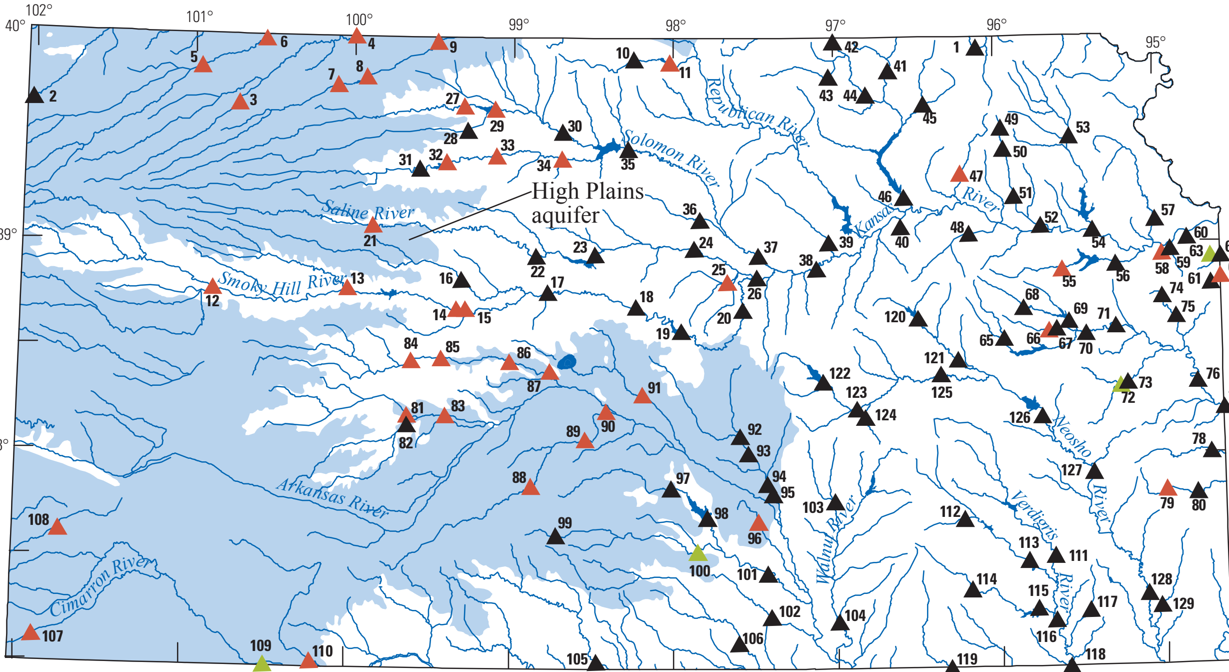
U.S. Geological Survey streamgage and identifier (table 2)—Mean October flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

109 ▲ Minimally altered flow condition

Figure 12. Condition of mean October flow normalized by drainage area for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

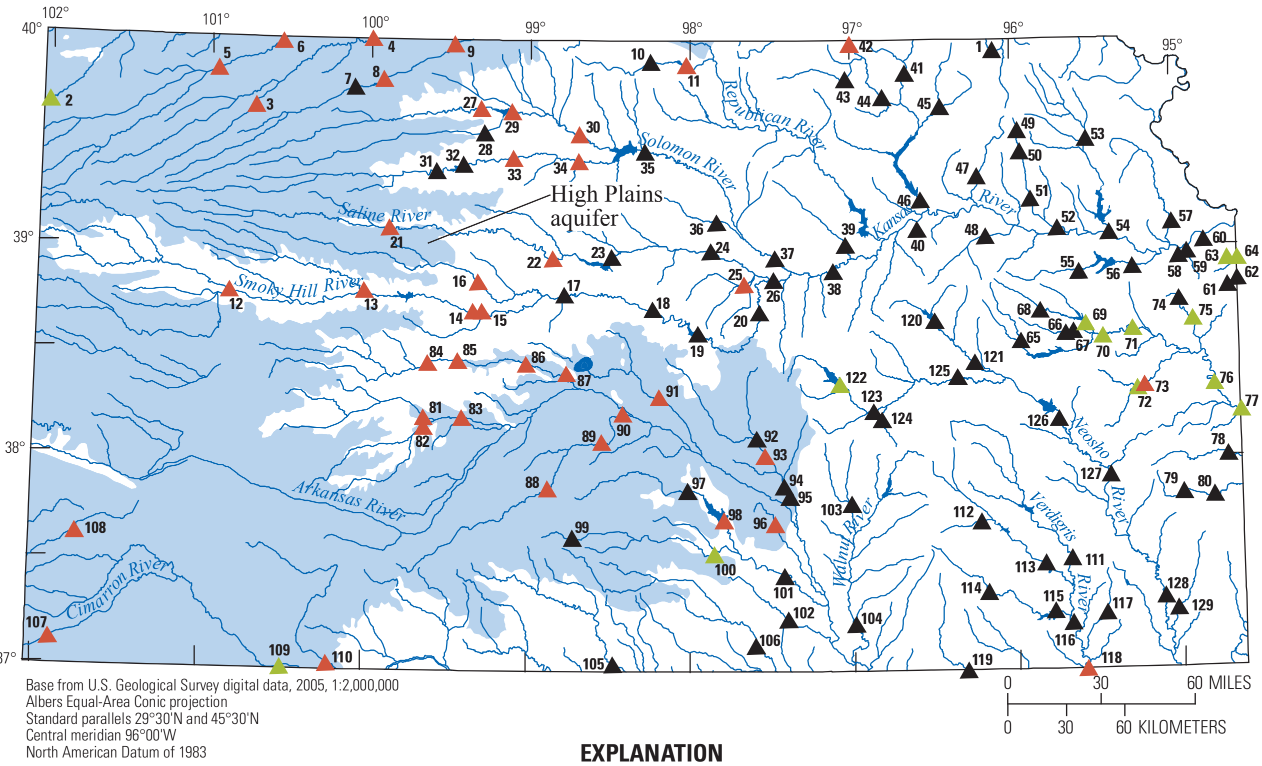
U.S. Geological Survey streamgage and identifier (table 2)—Mean November flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 13. Condition of mean November flow normalized by drainage area for 129 streamgages in Kansas.



EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Mean December flow normalized by drainage area

110 ▲ Diminished flow condition

100 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 14. Condition of mean December flow normalized by drainage area for 129 streamgages in Kansas.

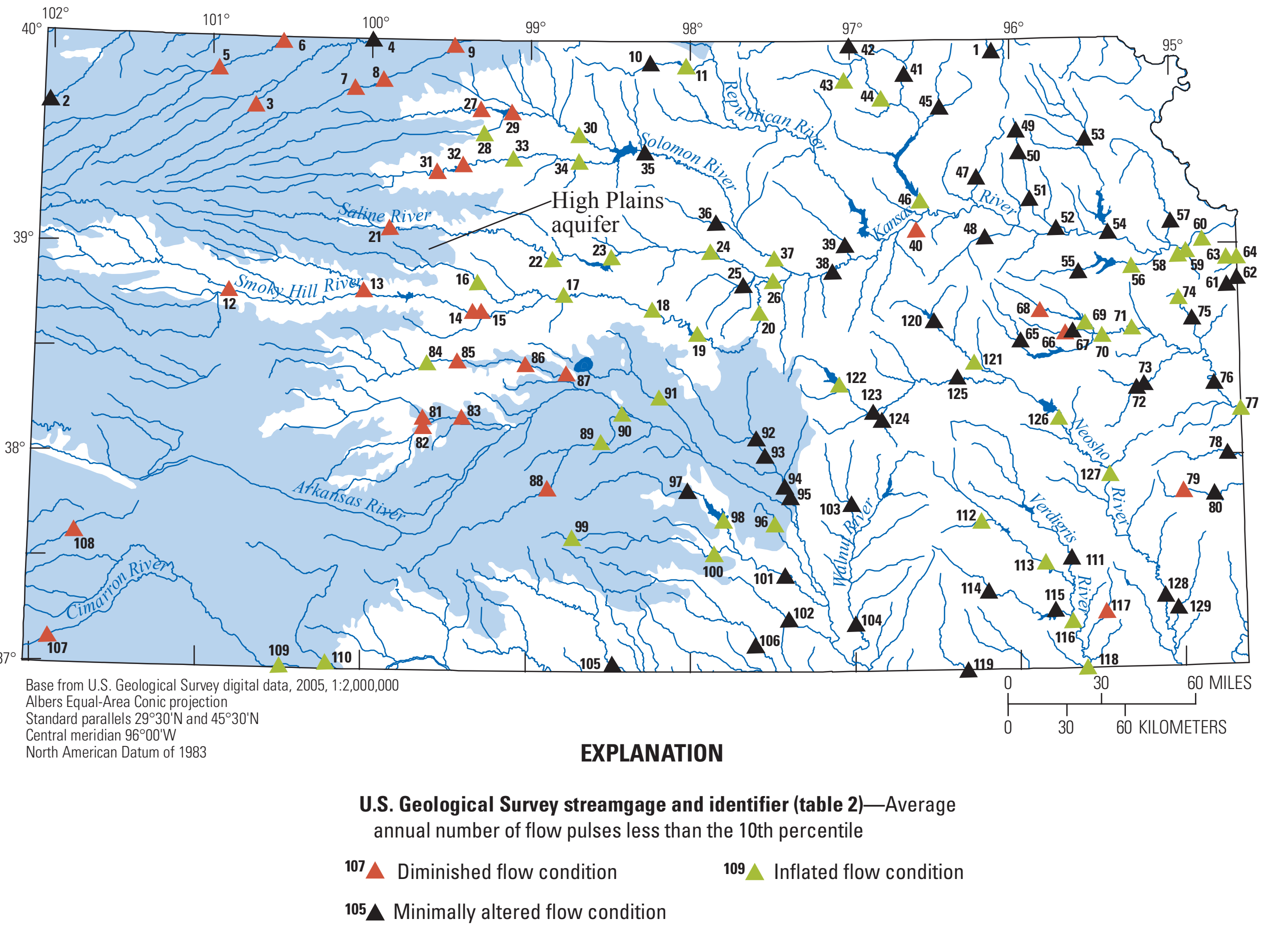


Figure 15. Condition of the average annual number of flow pulses less than the 10th percentile metric for 129 streamgages in Kansas.

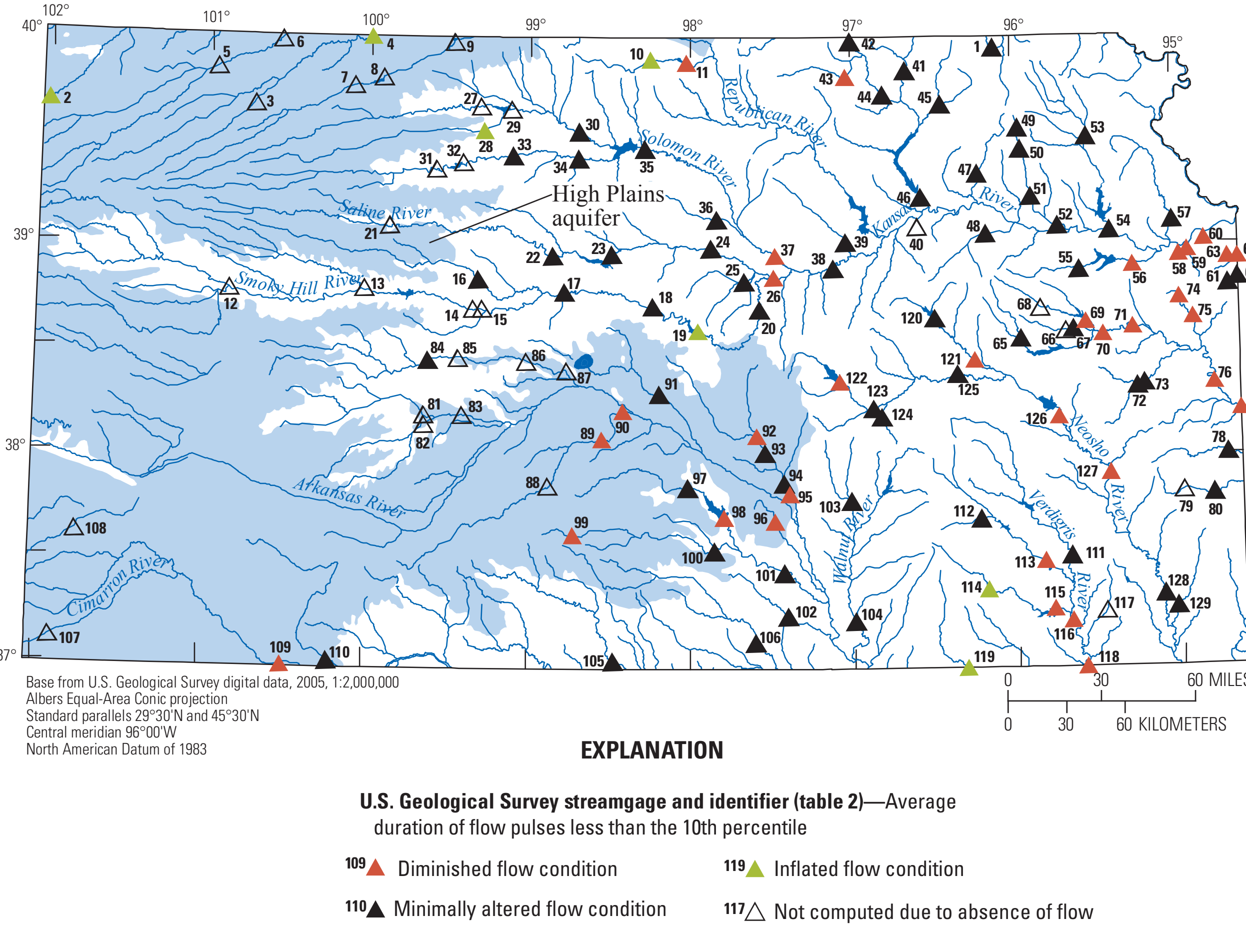
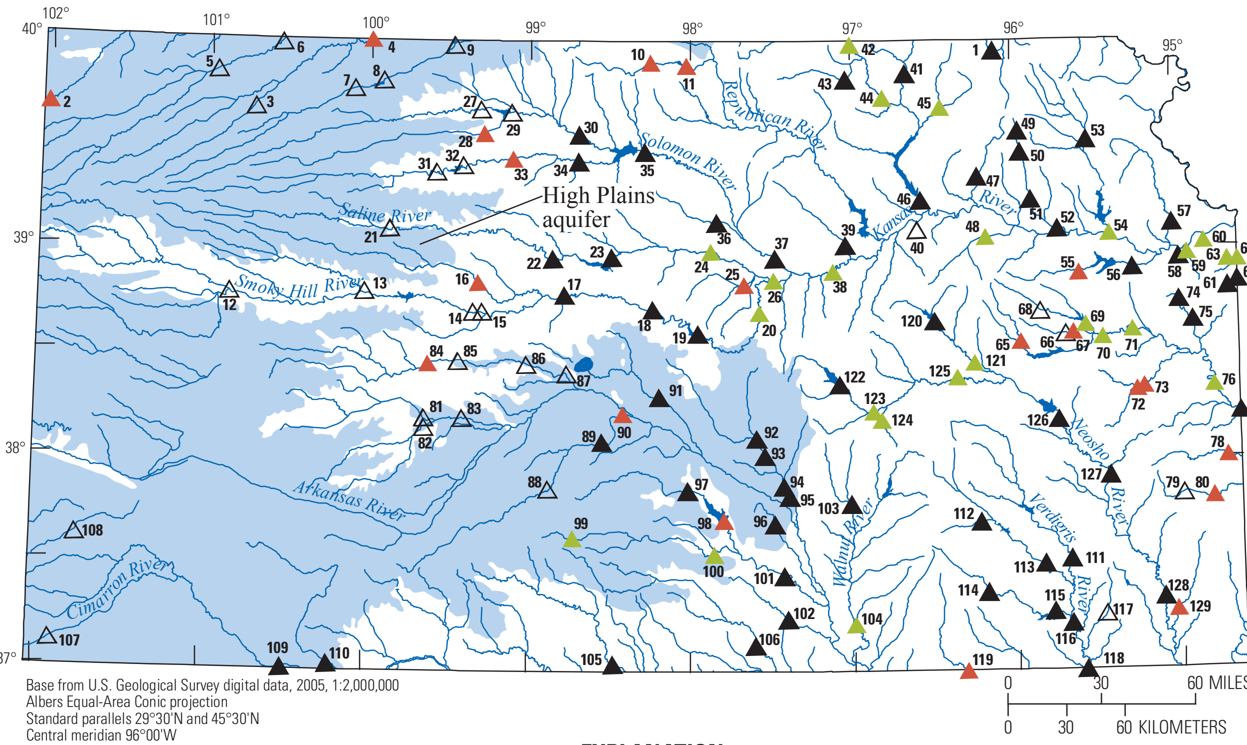


Figure 16. Condition of the average duration of flow pulses less than the 10th percentile metric for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Average flow of pulses less than the 10th percentile, normalized by drainage area

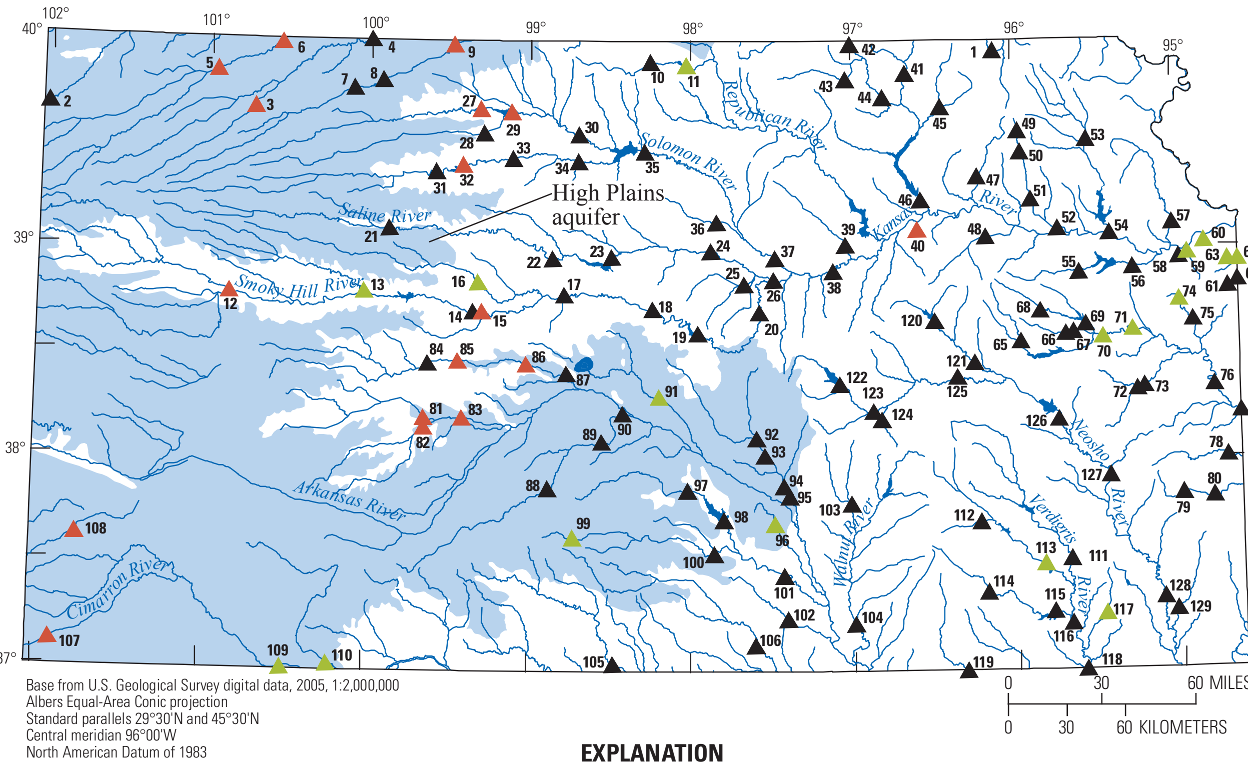
119 ▲ Diminished flow condition

100 ▲ Inflated flow condition

110 ▲ Minimally altered flow condition

107 △ Not computed due to absence of flow

Figure 17. Condition of the average magnitude of flow pulses less than the 10th percentile metric for 129 streamgages in Kansas.



EXPLANATION

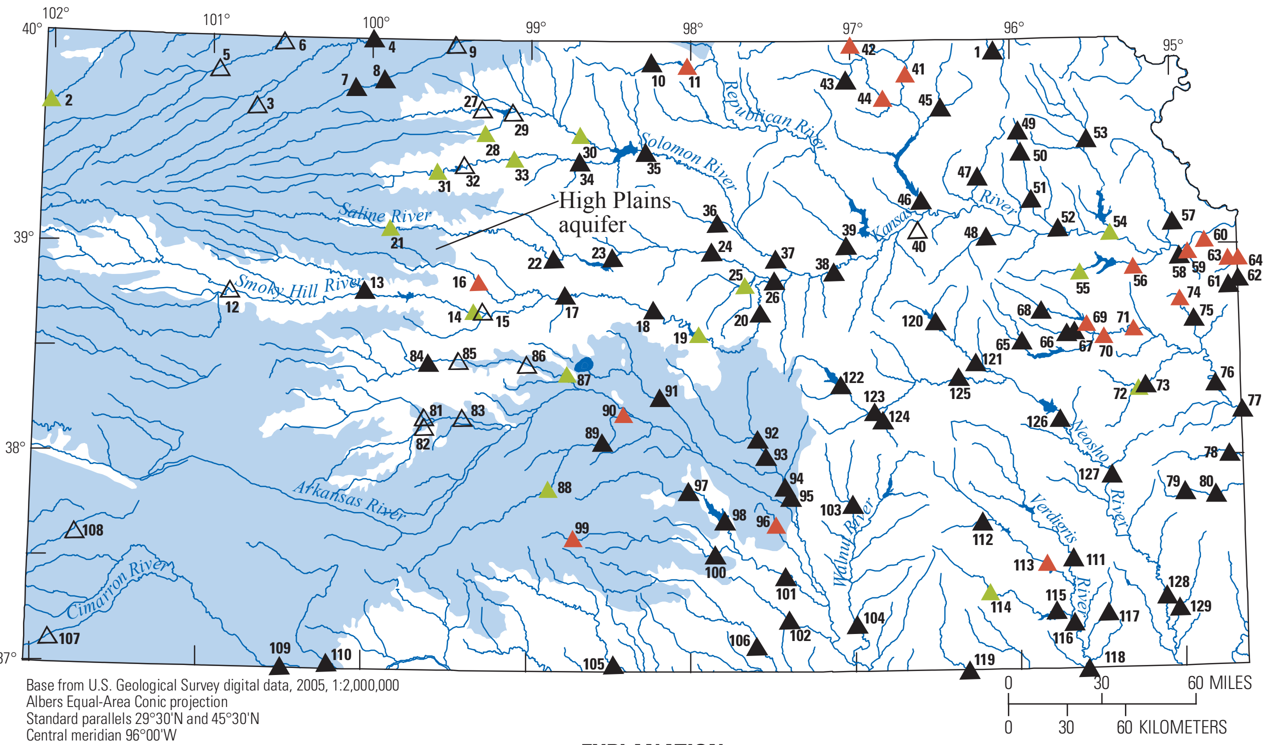
U.S. Geological Survey streamgage and identifier (table 2)—Average annual number of flow pulses less than the 25th percentile

107 Diminished flow condition

109 Inflated flow condition

105 Minimally altered flow condition

Figure 18. Condition of the average annual number of flow pulses less than the 25th percentile metric for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Average duration of flow pulses less than the 25th percentile

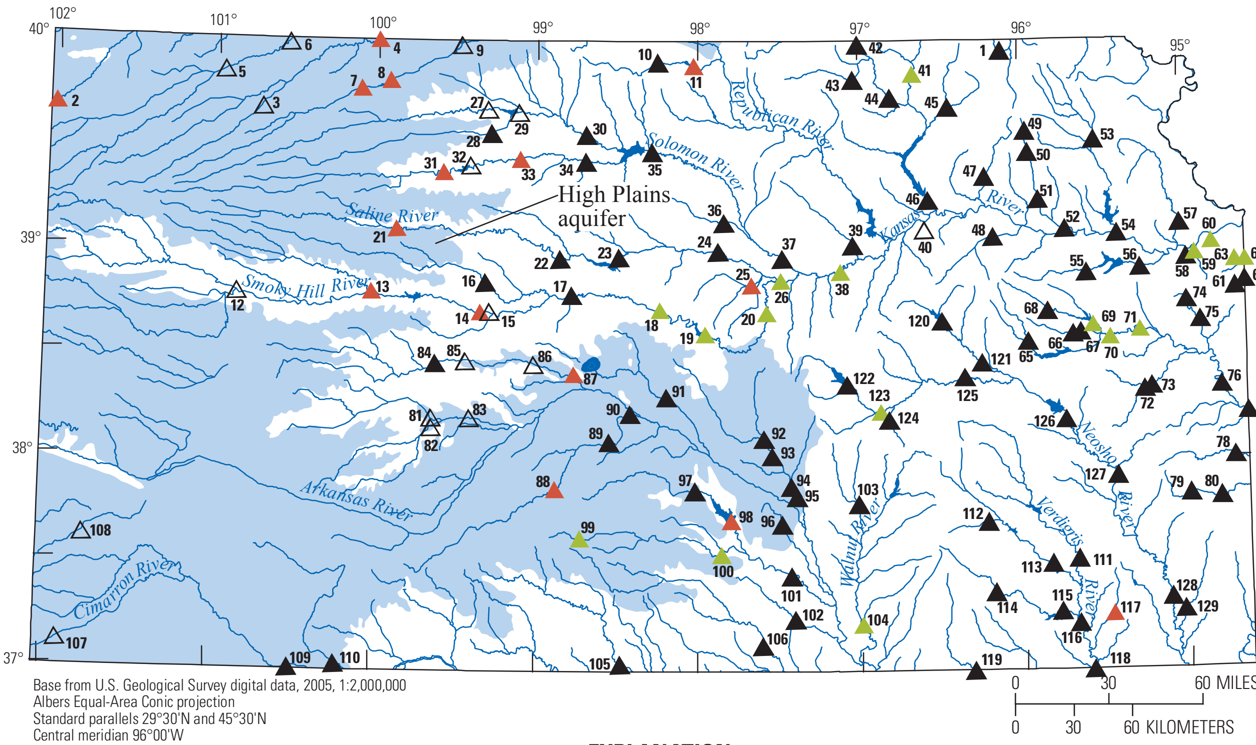
113 ▲ Diminished flow condition

114 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

107 △ Not computed due to absence of flow

Figure 19. Condition of the average duration of flow pulses less than the 25th percentile metric for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—Average flow of pulses less than the 25th percentile, normalized by drainage area

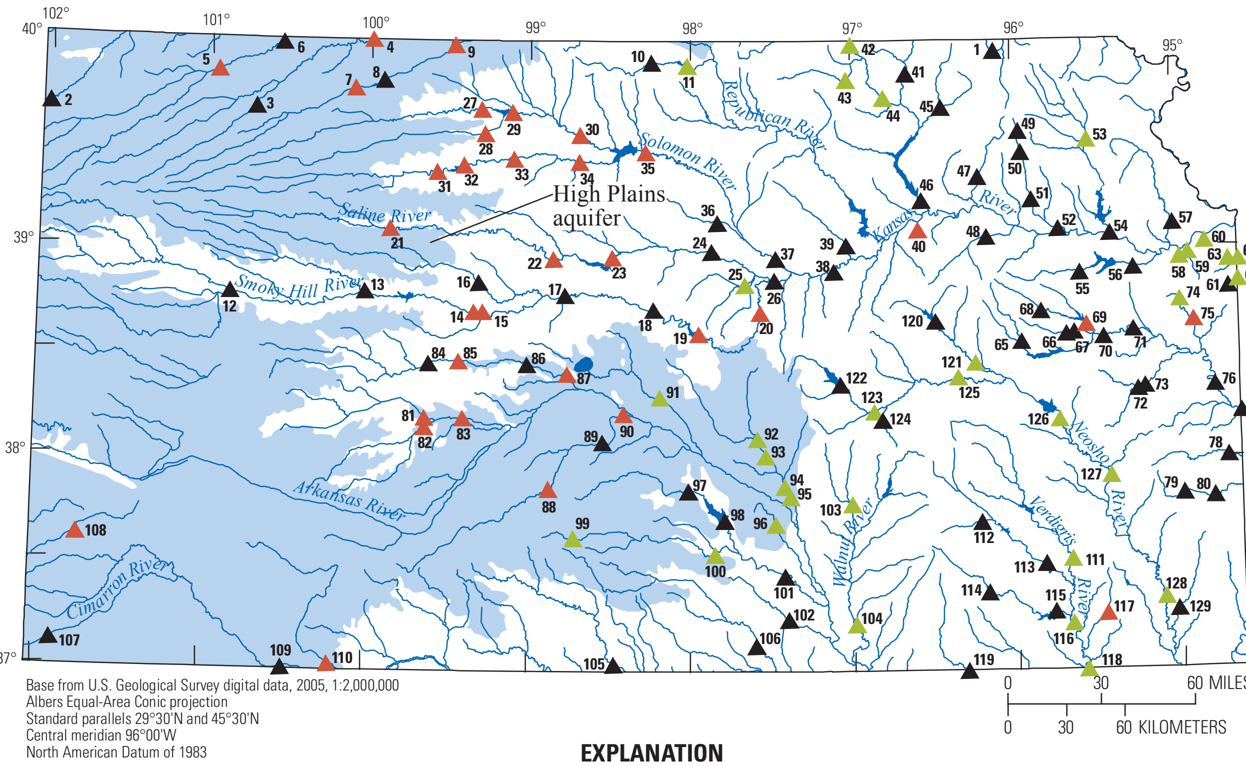
117 ▲ Diminished flow condition

104 ▲ Inflated flow condition

110 ▲ Minimally altered flow condition

107 △ Not computed due to absence of flow

Figure 20. Condition of the average magnitude of flow pulses less than the 25th percentile metric for 129 streamgages in Kansas.



EXPLANATION

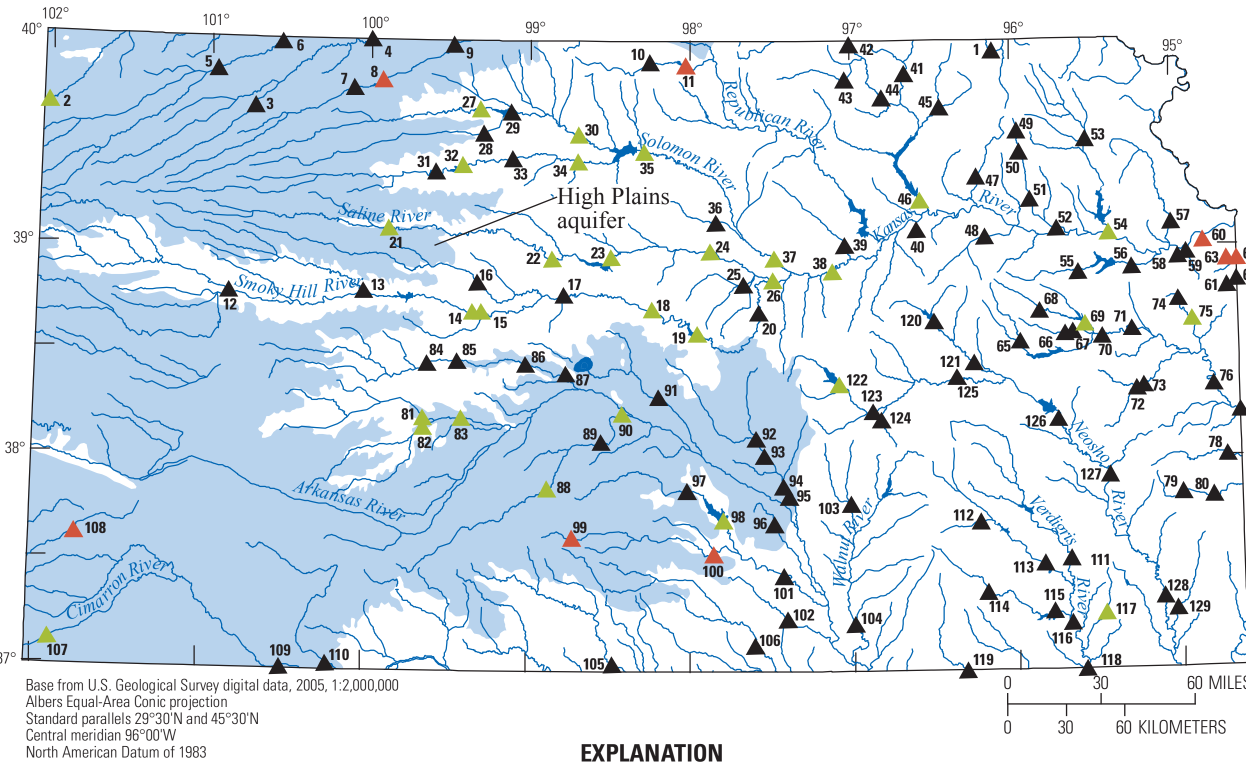
U.S. Geological Survey streamgage and identifier (table 2)—Average annual number of flow pulses greater than the 75th percentile

110 ▲ Diminished flow condition

104 ▲ Inflated flow condition

109 ▲ Minimally altered flow condition

Figure 21. Condition of the average annual number of flow pulses greater than the 75th percentile metric for 129 streamgages in Kansas.



EXPLANATION

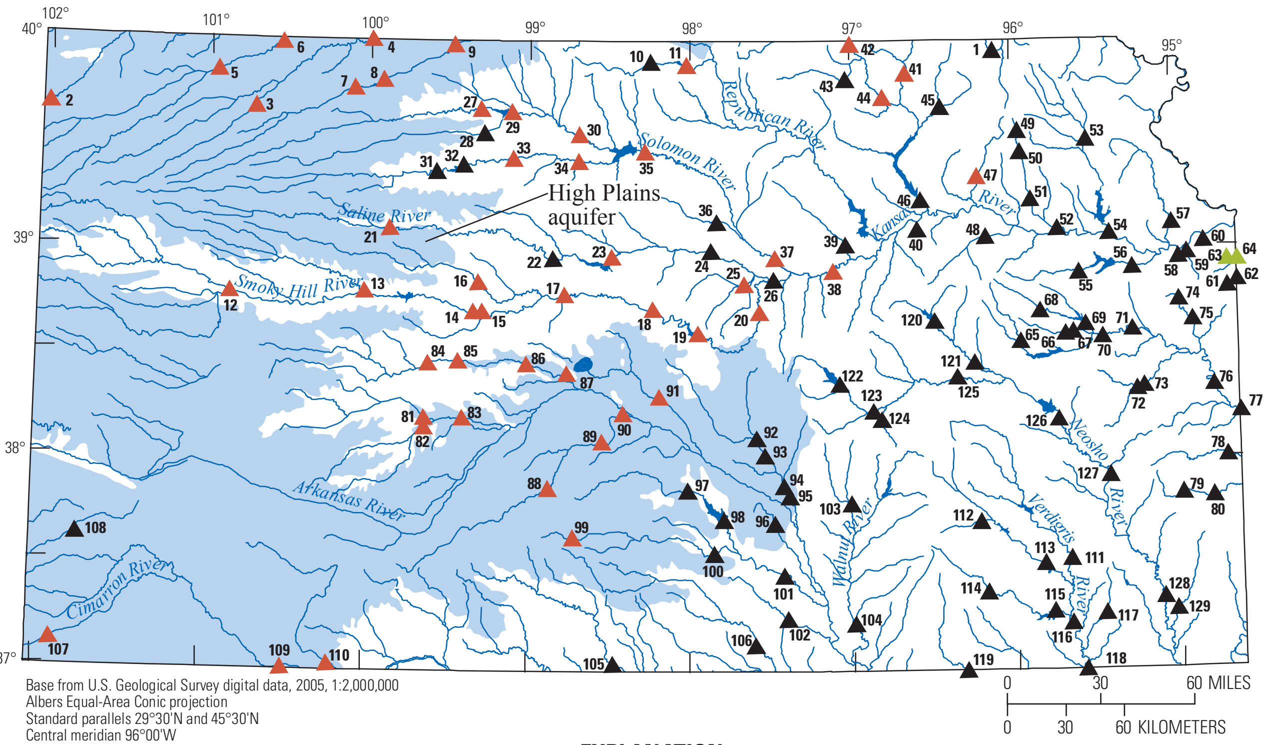
U.S. Geological Survey streamgage and identifier (table 2)—Average duration of flow pulses greater than the 75th percentile

108 ▲ Diminished flow condition

117 ▲ Inflated flow condition

110 ▲ Minimally altered flow condition

Figure 22. Condition of the average duration of flow pulses greater than the 75th percentile metric for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

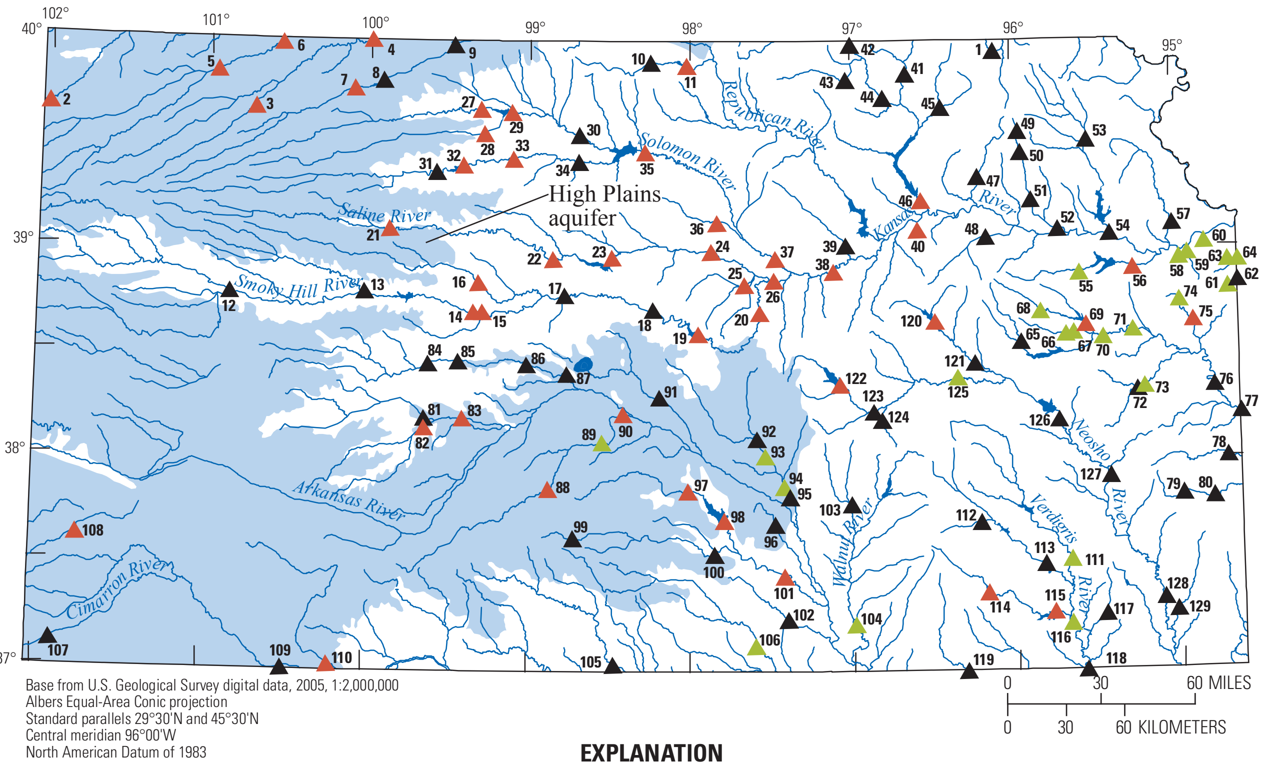
U.S. Geological Survey streamgage and identifier (table 2)—Average flow of pulses greater than the 75th percentile, normalized by drainage area

109 ▲ Diminished flow condition

64 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 23. Condition of the average magnitude of flow pulses greater than the 75th percentile metric for 129 streamgages in Kansas.



EXPLANATION

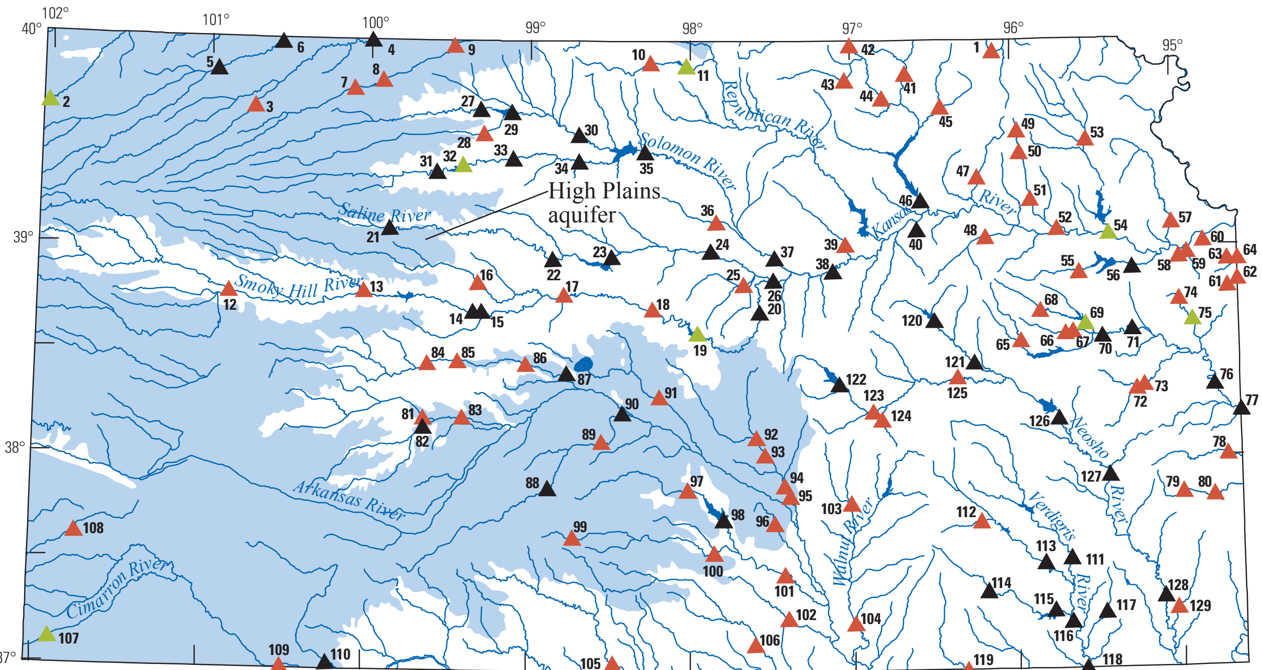
U.S. Geological Survey streamgage and identifier (table 2)—Average annual number of flow pulses greater than the 90th percentile

110 Diminished flow condition

106 Inflated flow condition

105 Minimally altered flow condition

Figure 24. Condition of the average annual number of flow pulses greater than the 90th percentile metric for 129 streamgages in Kansas.



Base from U.S. Geological Survey digital data, 2005, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 96°00'W
North American Datum of 1983

EXPLANATION

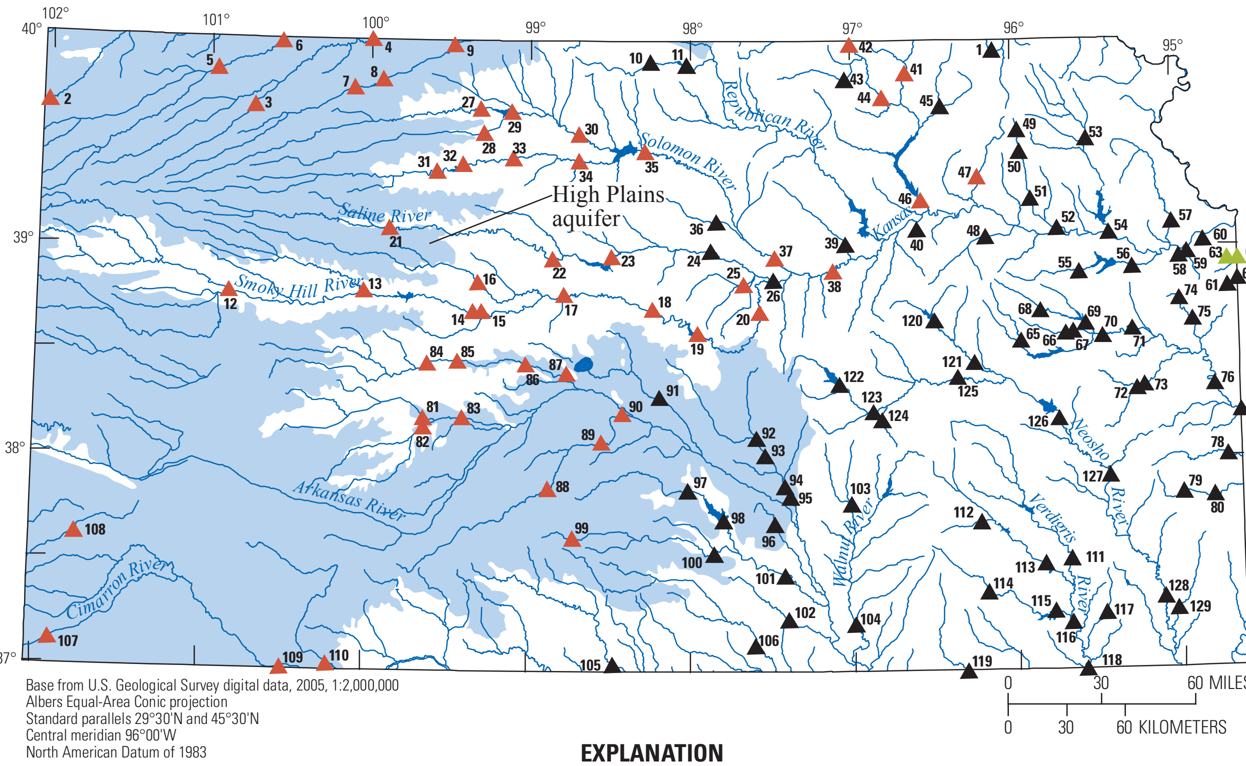
U.S. Geological Survey streamgage and identifier (table 2)—Average duration of flow pulses greater than the 90th percentile

105 ▲ Diminished flow condition

107 ▲ Inflated flow condition

110 ▲ Minimally altered flow condition

Figure 25. Condition of the average duration of flow pulses greater than the 90th percentile metric for 129 streamgages in Kansas.



EXPLANATION

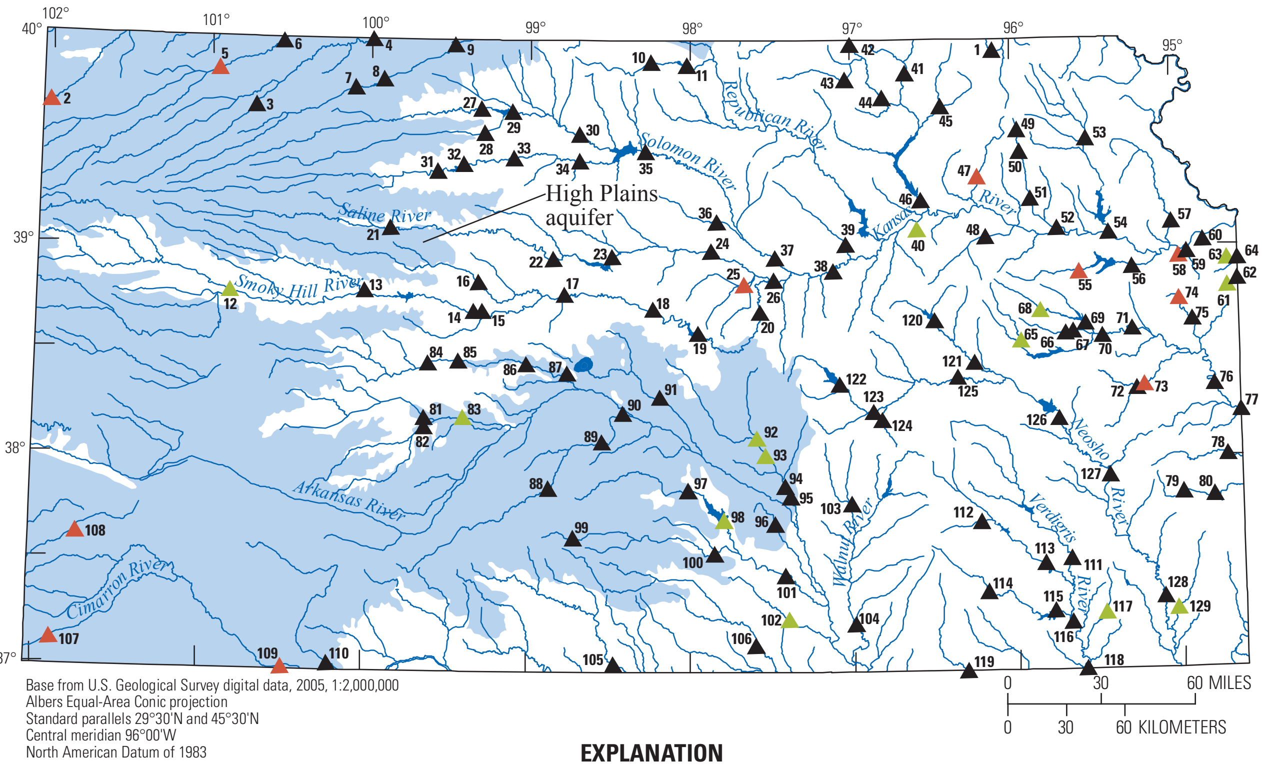
U.S. Geological Survey streamgage and identifier (table 2)—Average flow of pulses greater than the 90th percentile, normalized by drainage area

110 Diminished flow condition

64 Inflated flow condition

105 Minimally altered flow condition

Figure 26. Condition of the average magnitude of flow pulses greater than the 90th percentile metric for 129 streamgages in Kansas.



EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—
Percentage of flow that is base flow

109 ▲ Diminished flow condition

102 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 27. Condition of the percentage of flow that is base flow metric for 129 streamgages in Kansas.

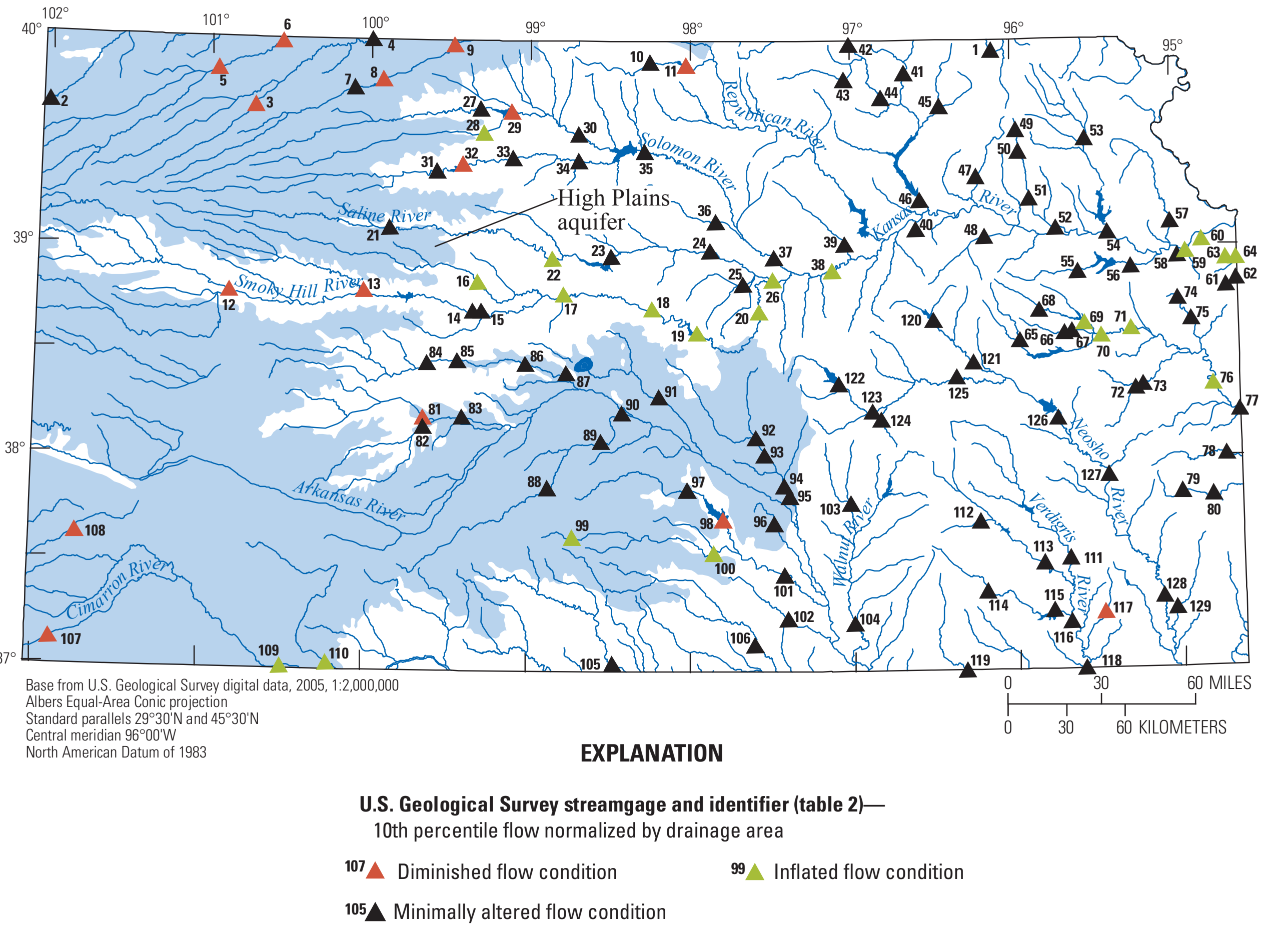


Figure 28. Condition of the 10th percentile flow normalized by drainage area metric for 129 streamgages in Kansas.

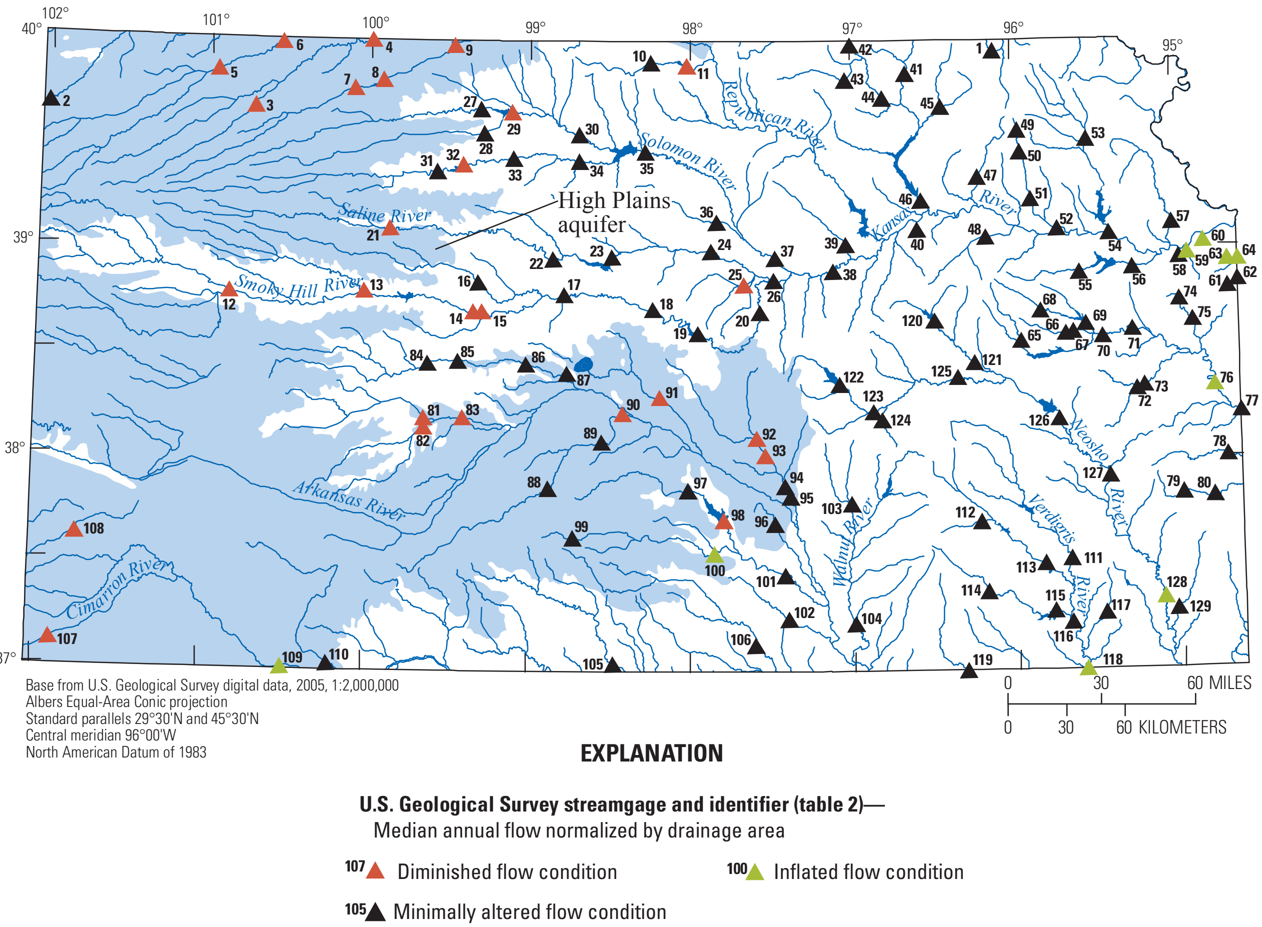
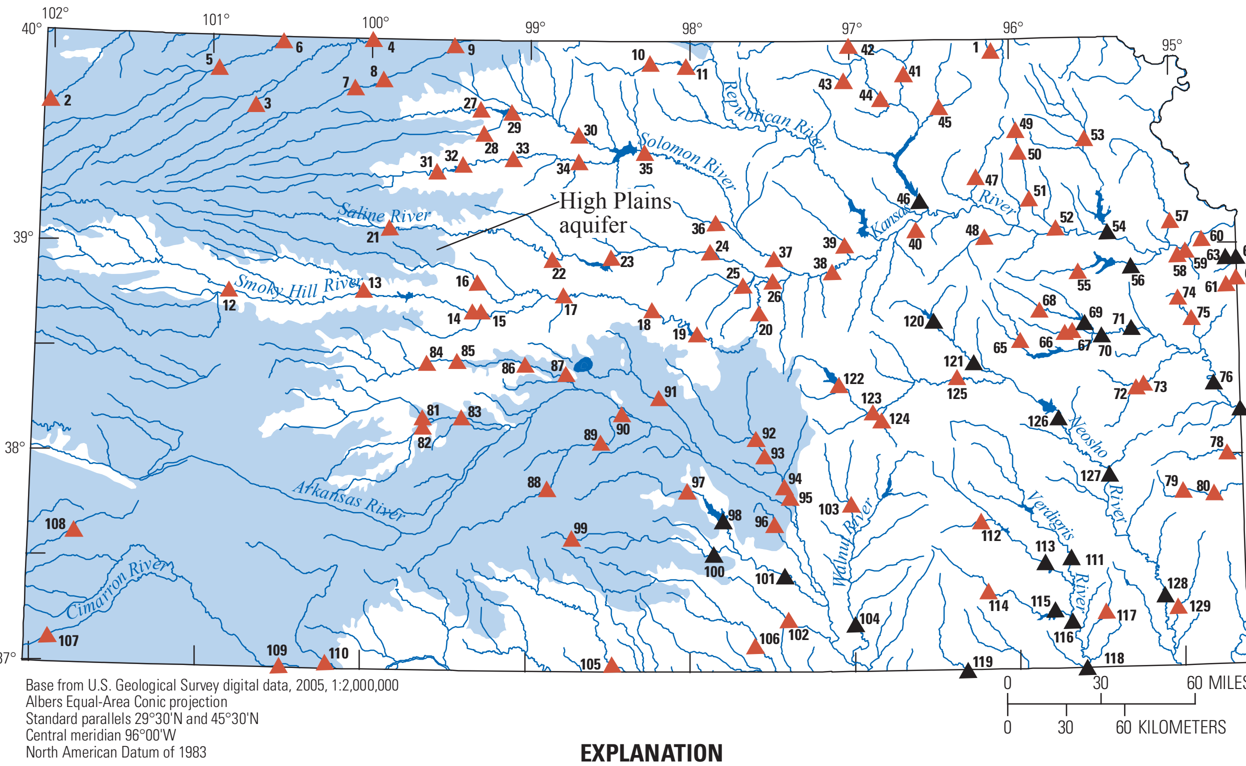


Figure 29. Condition of the median flow normalized by drainage area metric for 129 streamgages in Kansas.

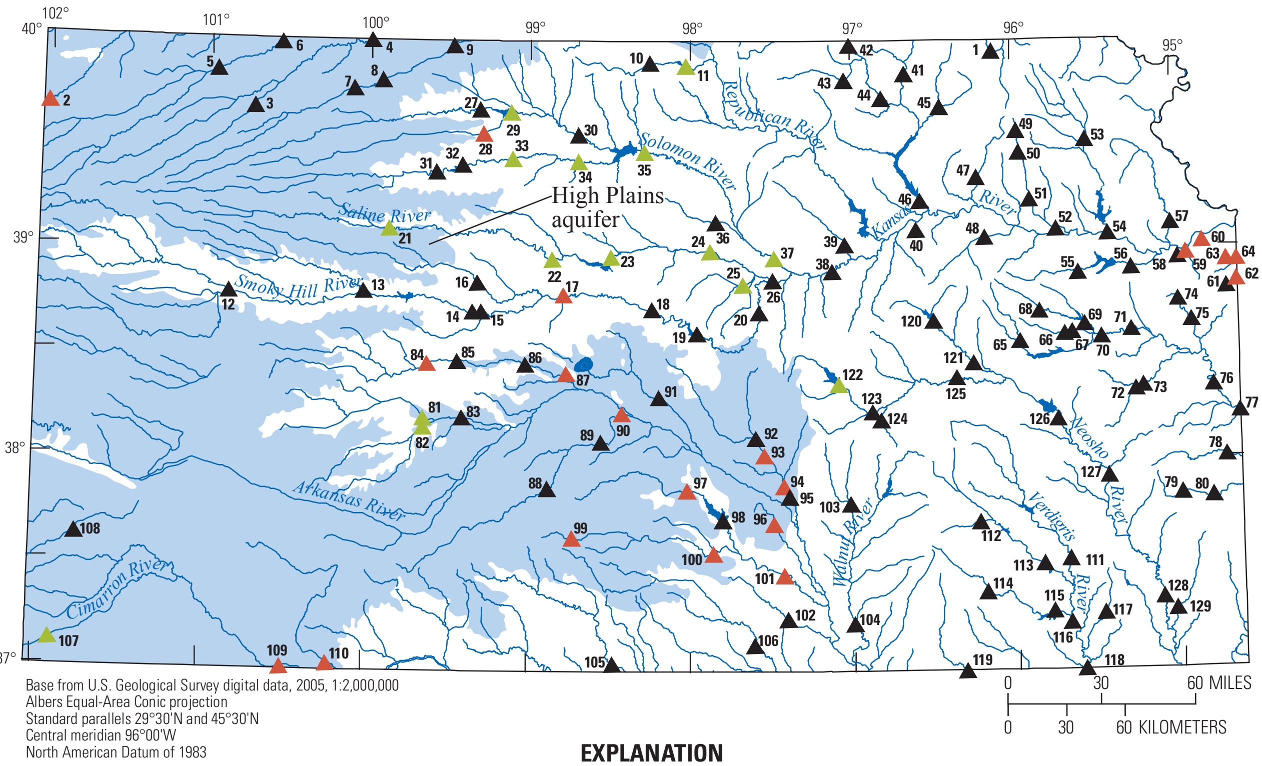


EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—
90th percentile flow normalized by drainage area

107 ▲ Diminished flow condition   100 ▲ Minimally altered flow condition

Figure 30. Condition of the 90th percentile flow normalized by drainage area metric for 129 streamgages in Kansas.



EXPLANATION

U.S. Geological Survey streamgage and identifier (table 2)—
Coefficient of variation of daily flows

109 ▲ Diminished flow condition

122 ▲ Inflated flow condition

105 ▲ Minimally altered flow condition

Figure 31. Condition of the coefficient of variation of daily flows metric for 129 streamgages in Kansas.

Appendix 1. Observed/Expected (O/E) Ratio Values for Streamflow Metrics Assessed in This Study

Table 1–1. Observed/Expected (O/E) ratio values for the January, February, March, and April flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_JAN[2]	AVG_FEB[3]	AVG_MAR[4]	AVG_APR[5]
1	06814000	1	0.919	0.992	1.009	1.174
2	06827000	2	1.207	0.876	**0.166**	**0.407**
3	06844900	2	**0.091**	**0.068**	**0.167**	**0.066**
4	06845110	2	**0.514**	**0.399**	**0.199**	**0.274**
5	06846000	2	**0.210**	**0.129**	**0.058**	**0.176**
6	06846500	1	**0.076**	**0.075**	**0.036**	**0.102**
7	06847900	1	0.588	**0.531**	**0.534**	**0.548**
8	06848000	2	**0.023**	**0.042**	**0.031**	**0.038**
9	06848500	2	**0.147**	**0.223**	**0.156**	**0.235**
10	06853800	1	0.717	0.794	0.639	0.749
11	06854000	2	**0.437**	**0.306**	**0.314**	0.882
12	06860000	2	**0.062**	**0.042**	**0.011**	**0.064**
13	06861000	2	**0.145**	**0.146**	**0.040**	**0.201**
14	06862700	2	**0.148**	**0.143**	**0.073**	**0.126**
15	06862850	2	**0.115**	**0.107**	**0.074**	**0.151**
16	06863500	2	**0.419**	**0.494**	**0.520**	0.825
17	06864050	2	**0.534**	0.642	**0.433**	1.056
18	06864500	2	0.600	0.767	**0.562**	*1.508*
19	06865500	2	**0.526**	0.686	**0.341**	0.952
20	06866500	2	0.670	0.697	**0.472**	1.053
21	06866900	2	**0.398**	**0.558**	**0.170**	**0.587**
22	06867000	2	**0.526**	0.649	0.652	1.274
23	06868200	2	0.758	**0.453**	**0.317**	**0.620**
24	06869500	2	0.762	0.606	**0.577**	0.850
25	06869950	1	**0.299**	**0.244**	**0.234**	**0.622**
26	06870200	2	0.640	0.752	0.685	1.201
27	06871000	2	**0.408**	**0.435**	**0.363**	0.703
28	06871500	2	**0.549**	0.612	**0.482**	1.084
29	06871800	2	**0.281**	**0.230**	**0.143**	**0.121**
30	06872500	2	0.629	0.645	0.615	0.683
31	06873000	2	0.825	0.899	0.627	*1.336*
32	06873200	2	**0.348**	**0.392**	**0.275**	**0.450**
33	06873460	2	**0.347**	**0.317**	**0.228**	**0.632**
34	06874000	2	**0.428**	**0.389**	**0.307**	0.703
35	06875900	2	0.694	**0.447**	**0.300**	**0.381**
36	06876700	1	**0.536**	0.823	0.694	1.029
37	06876900	2	0.761	0.631	**0.420**	**0.556**
38	06877600	2	0.633	0.598	**0.446**	0.832
39	06878000	1	0.842	0.989	0.813	1.108
40	06879650	1	0.664	0.789	0.987	1.144
41	06882510	2	0.616	**0.540**	0.630	**0.514**
42	06884025	2	0.686	0.674	**0.571**	**0.524**
43	06884200	2	0.623	0.893	0.754	1.007
44	06884400	2	0.735	0.688	0.584	**0.617**
45	06885500	1	0.921	1.000	0.881	1.118
46	06887000	2	0.724	0.714	**0.496**	0.736
47	06888000	1	0.790	0.661	0.599	0.851
48	06888500	1	0.925	0.972	0.992	1.209
49	06889140	1	0.803	0.933	0.939	1.090

Table 1–1. Observed/Expected (O/E) ratio values for the January, February, March, and April flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_JAN[2]	AVG_FEB[3]	AVG_MAR[4]	AVG_APR[5]
50	06889160	1	0.771	0.931	0.967	1.150
51	06889200	1	0.799	0.898	0.883	1.081
52	06889500	1	0.773	0.916	0.941	1.096
53	06890100	2	0.765	0.764	0.711	0.903
54	06890900	2	0.586	0.754	0.598	0.946
55	06891260	2	0.882	0.779	0.814	0.934
56	06891500	2	0.878	0.687	0.685	0.801
57	06892000	1	0.885	0.969	0.875	1.155
58	06892360	2	1.023	1.074	1.122	0.954
59	06892495	2	1.176	1.216	1.335	1.146
60	06892513	2	1.149	1.266	1.258	*1.395*
61	06893080	2	0.811	1.114	0.889	1.022
62	06893100	2	0.962	1.010	1.040	0.916
63	06893300	2	*2.019*	*1.929*	*1.508*	*1.750*
64	06893390	2	*1.672*	*1.752*	*1.623*	*1.564*
65	06910800	1	0.803	0.986	0.903	0.998
66	06911490	1	0.646	0.940	0.860	0.901
67	06911500	2	0.808	0.975	1.038	1.301
68	06911900	1	0.739	0.915	0.929	1.067
69	06912500	2	1.029	0.679	0.668	0.719
70	06913000	2	1.141	0.871	0.823	0.948
71	06913500	2	1.054	0.861	0.798	0.934
72	06914000	2	0.780	1.302	1.147	*1.338*
73	06914100	2	0.606	0.652	0.842	1.038
74	06914950	2	0.702	1.070	0.816	1.031
75	06915000	2	1.383	0.786	0.776	**0.499**
76	06915800	2	1.032	0.984	0.942	0.959
77	06916600	2	0.915	0.940	0.966	1.089
78	06917000	1	0.807	1.104	1.073	1.316
79	06917240	2	0.764	0.656	0.956	1.251
80	06917380	1	0.883	1.121	0.925	1.183
81	07140850	2	**0.030**	**0.058**	**0.053**	**0.157**
82	07141175	2	**0.193**	**0.103**	**0.092**	**0.208**
83	07141200	2	**0.054**	**0.043**	**0.098**	**0.249**
84	07141770	2	**0.192**	**0.169**	**0.175**	**0.319**
85	07141780	2	**0.132**	**0.155**	**0.288**	**0.580**
86	07141900	2	**0.164**	**0.244**	**0.344**	0.717
87	07142020	2	**0.155**	**0.180**	**0.212**	**0.601**
88	07142300	1	**0.331**	**0.314**	**0.301**	**0.391**
89	07142575	2	**0.564**	**0.535**	**0.529**	**0.540**
90	07142620	2	**0.317**	**0.429**	**0.465**	**0.537**
91	07143300	2	**0.238**	**0.476**	**0.497**	**0.570**
92	07143665	2	**0.319**	0.829	1.071	0.854
93	07143672	2	**0.360**	0.693	0.908	0.792
94	07144100	2	**0.430**	0.718	0.801	0.683
95	07144200	2	**0.455**	0.936	0.917	0.827
96	07144480	2	**0.522**	0.579	0.760	0.845
97	07144780	1	1.110	1.122	0.971	0.926
98	07144795	2	0.583	0.678	**0.567**	0.872

Table 1–1. Observed/Expected (O/E) ratio values for the January, February, March, and April flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_JAN[2]	AVG_FEB[3]	AVG_MAR[4]	AVG_APR[5]
99	07144910	2	0.894	0.677	0.697	0.858
100	07145200	2	*2.437*	*2.203*	*1.642*	*1.595*
101	07145500	2	1.295	1.180	1.014	1.211
102	07145700	1	1.067	1.131	1.140	1.135
103	07147070	2	0.746	0.965	0.942	0.996
104	07147800	2	0.974	1.024	1.212	1.235
105	07149000	1	1.212	1.120	1.125	1.182
106	07151500	1	1.247	1.161	1.287	1.312
107	07155590	2	**0.020**	**0.004**	**0.002**	**0.008**
108	07156220	1	**0.000**	**0.000**	**0.001**	**0.017**
109	07156900	2	*2.104*	1.265	**0.470**	1.005
110	07157500	2	**0.256**	**0.216**	**0.207**	**0.375**
111	07166500	2	0.918	0.968	1.154	1.267
112	07167500	1	0.916	1.210	1.218	1.272
113	07169500	2	1.171	0.972	1.183	1.287
114	07169800	2	0.830	0.982	1.171	1.136
115	07170060	2	*1.609*	1.000	1.455	1.117
116	07170500	2	1.107	0.989	1.213	1.257
117	07170700	2	0.799	0.717	0.865	0.976
118	07170990	2	1.057	0.696	1.031	1.044
119	07172000	2	0.984	1.080	1.412	*1.672*
120	07179500	2	0.658	0.725	0.677	0.810
121	07179730	2	0.707	0.881	0.871	0.997
122	07179795	2	**0.580**	0.655	**0.512**	0.710
123	07180400	2	0.851	0.861	0.764	0.856
124	07180500	1	1.091	1.167	1.134	*1.349*
125	07182250	2	0.876	0.895	0.914	1.203
126	07182510	2	1.003	0.765	0.925	1.112
127	07183000	2	0.924	0.797	0.903	1.161
128	07183500	2	0.898	0.843	0.857	1.020
129	07184000	1	0.879	1.020	0.943	1.011

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Mean January flow normalized by drainage area. Tenth percentile error bound is 0.580. Ninetieth percentile error bound is 1.550.

[3]Mean February flow normalized by drainage area. Tenth percentile error bound is 0.560. Ninetieth percentile error bound is 1.420.

[4]Mean March flow normalized by drainage area. Tenth percentile error bound is 0.580. Ninetieth percentile error bound is 1.470.

[5]Mean April flow normalized by drainage area. Tenth percentile error bound is 0.660. Ninetieth percentile error bound is 1.330.

Table 1–2. Observed/Expected (O/E) ratio values for the May, June, July, and August flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_MAY[2]	AVG_JUN[3]	AVG_JUL[4]	AVG_AUG[5]
1	06814000	1	1.211	1.071	1.169	0.741
2	06827000	2	**0.132**	**0.107**	**0.092**	**0.258**
3	06844900	2	**0.214**	**0.215**	0.708	**0.385**
4	06845110	2	**0.233**	**0.220**	**0.200**	**0.228**
5	06846000	2	**0.048**	**0.048**	**0.099**	0.546
6	06846500	1	**0.079**	**0.128**	**0.200**	**0.237**
7	06847900	1	**0.405**	**0.415**	0.532	**0.440**
8	06848000	2	**0.008**	**0.087**	0.919	**0.433**
9	06848500	2	**0.231**	**0.129**	**0.321**	**0.330**
10	06853800	1	1.084	0.648	1.030	0.719
11	06854000	2	**0.525**	**0.279**	**0.462**	1.225
12	06860000	2	**0.076**	**0.065**	**0.315**	**0.221**
13	06861000	2	**0.146**	**0.171**	**0.412**	**0.289**
14	06862700	2	**0.085**	**0.070**	**0.236**	**0.219**
15	06862850	2	**0.092**	**0.080**	**0.263**	**0.220**
16	06863500	2	0.648	**0.413**	0.761	1.272
17	06864050	2	**0.590**	**0.466**	1.154	0.945
18	06864500	2	0.764	0.607	1.345	1.134
19	06865500	2	0.655	0.977	0.796	*1.854*
20	06866500	2	0.844	1.233	0.942	*2.118*
21	06866900	2	**0.400**	**0.238**	0.555	0.631
22	06867000	2	0.720	**0.450**	1.377	1.021
23	06868200	2	**0.520**	**0.524**	0.613	0.974
24	06869500	2	0.690	0.632	1.155	1.023
25	06869950	1	1.310	0.569	**0.119**	0.779
26	06870200	2	0.892	0.985	1.175	*1.649*
27	06871000	2	0.814	**0.275**	**0.366**	0.728
28	06871500	2	0.861	**0.471**	0.704	0.809
29	06871800	2	**0.172**	**0.126**	**0.099**	**0.004**
30	06872500	2	0.907	**0.540**	1.026	0.692
31	06873000	2	0.759	**0.314**	0.581	0.815
32	06873200	2	**0.258**	**0.495**	1.389	*1.523*
33	06873460	2	**0.405**	**0.328**	0.755	0.533
34	06874000	2	**0.500**	**0.456**	1.204	0.747
35	06875900	2	**0.375**	**0.535**	0.850	1.132
36	06876700	1	0.983	0.818	1.258	0.886
37	06876900	2	0.630	0.623	1.043	1.147
38	06877600	2	0.763	0.821	1.258	1.283
39	06878000	1	1.083	0.824	1.140	1.132
40	06879650	1	1.140	1.077	1.032	0.683
41	06882510	2	0.714	0.850	1.077	1.025
42	06884025	2	0.741	0.712	1.002	1.112
43	06884200	2	0.982	1.158	1.060	0.812
44	06884400	2	0.813	0.857	0.989	1.134
45	06885500	1	1.116	1.082	1.254	0.940
46	06887000	2	0.690	0.883	1.268	*1.685*
47	06888000	1	0.930	0.834	**0.417**	0.475
48	06888500	1	1.260	1.093	1.235	1.177
49	06889140	1	1.387	1.032	*1.612*	0.775

Table 1–2. Observed/Expected (O/E) ratio values for the May, June, July, and August flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_MAY[2]	AVG_JUN[3]	AVG_JUL[4]	AVG_AUG[5]
50	06889160	1	1.286	1.082	1.426	0.744
51	06889200	1	1.170	1.102	1.118	0.841
52	06889500	1	1.235	1.028	1.110	0.921
53	06890100	2	1.204	1.120	1.263	0.946
54	06890900	2	0.823	1.065	*1.564*	*1.799*
55	06891260	2	1.219	1.043	0.787	1.183
56	06891500	2	1.020	1.084	1.225	1.322
57	06892000	1	1.280	1.133	1.056	0.945
58	06892360	2	1.079	1.391	0.537	1.431
59	06892495	2	*1.539*	1.465	0.821	*2.030*
60	06892513	2	1.446	*1.669*	1.183	*3.524*
61	06893080	2	*1.658*	1.426	0.838	0.878
62	06893100	2	1.248	*1.796*	0.611	1.506
63	06893300	2	*2.430*	*2.554*	*2.141*	*5.009*
64	06893390	2	*1.971*	*2.418*	*1.862*	*6.254*
65	06910800	1	1.182	0.857	0.966	0.831
66	06911490	1	1.324	1.137	0.546	0.596
67	06911500	2	1.272	1.023	0.995	0.632
68	06911900	1	1.274	0.923	0.878	0.694
69	06912500	2	0.881	1.297	1.176	1.124
70	06913000	2	1.031	1.241	1.180	1.018
71	06913500	2	1.052	1.217	1.140	0.942
72	06914000	2	1.012	0.866	1.234	1.329
73	06914100	2	1.422	1.292	1.228	0.947
74	06914950	2	1.497	1.524	0.529	0.966
75	06915000	2	0.747	*1.695*	1.064	1.363
76	06915800	2	1.255	1.203	1.298	1.082
77	06916600	2	1.226	1.241	1.192	0.921
78	06917000	1	1.315	1.056	1.177	1.231
79	06917240	2	1.419	*1.657*	1.267	1.493
80	06917380	1	1.194	1.032	1.218	1.064
81	07140850	2	**0.180**	**0.190**	1.067	0.685
82	07141175	2	**0.201**	**0.307**	0.886	1.331
83	07141200	2	**0.228**	**0.378**	1.137	0.712
84	07141770	2	**0.211**	**0.352**	0.696	1.112
85	07141780	2	**0.201**	**0.376**	1.161	1.180
86	07141900	2	**0.380**	0.563	0.956	*1.536*
87	07142020	2	**0.589**	0.668	0.562	1.465
88	07142300	1	**0.370**	**0.304**	**0.371**	**0.264**
89	07142575	2	**0.560**	**0.506**	0.743	**0.272**
90	07142620	2	**0.516**	**0.419**	**0.326**	**0.136**
91	07143300	2	0.899	0.811	1.130	*1.612*
92	07143665	2	1.050	0.880	1.304	*2.021*
93	07143672	2	0.949	1.154	1.051	*2.329*
94	07144100	2	1.060	1.101	0.979	*2.022*
95	07144200	2	0.940	0.934	1.284	*1.795*
96	07144480	2	0.935	1.378	1.386	*2.501*
97	07144780	1	1.141	1.029	1.220	1.243
98	07144795	2	0.660	0.780	1.056	0.497

Table 1–2. Observed/Expected (O/E) ratio values for the May, June, July, and August flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_MAY[2]	AVG_JUN[3]	AVG_JUL[4]	AVG_AUG[5]
99	07144910	2	0.901	0.734	1.294	*1.750*
100	07145200	2	1.511	1.310	*1.686*	*2.176*
101	07145500	2	1.029	1.047	1.264	1.305
102	07145700	1	1.172	1.305	1.234	*1.612*
103	07147070	2	1.031	1.276	1.242	*2.043*
104	07147800	2	1.197	1.307	1.191	*1.597*
105	07149000	1	1.137	1.039	1.387	1.225
106	07151500	1	1.106	1.153	1.103	1.284
107	07155590	2	**0.161**	**0.065**	**0.044**	**0.179**
108	07156220	1	**0.146**	**0.017**	1.016	0.920
109	07156900	2	**0.337**	**0.136**	**0.179**	**0.152**
110	07157500	2	**0.245**	**0.221**	**0.275**	**0.279**
111	07166500	2	1.191	1.254	1.054	*1.624*
112	07167500	1	1.261	1.346	0.822	1.374
113	07169500	2	1.147	1.143	1.419	*1.700*
114	07169800	2	1.272	1.338	0.712	0.681
115	07170060	2	0.940	1.424	1.058	0.923
116	07170500	2	1.234	1.280	1.340	*1.756*
117	07170700	2	1.312	1.338	0.931	0.958
118	07170990	2	*1.658*	1.534	*2.124*	*2.922*
119	07172000	2	*1.852*	*2.070*	1.019	0.830
120	07179500	2	0.847	1.010	0.935	1.376
121	07179730	2	0.964	1.030	1.047	1.387
122	07179795	2	0.831	0.740	0.912	1.139
123	07180400	2	0.999	0.960	1.131	1.422
124	07180500	1	1.277	1.136	1.118	*1.665*
125	07182250	2	1.067	0.975	0.967	*1.751*
126	07182510	2	0.905	1.208	1.202	*1.999*
127	07183000	2	0.878	1.067	1.159	*1.919*
128	07183500	2	0.992	1.080	1.236	*1.690*
129	07184000	1	1.284	1.220	1.323	1.348

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Mean May flow normalized by drainage area. Tenth percentile error bound is 0.600. Ninetieth percentile error bound is 1.530.

[3]Mean June flow normalized by drainage area. Tenth percentile error bound is 0.550. Ninetieth percentile error bound is 1.600.

[4]Mean July flow normalized by drainage area. Tenth percentile error bound is 0.490. Ninetieth percentile error bound is 1.510.

[5]Mean August flow normalized by drainage area. Tenth percentile error bound is 0.440. Ninetieth percentile error bound is 1.510.

Table 1–3. Observed/Expected (O/E) ratio values for the September, October, November, and December flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_SEP[2]	AVG_OCT[3]	AVG_NOV[4]	AVG_DEC[5]
1	06814000	1	0.768	0.723	0.943	1.292
2	06827000	2	**0.361**	0.796	1.357	*1.944*
3	06844900	2	**0.068**	**0.011**	**0.029**	**0.057**
4	06845110	2	**0.104**	**0.175**	**0.301**	**0.479**
5	06846000	2	**0.178**	**0.071**	**0.116**	**0.143**
6	06846500	1	**0.120**	**0.053**	**0.089**	**0.077**
7	06847900	1	**0.149**	**0.226**	**0.381**	0.626
8	06848000	2	**0.011**	**0.015**	**0.018**	**0.024**
9	06848500	2	**0.100**	**0.230**	**0.162**	**0.201**
10	06853800	1	**0.333**	0.602	0.846	0.799
11	06854000	2	0.519	0.558	**0.521**	**0.370**
12	06860000	2	**0.434**	**0.177**	**0.101**	**0.067**
13	06861000	2	**0.249**	**0.138**	**0.238**	**0.216**
14	06862700	2	**0.104**	**0.056**	**0.219**	**0.164**
15	06862850	2	**0.126**	**0.055**	**0.216**	**0.148**
16	06863500	2	0.768	0.521	0.636	**0.401**
17	06864050	2	0.521	**0.520**	1.101	0.609
18	06864500	2	0.703	0.796	1.065	0.707
19	06865500	2	1.273	1.188	0.928	1.034
20	06866500	2	*1.635*	1.540	1.039	1.028
21	06866900	2	**0.460**	**0.266**	**0.242**	**0.373**
22	06867000	2	0.511	0.643	0.702	**0.490**
23	06868200	2	0.691	0.728	0.917	1.127
24	06869500	2	0.629	0.585	0.889	1.001
25	06869950	1	**0.312**	**0.369**	**0.209**	**0.337**
26	06870200	2	1.006	0.795	0.934	0.794
27	06871000	2	**0.266**	0.534	**0.474**	**0.435**
28	06871500	2	**0.328**	0.610	0.648	0.603
29	06871800	2	**0.039**	**0.048**	**0.047**	**0.145**
30	06872500	2	0.467	**0.518**	0.601	**0.554**
31	06873000	2	0.502	**0.434**	0.708	0.920
32	06873200	2	**0.102**	**0.152**	**0.280**	0.700
33	06873460	2	**0.208**	**0.340**	**0.394**	**0.478**
34	06874000	2	**0.426**	**0.414**	**0.506**	**0.493**
35	06875900	2	0.570	**0.435**	0.709	0.825
36	06876700	1	0.514	**0.445**	0.642	0.665
37	06876900	2	0.731	**0.497**	0.784	0.936
38	06877600	2	0.801	0.611	0.836	0.830
39	06878000	1	0.702	0.682	1.093	1.274
40	06879650	1	**0.348**	0.776	0.901	0.921
41	06882510	2	0.905	0.809	0.720	0.606
42	06884025	2	0.744	0.844	0.699	**0.573**
43	06884200	2	0.758	0.683	0.676	0.625
44	06884400	2	0.719	0.825	0.742	0.637
45	06885500	1	0.839	0.831	1.059	1.374
46	06887000	2	0.941	0.868	0.833	1.260
47	06888000	1	**0.143**	**0.300**	**0.344**	0.826
48	06888500	1	0.626	0.781	1.002	1.067

Table 1–3. Observed/Expected (O/E) ratio values for the September, October, November, and December flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_SEP[2]	AVG_OCT[3]	AVG_NOV[4]	AVG_DEC[5]
49	06889140	1	0.801	0.780	1.149	0.988
50	06889160	1	0.697	0.773	1.151	0.836
51	06889200	1	0.742	1.023	0.893	0.955
52	06889500	1	0.830	0.968	0.957	0.964
53	06890100	2	0.670	0.697	0.793	0.910
54	06890900	2	0.510	1.306	0.935	1.504
55	06891260	2	0.501	**0.508**	**0.389**	0.585
56	06891500	2	0.604	0.914	0.912	1.318
57	06892000	1	0.824	1.176	0.897	1.217
58	06892360	2	**0.404**	0.738	**0.497**	0.862
59	06892495	2	0.744	0.915	0.671	1.122
60	06892513	2	0.973	1.183	0.772	1.340
61	06893080	2	0.738	0.952	0.974	1.228
62	06893100	2	**0.369**	0.715	**0.525**	0.841
63	06893300	2	*2.478*	*2.471*	*2.174*	*2.601*
64	06893390	2	*1.792*	*2.107*	1.398	*2.032*
65	06910800	1	0.684	0.933	0.981	0.970
66	06911490	1	0.829	**0.451**	**0.319**	0.657
67	06911500	2	0.619	1.583	1.483	1.331
68	06911900	1	0.581	0.816	0.966	0.987
69	06912500	2	**0.447**	0.675	1.208	*1.882*
70	06913000	2	0.614	0.815	1.261	*1.964*
71	06913500	2	0.603	0.833	1.187	*1.774*
72	06914000	2	0.594	1.479	*1.592*	*1.785*
73	06914100	2	1.054	0.788	0.611	**0.531**
74	06914950	2	0.833	1.022	1.068	0.948
75	06915000	2	**0.395**	0.923	0.851	*2.282*
76	06915800	2	0.634	1.174	1.352	*1.731*
77	06916600	2	0.518	0.896	1.165	*1.662*
78	06917000	1	0.900	1.129	1.107	1.268
79	06917240	2	0.763	0.672	**0.510**	0.634
80	06917380	1	0.891	1.143	1.001	1.090
81	07140850	2	0.521	**0.124**	**0.070**	**0.024**
82	07141175	2	*1.688*	0.578	0.693	**0.135**
83	07141200	2	0.571	**0.222**	**0.198**	**0.032**
84	07141770	2	**0.455**	**0.255**	**0.363**	**0.183**
85	07141780	2	**0.327**	**0.210**	**0.254**	**0.115**
86	07141900	2	0.471	**0.377**	**0.417**	**0.153**
87	07142020	2	0.591	0.563	**0.447**	**0.141**
88	07142300	1	**0.200**	**0.203**	**0.304**	**0.292**
89	07142575	2	**0.150**	**0.238**	**0.397**	**0.477**
90	07142620	2	**0.081**	**0.138**	**0.246**	**0.339**
91	07143300	2	0.581	**0.516**	**0.357**	**0.313**
92	07143665	2	0.506	0.972	1.087	0.672
93	07143672	2	0.648	0.922	1.153	**0.529**
94	07144100	2	0.763	0.955	1.201	0.647
95	07144200	2	0.735	1.007	1.092	0.819
96	07144480	2	*1.685*	1.258	**0.504**	**0.538**
97	07144780	1	0.632	0.709	0.994	1.086

Table 1–3. Observed/Expected (O/E) ratio values for the September, October, November, and December flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	AVG_SEP[2]	AVG_OCT[3]	AVG_NOV[4]	AVG_DEC[5]
98	07144795	2	**0.415**	0.526	0.554	**0.434**
99	07144910	2	0.852	0.827	0.881	0.950
100	07145200	2	*1.697*	*1.815*	*2.431*	*2.656*
101	07145500	2	1.027	1.145	1.531	1.320
102	07145700	1	1.105	1.107	1.234	1.263
103	07147070	2	1.024	1.293	1.527	1.253
104	07147800	2	1.122	1.025	1.450	1.246
105	07149000	1	0.969	0.974	1.205	1.243
106	07151500	1	1.027	1.175	1.293	1.389
107	07155590	2	**0.046**	**0.001**	**0.004**	**0.019**
108	07156220	1	0.585	**0.342**	**0.001**	**0.000**
109	07156900	2	**0.457**	1.051	*2.271*	*3.526*
110	07157500	2	**0.265**	**0.465**	**0.462**	**0.309**
111	07166500	2	0.839	0.967	1.186	1.377
112	07167500	1	0.720	0.929	1.138	1.176
113	07169500	2	0.931	0.998	1.126	1.472
114	07169800	2	**0.454**	0.886	0.955	1.140
115	07170060	2	**0.283**	1.513	1.198	1.405
116	07170500	2	0.789	1.076	1.119	1.369
117	07170700	2	0.738	1.148	0.798	0.734
118	07170990	2	1.245	0.586	0.673	**0.571**
119	07172000	2	0.505	1.431	1.094	1.211
120	07179500	2	0.568	0.685	0.908	0.770
121	07179730	2	0.611	0.725	0.938	0.848
122	07179795	2	**0.411**	0.681	0.832	*1.894*
123	07180400	2	0.899	0.941	1.406	1.596
124	07180500	1	1.022	1.103	1.368	1.333
125	07182250	2	0.830	0.932	1.307	1.181
126	07182510	2	0.784	0.803	1.192	1.252
127	07183000	2	0.865	0.903	1.169	1.202
128	07183500	2	0.857	0.960	1.059	1.353
129	07184000	1	1.209	1.335	0.959	1.146

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Mean September flow normalized by drainage area. Tenth percentile error bound is 0.460. Ninetieth percentile error bound is 1.490.

[3]Mean October flow normalized by drainage area. Tenth percentile error bound is 0.520. Ninetieth percentile error bound is 1.680.

[4]Mean November flow normalized by drainage area. Tenth percentile error bound is 0.530. Ninetieth percentile error bound is 1.560.

[5]Mean December flow normalized by drainage area. Tenth percentile error bound is 0.580. Ninetieth percentile error bound is 1.650.

Table 1–4. Observed/Expected (O/E) ratio values for the 10th percentile flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P10	[3]PUL_LEN_P10	[4]PUL_FLOW_P10
1	06814000	1	1.291	0.742	0.817
2	06827000	2	1.118	*3.225*	**0.016**
3	06844900	2	**0**	-999	-999
4	06845110	2	1.322	*1.886*	**0.023**
5	06846000	2	**0**	-999	-999
6	06846500	1	**0**	-999	-999
7	06847900	1	**0**	-999	-999
8	06848000	2	**0**	-999	-999
9	06848500	2	**0**	-999	-999
10	06853800	1	0.842	*1.455*	**0.105**
11	06854000	2	*1.613*	**0.498**	**0.006**
12	06860000	2	**0**	-999	-999
13	06861000	2	**0**	-999	-999
14	06862700	2	**0**	-999	-999
15	06862850	2	**0**	-999	-999
16	06863500	2	*4.513*	0.750	**0.007**
17	06864050	2	*4.034*	0.898	0.611
18	06864500	2	*3.315*	1.051	0.994
19	06865500	2	*2.223*	*1.585*	1.332
20	06866500	2	*3.924*	0.638	*2.615*
21	06866900	2	**0**	-999	-999
22	06867000	2	*3.260*	0.845	0.369
23	06868200	2	*2.948*	0.868	0.862
24	06869500	2	*2.191*	0.777	*1.963*
25	06869950	1	1.165	0.942	**0.014**
26	06870200	2	*4.094*	**0.542**	*2.265*
27	06871000	2	**0**	-999	-999
28	06871500	2	*2.681*	*2.410*	**0.066**
29	06871800	2	**0**	-999	-999
30	06872500	2	*2.360*	0.757	0.384
31	06873000	2	**0**	-999	-999
32	06873200	2	**0**	-999	-999
33	06873460	2	*2.846*	1.060	**0.030**
34	06874000	2	*2.206*	0.699	0.596
35	06875900	2	1.124	0.775	0.431
36	06876700	1	1.038	1.016	0.552
37	06876900	2	*1.901*	**0.458**	1.690
38	06877600	2	1.541	0.826	*2.502*
39	06878000	1	1.347	0.702	1.652
40	06879650	1	**0**	-999	-999
41	06882510	2	1.310	0.941	1.635
42	06884025	2	1.441	0.660	*1.973*
43	06884200	2	*1.699*	**0.572**	0.536
44	06884400	2	*1.623*	0.681	*1.808*
45	06885500	1	1.199	0.808	*1.910*
46	06887000	2	*1.843*	0.721	0.847
47	06888000	1	1.186	0.673	1.429
48	06888500	1	0.945	1.163	*2.176*
49	06889140	1	1.535	0.760	1.242

Table 1–4. Observed/Expected (O/E) ratio values for the 10th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P10	[3]PUL_LEN_P10	[4]PUL_FLOW_P10
50	06889160	1	1.232	0.775	1.053
51	06889200	1	1.130	0.927	1.046
52	06889500	1	0.957	1.088	1.553
53	06890100	2	1.246	0.858	1.022
54	06890900	2	1.128	1.003	*2.218*
55	06891260	2	0.904	1.175	**0.091**
56	06891500	2	*1.886*	**0.475**	1.201
57	06892000	1	1.322	0.860	1.248
58	06892360	2	*1.797*	**0.543**	1.380
59	06892495	2	*2.243*	**0.381**	*4.716*
60	06892513	2	*2.371*	**0.351**	*6.592*
61	06893080	2	0.818	1.247	0.118
62	06893100	2	1.419	0.626	0.511
63	06893300	2	*2.466*	**0.230**	*23.867*
64	06893390	2	*4.197*	**0.205**	*25.039*
65	06910800	1	0.881	1.307	**0.054**
66	06911490	1	**0**	-999	-999
67	06911500	2	1.366	0.721	**0.095**
68	06911900	1	**0**	-999	-999
69	06912500	2	*2.096*	**0.319**	*5.365*
70	06913000	2	*2.716*	**0.313**	*3.717*
71	06913500	2	*2.641*	**0.301**	*3.115*
72	06914000	2	0.927	0.979	**0.014**
73	06914100	2	0.845	0.923	**0.027**
74	06914950	2	*1.876*	**0.486**	0.521
75	06915000	2	1.404	**0.544**	1.249
76	06915800	2	1.544	**0.534**	*1.720*
77	06916600	2	*1.808*	**0.534**	0.962
78	06917000	1	0.915	0.886	**0.078**
79	06917240	2	**0**	-999	-999
80	06917380	1	1.082	0.855	**0.092**
81	07140850	2	**0**	-999	-999
82	07141175	2	**0**	-999	-999
83	07141200	2	**0**	-999	-999
84	07141770	2	*4.009*	0.887	**0.109**
85	07141780	2	**0**	-999	-999
86	07141900	2	**0**	-999	-999
87	07142020	2	**0**	-999	-999
88	07142300	1	**0**	-999	-999
89	07142575	2	*2.100*	**0.407**	0.166
90	07142620	2	*2.477*	**0.362**	**0.065**
91	07143300	2	*1.886*	0.632	0.503
92	07143665	2	1.150	**0.612**	0.317
93	07143672	2	0.803	0.867	0.469
94	07144100	2	0.884	0.777	0.625
95	07144200	2	1.205	**0.592**	0.813
96	07144480	2	*1.969*	**0.485**	1.225
97	07144780	1	0.932	0.886	0.746
98	07144795	2	*1.635*	**0.519**	**0.003**

Table 1–4. Observed/Expected (O/E) ratio values for the 10th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P10	[3]PUL_LEN_P10	[4]PUL_FLOW_P10
99	07144910	2	*2.429*	**0.479**	*2.850*
100	07145200	2	*1.703*	0.695	*5.682*
101	07145500	2	0.932	1.043	1.334
102	07145700	1	1.147	0.871	0.613
103	07147070	2	1.160	0.847	1.444
104	07147800	2	1.390	0.721	*2.663*
105	07149000	1	0.985	1.095	1.299
106	07151500	1	1.186	0.954	1.351
107	07155590	2	**0**	-999	-999
108	07156220	1	**0**	-999	-999
109	07156900	2	*3.724*	**0.577**	0.875
110	07157500	2	*4.237*	1.230	0.520
111	07166500	2	1.521	0.689	0.771
112	07167500	1	*2.002*	0.803	0.193
113	07169500	2	*2.891*	**0.326**	1.248
114	07169800	2	0.652	*1.493*	0.150
115	07170060	2	1.285	**0.582**	0.164
116	07170500	2	*1.804*	**0.402**	0.609
117	07170700	2	**0**	-999	-999
118	07170990	2	*1.581*	**0.418**	0.585
119	07172000	2	0.632	*1.610*	**0.042**
120	07179500	2	1.456	0.667	1.235
121	07179730	2	*2.022*	**0.381**	*2.146*
122	07179795	2	*2.070*	**0.403**	0.639
123	07180400	2	1.437	0.713	*3.572*
124	07180500	1	1.417	0.943	*1.878*
125	07182250	2	0.801	0.997	*2.313*
126	07182510	2	*1.829*	**0.432**	0.904
127	07183000	2	*2.147*	**0.513**	1.217
128	07183500	2	1.415	0.633	1.424
129	07184000	1	0.750	1.426	**0.003**

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Average annual number of flow pulses less than the 10th percentile. Tenth percentile error bound is 0.000. Ninetieth percentile error bound is 1.550.

[3]Average duration of flow pulses less than the 10th percentile. Tenth percentile error bound is 0.620. Ninetieth percentile error bound is 1.440.

[4]Average magnitude of flow pulses less than the 10th percentile, normalized by drainage area. Tenth percentile error bound is 0.110. Ninetieth percentile error bound is 1.710.

Table 1–5. Observed/Expected (O/E) ratio values for the 25th percentile flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P25	[3]PUL_LEN_P25	[4]PUL_FLOW_P25
1	06814000	1	1.106	0.738	0.869
2	06827000	2	0.991	*1.473*	**0.086**
3	06844900	2	**0**	-999	-999
4	06845110	2	1.152	1.022	**0.060**
5	06846000	2	**0**	-999	-999
6	06846500	1	**0**	-999	-999
7	06847900	1	0.999	0.957	**0.018**
8	06848000	2	1.058	1.014	**0**
9	06848500	2	**0**	-999	-999
10	06853800	1	0.896	0.931	0.397
11	06854000	2	*1.872*	**0.387**	**0.009**
12	06860000	2	**0**	-999	-999
13	06861000	2	*1.667*	0.666	**0.007**
14	06862700	2	0.732	*1.817*	**0.017**
15	06862850	2	**0**	-999	-999
16	06863500	2	*1.741*	**0.469**	0.716
17	06864050	2	1.267	0.786	1.193
18	06864500	2	1.032	0.892	*1.737*
19	06865500	2	0.719	*1.387*	*2.599*
20	06866500	2	1.096	0.883	*3.264*
21	06866900	2	0.899	*2.360*	**0**
22	06867000	2	0.780	1.277	0.735
23	06868200	2	0.907	1.077	0.838
24	06869500	2	1.015	0.757	1.384
25	06869950	1	0.727	*1.509*	**0.058**
26	06870200	2	1.009	0.863	*2.245*
27	06871000	2	**0**	-999	-999
28	06871500	2	0.890	*1.627*	1.336
29	06871800	2	**0**	-999	-999
30	06872500	2	1.080	*1.385*	0.346
31	06873000	2	0.669	*1.861*	**0.054**
32	06873200	2	**0**	-999	-999
33	06873460	2	0.771	*1.867*	**0.080**
34	06874000	2	1.318	0.893	0.564
35	06875900	2	0.809	0.929	0.434
36	06876700	1	1.044	0.822	0.722
37	06876900	2	1.064	0.615	1.043
38	06877600	2	1.029	0.837	*1.925*
39	06878000	1	0.972	0.774	1.313
40	06879650	1	**0**	-999	-999
41	06882510	2	1.141	**0.473**	*1.687*
42	06884025	2	1.401	**0.423**	1.436
43	06884200	2	1.141	0.619	0.583
44	06884400	2	1.386	**0.471**	1.577
45	06885500	1	1.141	0.747	1.301
46	06887000	2	1.296	0.548	1.010
47	06888000	1	1.155	0.826	0.989
48	06888500	1	0.950	0.855	1.412
49	06889140	1	1.049	0.934	1.298

Table 1–5. Observed/Expected (O/E) ratio values for the 25th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P25	[3]PUL_LEN_P25	[4]PUL_FLOW_P25
50	06889160	1	0.939	1.049	1.068
51	06889200	1	0.972	1.006	1.057
52	06889500	1	1.077	0.992	1.311
53	06890100	2	1.074	0.858	1.144
54	06890900	2	1.138	*1.485*	1.093
55	06891260	2	0.798	*1.298*	0.238
56	06891500	2	1.475	**0.499**	1.184
57	06892000	1	1.098	0.856	1.321
58	06892360	2	1.199	0.543	1.571
59	06892495	2	*2.080*	**0.336**	*3.416*
60	06892513	2	*1.951*	**0.355**	*4.703*
61	06893080	2	1.226	0.784	0.457
62	06893100	2	1.458	0.546	1.017
63	06893300	2	*2.647*	**0.212**	*12.649*
64	06893390	2	*2.921*	**0.225**	*11.077*
65	06910800	1	0.891	0.900	0.531
66	06911490	1	1.071	1.021	0.184
67	06911500	2	1.111	0.837	0.281
68	06911900	1	0.957	0.970	0.439
69	06912500	2	1.401	**0.493**	*4.020*
70	06913000	2	*1.723*	**0.434**	*2.736*
71	06913500	2	*1.633*	**0.478**	*2.183*
72	06914000	2	0.763	*1.456*	0.160
73	06914100	2	0.974	0.808	0.226
74	06914950	2	*1.584*	**0.448**	0.755
75	06915000	2	1.076	0.737	1.119
76	06915800	2	1.157	0.594	1.539
77	06916600	2	1.052	0.761	1.263
78	06917000	1	0.870	1.057	0.491
79	06917240	2	0.800	0.990	0.205
80	06917380	1	1.028	1.063	0.460
81	07140850	2	**0**	-999	-999
82	07141175	2	**0**	-999	-999
83	07141200	2	**0**	-999	-999
84	07141770	2	1.303	0.707	0.438
85	07141780	2	**0**	-999	-999
86	07141900	2	**0**	-999	-999
87	07142020	2	0.607	*1.520*	**0.008**
88	07142300	1	0.710	*1.434*	**0.048**
89	07142575	2	1.322	0.655	0.748
90	07142620	2	1.340	**0.486**	0.210
91	07143300	2	*1.606*	0.670	0.552
92	07143665	2	1.171	0.713	0.455
93	07143672	2	1.223	0.692	0.673
94	07144100	2	1.426	0.622	0.861
95	07144200	2	1.192	0.565	0.902
96	07144480	2	*1.578*	**0.491**	1.239
97	07144780	1	0.899	1.012	1.332
98	07144795	2	1.432	0.655	**0.004**
99	07144910	2	*1.808*	**0.483**	*2.154*

Table 1–5. Observed/Expected (O/E) ratio values for the 25th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey; -999, metric could not be computed]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P25	[3]PUL_LEN_P25	[4]PUL_FLOW_P25
100	07145200	2	1.196	0.934	*4.641*
101	07145500	2	1.157	0.979	1.528
102	07145700	1	1.148	0.832	0.796
103	07147070	2	0.962	0.941	1.249
104	07147800	2	1.107	0.690	*1.810*
105	07149000	1	0.980	0.986	1.557
106	07151500	1	1.027	0.989	1.391
107	07155590	2	**0**	-999	-999
108	07156220	1	**0**	-999	-999
109	07156900	2	*2.641*	0.603	1.194
110	07157500	2	*1.595*	0.931	1.085
111	07166500	2	1.334	0.670	0.752
112	07167500	1	0.795	1.154	0.746
113	07169500	2	*1.548*	**0.426**	1.121
114	07169800	2	0.733	*1.471*	0.435
115	07170060	2	1.378	0.565	0.445
116	07170500	2	1.189	0.615	0.688
117	07170700	2	*1.523*	0.609	**0.004**
118	07170990	2	1.010	0.660	0.913
119	07172000	2	0.620	1.232	0.610
120	07179500	2	1.310	0.740	0.599
121	07179730	2	1.407	0.530	0.916
122	07179795	2	1.330	0.627	0.497
123	07180400	2	1.063	0.855	*2.005*
124	07180500	1	1.000	1.005	1.453
125	07182250	2	0.727	1.181	1.431
126	07182510	2	1.296	0.537	0.515
127	07183000	2	0.966	0.727	0.782
128	07183500	2	0.939	0.823	1.231
129	07184000	1	0.877	1.201	0.193

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Average annual number of flow pulses less than the 25th percentile. Tenth percentile error bound is 0.540. Ninetieth percentile error bound is 1.520.

[3]Average duration of flow pulses less than the 25th percentile. Tenth percentile error bound is 0.500. Ninetieth percentile error bound is 1.280.

[4]Average magnitude of flow pulses less than the 25th percentile, normalized by drainage area. Tenth percentile error bound is 0.150. Ninetieth percentile error bound is 1.590.

Table 1–6. Observed/Expected (O/E) ratio values for the 75th percentile flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P75	[3]PUL_LEN_P75	[4]PUL_FLOW_P75
1	06814000	1	1.136	1.019	0.965
2	06827000	2	0.727	*2.562*	**0.113**
3	06844900	2	0.774	0.968	**0.357**
4	06845110	2	**0.468**	1.279	**0.173**
5	06846000	2	**0.323**	1.320	**0.621**
6	06846500	1	0.794	0.900	**0.141**
7	06847900	1	**0.700**	1.170	**0.502**
8	06848000	2	1.284	**0.609**	**0.158**
9	06848500	2	**0.697**	0.921	**0.375**
10	06853800	1	1.024	0.971	0.908
11	06854000	2	*1.984*	**0.478**	**0.212**
12	06860000	2	0.931	0.718	**0.096**
13	06861000	2	0.869	1.243	**0.196**
14	06862700	2	**0.470**	*1.760*	**0.118**
15	06862850	2	**0.358**	*2.813*	**0.132**
16	06863500	2	0.994	0.820	**0.654**
17	06864050	2	0.937	1.142	**0.539**
18	06864500	2	0.808	*1.447*	**0.489**
19	06865500	2	**0.371**	*1.871*	**0.497**
20	06866500	2	**0.647**	1.234	**0.562**
21	06866900	2	**0.521**	*1.713*	**0.402**
22	06867000	2	**0.461**	*2.407*	0.815
23	06868200	2	**0.561**	*1.959*	**0.537**
24	06869500	2	1.139	*1.796*	0.868
25	06869950	1	*1.506*	0.857	**0.570**
26	06870200	2	0.776	*1.725*	0.862
27	06871000	2	**0.455**	*1.434*	**0.728**
28	06871500	2	**0.675**	0.855	0.863
29	06871800	2	**0.539**	0.872	**0.067**
30	06872500	2	**0.695**	*1.508*	**0.712**
31	06873000	2	**0.433**	1.285	0.827
32	06873200	2	**0.116**	*6.001*	1.003
33	06873460	2	**0.697**	1.266	**0.313**
34	06874000	2	**0.572**	*1.580*	**0.447**
35	06875900	2	**0.418**	*1.845*	**0.573**
36	06876700	1	1.192	1.298	0.819
37	06876900	2	0.843	*2.019*	**0.710**
38	06877600	2	0.879	*1.946*	**0.740**
39	06878000	1	1.043	1.032	0.905
40	06879650	1	**0.565**	1.291	1.054
41	06882510	2	1.323	1.114	**0.637**
42	06884025	2	*1.554*	0.859	**0.496**
43	06884200	2	*1.892*	0.863	0.900
44	06884400	2	*1.689*	0.861	**0.571**
45	06885500	1	1.223	0.941	0.967
46	06887000	2	1.038	*1.499*	0.797
47	06888000	1	1.047	1.076	**0.625**
48	06888500	1	0.955	1.044	1.024
49	06889140	1	1.235	0.820	0.952

Table 1–6. Observed/Expected (O/E) ratio values for the 75th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P75	[3]PUL_LEN_P75	[4]PUL_FLOW_P75
50	06889160	1	1.094	0.830	0.989
51	06889200	1	1.108	0.938	0.974
52	06889500	1	1.175	0.929	0.919
53	06890100	2	*1.366*	0.969	0.807
54	06890900	2	1.312	*1.811*	1.085
55	06891260	2	1.104	1.131	0.839
56	06891500	2	0.821	1.314	1.021
57	06892000	1	1.183	0.927	0.977
58	06892360	2	*1.562*	0.847	0.809
59	06892495	2	*1.718*	0.735	1.055
60	06892513	2	*2.445*	**0.491**	1.289
61	06893080	2	1.313	0.833	0.981
62	06893100	2	*1.380*	0.833	1.011
63	06893300	2	*2.720*	**0.402**	*1.994*
64	06893390	2	*3.039*	**0.379**	*1.875*
65	06910800	1	1.055	0.968	0.924
66	06911490	1	1.055	1.049	0.831
67	06911500	2	1.131	0.942	1.083
68	06911900	1	1.055	0.980	0.942
69	06912500	2	**0.609**	*1.912*	1.142
70	06913000	2	1.311	1.078	1.022
71	06913500	2	1.320	1.114	1.004
72	06914000	2	1.107	0.929	1.060
73	06914100	2	1.038	1.030	0.937
74	06914950	2	*1.585*	0.823	0.959
75	06915000	2	**0.682**	*1.876*	1.104
76	06915800	2	1.307	1.125	1.008
77	06916600	2	1.304	1.174	0.969
78	06917000	1	1.138	0.918	1.098
79	06917240	2	0.864	1.127	1.097
80	06917380	1	1.171	0.926	1.052
81	07140850	2	**0.533**	*1.985*	**0.185**
82	07141175	2	**0.475**	*1.533*	**0.400**
83	07141200	2	**0.486**	*1.627*	**0.236**
84	07141770	2	0.944	0.704	**0.264**
85	07141780	2	**0.683**	1.309	**0.357**
86	07141900	2	0.713	1.178	**0.434**
87	07142020	2	**0.586**	1.347	**0.409**
88	07142300	1	**0.522**	*1.493*	**0.330**
89	07142575	2	0.720	0.844	**0.415**
90	07142620	2	**0.497**	*1.508*	**0.415**
91	07143300	2	*1.362*	1.281	**0.745**
92	07143665	2	*1.790*	0.837	0.861
93	07143672	2	*1.742*	0.791	0.887
94	07144100	2	*1.918*	0.852	0.837
95	07144200	2	*1.839*	0.924	0.836
96	07144480	2	*2.454*	0.821	1.026
97	07144780	1	1.081	0.887	0.955
98	07144795	2	0.720	*1.673*	1.160

Table 1–6. Observed/Expected (O/E) ratio values for the 75th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P75	[3]PUL_LEN_P75	[4]PUL_FLOW_P75
99	07144910	2	*2.929*	**0.357**	**0.584**
100	07145200	2	*1.871*	**0.611**	1.283
101	07145500	2	1.272	0.858	1.047
102	07145700	1	1.331	0.743	1.154
103	07147070	2	*1.396*	0.780	0.918
104	07147800	2	*1.536*	0.827	1.070
105	07149000	1	0.936	0.978	1.073
106	07151500	1	1.205	0.926	1.084
107	07155590	2	0.891	*1.910*	**0.132**
108	07156220	1	**0.461**	**0.269**	1.304
109	07156900	2	1.115	0.647	**0.132**
110	07157500	2	**0.705**	0.998	**0.163**
111	07166500	2	*1.444*	1.163	1.126
112	07167500	1	1.109	1.027	1.190
113	07169500	2	1.287	0.929	1.220
114	07169800	2	0.975	1.202	0.976
115	07170060	2	0.932	1.123	1.133
116	07170500	2	*1.420*	1.316	1.110
117	07170700	2	**0.603**	*1.752*	1.061
118	07170990	2	*1.660*	1.082	1.240
119	07172000	2	0.818	1.136	1.189
120	07179500	2	1.143	0.979	1.023
121	07179730	2	*1.388*	0.972	0.816
122	07179795	2	0.824	*1.533*	0.942
123	07180400	2	*1.564*	0.987	0.778
124	07180500	1	1.148	0.949	1.207
125	07182250	2	*1.509*	1.153	0.898
126	07182510	2	*1.363*	1.136	1.063
127	07183000	2	*1.711*	0.968	1.036
128	07183500	2	*1.481*	1.019	1.037
129	07184000	1	1.185	0.884	1.099

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Average annual number of flow pulses greater than the 75th percentile. Tenth percentile error bound is 0.710. Ninetieth percentile error bound is 1.360.

[3]Average duration of flow pulses greater than the 75th percentile. Tenth percentile error bound is 0.640. Ninetieth percentile error bound is 1.350.

[4]Average magnitude of flow pulses greater than the 75th percentile, normalized by drainage area. Tenth percentile error bound is 0.750. Ninetieth percentile error bound is 1.560.

Table 1–7. Observed/Expected (O/E) ratio values for the 90th percentile flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P90	[3]PUL_LEN_P90	[4]PUL_FLOW_P90
1	06814000	1	0.979	**0.481**	1.038
2	06827000	2	**0.229**	*1.707*	**0.105**
3	06844900	2	**0.409**	**0.503**	**0.237**
4	06845110	2	**0.481**	0.736	**0.138**
5	06846000	2	**0.388**	0.897	**0.442**
6	06846500	1	**0.475**	0.713	**0.192**
7	06847900	1	**0.594**	**0.547**	**0.416**
8	06848000	2	1.020	**0.504**	**0.178**
9	06848500	2	0.815	**0.389**	**0.285**
10	06853800	1	0.733	**0.507**	0.812
11	06854000	2	**0.178**	*1.599*	0.951
12	06860000	2	0.882	**0.478**	**0.097**
13	06861000	2	0.823	**0.535**	**0.191**
14	06862700	2	**0.571**	0.618	**0.121**
15	06862850	2	**0.473**	0.749	**0.155**
16	06863500	2	**0.527**	**0.438**	**0.574**
17	06864050	2	0.803	**0.497**	**0.514**
18	06864500	2	0.845	**0.557**	**0.510**
19	06865500	2	**0.291**	*1.586*	**0.570**
20	06866500	2	**0.593**	0.711	**0.578**
21	06866900	2	**0.583**	0.944	**0.469**
22	06867000	2	**0.490**	0.931	**0.722**
23	06868200	2	**0.644**	1.224	**0.678**
24	06869500	2	**0.683**	0.743	0.825
25	06869950	1	**0.686**	**0.311**	**0.567**
26	06870200	2	**0.482**	1.062	0.834
27	06871000	2	**0.286**	0.638	**0.478**
28	06871500	2	**0.373**	**0.492**	**0.667**
29	06871800	2	**0.278**	0.752	**0.051**
30	06872500	2	0.769	0.648	**0.537**
31	06873000	2	1.310	0.667	**0.661**
32	06873200	2	**0.337**	*2.188*	**0.649**
33	06873460	2	**0.399**	1.003	**0.441**
34	06874000	2	0.851	0.956	**0.456**
35	06875900	2	**0.339**	1.218	**0.513**
36	06876700	1	**0.624**	**0.610**	0.860
37	06876900	2	**0.584**	0.860	**0.668**
38	06877600	2	**0.581**	0.996	**0.586**
39	06878000	1	1.049	**0.359**	0.832
40	06879650	1	**0.458**	0.642	0.977
41	06882510	2	1.101	**0.566**	**0.584**
42	06884025	2	1.250	**0.446**	**0.481**
43	06884200	2	0.820	**0.388**	0.938
44	06884400	2	1.169	**0.454**	**0.557**
45	06885500	1	1.137	**0.457**	0.999
46	06887000	2	**0.467**	1.264	**0.660**
47	06888000	1	1.133	**0.492**	**0.638**
48	06888500	1	0.943	**0.603**	0.981
49	06889140	1	1.244	**0.473**	1.127

Table 1–7. Observed/Expected (O/E) ratio values for the 90th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P90	[3]PUL_LEN_P90	[4]PUL_FLOW_P90
50	06889160	1	1.222	**0.533**	1.112
51	06889200	1	1.081	**0.550**	1.014
52	06889500	1	0.910	**0.544**	0.978
53	06890100	2	1.070	**0.507**	0.853
54	06890900	2	0.917	*1.403*	0.898
55	06891260	2	*1.901*	**0.542**	0.813
56	06891500	2	**0.637**	0.942	0.888
57	06892000	1	1.079	**0.594**	1.027
58	06892360	2	*1.428*	**0.487**	0.860
59	06892495	2	*1.722*	**0.432**	1.023
60	06892513	2	*1.825*	**0.307**	1.182
61	06893080	2	*2.016*	**0.454**	1.005
62	06893100	2	1.026	**0.434**	0.933
63	06893300	2	*2.365*	**0.271**	*1.849*
64	06893390	2	*2.237*	**0.264**	*1.739*
65	06910800	1	1.071	**0.495**	0.914
66	06911490	1	*1.677*	**0.542**	0.839
67	06911500	2	*1.776*	**0.465**	1.146
68	06911900	1	*1.500*	**0.503**	0.948
69	06912500	2	**0.545**	*1.477*	0.900
70	06913000	2	*2.620*	0.741	0.974
71	06913500	2	*2.263*	0.690	0.936
72	06914000	2	1.081	**0.527**	1.115
73	06914100	2	*2.038*	**0.539**	0.950
74	06914950	2	*2.230*	**0.442**	1.120
75	06915000	2	**0.376**	*1.565*	0.977
76	06915800	2	1.276	0.835	0.867
77	06916600	2	1.161	0.869	0.821
78	06917000	1	1.060	**0.482**	1.096
79	06917240	2	1.173	**0.605**	0.966
80	06917380	1	0.944	**0.494**	1.027
81	07140850	2	0.726	**0.591**	**0.179**
82	07141175	2	**0.567**	0.649	**0.348**
83	07141200	2	**0.415**	**0.561**	**0.195**
84	07141770	2	0.971	**0.590**	**0.213**
85	07141780	2	0.817	**0.535**	**0.271**
86	07141900	2	0.695	**0.570**	**0.401**
87	07142020	2	1.210	0.703	**0.378**
88	07142300	1	**0.546**	0.628	**0.297**
89	07142575	2	*1.395*	**0.541**	**0.331**
90	07142620	2	**0.603**	0.718	**0.330**
91	07143300	2	0.842	**0.466**	0.819
92	07143665	2	1.044	**0.440**	0.947
93	07143672	2	*1.427*	**0.470**	0.966
94	07144100	2	*2.973*	**0.524**	0.917
95	07144200	2	0.904	**0.537**	0.932
96	07144480	2	0.878	**0.528**	1.042
97	07144780	1	**0.569**	**0.537**	0.756
98	07144795	2	**0.548**	1.051	0.896

Table 1–7. Observed/Expected (O/E) ratio values for the 90th percentile flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	[2]PUL_NO_P90	[3]PUL_LEN_P90	[4]PUL_FLOW_P90
99	07144910	2	0.774	**0.324**	**0.417**
100	07145200	2	0.910	**0.395**	0.973
101	07145500	2	**0.550**	**0.591**	0.941
102	07145700	1	0.881	**0.418**	1.214
103	07147070	2	1.055	**0.382**	0.912
104	07147800	2	*2.281*	**0.437**	0.974
105	07149000	1	1.232	**0.441**	0.833
106	07151500	1	*1.340*	**0.443**	0.975
107	07155590	2	1.015	*1.587*	**0.071**
108	07156220	1	**0.457**	**0.348**	**0.701**
109	07156900	2	1.248	**0.458**	**0.083**
110	07157500	2	**0.356**	0.885	**0.094**
111	07166500	2	*1.456*	0.751	0.971
112	07167500	1	1.215	**0.499**	1.080
113	07169500	2	1.323	0.622	1.168
114	07169800	2	**0.617**	0.658	0.930
115	07170060	2	**0.661**	1.265	1.080
116	07170500	2	*1.549*	0.863	0.961
117	07170700	2	0.820	1.002	0.981
118	07170990	2	1.298	0.643	0.969
119	07172000	2	0.866	**0.602**	1.104
120	07179500	2	**0.406**	0.855	0.850
121	07179730	2	0.698	0.654	0.927
122	07179795	2	**0.371**	1.128	1.030
123	07180400	2	1.100	**0.497**	0.829
124	07180500	1	0.983	**0.394**	1.062
125	07182250	2	*1.942*	**0.558**	0.824
126	07182510	2	0.734	0.944	0.887
127	07183000	2	1.100	0.731	0.898
128	07183500	2	1.159	0.698	0.837
129	07184000	1	1.268	**0.472**	1.139

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Average annual number of flow pulses greater than the 90th percentile. Tenth percentile error bound is 0.690. Ninetieth percentile error bound is 1.340.

[3]Average duration of flow pulses greater than the 90th percentile. Tenth percentile error bound is 0.610. Ninetieth percentile error bound is 1.280.

[4]Average magnitude of flow pulses greater than the 90th percentile, normalized by drainage area. Tenth percentile error bound is 0.730. Ninetieth percentile error bound is 1.430.

Table 1–8. Observed/Expected (O/E) ratio values for five annual flow metrics assessed in this study.

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	PER_BSFL[2]	[3]P10	[4]P50	[5]P90	CV_FLOW[6]
1	06814000	1	1.091	1.055	1.066	**0.567**	1.062
2	06827000	2	**0.042**	0.261	1.131	**0.375**	**0.434**
3	06844900	2	0.237	**0.043**	**0.046**	**0.024**	1.064
4	06845110	2	0.283	0.295	**0.306**	**0.116**	0.877
5	06846000	2	**0.093**	**0.013**	**0.138**	**0.072**	1.023
6	06846500	1	0.954	**0**	**0.099**	**0.065**	0.993
7	06847900	1	0.753	0.388	**0.357**	**0.243**	0.938
8	06848000	2	0.650	**0.055**	**0.014**	**0.093**	0.853
9	06848500	2	1.078	**0.189**	**0.146**	**0.075**	0.957
10	06853800	1	0.850	0.619	0.874	**0.361**	1.084
11	06854000	2	0.998	**0.007**	**0.253**	**0.518**	*1.966*
12	06860000	2	*2.411*	**0.017**	**0.074**	**0.084**	1.155
13	06861000	2	1.718	**0.169**	**0.215**	**0.132**	0.969
14	06862700	2	1.018	0.404	**0.203**	**0.079**	0.985
15	06862850	2	1.309	0.351	**0.179**	**0.085**	1.081
16	06863500	2	1.077	*1.965*	0.602	**0.179**	0.997
17	06864050	2	1.327	*3.590*	0.531	**0.478**	**0.742**
18	06864500	2	1.124	*7.737*	0.900	**0.607**	0.866
19	06865500	2	0.528	*7.086*	1.301	**0.683**	0.901
20	06866500	2	0.548	*8.914*	1.358	**0.667**	0.927
21	06866900	2	0.559	0.521	**0.240**	**0.166**	*1.300*
22	06867000	2	0.767	*2.351*	0.806	**0.271**	*1.282*
23	06868200	2	0.444	0.776	0.729	**0.372**	*1.568*
24	06869500	2	0.541	1.700	0.982	**0.361**	*1.413*
25	06869950	1	**0.050**	0.373	**0.325**	**0.190**	*1.261*
26	06870200	2	0.479	*3.288*	1.341	**0.439**	1.105
27	06871000	2	0.506	1.047	0.552	**0.228**	0.854
28	06871500	2	0.739	*2.296*	0.708	**0.247**	**0.775**
29	06871800	2	0.224	**0.001**	**0.052**	**0.115**	*1.874*
30	06872500	2	0.498	0.894	0.773	**0.266**	1.099
31	06873000	2	0.714	1.320	0.628	**0.293**	1.002
32	06873200	2	0.331	**0.029**	**0.349**	**0.484**	1.051
33	06873460	2	0.737	0.511	0.388	**0.213**	*1.654*
34	06874000	2	0.654	1.348	0.537	**0.215**	*1.852*
35	06875900	2	0.271	0.886	0.867	**0.309**	*1.489*
36	06876700	1	1.061	0.928	0.645	**0.537**	1.169
37	06876900	2	0.381	1.672	0.875	**0.365**	*1.315*
38	06877600	2	0.445	*2.821*	1.233	**0.407**	1.165
39	06878000	1	0.752	1.307	0.963	**0.498**	0.981
40	06879650	1	*13.167*	0.217	0.870	**0.570**	1.110
41	06882510	2	0.595	1.226	0.873	**0.569**	0.917
42	06884025	2	0.757	1.108	0.939	**0.457**	0.870
43	06884200	2	1.292	0.682	0.672	**0.608**	1.120
44	06884400	2	0.729	1.270	0.941	**0.550**	0.818
45	06885500	1	1.014	1.249	0.965	**0.608**	1.063
46	06887000	2	0.533	0.782	1.244	0.788	0.995
47	06888000	1	**0.017**	0.698	0.790	**0.426**	0.941
48	06888500	1	0.789	1.285	1.159	**0.593**	0.903
49	06889140	1	0.709	1.437	1.145	**0.555**	1.133
50	06889160	1	0.942	1.222	1.085	**0.565**	1.033

Table 1–8. Observed/Expected (O/E) ratio values for five annual flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	PER_BSFL[2]	[3]P10	[4]P50	[5]P90	CV_FLOW[6]
51	06889200	1	1.416	1.084	1.069	**0.543**	0.999
52	06889500	1	1.076	1.165	1.035	**0.532**	0.933
53	06890100	2	1.153	1.274	1.084	**0.563**	0.992
54	06890900	2	0.669	1.255	1.323	0.976	0.896
55	06891260	2	**0.067**	0.653	0.769	**0.468**	1.014
56	06891500	2	0.491	1.013	1.076	0.848	1.019
57	06892000	1	1.226	1.256	1.080	**0.642**	0.917
58	06892360	2	**0.169**	1.797	1.160	**0.514**	0.828
59	06892495	2	0.228	*2.946*	*1.855*	**0.571**	**0.757**
60	06892513	2	0.476	*4.185*	*1.905*	**0.720**	**0.602**
61	06893080	2	*6.483*	0.513	0.748	**0.476**	0.823
62	06893100	2	1.553	1.085	0.982	**0.532**	**0.729**
63	06893300	2	*2.321*	*13.038*	*3.120*	0.956	**0.498**
64	06893390	2	0.879	*11.417*	*2.887*	1.009	**0.364**
65	06910800	1	*1.839*	0.797	0.851	**0.514**	0.981
66	06911490	1	0.703	0.532	0.477	**0.380**	1.129
67	06911500	2	1.253	0.444	0.693	**0.540**	0.812
68	06911900	1	*1.894*	0.626	0.763	**0.455**	0.974
69	06912500	2	0.573	*2.747*	0.958	0.974	0.952
70	06913000	2	0.633	*2.620*	1.525	0.966	0.958
71	06913500	2	0.641	*2.300*	1.501	0.885	0.972
72	06914000	2	0.294	0.296	0.677	**0.711**	0.946
73	06914100	2	**0.175**	0.529	0.570	**0.622**	1.069
74	06914950	2	**0.068**	0.806	0.542	**0.359**	0.813
75	06915000	2	0.453	1.620	0.912	**0.716**	1.057
76	06915800	2	0.565	*2.115*	*1.780*	0.814	0.989
77	06916600	2	0.572	1.710	1.566	0.779	0.899
78	06917000	1	1.148	0.865	1.016	**0.588**	0.864
79	06917240	2	0.377	0.516	0.892	**0.599**	0.797
80	06917380	1	1.236	0.672	0.894	**0.509**	0.919
81	07140850	2	1.527	**0.061**	**0.124**	**0.066**	*1.335*
82	07141175	2	1.082	0.848	**0.331**	**0.148**	*1.378*
83	07141200	2	*3.210*	0.241	**0.104**	**0.110**	1.051
84	07141770	2	0.779	1.574	0.555	**0.136**	**0.709**
85	07141780	2	1.198	1.419	0.398	**0.132**	1.171
86	07141900	2	1.096	1.698	0.517	**0.176**	1.063
87	07142020	2	0.536	0.711	0.528	**0.276**	**0.734**
88	07142300	1	0.873	0.356	0.441	**0.161**	0.827
89	07142575	2	1.054	0.699	0.668	**0.222**	0.888
90	07142620	2	0.692	0.230	**0.296**	**0.229**	**0.761**
91	07143300	2	0.898	0.627	**0.319**	**0.348**	1.197
92	07143665	2	*3.355*	0.419	**0.307**	**0.642**	1.054
93	07143672	2	*1.862*	0.557	**0.356**	**0.574**	**0.722**
94	07144100	2	1.547	0.708	0.443	**0.534**	**0.716**
95	07144200	2	1.568	0.850	0.503	**0.672**	0.974
96	07144480	2	0.236	1.340	0.529	**0.497**	**0.713**
97	07144780	1	0.952	1.209	1.096	**0.517**	**0.701**

Table 1–8. Observed/Expected (O/E) ratio values for five annual flow metrics assessed in this study.—Continued

[Diminished values are shown in bold. Inflated values are shown in italics. USGS, U.S. Geological Survey]

Site identifier (fig. 1)	USGS streamgage number	Site type[1]	PER_BSFL[2]	[3]P10	[4]P50	[5]P90	CV_FLOW[6]
98	07144795	2	*1.815*	**0.007**	**0.126**	0.781	0.876
99	07144910	2	0.830	*2.143*	0.914	**0.332**	**0.653**
100	07145200	2	0.655	*4.092*	*2.689*	0.892	**0.364**
101	07145500	2	0.891	1.458	1.503	0.848	**0.579**
102	07145700	1	*2.603*	0.822	0.820	**0.546**	0.904
103	07147070	2	0.971	1.172	0.768	**0.515**	0.972
104	07147800	2	0.748	1.515	1.177	0.818	0.905
105	07149000	1	0.853	1.464	1.269	**0.617**	0.826
106	07151500	1	0.950	1.387	1.256	**0.627**	0.783
107	07155590	2	**0.164**	**0**	**0.001**	**0.008**	*1.610*
108	07156220	1	**0.102**	**0**	**0**	**0**	1.039
109	07156900	2	**0.146**	*3.528*	*4.241*	**0.404**	**0.184**
110	07157500	2	0.510	*7.200*	0.770	**0.139**	**0.413**
111	07166500	2	0.778	0.930	1.535	0.993	0.836
112	07167500	1	1.354	0.943	0.975	**0.585**	0.922
113	07169500	2	0.687	1.115	1.610	1.154	0.886
114	07169800	2	1.091	0.729	0.992	**0.640**	0.898
115	07170060	2	0.642	0.457	0.652	1.207	0.870
116	07170500	2	0.558	1.296	1.763	1.060	0.849
117	07170700	2	*1.960*	**0.131**	0.522	**0.589**	1.177
118	07170990	2	0.596	1.775	*2.190*	1.049	0.919
119	07172000	2	1.053	0.693	1.377	0.980	0.926
120	07179500	2	1.014	0.437	0.445	0.760	1.128
121	07179730	2	0.820	0.918	0.851	0.803	1.081
122	07179795	2	0.963	0.362	0.481	**0.514**	*1.403*
123	07180400	2	0.570	1.887	1.123	**0.598**	1.020
124	07180500	1	1.058	1.400	1.240	**0.606**	0.898
125	07182250	2	0.660	1.628	1.332	**0.700**	0.843
126	07182510	2	0.597	0.679	1.348	1.025	0.903
127	07183000	2	0.552	1.034	1.590	0.911	0.890
128	07183500	2	0.498	1.598	*1.885*	0.813	0.837
129	07184000	1	*2.140*	0.329	0.626	**0.581**	1.004

[1]Site type “1” indicates a reference (least-disturbed) site and site type “2” indicates a nonreference site (Falcone and others, 2010).

[2]Percentage of flow that is baseflow. Tenth percentile error bound is 0.180. Ninetieth percentile error bound is 1.810.

[3]Tenth percentile flow normalized by drainage area. Tenth percentile error bound is 0.200. Ninetieth percentile error bound is 1.900.

[4]Median annual flow normalized by drainage area. Tenth percentile error bound is 0.370. Ninetieth percentile error bound is 1.770.

[5]Ninetieth percentile flow normalized by drainage area. Tenth percentile error bound is 0.720. Ninetieth percentile error bound is 1.600.

[6]Coefficient of variation of daily flows. Tenth percentile error bound is 0.780. Ninetieth percentile error bound is 1.220.

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