Prepared in cooperation with the
KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

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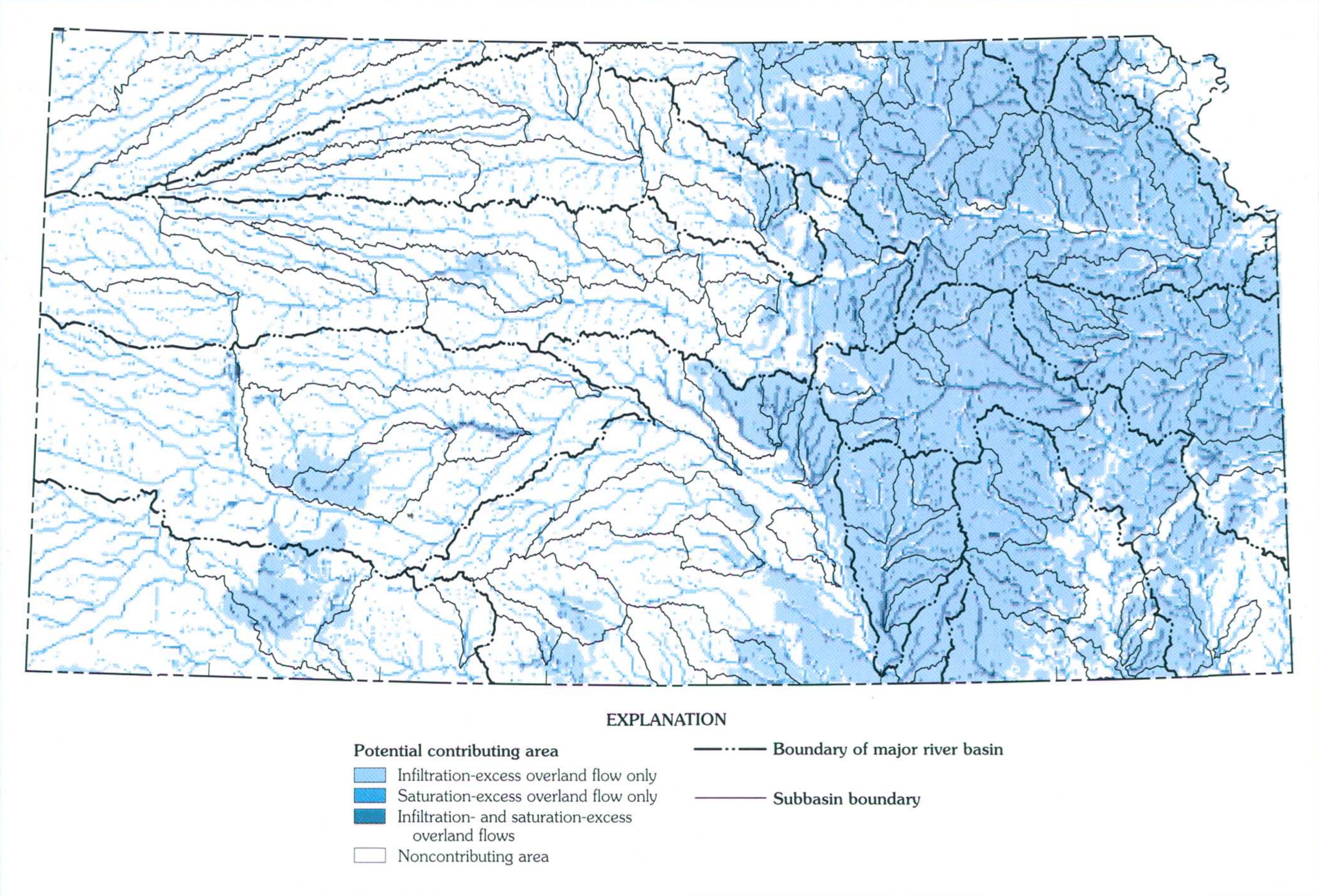
Water-Resources Investigations Report 99–4242



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Estimation of Potential Runoff-Contributing Areas in Kansas Using Topographic and Soil Information

By KYLE E. JURACEK

Water-Resources Investigations Report 99–4242

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Lawrence, Kansas
1999

U.S. Department of the Interior
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Denver, CO 80225–0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	2.54	centimeter
inch per hour (in/hr)	2.54	centimeter per hour
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
mile (mi)	1.609	kilometer
square kilometer (km^2)	0.3861	square mile
square mile (mi^2)	2.59	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Estimation of Potential Runoff-Contributing Areas in Kansas Using Topographic and Soil Information

By Kyle E. Juracek

Abstract

Digital topographic and soil information was used to estimate potential runoff-contributing areas throughout Kansas. The results then were used to compare 91 selected subbasins representing soil, slope, and runoff variability. Potential runoff-contributing areas were estimated collectively for the processes of infiltration-excess and saturation-excess overland flow using a set of environmental conditions that represented very high, high, moderate, low, very low, and extremely low potential runoff. For infiltration-excess overland flow, various rainfall-intensity and soil-permeability values were used. For saturation-excess overland flow, antecedent soil-moisture conditions and a topographic wetness index were used.

Results indicated that very low potential-runoff conditions provided the best ability to distinguish the 91 selected subbasins as having relatively high or low potential runoff. The majority of the subbasins with relatively high potential runoff are located in the eastern half of the State where soil permeability generally is less and precipitation typically is greater. The ability to distinguish the subbasins as having relatively high or low potential runoff was possible mostly due to the variability of soil permeability across the State.

INTRODUCTION

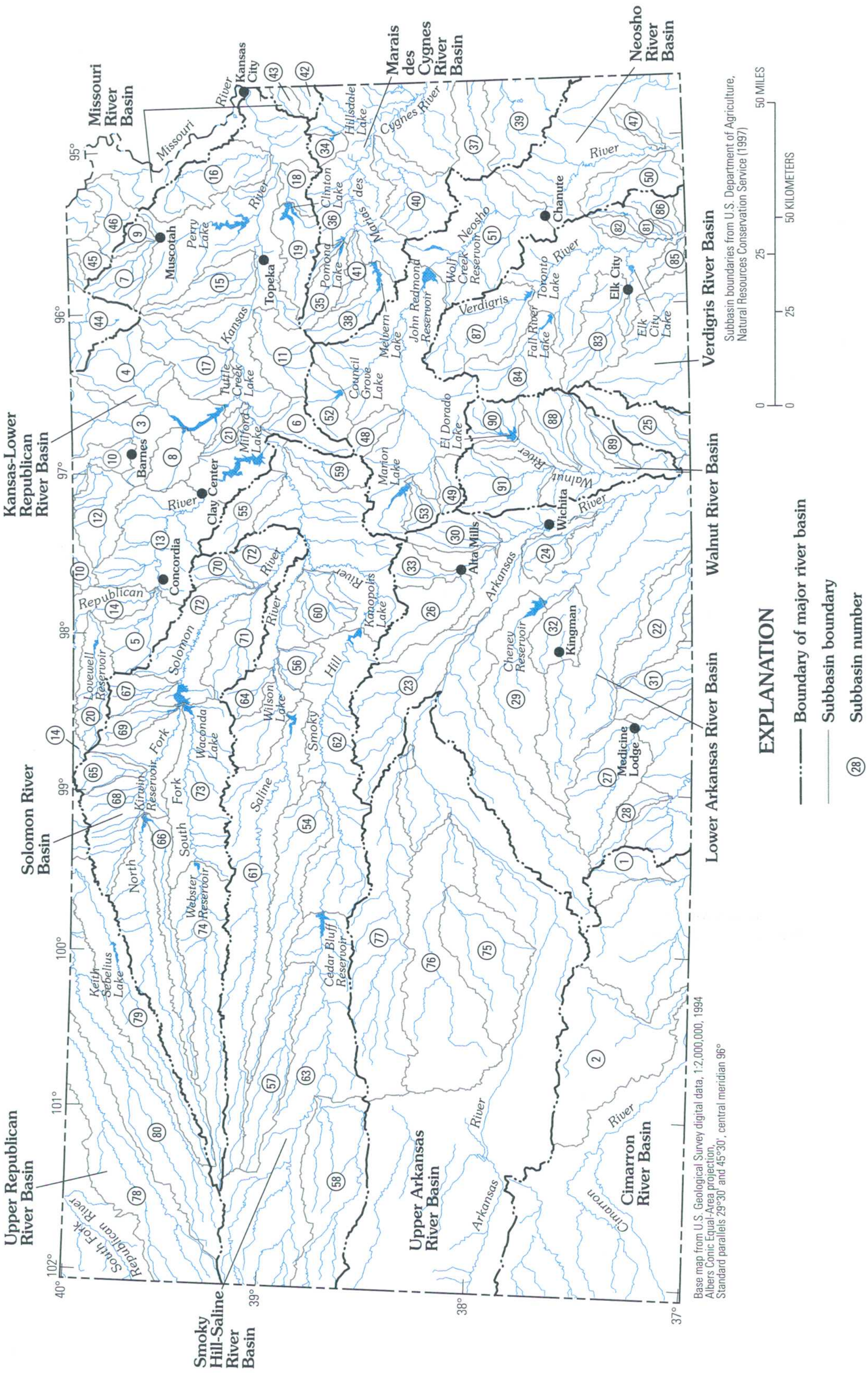
The State of Kansas is required by the Federal Clean Water Act of 1972 to develop a total maximum daily load (TMDL) for basins throughout the State. A TMDL is an estimate of the maximum pollutant load (material transported during a specified time period) from point and nonpoint sources that a receiving water can accept without exceeding water-quality standards (U.S. Environmental Protection Agency, 1991). Requisite for the development of TMDL's is an understanding of potential source areas of storm runoff that are the most likely contributors of nonpoint-source pollution within a basin.

A study by the U.S. Geological Survey (USGS), in cooperation with the Kansas Department of Health and Environment, was begun in 1999 to estimate the spatial extent and pattern of potential runoff-contributing areas in Kansas (fig. 1). The specific study objectives were to:

(1) Estimate potential runoff-contributing areas resulting from infiltration-excess and saturation-excess overland flows; and

(2) Compare potential runoff among major river basins and selected subbasins throughout the State.

The purpose of this report is to present the results of the study to estimate the spatial extent and pattern of potential runoff-contributing areas in Kansas. The methods presented in this report may be applicable nationwide as related to the development of TMDL's and the targeting and implementation of best-management practices (BMP's). This study is a statewide expansion of a recently completed study by Juracek (1999) in which the same type of data and similar methods were used to estimate potential runoff-contributing areas in the Kansas-Lower Republican River Basin in Kansas. This study was made possible in part by support from the Kansas State Water Plan Fund.



Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Kansas-Lower Republican River Basin
Verdigris River Basin
Walnut River Basin
Lower Arkansas River Basin
Solomon River Basin
Upper Republican River Basin
Smoky Hill-Saline River Basin
Upper Arkansas River Basin
Cimarron River Basin
EXPLANATION
Boundary of major river basin
Subbasin boundary
28 Subbasin number
Subbasin boundaries from U.S. Department of Agriculture, Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 1. Location of major river basins and selected subbasins in Kansas.

Background

Runoff-contributing areas within river basins primarily are the result of two processes, both of which produce overland flow. The first process is infiltration-excess overland flow (fig. 2*A*), which occurs when precipitation intensity exceeds the rate of water infiltration into the soil. This process may be dominant in basins where the land surface has been disturbed (for example, plowed cropland) or where natural vegetation is sparse. The second process is saturation-excess overland flow (fig. 2*B*), which occurs when precipitation falls on temporarily or permanently saturated land-surface areas that have developed from "outcrops" of the water table at the land surface (Hornberger and others, 1998). A temporary water table can develop during a storm when antecedent soil-moisture conditions in a basin are high. The saturated areas where saturation-excess overland flow develops expand during a storm and shrink during extended dry periods (Dunne and others, 1975).

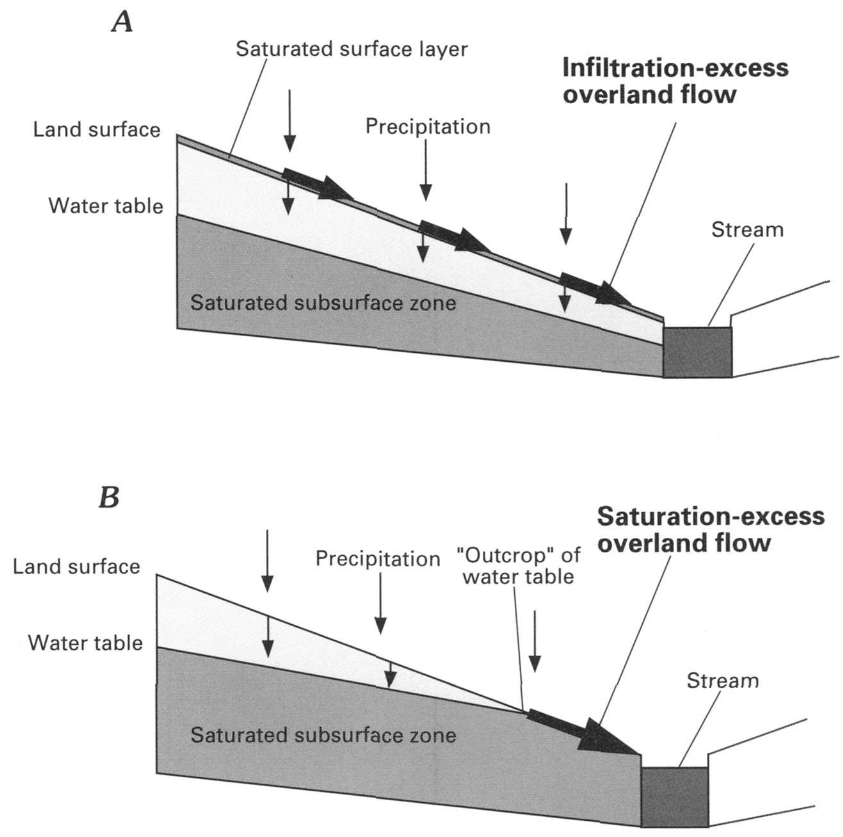


Figure 2. Schematic diagrams illustrating *(A)* infiltration-excess overland flow and *(B)* saturation-excess overland flow.

Historically, infiltration-excess overland flow has been assumed to be the most important runoff process in Midwestern agricultural areas. More recently, saturation-excess overland flow has been considered an important runoff process and is the subject of ongoing research.

Both runoff processes would be expected to affect the load of water-quality constituents in streams, although possibly in different ways due to different flow paths. The identification of potential runoff-contributing areas in a basin can provide guidance for the targeting of BMP's to reduce runoff and meet TMDL requirements. Implementation of BMP's within potential runoff-contributing areas is likely to be more effective at reducing constituent loads compared to areas less likely to contribute runoff.

The spatial extent and pattern of runoff-contributing areas are affected by climate, soil, and terrain characteristics. Contributing areas of infiltration-excess overland flow are determined by the combined effect of rainfall intensity and soil permeability. The least-permeable soils in a basin are the most likely to contribute infiltration-excess overland flow. As rainfall intensity increases, areas with more moderate permeability also may contribute overland flow.

Contributing areas of saturation-excess overland flow are determined by the combined effect of basin topography and antecedent soil-moisture conditions. The effect of topography on saturation-excess overland flow can be quantified by an index called the topographic wetness index (TWI) (Wolock and McCabe, 1995). The TWI is computed as $\ln(a/S)$ for all points in a basin, where "ln" is the natural logarithm, "*a*" is the upslope area per unit contour length, and "*S*" is the slope at that point. The locations in a basin with the highest TWI values (large upslope areas and gentle slopes) are the most likely to contribute saturation-excess overland flow. When antecedent soil-moisture conditions are dry, only areas with the highest TWI values may be saturated and potentially contribute overland flow. When antecedent soil-moisture conditions are wet, areas with lower TWI values may be saturated and potentially contribute overland flow.

Description of Kansas

Kansas encompasses an area of about 82,000 mi^2. Major river basins in Kansas include the Cimarron, Kansas-Lower Republican, Lower Arkansas, Marais des Cygnes, Missouri, Neosho, Smoky Hill-Saline, Solomon, Upper Arkansas, Upper Republican, Verdigris, and Walnut (fig. 1). Numerous Federal reservoirs are located throughout the eastern two-thirds of the State. Land use is predominantly agricultural, with cropland, grassland, and woodland accounting for 53.0, 42.7, and 2.5 percent of the State, respectively. Urban land use accounts for about 1 percent of the State (Kansas Applied Remote Sensing Program, 1993).

Terrain varies throughout Kansas and includes flat plains, rolling hills, sandhills, and steep slopes (Moody and others, 1986). Soil permeability ranges from about 0.3 to 12.5 in/hr (fig. 3), with a mean of about 1.6 in/hr. The highest soil-permeability values occur in the Cimarron and Upper and Lower Arkansas River Basins of southwest and south-central Kansas. Soil permeability also is generally higher in the western half of the State. Across the State, soil permeability is typically higher in the flood plains of the major rivers and streams (U.S. Department of Agriculture, 1993). Mean annual precipitation ranges from about 15 in. or less in extreme western Kansas to about 40 in. in the southeast (Paulson and others, 1991).

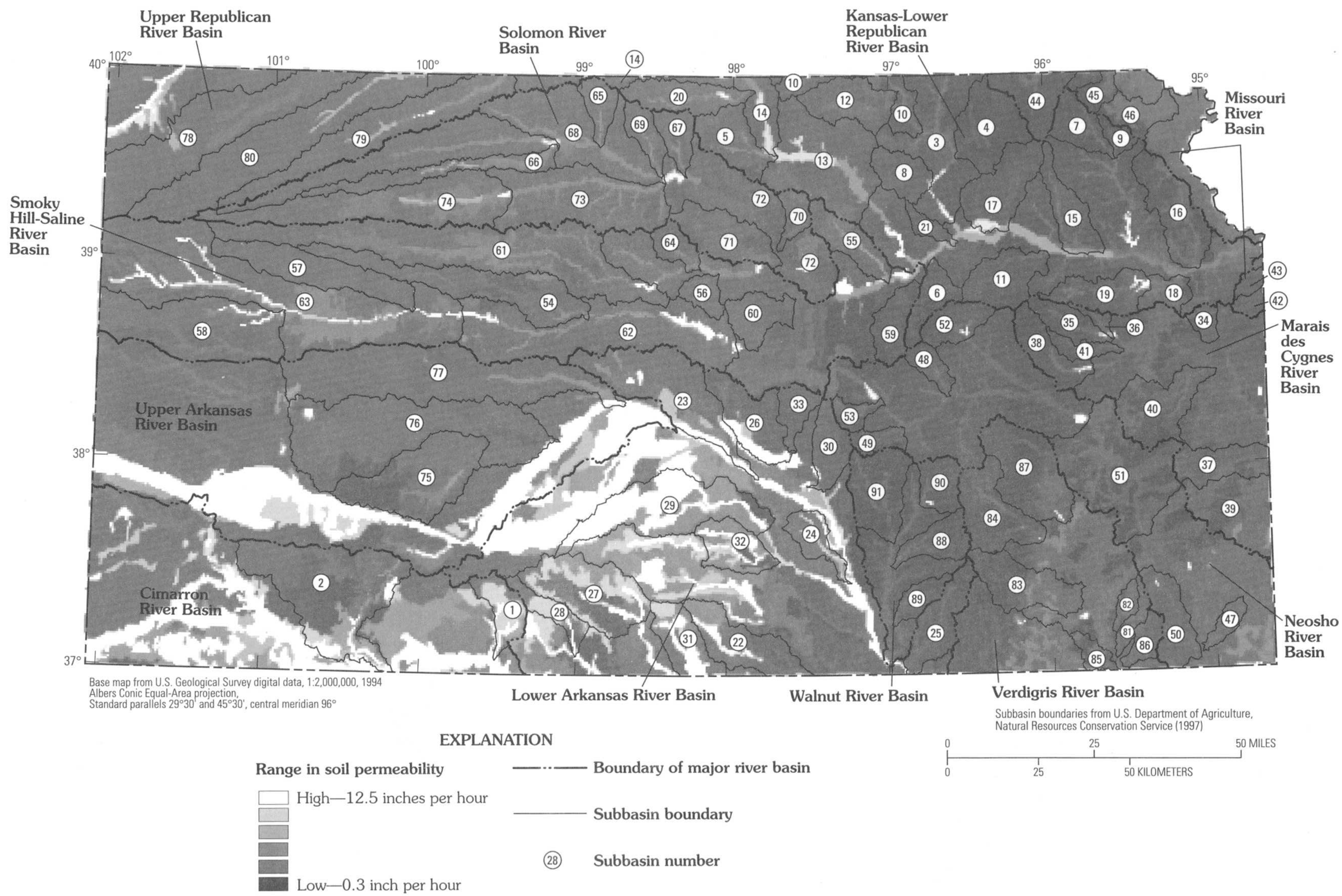
ESTIMATION OF POTENTIAL RUNOFF-CONTRIBUTING AREAS

Within the State, 91 subbasins representing soil, slope, and runoff variability were selected for analysis (fig. 1). The selected subbasin boundaries were obtained from a statewide data base of 11- and 14-digit hydrologic unit (basin) boundaries that was developed at a scale of 1:24,000 (U.S. Department of Agriculture, Natural Resources Conservation Service, 1997). For all selected subbasins, potential runoff-contributing areas were estimated collectively for the processes of infiltration-excess and saturation-excess overland flow. Geographic-information-system (GIS) techniques and available digital data were used to perform the spatial analyses required to estimate potential runoff-contributing areas. All analyses were done using the GRID module of the ArcInfo GIS software package. The digital data used in the analyses were in a grid (raster) format with a grid-cell size of 1 km^2. The digital data included the U.S. Department of Agriculture's 1:250,000-scale State soils geographic data base (STATSGO) (U.S. Department of Agriculture, 1993) and the USGS 1-km-resolution digital elevation model (DEM) (Verdin and Greenlee, 1996). These two digital data sets are suitable for comparing potential runoff among basins hundreds of square miles in size. Thus, in this study emphasis was placed on a comparison of potential runoff-contributing areas between, rather than within, individual subbasins.

The potential for infiltration-excess overland flow was estimated using STATSGO-derived soil-permeability digital data. In the STATSGO data set, soil permeability represents the infiltration rate when the soil is saturated (Soil Survey Staff, 1997). In general, there is an inverse relation between soil permeability and the potential for infiltration-excess overland flow. Using GIS techniques and digital maps of State and subbasin boundaries, the soil-permeability data were extracted from the STATSGO data base for the State and each subbasin (fig. 3). The mean soil permeability then was computed for each subbasin.

An equal-interval approach was used to select six threshold soil-permeability values that represent the rainfall intensity at which infiltration-excess overland flow would occur. In Kansas, soil permeability ranges from about 0.3 to 12.5 in/hr. However, because about 93 percent of the State has a soil permeability of 4.0 in/hr or less, the effective range used in this study was 0.3 to 4.0 in/hr. Thus, the threshold soil-permeability values, representing very high, high, moderate, low, very low, and extremely low rainfall intensity, were set at 3.38, 2.76, 2.14, 1.52, 0.90, and 0.45 in/hr, respectively. The extremely low threshold value was adjusted upward from 0.28 to 0.45 in/hr because the original value was less than the range of soil-permeability values for the State. In general, the lower rainfall intensities occur more frequently than the higher rainfall intensities. The higher soil-permeability thresholds imply a more intense storm during which areas with higher soil permeability potentially may contribute infiltration-excess overland flow. The threshold soil-permeability values were used to compare the selected subbasins on the basis of the percentage of each subbasin with soil-permeability values that were less than or equal to the threshold value and thus potentially contribute infiltration-excess overland flow.

The potential for saturation-excess overland flow was estimated using DEM-derived TWI digital data. In general, there is a direct relation between TWI and


Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Smoky Hill-Saline River Basin
Marais des Cygnes River Basin
Upper Arkansas River Basin
Cimarron River Basin
Neosho River Basin
Lower Arkansas River Basin
Walnut River Basin
Verdigris River Basin
40°
39°
38°
37°
102°
101°
100°
99°
98°
97°
96°
95°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture,
Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Range in soil permeability
High—12.5 inches per hour
Low—0.3 inch per hour
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

1 Cavalry Creek
2 Crooked Creek

Kansas-Lower Republican River Basin

3 Big Blue River upstream from Tuttle Creek Lake
4 Black Vermillion River
5 Buffalo Creek
6 Clarks Creek
7 Delaware River upstream from Muscotah
8 Fancy Creek
9 Grasshopper Creek
10 Little Blue River upstream from Barnes
11 Mill Creek (Wabaunsee County)
12 Mill Creek (Washington County)
13 Republican River between Concordia and Clay Center
14 Republican River upstream from Concordia
15 Soldier Creek
16 Stranger Creek
17 Vermillion Creek (Pottawatomie County)
18 Wakarusa River downstream from Clinton Lake
19 Wakarusa River upstream from Clinton Lake
20 White Rock Creek
21 Wildcat Creek

Lower Arkansas River Basin

22 Bluff Creek
23 Cow Creek
24 Cowskin Creek
25 Grouse Creek
26 Little Arkansas River upstream from Alta Mills
27 Medicine Lodge River and Elm Creek upstream from Medicine Lodge
28 Mule Creek
29 North Fork Ninnescah River upstream from Cheney Reservoir
30 Sand and Emma Creeks
31 Sandy and Little Sandy Creeks
32 South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
33 Sun and Turkey Creeks

Marais des Cygnes River Basin

34 Big Bull Creek upstream from Hillsdale Lake
35 Dragoon Creek upstream from Pomona Lake
36 Hundred and Ten Mile Creek upstream from Pomona Lake
37 Little Osage River
38 Marais des Cygnes River upstream from Melvern Lake
39 Marmaton River
40 Pottawatomie Creek
41 Salt Creek

Missouri River Basin

42 Blue River
43 Indian and Tomahawk Creeks
44 South Fork Big Nemaha River
45 Walnut Creek
46 Wolf River

Neosho River Basin

47 Cherry Creek
48 Diamond Creek
49 Doyle Creek
50 Labette Creek
51 Neosho River between John Redmond Reservoir and Chanute
52 Neosho River upstream from Council Grove Lake
53 South Cottonwood River

Smoky Hill-Saline River Basin

54 Big Creek
55 Chapman Creek
56 Elkhorn and Bullfoot Creeks
57 Hackberry Creek
58 Ladder Creek
59 Lyon Creek
60 Mulberry Creek
61 Saline River upstream from Wilson Lake
62 Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
63 Smoky Hill River upstream from Cedar Bluff Reservoir
64 Spillman Creek

Solomon River Basin

65 Beaver Creek
66 Bow Creek
67 Limestone Creek (Jewell County)
68 North Fork Solomon River between Kirwin Reservoir and Waconda Lake
69 Oak Creek
70 Pipe Creek
71 Salt Creek
72 Solomon River downstream from Waconda Lake
73 South Fork Solomon River between Webster Reservoir and Waconda Lake
74 South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

75 Buckner Creek
76 Pawnee River
77 Walnut Creek

Upper Republican River Basin

78 Beaver Creek
79 Prairie Dog Creek
80 Sappa Creek

Verdigris River Basin

81 Big Hill Creek
82 Drum Creek
83 Elk River upstream from Elk City
84 Fall River upstream from Fall River Lake
85 Onion Creek
86 Pumpkin Creek
87 Verdigris River upstream from Toronto Lake

Walnut River Basin

88 Little Walnut River
89 Timber Creek
90 Walnut River upstream from El Dorado Lake
91 Whitewater River

Figure 3. Soil permeability in Kansas (source of data: U.S. Department of Agriculture, 1993).

the potential for saturation-excess overland flow. Derivation of the TWI digital data followed the approach described by Wolock and McCabe (1995). Elevation differences among the grid cells in the DEM were compared and used to create a flow-direction grid (Jenson and Domingue, 1988). The flow-direction grid was used to derive a flow-accumulation grid by computing the number of upslope cells that drain into each cell. The upslope area per unit contour length (a) for each cell in the flow-accumulation grid was computed as:

$$a = \text{(number of upslope cells + 0.5) x (grid-cell length).} \quad (1)$$

Using the DEM and the flow-direction grid, the magnitude of the slope (S) was computed for each cell as:

$$S = \text{(change in elevation between neighboring grid cells) / (horizontal distance between centers of neighboring grid cells).} \quad (2)$$

The resultant slope (gradient) grid then was used in combination with the flow-accumulation grid to compute TWI for each cell as:

$$\text{TWI} = \ln (a / S). \quad (3)$$

Using GIS techniques and digital maps of State and subbasin boundaries, the TWI grid data were extracted for the State and each subbasin (fig. 4). The mean TWI was computed for each subbasin. An equal-interval approach was used to select six threshold TWI values that represented a range of wet-to-dry antecedent soil-moisture conditions. In Kansas, the TWI ranges from 8.6 to 28.7. However, because about 95 percent of the State has a TWI of 19 or less, the effective range used in this study was 8.6 to 19. Thus, the threshold TWI values, representing very wet, wet, moderate, dry, very dry, and extremely dry antecedent soil-moisture conditions, were set at 10.4, 12.1, 13.8, 15.6, 17.3, and 19.0, respectively. The lower TWI thresholds imply wetter antecedent soil-moisture conditions during which areas with lower TWI values potentially may contribute saturation-excess overland flow. The threshold TWI values were used to compare the selected subbasins on the basis of the percentage of each subbasin that had TWI values greater than or equal to the threshold value and thus potentially contribute saturation-excess overland flow.

The combined potential for runoff in Kansas and the selected subbasins due to infiltration-excess and saturation-excess overland flows was estimated by merging the previously described hypothetical conditions. A very high potential-runoff condition was created by combining very high rainfall intensity (soil permeability less than or equal to 3.38 in/hr) with very wet antecedent soil-moisture (TWI greater than or equal to 10.4) conditions. A high potential-runoff condition was created by combining high rainfall intensity (soil permeability less than or equal to 2.76 in/hr) with wet antecedent soil-moisture (TWI greater than or equal to 12.1) conditions. A moderate potential-runoff condition was created by combining moderate rainfall intensity (soil permeability less than or equal to 2.14 in/hr) with moderate antecedent soil-moisture (TWI greater than or equal to 13.8) conditions. A low potential-runoff condition was created by combining the low rainfall intensity (soil permeability less than or equal to 1.52 in/hr) with dry antecedent soil-moisture (TWI greater than or equal to 15.6) conditions. A very low potential-runoff condition was created by combining the very low rainfall intensity (soil permeability less than or equal to 0.90 in/hr) with very dry antecedent soil-moisture (TWI greater than or equal to 17.3) conditions. An extremely low potential-runoff condition was created by combining the extremely low rainfall intensity (soil permeability less than or equal to 0.45 in/hr) with extremely dry antecedent soil-moisture (TWI greater than or equal to 19.0) conditions. The combined conditions were used to compare the selected subbasins on the basis of the percentage of each subbasin that potentially contributes runoff by one or both overland-flow processes.

POTENTIAL RUNOFF-CONTRIBUTING AREAS

For very high potential-runoff conditions (soil permeability less than or equal to 3.38 in/hr, TWI greater than or equal to 10.4), 89 of 91 (98 percent) subbasins had potential contributing areas in greater than 90 percent of each subbasin (table 1). Thus, this set of environmental conditions was not useful for the purpose of distinguishing subbasins as having relatively high or low potential runoff. The spatial extent and pattern of combined potential contributing and noncontributing areas for very high potential-runoff conditions are shown in figure 5.

For high potential-runoff conditions (soil permeability less than or equal to 2.76 in/hr, TWI greater than or equal to 12.1), 85 of 91 (93 percent) subbasins had potential contributing areas in greater than 90 percent of each subbasin (table 1). Thus, with two exceptions, this set of environmental conditions was not useful for the purpose of distinguishing subbasins as having relatively high or low potential runoff. The two exceptions were within the Cimarron and Lower Arkansas River Basins (fig. 1). In the Cimarron Basin, Cavalry Creek (subbasin 1, 73.8 percent) had substantially less potential contributing area than Crooked Creek (subbasin 2, 96.4 percent). In the Lower Arkansas Basin, potential contributing areas ranged from 71.6 percent of the subbasin for Mule Creek (subbasin 28) to 100 percent for Sun and Turkey Creeks (subbasin 33). Of the 12 subbasins in the Lower Arkansas Basin, 5 (42 percent) had potential contributing areas between 70 and 90 percent. The spatial extent and pattern of combined potential contributing and noncontributing areas for high potential-runoff conditions are shown in figure 6.

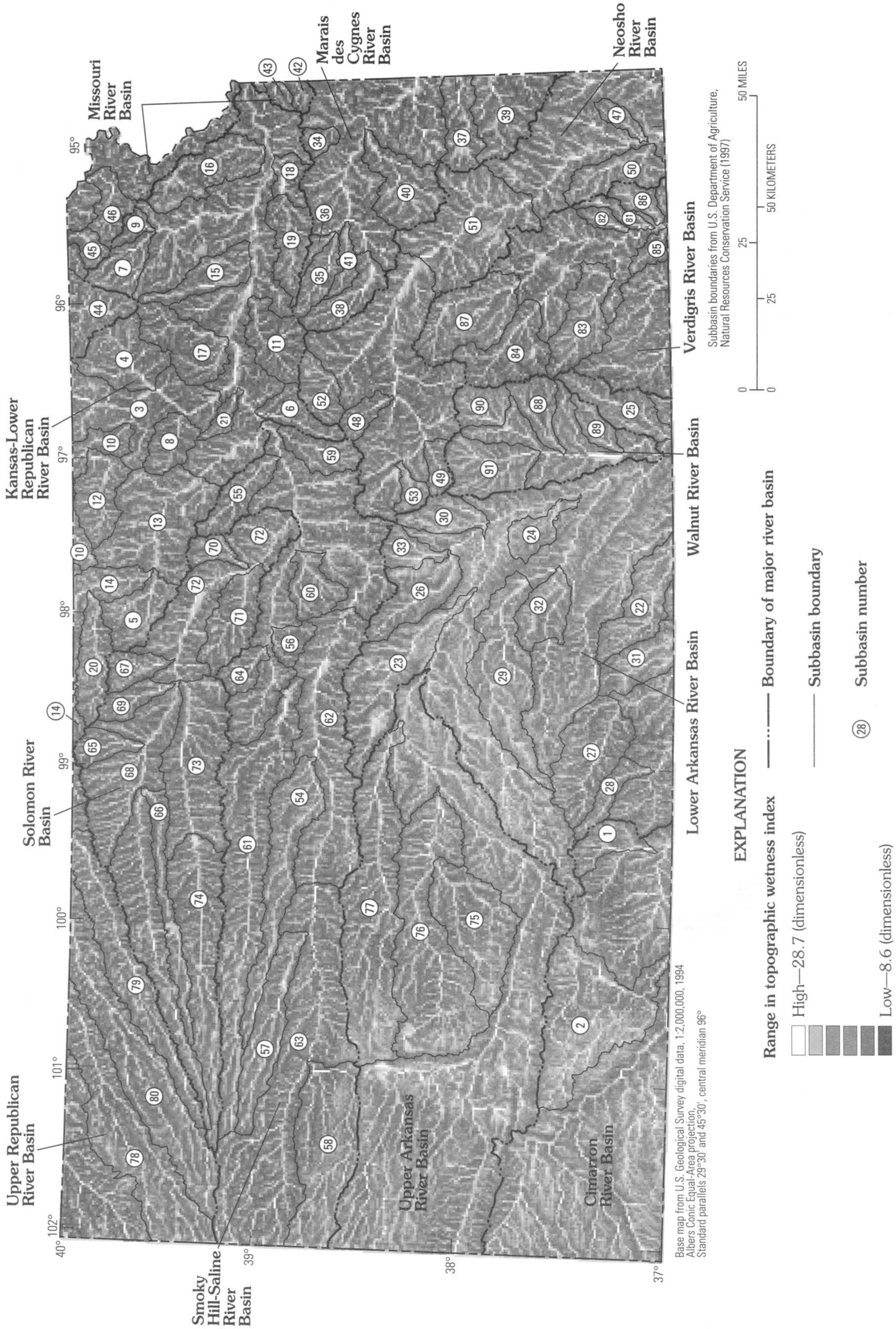
Potential contributing areas were greater than 90 percent for 82 of 91 (90 percent) subbasins for moderate potential-runoff conditions (soil permeability less than or equal to 2.14 in/hr, TWI greater than or equal to 13.8). The ability to distinguish subbasins as having relatively high or low potential runoff again was restricted to the Cimarron and Lower Arkansas River Basins. In the Cimarron Basin, Cavalry Creek (subbasin 1, 54.9 percent) again had substantially less potential contributing area than Crooked Creek (subbasin 2, 86.9 percent). In the Lower Arkansas Basin, potential contributing areas ranged from 63 percent of the subbasin for Mule Creek (subbasin 28) to 100 percent for Sun and Turkey Creeks (subbasin 33). Of the 12 subbasins in the Lower Arkansas Basin, 5 (42 percent) had potential contributing areas between 70 and 90 percent, and 2 (17 percent) had potential contributing areas less than 70 percent (table 1). In the remaining 10 major river basins, all subbasins had potential contributing areas greater than 90 percent. The spatial extent and pattern of combined potential contributing and noncontributing areas for moderate potential runoff conditions are shown in figure 7.

For low potential-runoff conditions (soil permeability less than or equal to 1.52 in/hr, TWI greater than or equal to 15.6), 75 of 91 (82 percent) subbasins had potential contributing areas in greater than 90 percent of each subbasin (table 1). Therefore, the ability to distinguish subbasins as having relatively high or low potential runoff was still limited. Again, the best ability to distinguish subbasins was observed in the Cimarron and Lower Arkansas River Basins. In the Cimarron Basin, the difference in potential contributing area between Cavalry Creek (subbasin 1, 44.2 percent) and Crooked Creek (subbasin 2, 82.9 percent) remained substantial. In the Lower Arkansas Basin, potential contributing areas ranged from 24.1 percent of the subbasin for the North Fork Ninnescah River upstream from Cheney Reservoir (subbasin 29) to 100 percent for Sun and Turkey Creeks (subbasin 33). Of the 12 subbasins in the Lower Arkansas Basin, 4 (33 percent) had potential contributing areas of between 70 and 90 percent, and 5 (42 percent) had potential contributing areas of between 20 and 60 percent.

Across the State, subbasins with potential contributing areas less than 90 percent were observed in three other major basins for low potential-runoff conditions. In the Kansas-Lower Republican River Basin, the Republican River upstream from Concordia (subbasin 14) had a potential contributing area of 85.3 percent of the subbasin. In the Smoky Hill-Saline River Basin, the Saline River upstream from Wilson Lake (subbasin 61) and the Smoky Hill River upstream from Cedar Bluff Reservoir (subbasin 63) had respective potential contributing areas of 82.1 and 77.9 percent. Finally, in the Solomon River Basin, Bow Creek (subbasin 66) and the South Fork Solomon River upstream from Webster Reservoir (subbasin 74) had respective potential contributing areas of 79.5 and 76.1 percent. The spatial extent and pattern of combined potential contributing and noncontributing areas for low potential-runoff conditions are shown in figure 8.

Overall, the best statewide ability to distinguish subbasins was observed for the very low potential-runoff conditions (soil permeability less than or equal to 0.90 in/hr, TWI greater than or equal to 17.3). Of the 91 subbasins, 32 (35 percent) had potential contributing areas in greater than 90 percent of each subbasin, 14 (15 percent) had potential contributing areas between 70 and 90 percent, 5 (5 percent) had potential contributing areas between 50 and 70 percent, 7 (8 percent) had potential contributing areas between 30 and 50 percent, 16 (18 percent) had potential contributing areas between 10 and 30 percent, and 17 (19 percent) had potential contributing areas less than 10 percent (table 1). The spatial extent and pattern of combined potential contributing and noncontributing areas for very low potential-runoff conditions are shown in figure 9.

For extremely low potential-runoff conditions (soil permeability less than or equal to 0.45, TWI greater than or equal to 19.0), the ability to distinguish subbasins varied by major river basin. Of the



Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Kansas-Lower Republican River Basin
Solomon River Basin
Upper Republican River Basin
Smoky Hill-Saline River Basin
Upper Arkansas River Basin
Cimarron River Basin
Lower Arkansas River Basin
Walnut River Basin
Verdigris River Basin
95°
96°
97°
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99°
100°
101°
102°
40°
39°
38°
37°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture,
Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Range in topographic wetness index
High—28.7 (dimensionless)
Low—8.6 (dimensionless)
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 4. Topographic wetness index (TWI) data for Kansas.

Table 1. Potential contributing areas for combined infiltration- and saturation-excess overland flows for selected subbasins in Kansas

[P, soil permeability, in inches per hour; TWI, topographic wetness index]

			Potential contributing area, in percentage of subbasin, for selected potential-runoff conditions					
Subbasin number (fig. 1)	Mean P	Mean TWI	Very high potential runoff[1]	High potential runoff[2]	Moderate potential runoff[3]	Low potential runoff[4]	Very low potential runoff[5]	Extremely low potential runoff[6]
			Cimarron River Basin					
1	3.7	12.9	91.6	73.8	54.9	44.2	8.5	2.8
2	1.7	13.8	99.2	96.4	86.9	82.9	45.8	5.0
			Kansas-Lower Republican River Basin					
3	.6	12.7	97.4	97.4	97.4	97.4	93.4	37.1
4	.4	12.5	100	100	100	100	99.6	90.8
5	1.1	12.9	100	99.5	99.4	96.5	20.8	3.9
6	.5	12.6	100	100	99.5	99.5	99.5	40.2
7	.4	12.7	100	100	100	100	95.9	95.7
8	.7	12.3	99.9	99.9	99.9	99.9	98.8	2.9
9	.4	12.4	100	100	100	100	93.0	91.8
10	.8	12.8	99.7	99.7	99.7	99.7	82.7	5.8
11	.5	12.0	100	100	99.8	99.8	96.2	13.5
12	.9	12.6	100	100	100	100	69.9	3.7
13	1.2	13.0	99.8	97.7	93.9	92.3	70.4	4.6
14	1.4	13.0	98.2	94.8	91.5	85.3	50.0	5.2
15	.6	12.7	100	100	97.0	95.7	84.0	83.4
16	0.5	12.8	100	100	100	99.9	93.7	66.4
17	.6	12.2	98.9	97.0	95.3	94.8	94.6	77.9
18	.8	12.9	99.3	99.3	99.3	98.4	84.0	18.8
19	.6	12.6	96.2	96.2	96.2	96.2	88.2	38.6
20	1.3	12.7	98.5	98.5	98.5	91.7	8.8	4.3
21	.6	12.4	100	100	98.1	97.3	96.5	3.5
			Lower Arkansas River Basin					
22	1.5	13.5	99.9	97.2	95.5	75.6	40.4	4.9
23	1.8	13.6	99.3	95.0	89.8	79.3	14.5	5.4
24	2.1	14.1	100	98.0	90.0	83.0	10.2	2.2
25	.5	12.7	99.9	99.9	99.9	99.9	99.9	21.7
26	2.8	13.4	99.8	92.0	85.4	82.0	74.4	4.3

Table 1. Potential contributing areas for combined infiltration- and saturation-excess overland flows for selected subbasins in Kansas—Continued

Subbasin number (fig. 1)	Mean P	Mean TWI	Potential contributing area, in percentage of subbasin, for selected potential-runoff conditions					
			Very high potential runoff[1]	High potential runoff[2]	Moderate potential runoff[3]	Low potential runoff[4]	Very low potential runoff[5]	Extremely low potential runoff[6]
Lower Arkansas River Basin—Continued								
27	2.5	12.4	89.8	78.2	73.1	52.2	26.4	3.2
28	2.9	12.3	88.2	71.6	63.0	54.1	21.1	3.8
29	5.1	13.7	98.4	85.3	69.5	24.1	13.2	3.7
30	.9	13.9	100	99.1	98.8	98.8	98.4	5.7
31	3.6	13.1	97.5	86.0	76.5	56.2	10.7	2.7
32	3.0	13.4	99.2	88.9	83.1	26.5	21.5	6.0
33	.8	13.7	100	100	100	100	100	5.3
Marais des Cygnes River Basin								
34	0.6	12.6	100	100	100	100	92.2	23.4
35	.5	12.7	99.0	99.0	99.0	99.0	92.7	79.0
36	.5	12.5	98.7	98.7	98.7	98.7	89.9	44.3
37	.7	12.9	100	100	100	100	75.7	9.4
38	.4	12.7	98.4	98.4	98.4	98.4	95.6	83.5
39	.9	12.7	100	100	100	96.8	37.8	5.9
40	.6	12.9	100	100	100	100	93.6	42.1
41	.5	12.9	100	100	100	100	93.6	63.4
Missouri River Basin								
42	.6	12.1	100	100	100	100	98.0	1.0
43	.7	12.3	100	100	100	100	88.0	1.1
44	.4	12.5	95.5	95.5	95.5	95.5	93.1	89.0
45	.5	12.7	97.4	97.4	97.4	97.4	96.1	71.9
46	.9	12.6	100	100	100	100	36.1	31.4
Neosho River Basin								
47	1.1	13.6	100	100	100	100	11.5	5.4
48	.5	12.5	100	100	100	100	95.6	32.1
49	.6	12.9	100	100	100	100	91.5	18.3
50	.8	13.1	99.3	99.3	99.3	99.3	84.2	4.5
51	.6	13.2	100	100	100	99.9	81.6	48.6
52	.4	12.6	98.5	98.5	98.5	98.5	94.9	48.2
53	.7	13.1	99.7	99.7	99.7	99.7	76.4	9.1
Smoky Hill-Saline River Basin								
54	1.2	12.9	100	100	100	95.0	21.4	6.2

Table 1. Potential contributing areas for combined infiltration- and saturation-excess overland flows for selected subbasins in Kansas—Continued

Subbasin number (fig. 1)	Mean P	Mean TWI	Potential contributing area, in percentage of subbasin, for selected potential-runoff conditions					
			Very high potential runoff[1]	High potential runoff[2]	Moderate potential runoff[3]	Low potential runoff[4]	Very low potential runoff[5]	Extremely low potential runoff[6]
Smoky Hill-Saline River Basin—Continued								
55	1.0	12.5	99.9	99.8	95.4	94.3	64.1	4.3
56	1.2	12.1	100	100	100	99.5	5.3	1.5
57	1.3	12.9	99.9	99.9	99.9	99.7	10.6	5.9
58	1.4	13.1	98.7	98.2	98.0	92.0	9.8	5.9
59	.5	12.7	100	100	100	100	100	14.2
60	1.1	12.5	100	100	100	100	16.6	3.4
61	1.4	12.7	99.5	99.5	99.5	82.1	9.2	5.4
62	1.5	12.9	99.6	98.3	97.1	91.4	10.2	4.9
63	1.7	12.7	98.7	97.7	97.2	77.9	8.4	5.3
64	1.1	12.6	100	100	100	96.0	8.4	3.1
Solomon River Basin								
65	1.3	12.5	99.6	99.6	99.6	94.9	9.5	3.8
66	1.5	12.9	99.5	97.4	97.1	79.5	10.9	4.6
67	1.2	12.7	100	100	100	96.2	8.5	2.7
68	1.3	12.7	99.8	99.8	99.8	90.7	8.9	4.7
69	1.2	12.6	100	100	100	95.1	8.4	3.7
70	.9	12.8	100	100	100	100	76.6	5.7
71	1.1	12.4	100	100	100	100	12.0	3.8
72	1.1	13.2	98.5	98.1	97.8	96.5	30.4	4.9
73	1.3	12.6	99.9	99.9	99.9	90.3	7.8	4.5
74	1.5	12.8	99.6	97.8	97.1	76.1	8.6	4.3
Upper Arkansas River Basin								
75	1.1	13.0	100	100	98.8	92.9	35.2	4.1
76	1.1	13.2	100	99.8	98.9	98.7	19.7	4.3
77	1.2	13.1	100	99.9	98.9	95.2	9.3	4.5
Upper Republican River Basin								
78	1.3	12.9	99.9	99.3	99.0	91.4	9.8	5.6
79	1.4	12.9	99.6	98.5	98.0	93.8	8.8	4.8
80	1.4	12.9	99.8	97.9	97.4	97.0	9.6	5.4

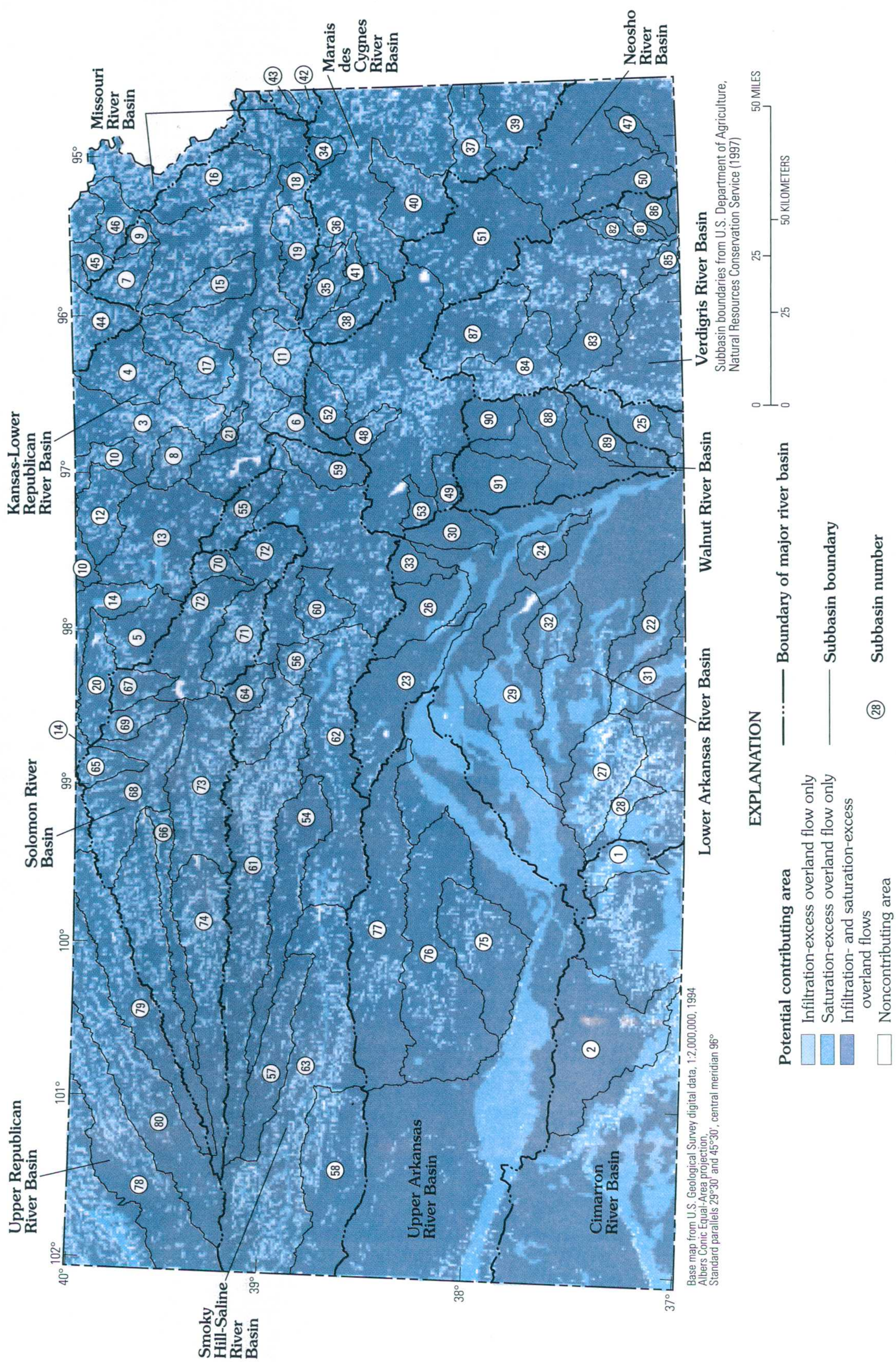
Table 1. Potential contributing areas for combined infiltration- and saturation-excess overland flows for selected subbasins in Kansas—Continued

Subbasin number (fig. 1)	Mean P	Mean TWI	Potential contributing area, in percentage of subbasin, for selected potential-runoff conditions					
			Very high potential runoff[1]	High potential runoff[2]	Moderate potential runoff[3]	Low potential runoff[4]	Very low potential runoff[5]	Extremely low potential runoff[6]
			Verdigris River Basin					
81	.8	13.2	100	100	100	100	58.5	7.3
82	.8	12.8	100	100	100	100	61.7	5.5
83	.7	12.8	100	100	100	95.0	84.7	26.6
84	.5	12.3	99.9	99.9	99.9	99.8	95.1	29.7
85	.8	12.5	98.3	98.3	98.3	98.3	49.7	28.8
86	.8	13.2	100	100	100	100	91.1	5.6
87	.5	12.8	99.6	99.6	99.6	99.6	90.7	44.4
			Walnut River Basin					
88	.5	12.8	100	100	100	100	93.6	37.7
89	.5	13.3	100	100	100	100	100	31.9
90	.5	13.2	99.1	99.1	99.1	99.1	95.9	94.5
91	.5	13.4	100.0	100	100	100	92.5	77.2

[1] Very high potential runoff = soil permeability less than or equal to 3.38 inches per hour and topographic wetness index greater than or equal to 10.4.
[2] High potential runoff = soil permeability less than or equal to 2.76 inches per hour and topographic wetness index greater than or equal to 12.1.
[3] Moderate potential runoff = soil permeability less than or equal to 2.14 inches per hour and topographic wetness index greater than or equal to 13.8.
[4] Low potential runoff = soil permeability less than or equal to 1.52 inches per hour and topographic wetness index greater than or equal to 15.6.
[5] Very low potential runoff = soil permeability less than or equal to 0.90 inch per hour and topographic wetness index greater than or equal to 17.3.
[6] Extremely low potential runoff = soil permeability less than or equal to 0.45 inch per hour and topographic wetness index greater than or equal to 19.0.

91 subbasins statewide, 4 (4 percent) had potential contributing areas greater than 90 percent of each subbasin, 7 (8 percent) had potential contributing areas between 70 and 90 percent, 2 (2 percent) had potential contributing areas between 50 and 70 percent, 12 (13 percent) had potential contributing areas between 30 and 50 percent, 9 (10 percent) had potential contributing areas between 10 and 30 percent, and 57 (63 percent) had potential contributing areas less than 10 percent (table 1). The spatial extent and pattern of combined potential contributing and noncontributing areas for extremely low potential-runoff conditions are shown in figure 10.

Using very low potential-runoff conditions, the major river basins were categorized as having either relatively high or relatively low potential runoff. The very low potential-runoff conditions are meaningful because they provide the best ability to distinguish subbasins and because the 0.90-in/hr rainfall intensity occurs more frequently than the higher rainfall intensities. A basin was categorized as having relatively high potential runoff if the majority of its subbasins (those selected for analysis) had potential contributing areas greater than 70 percent of each subbasin. A basin was categorized as having relatively low potential runoff if the majority of its subbasins (those selected for analysis) had potential contributing areas less than 30 percent of each subbasin. The major basins having relatively high potential runoff were the Kansas-Lower Republican (15 of 19 subbasins had potential contributing areas greater than 70 percent of each subbasin), Marais des Cygnes (7 of 8 subbasins), Missouri (4 of 5 subbasins), Neosho (6 of 7 subbasins), Verdigris (4 of 7 subbasins), and Walnut (4 of 4 subbasins). The major basins having relatively low potential runoff were the Cimarron (1 of 2 subbasins had potential contributing areas less than 30 percent of each subbasin), Lower Arkansas (7 of 12 subbasins), Smoky Hill-Saline (9 of 11 subbasins), Solomon (8 of



Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Verdigris River Basin
Walnut River Basin
Lower Arkansas River Basin
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Smoky Hill-Saline River Basin
102°
101°
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40°
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37°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture, Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

1. Cavalry Creek
2. Crooked Creek

Kansas-Lower Republican River Basin

3. Big Blue River upstream from Tuttle Creek Lake
4. Black Vermillion River
5. Buffalo Creek
6. Clarks Creek
7. Delaware River upstream from Muscotah
8. Fancy Creek
9. Grasshopper Creek
10. Little Blue River upstream from Barnes
11. Mill Creek (Wabaunsee County)
12. Mill Creek (Washington County)
13. Republican River between Concordia and Clay Center
14. Republican River upstream from Concordia
15. Soldier Creek
16. Stranger Creek
17. Vermillion Creek (Pottawatomie County)
18. Wakarusa River downstream from Clinton Lake
19. Wakarusa River upstream from Clinton Lake
20. White Rock Creek
21. Wildcat Creek

Lower Arkansas River Basin

22. Bluff Creek
23. Cow Creek
24. Cowskin Creek
25. Grouse Creek
26. Little Arkansas River upstream from Alta Mills
27. Medicine Lodge River and Elm Creek upstream from Medicine Lodge
28. Mule Creek
29. North Fork Ninnescah River upstream from Cheney Reservoir
30. Sand and Emma Creeks
31. Sandy and Little Sandy Creeks
32. South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
33. Sun and Turkey Creeks

Marais des Cygnes River Basin

34. Big Bull Creek upstream from Hillsdale Lake
35. Dragoon Creek upstream from Pomona Lake
36. Hundred and Ten Mile Creek upstream from Pomona Lake
37. Little Osage River
38. Marais des Cygnes River upstream from Melvern Lake
39. Marmaton River
40. Pottawatomie Creek
41. Salt Creek

Missouri River Basin

42. Blue River
43. Indian and Tomahawk Creeks
44. South Fork Big Nemaha River
45. Walnut Creek
46. Wolf River

Neosho River Basin

47. Cherry Creek
48. Diamond Creek
49. Doyle Creek
50. Labette Creek
51. Neosho River between John Redmond Reservoir and Chanute
52. Neosho River upstream from Council Grove Lake
53. South Cottonwood River

Smoky Hill-Saline River Basin

54. Big Creek
55. Chapman Creek
56. Elkhorn and Bullfoot Creeks
57. Hackberry Creek
58. Ladder Creek
59. Lyon Creek
60. Mulberry Creek
61. Saline River upstream from Wilson Lake
62. Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
63. Smoky Hill River upstream from Cedar Bluff Reservoir
64. Spillman Creek

Solomon River Basin

65. Beaver Creek
66. Bow Creek
67. Limestone Creek (Jewell County)
68. North Fork Solomon River between Kirwin Reservoir and Waconda Lake
69. Oak Creek
70. Pipe Creek
71. Salt Creek
72. Solomon River downstream from Waconda Lake
73. South Fork Solomon River between Webster Reservoir and Waconda Lake
74. South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

75. Buckner Creek
76. Pawnee River
77. Walnut Creek

Upper Republican River Basin

78. Beaver Creek
79. Prairie Dog Creek
80. Sappa Creek

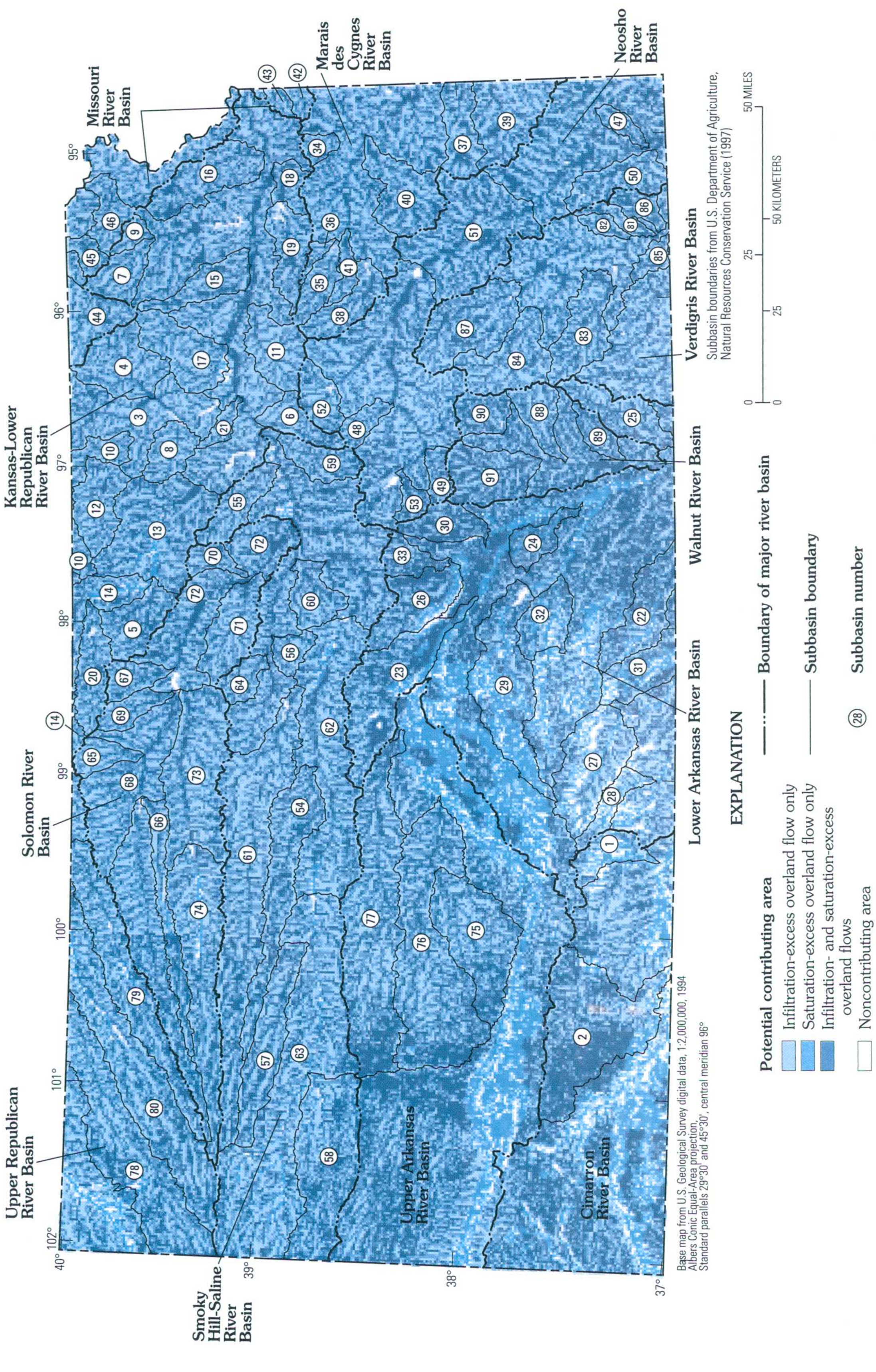
Verdigris River Basin

81. Big Hill Creek
82. Drum Creek
83. Elk River upstream from Elk City
84. Fall River upstream from Fall River Lake
85. Onion Creek
86. Pumpkin Creek
87. Verdigris River upstream from Toronto Lake

Walnut River Basin

88. Little Walnut River
89. Timber Creek
90. Walnut River upstream from El Dorado Lake
91. Whitewater River

Figure 5. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for very high potential-runoff conditions.


Upper Republican River Basin
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102°
101°
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95°
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Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture,
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0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

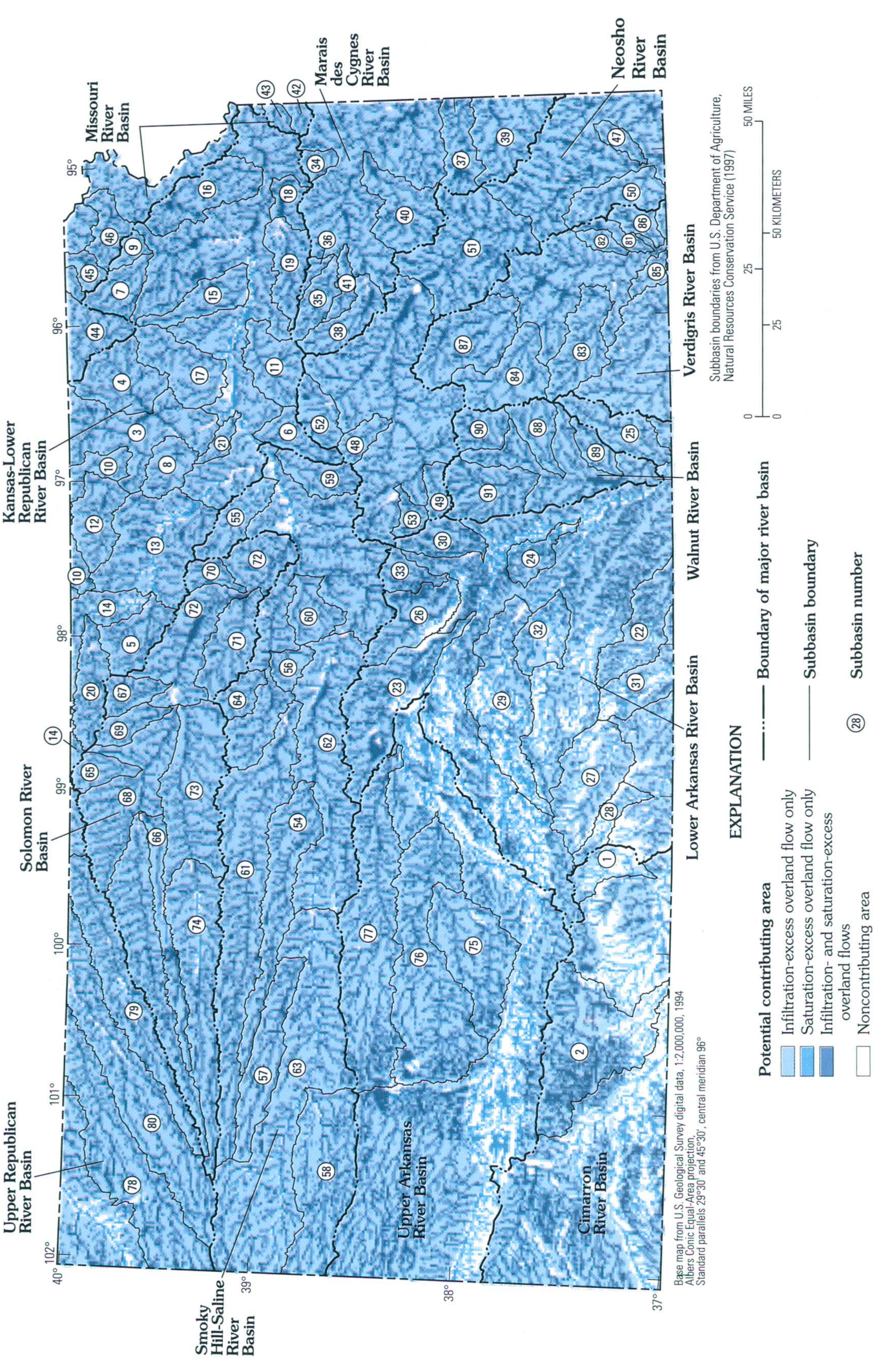
Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 6. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for high potential-runoff conditions.



Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Verdigris River Basin
Walnut River Basin
Lower Arkansas River Basin
Upper Arkansas River Basin
Cimarron River Basin
Smoky Hill-Saline River Basin
102°
101°
100°
99°
98°
97°
96°
95°
40°
39°
38°
37°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture, Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

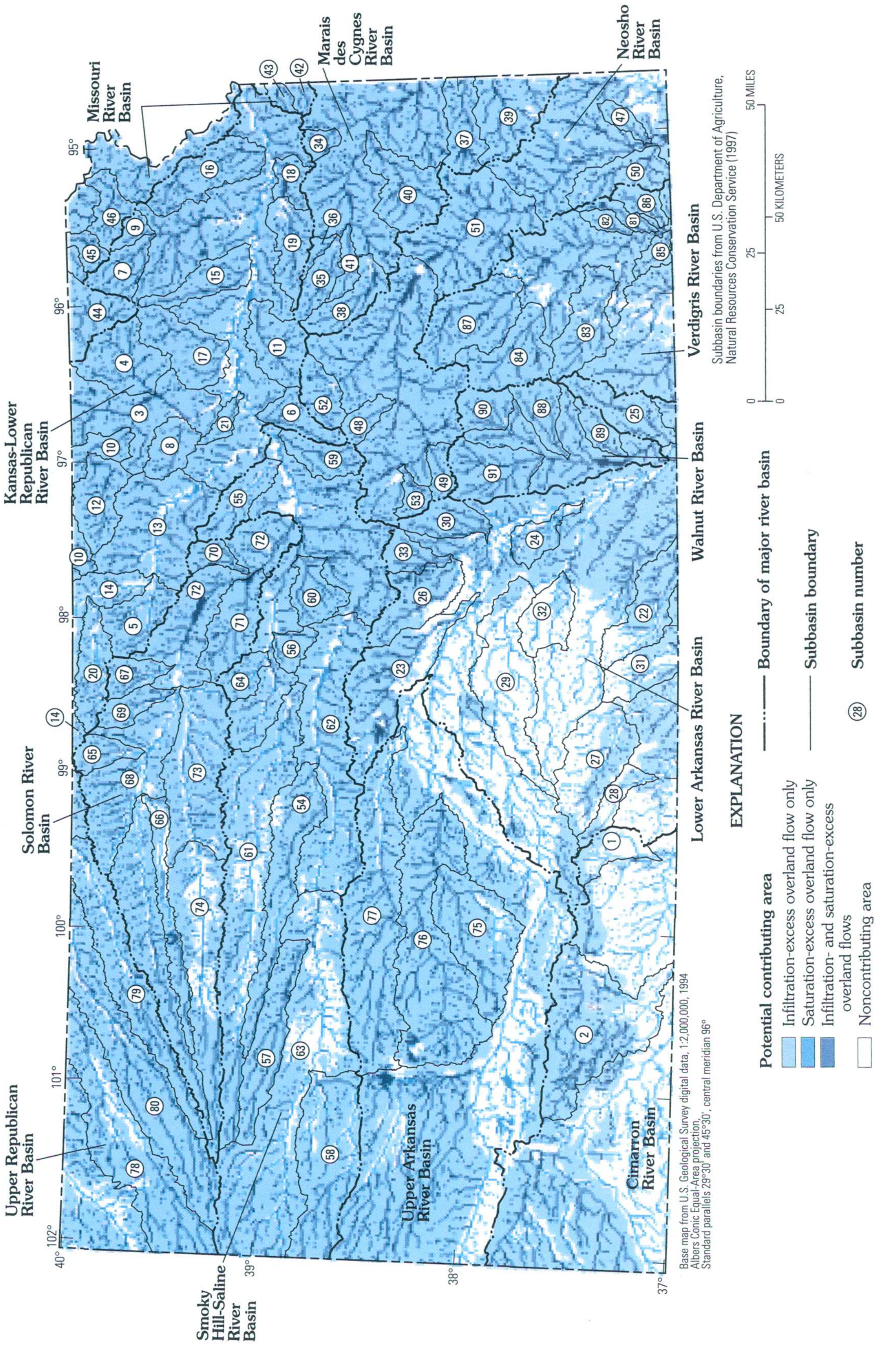
Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 7. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for moderate potential-runoff conditions.


Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Verdigris River Basin
Walnut River Basin
Lower Arkansas River Basin
Smoky Hill-Saline River Basin
Upper Arkansas River Basin
Cimarron River Basin
102°
101°
100°
99°
98°
97°
96°
95°
40°
39°
38°
37°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture, Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

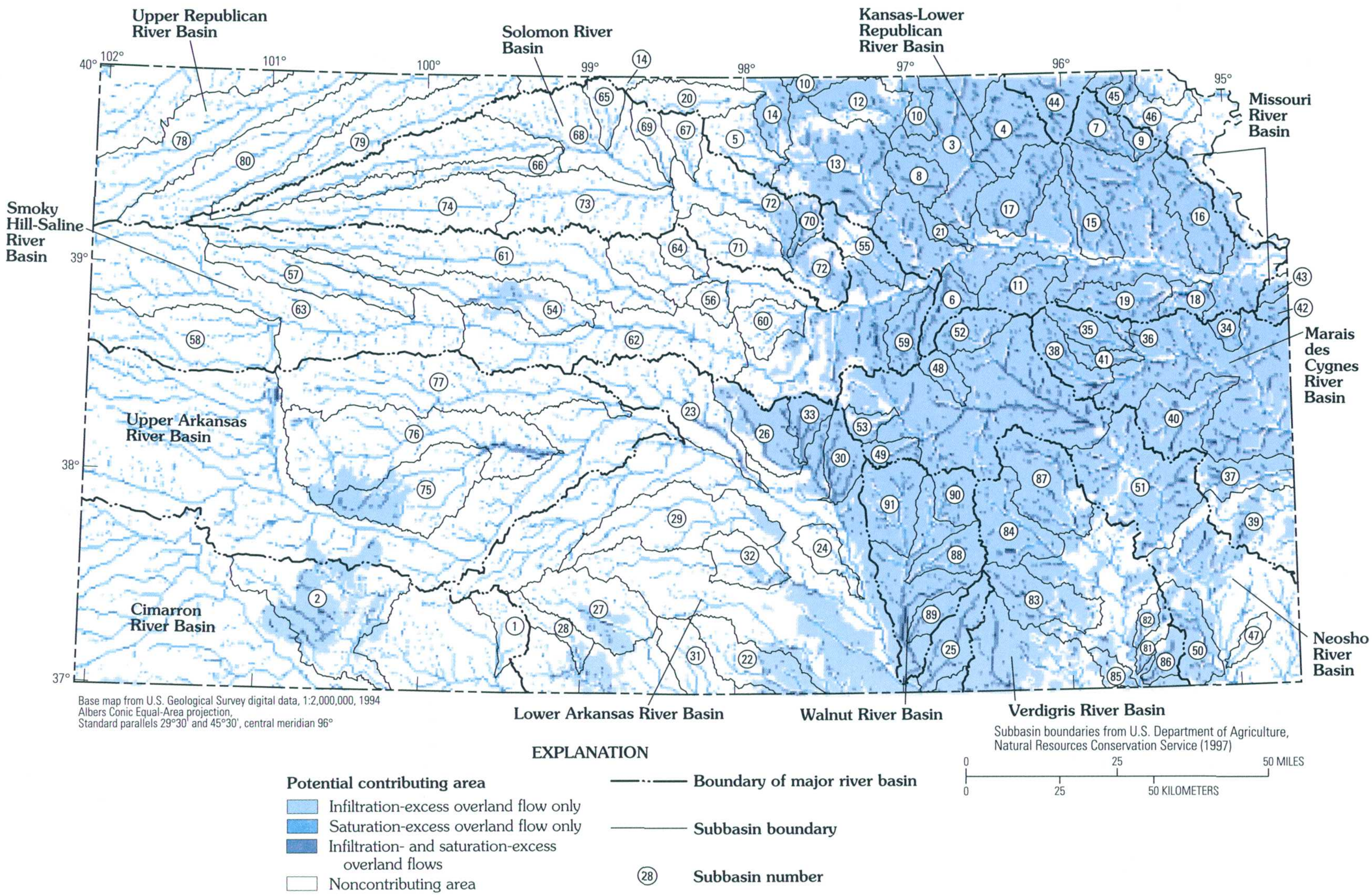
Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 8. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for low potential-runoff conditions.



Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Smoky Hill-Saline River Basin
Marais des Cygnes River Basin
Upper Arkansas River Basin
Cimarron River Basin
Neosho River Basin
Lower Arkansas River Basin
Walnut River Basin
Verdigris River Basin
40°
39°
38°
37°
102°
101°
100°
99°
98°
97°
96°
95°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture, Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

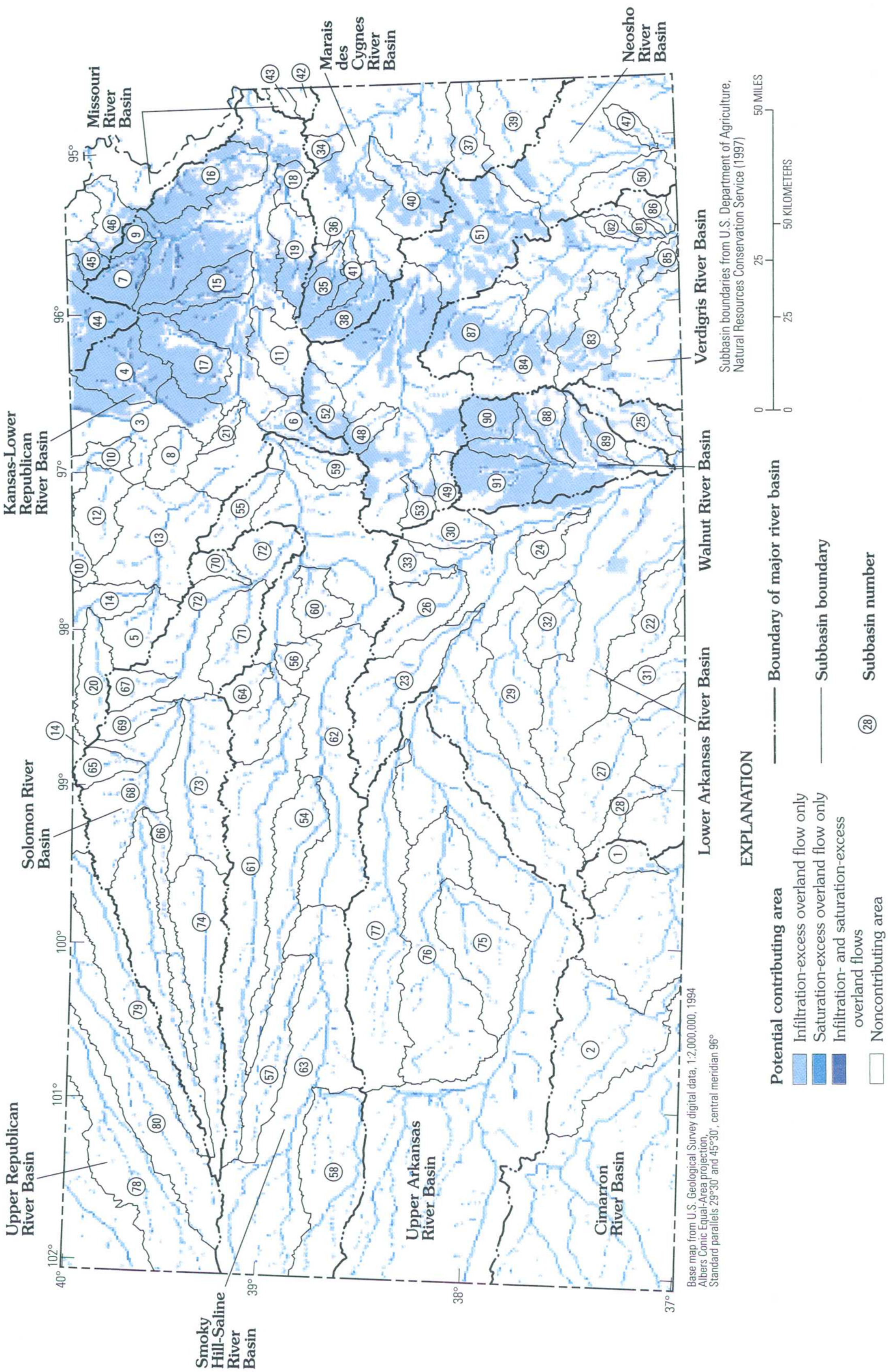
Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 9. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for very low potential-runoff conditions.


Upper Republican River Basin
Solomon River Basin
Kansas-Lower Republican River Basin
Missouri River Basin
Marais des Cygnes River Basin
Neosho River Basin
Verdigris River Basin
Walnut River Basin
Lower Arkansas River Basin
Upper Arkansas River Basin
Cimarron River Basin
Smoky Hill-Saline River Basin
95°
96°
97°
98°
99°
100°
101°
102°
40°
39°
38°
37°
Base map from U.S. Geological Survey digital data, 1:2,000,000, 1994
Albers Conic Equal-Area projection,
Standard parallels 29°30' and 45°30', central meridian 96°
Subbasin boundaries from U.S. Department of Agriculture,
Natural Resources Conservation Service (1997)
0 25 50 MILES
0 25 50 KILOMETERS
EXPLANATION
Potential contributing area
Infiltration-excess overland flow only
Saturation-excess overland flow only
Infiltration- and saturation-excess overland flows
Noncontributing area
Boundary of major river basin
Subbasin boundary
28 Subbasin number

EXPLANATION (continued)

Subbasins selected for analysis

Cimarron River Basin

(1) Cavalry Creek
(2) Crooked Creek

Kansas-Lower Republican River Basin

(3) Big Blue River upstream from Tuttle Creek Lake
(4) Black Vermillion River
(5) Buffalo Creek
(6) Clarks Creek
(7) Delaware River upstream from Muscotah
(8) Fancy Creek
(9) Grasshopper Creek
(10) Little Blue River upstream from Barnes
(11) Mill Creek (Wabaunsee County)
(12) Mill Creek (Washington County)
(13) Republican River between Concordia and Clay Center
(14) Republican River upstream from Concordia
(15) Soldier Creek
(16) Stranger Creek
(17) Vermillion Creek (Pottawatomie County)
(18) Wakarusa River downstream from Clinton Lake
(19) Wakarusa River upstream from Clinton Lake
(20) White Rock Creek
(21) Wildcat Creek

Lower Arkansas River Basin

(22) Bluff Creek
(23) Cow Creek
(24) Cowskin Creek
(25) Grouse Creek
(26) Little Arkansas River upstream from Alta Mills
(27) Medicine Lodge River and Elm Creek upstream from Medicine Lodge
(28) Mule Creek
(29) North Fork Ninnescah River upstream from Cheney Reservoir
(30) Sand and Emma Creeks
(31) Sandy and Little Sandy Creeks
(32) South Fork Ninnescah River from confluence with North Fork Ninnescah River upstream to Kingman
(33) Sun and Turkey Creeks

Marais des Cygnes River Basin

(34) Big Bull Creek upstream from Hillsdale Lake
(35) Dragoon Creek upstream from Pomona Lake
(36) Hundred and Ten Mile Creek upstream from Pomona Lake
(37) Little Osage River
(38) Marais des Cygnes River upstream from Melvern Lake
(39) Marmaton River
(40) Pottawatomie Creek
(41) Salt Creek

Missouri River Basin

(42) Blue River
(43) Indian and Tomahawk Creeks
(44) South Fork Big Nemaha River
(45) Walnut Creek
(46) Wolf River

Neosho River Basin

(47) Cherry Creek
(48) Diamond Creek
(49) Doyle Creek
(50) Labette Creek
(51) Neosho River between John Redmond Reservoir and Chanute
(52) Neosho River upstream from Council Grove Lake
(53) South Cottonwood River

Smoky Hill-Saline River Basin

(54) Big Creek
(55) Chapman Creek
(56) Elkhorn and Bullfoot Creeks
(57) Hackberry Creek
(58) Ladder Creek
(59) Lyon Creek
(60) Mulberry Creek
(61) Saline River upstream from Wilson Lake
(62) Smoky Hill River between Cedar Bluff Reservoir and Kanopolis Lake
(63) Smoky Hill River upstream from Cedar Bluff Reservoir
(64) Spillman Creek

Solomon River Basin

(65) Beaver Creek
(66) Bow Creek
(67) Limestone Creek (Jewell County)
(68) North Fork Solomon River between Kirwin Reservoir and Waconda Lake
(69) Oak Creek
(70) Pipe Creek
(71) Salt Creek
(72) Solomon River downstream from Waconda Lake
(73) South Fork Solomon River between Webster Reservoir and Waconda Lake
(74) South Fork Solomon River upstream from Webster Reservoir

Upper Arkansas River Basin

(75) Buckner Creek
(76) Pawnee River
(77) Walnut Creek

Upper Republican River Basin

(78) Beaver Creek
(79) Prairie Dog Creek
(80) Sappa Creek

Verdigris River Basin

(81) Big Hill Creek
(82) Drum Creek
(83) Elk River upstream from Elk City
(84) Fall River upstream from Fall River Lake
(85) Onion Creek
(86) Pumpkin Creek
(87) Verdigris River upstream from Toronto Lake

Walnut River Basin

(88) Little Walnut River
(89) Timber Creek
(90) Walnut River upstream from El Dorado Lake
(91) Whitewater River

Figure 10. Potential contributing and noncontributing areas of combined infiltration- and saturation-excess overland flows in Kansas for extremely low potential-runoff conditions.

10 subbasins), Upper Arkansas (2 of 3 subbasins), and Upper Republican (3 of 3 subbasins).

SUMMARY AND CONCLUSIONS

Digital topographic and soil information was used to estimate and compare potential runoff-contributing areas for 91 selected subbasins in Kansas. Potential contributing areas were estimated collectively for the processes of infiltration-excess and saturation-excess overland flow using a set of environmental conditions that represented very high, high, moderate, low, very low, and extremely low potential runoff. For infiltration-excess overland flow, various rainfall-intensity and soil-permeability values were used. For saturation-excess overland flow, antecedent soil-moisture conditions and a topographic wetness index were used.

Results indicated that nearly all subbasins had large percentages of potential runoff-contributing area for the low to very high potential-runoff conditions. Thus, the ability to distinguish subbasins as having relatively high or low potential runoff for those conditions was very limited. The best statewide ability to distinguish subbasins as having relatively high or low potential runoff was provided by the very low potential-runoff conditions. Within the major river basins, the ability to distinguish subbasins as having relatively high or low potential runoff varied. For the Smoky Hill-Saline and Upper Arkansas River Basins, the very low potential-runoff conditions provided the best ability to distinguish subbasins. For the Kansas-Lower Republican, Missouri, Neosho, and Verdigris River Basins, good ability to distinguish subbasins was provided by both the very low and extremely low potential-runoff conditions. For the Lower Arkansas and Solomon River Basins, the best ability to distinguish subbasins was provided by the low and very low potential-runoff conditions. The extremely low potential-runoff conditions provided the best ability to distinguish subbasins for the Marais des Cygnes and Walnut River Basins. In the Cimarron River Basin, good ability to distinguish subbasins was provided by the high, moderate, low, and very low potential-runoff conditions.

The major river basins having relatively high potential runoff were the Kansas-Lower Republican, Marais des Cygnes, Missouri, Neosho, Verdigris, and Walnut. These basins are located in eastern Kansas where soil permeability generally is less and precipitation typically is greater. The major river basins having relatively low potential runoff were the Cimarron, Lower Arkansas, Smoky Hill-Saline, Solomon, Upper Arkansas, and Upper Republican. These basins are located in western Kansas where soil permeability generally is higher and precipitation typically is less.

The ability to distinguish the subbasins as having relatively high or low potential runoff was possible mostly due to the variability of soil permeability across the State. Due to this variability, the subbasins had a wide range of potential contributing areas for infiltration-excess overland flow, particularly for very low potential-runoff conditions. In contrast, the topographic wetness index had a relatively uniform distribution across the State. Thus, the subbasins had a narrow range of potential contributing areas for saturation-excess overland flow. The results presented in Juracek (1999) provide an example of the relative importance of the two overland flow processes for estimating and comparing potential contributing areas within a basin.

Under low potential-runoff conditions characterized by low antecedent soil-moisture content and low rainfall intensity, potentially contributing areas for infiltration-excess and saturation-excess overland flows are limited to areas of lower soil permeability and saturated areas adjacent to rivers and streams, respectively (fig. 10). As antecedent soil-moisture content and rainfall intensity increase, the potential contributing areas for both infiltration-excess and saturation-excess overland flow processes increase. Under high potential-runoff conditions characterized by high antecedent soil-moisture content and high rainfall intensity, the distinction between infiltration-excess and saturation-excess overland flow becomes less meaningful as the ground becomes increasingly saturated and the potential contributing areas for both runoff processes coalesce (fig. 5).

This study had some limitations. First, the digital data sets used were only suitable for use in a comparison of areas hundreds of square miles in size. Thus, the analysis emphasized a comparison of potential runoff-contributing areas between, rather than within, individual subbasins. Improved results will be possible with more spatially detailed digital topographic and soil data sets. Such data sets are currently (1999) being developed and will include the U.S. Department of Agriculture's 1:24,000-scale soil survey geographic data base (SSURGO) and the USGS 30-m-resolution DEM. When available, these data sets will enable a comparison of potential contributing areas for areas tens of square miles in size. Then, a comparison of areas within individual subbasins will be possible. As a result, the spatial extent and pattern of potential contributing areas for infiltration- and saturation-excess overland flows will provide guidance for the implementation of BMP's within individual subbasins.

In addition, the estimation of potential runoff-contributing areas was limited in this study in that only topographic and soil characteristics were considered. The incorporation of additional factors such as land use and climatic variability may improve the results. For example, an overlay analysis to determine the location of cropland with respect to potential contributing areas may identify the most likely source areas of certain nonpoint-source pollutants within a subbasin. Such information may provide additional guidance for the targeting of BMP's.

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