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Vulnerability of Missouri groundwater to nitrate and pesticide contamination

Tony Prato and Chris Fulcher

Contents

Vulnerability of Missouri groundwater to nitrate and pesticide contamination

*Tony Prato and Chris Fulcher**

This report examines the vulnerability of Missouri groundwater to contamination from nitrogen fertilizers and pesticides applied to cropland. Previous assessments are reviewed and discrepencies between those reports and our findings are noted.

Evidence is mounting that beneficial uses of surface and/or groundwater resources are being impaired by the transport of sediment from agricultural and urban lands to lakes, streams and rivers; leaching of chemicals from agricultural and urban lands; inadequate and faulty systems for disposal of human, animal and hazardous wastes; leaks from underground storage tanks; rinsate from chemical application equipment; and other sources. The Environmental Protection Agency (EPA) has identified 74 pesticides in drinking water wells in 38 states (U.S. Environmental Protection Agency). Much of this pollution has been attributed to agriculture.

Despite limited knowledge regarding the health and environmental effects of water pollution, more restrictions are likely to be placed on the use of agricultural chemicals. Bills have already been introduced in Congress to encourage farmers to develop chemical management plans in areas experiencing water quality problems. In the Executive Branch, water quality has been elevated to a Presidential initiative.

In support of this initiative, the Soil Conservation Service and Extension Service are developing technical assistance and educational programs to assist farmers in managing agricultural chemicals and animal wastes. States have become more proactive in protecting water quality. For example, Iowa, Wisconsin and Illinois have a tax on fertilizers and chemicals. Connecticut and California have laws that hold farmers legally liable for misuse of chemicals.

Missouri has four major sources of agricultural water pollution. In northern Missouri, surface water impoundments that provide drinking water supplies and water-based recreation are being adversely affected by sediment from agricultural lands. Since the groundwater in northern Missouri's deep bedrock aquifers is unfit for most purposes (Missouri Dept. of Natural Resources), preventing harmful nitrate contamination of shallow aquifers that are a source of drinking water is a major groundwater

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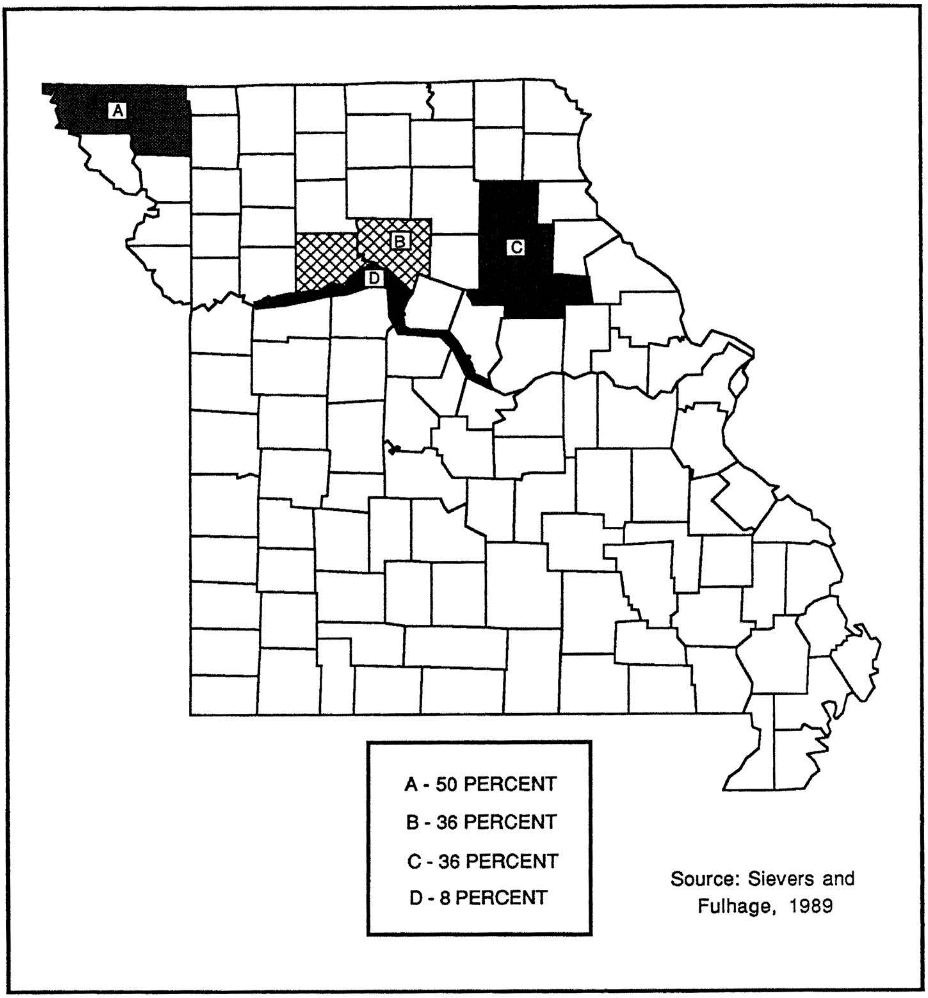
Figure 1. Percentage of test wells exceeding nitrate water standard.

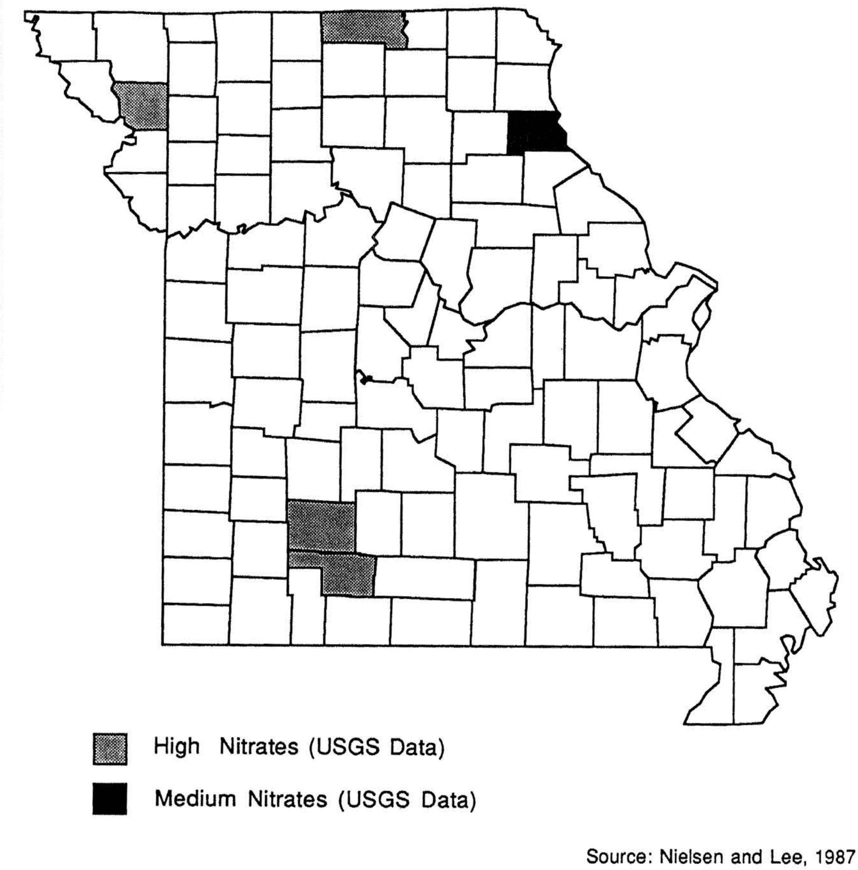


concern in northern Missouri. Land application of livestock and poultry wastes is the second source of water pollution. Contamination that occurs during the transportation and handling of agricultural chemicals is the third major source. Finally, intensive agricultural production and chemical use in areas with permeable soils, such as in Missouri's Bootheel region, constitute the fourth major source of water contamination.

Previous assessments

Portions of Missouri are experiencing groundwater contamination. Recently, water quality was tested in 101 private rural wells in four agricul-

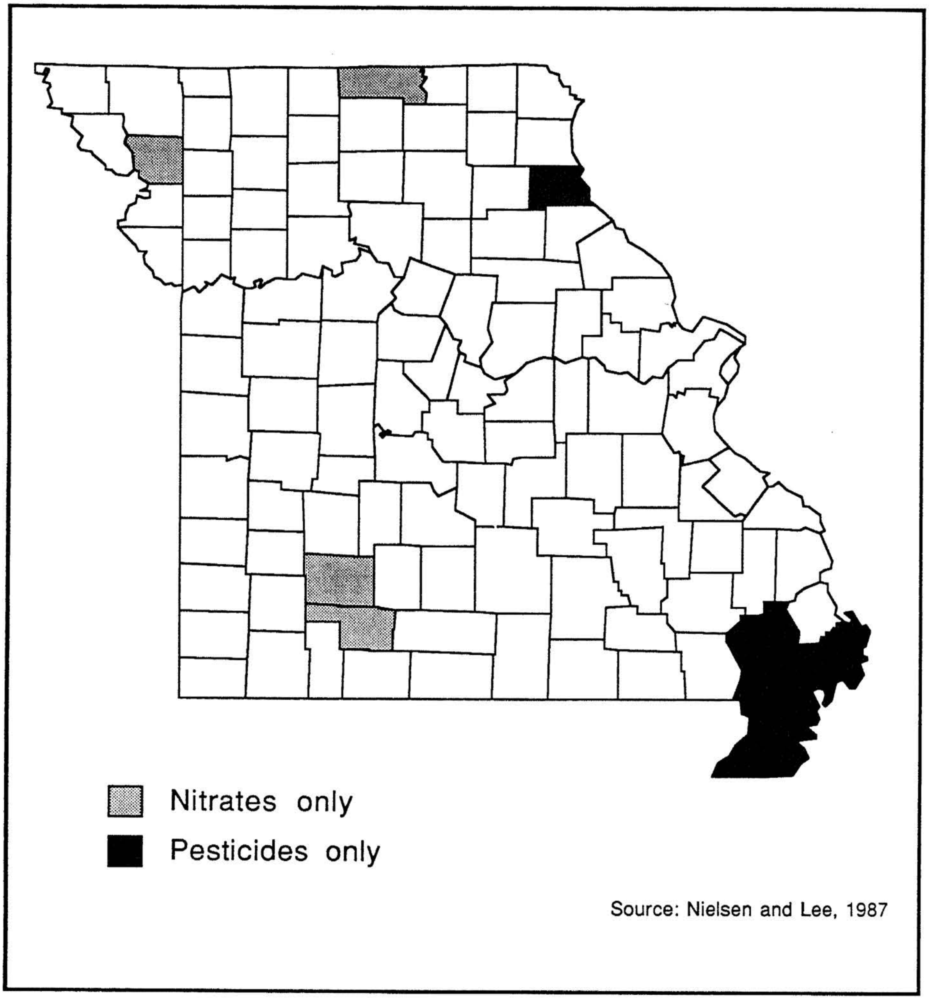
Figure 2. Nitrate levels in sampled wells.



tural regions of northern Missouri (Sievers and Fulhage). Each well was sampled four times per year (December, March, May and September). Results indicated that the percent of tested wells exceeding the safe drinking water standard for nitrate was about 8 percent in the alluvium region (D), 36 percent in the north central regions (B and C) and 50 percent in the northwest region (A) (Figure 1).

A nationwide study by Nielsen and Lee revealed several instances of nitrate contamination of groundwater in Missouri. Using USGS' WATSTORE data base, which contains nitrate concentrations in wells throughout the U.S., they identified two counties in northern Missouri and two

Figure 3. Potential nitrate and pesticide contamination in groundwater.



counties in southern Missouri in which 25 percent or more of the sampled wells had nitrate-nitrogen concentrations that exceeded 3 mg/l (Figure 2).[1]

More than 25 percent of the sampled wells in Marion county had nitrate-nitrogen levels that exceeded 10 mg/l, which is the safe drinking water standard established by EPA.

Nielsen and Lee also evaluated the potential for nitrate and pesticide contamination of groundwater by combining DRASTIC assessments done by Alexander et al. (1986) with estimated nitrogen and pesticide application rates. Dunklin county showed high vulnerability to nitrate contamina-

[1]This assessment by Nielsen and Lee excluded counties with little or no agriculture and fewer than five wells.

tion based on a DRASTIC assessment. Five counties in the Bootheel region of Missouri showed potential contamination from agricultural pesticides (Figure 3). While Nielsen and Lee found that all the counties in southern Iowa and many of the counties in northern Missouri had similar (medium or high) contamination from pesticides, the Missouri counties were found to have low pesticide use. Since southern Iowa and northern Missouri have similar soils and crops, Nielsen and Lee's finding is questionable.

DRASTIC Assessment

Groundwater vulnerability to nitrate and pesticide contamination was evaluated using the DRASTIC system and supporting data on DRASTIC factors obtained from the Economic Research Service, U.S. Department of Agriculture. The DRASTIC system was developed by the EPA to assess an area's relative vulnerability to groundwater contamination from either nitrates or pesticides (Aller et al.). A DRASTIC score is determined by taking a weighted average of seven DRASTIC factors:

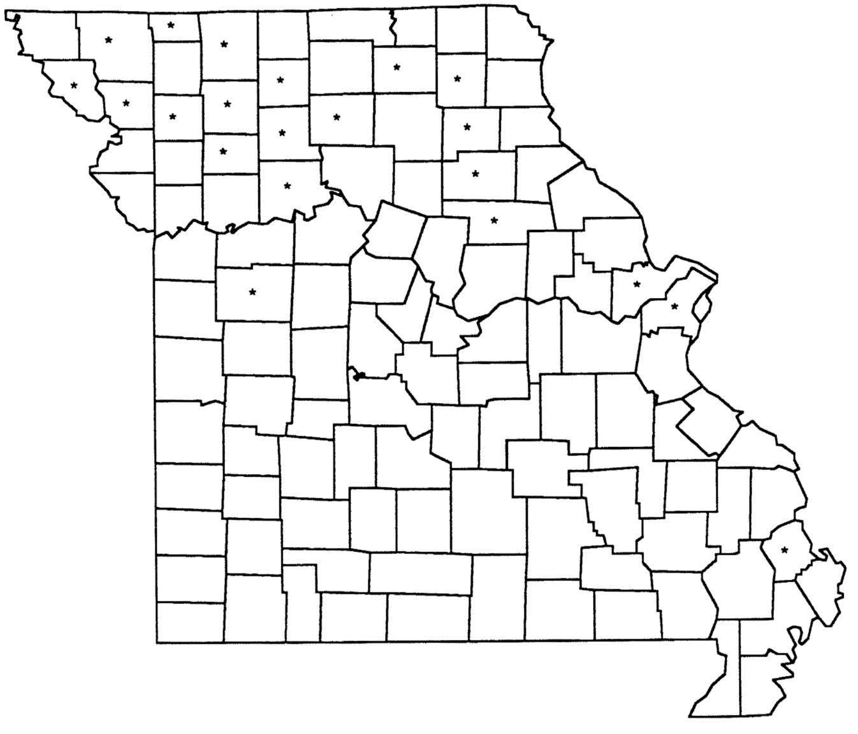
D = depth to water (5,5)
R = net recharge rate of aquifer (4,4)
A = aquifer media (3,3)
S = soil media (2,5)
T = topography (slope) (1,3)
I = impact of the vadose zone (5,4)
C = hydraulic conductivity of the aquifer (3,2)

The weight for the regular (RDRASTIC) index is the first term and the weight for the pesticide (PDRASTIC) index is the second term in parentheses following each DRASTIC factor. (See appendix for example.) These weights were determined by a consensus procedure. Weights are assumed to be constant across areas. Data for the D, R, A, I and C factors are county-wide weighted averages. Data for the S and T factors came from the 1982 National Resources Inventory (NRI) (U.S. Department of Agriculture, 1982). Although the NRI data base includes in excess of 10,000 primary sampling points for Missouri, not all counties have a sufficient number of sampling points for the data elements to be statistically reliable.

Figure 4 shows the counties in Missouri that have county reliable NRI data. NRI data is reliable for geographic regions known as Major Land Resource Areas (MLRAs). MLRAs are regions that are characterized by a particular pattern of soils, climate, water resources and land uses (U.S. Department of Agriculture, 1981). Missouri's nine MLRAs are shown in Figure 5. DRASTIC assessments, for this report, were done at the county and MLRA levels.

Developers of the DRASTIC system recommend that the regular DRASTIC index be used for nitrate assessments. The pesticide weights are for a generic pesticide. The higher the index, the greater an area's relative

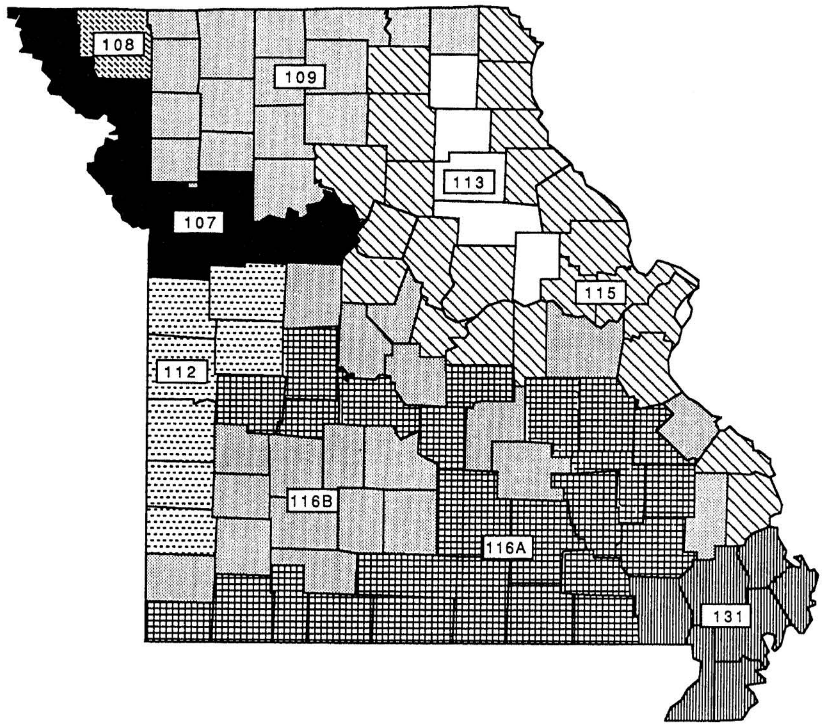
Figure 4. County reliable NRI data.



vulnerability to groundwater contamination. Since the DRASTIC scores can exaggerate the sensitivity of the index, the scores were grouped into three categories:

	RDRASTIC	PDRASTIC
Low	<89	<107
Medium	89-121	107-147
High	>121	>147

Figure 5. Major land resource areas.

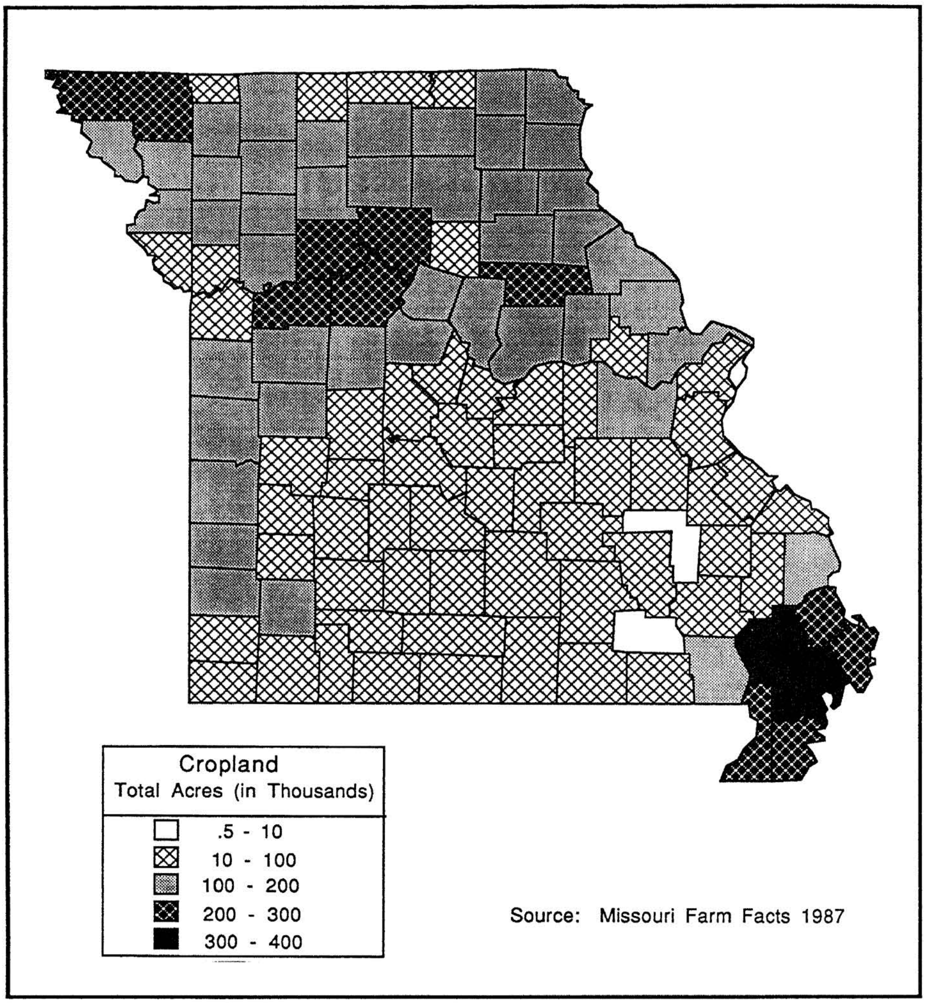


Source: USDA, 1981

These are the same ranges used by Nielsen and Lee. Choosing a relatively large medium category reduces the risk of classifying a highly vulnerable area as having low vulnerability and vice versa (Crutchfield and Algozin). County average DRASTIC factors and scores are given in the Appendix.

A high DRASTIC score indicates that the hydrogeologic conditions in an area are such that there is a high likelihood that fertilizers and pesticides will leach to groundwater. Using fertilizers and pesticides in areas having high DRASTIC scores is more likely to result in groundwater contamination than in areas having moderate DRASTIC scores, other things equal. A

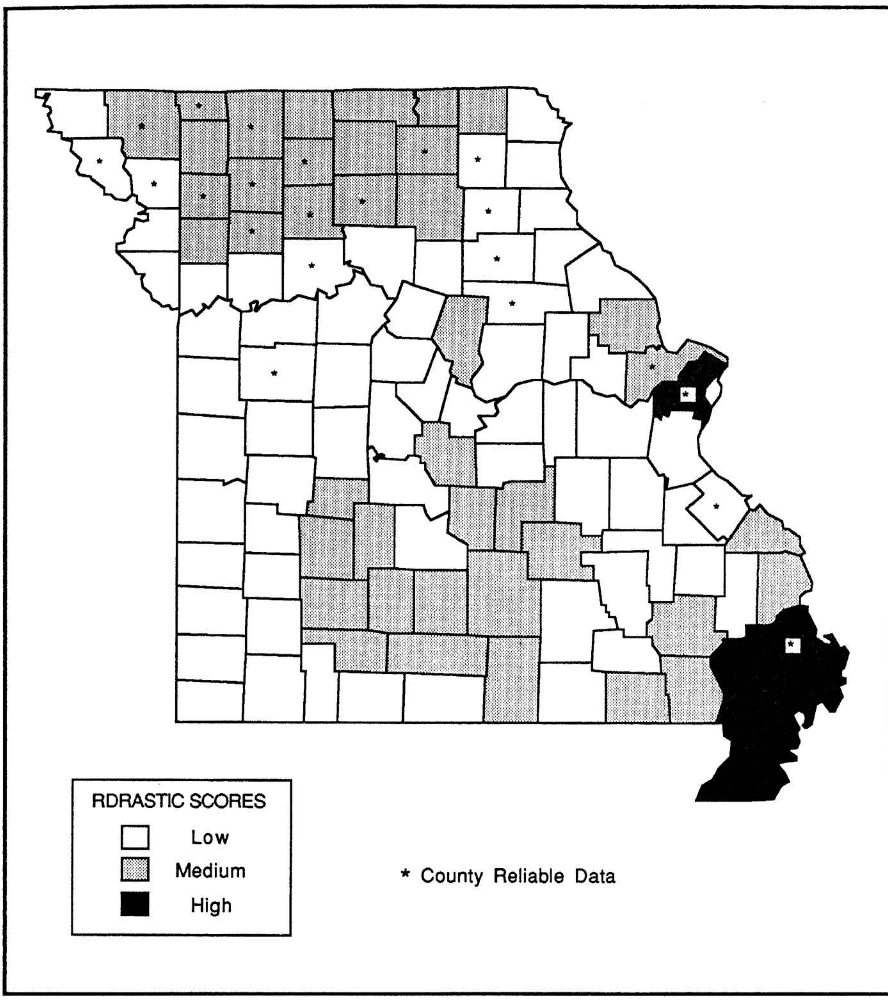
Figure 6. 1987 cropland acreage.



low or moderate average countywide score does not preclude subcounty areas from having high DRASTIC scores. For example, the alluvial areas in counties bordering the Missouri River may be highly vulnerable to groundwater contamination. However, if a major portion of the county has low or moderate vulnerability, then the average county score is unlikely to be high.

Since this study is concerned with groundwater vulnerability in areas with heavy cropland application of nitrogen fertilizers and pesticides, DRASTIC scores should be evaluated for counties having moderate to high application of nitrogen fertilizers and pesticides. Fertilizer data are available at the county level. However, there is no data base on pesticide use in

Figure 7. Regular DRASTIC scores.

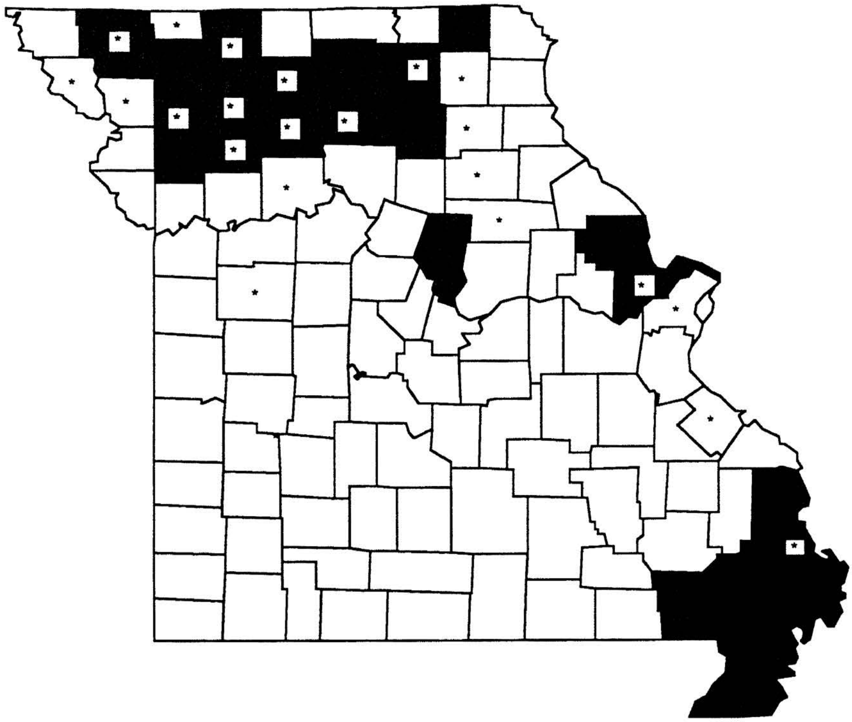


Missouri. For this reason, acreage was used as a proxy for fertilizer and pesticide use. In particular, DRASTIC scores were compared for counties having more than 100,000 acres of cropland in 1987 (Figure 6). Acreage is a good proxy for fertilizer use because of their high correlation (0.91).

Results of DRASTIC Assessment

County-level nitrate assessment. Figure 7 depicts the counties having low, medium and high RDRASTIC scores. Only St. Louis county and the six counties in the Bootheel region had high RDRASTIC scores. Twenty-one counties north of the Missouri River (northern counties) and 19 counties south of the Missouri River (southern counties) had medium RDRASTIC

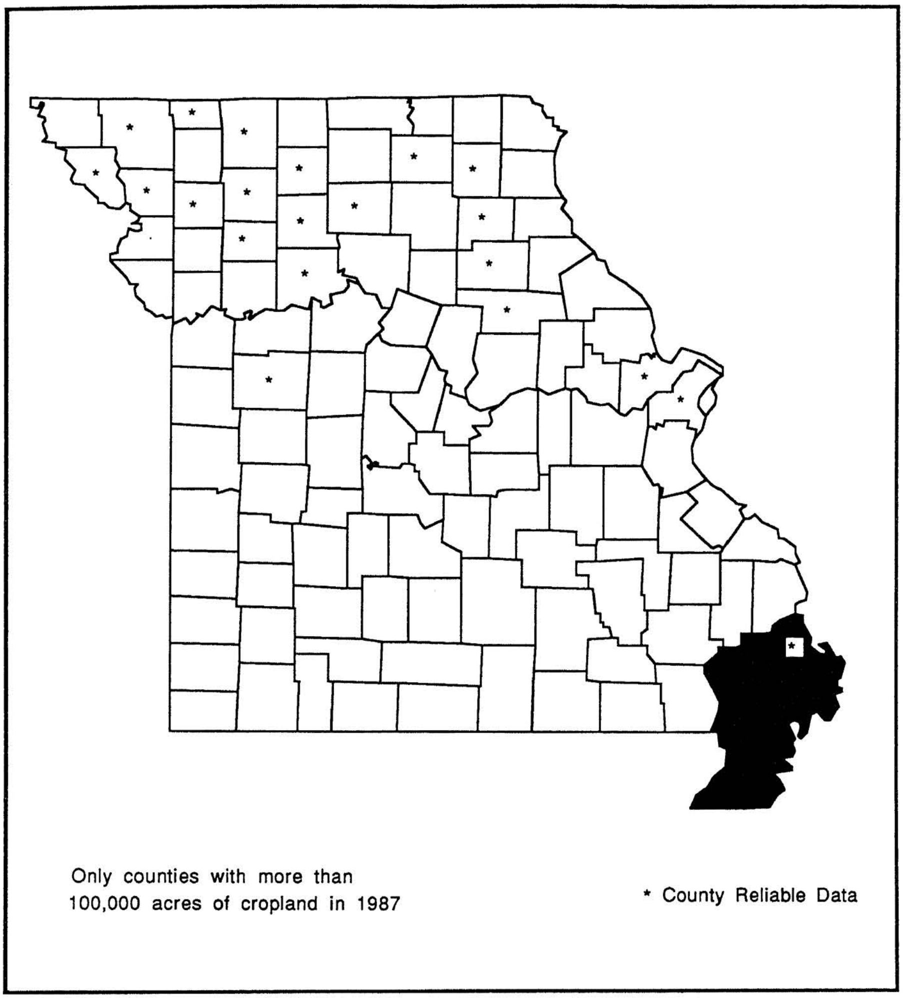
Figure 8. Medium RDRASTIC and PDRASTIC scores.



scores. Counties with at least 100,000 acres of cropland and a medium or high RDRASTIC score are shown in Figures 8 and 9, respectively. Seventeen northern counties and seven counties in the Bootheel region had medium RDRASTIC scores. Only six counties in the Bootheel region had high RDRASTIC scores.

County-level pesticide assessment. Twenty-two northern counties and 16 southern counties had medium PDRASTIC scores (Figure 10). Except for Randolph county, the same northern counties had medium RDRASTIC and medium PDRASTIC scores. With few exceptions, counties with medium RDRASTIC scores had medium PDRASTIC scores. Only five counties in the Bootheel region had high PDRASTIC scores. Counties that had more

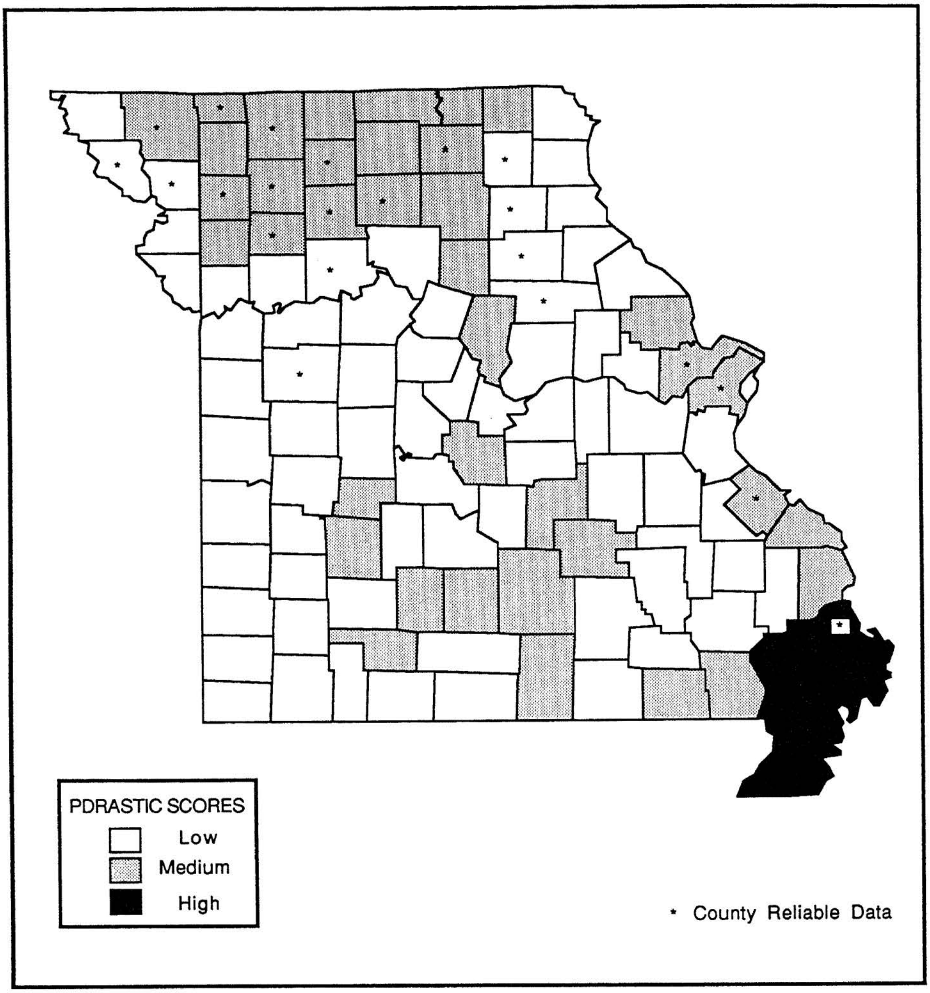
Figure 9. High RDRASTIC and PDRASTIC scores.



than 100,000 acres of cropland and medium or high PDRASTIC scores are the same counties as identified in the RDRASTIC assessment (Figures 8 and 9).

MLRA assessment. Of Missouri's nine MLRAs, two northern MLRAs (108 and 109) had medium RDRASTIC and PDRASTIC scores and one southern MLRA (131) had high RDRASTIC and PDRASTIC scores (Figure 11). Although St. Charles, Lincoln and Boone counties had medium RDRASTIC and PDRASTIC scores and cropland acreage in excess of 100,000 acres, the combined area of these three counties is too small relative to the size of MLRA 115 to result in a medium or high DRASTIC score for this MLRA.

Figure 10. Pesticide DRASTIC scores.



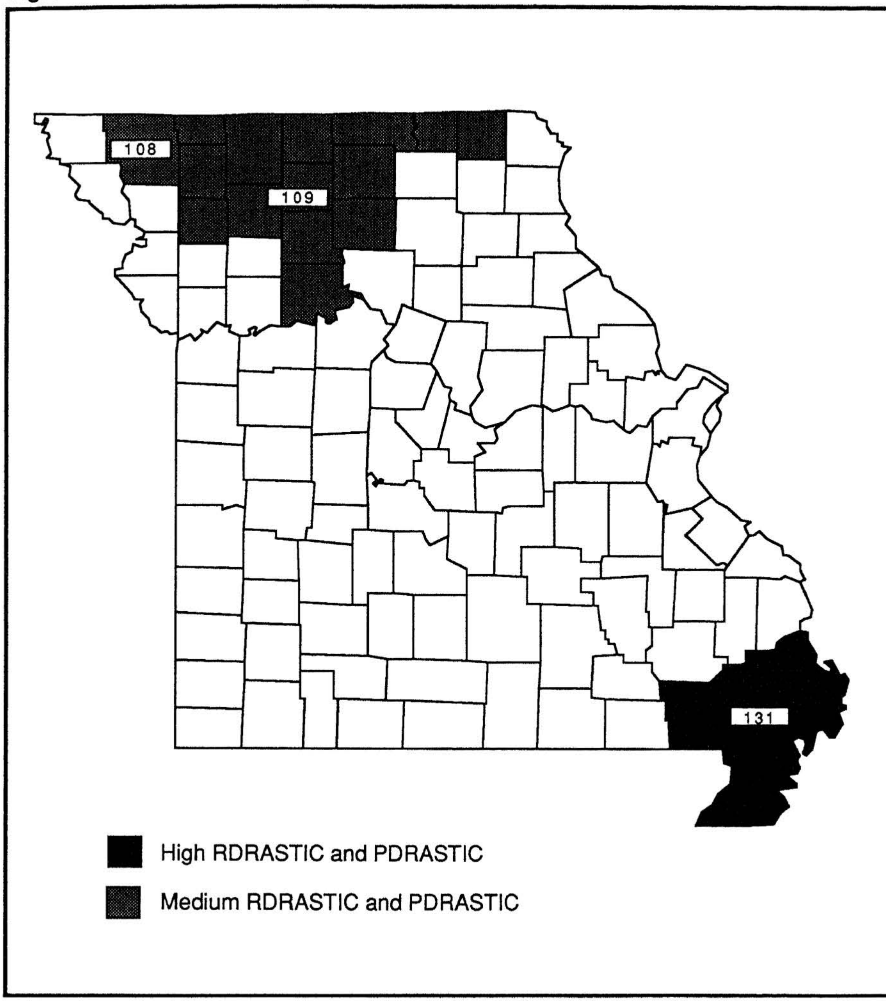
Conclusions

This report supports several conclusions regarding the vulnerability of Missouri's groundwater to nitrate and pesticide contamination:

1. The high RDRASTIC scores combined with results from Nielsen and Lee's study indicate that groundwater in the Bootheel region is highly susceptible to nitrate contamination. Despite this high potential, data published by the U.S. Geological Survey indicate that nitrate concentrations in the Bootheel region are considerably below the drinking water standard.

2. Since 17 of the 36 counties in northern Missouri with cropland acreage in excess of 100,000 acres have medium RDRASTIC scores and ele-

Figure 11. DRASTIC scores by MLRAs.



vated nitrate levels have been detected in one-third of the agricultural wells tested in this region, portions of northern Missouri have moderate potential for nitrate contamination of groundwater from agricultural sources.

3. Since 21 of the 50 counties in southern Missouri with cropland acreage in excess of 100,000 acres have medium PDRASTIC scores, portions of southern Missouri have moderate potential for pesticide contamination of groundwater from agricultural sources.

4. The high PDRASTIC scores for the Bootheel region imply that groundwater in this region has a high potential for pesticide contamination.

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Appendix

Average DRASTIC factors and scores for Missouri counties

Example: Figuring RDRASTIC and PDRASTIC scores for Adair County. Use weights from page 5.

Adair County RDRASTIC score = 6.80(5) + 1.00(4) + 7.67(3) + 2.20(2) + 9.33(1) + 2.00(5) + 1.50(3) = 89

Adair County PDRASTIC score = 6.80(5) + 1.00(4) + 7.67(3) + 2.20(5) + 9.33(3) + 2.00(4) + 1.50(2) = 111

COUNTY	D	R	A	S	T	I	C	RDRASTIC	PDRASTIC
ADAIR	6.80	1.00	7.67	2.20	9.33	2.00	1.50	89	111
ANDREW	2.60	1.00	6.67	3.60	9.33	3.00	3.50	79	102
ATCHISON	2.20	1.00	6.67	3.40	9.00	2.75	2.50	72	95
AUDRAIN	1.00	1.00	6.33	1.40	9.67	1.00	1.00	49	70
BARRY	1.00	1.00	6.00	2.60	5.00	6.00	1.00	70	81
BARTON	1.40	0.75	6.00	4.00	8.67	6.00	1.00	78	100
BATES	1.60	1.00	6.33	4.40	8.67	4.25	1.50	74	99
BENTON	1.60	1.00	6.33	3.20	8.00	6.25	1.00	80	98
BOLLINGER	1.40	1.00	6.00	4.60	7.67	6.00	1.50	80	102
BOONE	1.40	1.00	8.33	5.20	8.33	8.25	2.50	104	125
BUCHANAN	2.00	1.00	6.67	3.80	8.00	4.75	3.00	82	102
BUTLER	5.60	1.00	7.00	5.00	8.67	6.00	5.00	117	138
CALDWELL	6.80	1.00	7.67	3.60	9.67	2.00	1.50	92	119
CALLAWAY	1.60	1.00	6.33	3.80	8.00	3.25	1.50	67	90
CAMDEN	1.00	1.00	8.33	1.80	5.33	8.50	1.00	88	95
CAPE GIRARD.	6.00	1.00	7.00	4.20	8.33	6.75	2.00	112	132
CARROLL	2.20	1.00	6.67	4.20	9.33	2.25	2.00	70	97
CARTER	0.80	1.00	6.00	3.80	5.00	6.00	1.00	72	86
CASS	2.00	1.00	4.33	3.40	8.33	4.75	1.50	70	91
CEDAR	1.00	1.00	6.00	3.20	8.67	6.00	1.00	75	95
CHARITON	2.60	1.00	6.67	4.00	9.67	2.25	2.00	72	99
CHRISTIAN	1.00	1.00	8.67	2.80	8.33	8.75	1.00	96	111
CLARK	1.80	1.00	6.33	4.00	9.33	2.00	1.50	64	91

COUNTY	D	R	A	S	T	I	C	RDRASTIC	PDRASTIC
CLAY	2.00	0.75	6.67	4.20	9.00	4.00	2.50	78	102
CLINTON	6.80	1.00	7.67	4.20	9.67	2.00	1.00	92	121
COLE	1.40	1.00	6.33	3.40	7.67	6.00	1.00	78	96
COOPER	1.20	1.00	6.67	3.40	9.67	5.50	1.00	77	100
CRAWFORD	1.00	1.00	6.00	3.60	9.00	6.00	1.00	76	98
DADE	1.00	1.00	5.67	3.20	7.67	5.75	1.00	72	90
DALLAS	2.20	1.00	6.67	3.20	8.33	6.75	2.00	90	107
DAVIESS	6.80	1.00	7.67	3.80	7.67	2.00	1.50	91	114
DE KALB	6.80	1.00	7.67	3.00	9.67	2.00	1.50	91	116
DENT	2.00	1.00	8.33	3.20	7.67	8.25	3.50	105	118
DOUGLAS	2.40	1.00	7.33	3.20	5.33	7.25	2.50	94	104
DUNKLIN	7.40	1.00	8.00	4.20	10.00	6.00	8.00	137	156
FRANKLIN	1.40	1.00	6.33	3.20	5.67	6.25	1.00	76	90
GASCONADE	1.40	1.00	6.33	3.20	5.33	6.25	1.00	76	89
GENTRY	6.80	1.00	7.67	3.80	10.00	2.00	2.00	95	122
GREENE	1.00	1.00	8.00	2.80	8.67	8.00	1.00	90	107
GRUNDY	6.80	1.00	7.67	3.20	9.00	2.00	2.00	92	116
HARRISON	6.80	1.00	7.67	3.80	9.33	2.00	2.00	94	120
HENRY	3.80	1.00	6.67	3.60	8.67	4.00	1.00	82	105
HICKORY	2.20	1.00	7.33	3.40	7.67	7.25	2.50	95	111
HOLT	3.40	1.00	6.67	4.00	8.33	3.00	4.00	84	106
HOWARD	2.00	1.00	6.33	4.00	8.33	3.25	1.50	70	94
HOWELL	2.20	1.00	8.33	3.00	6.67	8.00	3.50	103	114
IRON	1.00	1.00	5.33	3.60	4.33	5.50	1.00	67	80
JACKSON	2.20	1.00	6.33	3.80	5.67	6.50	2.00	86	100
JASPER	2.00	1.00	6.33	4.00	7.67	5.50	3.50	87	105
JEFFERSON	2.40	1.00	6.33	3.20	5.67	6.00	1.50	82	95
JOHNSON	1.00	1.00	6.33	3.20	9.00	5.00	1.00	71	93
KNOX	6.80	1.00	7.67	1.80	8.33	2.00	1.00	86	105
LACLEDE	1.00	1.00	6.67	2.20	7.67	6.75	1.00	78	92
LAFAYETTE	1.60	1.00	6.33	5.00	9.00	1.50	1.50	62	92
LAWRENCE	1.00	1.00	5.67	3.20	8.67	5.75	1.00	73	93
LEWIS	1.80	1.00	6.33	4.00	9.33	2.00	1.50	64	91
LINCOLN	1.80	1.00	8.33	3.60	8.00	8.00	3.50	104	119

COUNTY	D	R	A	S	T	I	C	RDRASTIC	PDRASTIC
LINN	6.80	1.00	7.67	4.00	9.33	2.00	1.50	93	120
LIVINGSTON	6.80	1.00	7.67	3.80	9.33	2.00	2.50	95	121
MACON	6.80	1.00	7.67	2.00	9.67	2.00	1.50	89	111
MADISON	1.00	1.00	5.00	3.20	5.00	5.50	1.00	66	79
MARIES	1.00	1.00	6.00	2.40	8.00	6.00	1.00	73	89
MARION	2.20	1.00	6.67	3.40	8.67	2.75	2.00	70	93
MCDONALD	1.80	1.00	5.67	4.80	5.67	6.00	3.50	86	102
MERCER	6.80	1.00	7.67	4.00	8.00	2.00	2.50	95	118
MILLER	2.20	1.00	7.67	2.20	8.33	7.75	3.00	99	111
MISSISSIPPI	8.00	1.00	8.00	3.80	10.00	6.00	8.00	140	157
MONITEAU	1.80	1.00	6.33	3.00	8.33	4.75	1.00	73	93
MONROE	6.80	1.00	7.67	1.40	8.33	2.00	1.50	87	104
MONTGOMERY	1.60	1.00	6.33	3.40	8.00	3.25	1.50	67	88
MORGAN	2.00	1.00	6.33	3.20	7.67	6.25	1.50	83	100
NEW MADRID	7.80	1.00	8.00	3.80	10.00	6.00	8.00	139	156
NEWTON	1.60	1.00	6.00	4.80	6.67	6.00	3.50	87	105
NODAWAY	6.80	1.00	7.67	3.40	9.00	2.00	2.00	93	117
OREGON	1.00	1.00	6.00	3.00	9.00	6.00	1.00	75	95
OSAGE	1.60	1.00	6.33	3.40	6.67	6.00	1.00	78	94
OZARK	1.80	1.00	6.67	3.20	5.00	6.50	2.00	83	94
PEMISCOT	7.60	1.00	8.00	2.40	10.00	6.00	8.00	135	148
PERRY	1.60	1.00	8.00	5.00	6.00	7.75	8.00	115	126
PETTIS	1.20	1.00	6.00	3.40	7.67	5.00	1.00	71	90
PHELPS	2.20	1.00	7.33	3.80	7.33	7.25	2.50	96	112
PIKE	1.60	1.00	6.33	2.80	8.00	4.25	1.50	70	89
PLATTE	2.60	1.00	6.67	4.20	8.67	4.25	2.00	81	105
POLK	5.00	1.00	7.33	3.20	9.33	7.25	2.50	111	129
PULASKI	2.20	1.00	6.67	3.80	5.33	6.50	3.50	91	103
PUTNAM	6.80	1.00	7.67	3.60	8.00	2.00	2.00	92	115
RALLS	1.80	1.00	6.67	2.20	8.67	2.75	2.50	67	86
RANDOLPH	6.80	1.00	7.67	2.00	9.33	2.00	1.50	88	110
RAY	2.20	1.00	6.67	4.20	8.67	2.75	2.00	72	97
REYNOLDS	1.00	1.00	7.67	3.00	5.00	7.75	1.00	85	95
RIPLEY	4.20	1.00	6.33	5.00	7.33	6.00	1.50	96	118
SALINE	3.00	1.00	6.33	4.60	9.33	3.25	1.50	77	105

COUNTY	D	R	A	S	T	I	C	RDRASTIC	PDRASTIC
SCHUYLER	6.80	1.00	7.67	2.40	9.67	2.00	1.50	90	113
SCOTLAND	6.80	1.00	7.67	4.00	8.67	2.00	1.50	92	118
SCOTT	6.20	1.00	7.67	4.40	9.00	6.00	8.00	130	147
SHANNON	1.00	1.00	6.67	4.00	4.67	6.75	1.00	78	92
SHELBY	6.80	1.00	7.67	1.80	8.33	2.00	1.50	87	106
ST CHARLES	2.40	1.00	6.67	4.60	8.67	7.50	2.50	99	120
ST CLAIR	1.00	1.00	6.00	2.80	8.67	6.00	1.00	74	93
ST FRANCOIS	2.00	1.00	5.67	6.40	4.00	6.00	1.00	81	101
ST LOUIS	8.00	1.00	7.00	4.00	9.00	6.50	3.50	125	145
STE GENEV.	2.60	1.00	6.67	5.40	5.33	6.50	1.00	88	108
STODDARD	7.00	1.00	7.33	4.60	9.67	6.00	8.00	134	153
STONE	1.00	1.00	7.33	2.80	4.67	7.50	1.00	82	91
SULLIVAN	6.80	1.00	7.67	3.20	8.33	2.00	1.50	90	113
TANEY	1.00	1.00	6.67	2.80	4.67	6.75	1.00	76	86
TEXAS	2.20	1.00	7.67	3.00	5.33	7.50	3.00	106	115
VERNON	2.00	1.00	4.67	4.00	8.33	5.00	1.50	74	96
WARREN	2.00	1.00	6.33	3.80	8.00	3.75	1.50	72	94
WASHINGTON	2.20	1.00	6.00	3.20	6.67	6.00	2.00	82	97
WAYNE	2.20	1.00	7.00	4.00	5.67	7.00	2.50	92	106
WEBSTER	2.40	1.00	7.67	3.00	8.00	7.75	4.00	114	127
WORTH	6.80	1.00	7.67	2.40	10.00	2.00	2.00	92	115
WRIGHT	2.00	1.00	8.00	4.00	6.33	8.00	3.50	111	124