1996

Regional Analysis of Rural Domestic Well-water Quality – Southern Panhandle Tablelands

D. C. Gosselin
University of Nebraska - Lincoln

J. Headrick

X- H. Chen

S. E. Summerside

GIM-108

Rural Domestic Well-water Quality in the *Southern Panhandle Tablelands*

Groundwater Region 7 from *Domestic Water-well Quality in Rural Nebraska*
(A data-analysis report for the Nebraska Department of Health compiled by D. C. Gosselin and others, 1996)

Geology and Hydrogeology

Groundwater Region 7 occupies the area south of the North Platte River in the Nebraska Panhandle (Figure 1). The base of the principal groundwater-bearing units is generally the Brule Formation, composed of relatively impermeable siltstone interbedded with thin layers of claystone and locally with beds of sand and gravel. The Arikaree Group overlies the Brule and consists of up to 600 feet of interlayered fine sandstone and siltstone in which there are local occurrences of uncemented sand and gravel. Overlying the Arikaree Group is the Ogallala Group, composed of up to 500 feet of interbedded clays, silts, sands, sandstones, and gravel with various degrees of cementation. The Ogallala Group generally occurs as channel deposits trending west to east. Overlying the Ogallala Group is Quaternary alluvium consisting of unconsolidated sands and gravel and generally less than 100 feet thick. (Geologic cross sections of Region 7 are available at the Conservation and Survey Division; Figure 1.)

The most widespread groundwater-bearing unit is the Ogallala Group (Table 1). The alluvium along the major drainages is also very important. The Arikaree Group was largely removed by erosion prior to the deposition of the Ogallala Group and is not as important as the other groundwater reservoirs. Fracture zones and possibly pseudokarst have created significant secondary permeability in localized areas in the valleys of Lodgepole and Pumpkin creeks. Most of these secondary permeability zones are fairly shallow, highly permeable and can yield high volumes of groundwater. The thicknesses of the saturated groundwater-bearing units are generally less than 300 feet. Depth to the regional water table differs with topographic location. In upland areas, depth to water may be about 200 feet or more, whereas it may be about 50 feet or less beneath the bottomlands in the principal valleys. The groundwater generally contains between 200 and 500 parts per million (ppm) total dissolved solids, except along the North Platte Valley, where total dissolved solids range from about 500 to 1,000 ppm.

Results*

Well Characteristics

Characteristics of the wells in the 1994-1995 study are summarized in Table GW7.1. The average year of installation was 1960; less than 50 percent of the wells were installed between 1960 and 1979. The oldest well was installed in 1900. Available information indicates 108 of 109 wells were drilled. Steel or PVC casing was used in more than 96 percent of the wells; only 65 percent had sanitary seals. The depth of the wells averaged 210 feet and ranged from 20 to 550 feet. Fifty-four percent of the wells had depths greater than 200 feet. Of the 108 wells for which information is available, the average well diameter is 5 inches; 64 percent have diameters between 4 and 5 inches. The minimum diameter was 3 inches, and the maximum was 26 inches. Each well is used by an average of 3 individuals. Nitrate was used at nearly 77 percent of the 111 sites. Pesticides were used at 67 percent of the sites.

Nitrates

Nitrate data for the 111 wells sampled during the 1994-1995 study are summarized in Table GW7.1. Their locations are shown in Figure GW7.1. The nitrate-nitrogen concentrations ranged from less than 0.1 ppm to a maximum of 42.1 ppm. Nearly 48 percent of the wells had concentrations less than 3 ppm (Figure GW7.2), indicating that the other 52 percent have been affected by nitrate contamination. Only 6.3 percent of the wells exceeded the 10-ppm maximum contaminant level (mcl) for nitrate. The average value for all samples is 4.5 ppm with a median value of 3.1 ppm.

Figure GW7.2 shows a nearly 3-percent increase in wells with nitrate-nitrogen concentrations less than 3 ppm and a nearly 4-percent decrease in wells with nitrate-nitrogen greater than 10 ppm from 1985-1989 to 1994-

---

** Where associations, relationships, increases or decreases are discussed, our analyses have determined they are statistically significant. If the relationship between contaminant concentrations and various factors are not discussed, they have not been demonstrated to be statistically significant.*

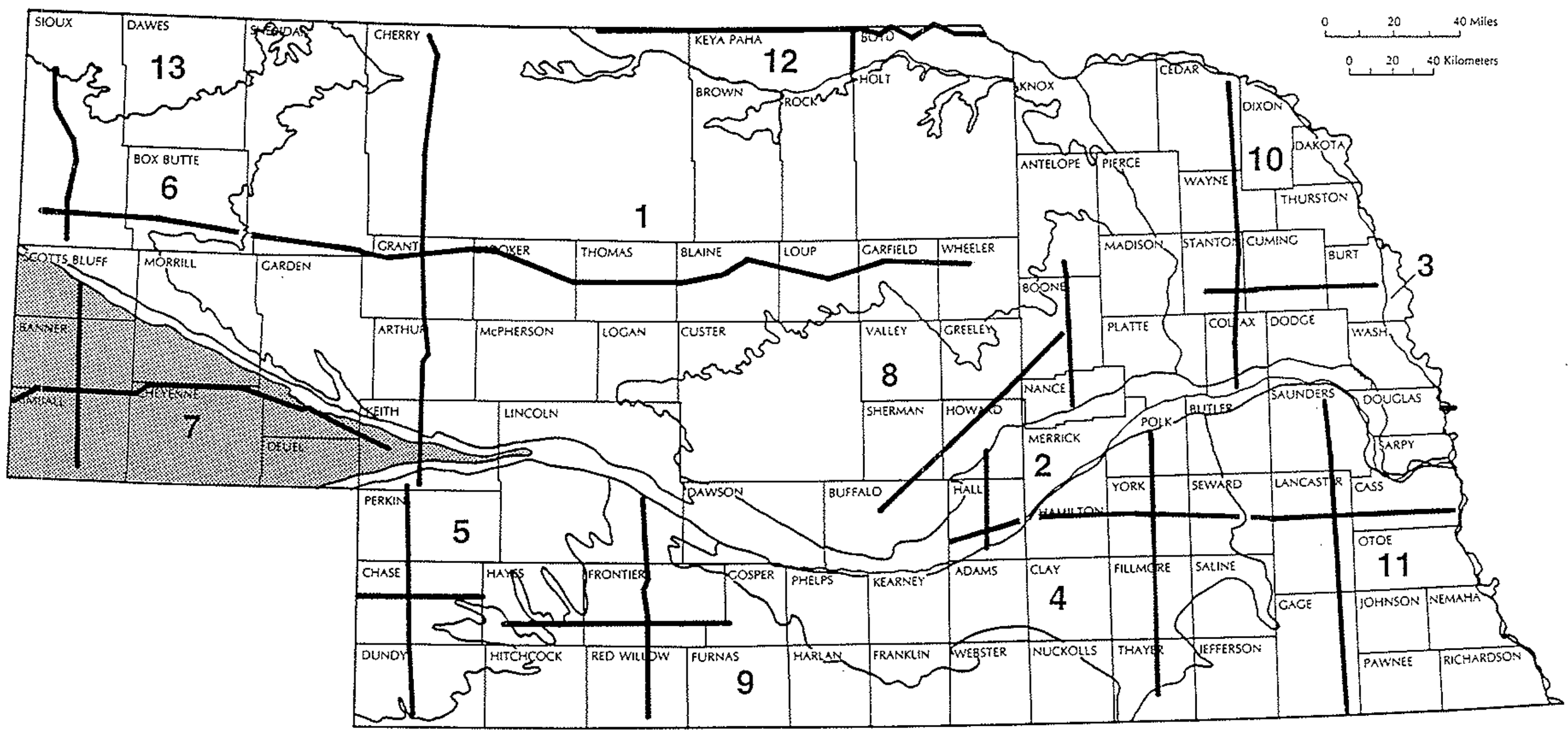


Fig. 1—*Locations of geologic cross sections* (Region 7 in gray)

Water-bearing Properties of Major Rock Units in Nebraska

From *The Groundwater Atlas of Nebraska* — Conservation and Survey Division, University of Nebraska-Lincoln

Era	Period	Epoch	Millions of years	Group or Formation	Lithology	Water-bearing Properties
Cenozoic	Quaternary	Holocene	0.01		Sand, silt, gravel and clay	Principal groundwater reservoir; Ogallala is absent in east and northwest. Arikaree is present primarily in west.
		Pleistocene	~2.0			
		Pliocene	5		Sand, gravel and silt	
		Miocene	24	Ogallala	Sand, sandstone, siltstone and some gravel	
		Oligocene		Arikaree	Sandstone and siltstone	
			37	White River	Siltstone, sandstone and clay in lower part	Secondary aquifer in west; water may be highly mineralized.
		Eocene	58	Rocks of this age are not identified in Nebraska.		
		Paleocene	67			
Mesozoic	Cretaceous	Late Cretaceous		Lance	Sandstone and siltstone	Generally not an aquifer; yields water to few wells in west.
				Fox Hills		
				Pierre	Shale and some sandstone in west	Generally not an aquifer; sandstones in west yield highly mineralized water to few industrial wells.
				Niobrara	Shaly chalk and limestone	Secondary aquifer where fractured and at shallow depths, primarily in east.
				Carlile	Shale; in some areas contains sandstones in upper part	Generally not an aquifer; sandstones yield water to few wells in northeast.
			98	Greenhorn-Graneros	Limestone and shale	Generally not an aquifer, yields water to few wells in east.
		Early Cretaceous	144	Dakota	Sandstone and shale	Secondary aquifer, primarily in east; water may be highly mineralized.
	Jurassic		208		Siltstone and some sandstone	Not an aquifer
	Triassic		245		Siltstone	Not an aquifer
Paleozoic	Permian		286		Limestone, dolomites, shales and sandstone.	Some sandstone, limestone and dolomites are secondary aquifers in east. Water may be highly mineralized.
	Pennsylvanian		320			
	Mississippian		360			
	Devonian		408			
	Silurian		438			
	Ordovician		505			
	Cambrian		570			
Precambrian						

Table 1—Hydrostratigraphic chart (showing water-bearing rock units) of Nebraska
Time divisions are not to scale.

Table GW7.1. Summary of Domestic Well Characteristics and Water Quality Data (1994-95)

Well characteristics

	Number of wells	Mean	Minimum	Maximum	Standard deviation
Well Installation Date					
All	98	1960	1900	1987	22
<1940	16				
1940-1969	19				
1960-1979	48				
1980-present	15				
Well Depth (feet)					
All	97	210	20	550	117
<50	4				
50-99	16				
100-199	25				
>200	52				
Well Diameter (inches)					
All	108	5.0	3	26	2.7
<2	0				
2-3	8				
4-5	69				
6-7	27				
>8	4				
Number of Well Users	109	3.0	0	9	1.7
Distance to Contaminant Source (feet):					
cesspool	21	215	45	550	135
septic	107	192	25	1300	217
waste lagoon	4	1038	150	2300	976
barnyard	83	265	5	2600	472
pasture land	81	789	2	5200	1088
cropland	108	435	10	3900	579
Well Type:					
drilled	108				
driven	1				
dug	0				
other	0				
Casing Material:					
steel	59				
plastic	43				
concrete	0				
brick	0				
tile	0				
other	4				
Sanitary Seal:					
yes	69				
no	37				
Casing in Pit:					
yes	52				
no	59				
Nitrate Used:					
yes	85				
no	26				
Pesticide Used:					
yes	74				
no	36				

Water Quality Data

	Number of wells	Mean	Median	Minimum	Maximum	Standard deviation	Detections
Nitrate as Nitrogen (ppm NO3-N)							
1994-1995	111	4.5	3.1	0.1	42.1	5.6	
Bacteria (colonies per 100 ml)							
1994-1995	101			0	100		14
Pesticides (ppb)							
1994-1995							
Atrazine	112			0	0.3		1

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Locations - Region #7

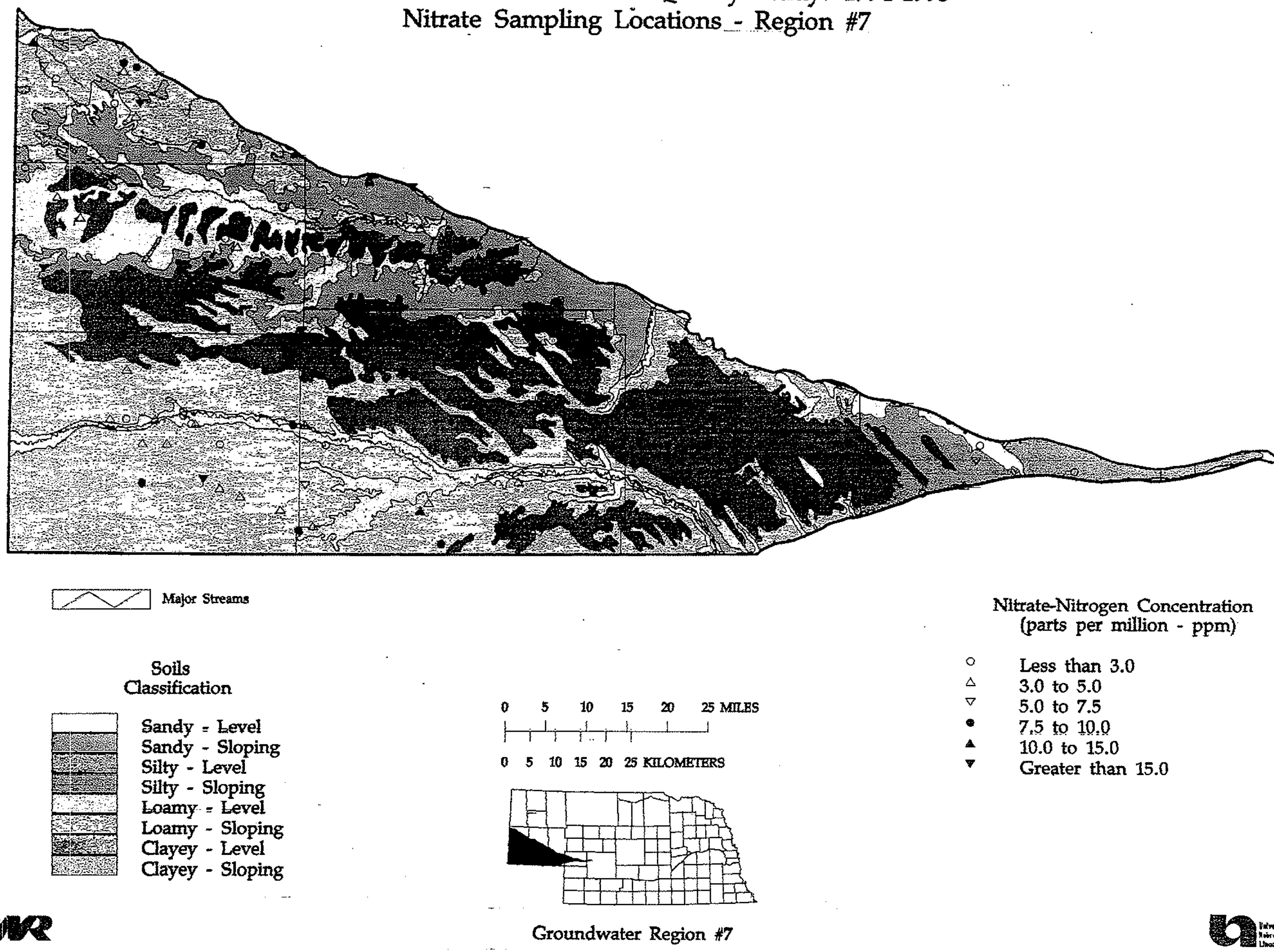
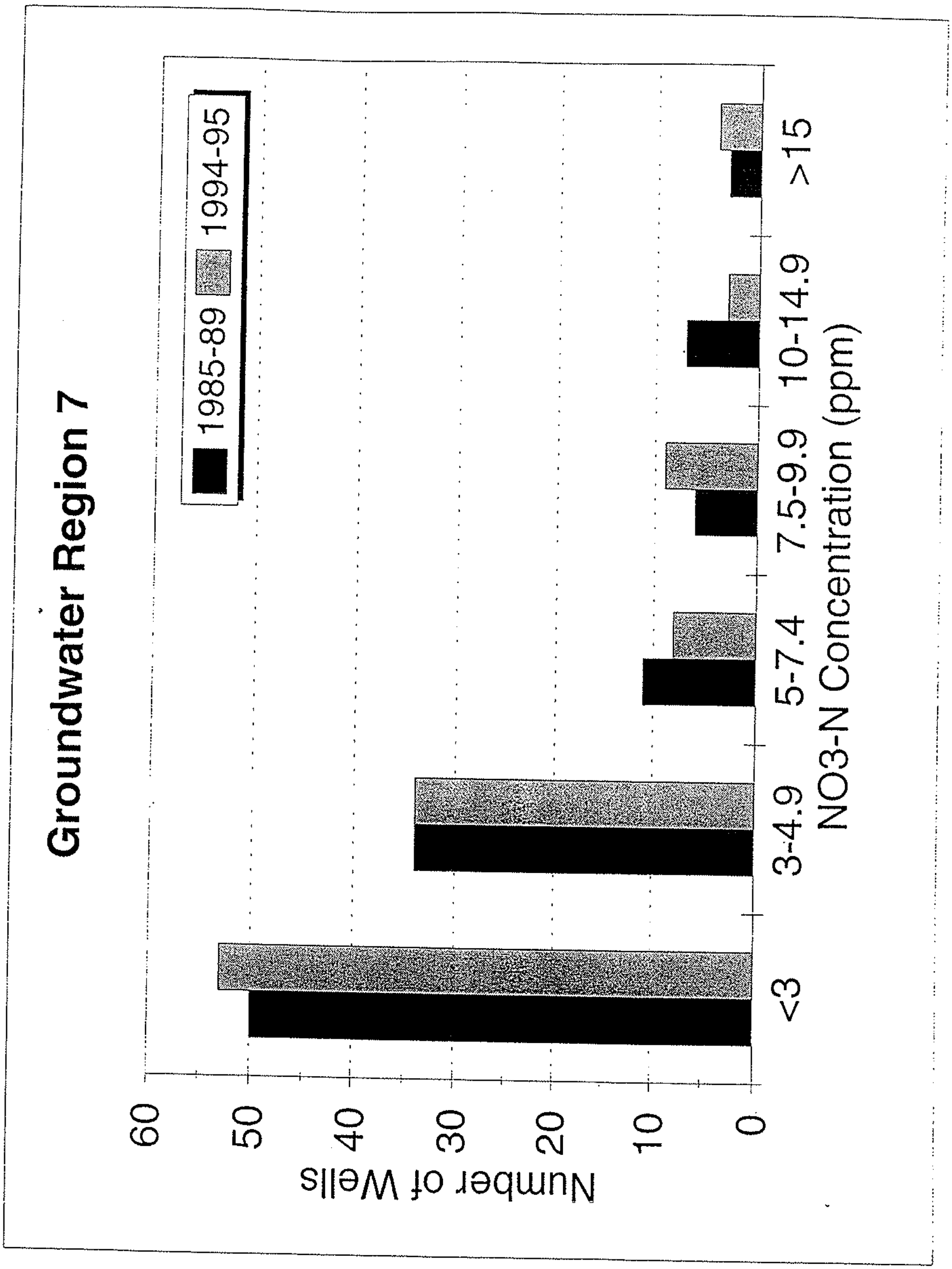


Figure GW7.1



Groundwater Region 7
1985-89
1994-95
Number of Wells
0
10
20
30
40
50
60
<3
3-4.9
5-7.4
7.5-9.9
10-14.9
>15
NO3-N Concentration (ppm)

Figure GW7.2

1995. Using the Wilcoxon Signed Rank Test to examine the 99 wells in which nitrate concentrations differed from one period to the next indicates no significant change in nitrate concentrations between the two sampling periods.

The factors that may influence the nitrate-nitrogen concentrations in rural domestic wells are divided into three groups: 1) well-construction factors: casing type, age, diameter, well completed in or out of a pit, sanitary seal, and well type; 2) distance factors: distance to cesspools, septic systems, waste lagoons, barnyards, pasture, and cropland; and 3) hydrogeologic and site factors: well depth, depth to water, landscape and soil characteristics (Figure GW7.1), and agricultural chemical use.

Well-construction factors

Using the Mann-Whitney Rank Sum Test to examine nitrate-nitrogen concentrations grouped by casing type (steel or PVC), sanitary seal (yes or no), casing completion (in or out a pit), and well type (drilled or not) indicates that casing completion in or out of a pit was associated with significant differences in nitrate concentrations. The Mann-Whitney Test indicated that those wells where the casing ended in a pit had higher concentrations (a median of 3.6 ppm) than those wells where the casing did not end in a pit (a median of 2.6 ppm).

Neither the Spearman Rank Order Correlation Test nor the Kruskal-Wallis Test indicated any significant relationships between nitrate-nitrogen concentrations and age or diameter.

Distance factors

No significant relationships were indicated between nitrate-nitrogen and point sources, as reflected by the distance factors.

Hydrogeologic and site factors

Nitrogen was used on the premises in nearly 77 percent of the 111 wells. The Mann-Whitney Test suggested that the use of nitrogen did not necessarily relate to the nitrate-nitrogen concentrations observed in the wells. The Spearman Test indicated a statistically significant association between higher nitrate concentration and shallower well depths. Use of the Kruskal-Wallis Test on well groups given in Table GW7.1, followed by the Mann-Whitney Test, indicated that wells with depths less than 200 feet were more likely to have higher nitrate-nitrogen concentrations than those with depths greater than 200 feet. For wells having nitrate-nitrogen concentrations greater than 3 ppm, there was a statistically significant association between higher nitrate-concentrations and decreasing depth to the water table for the 29 wells for which data was available.

Eighty-eight percent of the area in which the wells were located is dominated by soils in class 3 (silty-level), class 5 (loamy-level), and class 6 (loamy-sloping) (Figure. GW7.1). Use of the Chi-Square Test to analyze soil characteristics and nitrate-nitrogen concentrations groups (<3, ≥ 3 to <5, ≥ 5 to < 10, ≥ 10 ppm) indicated statistical differences between loamy-sloping and the other two dominant soil classes. The Fisher Exact Test indicated that these differences are related to the loamy-sloping soils being more likely to have nitrate-concentrations greater than 5 ppm.

Pesticides

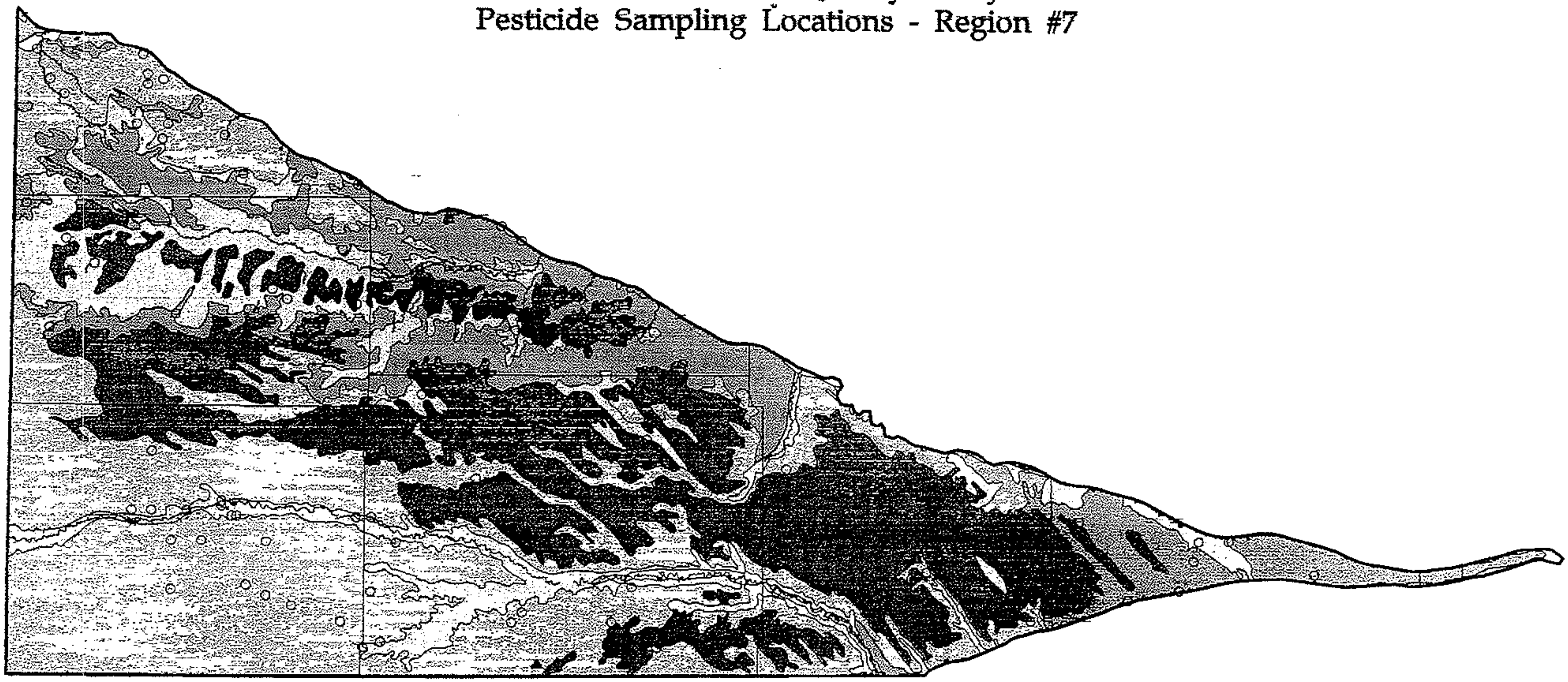
Of the 112 wells analyzed for pesticides, only one well had detectable atrazine at 0.3 parts per billion (ppb) (Figure. GW7.3). This same well had a nitrate-nitrogen concentration of 8.2 ppm. In the 1985-1989 sampling period, there were no detections.

Bacteria

Coliform-bacteria data for the 101 sites sampled during the 1994-1995 study are summarized in Table GW7.1. Their locations are shown in Figure GW7.4. The bacteria data expressed in colonies per 100 ml of water range from 0 to greater than 100. More than 86 percent of the wells had no detectable coliform bacteria, indicating that less than 14 percent of the wells had been affected by bacterial contamination and exceeded the mcl for bacteria. None of these wells had nitrate-nitrogen greater than 10 ppm.

The Wilcoxon Signed Rank Test indicated no statistical differences for the 29 wells that had different counts between the 1985-1989 and 1994-1995 periods.

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #7



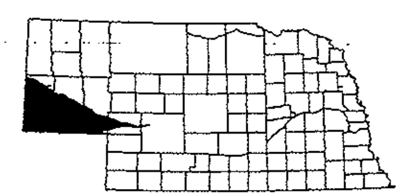
Major Streams

Soils Classification

- Sandy - Level
- Sandy - Sloping
- Silty - Level
- Silty - Sloping
- Loamy - Level
- Loamy - Sloping
- Clayey - Level
- Clayey - Sloping

0 5 10 15 20 25 MILES

0 5 10 15 20 25 KILOMETERS



Groundwater Region #7

Pesticide Concentrations (parts per billion - ppb)

- ○ None Detected
- ▲ 0.10 - 2.99
- ● 3.00 or More

IANR

University of Nebraska Lincoln

Figure GW7.3

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Bacteria Sampling Locations - Region #7

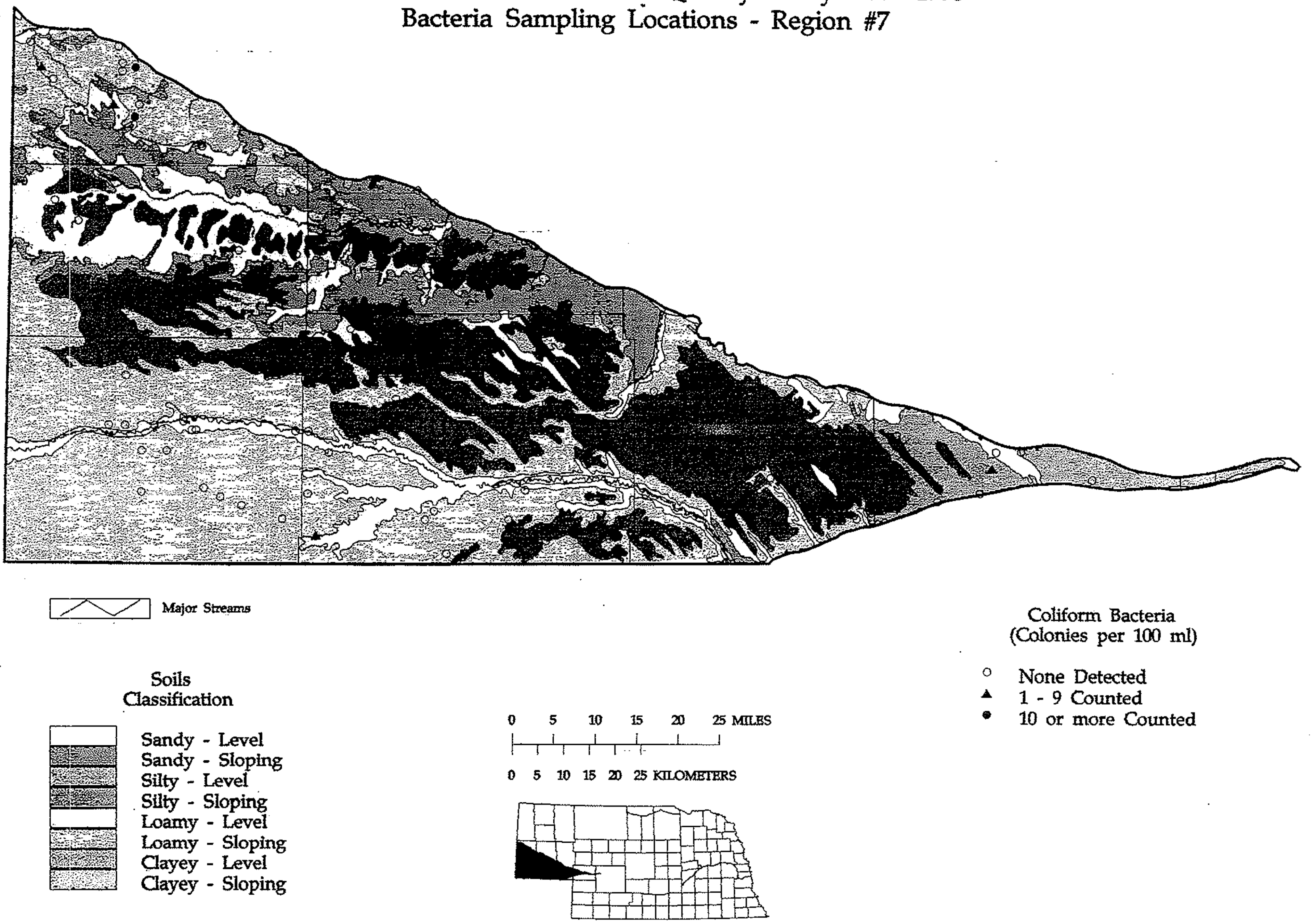


Figure GW7.4

The Spearman Test did not indicate any statistical relationship between the occurrence of coliform bacteria and distance to any of the possible point sources such as barnyards or septic systems. However, five of the wells with bacteria contamination were installed prior to 1945. Two are less than 80 feet deep. Two wells, installed in 1970, are 50 feet and 5 feet from barnyards, respectively.

Discussion

Significant associations indicated by the statistical analyses are that higher nitrate-nitrogen concentrations are associated with: 1) wells completed in a pit; 2) lesser well depths (for all wells) and lesser depths to water in wells having nitrate-nitrogen concentrations greater than 3 ppm; and 3) loamy-sloping soils and not with silty-level or loamy-level soils. The analyses also indicate no change in nitrate concentrations between the 1985-1989 and 1994-1995 sampling periods.

The relationship between generally higher nitrate concentrations and wells completed in a pit clearly indicates that this installation practice should be avoided in this region.

As in other areas in Nebraska, decreasing well depth and depth to water associated with higher nitrate concentrations is expected. Furthermore, our analyses indicate that wells drilled to depths greater than 200 feet are less likely to become contaminated.

Nitrate concentrations more than 5 ppm are associated with loamy-sloping soils in upland areas (Figure GW7.1). Such areas may be predominantly net-recharge areas. In contrast, loamy-level soils occur more often in stream valleys, which generally are associated with net groundwater discharge. Loamy soils have a substantial component of sand that makes them more permeable than the silty-level soils.

Lack of association of nitrate with distance and most well-construction factors, which are often related to point sources, indicates that these sources have not contributed significantly to variations in the concentration of nitrate-nitrogen in individual wells. However, distance between a well and a point source of contamination is only one of the factors that determines whether a well will become contaminated. Other factors are the spatial relationship of the well to the point source--that is, whether the well is near or far, upgradient, downgradient, or sitting laterally from the point source. Furthermore, another important factor is whether the groundwater-bearing units have similar properties. The groundwater-bearing units include stratigraphic layers that affect the direction and rate of local groundwater movement.

References

Swinehart, J.B., V.L. Souders, H.M. DeGraw, and R.F. Diffendal, Jr., 1985, Cenozoic Paleogeography of Western Nebraska, in Flores, R.M. and S.S. Kaplan, eds., Cenozoic Paleogeography of West-Central United States, Denver, Colorado, pp. 209-229.