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Regional Analysis of Rural Domestic Well-water Quality – Platte River Valley

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Rural Domestic Well-water Quality in the *Platte River Valley*

Groundwater Region 2 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 2 occupies the North Platte, South Platte and Platte river valleys (Figure 1). Groundwater is primarily derived from river-deposited (alluvial) sand and gravel interlayered with lesser amounts of silt and clay. Large groundwater yields are obtained from these deposits. Where present, the Tertiary Ogallala Group is also used for groundwater. The Ogallala Group occurs beneath the alluvial deposits west of Grand Island to near Lake McConaughy on the North Platte and to the Colorado border on the South Platte. The Ogallala consists of complex deposits of sand, silt, clay, and gravel interbedded with lime- or silica-cemented sandstone. Thicknesses of individual layers differ significantly over short lateral and vertical distances. Depth to the water table is usually less than 50 feet. The saturated thickness of the principal aquifer ranges from about 100 feet or less throughout the regions to about 500 feet or more in Lincoln County. (Geologic cross-sections for Region 2 are available at the Conservation and Survey Division; Figure 1.)

The geologic units that provide the base of the groundwater system differ along the Platte River valley (Table 1). Downstream from Ashland to the Missouri River, the base of the groundwater system is Pennsylvanian limestones and shales. From Ashland to central Dawson County, the base of the groundwater system is Cretaceous rocks. These rock units include sandstone and shale of the Dakota Group, Greenhorn limestone, Graneros shale, Carlile shale, Niobrara chalk, and Pierre shale. West of central Dawson County, the base of the groundwater system is generally the siltstones and claystones of the Tertiary White River Group.

Results*

Well Characteristics

Characteristics of the wells sampled during the 1994-1995 study are summarized in Table GW2.1. The average year of installation was 1971; nearly 58 percent of the wells were installed between 1960 and 1979. The oldest well was installed in 1920. Available information indicates that about 87 percent of the wells were drilled and completed mostly with PVC or steel casing.

Of these wells, 76 percent have sanitary seals. The average depth of the wells is 100 feet, reflecting the shallow depths to groundwater. The well depths ranged from 12 to 325 feet. Thirty- four percent of the wells had depths between 50 and 99 feet, and about 28 percent were from 100 to 199 feet deep. For the 131 wells for which information is available, the average well diameter is 4.7 inches, reflecting the 81 percent of the wells with diameters between 4 and 5 inches. The minimum diameter was 3 inches, and the maximum was 18 inches. On average, 3.4 individuals use each well. For the 172 locations reporting information on agricultural chemicals used on the premises, nitrate was used at 91 percent of them. Pesticides were used at 14 percent of the sites.

Nitrates

Nitrate data for the 178 wells sampled during the 1994-1995 study are summarized in Table GW2.1. Their locations are shown in Figure GW2.1. The nitrate-nitrogen concentrations ranged from less than 0.1 parts per million (ppm) to a maximum of 55.2 ppm. Approximately 52 percent of the wells had concentrations less than 3 ppm (Figure GW2.2), indicating that at least 48 percent of the wells have been affected by nitrate contamination to some degree. More than 23 percent of the wells exceeded the 10 ppm maximum contaminant level (mcl) for nitrate-nitrogen. The average value for all samples was 7.4 ppm, and the median value is 2.7 ppm.

Figure GW2.2 does not show any coherent changes in nitrate concentrations from 1985-1989 to 1994-1995. The Wilcoxon Signed Rank Test also indicates no significant changes between the two sampling episodes.

**** Where associations, relationships, increases or decreases are discussed, our analyses have determined that 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.***

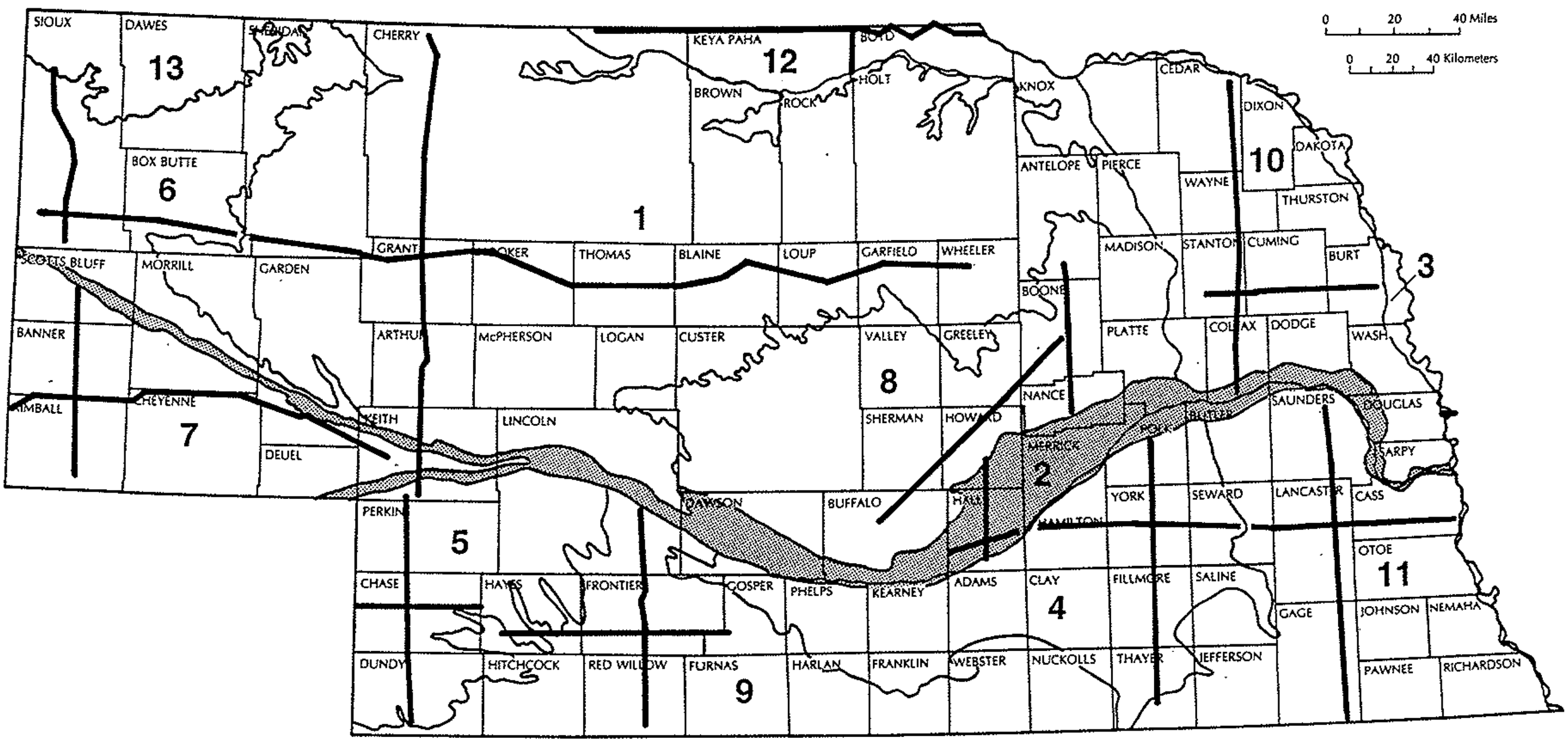


Fig. 1—*Locations of geologic cross sections* (Region 2 in gray)

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			Sand, silt, gravel and clay	Principal groundwater reservoir; Ogallala is absent in east and northwest. Arikaree is present primarily in west.
		Pleistocene	0.01			
		Pliocene	~2.0		Sand, gravel and silt	
		Miocene	5	Ogallala	Sand, sandstone, siltstone and some gravel	
		Oligocene	24	Arikaree	Sandstone and siltstone	
				White River	Siltstone, sandstone and clay in lower part	Secondary aquifer in west; water may be highly mineralized.
		Eocene	37	Rocks of this age are not identified in Nebraska.		
		Paleocene	58			
Mesozoic	Cretaceous	Late Cretaceous	67	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.
				Greenhorn-Graneros	Limestone and shale	Generally not an aquifer, yields water to few wells in east.
		Early Cretaceous	98	Dakota	Sandstone and shale	Secondary aquifer, primarily in east; water may be highly mineralized.
	Jurassic		144		Siltstone and some sandstone	Not an aquifer
	Triassic		208		Siltstone	Not an aquifer
Paleozoic	Permian		245		Limestone, dolomites, shales and sandstone.	Some sandstone, limestone and dolomites are secondary aquifers in east. Water may be highly mineralized.
	Pennsylvanian		286			
	Mississippian		320			
	Devonian		360			
	Silurian		408			
	Ordovician		438			
	Cambrian		505			
Precambrian			570			

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

Table GW2.1. 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	156	1971	1920	1989	13.1
	<1940	5				
	1940-1969	20				
	1960-1979	90				
	1980-present	41				
Well Depth (feet)	All	160	101	12	325	69
	<50	39				
	50-99	55				
	100-199	45				
	>200	21				
Well Diameter (inches)	All	131	4.7	3	18	1.9
	<2	0				
	2-3	4				
	4-5	106				
	6-7	8				
	>8	13				
Number of Well Users		138	3.4	0	14	2.0
Distance to Contaminant Source (feet):	cesspool	15	81	20	160	43
	septic	163	112	2	1260	120
	waste lagoon	6	700	0	1400	613
	barnyard	98	360	10	3750	606
	pasture land	77	761	10	2600	812
	cropland	136	231	0	1600	252
Well Type:	drilled	151				
	driven	22				
	dug	0				
	other	0				
Casing Material:	steel	37				
	plastic	104				
	concrete	1				
	brick	0				
	tile	0				
	other	0				
Sanitary Seal:	yes	137				
	no	16				
Casing in Pit:	yes	35				
	no	131				
Nitrate Used:	yes	158				
	no	15				
Pesticide Used:	yes	148				
	no	25				

Water Quality Data

		Number of wells	Mean	Median	Minimum	Maximum	Standard deviation	Detections
Nitrate as Nitrogen (ppm NO3-N)	1994-1995	178	7.4	2.7	0.1	55.2	10.5	
Bacteria (colonies per 100 ml)	1994-1995	163			0	100.0		21
Pesticides (ppb)	1994-1995							
	Atrazine	179			0	4.1		24
	Dyfonate	179			0	0.7		7
	Dual	179			0	5.0		1

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Locations - Region #2, West Half

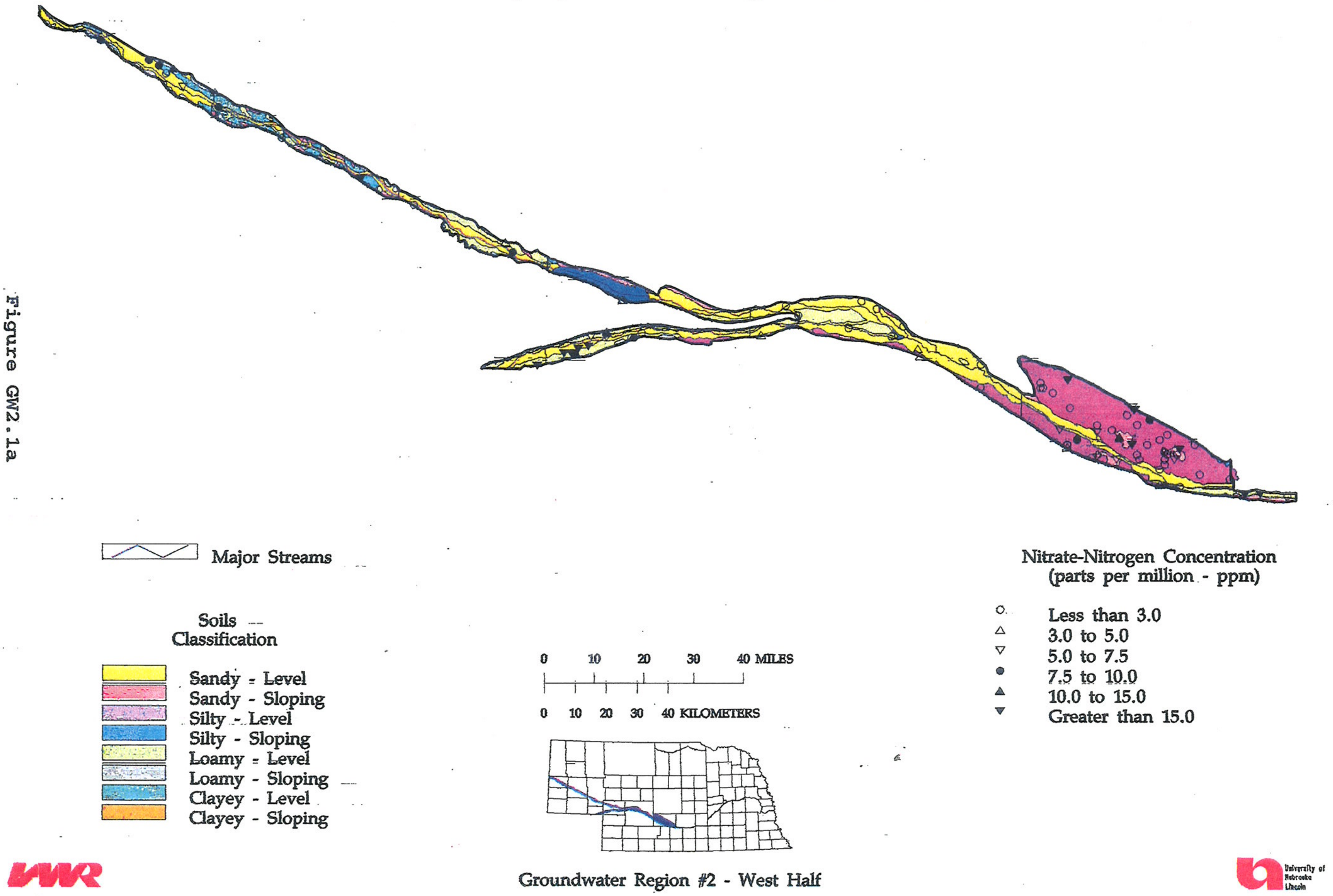


Figure GW2.1a

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Nitrate Sampling Location - Region #2, East Half

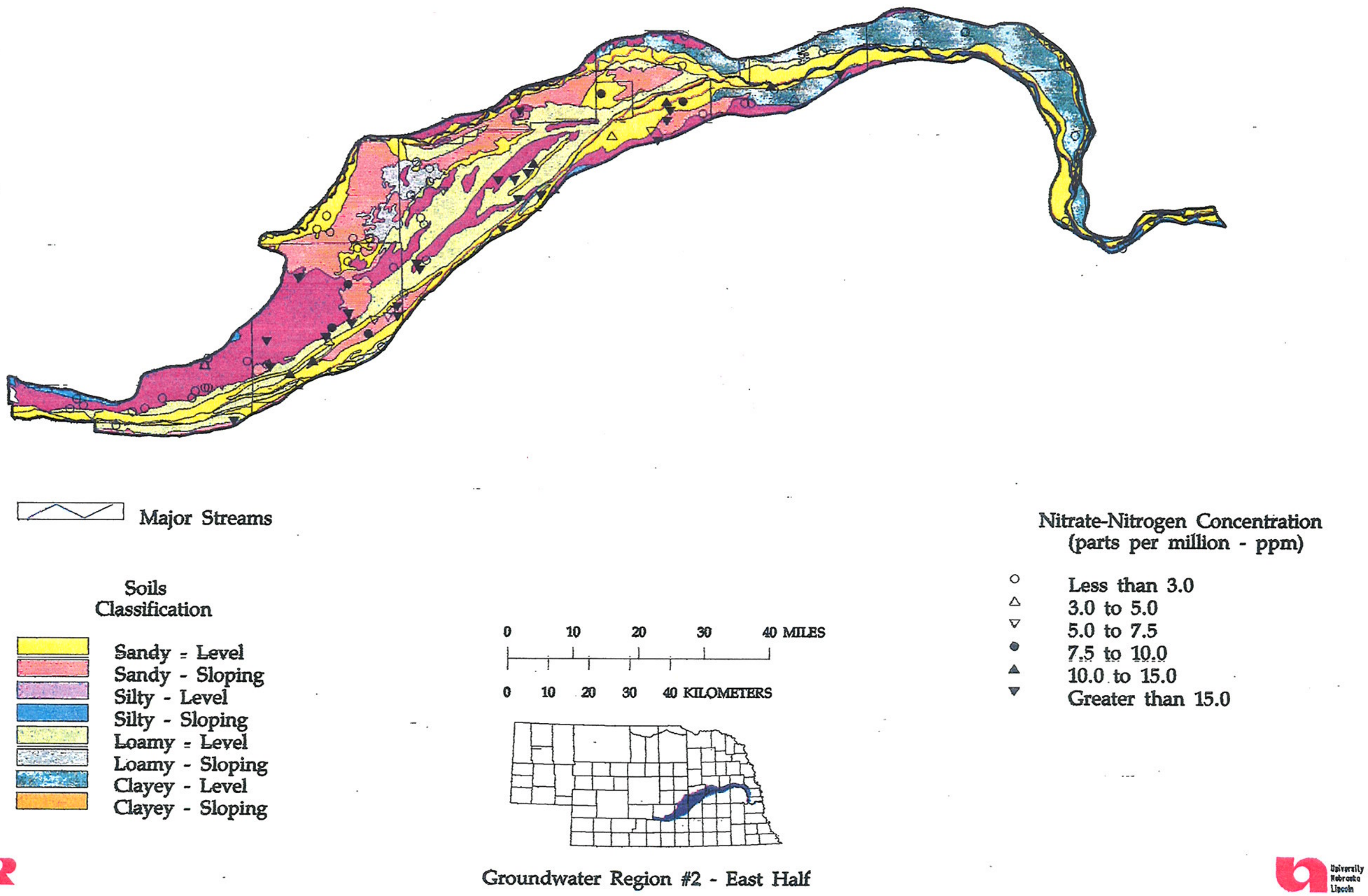
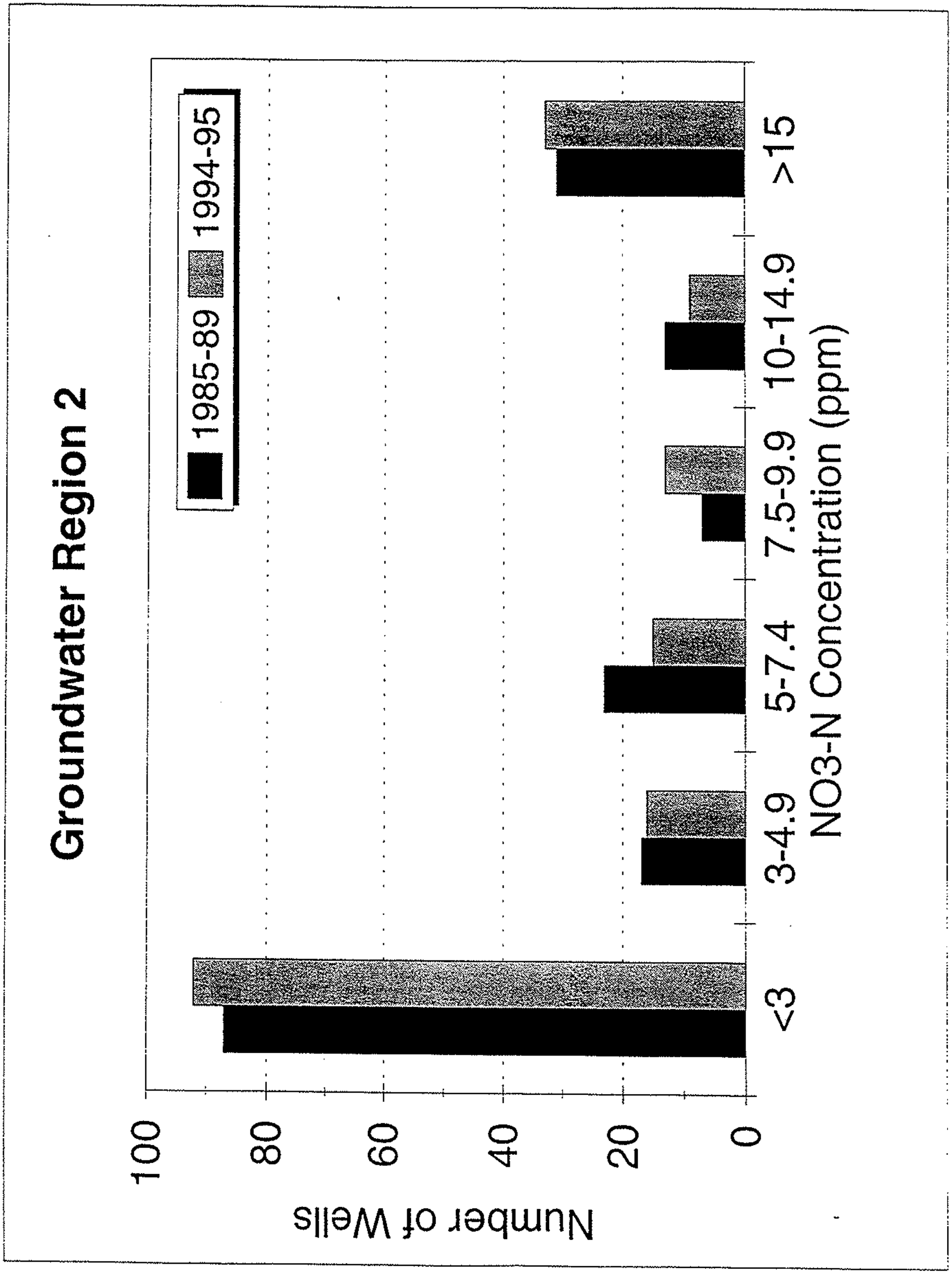


Figure GW2.1b



Groundwater Region 2
1985-89
1994-95
Number of Wells
0
20
40
60
80
100
<3
3-4.9
5-7.4
7.5-9.9
10-14.9
>15
NO3-N Concentration (ppm)

Figure GW2.2

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 pit, sanitary seal, and well type; 2) distance factors: distance to cesspool, septic systems, waste lagoons, barnyards, pasture, and cropland; and 3) hydrogeologic and site factors: well depth, depth to water, landscape and soil characteristics (Figure GW2.1), and agricultural chemical use.

Well-construction factors

We used the Mann-Whitney Rank Sum Test to examine the nitrate concentrations related to the following groups of well-construction factors: casing type (steel or PVC), sanitary seal (yes or no), casing completed (in or out of pit), and well type (drilled or not). The Mann-Whitney Test indicated that driven wells had generally higher nitrate concentrations than drilled wells. Furthermore, the Fisher Exact Test demonstrated that a driven well was more likely to have nitrate-nitrogen concentrations greater than 5 ppm. Wells lacking sanitary seals also had higher concentrations than those wells having sanitary seals.

The Spearman Rank Order Correlation Test was also used to evaluate the association between nitrate-nitrogen concentrations, installation date (age), and well diameter. No statistically significant associations were indicated, although there was a weak negative correlation of nitrate-nitrogen concentrations and installation date (that is, older wells tend to have higher concentrations). To further evaluate this relationship, the nitrate concentrations for the age groups in Table GW2.1 were evaluated using the Kruskal-Wallis Test. This test indicated that there were statistically significant differences in nitrate concentrations associated with the various groups.

Distance factors

The Spearman test did not indicate any associations of nitrate-nitrogen concentrations and distances to potential contaminant sources.

Hydrogeologic and site factors

Nitrogen was used on the premises for 91 percent of the 172 wells where this data was provided. The Mann-Whitney Rank Sum Test indicated that where nitrogen was used, wells have higher nitrate concentrations than wells where nitrogen was not used. Not surprisingly, the Fisher Exact Test indicated that wells where nitrogen was used were more likely to have nitrate-nitrogen concentrations greater than 5 ppm.

The Spearman test indicated a statistically significant tendency for the nitrate concentrations to increase as well depth decreased. Application of the Kruskal-Wallis Test and the Mann-Whitney Test to the depth groups in Table GW2.1 demonstrated that wells less than 100 feet deep had significantly higher nitrate concentrations (a median of 5.2 ppm) than wells greater than 100 feet deep (a median of 1.3 ppm).

The landscape and soil characteristics are complex enough that seven out of the eight generalized soil classifications created for this report occur in this region. Ninety percent of the wells occur in four soil classes: class 1 (25 percent; sandy-level); class 2 (11 percent; sandy-sloping); class 3 (35 percent; silty-level); and class 5 (18 percent; loamy-level) (Figure GW2.1). Using the Chi-Square Test to analyze soil characteristics and nitrate-nitrogen concentrations groups (<3.0; ≥ 3.0 to <5.0; ≥ 5.0 to < 10; ≥ 10 ppm) indicated that the nitrate-nitrogen characteristics were statistically similar for nearly all the groups; the exception was the comparison of sandy-level and loamy-level soils. The Fisher Exact Test indicated that the loamy-level soils had a greater tendency than sandy-level soils to have nitrate concentrations greater than 10 ppm.

Pesticides

Of the 179 wells analyzed for pesticides, 24 (18 percent) had detections. Pesticide data are summarized in Table GW2.1. The majority of the pesticide detections were in Merrick County (Figure GW2.3). All were for atrazine: seven for Dyfonate and one for Dual. The values ranged from no detection to 4.1 ppb for atrazine; no detection to 0.7 for Dyfonate; and a value for Dual of 5.0 ppb. Two wells with 3.3 and 4.1 ppb exceeded the MCL for atrazine. The Wilcoxon test indicated no statistically significant difference between the 38 wells that had different pesticide concentrations for the 1985-1989 and 1994-1995 sampling periods.

The Spearman test indicated an association of pesticides and nitrate concentrations. The strength of this association increased when using data for wells that had an increasing degree of contamination, reflected by nitrate concentrations greater than 3 ppm and 5 ppm. This is consistent with data from these wells having an average value

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #2, West Half

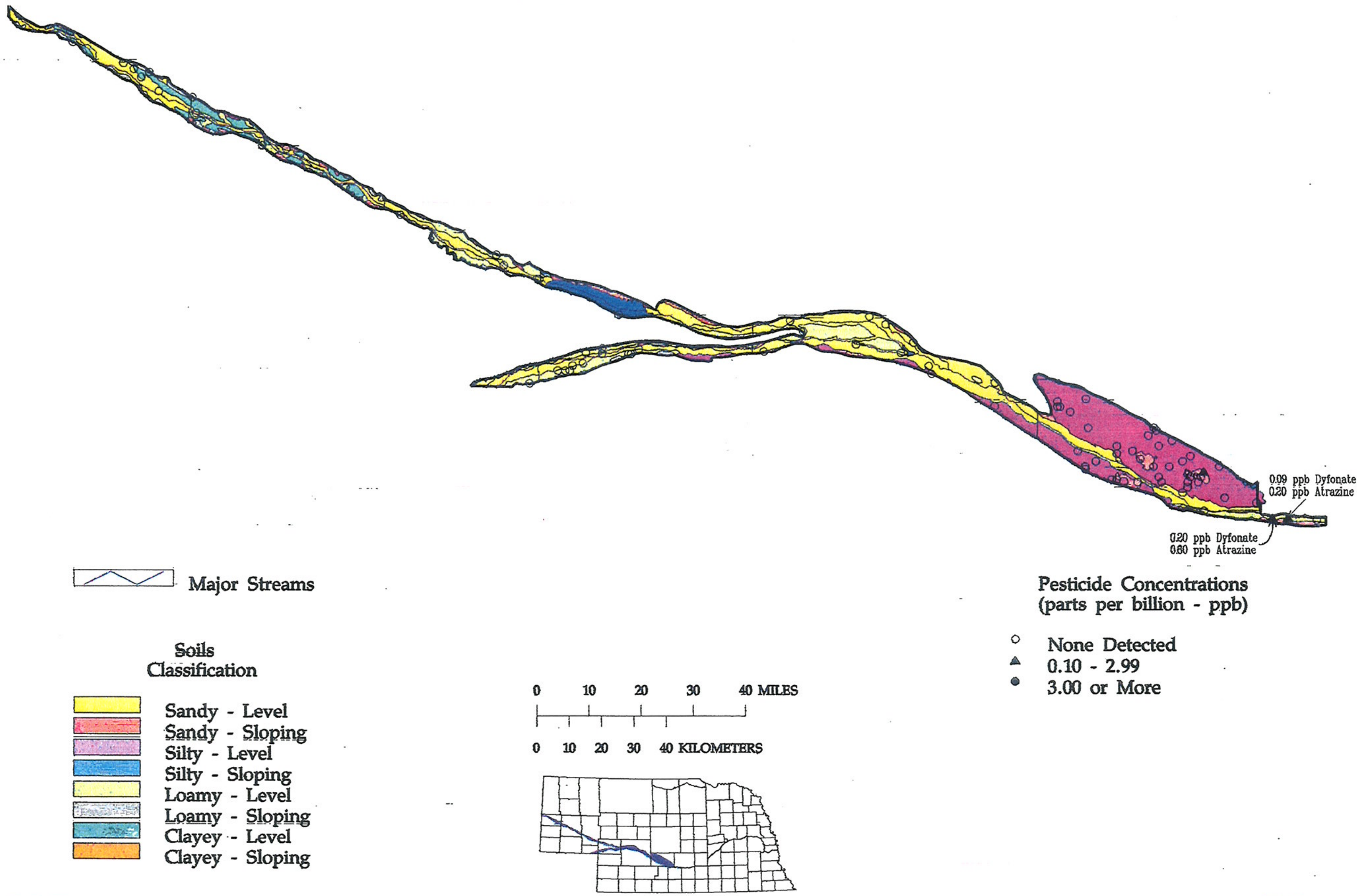


Figure GW2.3a

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Pesticide Sampling Locations - Region #2, East Half

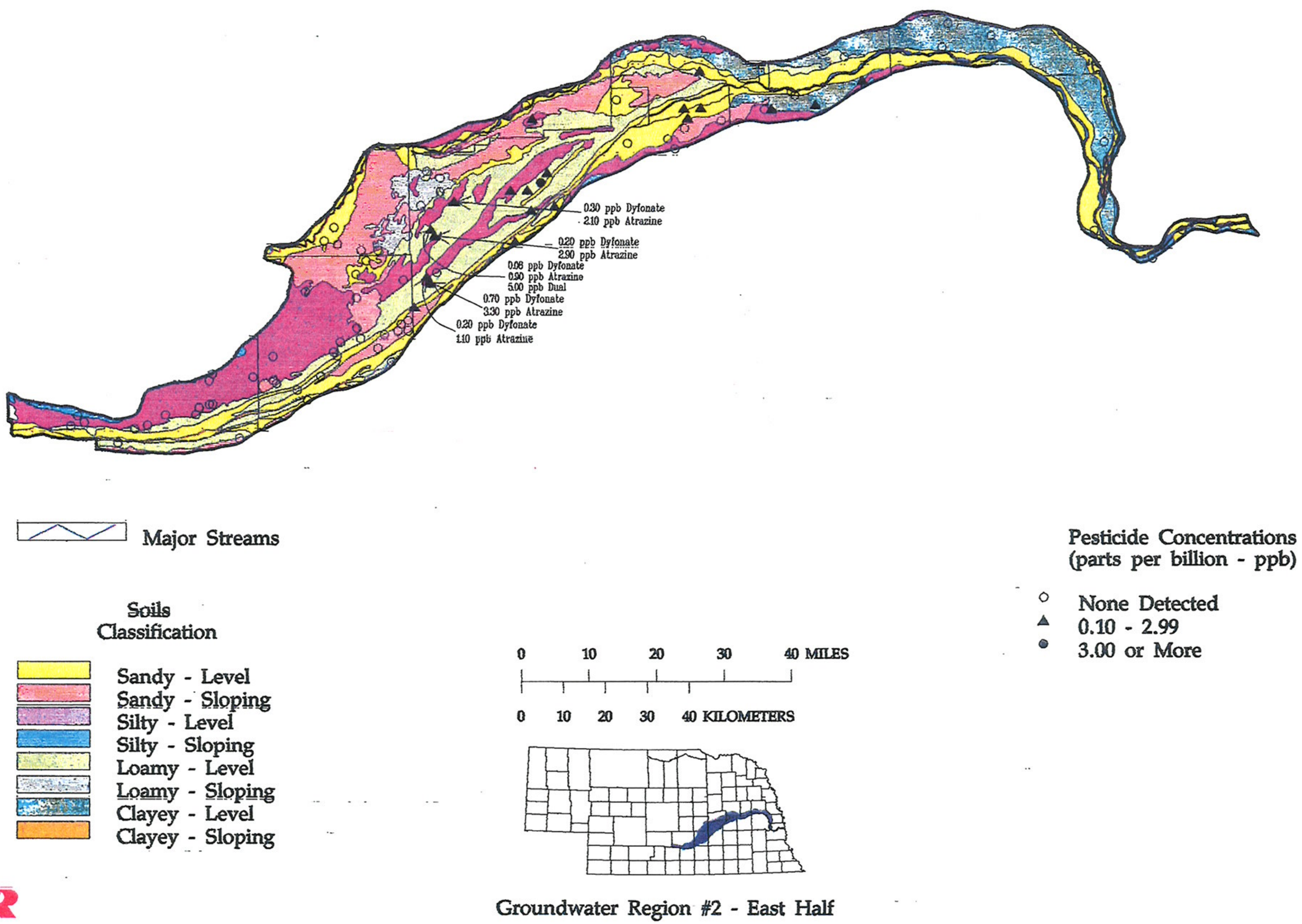


Figure GW2.3b

for nitrate-nitrogen of 18.2 ppm and 16 of 24 wells having nitrate-nitrogen concentrations exceeding 10 ppm. These pesticide-contaminated wells had an average depth of 40 feet. Ninety percent of the wells were less than 60 feet deep; of these, 12 wells were less than 40 feet. Seven Dyfonate detections were in wells less than 65 feet deep.

Bacteria

Coliform-bacteria data for the 163 wells sampled during the 1994-1995 study are summarized in Table GW2.1. Their locations are shown in Figure GW2.4. Bacteria data ranged from 0 to greater than 100 colonies per 100 ml. Eighty-seven percent of the wells had no detectable coliform bacteria, whereas 13 percent of the wells have been affected by bacterial contamination and exceed the maximum contaminant level (mcl) for bacteria. Of the wells affected by bacteria, 33 percent had nitrate-nitrogen concentrations that exceeded the mcl of 10 ppm.

The Wilcoxon test indicated that there was not a statistically significant difference between the 33 wells that had different coliform-bacteria values during the 1994-1995 and 1985-1989 sampling periods. The Spearman test did not indicate any relationships between coliform bacteria and distances to possible point sources such as barnyards or septic systems. Of the 19 wells affected by bacteria for which there is depth data, ten wells (53 percent) have depths less than 65 feet. Five of the remaining wells are less than 80 feet from barnyards.

Discussion

Results of our analyses indicate statistically significant associations between higher nitrate-nitrogen concentrations and: 1) driven wells and those without sanitary seals; 2) nitrogen use on the premises; 3) shallower well depth; 4) loamy-level soils relative to sandy-level soils; and 5) increasing pesticide concentrations.

The impact of agrichemical contamination of groundwater in the Platte Valley has been well documented (for example, Exner and Spalding, 1979; Gormly and Spalding, 1979; Exner and Spalding, 1985; Exner and Spalding, 1990; and Spalding and Exner, 1993). Associations 2, 3, 4, and 5, as defined in the previous paragraph, correspond with the conclusions of these investigators. More specifically, wells in areas with well-drained loamy-level soils where nitrogen fertilizers are extensively applied and depths to water are less than 100 feet are more likely to be affected by nonpoint-source agrichemical contamination. Our analysis indicates that wells drilled to depths greater than 100 feet will minimize the potential of nitrate-nitrogen contamination affecting the well. Wells less than 65 feet deep appear to be more susceptible to pesticide contamination. This depth could be suggested as a minimum well depth; however, in more than half of Merrick County, this would not be possible.

Nonpoint-source contamination appears to contribute most significantly to degradation of well-water quality in this region. However, the association of higher nitrate-nitrogen concentrations with the well-construction factors, driven wells and lack of sanitary seals, indicates that well-construction requirements are also important. They help minimize the influence of local point sources, which are likely contributing to bacterial contamination.

Lack of association of nitrate and bacteria with distance 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 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.

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Bacteria Sampling Locations - Region #2, West Half

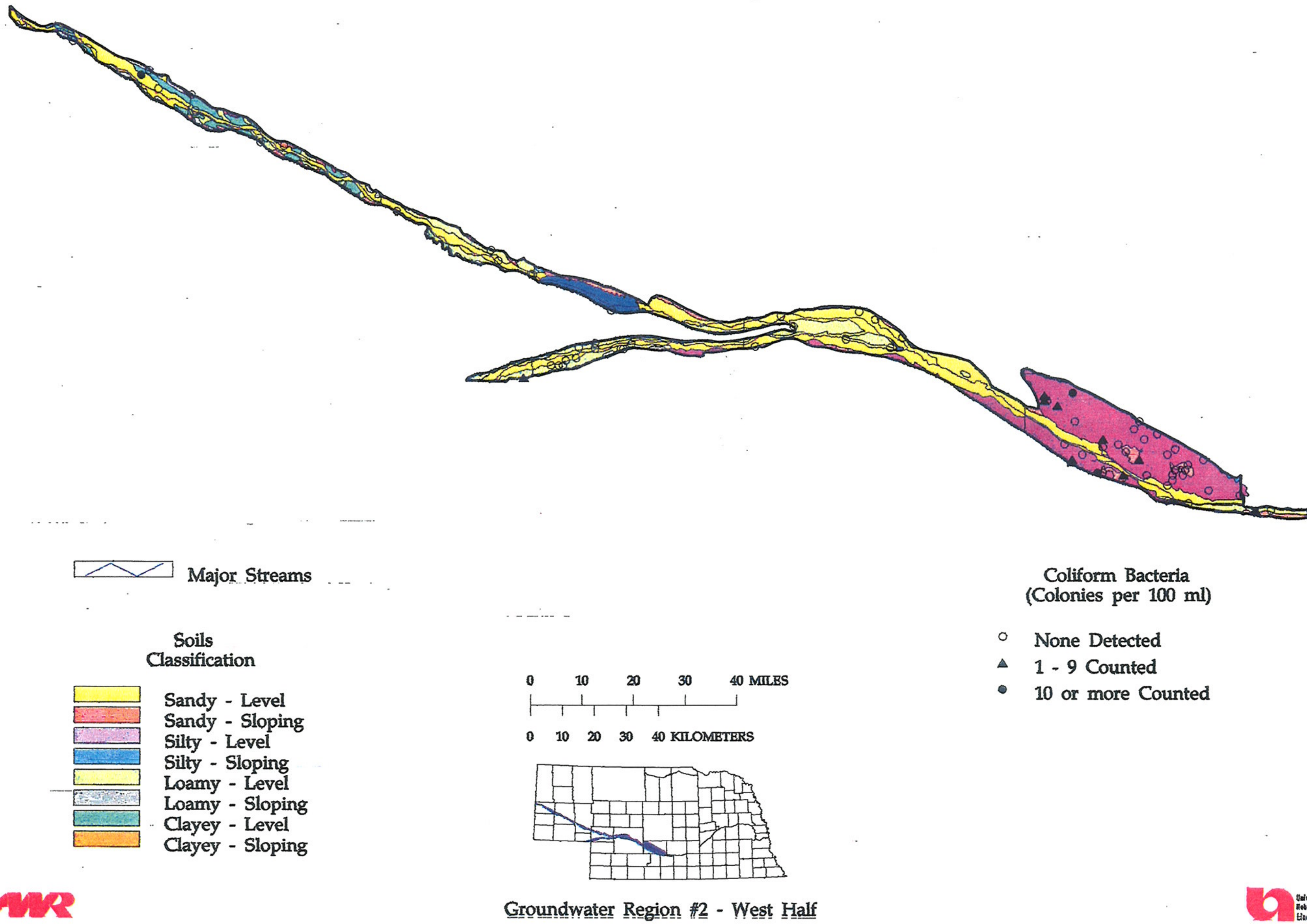

Figure GW2.4a

Nebraska Department of Health
Rural Domestic Well Water Quality Study: 1994-1995
Bacteria Sampling Locations - Region #2, East Half

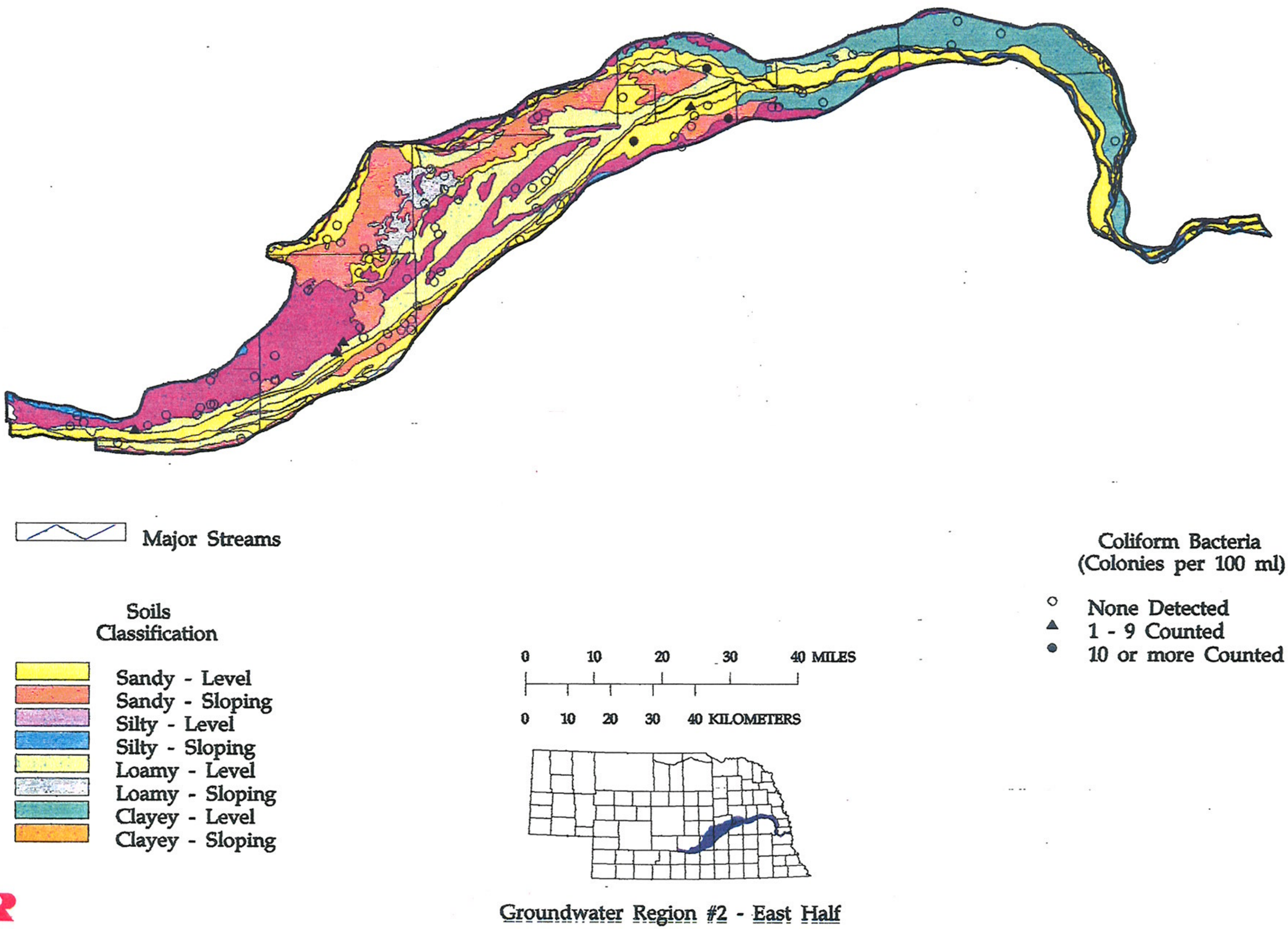

Figure GW2.4b

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