A Study of Nonpoint Source Ground Water Contamination in the Vicinity of Superior, Nebraska: A Ground Water Management Area Report

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Executive Summary

The Nebraska Department of Environmental Control (DEC) undertook a study in 1988 to determine if nonpoint source (NPS) contamination is occurring in the vicinity of Superior, Nebraska. If so, designation of a Special Protection Area (SPA) would help the local Natural Resources Districts (NRDS) manage the problem.

The study area consists of an agricultural (both irrigated and non-irrigated)) area underlain by fine-grained loess sediments in the uplands and coarser alluvial sediments in the drainages, especially the Republican River Valley. Irrigation is practiced primarily in the Republican Valley and the southeast and northeast corners of the study area, as these portions have aquifers sufficient to yield water to high capacity wells. The aquifer in the remainder of the study area is sufficient only for low yield domestic and stock wells.

100 samples obtained in the spring and summer of 1988 were analyzed for a variety of parameters. Nitrate-nitrogen (NO3-N) contents of these samples were highest in the south-central and southeast portions of the study area. These areas exhibited widespread, homogeneous levels of NO3-N often exceeding 10 mg/I, even after point sources were eliminated. In addition, several irrigation and municipal wells contained residues of atrazine, a common corn and sorghum herbicide.

In view of the above information, it is concluded that NPS ground water contamination is occurring in a portion of the study area. It is recommended that an SPA be declared in this region to help the local NRDs manage the problem. Boundaries for the SPA are suggested, but could be adjusted after consultation with the NRDs or after a public hearing.

Introduction

The Nebraska Department of Environmental Control (DEC) undertook a study in March 1988 to determine the presence and extent of nonpoint source (NPS) ground water contamination in the vicinity of Superior, Nebraska (Figure 1). This activity was initiated by a request from the Lower Republican Natural Resources District (LRNRD) to DEC dated November 9, 1987 (**Appendix A**). Under portions of the Nebraska Ground Water Management and Protection Act (Neb. Rev. Stat. Sec. 46-674.02-46-674.20) and DEC's Title 196 (DEC, 1988), any political subdivision in the State having evidence of nonpoint source (NPS) ground water contamination occurring within its jurisdiction can request that DEC investigate the contamination. In the event that NPS contamination is occurring, DEC can designate a Special Protection Area (SPA), which gives the NRD(s) in that area the power to manage sources and potential sources of contamination (DEC, 1988).

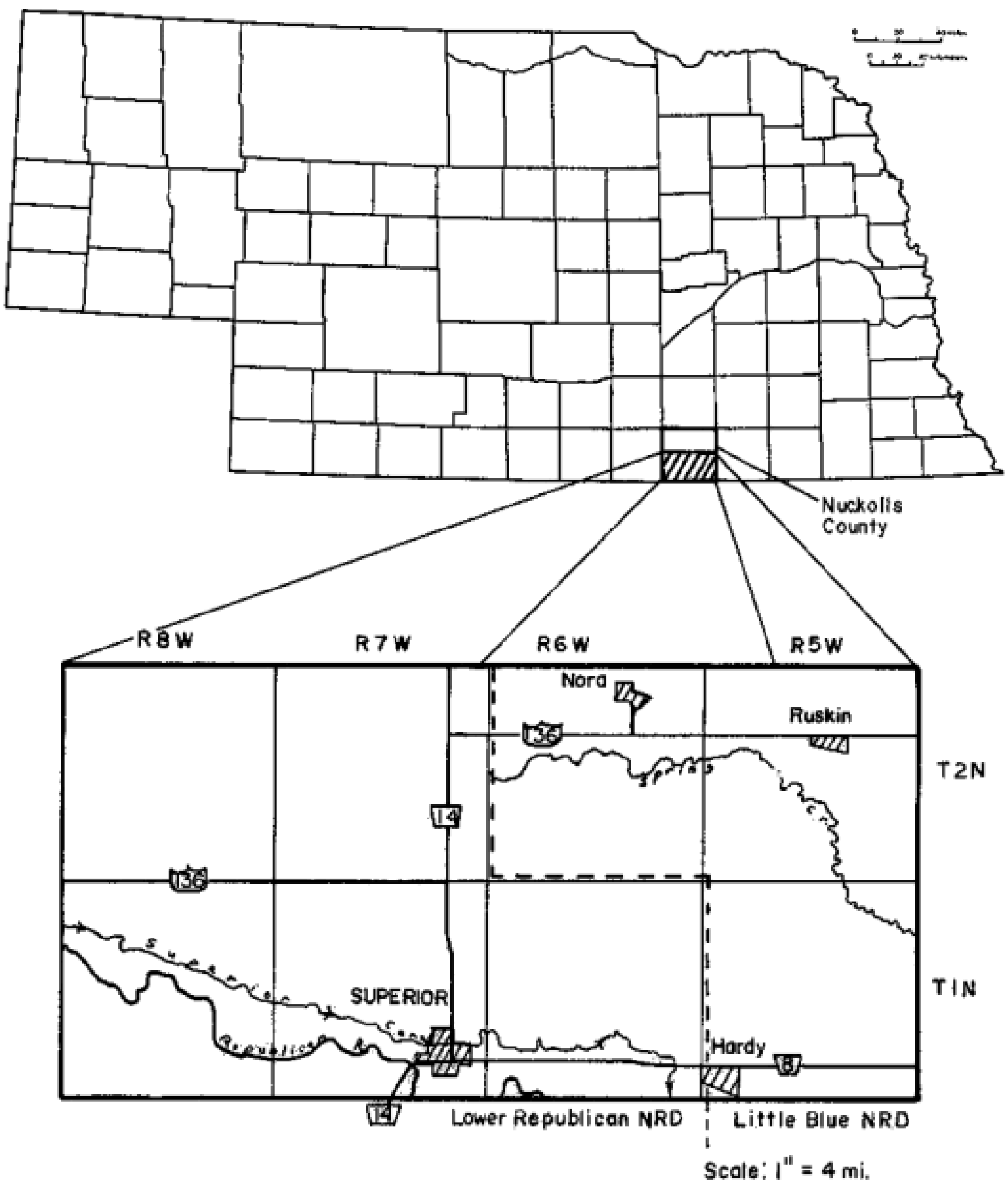


Figure 1: Location of Study Area

NPS ground water contamination results from widespread activities, and cannot be traced to a single event or location. In Nebraska, most NPS ground water contamination results from application of fertilizers on farmland. It is also possible that other agrichemicals such as herbicides or insecticides can cause NPS ground water pollution. Nonpoint sources can be contrasted with point sources of ground water contamination. Point sources are specific, identifiable events or sources which cause ground water pollution. Common examples of point sources include septic tanks, underground storage tanks, feedlots, above-ground chemical spills, and poorly-constructed or abandoned wells.

The widespread use of fertilizers leads primarily to an increase in nitrate as nitrogen (NO3-N) in ground water. Nitrate fertilizers are usually applied as a form of ammonium nitrogen. Soil bacteria then convert the ammonium nitrogen to NO3-N through the process of nitrification (Jackson et al, 1987). NO3-N is a highly soluble and mobile form, and it is NO3-N in ground water which is a primary health concern. A maximum contaminant level (MCL) for NO3-N has been set at 10 mg/l (milligrams/liters, roughly equal to parts per million) by the U.S. Environmental Protection Agency (EPA, 1976). This health concern is due primarily to the ability of higher concentrations of NO3-N in drinking water to affect the oxygen-carrying capacity of blood, Particularly in infants (Jackson et al, 1987). Separate MCLs or comparable Lifetime Health Advisories (LHAs) have been adopted by EPA for various pesticides.

In their request for consideration as an SPA, the LRNRD submitted information indicating that in the period of 1985-1987, several domestic wells in the area surrounding the city of Superior, particularly to the north and east of the city, had sample results of greater than 10 mg/l NO3-N. These results included an area spanning the boundary between the Little Blue Natural Resources District (LBNRD) and the LRNRD (Figure 2). Some of these samples were initially analyzed using a Hach NO3-N test kit and later resampled and analyzed by the Nebraska Department of Health laboratory (Table 1) . Similarly, data submitted by LBNRD indicated some elevated NO3-N levels in the same area (LBNRD data, Fall 1987). The LBNRD samples were analyzed using a Hach NO3-N kit with photometer. In November 1985, 20 samples were taken by LBNRD from domestic wells in the general area of Superior. Of these 20, 6 were at or above the 10 mg/l level, 9 were at or above 8 mg/l, and 15 were at or above 5 mg/l. In April 1986, these same 20 site were resampled; 9 were at above 10 mg/l, 11 at or above 8 mg/I, and 15 at or above 5 mg/l. In October 1986, the same 20 wells plus 15 additional domestic wells were sampled; of the 35, 13 were at or above 10 mg/l, 17 at or above 8 mg/I, and 26 at or above 5 mg/l. In 1987, 6 of these wells plus 3 new wells were sampled. Of these 9, 5 were above 10 mg/l, and 5 were at or above 8 mg/l. In addition, 7 of these wells showed residues of atrazine, a common herbicide. These results, when combined with the laboratory and test kit results submitted by LBNRD, indicated that the potential for NPS ground water contamination existed in the area around Superior.

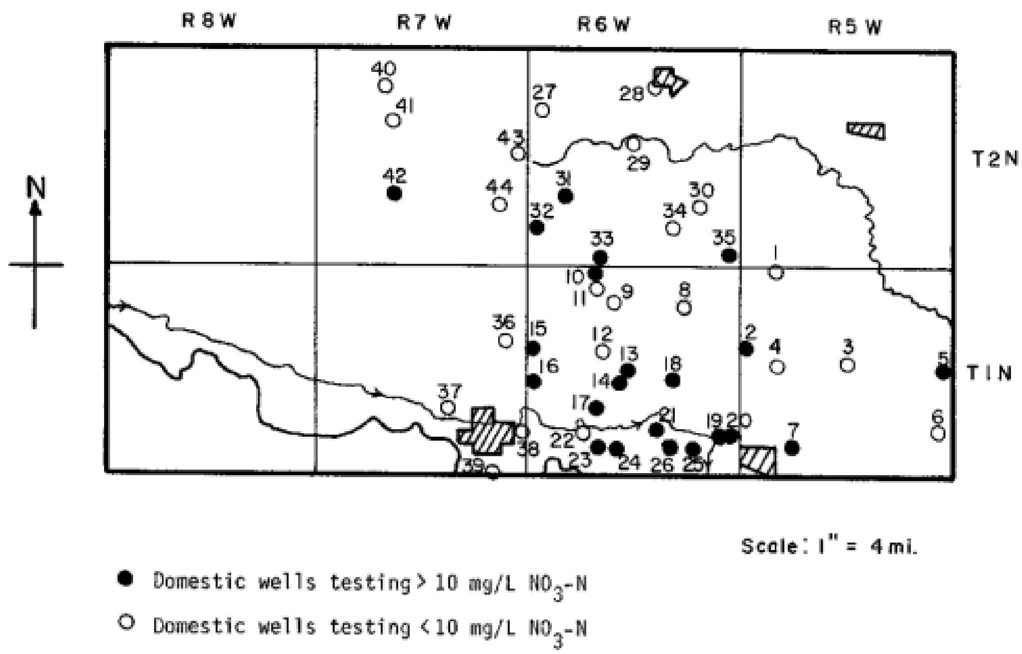


Figure 2: Locations and results of domestic well sampling submitted by LRNRD in request for SPA consideration

Table 1: Results of initial LRNRD sampling, submitted with initial request for SPA consideration.

Map #	Legal Description	1985 N03-N, mg/L (Hach)	1986 N03-N, mg/L (Hach)	1987 N03-N, mg/L (Hach)	1987 Atrazine, µg/l (DOH)	1987 CCl4, µg/l (DOH)
1	T1N R5W Sec 06 NE	6.4				
2	T1N R5W Sec 07 SW	13.0				
3	T1N R5W Sec 16 SE	9.0				
4	T1N R5W Sec 18 SE	8.0				
5	T1N R5W Sec 24 NE	13.0				
6	T1N R5W Sec 25 SE	4.8				
7	T1N R5W Sec 32 NE	11.2				
8	T1N R6W Sec 02 SW	1.0	0.9	2.3		
9	T1N R6W Sec 04 SE	2.0	0.4			
10	T1N R6W Sec 05 NE	20.0	47.1	60.0	0.723	20.0
11	T1N R6W Sec 05 SE	6.5	8.7			
12	T1N R6W Sec 09 SW	4.0	5.2			
13	T1N R6W Sec 16 NE		12.1	12.3	0.4	
14	T1N R6W Sec 16 SE	14.0	21.6			
15	T1N R6W Sec 18 NW	18.0	17.6	18.3	0.14	
16	T1N R6W Sec 18 SW	9.0	14.5			
17	T1N R6W Sec 20 SE	11.0	6.8			
18	T1N R6W Sec 23 NW	12.0	12.6	12.9	0.11	
19	T1N R6W Sec 25 SW		11.9			
20	T1N R6W Sec 25 SE	30.0	36.3			
21	T1N R6W Sec 27 SE	12.0	3.1			
22	T1N R6W Sec 29 SW			7.7	2.15	
23	T1N R6W Sec 32 NE	10.0	12.2			

24	T1N R6W Sec 33 NE		11.6			
25	T1N R6W Sec 35 NE	15.5	16.5	12.8	2.14	
26	T1N R6W Sec 35 NW		10.4			
27	T2N R6W Sec 07 SE	5.4				
28	T2N R6W Sec 10 NW	4.7				
29	T2N R6W Sec 16 SE	5.5				
30	T2N R6W Sec 25 NW	5.6				
31	T2N R6W Sec 29 NW	14.5				
32	T2N R6W Sec 30 SW		62.2			
33	T2N R6W Sec 33 SW	26.0				
34	T2N R6W Sec 35 NW	4.0				
35	T2N R6W Sec 36 SE	11.8				
36	T1N R7W Sec 12 SW	6.5	4.9			
37	T1N R7W Sec 22 SE					
38	T1N R7W Sec 25 NE			8.0	1.48	
39	T1N R7W Sec 35 SE	2.0	4.2			
40	T2N R7W Sec 04 SW	3.0				
41	T2N R7W Sec 15 NW	6.5				
42	T2N R7W Sec 21 SW	16.0		7.5		
43	T2N R7W Sec 24 NE		7.6			
44	T2N R7W Sec 25 NW		1.1			

As outlined in DEC protocol (Ehrman, 1988), the area to be studied for potential SPA designation is to-be large enough to encompass the entire area of NPS ground water contamination, if that area can be determined from the data submitted. As most of the elevated NO3-N levels were north and east of the city of Superior, it was determined by DEC that the study area would consist of the southern half (eight townships) of Nuckolls County. This study area would extend out of the jurisdiction of the requesting agency (LRNRD) and into the LBNRD. LBNRD officials were notified of this, and they agreed to cooperate in the process.

GEOGRAPHY

The southern half of Nuckolls County (see **Figure 1**) is located in south-central Nebraska along the Kansas-Nebraska border. The area is bounded approximately by 97º49' and 98º01' west longitude and 40º and 40º11' north latitude. The county seat, Nelson, is located just out of the study area to the north. The county's largest city, Superior, has a population (1980 census) of 2502, and is located along the Republican River in the south-central part of the study area. Other population centers in the study area include Hardy (pop. 232), Ruskin (pop. 224) and Nora (pop. 24). The study area comprises eight townships and covers an area of 288 square miles.

CLIMATE

The climate of the study area is similar to that of the interior of many large continental landmasses, characterized by light to moderate rainfall, low to moderate humidity, hot summers, cold winters, and rather high variability in precipitation, temperature, and weather patterns. Average annual precipitation is 66.2 cm (26 in.), and average length of the growing season (last spring frost until first fall frost) is approximately 159 days (Neb. Dept. Econ. Devel., 1987; LRNRD, 1985).

PHYSIOGRAPHY

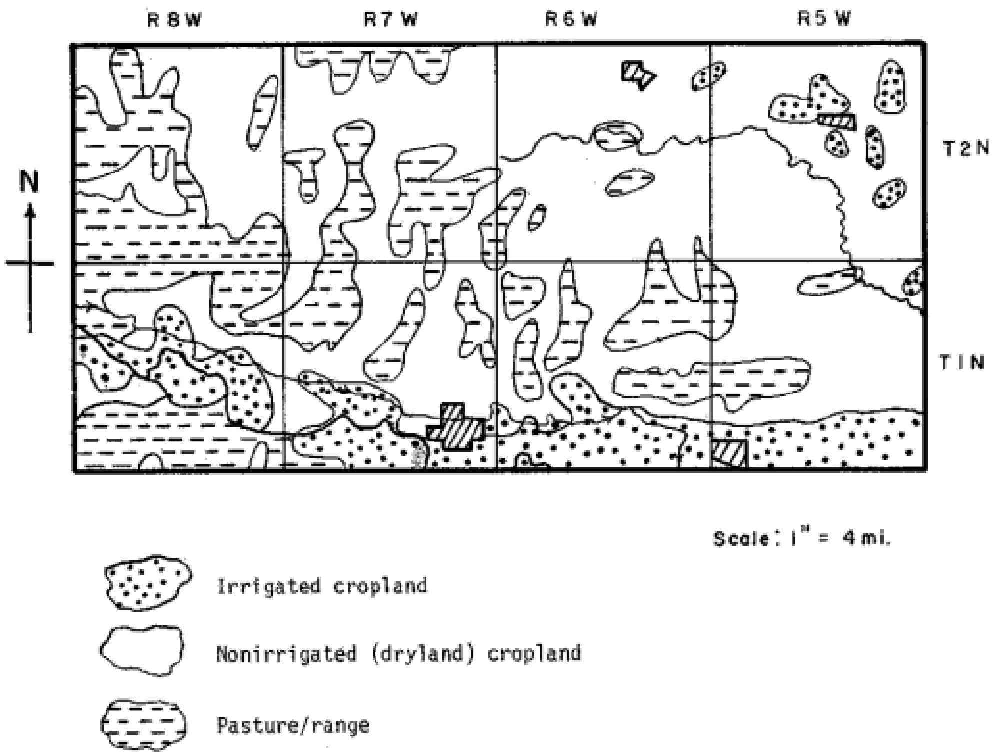
The southern half of Nuckolls County lies along the border of two physiographic sections of the Great Plains Province (Fenneman, 1931). The extreme northern portion of the study area is within the High Plains section, and consists of moderately rolling topography with poor drainage and fairly low relief. The majority of the study area drains into the Republican River, and is contained in the Plains Border section. This area is characterized by more moderate relief and dissected topography, grading into the floodplain of the Republican (Miller et al, 1964).

The major streams in the study area consist of the Republican River and its tributaries, and tributaries of the Little Blue River. The divide between the Republican and Little Blue drainage cuts across the northeast corner of the study area, with Little Blue tributaries flowing north, and Republican tributaries flowing south. The Republican Valley floor elevation varies from approximately 1600 feet above MSL at the western boundary of Nuckolls County to about 1500 feet where the river enters Kansas southeast of Superior. This equates to a slope of slightly more than 7 feet per mile. Overall, the study has a maximum relief of about 380 feet, with the high in the uplands in the northwest portion of the study area, and the low in the Republican River valley at the Kansas State line.

LAND USE

Land use in the southern half of Nuckolls County is similar to that in the rest of the mid-continental plains. Dryland (non-irrigated) agriculture prevails in much of the area, with significant portions of range-pasture and irrigated cropland, and small amounts of other uses (Figure 3; Table 2).

Figure 3: Generalized land use in the study area (Source: NRC Databank)



Crops raised in the area include corn, sorghum, soybeans, wheat, oats, alfalfa, and hay. The non-irrigated cropland is dominated by dryland corn, sorghum, and small grain, while the irrigated ground is dominantly corn and soybeans (Nebraska Dept. of Agriculture, 1987).

Noncropland is primarily pasture and range. Cattle are commonly grazed on this land or raised in a number of feedlots. Hogs are also raised in a number of feedlots and allowed to run on harvested cropland. Sheep and chickens are also raised in various parts of the area (Nebraska Dept. of Agriculture, 1987; Pollock and Davis, 1978).

Table 2: Land use percentages in study area (Source: NRC databank).

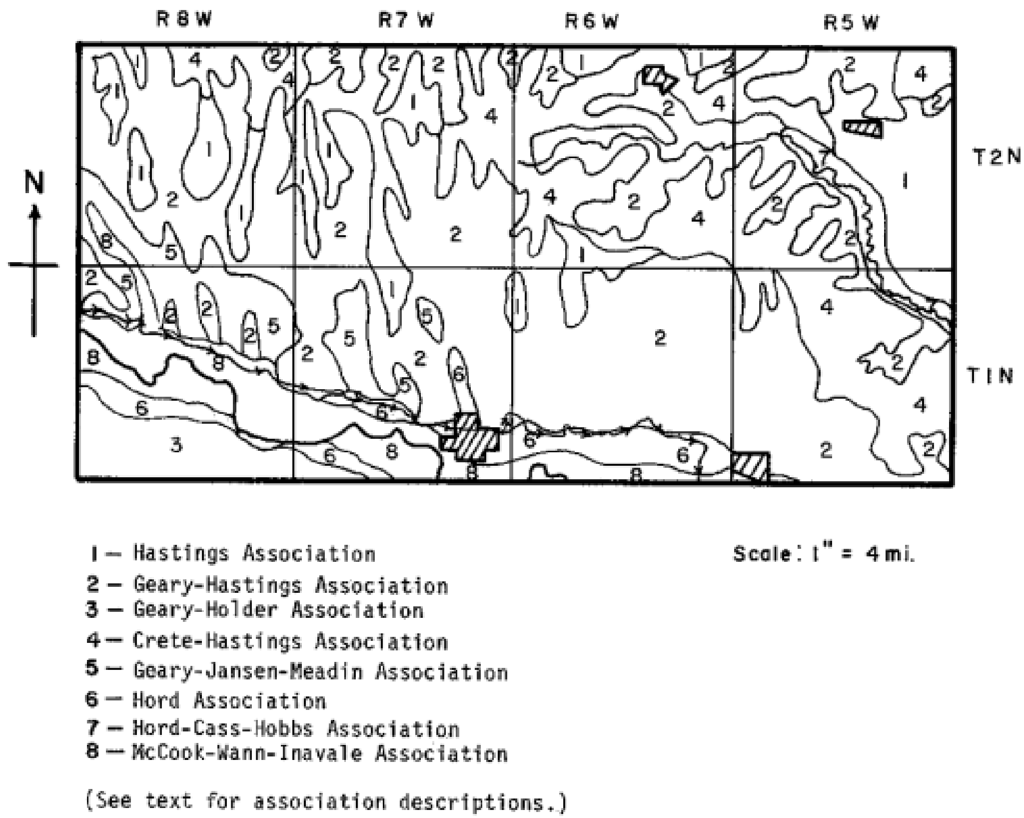
Land Use	Percentage Use
Nonirrigated cropland	55%
Pasture/range	35%
Irrigated cropland	7%
Forest	1%
Urban/built up	1%
Other	1%

Soils

The soils in the study area formed mainly in the loess of the uplands and in the silty-sandy alluvium of the stream valleys (Pollock and Davis, 1978). The loess-derived upland and side-slope soils typically have low permeabilities and high available water capacities (Peckenpaugh et al, 1987). The somewhat coarser soils of the valleys and terraces typically have higher permeabilities, and are often more well-drained than the upland soils (Pollock and Davis, 1978).

The soils in the southern half of Nuckolls County may be divided into three broad categories based on physiographic position: upland soils, soils of side-slopes, and valley-terrace soils (Figure 4).

Figure 4: Generalized soil association map of study area (Redrawn from Pollock and Davis, 1978)



The upland soils formed in the rather thick loess deposits on the higher ground in the northwest, west, and northeast sections of the study area north of the Republican River. These soils are deep, nearly level to gently sloping silty loams, with the primary difference between them being drainage. The Hastings association is mostly well-drained, the Crete-Hastings association is moderately drained to well-drained, and the Geary-Jansen-Meadin association can be excessively well-drained due to its formation over sand and gravel (Pollock and Davis, 1978).

The soils of side-slopes and divides also formed in loess. Their position on the slopes and divides gives them a more sloping aspect than the soils of the uplands. Apart from that, the side-slope and divide soils are quite similar - deep, well drained, silty loams of the Geary-Hastings and Geary-Holder associations (Pollock and Davis, 1978). The Geary-Hastings soils occupy a large portion of the study area north of the Republican. The Geary-Holder soils occupy much of the triangle of land south of the Republican in-the southwest corner of the study area, where topography becomes slightly rougher and the loess mantle becomes thinner or nonexistent (Wolfanger et al, 1925).

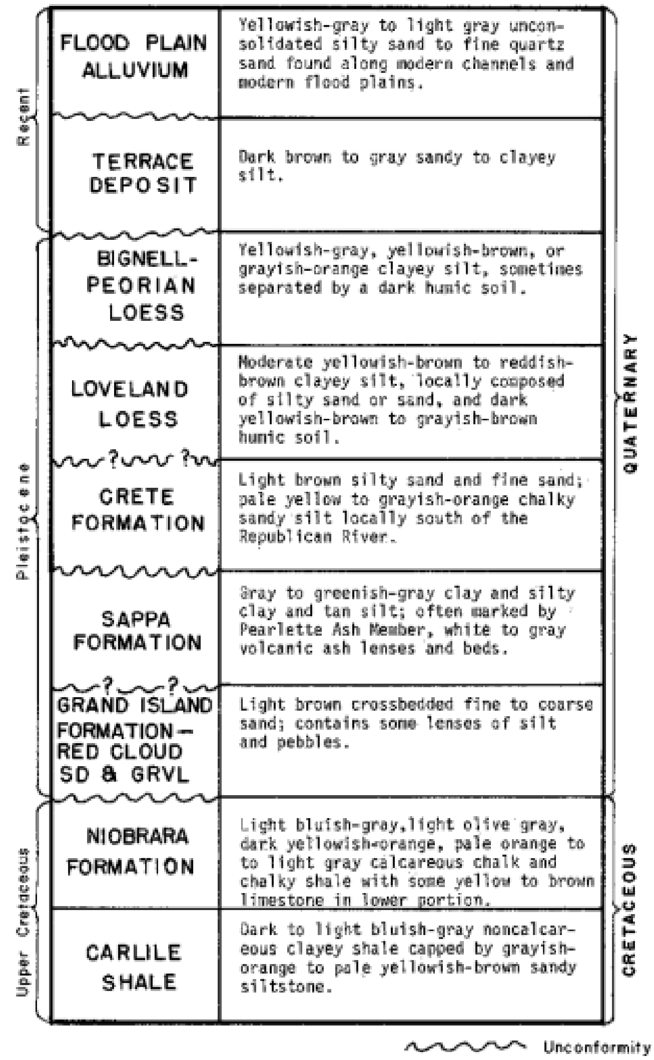
Soils on the terraces and valley bottomlands are deep, nearly level (bottomland) to gently sloping (terrace) silty, loamy or sandy soils. The Hord and Hord-Cass-Hobbs associations are deep, nearly level to gently sloping, well drained to moderately well drained silty and loamy soils on bottomland and terraces. They predominate in the Spring Creek valley in the eastern portion of the study area and in the terraces along the Republican. The McCook-Wann-Inavale association occurs in the bottomland of the Republican valley. Originating in the alluvium deposited by that river, this association is comprised of deep, nearly level silty, loamy, or sandy soils of varying drainage (Pollock and Davis, 1978).

Approximately 64% of the land in the study area is under cultivation (see Table 2), the dominant use being non-irrigated cropland. However, this is not a function of soil type, as most soils in the study area would be suitable for irrigation if sufficient water supply were available (Pollock and Davis, 1978). Currently, irrigated agriculture is practiced mainly in the Republican River valley and in the vicinity of Ruskin in the northeast portion of the study area.

Geology

The geology of the southern half of Nuckolls County consists of Upper Cretaceous bedrock unconformably overlain by various Quaternary sand, silt, and clay deposits (Figure 5, Figure 6). The Quaternary deposits mantle virtually the entire study area except where bedrock has been exposed due to weathering and erosion (Miller et al, 1964; Figure 7).

Figure 5: Stratigraphic section of units present in study area (Redrawn from Miller et al., 1964)



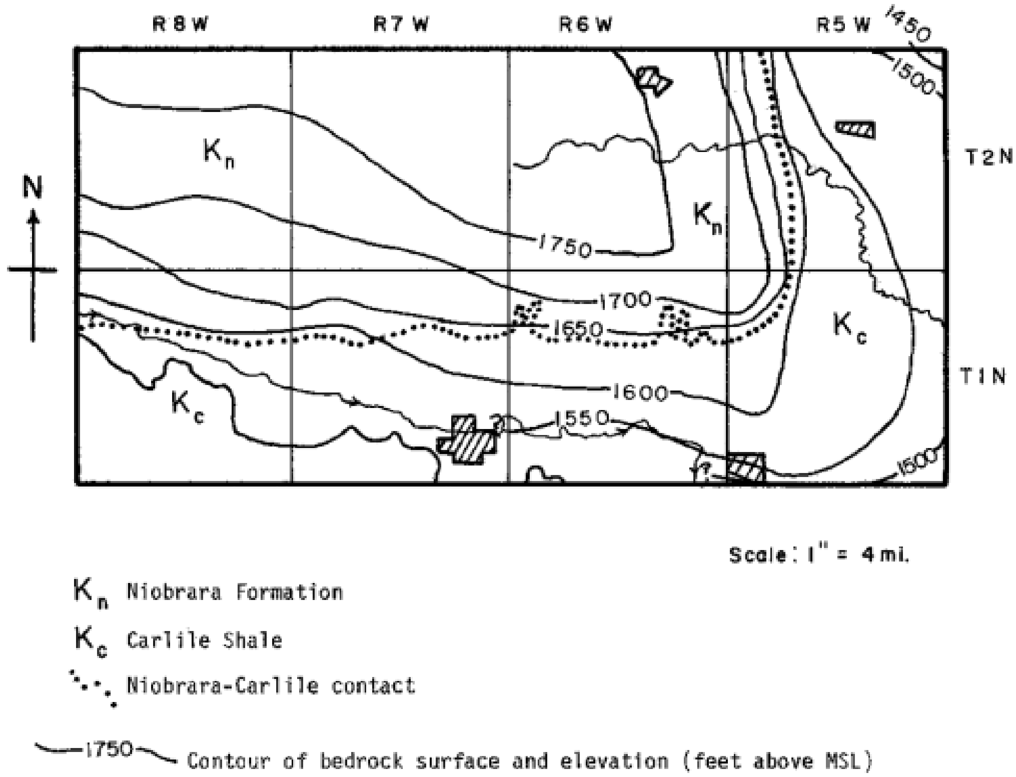


Figure 6: Contour map of upper bedrock surface, study area (Redrawn from Miller et al., 1964)

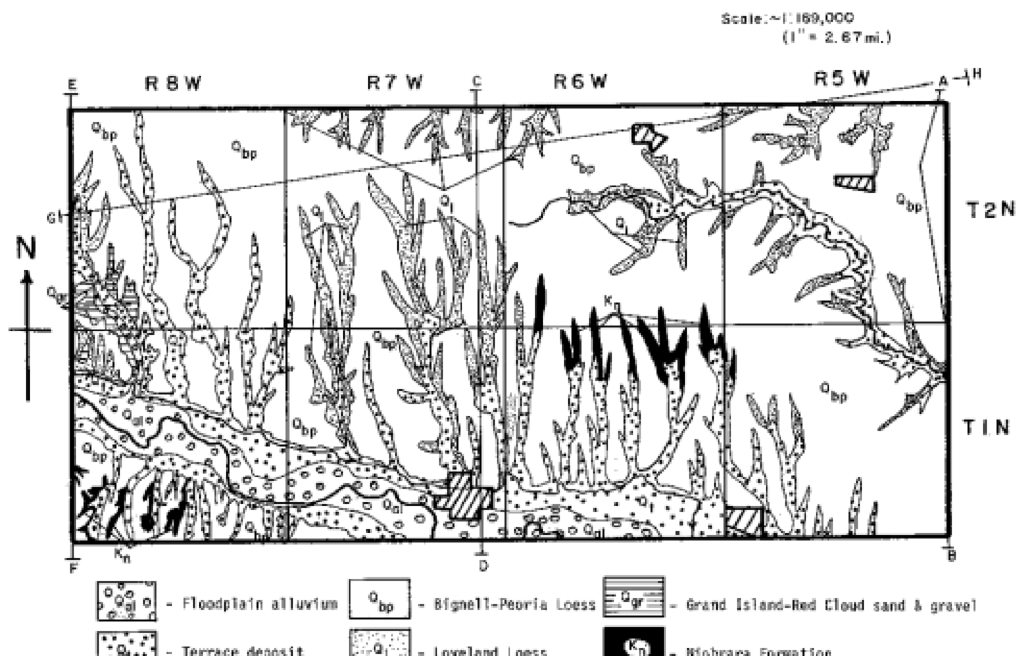


Figure 7: Generalized geologic map of study area, with location of cross-sections (Redrawn from Miller et al., 1964)

The lower most Cretaceous unit present in the study area is the Carlile Shale. It generally consists of dark to light gray, noncalcareous, fissile, clayey shale (Blue Hill Shale Member) capped by the Codell Sandstone Member, a 6-inch thick orange to yellow-brown, noncalcareous, soft, sandy siltstone which locally contains fossil shark teeth and Inoceramus (a large clam) fragments (Waite et al, 1946; Miller et al, 1964). Both of these units can be found exposed a-long the sides of ravines and valleys along the Republican.

Lying above the Carlile is the Niobrara Formation. The Fort Hays Limestone Member is grayish yellow to light brown, thin bedded to massive, and composed primarily of coccolith fragments, with some foraminifers and Inoceramus fragments (Miller et al, 1964). The Smoky Hill Chalk Member consists of light bluish gray to olive gray, soft, silty chalk interbedded with chalky shale and some bentonite (Miller et al, 1964). The Niobrara is present and outcrops in the northern and western portion of the study area, but at the southeastern extremity of the area, it has been almost completely eroded away (Waite et al, 1946; Burchett, 1986).

In areas further to the west of the study, the Niobrara (and/or Pierre shale) is unconformably overlain by the Miocene (Burchett, 1986) Ogallala Group sediments. Earlier authors (Condra, 1901; Waite et al, 194b) considered the Ogallala to be-absent in the study area. However, reports by the Conservation and Survey Division (CSD) of the University of Nebraska (CSD, 194b and 1953) and Miller et al (1964) indicate that the Ogallala is present in the subsurface of the study area north of the Republican (Figure 8, Figure 10, Figure 11). at least as isolated patches or lenses. in these areas, the Ogallala is described as a yellowish clay with some rounded limestone fragments (CSD, 1953).

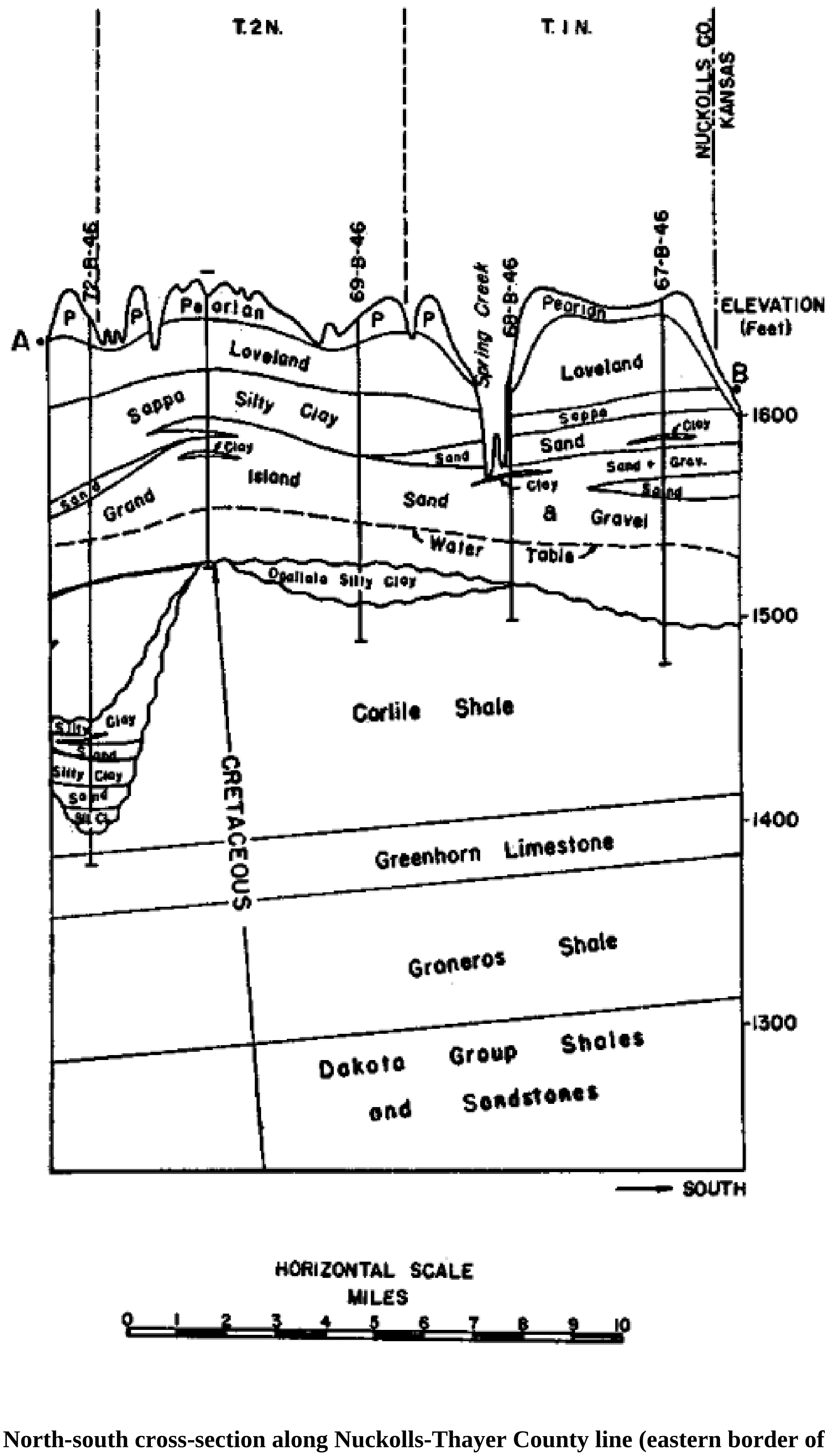


Figure 8: North-south cross-section along Nuckolls-Thayer County line (eastern border of study area)
(Reproduced with permission from CSD, 1948)

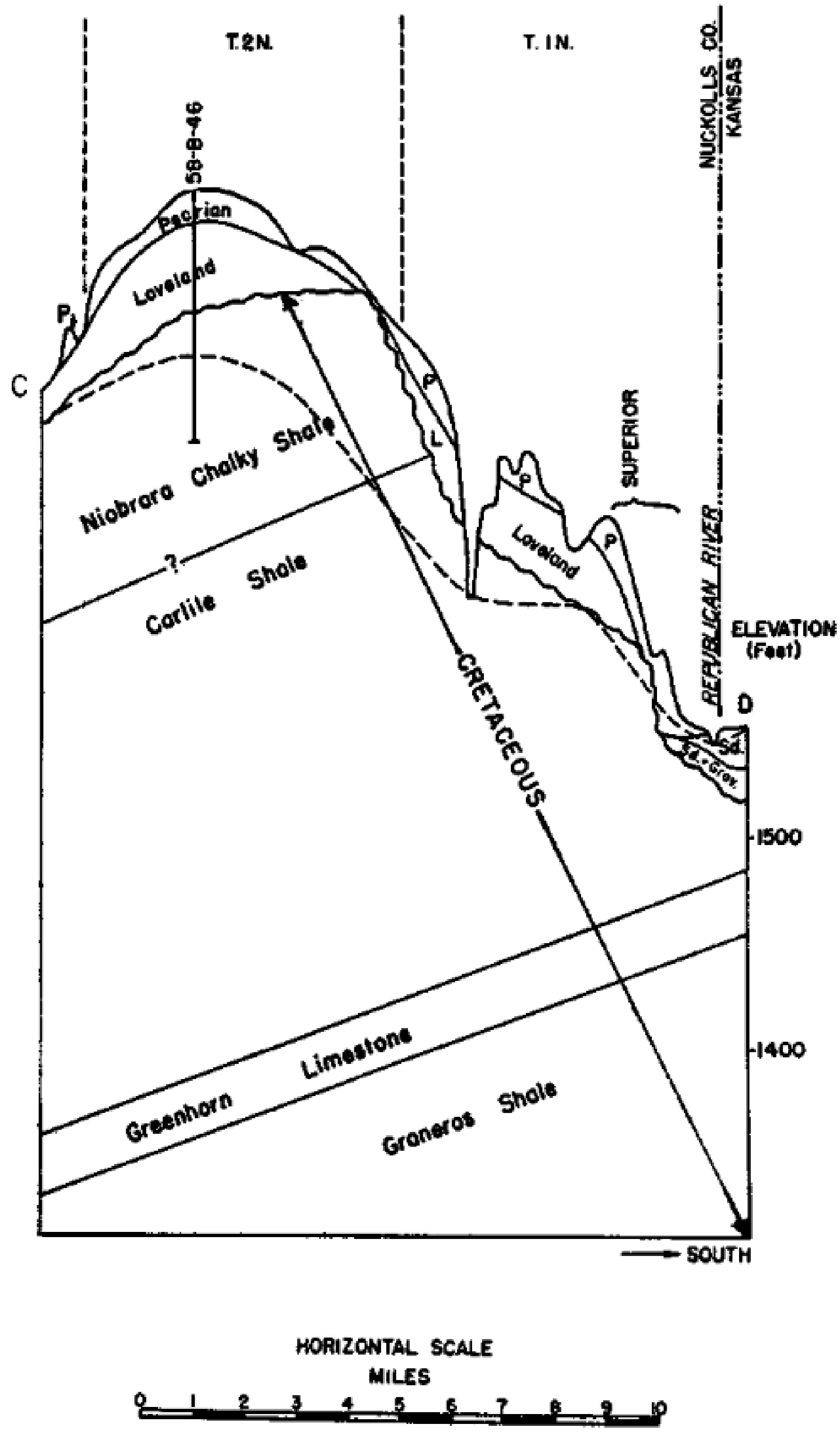


Figure 9: North-south cross-section through central portion of study area (Reproduced with permission from CSD, 1948)

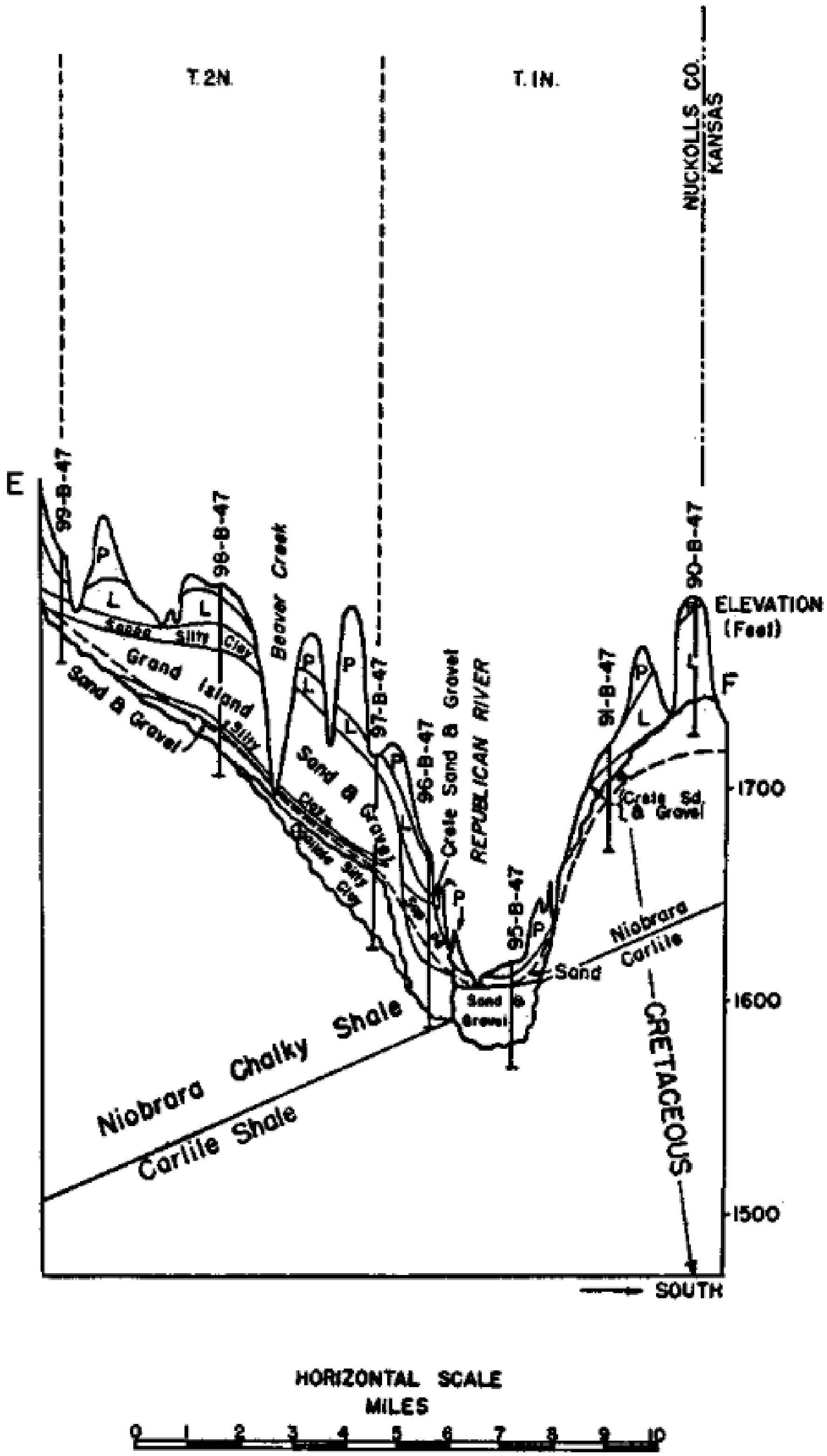


Figure 10: North-south cross-section along Nuckolls-Webster County line (western boundary of study area) (Reproduced with permission from CSD, 1948)

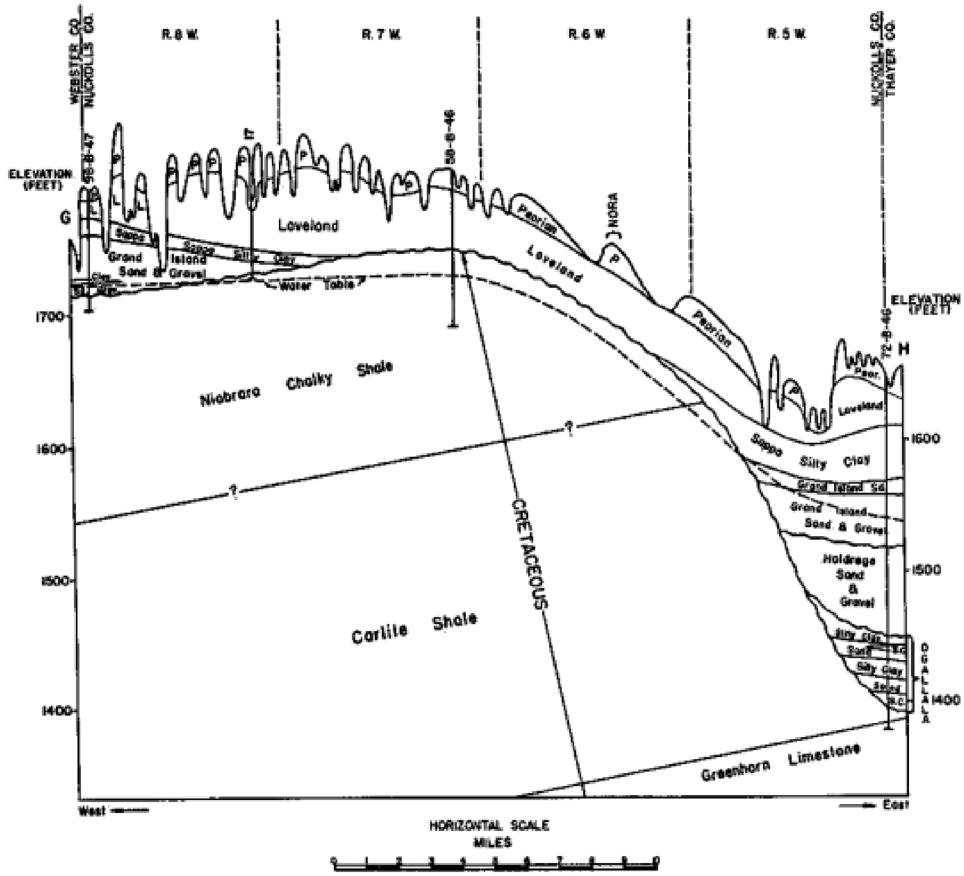


Figure 11: East -west cross-section through northern portion of study area (Reproduced with permission from CSD, 1948)

Unconformably overlying the Ogallala or, in the majority of the study area, the Niobrara or Carlile, are unconsolidated, nonglacial Pleistocene sediments. In general, these sediments consist of alternating sequences of sand, gravel, and loess.

The lowermost Pleistocene unit is composed of Red Cloud-type, western source sand and gravels (Red Cloud Formation and Grand Island Member of the Sappa Formation of Reed and Dreeszen, 1965; Grand Island Formation of Miller et al. 1964). Some of these sediments may be as old as late Pliocene (V.-T Dreeszen, pers. comm.). It generally consists of a light brown, light gray, or dark yellowish orange, fine to coarse, cross-bedded sand with local lenses of silt and pebbly sand, and isolated clay balls (Miller et al, 1964). The Grand Island-Red Cloud sands and gravels crop out among the sides of tributary valleys north of the Republican River and in isolated spots south of the river. It is present in the subsurface in the eastern portion of the study area, but appears to be absent in the central portion (See Figures 8-11).

Overlying these sands and gravels is the Sappa Formation, which consists of gray to greenish gray clay or siIty cIay and aIluvium, and tan silt (loess). The Sappa also includes the Pearlette Ash Member, a white to gray volcanic ash layer shorting considerable lateral persistence and thicknesses around 5 feet (Miller et al, 1964). The Sappa is most abundantly exposed north of the Republican in the western portion of the study area. It is also present in the subsurface in the eastern part of the area (CSD, 1948).

Unconformably overlying the Sappa is the Crete Formation (Crete Member of the Loveland Formation of Reed and Dreeszen, 1965). It consists of pale orange chalky silt and sand, reddish brown silty sand, and reddish brown fine to coarse sand, mostly alluvial or colluvial (Miller et al, 1964). The Crete is exposed in scattered localities south of the Republican in the southwest portion of the study area, but is absent in virtually all of the rest of the southern half of Nuckolls County (CSD, 1948).

The Crete is overlain, possibly unconformably. by the Loveland Loess. As the name suggests, the Loveland is a primarily eolian deposit consisting of yellowish brown clayey to sandy silt and fine sand (Miller et al, 1964). The Loveland is present over the entire study area, in some places blanketing older Pleistocene deposits and in others (particularly the central portion of the study area) directly overlying the Cretaceous bedrock (CSD, 1948). It is best exposed in the valleys of the tributaries to the Republican, and in the valleys of Spring Creek and the other Little Blue tributaries in the north and east of the study area (Miller et al, 19b4).

The uppermost Pleistocene unit is composed of the Peorian and Bignell Loesses. These loesses are nearly identical and are not commonly differentiated in the field or on maps (Miller et a.1, 1964). They consist of yellowish gray, yellowish brown, or grayish orange, eolian or partially fluvial clayey silt, with up to approximately 10% sand (Miller et al, 1964). The Peorian-Bignell Loess is at the surface in most of the uplands in the study area (See Figure 7). The loess is characterized by its ability to stand in vertical section and by columnar jointing; it tends to be somewhat coarser nearer the major drainages in the area and finer in the uplands (Miller et al, 1964).

The drainage in the study area are characterized by two Holocene deposits: terraces and alluvium. The terrace deposits consist of clayey to sandy silt forming flat-topped valley fills standing 15 to 40 feet above stream level. The floodplain alluvium is composed of fluvial silt and fine quartz sand up to 50 feet thick, normally yellowish brown, yellowish gray, or light gray, with isolated lenses of coarser sand and gravel occurring within the fill (Miller et al, 1964). The terrace deposits line the sides of the major drainages, while the alluvium is confined mainly to the bottomland of the Republican River Valley.

Ground Water Geology

The study area may be divided into four regions based upon the thickness of the saturated sediments: 1) The area north and northeast of the valley of the Republican River; 2) The Republican Valley; 3) The area southwest of the Republican Valley; and, 4) The northeast portion of the study area, which is part of the Little Blue drainage.

North and northeast of the Republican Valley, the Cretaceous bedrock is relatively near the surface and overlain mainly by loess (See Figures 8-11). In this area, much of the sand and gravel present is dry (V.H. Dreeszen, pers. comm.). What wells that can be developed are commonly completed in thin sand and gravel lenses formed on top of the bedrock, or in the upper fractured zone near the upper limit of the bedrock (Waite et al, 1946). These wells are typically low-yielding; farm and stock wells, can, with some effort, be successfully developed in most of this area, but irrigation or other high capacity wells are notably absent (Figure 12).

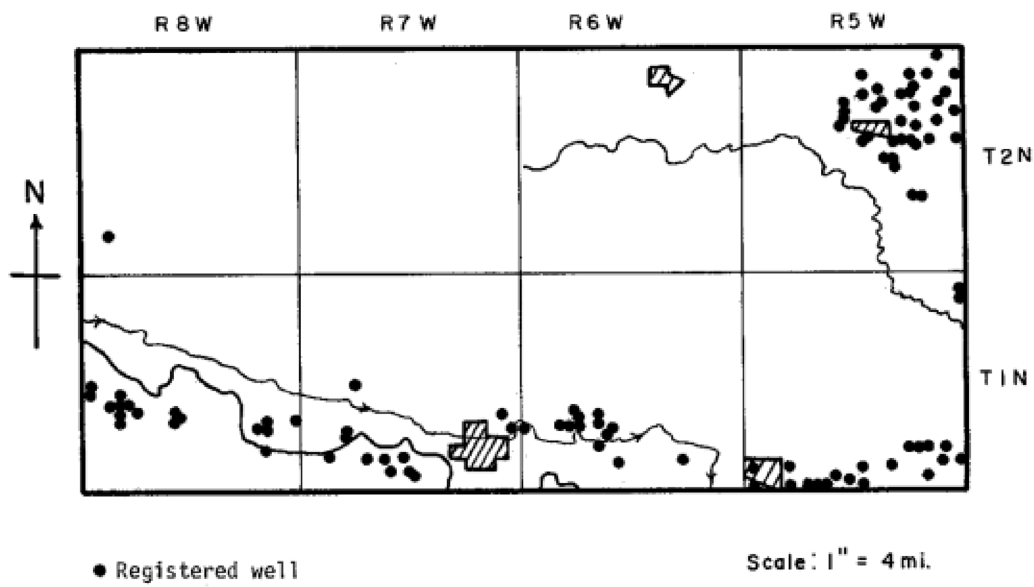


Figure 12: Location of registered wells in study area

The Republican River Valley consists mainly of alluvial sand and gravel in thickness up to 30 feet (CSD, 1953; Waite et al, 1946). In addition, water table elevations are relatively close to the surface (Figure 13). Domestic and irrigation wells are more easily developed, and yields are likely to be substantially greater in the valley.

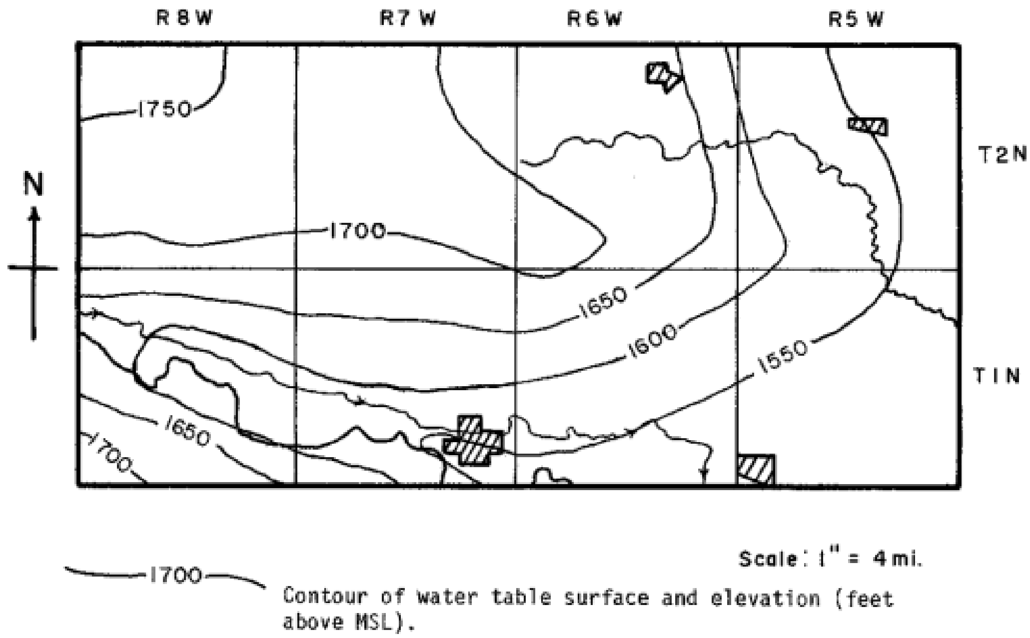


Figure 13: Generalized water table map of study area (Redrawn from DEC-CSD, 1980)

The area south of the Republican is, like that north of the valley, characterized by high bedrock overIain by fine-grained Ioess (CSD 1948). Yields here are very low and, as pointed out by Waite et al (1946), it is nearly impossible in this area to find adequate ground water supplies.

The northeast corner of the study area is part of the drainage basin of the Little Blue River. In this part of the study area, significant thicknesses of sand and gravel are present, as much 50 feet (CSD, 1953). These coarse sediments are also at least partially saturated, and domestic and irrigation well development is more successful here than in the high bedrock areas (Figure 12).

The water table surface in the study area slopes gently east-southeast, at an overall gradient of approximately 12.5 feet/mile (Figure 13). Depths to ground water can range from a few feet in the bottom of the Republican Valley up to nearly 100 feet in the uplands north of the river (CSD, 1953; LRNRD, 1985).

As would be expected from the location of the sand and gravel units, transmissivity of the principal aquifer is greatest in the Republican Valley and the eastern end of the study area, and lowest in the central uplands (Figure 14). Transmissivities in the Republican Valley west of Superior range up to 100,000 gallons per day/foot (gpd/ft) in the valley bottom and 50,000 gpd/ft on the terraces. Transmissivities in the upland aquifer are much lower, ranging up to 20,000 gpd/ft (LRNRD, 1985). The eastern portion of the study area, where some saturated sand and gravel is present (Figure 8), includes aquifer material having transmissivities varying from less than 20,000 to more than 100,000 gpd/ft (LBNRD, 1986).

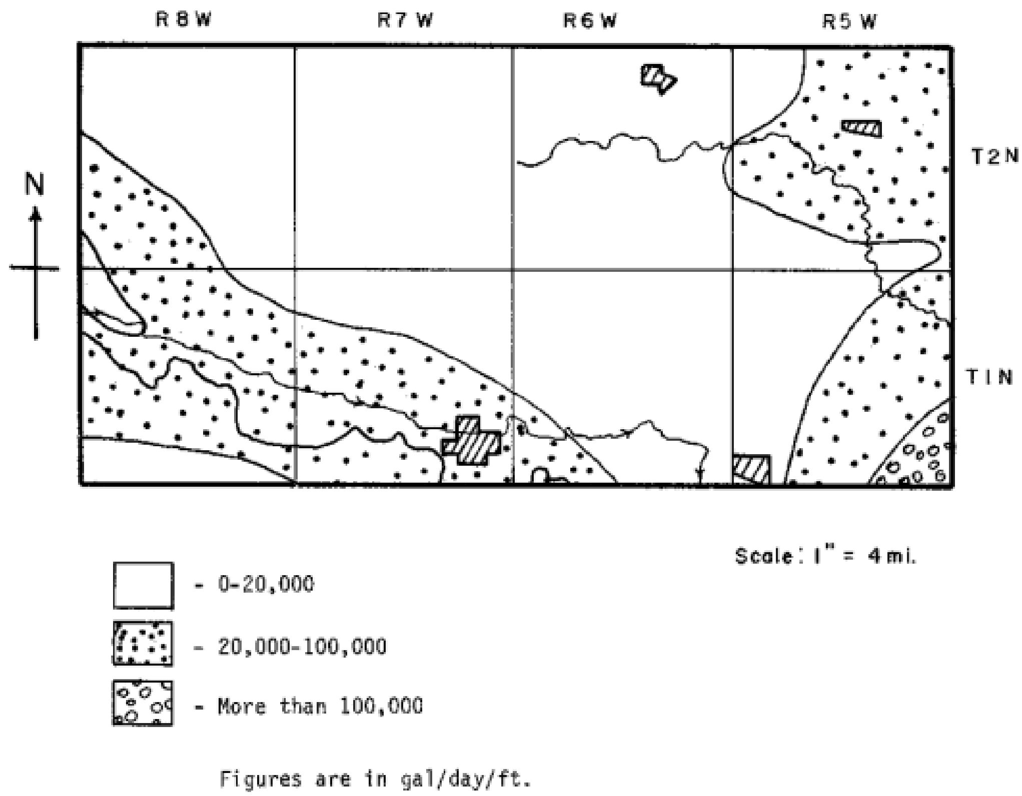


Figure 14: Generalized transmissivity map of study area (Redrawn from LRNRD, 1985, and LBNRD, 1986)

Sampling Methods

Sampling was performed according to DEC protocol (Ehrman, 1988). Since the allotted time for studying NPS pollution under the SPA program is one year (DEC, 1988), sampling for the Superior project was limited to two sampling runs, one in March 1988 consisting exclusively of domestic wells, and one in August 1988 consisting of irrigation, municipal, and industrial wells.

Domestic Wells

Sites of domestic wells for sampling were selected at random from the available pool of rural residents served by private wells. Laboratory capacity limited the number of samples per SPA sampling run to 60; thus, 60 names of rural residents were selected at random from the rural residence directory for Nuckolls County. Since residential status changes frequently, some modifications to the original list were necessary; the location of points actually sampled is shown in Figure 15. Of the 60 sites selected, 56 were actually sampled.

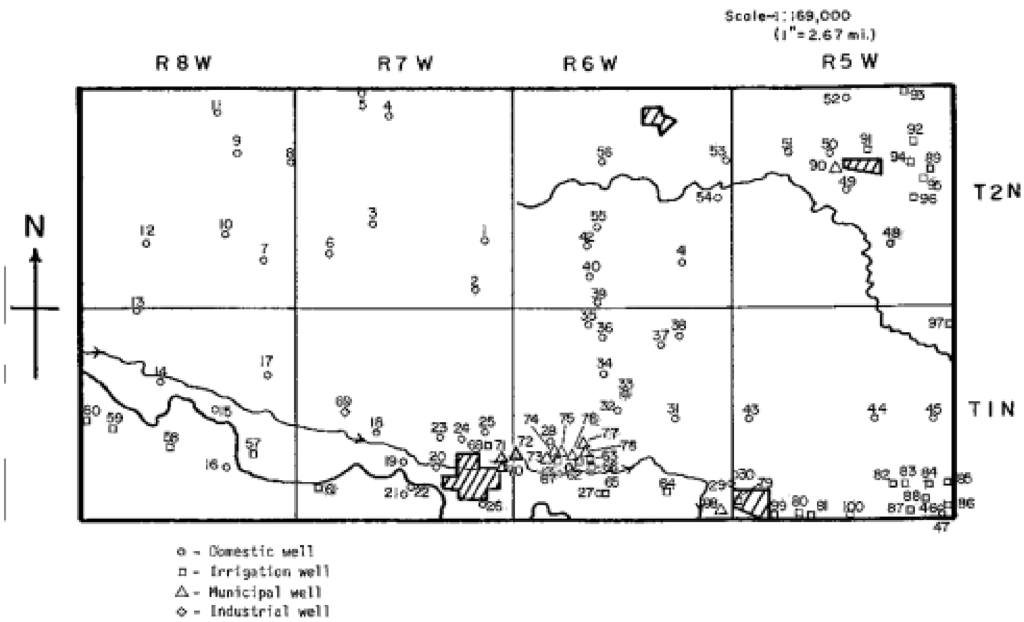


Figure 15: Location of sampling sites

Before sampling, the well was located and as much site-specific data (see **Appendix B**) as possible was collected. The tap closest to the well was located, opened, and allowed to run at full pressure for at least 15 minutes which, in most cases, would provide a volume of water sufficient to purge both the pressure tank and three well casing volumes. As a further precaution, field conductivity was measured using a Beckman conductivity meter, and sampling was initiated only after consecutive readings had stabilized to within +/- 10%.

Field conductivity was determined using a Beckman conductivity meter. Field pH was recorded using a Leeds and Northrup pH meter. Field temperature was determined by the use of a hand-held, alcohol-filled thermometer. All three-measurements were taken from the same dedicated container, and leftover sample water was discarded.

Samples were collected and preserved in the following manner: one 1000 ml plastic cubitainer filled nearly full and left unpreserved for analysis of major ions (chloride, sulfate, sodium, magnesium, calcium, and potassium); one cubitainer filled nearly full and preserved with 5 ml concentrated sulfuric acid for NO3-N analysis; one cubitainer filled to the exclusion of air and left unpreserved for bicarbonate analysis; and one 250 ml sterilized brown glass bottle filled nearly full and left unpreserved for coliform bacteria analysis. Prior to collection of the bacteria sample, the hose or tap outlet was sterilized using a propane torch. One field blank set consisting of deionized water and one duplicate set of samples were collected per sampling day. These were preserved and handled in the same manner as the actual samples. All samples were packed on ice in coolers for transport to the laboratory. The first nine sample sets were transported to the laboratory via bus; remaining sample sets were delivered via DEC personnel. Holding times for all parameters with the exception of bacteria and laboratory pH were met. Nonetheless, the bacteria samples can, in a very general way, indicate possible point source contamination from animal waste.

Irrigation, Municipal, Industrial Wells

Sites of deeper, higher capacity wells were selected from well registration information provided by the Nebraska Natural Resources Commission databank. This information indicated that there were 129 registered wells in the study area, 127 of these being located in five of the eight townships under study (see Figure 15). In addition, the domestic well sampling results indicated the more elevated nitrate levels were found along the Republican River in T1N, R5W and T1N, R6W. Therefore, it was decided to attempt to sample all available wells in these townships (including 9 municipal wells belonging to the city of Superior and 1 belonging to the Village of Hardy). The remainder of the available sampling points were divided among the 4 remaining townships. As with the domestic wells, modifications of the original list were necessary; of the 60 wells selected for sampling, 44 were actually sampled (see Figure 15).

All wells sampled had been pumping for several hours before sampling. As with the domestic wells, site-specific data was collected for each well (see Appendix B). Before sampling, a tap. pipe gate, or outlet. was located as close as possible to the well. The outlet was opened and allowed to run to clarity and temperature stabilization. Field pH and temperature were recorded. Samples were collected and preserved in the following manner: one 1000 ml plastic cubitainer filled nearly full and left unpreserved for analysis of major ions (chloride, sulfate, sodium, magnesium, calcium, and potassium); and one cubitainer filled nearly full and preserved with 5 ml concentrated sulfuric acid for NO3-N analysis At each sampling point, a field screen for NO3-N was performed using a Hach NO3-N test kit. On those samples showing a moderate NO3-N level (approximately 8 mg/l). a Res-l-Mune triazine test kit was employed to detect the presence of triazine herbicides. Samples were screened utilizing a 0.5 µg/l (part per billion) triazine conjugate. Those showing positive results (i.e., containing > 0.5 µg/l triazines) were then sampled for laboratory pesticide analysis. Pesticide samples were collected in sterilized 1000 ml clear glass jars with Teflon-lined plastic lids.

As with the domestic samples, one field blank set consisting of deionized water and one duplicate set of samples were collected each day. These were preserved and handled in the same manner as the actual samples. All samples were packed on ice in coolers for transport to the laboratory by DEC personnel.

Sample Analysis

All parameter analyses except total coliform bacteria were performed by the DEC laboratory. Total coliform bacteria counts were provided by the Nebraska Department of Health (NDOH) laboratory. All analyses were conducted in accordance with EPA standard methods (EPA, 1979). Table 3 lists these analyses and the corresponding method references.

Sample Results And Discussion

Appendix C lists the results of the domestic sampling, while **Appendix D** indicates the results of the sampling run including irrigation, municipal, and industrial wells.

Nitrates

Univariate analysis was performed on the data (domestic and irrigation results were taken as one dataset), generating mean, median, variance, standard deviation, skewness, kurtosis, histograms, and boxplots for each set. Outliers as determined from boxplots can be used to determine extreme values as compared with the rest of the dataset. The mild and extreme upper outliers of the NO3-N dataset of all 100 samples are here considered to be the results of point sources of contamination. The minimum NO3-N value in mg/l of the upper outliers was determined by subtracting tee data value of the 25th percentile from that of the 75th percentile, multiplying that number by 1.5, and adding that value to the value of the 75th percentile. Using this procedure, the cutoff value for upper outliers (and therefore point source of NO3-N contamination) was determined to be 20-99 mg/I, rounded to 21.0 mg/l NO3-N. This figure compares favorably with the figure of 25.0 mg/I used in a statewide study of NPS ground water contamination by the U.S. Geological Survey (Chen and Druliner, 1987).

Table 3: Methods for parameter analysis.

Parameter	**EPA Method Number**	**Description**
Calcium	215.1	Atomic adsorption, direct aspiration
Chloride	325.2	Colorimetric
Conductivity	120. 1	Specific conductance
Magnesium	242.1	Atomic adsorption, direct aspiration
Nitrate-nitrite, as nitrogen	353.2	Colorimetric automated cadmium reduction
Sodium	273.1	Atomic adsorption, direct aspiration
Sulfate	375.4	Turbidimetric
pH	150.2	Electrometric probe
Pesticides	----	Gas chromatography
Potassium	258.1	Atomic adsorption, direct aspiration
Bicarbonate	310.1	Titration
Total coliform bacteria	141.27	Membrane filtration

Statistical analysis indicated that the data were not normally distributed. Nonparametric statistical analysis provided Spearman correlation coefficients which indicate the presence and strength of correlation between analyzed parameters. Spearman correlation coefficients for each parameter are appended (**Appendix E**). Coefficients correlated at the 5% level and having r values greater than 0.60 are here considered to be strongly correlated. NO3-N is not strongly correlated with any of the other parameters. The weak correlation of NO3-N with chloride (r= 0.39). indicates that animal wastes are not the main cause of NO3-N contamination of the ground water (Spalding and Exner, 1987).

The results of the NO3-N analysis are displayed as a contour map in Figure 16. This map is composite of the two samplings. The contour lines represent isolines of equal concentration of NO3-N in samples taken during the spring and summer of 1988. Note that the assumed point sources of contamination (those samples with values above 21.0 mg/l) have been removed before contouring.

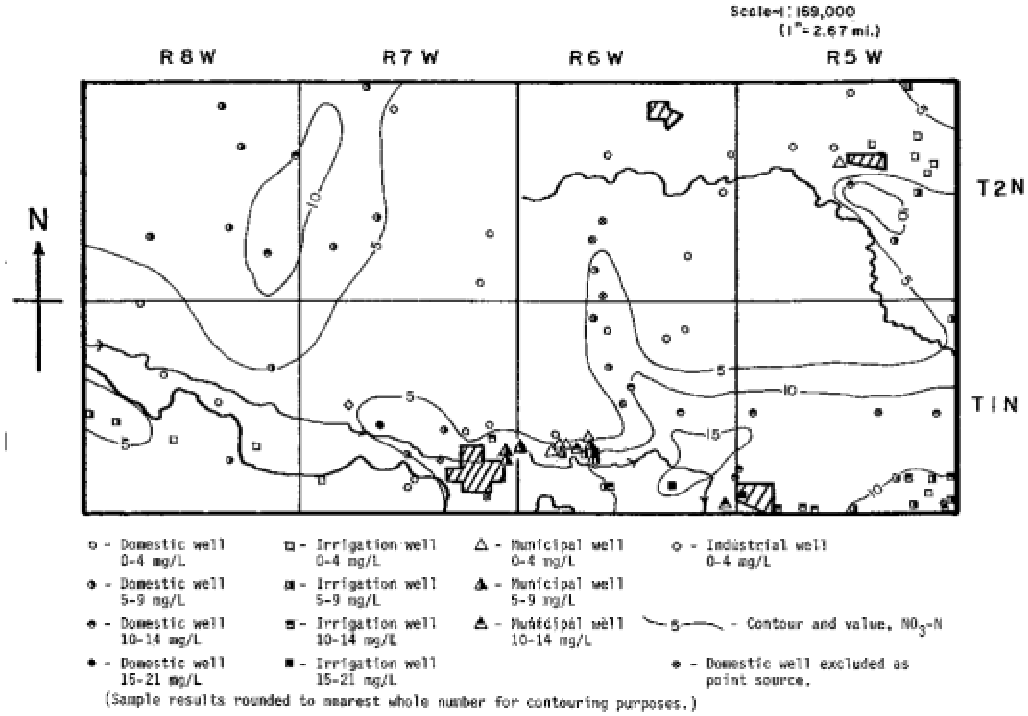


Figure 16: Sampling results and contour map of nitrate-nitrogen levels, study area

The results of the domestic and irrigation samplings can be contoured on the same map because well depth in all areas is similar for both domestic and irrigation supplies. In the Republican River valley, and the southeast corner of the study area, well depths are fairly shallow, with most being between 50 and 100 feet deep. In the uplands, in the northeastern portion, these depths are typically between 100 and 200 feet, for both irrigation and domestic wells. In the north-central and northwestern areas, there are no irrigation wells, and domestic wells are generally around 100 feet deep (data provided by individual landowners and irrigation well registrations in NRC databank).

Once the point sources are removed from consideration, the overall pattern of concentrations of NO3-N in the southern half of Nuckolls County emerges. Concentrations are highest in the south-central, southeastern, and northwestern portions of the study area, with a relatively thin band of higher concentrations up to approximately 15 mg/I in the area east of Superior around Hardy. These higher concentrations show areal persistence and consistency over several miles and do not exhibit the "bullseye" pattern of widely varying values that is characteristic of widespread point source contamination (Lindau and Spalding, 1983; Exner and Spalding. 1985).

The distribution of higher NO3-N values correlates well with the location of irrigated cropland in the southern portion of the study area (compare Figure 3 and Figure 16). This would tend to agree with the heavier usage of fertilizers and greater potential for leaching of those fertilizers on irrigated land (Exner and Spalding, 1985). The contamination appears not to correlate with major soil associations (compare Figure 4 and Figure 16). The NO3-N contours cut across the soil association boundaries, from bottom land to terrace land to loess upland soils. This is understandable in that all of the soil associations have somewhat similar characteristics as well as moderate potential for leaching of agricultural chemicals (USDA-SCS, 1988).

The concentrations of NO3-N in ground water samples taken in the area roughly bounded by Superior on the west, the Nuckolls County line on the east, the Kansas-Nebraska border on the south, and the T1N township line on the north, approach and sometimes exceed the maximum contaminant level (MCL) of 10 mg/l prescribed for NO3-N(EPA, 1976). 56 samples were taken in the area described above. The average NO3-N level for all bb of these samples is 12.9 mg/l. If all obvious point sources of contamination (values above 21 mg/I, wells located in pits, wells with cracked pads or casings, etc.). and those wells outside the 5 mg/l contour line (Figure 16) are eliminated, 32 samples remain. The average NO3-N content for these 32 samples is 10.1 mg/l. Several of the irrigation and municipal wells in these 32 samples were located ' near drainage features, especially road ditches. This is particularly true of the Superior municipal wells (location numbers 70, 78). It is uncertain how much effect surface runoff accumulating in road ditches could have on the water quality of wells located nearby (within several tens of feet). However, if all wells located near such drainage are eliminated, 20 samples remain. The average NO3-N concentration of these 20 samples is 10.7 mg/l. still above the MCL for NO3-N.

There is also an area in the northwestern portion of the study area in which NO3-N levels in the samples approach or exceed 10 mg/l. The area roughly bounded by the 5 mg/l contour on Figure 15 consists of 10 samples; the average NO3-N value of these 10 samples is 8.4 mg/I. However, of these 10 samples, 6 were identified as likely point sources. Most of these wells were located in pits which showed evidence of water accumulation; one well was located a few feet away from a small grain elevator-storage facility. The average of the 4 remaining samples is 8.4 mg/I. This value is still fairly high, however the 4 samples shown do not form a sufficient database to make any further generalizations. Thus, further sampling in this area is needed to indicate whether or not NPS ground water contamination is occurring.

Pesticides

Laboratory restrictions in space and budget did not allow for widespread analysis for pesticides. Thus, field screens for NO3-N and triazine herbicides were used to get a field indication as to the presence of pesticides in samples from irrigation and municipal wells.

The triazine field kit indicates the presence of triazines at concentrations as low as 0.5 µg/l (micrograms/liter, roughly equal to parts per billion). Triazines which can be detected by use of the kit include commonly used herbicides such as atrazine, cyanazine, propazine, prometon, and simazine. Atrazine is the most commonly used herbicide in Nebraska, particularly on corn and sorghum (Johnson and Kamble, 1982). Corn and sorghum are the most common crops in the study area, thus it is reasonable to assume that if any pesticides were present in the ground water, atrazine would likely be among them. The occurrence of atrazine in ground water samples has also been linked to higher NO3-N values (Spalding. et al , 1980) . thus the Hach kit was used to give a field estimate of NO3-N content. In addition, sampling by the Nebraska Department of Health (DOH) , and LRNRD staff indicated that several wells, including Superior and Hardy municipal wells. had already been contaminated by atrazine (unpublished data, NDOH and LRNRD).

The results of pesticide scans are summarized in Table 4. Locations of these samples are given in Figure 17. No attempt is made to extrapolate these results to the rest of the study area. However, detection of atrazine residues in 1 out of 8 samples taken indicates that atrazine contamination is occurring, and further attempts should be made to understand and manage it.

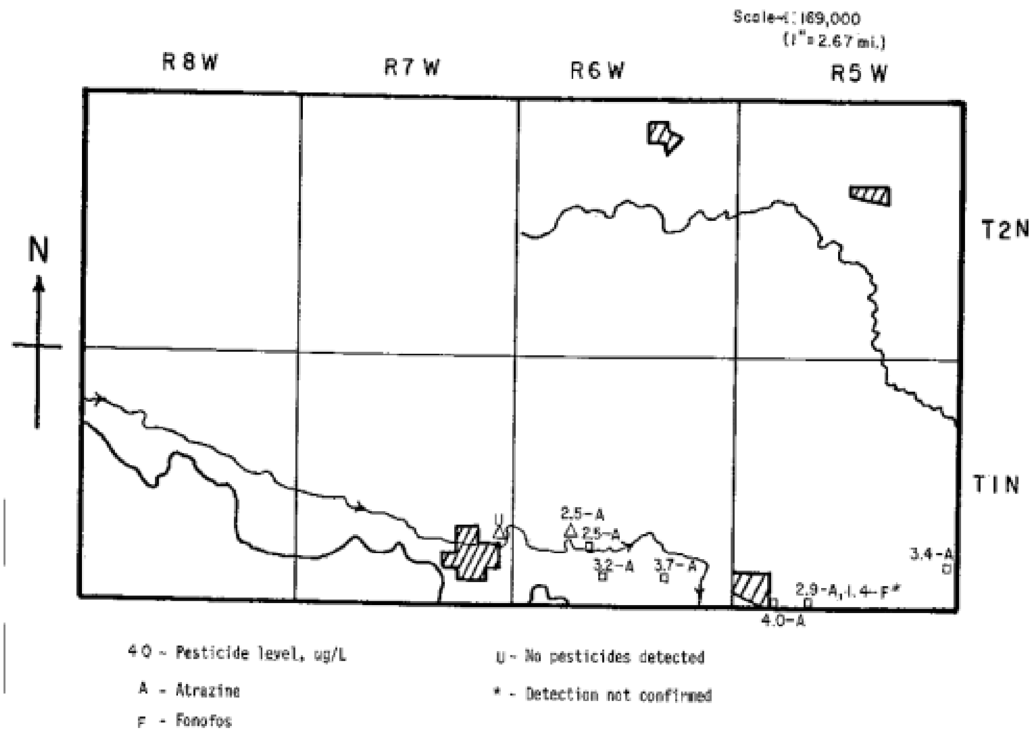


Figure 17: Locations and results of pesticide sampling

Table 4: Results of pesticide analysis.

Sample #:	**64**	**65**	**66**	**71**	**76**	**81**	**85**	**99**
Pesticides:								
Propachlor	u	u	u	u	u	u	u	u
Terbufos	u	u	u	u	u	u	u	u
Fonofos	u	u	u	u	u	1.38*	u	u
Carbofuran	u	u	u	u	u	u	u	u
Alachlor	u	u	u	u	u	u	u	u
Metribuzin	u	u	u	u	u	u	u	u
Metolachlor	u	u	u	u	u	u	u	u
Chlorpyrifos	u	u	u	u	u	u	u	u
EPTC	u	u	u	u	u	u	u	u
Butylate	u	u	u	u	u	u	u	u
Trifluralin	u	u	u	u	u	u	u	u
Atrazine	3.70	3.24	2.47	u	2.45	2.94	3.35	4.02
Simazine	u	u	u	u	u	u	u	u
Cyanazine	u	u	u	u	u	u	u	u
Prometon	u	u	u	u	u	u	u	u
Cyprazine	u	u	u	u	u	u	u	u
Ametryn	u	u	u	u	u	u	u	u
Propazine	u	u	u	u	u	u	u	u
2,4-D	u	u	u	u	u	u	u	u u - Pesticide undetected

* - Pesticide detection unconfirmed
All concentrations listed are in µg/l

Conclusions

1. Nonpoint source NO3-N ground water contamination is occurring in a portion of the southern half of Nuckolls County, Nebraska. This area is around and east of the city of Superior, extending to the Thayer County line, and corresponds well with the irrigated cropland in that area.

2. The same area has experienced ground water contamination by the herbicide atrazine. Due to sampling constraints, the extent of this contamination was not determined.

3. The northwestern portion of the area has experienced some elevated ground water levels of NO3-N. However, because most of the domestic wells sampled in that area were affected by point sources of contamination, it is unclear if nonpoint sources could be affecting the ground water to any extent.

Recommendations

1. A Special Protection Area should be declared in the area around and east of Superior to allow the Lower Republican and Little Blue Natural Resources Districts to manage the nonpoint source ground water contamination occurring there.

2. The Special Protection Area should enclose the following area: Beginning at the northeast corner of Sec. 12, T1N, R5W, Nuckolls County, Nebraska; proceeding 10 miles west along county road to the northwest corner of Sec. 9, T1N, R6W; then 1 mile South along county road to the southwest corner of the same section; then 6 miles west along county road across US Highway 136 to the southwest corner of Sec. 9, T1N, R7W; then 1 mile south along county road to the southwest corner of Sec. 16, T1N, R7W; then 2 miles west along county road to the southwest corner of Sec. 18, T1N, R7W; then approximately 1.9 miles south along county road and trail road to the Republican River; then east and south along the north and east side of the Republican River to the point where that river enters the State of Kansas in the southeast corner of Sec. 34, T1N, R7W; then 14 miles east along the Kansas state line to the southeast corner of Sec. 36, T1N, R5W; and finally 5 miles north along Thayer County line to the original point, northeast corner of Sec. 12, T1N. R5W (see Figure 18). After consultation with the affected NRDs, these suggested boundaries can be changed.

Figure 18: Proposed boundaries of Special Protection Area in southern Nuckolls County, Nebraska

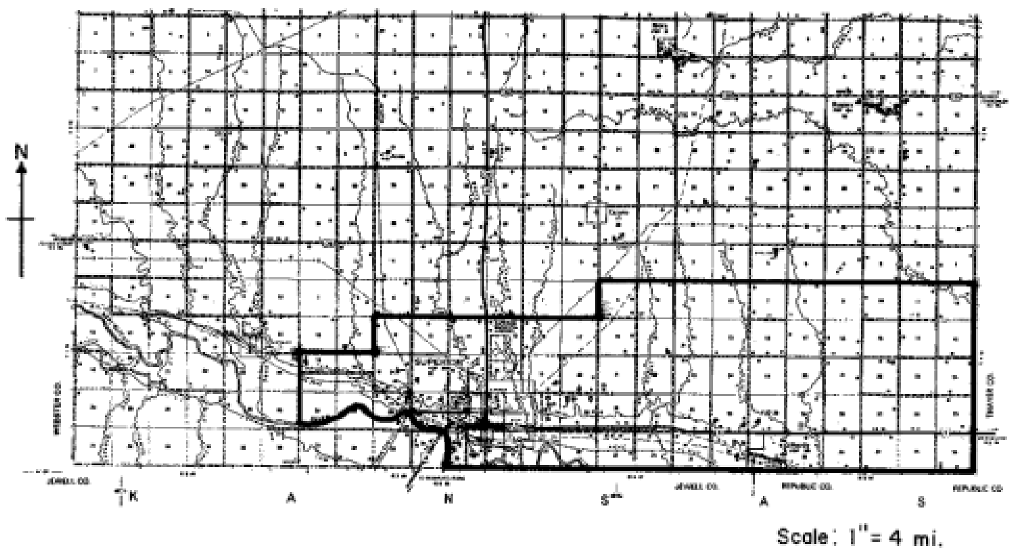


Figure 18: Proposed boundaries of Special Protection Area in southern Nuckolls County, Nebraska

3. The Special Protection Area should include all soil, sediment, and rock strata within the geographic area outlined above from ground surface downward to the top of the Cretaceous bedrock surface.

4. Provisions Should be made to continue ground water sampling in the northwest corner of the study area and surrounding region outside the study area to determine it nonpoint source contamination is occurring.

5. Provisions should be made to extend ground water sampling east of the proposed Special Protection Area into Thayer County, and beyond it necessary, to ensure that the area of nonpoint source ground water contamination is enclosed by the SPA.

ADDENDUM
July 1989

Upon further consultation with the Lower Republican and Little Blue NRDs and the Conservation and Survey

Division of the University of Nebraska, the originally proposed boundaries (see p. 32 and 35 of the Nuckolls County report) were revised. The currently proposed SPA is depicted by the stippled area in the above map, and would enclose the following area: Beginning at the northeast corner of Sec. 25, T1N, R5W, Nuckolls County; proceeding nine miles west along county road and section lines to the northeast corner of Sec. 28, TIN, R6W; then one mile north along county road to the northeast corner of Sec. 21, TIN, R6W; then four miles west along county road and section lines to the northeast corner of Sec. 23, TIN, R7W; then one mile south along U.S. 136 to the northeast corner of Sec. 26. TIN, R7W; then one mile west along county road to the northeast corner of Sec. 27, TIN. R7W; then two miles south along county road and the Republican River to the Nebraska-Kansas border; then 14 miles east along the Nebraska-Kansas border to the Nuckolls-Thayer County line at the southeast corner of Sec. 36, TIN, R5W; and finally two miles north along the Nuckolls-Thayer County line to the original point.

The boundaries were revised for the following reasons:

1. The revised area corresponds more closely with the irrigated farmland in the Superior-Hardy area. This area also corresponds more closely to the areas characterized by higher nitrate levels in both irrigation and domestic wells sampled during the study.

2. The uplands area to the north of the irrigated land is characterized by dryland agriculture and pasture. Solid information as to the occurrence or likelihood of nonpoint source ground water contamination in this type of area is currently lacking.

3. The irrigated area west of Superior is characterized by mostly surface water irrigation. Domestic well readings in the area are scattered, and do not closely indicate the occurrence or likelihood of nonpoint contamination.

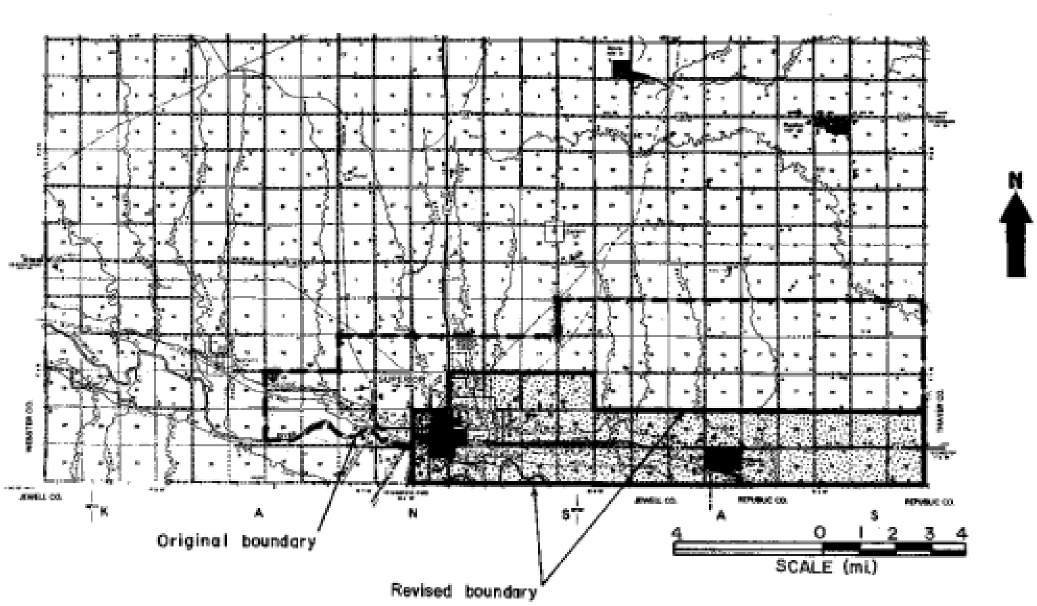


Figure 18a: Proposed boundaries of Special Protection Area in southern Nuckolls County, Nebraska

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Appendix A: Request for SPA Study

Lower Republican Natural Resources District
Phone (308) 928-2182 BOX 618 Alma, Nebraska 68920

November 9, 1987

Dennis Grams
Director, D.E.C.
301 Centennial Mall South
Lincoln, Nebraska 68509

Dear Mr. Grams:

The Lower Republican Natural Resources District is asking for your assistance in designing Special Protection Area designation for portions of our NRD around the city of Stamford (located in Harlan County) and around the city of Superior (located in Nuckolls County).

Our Board considered the SPA requests at some length at our October 8, 1987, Board of Directors meeting before deciding to submit this request. Based on the water quality monitoring information available to our District, it appears that at least a nitrate contamination problem exists around both communities, This summer our NRD utilized the State Department of Health lab to sample a few wells in the Stamford and Superior areas for other possible contaminates. We sampled eight wells in the Superior area and four wells in the Stamford area for a total of seventy-two different contaminates (other than nitrates and coliform). The DOH suggested the sampling of these specific contaminants because of health concerns connected to these contaminants. However, the recently adopted guidelines for the administration of SPAs have entered questions into our District's mind regarding sampling procedures and what contaminants we should be sampling for.

Our staff has compiled the results of wells the LRNRD has sampled since 1985. Along with this table we have placed location (reference) numbers on a map to help you quickly see where the nitrate sample result table also shows any other contaminants found by the Department of Health lab (and the concentration of the contaminant found).

We would greatly appreciate any assistance we can receive from DEC on the SPA consideration for these two communities. I have already visited with your staff on various occasions (especially Dave Jensen) about this matter and they encouraged our NRD to consider requesting SPA designation.

The local citizens in the two areas being considered for SPA designation appear to be concerned about this apparent problem.

Thank you, in advance, for your assistance on this matter.

Sincerely,

Ron Wunibald

Ron Wunibald, Manager
Lower Republican NRD

RW:jrb

cc: Terry Woollen, Chairman LRNRD

Jim Miller, LDC, SCS Alma
Richard Nelson, Director LRNRD
Roy Anderson, Director LRNRD
John Burkholder, Director LRNRD
Dean Artz,, Director LRNRD

Appendix B: Sampling Forms

SUPERIOR
DATE:

SPA SAMPLING DATA

Well Location: T. _____ N, R. _____ E or W, Sec _____, _____ 1/4 _____ 1/4

Well Data:
Type: Irrigation Household Stock Municipal Monitoring
Depth: _____ ft.
Casing: Concrete Steel Plastic Transite Brick Other
Screened Interval: _____ ft.
Location: Pit Lowlying area Near drainage High point
Age: _____ yrs.
Construction: Drilled Driven Dug
Output: _____ gpm
Driller (if available):

Point Sources:
Barnyard _____ ft. _____ of well Active Inactive
Animal: Cattle Pigs Horses Poultry Other
Approx. number: _____
Septic tank _____ ft _____ of well
Other:

Nonpoint Sources: describe crops, direction and distance from well

Pesticides used on these fields? Y N
Which ones and rates:

Nitrogen fertilizer, manure used on these fields? Y N
Rate(s):

Ground water data:
Temperature: _____ º C
Conductivity: _____ umho/cm
N03-N: _____ ppm
Pesticides:
Type:______________, _____ ppb
Type:______________, _____ ppb
Type:______________, _____ ppb
Total coliform: _____

Owner:
Name:
Address:

Results sent: Y N

SUPERIOR IRRIGATION WELLS

SPA SAMPLING DATA

Well Location: T. _____ N, R. _____ E or W, Sec _____, _____ 1/4 _____ 1/4
Well # ___________
Sampling Date: ___________
Well Data:
Type: Irrigation Household Stock Municipal Monitoring
Depth: _____ ft.
Casing: Concrete Steel Plastic Transite Brick Other
Screened Interval: _____ ft.
Location: Pit Lowlying area Near drainage High point
Age: _____ yrs.
Construction: Drilled Driven Dug
Output: _____ gpm

Point Sources:
Barnyard _____ ft. _____ of well Active Inactive
Animal: Cattle Pigs Horses Poultry Other
Approx. number: _____
Septic tank _____ ft _____ of well
Other:

Nonpoint Sources: describe crops, direction and distance from well

Pesticides used on these fields? Y N
Which ones and rates:

Nitrogen fertilizer, manure used on these fields? Y N
Rate(s):

Ground water data:
(Field) Temperature: _____ º C
(Field) Conductivity: _____ umho/cm
(Field) pH, S.U.: _____
(Field) Nitrate-nitrogen, ppm: _____
(Field) Triazines, ppb: _____
Pesticides:
Type:_____________, _____ ppb
Type:_____________, _____ ppb
Total coliform 100 ml: _____
Nitrate-nitrogen, ppm: _____

CATIONS	**ppm**	**meq/l**	**ANION**	**ppm**	**meq/l**
Calcium	______	______	Bicarbonate	______	______
Magnesium	______	______	Nitrate	______	______
Potassium	______	______	Sulfate	______	______
Sodium	______	______	Chloride	______	______
Total		______			______

Owner:
Name:
Address:

Results sent: Y N

Appendix C: Domestic Well Sampling Results

No.	Temp. field	Cond. field	pH field	Cond. lab	N03-N	Cl-	S04+2	HCO3-	Na+	Mg+2	Ca+2	K+
FLD BLK	N/A	N/A	N/A	4.48	0.02/K	1.0/U	2.0/K	N/A	0.01/U	0.01/U	0.02/U	0.01/U
SPAS01	14	950	8	788	2.13	59.3	17.8	391.6	35.7	11.7	125.5	3.6
SPAS02	14	850	6.5	608	1.48	24.7	14	332.4/A	28.1	10.1	96.3	3.4
SPAS03	13	1200	7.8	987	6.35	43.7	146.3	328.8	22.6	20	238.4	4.1
DUP 3	N/A	N/A	N/A	919	7.17/A	44.3	145.9	332.5	24.2/A	18.1/A	177.2/A	4.1
SPAS04	13	850	7.8	637	3.09	32.7/A	28	298.9	25	11.1	107.6	3.2
SPAS05	15	900	7.5	674	8.98	38.1	10	344.7	23.5	10.1	120.7	5.1
SPAS06	14	1100	7.9	827	9.11	59.3	36.8	367.2	62.8	14.3	122	4.4
SPAS07	14	1000	7.8	763	12.8	44.6	49.8	329.4	78	15.8	90.7	9
SPAS08	13	900	8	650	10.35	27.5	19.2	342.8	27.2	11.3	117	2.8
SPAS09	13	950	8.2	685	7.45	36.1	16.8	374.5	31.4	10.2	123.1	4.5
SPAS10	13	800	7.8	586	9.17	22.5	23.2	309.3	36.9	9	97	4.5
SPAS11	14	950	7.9	726	5.89	43.6	50.3	371.5	63.4	11	117.9	4.1
SPAS12	13	900	8	505	8.71	20.2	24	256.2	43.7	8.3	72.2	5.7
SPAS13	14	750	8	544	2.76	23.7	23.2	317.2	37.8	10.6	87.4	4.7
FLD BLK	N/A	N/A	N/A	3.36	0.07	1.0/K	2.0/U	N/A	0.01/U	0.01/U	0.02/U	0.01/U
SPAS14	15	800	7.5	551	1.16	25.4	68.3	238.5	37.8	10.7	80	9.9
SPAS15	13	850	7.7	619	.02/U	17.8	63.5	336.7	42	10.8	100.2	7.4
DUP 15	N/A	N/A	N/A	630	0.02/U	17.8	71.9	340.4	42.1/A	10.9	100.3	7.45/A
SPAS16	17	1100	7.7	748	6.22	29.2	74.7	323.3	46.4	19.7	110.3	17.8
SPAS17	15	800	8.2	598	5.02	43.6	39.2	271.8/A	37.5	9.5	93.8	4.9
SPAS18	14	825	8.1	589	16.43	45.6	39.6	273.3	38.6	11.1	86.2	6
SPAS19	14	900	8	652	5.53	23.6	67.3	309.9	60.6	15.6	83.6	12.2
SPAS20	15	1300	8.1	960	37.51	57.3	82.1	313.5	61.2	20.1	156.2	8
SPAS21	15	1000	7.7	711	0.04	15.9	86.2	408.1	35.5	18.5	121.4	12.4
SPAS22	16	1700	8	1180	1.52	52.8	215.5	524.6	59	30.5	200	28.3
SPAS23	13	800	8	628	9.16	55.3	45.8	237.9	69.8	11.9	71.6	6.9
SPAS24	14	950	8.1	735	3.38	34.5	61	384.3	44.9	15.2	121.4	8.9
SPAS25	13	1050	8.1	804	3.42	39	61.9	437.4	66	16.3	124.9	7.2
SPAS26	14	2300	7.9	1775/A	34.96	103.7	280.3/A	549.6	52	42.7/A	245	20.1
SPAS27	13	775	8.1	630	7.82	19.59/A	65.9	256.2	43	13.3	81.7	6.8
SPAS28	14	725	8.1	578	4.8	5.6	17	342.2	51.5	11.6	73.2	5.8/A
SPAS29	12	1400	7.7	1125/A	11.17	135.9	69.2	384.3	100	19.9	130.2	7.9
DUP 29	N/A	N/A	N/A	1103	11.27	131.4	61.5	366.6	100	19.6	128.8	7.8
SPAS30	12	850	7.9	700	14.04	21.2	42.1	276.9	47.2	14.3	89.1	6.2
SPAS31	13	850	7.9	688	12.53	23.2	39.5	317.8	56.4	11.2	89.5	4.8
SPAS32	13	1200	707	979	23.95	50.3	42.1	461.4	66.6	15.7	143	5
SPAS33	12	1100	7.9	935	14.09	58.1	24.4	430.7	48.1	15.6	146.3	4.9
SPAS34	12	1100	7.5	873	6.22	42.8	63.9	420.9/A	55.8	10.4	138.8	3.3
FLD BLK	N/A	N/A	N/A	3.79	0.02/K	1.0/U	2.0/U	N/A	0-01/U	0.01/U	0.02/U	0.01/U
SPAS35	13	1000	7.6	795	6.49	50.8	18.2	397.1	59.8	10.1	117.4	3.6
SPAS36	14	1050	7.5	857	1.42	36.3	29.1	499.6	60.8	12.6	134.8	4.8
SPAS37	14	850	7.5	770	1.39	31.2	28.5	427	50.8	8.2	121	3.2
SPAS38	12	1600	7.5	1420	1.22	124.5	130.5	531.3	80.8	20.9	223.8	5.4
SPAS39	13	1350	7.1	1088	33.75	40.9	26.4	445.3	86.6	11.8	149.5	5.3

SPAS40	14	1000	7.1	822	7.96	51.1	25.2	378.2	44.8	12.1	126.2	3.1
SPAS41	14	950	7.1	781	3.91	40	22	396.5	55	11.6	110.8./A	4
SPAS42	13	1500	7	1276	39.41/A	68	119.6	377	75.8	21.6	191.6	6.8
SPAS43	13	875	7.3	704	13.13	52.6	22	262.3	31	13.8	99.4	7.3
SPAS44	12	850	7.4	812	31.99	36.3	31.3	276.9	26.6	13.2	126.3	5.5
FLD BLK	N/A	N/A	N/A	1.87	0.02/U	1.0/U	2.0/U	N/A	0.01/U	0.01/U	0.02/U	0.01/U
SPAS45	13	675	7.4	628	13.39	30	21.8	272.7	28.2	11.8	95.8	5
SPAS46	13	2000	6.6	2060	163.16	115.5/A	102.3	342.2	102	49.7/A	282	12.5
SPAS47	13	560	7.7	539	12.08	37.1/A	47.2	172.6	31.6	12.6	65.5	7.8
SPAS48	11	460	7.5	476	8.11	19.3	28.7	214.1	24	10.4	66.9	5.7
SPAS49	13	700	7.3	695	13.64	21.3	23.5	347.7	20	13.5	120.9	3.6
DUP 49	N/A	N/A	N/A	699	13.99	21.3	23.2	350.8	20/A	13.5/A	120.3/A	3.6/A
SPAS50	13	600	7.4	598	1.78	35	16	323.3	23	12.4	96	4.2
SPASS1	13	520	7.4	588	1.69	31.2	10.5	310.8/A	19.2	12.1	94.1	4.5
SPASS2	12	540	7.6	581	3.7	26.6	32.6	281.2	21.8	12.4	88	4.2
SPAS53	12	580	7.4	595	1.04	38.2	20.8	294	20.4	11.2	93.3	3.6
SPAS54	12	580	7.3	605	3.71	22.5/A	13.4	334.3	23.8	11.7	95.2	3.7
SPAS55	13	1000	7.3	1117/A	22.19	141.1/A	33.8	336.1	33	19.3	189	2.2
SPAS56	12	1400	7.3	1510	38.28	212.6	31.3	344	61.4	25.6	222	5.0/A

Remark Codes:
N/A - Non-Applicable
A - Average Values. Mean of two or more determinations.
K - Some instrument response. No confirmed detection. Value given is detection limit.
U - Material analyzed for but not detected. Value given is detection limit.

Appendix D: Irrigation, Municipal, and Industrial Well Sampling Results

No.	Temp. field	Cond. field	pH field	Cond. lab	N03-N	Cl-	S04+2	Na+	Mg+2	Ca+2	K+
FLD BLK	N/A	N/A	N/A	2.49	0.02/U	1.0/U	2.0/U	0.01/U	0.01/U	0.01/U	0.01/U
SPAS57	13	7.1	7.64/Q	839.0	1.56	22.3	104.8/A	43.2	16.8	130.2	9.7
SPAS58	14	7.0	7.68/Q	774.0	0.82	20.4/A	114.4	50.2	12.0	118.9	7.9
SPAS59	17	7.1	7.68/Q	785.0	5.32	24.8	93.7	55.6	13.6	110.5	12.5
DUP59	N/A	N/A	7.62/Q	785.0	5.65	24.0/A	94.1	55.8	13.4	110.9	12.3
SPAS60	19	7.2	7.95/Q	810.0	5.70	31.2	118.1	45.6	16.2	120.8	13.5
SPAS61	14	7.0	7.58/Q,A	806.0/A	0.09	22.3	126.6	36.5	17.4	134.8	10.7
SPAS62	14	6.8	7.56/Q	570.0	3.34	25.2	56.0	34.6	10.0	80.8	5.2
SPAS63	14	6.9	7.65/Q	680.0	16.55	25.3	32.6	50.5	12.7	95.9	5.4
SPAS64	14	6.9	7.60/Q	866.0	15.52	30.9	90.7	80.0	17.1	109.3	11.9
SPAS65	13	6.7	7.31/Q	634.0	9.97	22.4	68.2	41.6	13.9	84.6	8.8
FLD BLK	N/A	N/A	N/A	2.64	0.02/U	1.0/U	2.0/U	0.01/U	0.01/U	0.02/U	0.01/U
SPAS66	13	6.8	7.45/Q	571.0	6.88	19.8	46.0	36.1	9.9	80.0	5.3
SPAS67	13	7.2	8.05/Q	590.0	5.34	19.5	58.7	46.0	10.1	79.8	5.3
SPAS68	15	7.3	7.78/Q	997.0	8.94	82.3	63.6	80.0	16.3	136.5	6.0
SPAS69	14	6.9	7.43/Q	578.0	2.93	31.7	40.1	43.4	9.8	76.7	6.7
DUP69	N/A	N/A	7.36/Q	581.0	3.28	31.9	39.9	44.0	9.7	76.2	6.65/A
SPAS70	14	7.0	7.64/Q	800.0	8.73	42.4	74.4	51.7	15.2	119.4	6.4
SPAS71	14	7.0	7.46/Q	835.0	8.32	39.9	60.9	70.7	14.3	115.7	6.1
SPAS72	14	7.0	7.43/Q	718.0	4.52	12.0	69.2	60.0	12.8	98.1	6.6
SPAS73	15	7.0	7.54/Q	600.0	4.06	19.8	45.8	45.3	9.6	81.4	4.9
SPAS74	14	7.1	5.54/Q,A	551.5/A	3.70	19.6	46.7	37.3	9.8	79.0	5.3
SPAS75	14	7.1	7.54/Q	587.0	4.01	19.6	46.5	42.9	10.4	83.0	4.8
SPAS76	14	7.0	7.50/Q	681.0	9.76	26.8	48.7	50.5	12.2	93.9	4.8
SPAS77	15	6.9	7.42/Q	703.0	3.49	33.7	68.2	48.1	12.7	98.8	5.5
SPAS78	14	7.0	7.50/Q	768.0	7.10	35.1	38.4	57.8	13.2	105.8	5.2
SPAS79	13	6.9	7.29/Q	935.0	13.67	61.2	63.8	79.5	20.0	117.3	7.1
SPAS80	14	7.1	7.61/Q	733.0	10.06	46.7/A	53.6	55.8	15.6	91.8	5.2
SPAS81	13	6.9	7.22/Q	714.0	13.17	45.6	43.3	45.4	11.9	91.1	5.0
SPAS82	14	7.0	7.56/0	599.0	6.21	44.5	18.9	26.2	9.7	87.4	4.1
SPAS83	14	7.1	7.52/Q	633.0	10.50	41.0	18.9/A	25.7	10.2	97.3	4.4
SPAS84	14	7.0	7.49/0	634.0	6.10	38.0	17.6	26.0	10.9	99.6	4.5
SPAS85	14	7.1	7.62/Q	710.0	11.04	54.5	25.5	38.0	11.1	103.6	4.9
SPAS86	15	7.1	7.85/Q	498.0	6.72/A	22.9	22. 5	29.3	8.8	68.8	3.9
SPAS87	15	7.0	7.47/Q	639.0	8.27	38.7	23.0	31.1	12.5	93.2	4.8
SPAS88	14	7.1	7.72/Q	448.0	2.85	23.4	16.6	24.8	8.6	65.2	3.8
FLD BLK	N/A	N/A	N/A	1.84	1.0/U	1.0/U	2.0/U	0.01/U	0.01/U	0.02/U	0.01/U
SPAS89	17	7.0	7.58/g	606.0	3.44	42.1	19.8	22.7	12.2	99.2	3.7
SPAS90	14	7.1	7.69/2	561.0	2.78	31.7	15.3	20.8	11.9	92.6	3.6
SPAS91	14	7.1	7.74/Q	609.0	3.20	42.1	20.0	23.9	12.9	97.8	3.9
SPAS92	13	7.1	7.65/Q,A	572.0/A	3.74	36.8	18.0	26.0/A	12.0	86.3/A	3.8/A
DUP92	N/A	N/A	8.36/Q	573.0	3.53	34.8	8.5	25.7	11.8	88.0	3.8
SPAS93	16	6.9	7.35/Q	519.0	5.41	26.4	16.6	19.6	10.6	81.7	4.0

SPAS94	15	7.2	7.65/0	587.0	3.45	39.4	20.5	24.2	11.2	94.6	3.4
SPAS95	14	7.1	8.63/Q	629.0	4.04	33.4	30.7	27.5	10.9	91.4	3.7
SPAS96	14	6.9	8.66/Q	621.0	6.81	31.0	26.5	32.6	10.7	84.9	3.7
SPAS97	15	7.1	8.64/Q	625.0	7.85	35.6	24.0	33.1	10.8	84.0	5.2
SPAS98	14	7.1	8.71/Q	822.0	9.48	25.7	95.8	74.1	16.6	93.3	10.6
SPAS99	14	6.8	8.69/Q	796.0	9.97	39.1	59.6	65.4	16.9	96.2	5.9
SPAS100	14	7.0	8.65/Q	605.0	7.10	36.9	23.5	40.8	11.4	84.8	4.8

Remark Codes:

N/A - Non-Applicable

A - Average Values. Mean of two or more determinations.

K - Some instrument response. No confirmed detection. Value given is detection limit.

Q - Beyond holding time.

U - Material analyzed for but not detected. Value given is detection limit.

Appendix E: Statistical Data

Variable	N	Mean	Standard Deviation	Median	Minimum	Maximum
Temp	100	13.77	1.21318514	14.0	11.0	19.0
pH	100	7.371	0.43281904	7.3	6.5	8.2
Cond	100	751.935	253.48396294	686.5	448	2060
NO3-N	100	10.2321	17.55968565	6.605	0.02	163.16
Cl-	100	41.0219	29.33175618	35.35	5.6	212.6
SO4+2	100	50.299	41.82285513	39.35	10.0	280.3
Na+	100	45.161	18.86034210	43.1	19.2	102.0
Mg+2	100	13.901	5.99289976	12.1	8.2	49.7
Ca+2	100	111.477	3970399531	97.95	65.2	282.0
K+	100	6.273	3.77066977	5.15	2.2	28.3

Spearman Correlation Coefficients / Prob > |R| Under HO:RHO=0 / N = 100

	Temp	pH	Cond	NO3-N	Cl-	SO4+2	Na+	Mg+2	Ca+2	K+
Temp	1.00000	-0.20586	-0.09770	-0.25469	-0.05697	0.07507	0.00589	-0.08533	-0.10289	0.12602
	0.0000	0.0399	0.3335	0.0106	0.5735	0.4579	0.9536	0.3986	0.3084	0.2115
pH	-0.20586	1.00000	0.05049	-0.00827	0.09954	-0.02005	0.04584	0.04980	0.15401	0.04216
	0.0399	0.0000	0.6179	0.9349	0.3245	0.8431	0.6506	0.6227	0.1260	0.6770
Cond	-0.09770	0.05409	1.00000	0.36026	0.57314	0.52324	0.65497	0.73841	0.87182	0.29834
	0.3335	0.6179	0.0000	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0026
NO3-N	-0.25469	-0.00827	0.36026	1.00000	0.38776	0.08981	0.32670	0.30892	0.15737	0.17263
	0.0106	0.9349	0.0002	0.0000	0.0001	0.3742	0.0009	0.0018	0.1179	0.0859
Cl-	-0.5697	0.09954	0.57314	0.38776	1.00000	0.03082	0.30698	0.39397	0.54421	-0.08096
	0.5735	0.3245	0.0001	0.0001	0.0000	0.7608	0.0019	0.0001	0.0001	0.4233
SO4+2	0.07507	-0.02005	0.52324	0.08981	0.03082	1.00000	0.61616	0.58536	0.29748	0.73788
	0.4579	0.8431	0.0001	0.3742	0.7608	0.0000	0.0001	0.0001	0.0026	0.0001
Na+	0.00589	0.04584	0.65497	0.32670	0.30698	0.61616	1.00000	0.45891	0.34912	0.52792
	0.9536	0.6506	0.0001	0.0009	0.0019	0.0001	0.0000	0.0001	0.0004	0.0001
Mg+2	-0.08533	0.04980	0.73841	0.30892	0.39397	0.58536	0.45891	1.00000	0.59143	0.52226
	0.3986	0.6227	0.0001	0.0018	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001
Ca+2	-0.10289	0.15401	0.87182	0.15737	0.54421	0.29748	0.34912	0.59143	1.00000	0.07400
	0.3084	0.1260	0.0001	0.1179	0.0001	0.0026	0.0004	0.0001	0.0000	0.4644
K+	0.12602	0.04216	0.29834	0.17263	-0.08096	0.73788	0.52792	0.52226	0.07400	1.00000
	0.2115	0.6770	0.0026	0.0859	0.4233	0.0001	0.0001	0.0001	0.4644	0.0000