STATE OF SOUTH DAKOTA
Walter D. Miller, Governor

DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
Robert E. Roberts, Secretary

DIVISION OF GEOLOGICAL SURVEY
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OPEN-FILE REPORT 68–UR

GROUND WATER QUALITY INVESTIGATION IN SELECTED AREAS OF TODD AND MELLETTE COUNTIES, SOUTH DAKOTA

by

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INTRODUCTION

The field investigation was conducted in July 1990 and June 1991 by the South Dakota Geological Survey (SDGS), a division of the Department of Environment and Natural Resources, at the request of the Rosebud Sioux Tribe and the Mellette-Todd Water Quality Advisory Board. The investigation was financed by the Mellette County Conservation District, the Todd County Conservation District, the Rosebud Sioux Tribe, and the SDGS.

Purpose and Scope

The purpose of the investigation was to further determine concentrations of nitrate in ground water in parts of Todd and Mellette Counties. For this report, the term nitrate will be used to represent nitrate as nitrogen plus nitrite as nitrogen.

In 1989, the Mellette County and Todd County Conservation Districts began the *Mellette-Todd Water Quality Inventory*. That project encouraged well owners to have their private-well waters sampled and analyzed by the South Dakota Department of Health. A total of 213 wells were sampled and the study found nitrate concentrations ranging from below the detection limit of 0.1 milligrams per liter (mg/L) to 100 mg/L. These results prompted the request by the Rosebud Sioux Tribe and the Mellette-Todd Water Quality Advisory Board for the SDGS to conduct the investigation described in this report.

Based on results from the *Mellette-Todd Water Quality Inventory*, specific areas in Todd County and Mellette County were identified for further study (figs. 1 and 2). These areas were known to contain elevated nitrate concentrations in ground water collected from several private wells.

Because nitrate has been found to be stratified within an aquifer (Freeze and Cherry, 1979; Hill, 1982; Ritter and Chirnside, 1984; Pěkný and others, 1989; Rajagopal and Tobin, 1989; Townsend and Marks, 1990; Hammond, 1994), it is necessary to place monitoring wells at various depths (nested monitoring wells at each site) in order to monitor the water quality vertically within the aquifer. In Todd and Mellette Counties, nested monitoring wells were installed at several depths and at multiple locations to monitor the water quality. In addition, shallow monitoring wells were installed generally upgradient from selected farmsteads and an irrigated area. These shallow wells were constructed so that the screen intersected the water table to allow for the monitoring of nitrate at the water table.

This study considered point and nonpoint sources of contamination in the evaluation of ground-water quality. Examples of possible point source contamination would be waste from a septic system or from a concentration of farm animals. An example of possible nonpoint source contamination would be fertilizer applied to an area such as a field.

METHODS AND PROCEDURES

Drilling and Well Installation

Drilling occurred twice during this investigation: July 9 through July 25, 1990, and June 10 through June 26, 1991. All test holes were advanced using the mud rotary drilling method. Twenty-

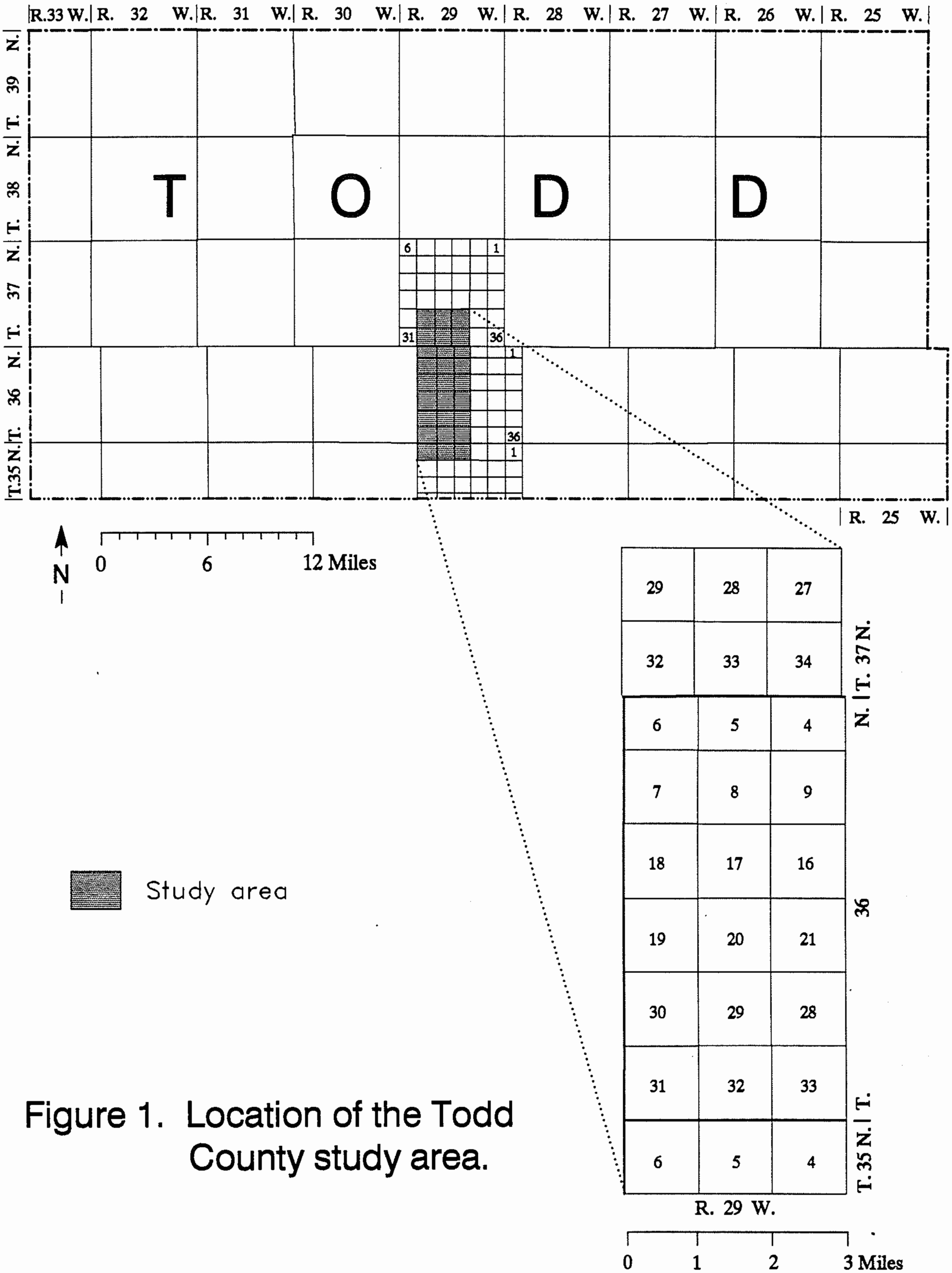
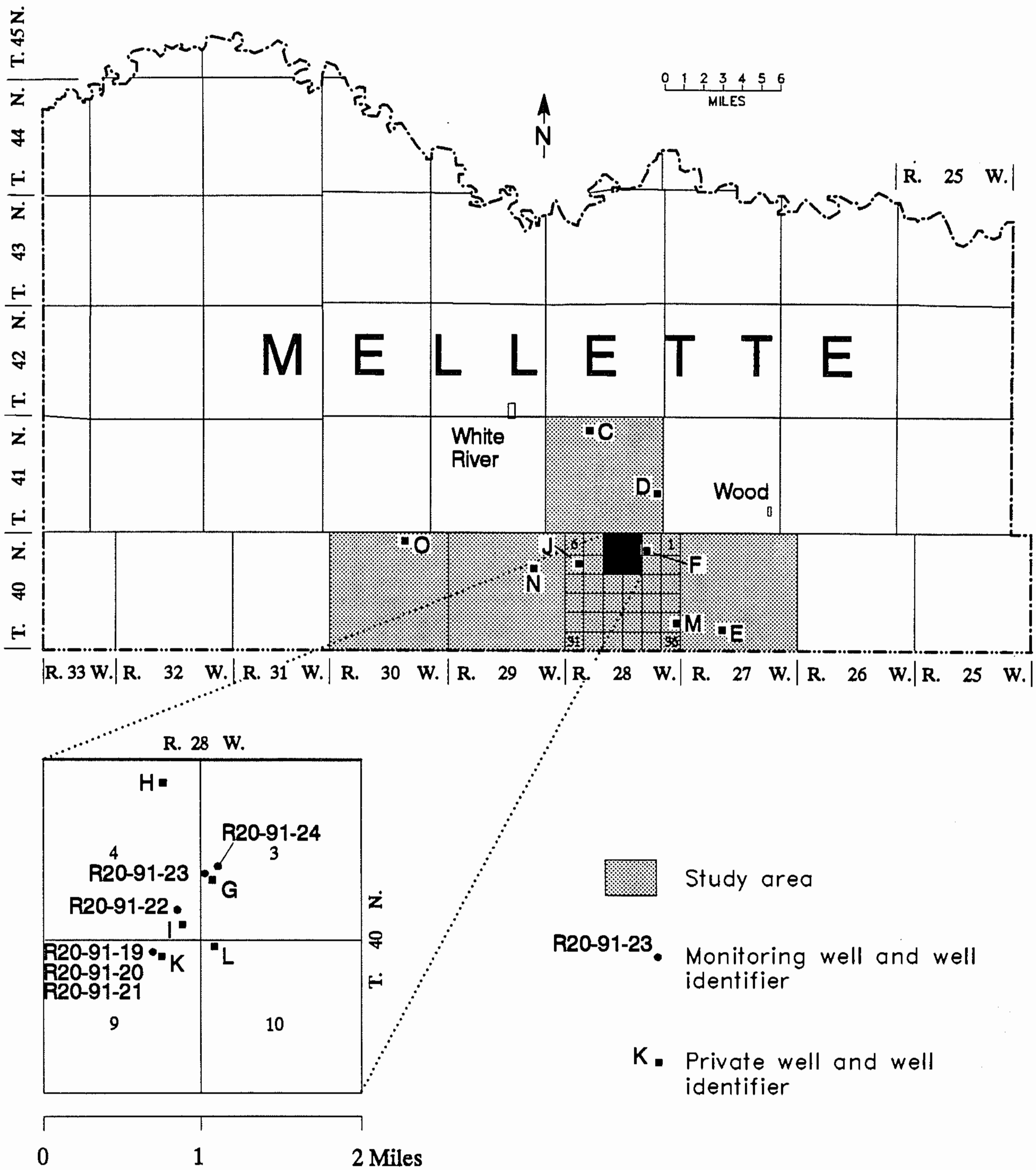


Figure 1. Location of the Todd County study area.

Figure 2. Locations of monitoring wells and private wells sampled in the Mellette County study area.



three test holes were drilled (figs. 2 and 3) and all were completed as monitoring wells (tables 1 and 2). Geophysical logs are available at the SDGS for four of the test holes and include the parameters of single-point resistivity and natural gamma.

Monitoring wells were constructed using 2-inch diameter, schedule 80, flush threaded, polyvinyl chloride (PVC) casing and screen. Blank casing (closed at the bottom and open to the screen) was installed below the well screen in one well (R20–90–30), in Todd County, allowing the blank casing to act as a reservoir that collects water from the formation. A filter pack is present around all well screens, up to at least 4 feet above the top of the screen, and consists of native sediment that collapsed around the screen and/or a well-sorted, washed, coarse sand that was placed around the well screen. Bentonite grout was pumped into the annular space (from the top of the filter pack up to at least 2 feet above the top of the filter pack) around the outside of the casing. The remaining upper portion of the annular space was filled with cement grout and finally topped with 3 inches of soil. A locking steel well protector was installed into the cement and secured shut with a padlock. See the appendix for monitoring well construction diagrams and hydrostratigraphic cross sections for nested monitoring well sites.

Water-Level Measurements

In the Todd County and Mellette County study areas, the depth to water in the monitoring wells was measured on three occasions to the nearest 0.01 foot. Measurements were made using an electronic measuring device that emits an audible sound and a visual indication upon contact with the water.

Well Development and Water Sampling

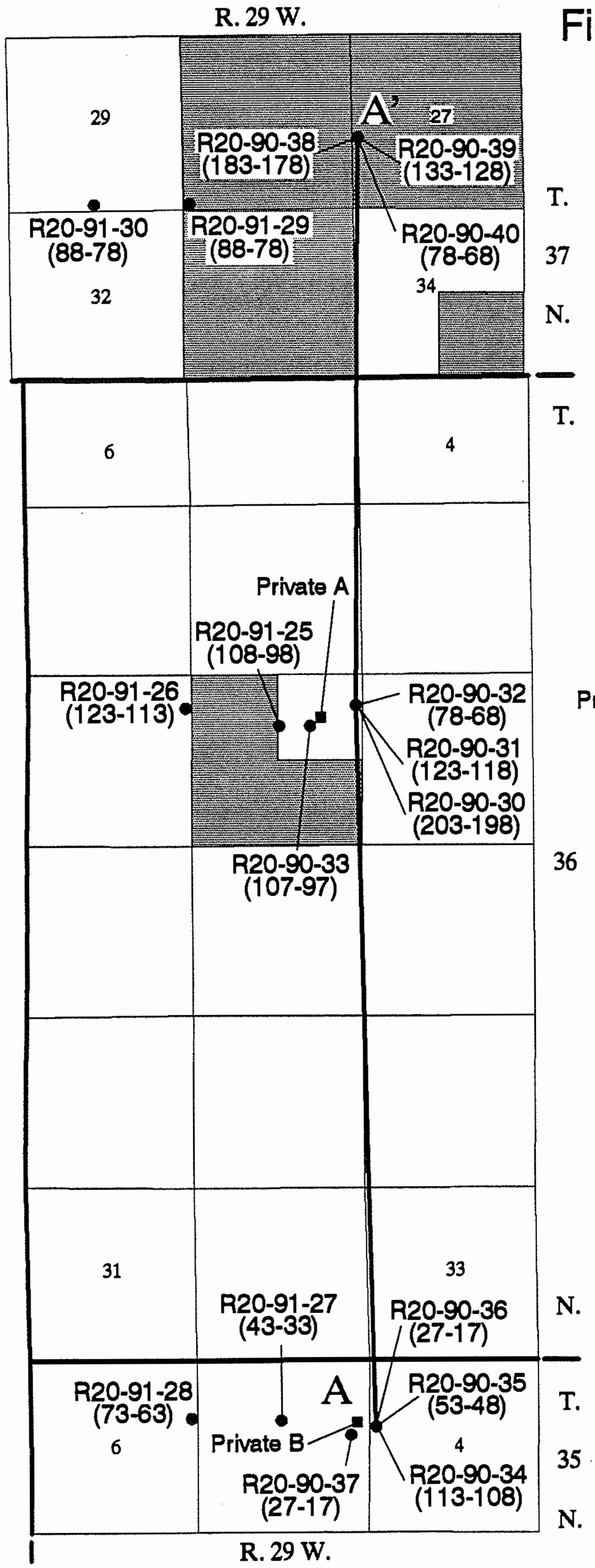
All monitoring wells were developed by pumping with compressed air. Development was conducted by the SDGS and the Division of Water Rights, Department of Environment and Natural Resources. Generally, 20 to 30 well volumes were removed from each well during development. However, in Mellette County, some monitoring wells were installed in low permeability material and only 3 well volumes were removed during development.

Water samples were collected from all monitoring wells installed for this investigation and from some private wells (tables 1 and 2). Monitoring wells were sampled within 1 hour after well development. Thus, the development procedure also served as the water-removal event before sampling of the monitoring wells.

Temperature and specific conductance of the water were measured during well development. Sampling was not initiated until temperature and specific conductance had reached steady-state conditions in three consecutive measurements taken at 5-minute intervals, and only after a minimum of 3 well volumes had been evacuated.

Water samples from monitoring wells were collected using a bailer or a submersible pump. Water samples from private wells were collected from the farmstead's hydrant, house faucet, or hand pump. All development and sampling information are on file at the SDGS.

Figure 3. Locations of monitoring wells and hydrogeologic cross section in the Todd County study area.



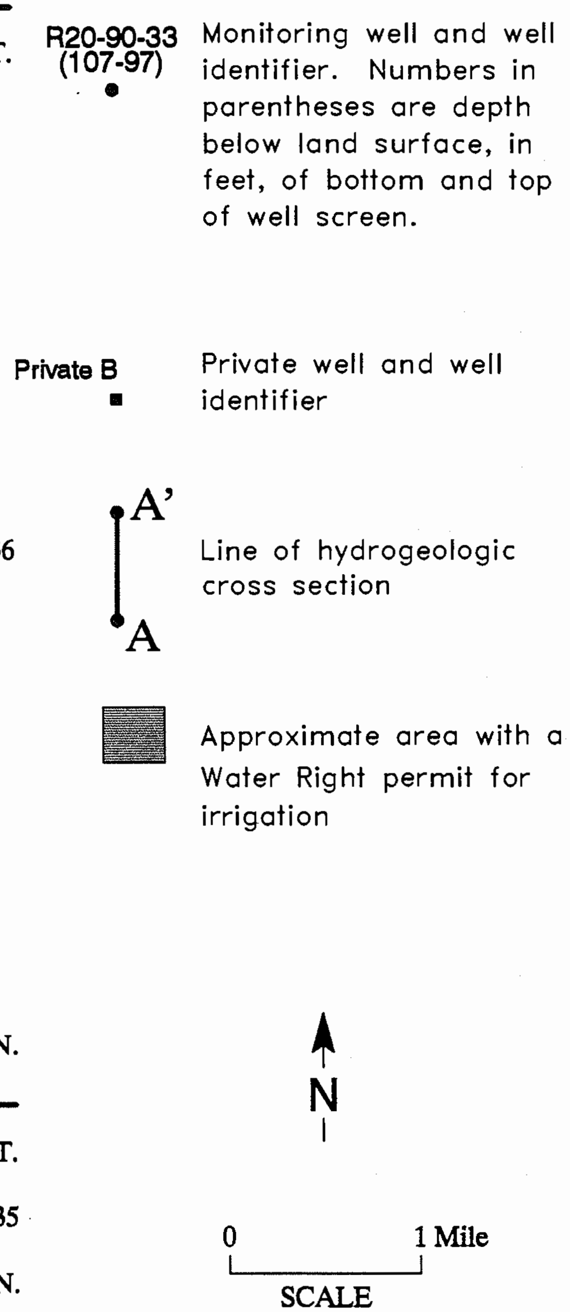


Table 1. Well identifiers and legal locations of monitoring wells and private wells in the Todd County study area

Legal Location	Well Identifier	Comments
NORTHERN AREA		
SW NW NW SW sec. 27, T. 37 N., R. 29 W.	R20–90–38 R20–90–39 R20–90–40	
SW SW SW SW sec. 28, T. 37 N., R. 29 W.	R20–91–29	
SE SE SE SW sec. 29, T. 37 N., R. 29 W.	R20–91–30	
MIDDLE AND SOUTHERN AREAS		
SE SE NE NE sec. 17, T. 36 N., R. 29 W.	R20–90–30 R20–90–31 R20–90–32	
NE NE SW NE sec. 17, T. 36 N., R. 29 W.	R20–90–33	
NW NW SE NE sec. 17, T. 36 N., R. 29 W.	Private A	Well installed in Ogallala Group
SW NW SW NE sec. 17, T. 36 N., R. 29 W.	R20–91–25	
SE SE NE NE sec. 18, T. 36 N., R. 29 W.	R20–91–26	
NW SW SW NW sec. 4, T. 35 N., R. 29 W.	R20–90–34 R20–90–35 R20–90–36	
NE SE SE NE sec. 5, T. 35 N., R. 29 W.	Private B	Well installed in Rosebud Formation
NW SE SE NE sec. 5, T. 35 N., R. 29 W.	R20–90–37	
NE SE SE NW sec. 5, T. 35 N., R 29 W.	R20–91–27	
SE NE SE NE sec. 6, T. 35 N., R. 29 W.	R20–91–28	

Table 2. Well identifiers and legal locations of monitoring wells and private wells in the Mellette County study area

Legal Location	Well Identifier	Comments
SE NW SW sec. 4, T. 41 N., R. 28 W.	Private C	Well located in farm yard
SE SW SE sec. 24, T. 41 N., R. 28 W.	Private D	Well located in farm yard
SW SE SE sec. 29, T. 40 N., R. 27 W.	Private E	Well approximately 50 years old; located in farm yard near creek
NE SW SW sec. 2, T. 40 N., R. 28 W.	Private F	Well located near corrals
SE NW NW SW sec. 3, T. 40 N., R. 28 W.	R20–91–24	
SW NW SW sec. 3, T. 40 N., R. 28 W.	Private G	
NW SW NW SW sec. 3, T. 40 N., R. 28 W.	R20–91–23	
SE NE NW NE sec. 4, T. 40 N., R. 28 W.	Private H	Well located in farm yard
NE SW SE SE sec. 4, T. 40 N., R. 28 W.	R20–91–22	
SE SW SE SE sec. 4, T. 40 N., R. 28 W.	Private I	Well located in farm yard
SE SW NE sec. 7, T. 40 N., R. 28 W.	Private J	Well approximately 40 years old and has not been used for approximately 25 years
SW NE NW NE sec. 9, T. 40 N., R. 28 W.	R20–91–19 R20–91–20 R20–91–21	
SE NE NW NE sec. 9, T. 40 N., R. 28 W.	Private K	Well located at the bottom of a draw, downhill from a farmstead
NW NW NW sec. 10, T. 40 N., R. 28 W.	Private L	Well located in farm yard near creek
NE NW SE sec. 25, T. 40 N., R. 28 W.	Private M	Well located in farm yard
SW SW NE SW sec. 11, T. 40 N., R. 29 W.	Private N	Well located in farm yard; after ½ hour of pumping the well is dry
SW NE sec. 3, T. 40 N., R. 30 W.	Private O	Deep artesian well located in farm yard

TODD COUNTY STUDY AREA

An investigation of sediments named the Ogallala Group was conducted in a small area of Todd County known to contain elevated nitrate concentrations in ground water produced from numerous private wells. Seventeen monitoring wells were installed in Todd County for this investigation (fig. 3). The northern portion of the Todd County study area (sections 27, 28, and 29, T. 37 N., R. 29 W.) is located within an area that is heavily irrigated. The middle portion (sections 17 and 18, T. 36 N., R. 29 W.) and southern portion (sections 4, 5, and 6, T. 35 N., R. 29 W.) are located near farmsteads with private wells that contain elevated concentrations of nitrate. These three portions of the overall Todd County study area will hereafter be referred to as the northern, middle, and southern areas.

Hydrogeologic Setting

Geologic deposits in the Todd County study area are composed of sedimentary rocks of Tertiary age (table 3). For an additional description of the Tertiary bedrock units in the study area, refer to

Table 3. General description of Tertiary bedrock units found in the study areas for this investigation

TERTIARY PERIOD

PLIOCENE EPOCH

Ogallala Group

Ash Hollow Formation – Greenish-tan to brown, fine to medium grained calcareous sand and sandstone, generally somewhat cemented; lower portion of the formation is composed of poorly consolidated sand, silt, and clay

Valentine Formation – Greenish-tan to brown, very fine to fine-grained sand; poorly consolidated

MIOCENE EPOCH

Arikaree Group

Rosebud Formation – Red-brown clayey siltstone

OLIGOCENE EPOCH

White River Group

Brule Formation – Pink to reddish-brown sands, silts, and clays; highly fossiliferous

Chadron Formation – Greenish-yellow clay to greenish-brown claystone and calcareous siltstone; with a basal layer composed of silty sand and gravel

General descriptions from Harksen and Macdonald (1969), Ellis and others (1971), and from the drillers' logs from this investigation.

Ellis and others (1971). If all commonly encountered bedrock units in the study area were present at one location, they would be encountered in descending order (youngest to oldest) as follows: Tertiary age Ash Hollow Formation and Valentine Formation (comprising the Ogallala Group), Rosebud Formation (within the Arikaree Group), and White River Group followed by units of Mesozoic, Paleozoic, and Precambrian age. Only the Ogallala Group and Arikaree Group were encountered during drilling in Todd County during this portion of the investigation; therefore, only these units will be discussed. The Ash Hollow Formation and the Valentine Formation comprise the Ogallala Group and are thought to be alluvial deposits (Harksen and Macdonald, 1969; Skinner and Johnson, 1984; Swinehart and Diffendal, 1990). The Rosebud Formation (Arikaree Group) is overlain by the Valentine Formation and is believed to be an eolian and/or alluvial deposit (Swinehart and Diffendal, 1990).

Ogallala Group

Surficial deposits in the study area consist of the Tertiary age (Pliocene) Ogallala Group that includes the Ash Hollow and Valentine Formations. Figure 4 illustrates the vertical distribution of Tertiary deposits in the Todd County study area. Directly underlying the soil profile is the upper unit of the Ogallala Group, the Ash Hollow Formation. The upper part of the Ash Hollow Formation was found to consist of a somewhat cemented, greenish-tan to brown, fine to medium grained calcareous sand and sandstone, while the lower part is composed of poorly consolidated sand, silt, and clay. Directly underlying the Ash Hollow Formation is the lower unit of the Ogallala Group, the Valentine Formation. The Valentine Formation was found to consist primarily of a poorly consolidated, greenish-tan to brown, very fine to fine-grained sand.

The contact between the Ash Hollow Formation and the Valentine Formation is difficult to determine in the study area. Normally, the contact is identified by a thin layer of silty volcanic ash but, locally, silty limestone or gravel beds may be found at the base of the Ash Hollow Formation (Ellis and others, 1971). In the study area, however, neither of these marker beds were identified and, consequently, one unit of the Ogallala Group could not accurately be discerned from the other. Therefore, when discussing the Ogallala Group in this report, it should be understood that the Ash Hollow Formation and the Valentine Formation will be considered as one unit.

The Miocene age Rosebud Formation (within the Arikaree Group) underlies the Valentine Formation and was found to be a red-brown, clayey siltstone. The Rosebud Formation was not totally penetrated during drilling so only the upper portion of this formation was identified in the study area.

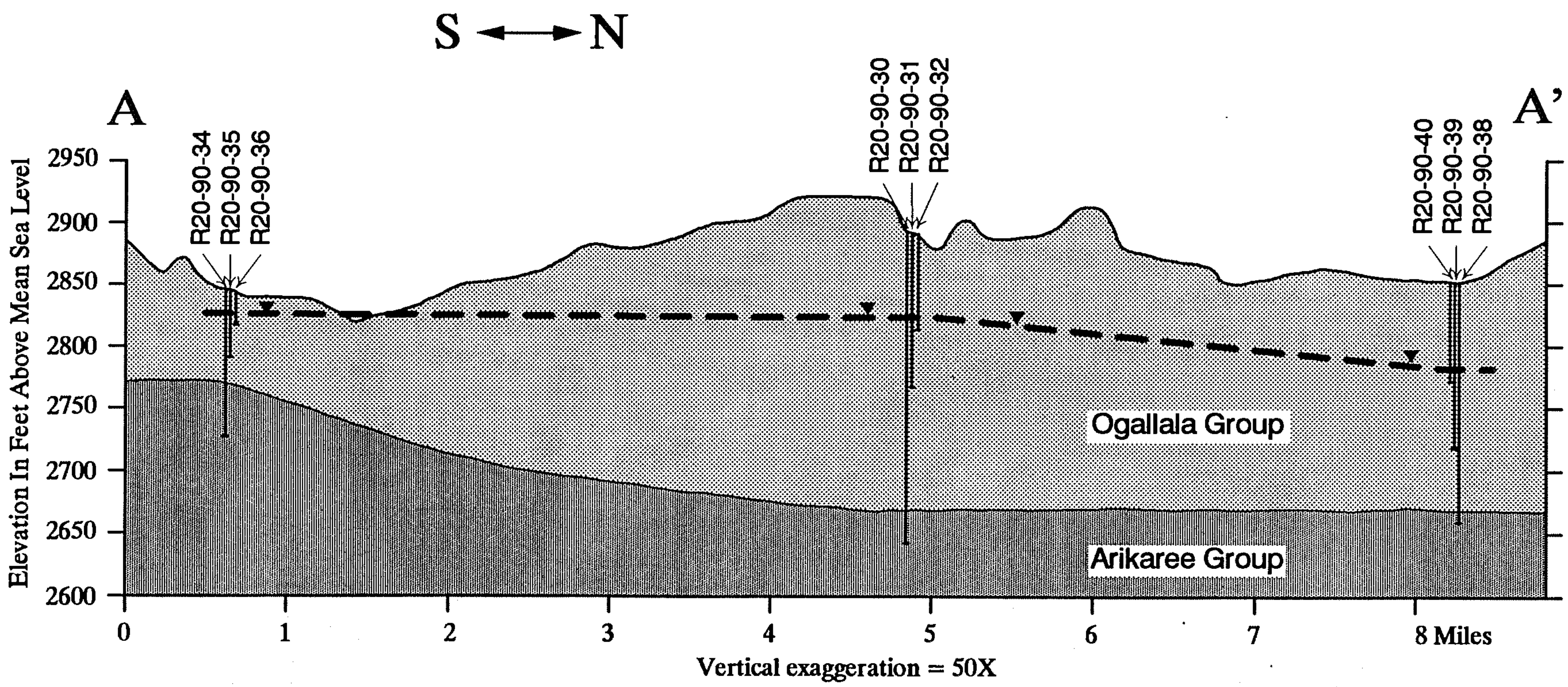
In the study area, the Ogallala Group was found to be an unconfined surficial aquifer composed of very fine to fine sand with some interbedded siltstone and clay lenses. The Ogallala Group readily yields water to private, irrigation, and rural-water wells and generally the water quality in the Ogallala Group is quite good with total dissolved solids usually less than 350 mg/L (Ellis and others, 1971; Hammond, 1990). The Ogallala Group underlies the entire Todd County study area and ranges in thickness (fig. 5) from 230 feet (R20-90-30) to 76 feet (R20-90-34). Saturated thickness (fig. 5) varies from 160 feet (R20-90-30) to 57 feet (R20-90-34). Depth to water in the Todd County monitoring wells was measured on three occasions (table 4). The water-table surface slopes downward to the northeast in the northern portion of the Todd County study area and to the east-southeast in the southern portion of the study area (figs. 6 and 7).

Figure 4. Hydrogeologic cross section A - A'.

Monitoring well

Approximate water level in Ogallala Group, August 7, 1990

See figure 3 for location of cross section.



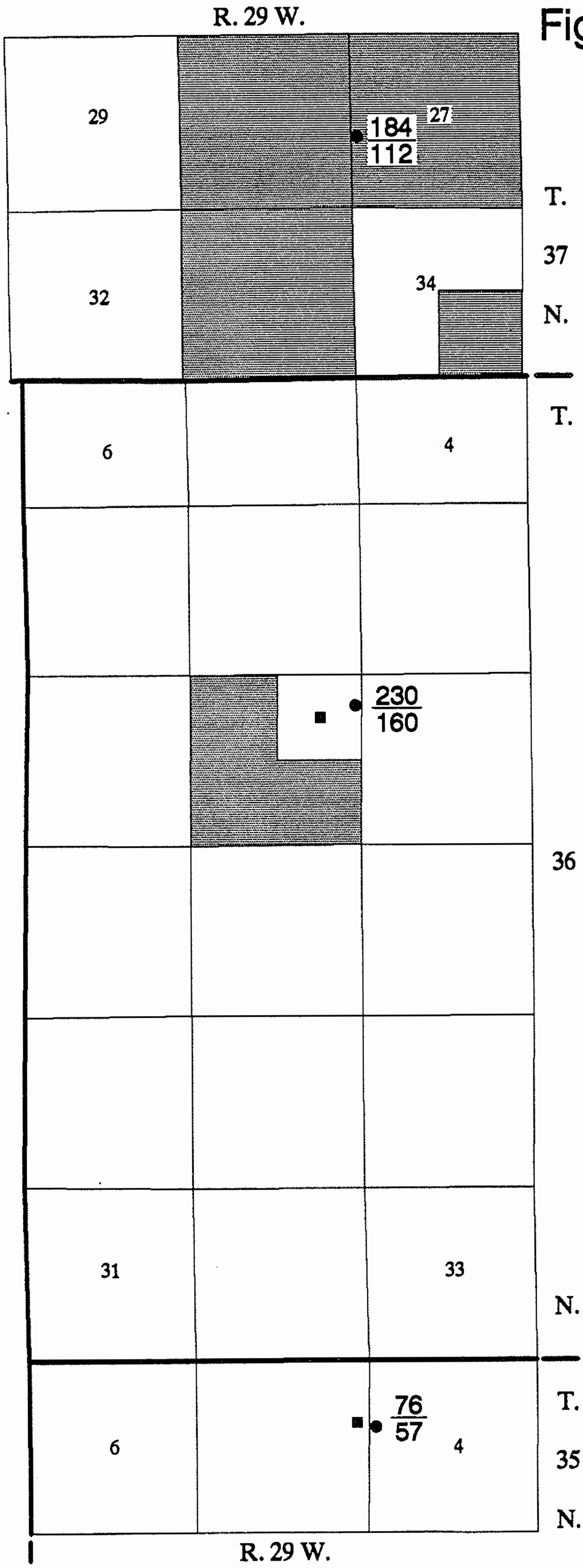


Figure 5. Formation thickness and saturated thickness of the Ogallala Group in the Todd County study area.

184/112 ● Monitoring well, upper number is formation thickness and lower number is saturated thickness, in feet. See figure 3 for well identifier.

■ Farmstead with private well

Approximate area with a Water Right permit for irrigation

N

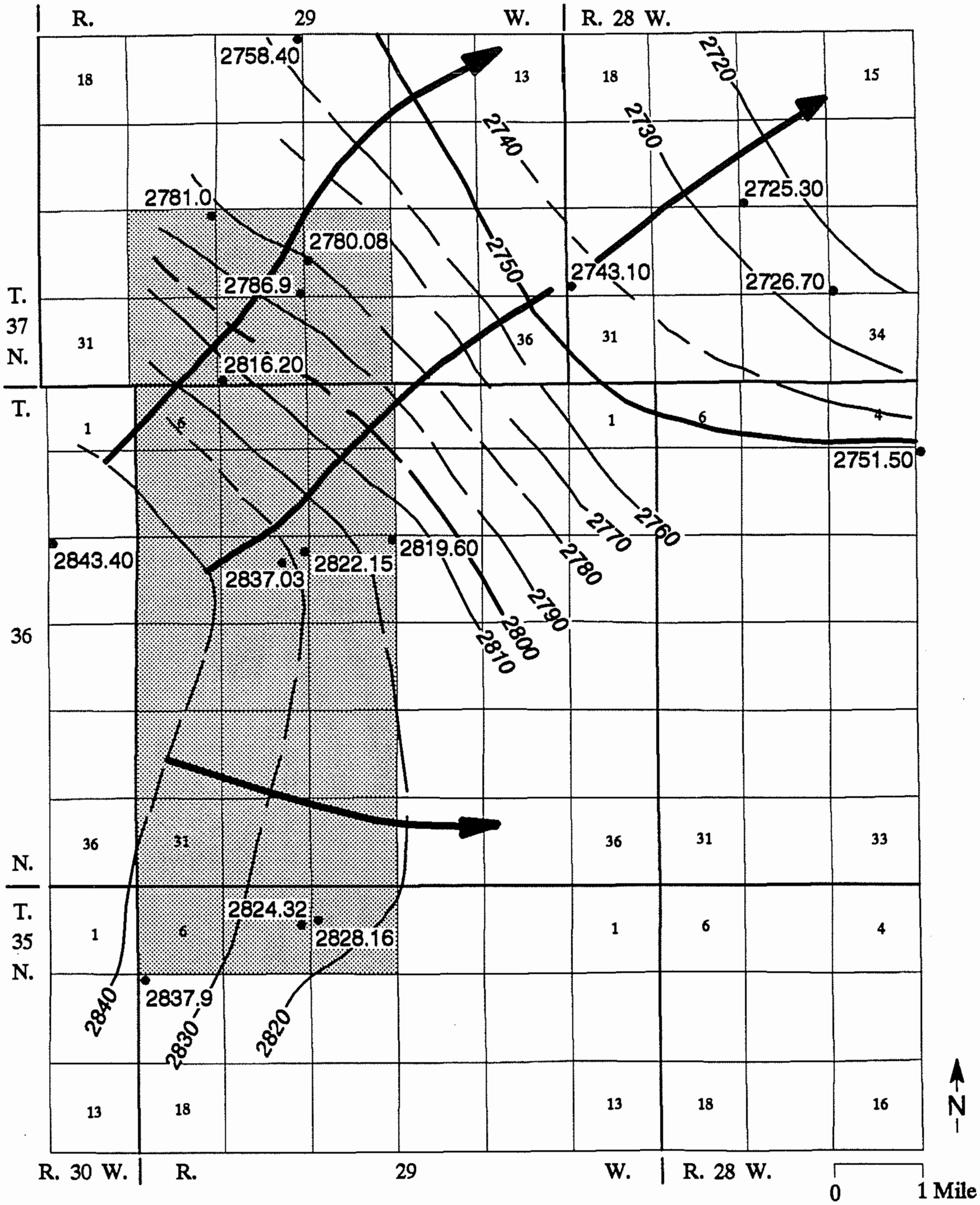
0 — 1 Mile

SCALE

Table 4. Water levels in monitoring wells

Location	Well identifier[1]	Casing-top elevation[2]	Depth to water 8/07/90[3]	Depth to water 06/17/91[3]	Depth to water 07/17/91[3]	Water elevation 08/07/90[4]	Water elevation 06/17/91[4]	Water elevation 07/17/91[4]
TODD COUNTY								
Northern area	R20–90–38	2852	71.97	—	72.96	2780.03	—	2779.04
	R20–90–39	2852	71.92	—	72.92	2780.08	—	2779.08
	R20–90–40	2852	71.86	—	73.01	2780.14	—	2778.99
	R20–91–29	2879	—	—	82.58	—	—	2796.42
	R20–91–30	2887	—	—	74.76	—	—	2812.24
Middle and Southern areas	R20–90–30	2892	69.86	—	70.48	2822.14	—	2821.52
	R20–90–31	2892	70.10	—	70.74	2821.90	—	2821.26
	R20–90–32	2892	69.60	—	70.17	2822.40	—	2821.83
	R20–90–33	2932.5	95.47	—	96.24	2837.03	—	2836.26
	R20–91–25	2927	—	—	92.63	—	—	2834.37
	R20–91–26	2942	—	—	99.62	—	—	2842.38
	R20–90–34	2847	19.35	—	20.16	2827.65	—	2826.84
	R20–90–35	2847	18.81	—	19.65	2828.19	—	2827.35
	R20–90–36	2848	19.37	—	20.21	2828.63	—	2827.79
	R20–90–37	2848	23.68	—	24.23	2824.32	—	2823.77
	R20–91–27	2857	—	—	27.23	—	—	2829.77
	R20–91–28	2897	—	—	61.37	—	—	2835.63
MELLETTE COUNTY								
	R20–91–24	2482	—	—	19.19	—	—	2462.81
	R20–91–23	2447	—	—	19.93	—	—	2427.07
	R20–91–22	2442	—	—	44.66	—	—	2397.34
	R20–91–19	2402	—	34.40	—	—	2367.60	—
	R20–91–20	2402	—	35.00	—	—	2367.00	—
	R20–91–21	2402	—	35.00	—	—	2367.00	—

[1] See tables 1 and 2 for legal location of well identifier.
[2] Presented in feet above mean sea level and determined by topographic-map elevation plus height of casing above ground.
[3] All water levels are presented in feet below top of casing.
[4] Presented in feet above mean sea level.



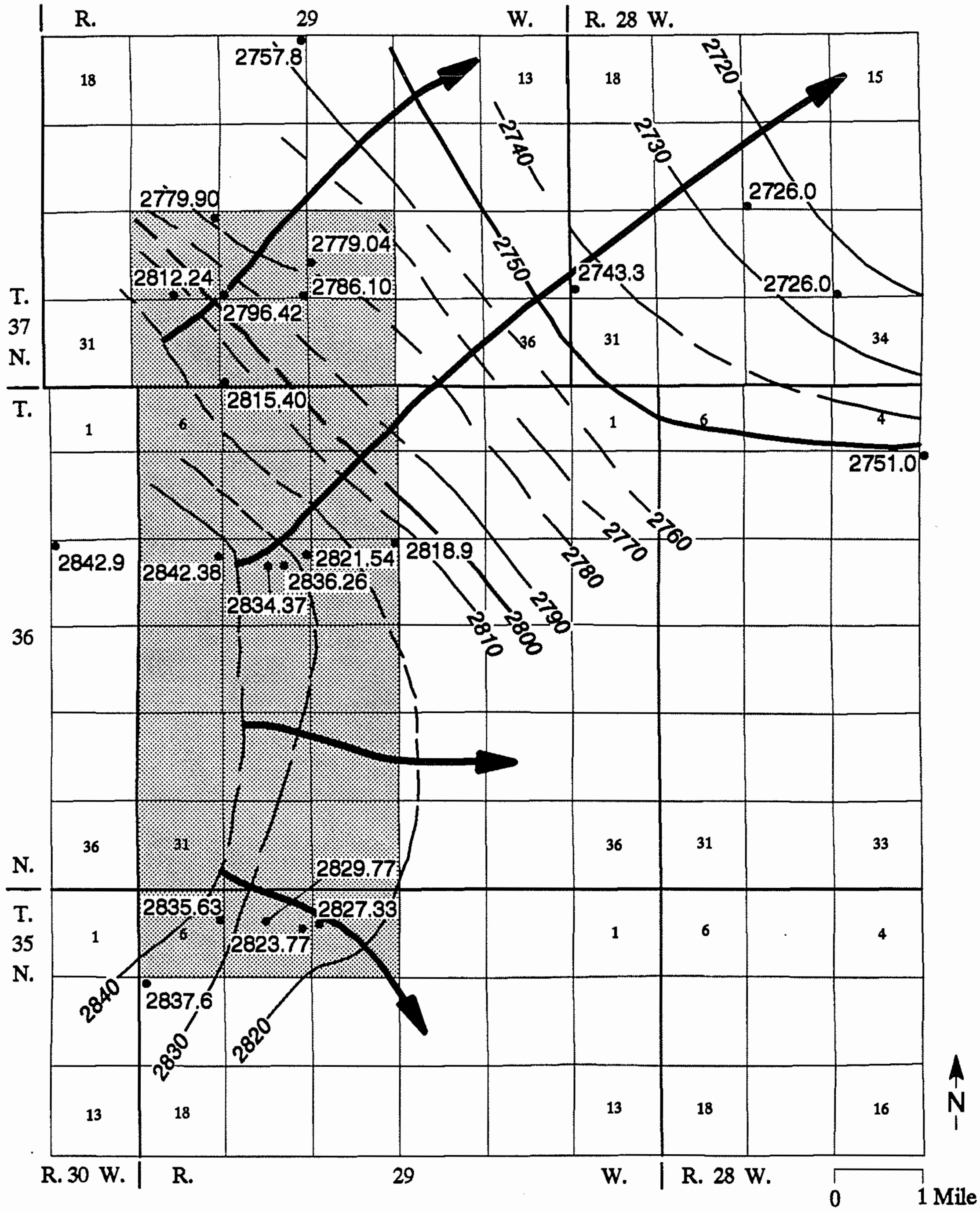
2824.32 Monitoring well, number is elevation of the water table in feet above mean sea level.

Generalized contour line connecting points of equal elevation on the water surface. Dashed where approximate. Contour interval = 10 feet.

General direction of ground-water flow

Study area for this investigation

Figure 6. Water-table surface of the Ogallala Group in and near the Todd County study area, August 1990.



2837.6 • Monitoring well, number is elevation of the water table in feet above mean sea level.

Generalized contour line connecting points of equal elevation on the water surface. Dashed where approximate. Contour interval = 10 feet.

General direction of ground-water flow

Study area for this investigation

Figure 7. Water-table surface of the Ogallala Group in and near the Todd County study area, July 1991.

Results

Northern Area

Irrigated cropland is the predominant land use in the northernmost portion of the Todd County study area. Figure 8 illustrates the location of areas permitted for irrigation by the Division of Water Rights, Department of Environment and Natural Resources. In this area, next to irrigated cornfields, three monitoring wells (nested) were installed into the Ogallala Group (R20–90–38, R20–90–39, and R20–90–40). Using water-level information from these monitoring wells and other monitoring wells located outside the immediate Todd County study area, a general direction of ground-water flow was estimated for the area. With this information, two shallow monitoring wells (R20–91–29 and R20–91–30), screened at, through, or near the water table were installed generally upgradient from the nested well site in order to determine ground-water quality upgradient from the most heavily irrigated area (figs. 3, 6, 7, and 8).

Water samples were collected from all five monitoring wells installed in the northern area. Table 5 indicates, that with the exception of nitrate, the overall quality of water in the Ogallala Group, in the northern area, is quite good. Total dissolved solids in water collected from the monitoring wells ranged from 225 to 351 mg/L. Figure 9 and table 5 show nitrate concentrations in the monitoring wells in the Ogallala Group to range from 1.06 to 7.34 mg/L. For reference, the federal enforceable drinking water standard for public water systems is 10 mg/L for nitrate (U.S. Environmental Protection Agency, 1985a).

Because nitrate tends to be stratified in the aquifer (highest concentrations near the top), the wells with the highest concentrations of nitrate are the wells that are screened at, near, or through the water table. Monitoring well R20–90–40, which is screened through the water table, had a nitrate concentration of 7.34 mg/L when sampled in August 1990, and 5.21 mg/L when sampled in July 1991. For reference, it has been suggested that nitrate concentrations greater than 3 mg/L may be the result of human activities (Madison and Brunett, 1984). Well R20–91–29 had water with a nitrate concentration of 4.66 mg/L while the well farther upgradient (R20–91–30) had a nitrate concentration of 2.69 mg/L.

In addition to the work described above, in August 1991, the U.S. Geological Survey (USGS) collected a water sample from well R20–90–40 for analyses of nitrogen isotope ratios (Steve Sando, USGS, written communication, 1992). Nitrogen isotope ratios are used as an aid in identifying the sources of elevated nitrate concentrations. The USGS study found that R20–90–40 had a nitrogen isotope value in the range typically associated with commercial fertilizer. Because this well is located next to irrigated corn fields, and irrigated cropland is the predominant land use in the area of this monitoring well, the USGS study suggests that fertilizer is the probable source of the elevated nitrate concentration in the water collected from that monitoring well.

Selenium has been found to be present in the Ogallala Group sediments of southwest and south-central South Dakota and concentrations have been reported to range from less than 1.0 micrograms per liter (ug/L) to 60 ug/L (Stach and others, 1990). The earlier water quality study of private wells in Todd and Mellette Counties, conducted by the Mellette County and Todd County Conservation Districts in 1989, also found elevated selenium concentrations in several private wells. For these reasons, selenium was analyzed in this investigation. Selenium can be toxic and an enforceable maximum limit of 50 ug/L has been established for public water systems (U.S. Environmental Protection

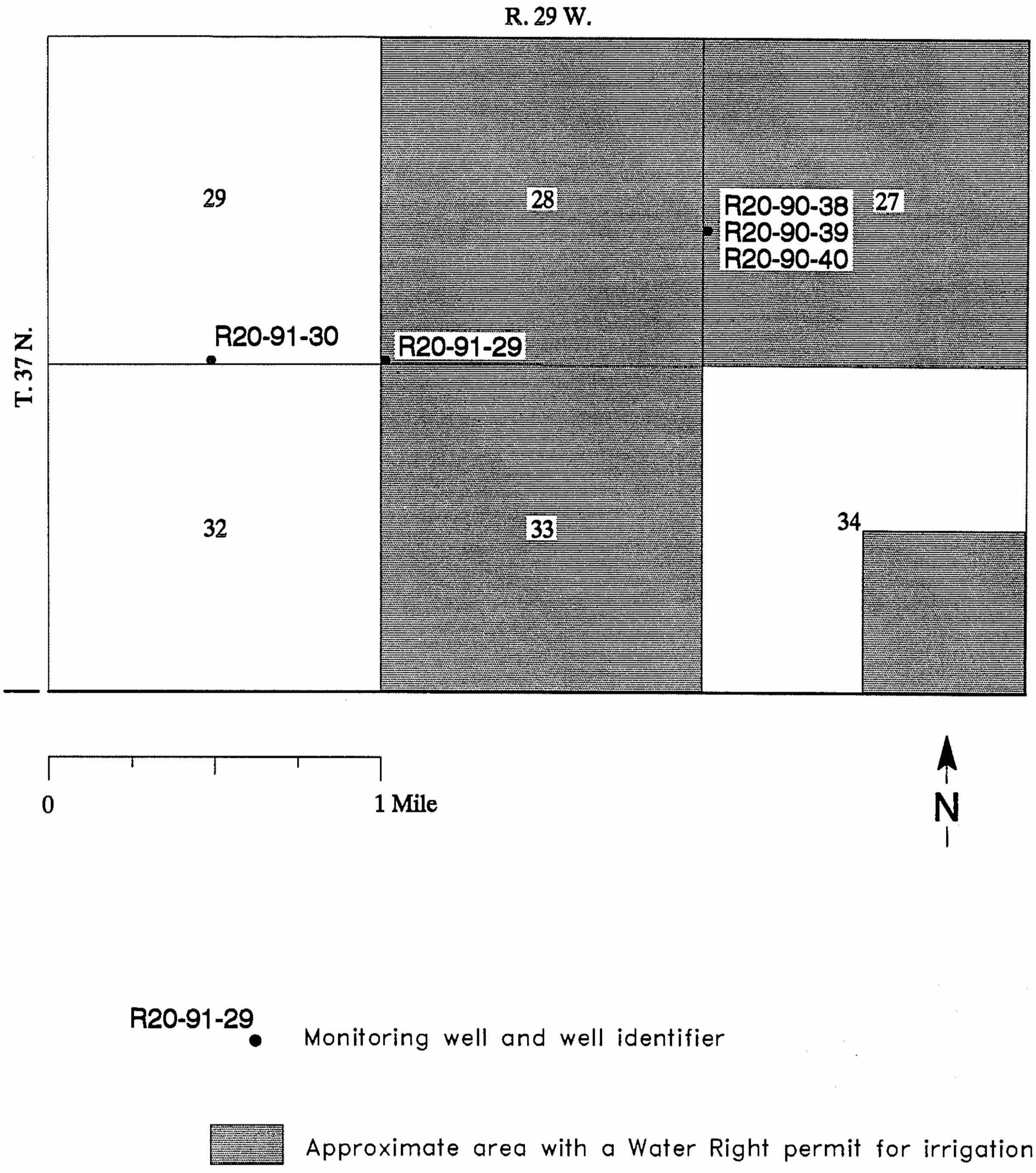


Figure 8. Locations of land-use activities and monitoring wells in the northern portion of the Todd County study area.

Table 5. Chemical analyses of water samples – Todd County study area

Well identifier[2]	Date collected	Well depth[3]	Conductivity[4]	Field pH	Se[5]	Concentrations in milligrams per liter (mg/L)[1] Alk-T	Alk-P	HCO_3	CO_3	Ca	Cl	F	Fe	K	Mg	Mn	Na	NO_3-N + NO_2-N	SO_4	TDS	Hardness as $CaCO_3$	NH_3-N	Total P
NORTHERN AREA																							
Ogallala Group																							
R20-90-38	08/06/90	185	328	8.09	0.6	165	0	201	0	45	1.6	0.29	0.07	7.5	9.2	<0.05	9.3	1.11	9	241	150	<0.05	0.013
R20-90-38	07/08/91	185	319	7.58	0.6	168	0	205	0	46	1.2	0.29	<0.05	7.1	9.4	<0.05	6.4	1.07	4.8	225	154	--	---
R20-90-39	08/06/90	135	335	8.04	0.6	179	0	218	0	51	3.4	0.29	<0.05	6.7	9.6	<0.05	7.8	1.09	5	252	167	<0.05	0.019
R20-90-39	07/09/91	135	327	7.51	0.6	176	0	215	0	49	1.8	0.27	<0.05	6.5	10	<0.05	3.4	1.06	2.9	246	164	--	---
R20-90-40	08/07/90	80	484	7.72	0.8	199	0	243	0	71	1.4	0.27	<0.05	7.8	6.2	<0.05	26	7.34	32	351	203	<0.05	0.058
R20-90-40	07/09/91	80	467	7.44	0.4	231	0	282	0	69	1.6	0.33	<0.05	7.2	6.0	<0.05	25	5.21	20	336	197	--	---
R20-91-29	07/08/91	90	418	7.69	1.0	182	1	219	1	38	2.4	0.47	0.08	7.5	3.8	<0.05	54	4.66	30	306	111	--	---
R20-91-30	07/08/91	90	363	7.52	2.1	170	0	207	0	55	4.7	0.33	<0.05	6.2	5.5	<0.05	15	2.69	16	274	160	--	---
MIDDLE AND SOUTHERN AREAS																							
Ogallala Group																							
R20-90-30	08/07/90	205	322	7.94	1.0	161	0	196	0	51	1.7	0.22	<0.05	7.6	5.4	<0.05	7.3	1.26	5	236	150	<0.05	0.021
R20-90-30	07/09/91	205	310	7.32	1.1	152	0	185	0	49	1.6	0.21	<0.05	7.4	5.8	<0.05	5.2	1.2	3.3	226	146	--	---
R20-90-31	08/07/90	125	360	7.99	1.0	176	0	215	0	55	3.5	0.28	<0.05	8.9	5.2	<0.05	11	0.93	9	256	159	<0.05	0.035
R20-90-31	07/09/91	125	349	7.46	1.0	181	0	221	0	58	3.0	0.26	<0.05	8.5	5.4	<0.05	7.0	0.88	4.8	248	167	--	---
R20-90-32	08/07/90	80	380	7.90	0.4	192	0	234	0	60	1.4	0.39	<0.05	6.9	5.9	<0.05	14	1.17	8	260	174	<0.05	0.077
R20-90-32	07/09/91	80	390	7.43	0.6	203	0	247	0	69	1.3	0.30	<0.05	6.2	7.1	<0.05	3.2	1.28	13	278	202	--	---
R20-90-33	08/07/90	110	748	7.77	0.7	160	0	195	0	125	14	0.48	<0.05	8.9	8.6	<0.05	14	51.4	15	594	348	<0.05	0.068
R20-90-33	07/09/91	110	906	7.44	0.9	189	0	230	0	141	16	0.20	<0.05	8.9	10	<0.05	12	65.4	16	802	393	--	---
Private A	08/07/90	180	582	7.64	0.4	178	0	217	0	91	14	0.18	<0.05	8.4	10	<0.05	7.2	23.8	11	460	268	<0.05	0.033
Private A	07/17/91	180	559	7.51	0.4	180	0	219	0	87	14	0.20	<0.05	8.1	9.7	<0.05	7.0	23.2	9.4	486	257	--	---
R20-91-25	07/10/91	110	443	7.64	2.1	172	0	210	0	48	7.6	0.47	<0.05	7.5	6.0	<0.05	42	3.33	39	320	145	--	---
R20-91-26	07/15/91	125	322	7.61	1.4	160	0	195	0	48	2.8	0.11	<0.05	8.4	4.6	<0.05	11	1.65	6.1	236	139	--	---
R20-90-35	08/07/90	55	342	7.93	0.8	163	0	199	0	53	3.7	0.40	<0.05	7.8	7.6	<0.05	6.6	2.56	6	254	164	<0.05	0.012
R20-90-35	07/16/91	55	349	7.55	0.9	166	0	202	0	52	4.1	0.39	<0.05	7.4	8.1	<0.05	5.5	3.11	5.0	269	163	--	---
R20-90-36	08/07/90	30	1070	7.38	0.9	223	0	272	0	158	44	0.62	<0.05	30	15	<0.05	37	67.3	28	861	456	<0.05	0.033
R20-90-36	07/16/91	30	803	7.29	1.3	251	0	306	0	114	21	0.59	<0.05	25	11	<0.05	18	31.7	20	638	330	--	---
R20-90-37	08/07/90	30	485	7.73	0.9	178	0	217	0	72	4.4	0.62	<0.05	15	5.0	<0.05	18	15.1	11	365	200	<0.05	0.045
R20-90-37	07/16/91	30	634	7.35	0.9	205	0	250	0	94	6.8	0.41	<0.05	13	4.2	<0.05	22	27.7	14	499	252	--	---
R20-91-27	07/16/91	45	361	7.50	1.4	178	0	217	0	56	4.2	0.42	<0.05	8.6	5.1	<0.05	9.3	1.36	8.1	263	161	--	---
R20-91-28	07/16/91	75	386	7.55	3.7	161	0	196	0	48	12	0.46	<0.05	7.2	5.4	<0.05	24	1.77	25	299	142	--	---
Rosebud Formation																							
R20-90-34	08/07/90	115	318	8.07	1.1	149	0	182	0	39	4.5	0.75	<0.05	9.5	7.5	<0.05	14	1.18	8	239	128	<0.05	0.020
R20-90-34	07/15/91	115	343	7.62	1.3	166	0	202	0	42	4.8	0.68	<0.05	9.7	8.2	<0.05	15	1.08	9.4	257	139	--	---
Private B	08/07/90	120	328	7.77	1.2	161	0	196	0	48	3.8	0.39	0.85	8.0	9.4	<0.05	8.7	1.25	9	279	159	<0.05	0.075
Private B	07/17/91	120	327	7.58	1.3	163	0	199	0	43	3.7	0.41	<0.05	7.7	8.9	<0.05	8.8	1.35	6.9	254	144	--	---

[1] **Alk-T** – total alkalinity; **Alk-P** – phenolphthalein alkalinity; **HCO_3** – bicarbonate; **CO_3** – carbonate; **Ca** – calcium; **Cl** – chloride; **F** – fluoride; **Fe** – iron; **K** – potassium; **Mg** – magnesium; **Mn** – manganese; **Na** – sodium; **NO_3-N+NO_2-N** – nitrate+nitrite as nitrogen; **SO_4** – sulfate; **TDS** – total dissolved solids; **Hardness as $CaCO_3$** – hardness as calcium carbonate; **NH_3-N** – ammonia; **Total P** – total phosphorus.

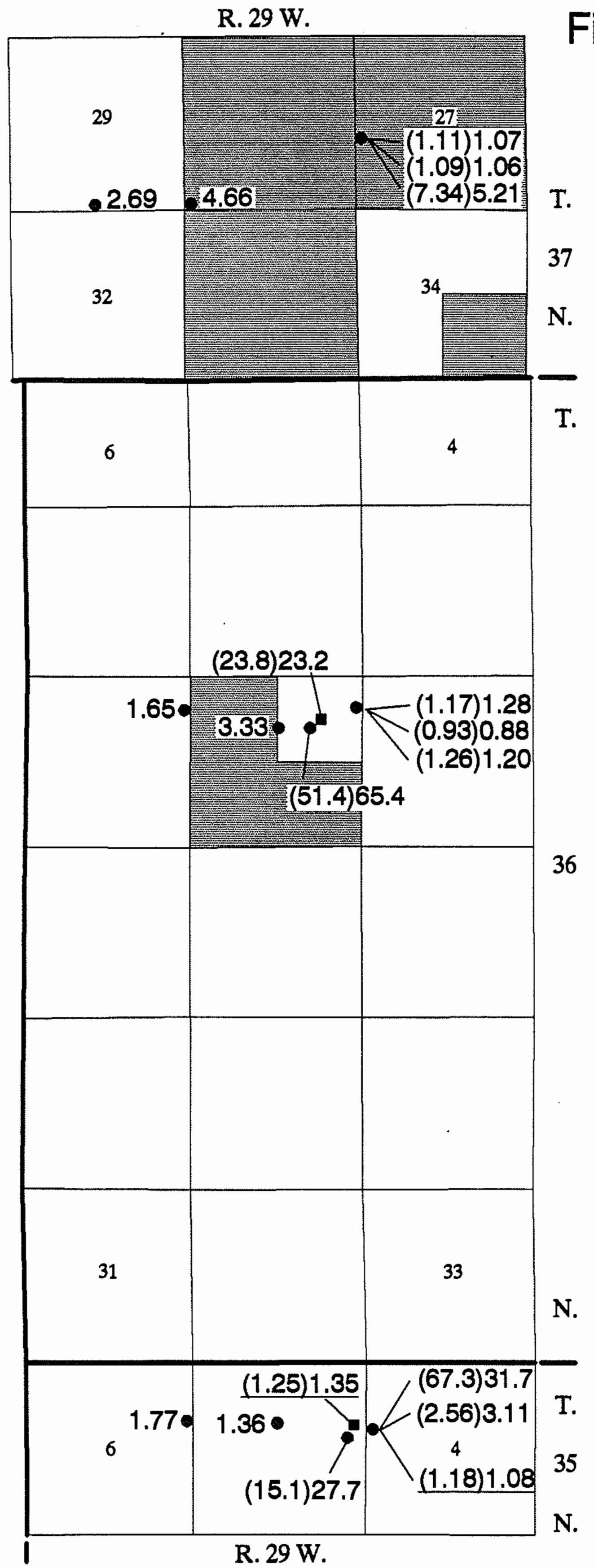
[2] See table 1 for legal location of well identifier and figures 1 and 3 for location of the Todd County study area.

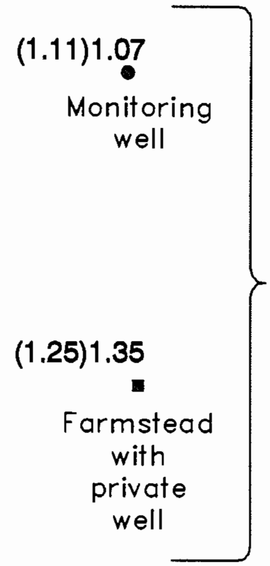
[3] Well depth is presented in feet below top of casing.

[4] Conductivity is presented in μmhos/cm (micromhos per centimeter).

[5] **Se** – selenium in micrograms per liter (ug/L).

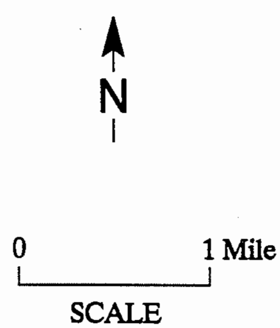
Figure 9. Nitrate concentrations in the Ogallala Group and Rosebud Formation in the Todd County study area.





Number is nitrate concentration in milligrams per liter. Number in parentheses denotes samples collected August 1990, all other samples collected July 1991. Underlined number indicates sample collected from well installed in the Rosebud Formation. All other samples collected from wells installed in the Ogallala Group. See figure 3 for well identifier.

Approximate area with a Water Right permit for irrigation



Agency, 1985a). In water samples collected from monitoring wells for this investigation in the northern area, selenium concentrations ranged from 0.4 to 2.1 ug/L (table 5). These concentrations are low and indicate that selenium is not a problem in water collected from the Ogallala Group in the northern area.

Middle and Southern Areas

As previously mentioned, the Todd County study area was selected for further investigation primarily because the area contains elevated nitrate concentrations in ground water collected from several private wells. Two farmsteads are located in the middle and southern portions of the study area and it is in these two locations that additional monitoring wells were installed. Using water-level information from monitoring wells located outside the immediate Todd County study area, a general direction of ground-water flow was estimated for the area. A set of three nested monitoring wells was installed downgradient from each of the two farmsteads (figs. 3, 6, 7, 10, and 11). In addition to the downgradient wells, three shallow monitoring wells were installed next to and generally successively upgradient from each farmstead. A total of 12 monitoring wells were installed near these two farmsteads. Figures 10 and 11 illustrate current farming and domestic activities associated with each of the two farmsteads.

Water samples were collected from all 12 monitoring wells installed and from 2 private wells (private wells A and B, fig. 3, and table 1). One of the 12 monitoring wells was installed in the Rosebud Formation of the Arikaree Group and the remaining 11 monitoring wells were installed in the Ogallala Group. Of the 11 monitoring wells installed in the Ogallala Group, 8 were constructed with the screen positioned at, near, or through the water table. One private well (private B) is constructed into the Rosebud Formation and the other private well (private A) is constructed into the Ogallala Group.

Table 5 indicates that the overall quality of water in the Ogallala Group in the middle and southern areas is quite good with total dissolved solids ranging from 226 to 861 mg/L. However, as mentioned earlier in this report, elevated nitrate concentrations had been previously found in private wells in the Todd County study area. Figure 9 and table 5 show nitrate concentrations in the monitoring wells in the Ogallala Group and Rosebud Formation to range from 0.88 to 67.3 mg/L. For reference, the federal enforceable drinking water standard for public water systems is 10 mg/L for nitrate (U.S. Environmental Protection Agency, 1985a) and it has been suggested that nitrate concentrations greater than 3 mg/L may be the result of human activities (Madison and Brunett, 1984).

In the area of private well A (fig. 10), a septic tank drainfield is located to the east of the farm-house, an animal-holding area for cattle, used in the winter, is located to the southwest of the farm-house, and the entire half section to the west and the quarter section to the south of the farmstead is permitted for irrigation.

Three nested monitoring wells (R20–90–30, R20–90–31, and R20–90–32) were installed generally downgradient from the farmstead. In addition to the nested site, three shallow monitoring wells, screened through the water table, were installed; one well (R20–90–33) is located next to the animal-holding area (fig. 10), one well (R20–91–25) is located just upgradient from the farmstead, and the other well (R20–91–26) is located upgradient of the irrigated half section.

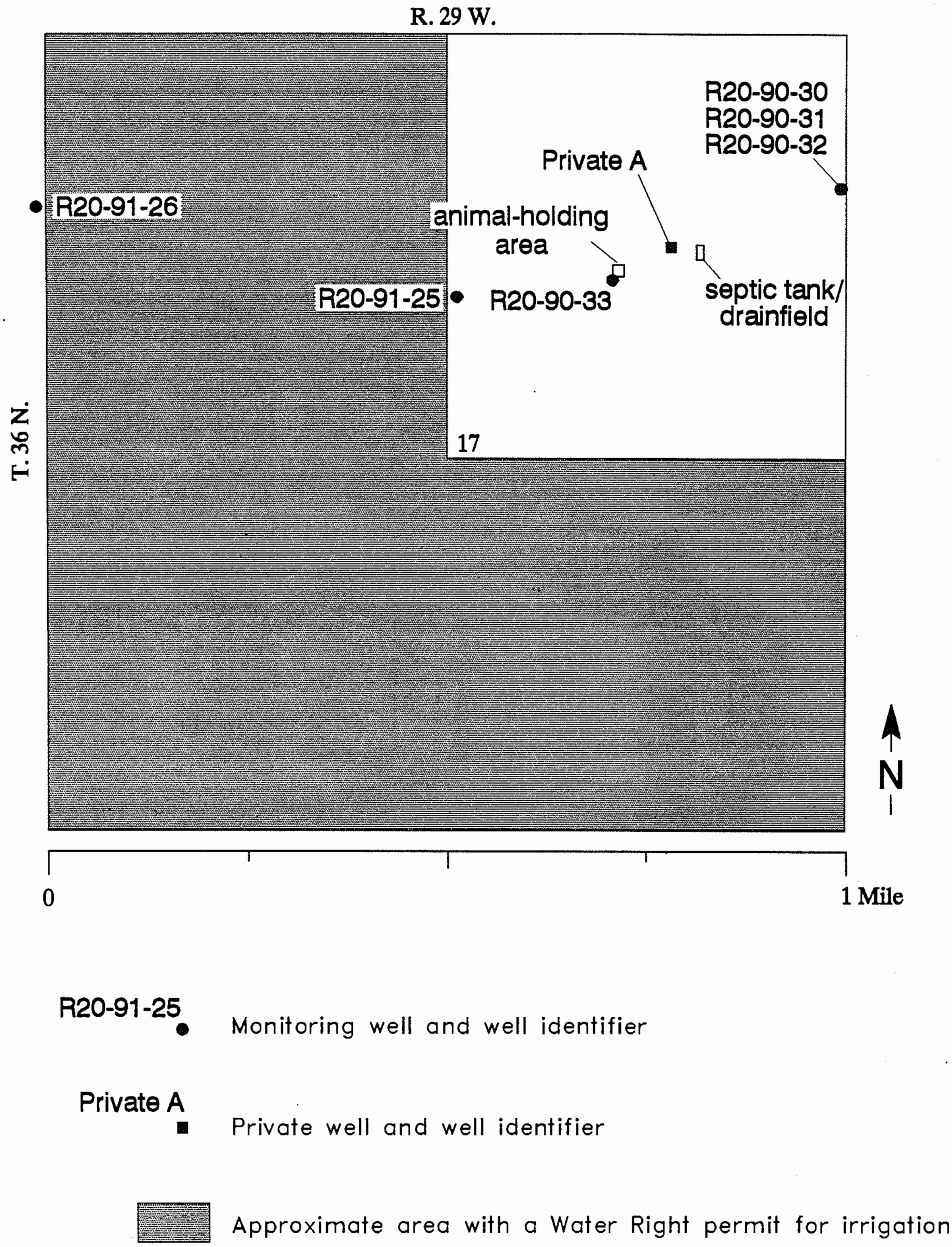


Figure 10. Locations of land-use activities and monitoring wells near private well A.

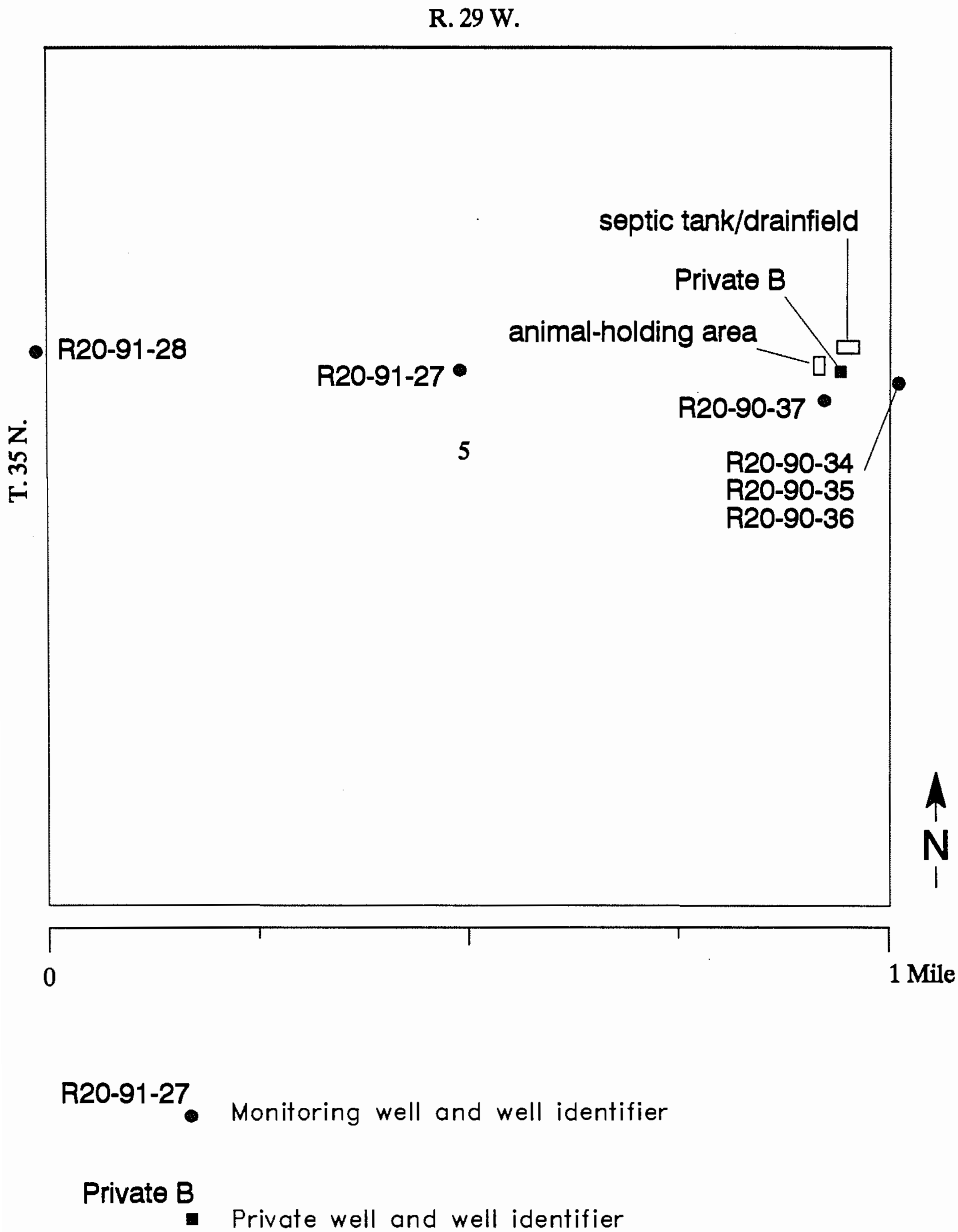


Figure 11. Locations of land-use activities and monitoring wells near private well B.

Nitrate concentrations in water collected from the downgradient nested wells ranged from 0.88 to 1.28 mg/L. See table 5 and figure 9 for nitrate data. The shallow downgradient monitoring well (R20–90–32), screened through the water table, contained water with nitrate concentrations of 1.17 and 1.28 mg/L when collected in August 1990 and July 1991, respectively. The monitoring well (R20–90–33) installed next to the animal-holding area had nitrate concentrations of 51.4 mg/L (August 1990) and 65.4 mg/L (July 1991). The monitoring well (R20–91–25) located upgradient from the farmstead had a nitrate concentration of 3.33 mg/L in July 1991, and the monitoring well (R20–91–26) located farther upgradient from the farmstead and upgradient from the irrigation system had a nitrate concentration of 1.65 mg/L in July 1991. Private well A is located in the basement of the farmhouse and is installed approximately 180 feet into the Ogallala Group. This private well had a nitrate concentration of 23.8 mg/L in August 1990 and 23.2 mg/L in July 1991. Elevated nitrate concentrations were found only in water collected from private well A and from a shallow monitoring well located next to an animal-holding area. These findings suggest that a likely source for nitrogen in this area is animal waste. With a septic tank drainfield located in the vicinity of the farmhouse, although probably downgradient, human waste may also be a source of nitrogen at this location.

The residents of the farmstead were informed of the elevated nitrate concentrations found in their shallow well. Because of the location of the private well relative to the septic tank drainfield and the animal-holding area, the farm owners have taken steps to try to reduce the amount of nitrogen available for leaching to the ground water. First, the septic system is maintained more frequently and second, waste from the animal-holding area is removed in the spring before the frost is out of the ground. The waste material is taken to other properties and spread out over various fields. This practice was begun in 1992. In order to determine if these farm-management practices are aiding in reducing the load of nitrogen to the ground water, the monitoring wells in this location must be sampled again.

In the area of private well B (fig. 11), a septic tank drainfield is located to the north of the farmhouse and a holding area for cattle and a corral for horses are located to the west and southwest of the farmhouse. There is no irrigation in the area.

Three nested monitoring wells (R20–90–34, R20–90–35, and R20–90–36) were installed generally downgradient from the farmstead. In addition to the nested site, three shallow monitoring wells, screened through the water table, were installed: one well (R20–90–37) is located next to the animal-holding area, one well (R20–91–27) is located just upgradient from the farmstead, and the other well (R20–91–28) is located farther upgradient.

Nitrate concentrations in water collected from the downgradient nested wells ranged from 1.08 to 67.3 mg/L. See table 5 and figure 9 for nitrate data. The deep monitoring well at this nested site (R20–90–34) is installed in the Rosebud Formation. Water collected from this monitoring well showed a nitrate concentration of 1.18 mg/L (August 1990) and 1.08 mg/L (July 1991). Private well B is located south of the farmhouse and is also installed in the Rosebud Formation. Nitrate concentrations in water collected from private well B varied from 1.25 mg/L in August 1990 to 1.35 mg/L in July 1991. Nitrate contamination is not a problem in the Rosebud Formation in this area because the Rosebud Formation lies below the Ogallala Group at a greater depth.

The shallow downgradient monitoring well (R20–90–36), screened through the water table, contained water with nitrate concentrations of 67.3 and 31.7 mg/L when collected in August 1990 and July 1991, respectively. See table 5 and figure 9 for nitrate data. The shallow monitoring well

(R20–90–37) installed next to the animal-holding area had nitrate concentrations of 15.1 mg/L (August 1990) and 27.7 mg/L (July 1991). The shallow monitoring well (R20–91–27) located upgradient from the farmstead had a nitrate concentration of 1.36 mg/L in July 1991, and the shallow monitoring well (R20–91–28) located farther upgradient from the farmstead had a nitrate concentration of 1.77 mg/L in July 1991. Elevated nitrate concentrations were found only in water collected from the shallow monitoring well located immediately downgradient from the septic tank drainfield and in the shallow monitoring well located next to an animal-holding area. These findings suggest that a likely source of nitrogen in this area is animal and/or human waste.

Another parameter of interest is chloride. Chloride is a naturally occurring constituent of surface and ground water and is also found in waste water, primarily the result of human culinary sources. Because septic systems do not effectively remove chloride, chloride has been used as an indicator of ground-water contamination from septic systems (Alhajjar and others, 1990). Viraraghavan and Warnock (1976) found chloride concentrations to range from 37 to 101 mg/L in septic tanks and in the effluent discharged to the soil through soil-absorption systems. Figure 12 and table 5 show generally low chloride values in the Ogallala Group and Rosebud Formation in the middle and southern areas. However, higher chloride concentrations were found in three monitoring wells (R20–91–28, R20–90–36, and R20–90–33) and one private well (private A) installed in the Ogallala Group. In the middle and southern areas, two of the three elevated chloride concentrations occur in water where nitrate concentrations are also elevated (R20–90–36 and R20–90–33). Chloride concentrations of less than 5 mg/L are common in the Ogallala Group elsewhere in the state (Ellis and others, 1971; Hammond, 1990) and the federal recommended maximum limit for public water supplies is 250 mg/L (U.S. Environmental Protection Agency, 1985b). Monitoring well R20–90–36 showed a chloride concentration of 44 mg/L in 1990 and 21 mg/L in 1991. Because this well is (1) located immediately downgradient from a septic system, (2) contains water with elevated nitrate concentrations, and (3) the chloride concentrations fall within the range of concentrations of septic tanks and effluent as suggested by Viraraghavan and Warnock (1976), it appears likely that a possible source of nitrogen in this area is the septic system.

In August 1991, the USGS collected a water sample from the shallow well R20–90–36 for analyses of nitrogen isotope ratios (Steve Sando, USGS, written communication, 1992). Nitrogen isotope ratios aid in identifying the sources of elevated nitrate concentrations. Well R20–90–36 is a shallow well, constructed so that the screen intersects the water table, and is located immediately downgradient from a farmstead. Monitoring well R20–90–36 had a nitrogen isotope value in the range typically associated with animal/human waste. Possible sources of nitrogen in this area include septic systems and leaching of soils beneath barnyards and feedlots. Based on nitrogen isotope ratios, it is difficult to distinguish between animal waste and nitrogen derived from septic systems. Using nitrogen isotope data, nitrate concentrations, and chloride concentrations, it is concluded that the elevated nitrate concentrations found in the ground water at this location are due to animal and/or human waste.

In water samples collected from monitoring and private wells for this investigation in the middle and southern areas, selenium concentrations ranged from 0.4 to 3.7 ug/L (table 5). These concentrations are low and indicate that selenium is not a problem in water collected from the Ogallala Group and the Rosebud Formation in the middle and southern areas.

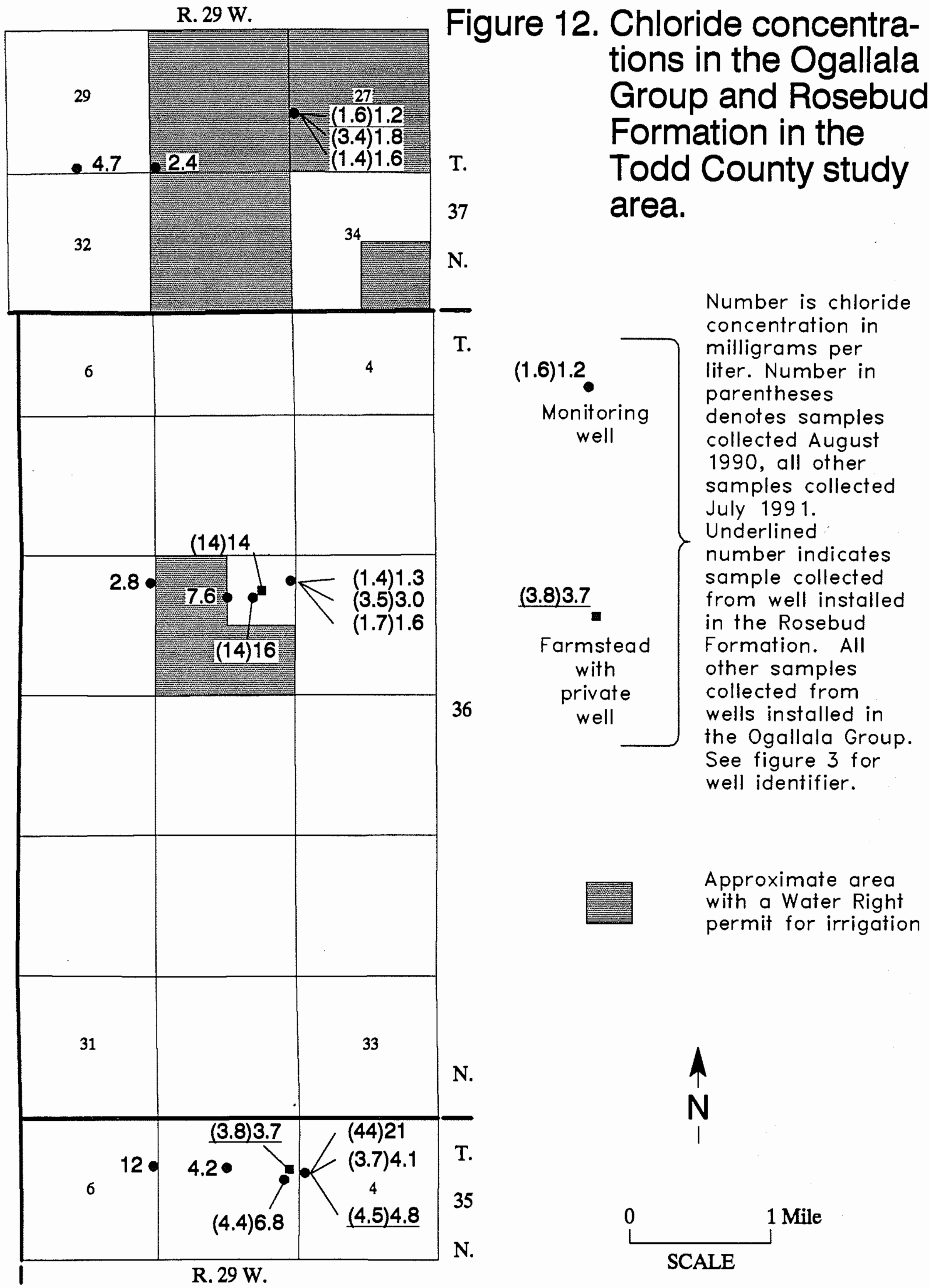


Figure 12. Chloride concentrations in the Ogallala Group and Rosebud Formation in the Todd County study area.

Conclusions

Monitoring wells were installed into the Ogallala Group and the Rosebud Formation in the Todd County study area. Overall, the quality of water collected from these wells is very good. However, elevated nitrate concentrations are a problem in some of the wells. Nitrate concentrations are elevated in several shallow wells, screened at, near, or through the water table, and located downgradient from farmsteads or an irrigated area. Nitrate concentrations are low in shallow wells located upgradient from farmsteads or an irrigated area. These findings suggest that contamination in the study area is not widespread but is instead localized and associated with both point and nonpoint sources of contamination. Selenium is not a problem in water collected from monitoring wells and private wells in the Todd County study area.

MELLETTE COUNTY STUDY AREA

An investigation of the White River Group was conducted in a small area of Mellette County known to contain elevated nitrate concentrations in ground water produced from numerous private wells. Six monitoring wells were installed in Mellette County for this investigation (fig. 2). In addition to the installation of monitoring wells, 13 private wells (selected by the Mellette County Conservation District) were sampled.

Hydrogeologic Setting

Geologic deposits in the Mellette County study area include sedimentary rocks of Tertiary (table 3) and Cretaceous age. For a brief description of the Tertiary and Cretaceous bedrock units in the study area, refer to Ellis and others (1971). If all commonly encountered bedrock units in the study area were present at one location, they would be encountered in descending order (youngest to oldest) as follows: Tertiary age Arikaree Group and White River Group, followed by units of Mesozoic, Paleozoic, and Precambrian age. Also present in limited areas in Mellette County are Pleistocene age terrace deposits that overlie Tertiary sediments. Only the Tertiary age sediments of the White River Group were encountered during drilling in Mellette County during this investigation.

Much of the surficial geology in Mellette County consists of Cretaceous age (Mesozoic) Pierre Shale or the Tertiary age White River Group. Because of the surficial geology in Mellette County, it is often difficult to find an easily available source of water. Many private wells are installed in (1) isolated sand and gravel terrace deposits associated with streams and rivers, (2) the White River Group, or (3) the Cretaceous age (Mesozoic) Dakota Formation.

White River Group

In the Mellette County study area, the White River Group is the predominant surface sediment and includes the Brule and Chadron Formations that are believed to be fluvial and/or eolian deposits (Seeland, 1985; Swinehart and Diffendal, 1990). The Brule Formation is the uppermost formation in the White River Group and consists of highly fossiliferous pink to reddish-brown sands, silts, and clays. The Chadron Formation is the lower of the two formations in the White River Group and was deposited in a 175-foot deep paleovalley (Harksen and Macdonald, 1969). The Chadron Formation is primarily a greenish-yellow clay to greenish-brown claystone and calcareous siltstone. The base of the Chadron Formation often consists of a layer of silty sand and gravel. This basal unit consists of a fine-grained, well-rounded, quartz-feldspar sand and gravel with a thickness of approximately 20 feet (Skinner and Johnson, 1984). The Chadron Formation directly overlies the Cretaceous age Pierre Shale. The contact between the Chadron Formation and Pierre Shale is often noted by a reddish-purple to purple bentonitic shale that marks the upper weathering zone of the Pierre Shale. The contact between the Brule and Chadron Formations is also marked by a color change; the Brule Formation is pink to reddish-brown while the Chadron Formation is greenish-yellow to greenish-brown.

The Brule Formation of the White River Group is relatively impermeable. The Chadron Formation does yield some water to wells, and the basal sand and gravel layer is considered moderately permeable (Ellis and others, 1971). Generally, the water quality in the White River Group is good to fair, depending on the proximity of the aquifer to the underlying Pierre Shale, with total dissolved solids ranging from 300 to 700 mg/L (Ellis and others, 1971). Generally, the closer a well is to the Pierre Shale, the poorer the water quality within that well.

Pleistocene Terrace Deposits and Other Aquifers

Many of the domestic and stock wells in the Mellette County study area are believed to be installed in isolated surficial sand and gravel terrace deposits. Some of these private wells can easily be pumped dry and many wells show elevated concentrations of nitrate. Other private wells are installed in the deep Dakota Formation.

In Mellette County, terrace deposits consist of silty clay, sand, and gravel. These deposits form flat, isolated terraces which are generally aligned parallel to present streams and slope gently toward the stream or river (Ellis and others, 1971). Water yields from these deposits are usually adequate for domestic and stock needs depending on the saturated thickness of the deposit. Where the terrace deposits directly overlie the Pierre Shale, water quality is poor. However, terrace deposits that overlie Tertiary sediments yield water of good quality (Ellis and others, 1971).

Wells installed into the Dakota Formation range in depth from approximately 1,500 feet to 2,300 feet below ground level and have an average total dissolved solids content of approximately 1,800 mg/L (Ellis and others, 1971).

Results

Monitoring Wells in the White River Group

Six monitoring wells were installed in a small area of Mellette County (sections 3, 4, and 9, T. 40 N., R. 28 W.) specifically chosen for further study (fig. 2). Three wells were nested at one location and all six monitoring wells were installed in the White River Group. The monitoring wells are located around a farmstead with a private well known to contain water with an elevated nitrate concentration. This small study area in Mellette County was chosen by the Mellette County and Todd County Conservation Districts.

The White River Group at this location has a thickness of approximately 158 feet and consists primarily of bentonitic clay and claystone with some interbedded silt and sand. Water is present in the formation but recharge to the monitoring wells is slow. Saturated thickness in the study area is approximately 123 feet (R20–91–19). The water-table surface was determined to slope downward to the south/southwest.

Water samples were collected from all six monitoring wells installed in the Mellette County study area for this investigation. Of the six wells installed in the White River Group, four wells (R20–91–19, R20–91–22, R20–91–23, and R20–91–24) were constructed with the screen intersecting the water table. Three wells (R20–91–19, R20–91–20, and R20–91–21) are nested and located downgradient of a farmstead, and three shallow wells are located upgradient from the same farmstead.

Generally, the water quality in the White River Group was found to be good to fair. Table 6 indicates that the total dissolved solids in water collected from the six monitoring wells installed into the White River Group range from 287 to 688 mg/L. For reference, the federal recommended maximum limit is 500 mg/L for public water supplies (U.S. Environmental Protection Agency, 1985a). Hardness ranges from 19 to 79 mg/L, and pH ranges from 7.95 to 9.05.

Figure 13 shows nitrate concentrations in the monitoring wells range from <0.04 to 2.10 mg/L. It does not appear that nitrate contamination is a problem in the White River Group at this location. Chloride concentrations were variable ranging from 3.0 to 18 mg/L. See table 6 for chloride data. Nested monitoring wells (R20–91–19, R20–91–20, and R20–91–21), installed in the White River Group and located downgradient from the farmstead, showed the highest chloride concentrations with 15 mg/L chloride in the shallow well, 12 mg/L chloride in the intermediate-depth well, and 7.8 mg/L chloride in the well screened at the bottom of the White River Group. Another monitoring well (R20–91–22) showing a comparatively elevated chloride concentration (18 mg/L) is a shallow well located just upgradient from the farmstead. Even though this well is located in a pasture area that was recently used to hold 300 head of cattle, these chloride concentrations do not necessarily indicate contamination as these concentrations are typical of water from the White River Group. Selenium concentrations were found to range from <0.2 to 5.6 ug/L (table 6); therefore, selenium is not a problem in water found in the monitoring wells at this location.

Private Wells in Pleistocene Terrace Deposits and Other Aquifers

In addition to installing and sampling monitoring wells, 13 private wells were sampled in Mellette County (fig. 2). These private wells were selected for sampling by the Mellette County Conservation District. All but one of the private wells selected are believed to be installed in isolated sand and gravel units (terrace deposits), the Arikaree Group, or the White River Group. The exception is a well (private O, tables 2 and 6) which is believed to be installed in the Dakota Formation at a depth of 2,205 feet. Driller's logs were not available for any of the private wells, consequently, assumptions were made in order to determine in which aquifer the private well was installed. Nearly all of the private wells are located in a farmyard and at least two private wells are 40 to 50 years old. One well, private J, is approximately 40 years old and has not been used for at least 25 years.

The Dakota Formation well (private O) has a chloride concentration of 146 mg/L and a total dissolved solids concentration of 1,944 mg/L. Values like these are common in the Dakota Formation in this area (Ellis and others, 1971).

Table 6. Chemical analyses of water samples – Mellette County study area

Well identifier[2]	Date collected	Well depth[3]	Conductivity[4]	Field pH	Se[5]	Alk-T	Alk-P	HCO_3	CO_3	Ca	Cl	F	Fe	K	Mg	Mn	Na	NO_3-N + NO_2-N	SO_4	TDS	Hardness as $CaCO_3$	NH_3-N	Total P
						Concentrations in milligrams per liter (mg/L)[1]																	
White River Group																							
R20-91-19	06/18/91	140	576	8.18	2.8	197	8	221	10	17	15	0.93	0.13	8.2	2.3	<0.05	112	0.65	84	390	52	--	---
R20-91-20	06/18/91	110	914	8.26	4.6	219	10	243	12	26	12	1.20	<0.05	10	3.3	<0.05	171	1.74	227	635	79	--	---
R20-91-21	06/18/91	65	415	8.90	1.7	143	21	123	25	6.3	7.8	0.83	0.05	7.0	0.9	<0.05	79	0.29	56	287	19	--	---
R20-91-22	06/19/91	75	981	9.05	5.6	183	30	150	36	12	18	1.32	<0.05	16	2.3	<0.05	209	2.10	270	688	39	--	---
R20-91-23	07/01/91	60	619	7.95	0.7	241	15	257	18	18	8.4	0.83	0.32	9.2	2.0	<0.05	123	0.08	68	413	53	--	---
R20-91-24	07/01/91	65	466	7.98	<0.2	210	0	256	0	11	3.0	0.61	<0.05	6.8	0.8	<0.05	98	<0.04	36	320	31	--	---
Aquifer unknown due to limited well information																							
Private C	08/08/90	32	6950	7.22	60	544	0	663	0	441	129	0.42	<0.05	38	235	0.25	1390	10.3	4200	6800	2069	<0.05	0.025
Private D	08/23/90	70	683	7.58	1.2	166	0	203	0	72.0	52.0	0.28	<0.01	18.0	8.8	<0.01	38.4	14.4	45.9	474	--	--	---
Private E	08/08/90	35	565	7.57	2.1	180	0	219	0	67	17	0.19	<0.05	12	5.5	<0.05	45	17.0	25	389	190	<0.05	0.049
Private F	08/08/90	35	404	7.22	1.3	148	0	180	0	61	1.5	0.17	<0.05	7.4	6.9	<0.05	8.2	12.6	11	313	181	<0.05	0.292
Private G	08/08/90	6	551	7.59	2.2	262	0	319	0	71	4.1	0.53	<0.05	13	6.1	<0.05	44	3.89	18	359	202	--	0.014
Private H	06/19/91	42	783	7.15	1.3	319	0	389	0	112	27	0.28	0.05	10	11	<0.05	42	10.4	34	520	325	--	---
Private I	08/08/90	42	687	7.26	2.7	291	0	355	0	90	19	0.28	<0.05	10	8.6	<0.05	50	6.58	27	460	260	<0.05	0.119
Private J	08/08/90	70	5960	7.43	410	420	0	512	0	606	238	0.31	6.25	48	79	0.14	818	240	1960	4940	1839	3.29	0.363
Private K	08/08/90	16	845	7.29	1.9	327	0	399	0	119	28	0.25	<0.05	11	11	<0.05	53	13.7	37	559	342	<0.05	0.102
Private L	08/08/90	40	657	7.21	3.0	168	0	205	0	83	20	0.23	<0.05	12	7.4	<0.05	37	31.5	17	470	238	<0.05	0.054
Private M	08/23/90	65	795	7.32	<1.0	355	0	433	0	91.2	20.9	0.41	<0.01	17.4	9.0	0.01	67.3	<0.1	33.0	532	--	--	---
Private N	08/23/90	30	1213	7.71	5.0	311	0	379	0	150	12.6	0.82	0.06	22.7	23.7	0.02	85.2	1.4	331	908	--	--	---
Dakota Formation																							
Private O	08/23/90	2205	2899	7.72	4.1	552	0	673	0	14.8	146	4.11	0.18	17.1	2.7	0.02	664	<0.1	692	1944	--	--	---

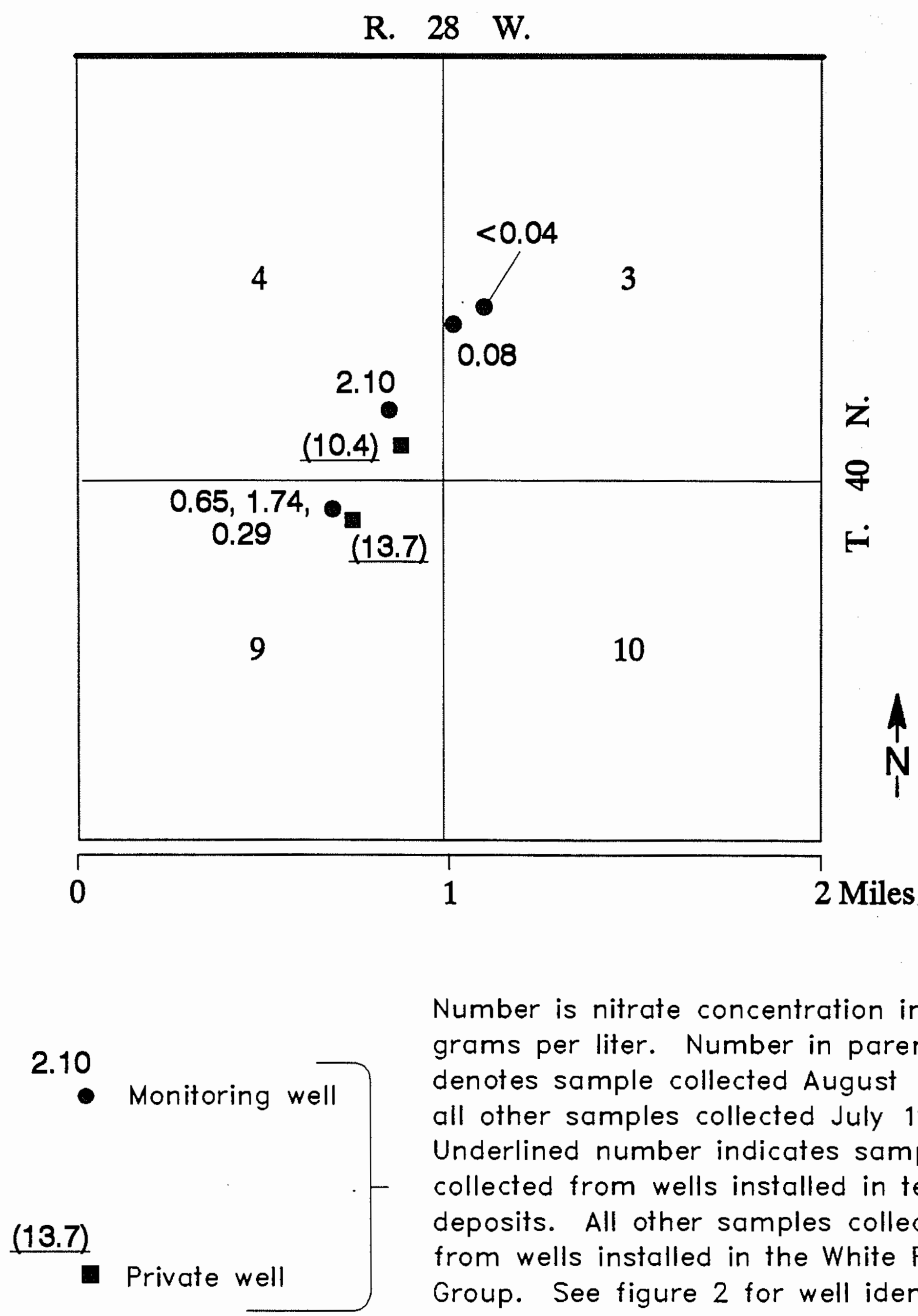
[1] **Alk-T** – total alkalinity; **Alk-P** – phenolphthalein alkalinity; **HCO_3** – bicarbonate; **CO_3** – carbonate; **Ca** – calcium; **Cl** – chloride; **F** – fluoride; **Fe** – iron; **K** – potassium; **Mg** – magnesium; **Mn** – manganese; **Na** – sodium; **NO_3-N+NO_2-N** – nitrate+nitrite as nitrogen; **SO_4** – sulfate; **TDS** – total dissolved solids; **Hardness as $CaCO_3$** – hardness as calcium carbonate; **NH_3-N** – ammonia; **Total P** – total phosphorus.

[2] See table 2 for legal location of well identifier, and figures 2 and 13 for location of the Mellette County study area.

[3] Well depth is presented in feet below top of casing.

[4] Conductivity is presented in μmhos/cm (micromhos per centimeter).

[5] **Se** – selenium in micrograms per liter (ug/L).



Number is nitrate concentration in milligrams per liter. Number in parentheses denotes sample collected August 1990; all other samples collected July 1991. Underlined number indicates sample collected from wells installed in terrace deposits. All other samples collected from wells installed in the White River Group. See figure 2 for well identifier and table 2 for comments regarding well location.

Figure 13. Nitrate concentrations in terrace deposits and White River Group in the Mellette County study area.

With the exception of the deep Dakota Formation well, all wells are believed to draw water from at or near the water table. Table 6 lists the results of analyses of water samples collected from private wells in Mellette County. When discussing water quality in the private wells, the deep Dakota Formation well will not be used in comparison with the shallow wells. The following is a discussion of water quality in the 12 shallow private wells.

Nitrate concentrations ranged from <0.1 to 240 mg/L with 8 of the 12 shallow private wells showing nitrate concentrations above the enforceable drinking water standard for public water systems of 10 mg/L (U.S. Environmental Protection Agency, 1985a). The private well (private J) with a nitrate concentration of 240 mg/L is an old well that had not been utilized for approximately 25 years prior to sampling.

One private well (private K) was sampled within the smaller portion of the study area where the monitoring wells were installed (figs. 2 and 13). This well, located at the bottom of a draw and downhill from the farmstead, is thought to be drilled into an isolated terrace sand unit associated with a small nearby stream which flows intermittently. Water from this shallow private well had a nitrate concentration of 13.7 mg/L. Water from a shallow monitoring well (R20–91–21), located near the private well but installed in the White River Group, had a nitrate concentration of 0.29 mg/L. See table 6 for nitrate data.

Chloride concentrations in the private wells range from 1.5 to 238 mg/L. See table 6 for chloride data. Ten of the shallow wells have comparatively elevated chloride concentrations indicating possible contamination from human and/or animal waste. Wells with elevated chloride concentrations also showed elevated nitrate concentrations. The highest chloride concentration (238 mg/L) is found in the old unused well (private J) that also had the highest nitrate concentration (240 mg/L).

Selenium concentrations in the private wells range from less than 1.0 to 410 ug/L. See table 6 for selenium data. The highest selenium concentration is found in the old unused well (private J) that also had the highest concentrations of chloride and nitrate. One well (private C) has a selenium concentration of 60 ug/L. This value is above the federal recommended drinking water standard for public water systems of 50 ug/L (U.S. Environmental Protection Agency, 1985a). Because so little information is available for this well, it is unknown why selenium concentrations are elevated in water collected from this well.

Generally, the total dissolved solids concentrations indicate a good to fair quality ground water in the shallow wells with concentrations ranging from 313 to 908 mg/L with two exceptions. Water from the old unused well (private J) had a total dissolved solids concentration of 4,940 mg/L. This old unused well also showed elevated concentrations of other parameters including chloride, nitrate, sulfate, and selenium and is not believed to be representative of the regional shallow water quality. The other shallow well (private C) with an elevated concentration of total dissolved solids (6,800 mg/L) also had other parameters which were elevated including selenium and sulfate. Not enough information is known about the construction of the private wells or the aquifer material into which the wells are installed to determine the cause of the poor water quality in many of these private wells.

Conclusions

Monitoring wells were installed in the White River Group in the Mellette County study area. Overall, the quality of water collected from these wells is good. Because the sediments of the White River Group have a moderate permeability at best, recharge to the wells installed in the White River Group is slow. Even though the water quality is good, water quantity may be a problem.

Water samples were collected from private wells in Mellette County. The overall quality of water collected from these wells was variable with the nitrate concentration elevated in nearly all of the wells sampled. Ten of the 12 shallow wells have comparatively elevated chloride concentrations indicating possible contamination from human and/or animal waste. Wells with elevated chloride concentrations also showed elevated nitrate concentrations. Most of the private wells are shallow, screened at or near the water table, and located next to a farmstead. In these cases, nitrate contamination may be caused by a variety of factors; for example, poor well construction, the age/integrity of the well, or the location of the well with regard to septic systems or animal-holding areas. In any case, it appears that the nitrate contamination found in the private wells is due to point-source contamination rather than nonpoint-source contamination.

SUMMARY

The purpose of the investigation was to examine ground-water quality in selected parts of Todd and Mellette Counties and to determine how extensive ground-water contamination may be in these areas. In the Todd County and Mellette County study areas, the results of this investigation indicate that the water quality, including selenium, in the Ogallala Group (Todd County) and the White River Group (Mellette County) is generally good. The primary water quality problem identified by this study was elevated concentrations of nitrate in the ground water.

In the Todd County study area, the Ogallala Group is an unconfined surficial aquifer that underlies the entire study area. In the northern part of the Todd County study area, water quality in shallow monitoring wells, screened through or near the water table and located upgradient of an irrigated area, show that nitrate concentrations range from 2.69 to 4.66 mg/L. A monitoring well installed downgradient from this irrigated area, and screened through or near the water table, shows nitrate concentrations ranging from 5.21 to 7.34 mg/L. Water quality in shallow monitoring wells, screened through or near the water table and located upgradient of two farmsteads show nitrate concentrations ranging from 1.36 to 3.33 mg/L. Monitoring wells installed downgradient from the farmsteads, and screened through or near the water table, show nitrate concentrations ranging from 0.88 to 67.3 mg/L. The monitoring wells that are screened through or near the water table, and located next to or immediately downgradient from a farmstead, showed the highest concentrations of nitrate.

In the Mellette County study area, the White River Group is the predominant surface sediment. Generally, the water quality in the White River Group is good to fair, however, the sediments of the White River Group are moderately permeable to relatively impermeable and, therefore, water quantity can be more of a problem than water quality.

Numerous private wells are located in isolated sand and gravel terrace deposits in the Mellette County study area. Some of these private wells can easily be pumped dry. Many of the private wells sampled showed elevated concentrations of nitrate and chloride which are attributed to nearby point sources of contamination.

The conclusions that can be drawn from this investigation indicate that in Todd County both point and nonpoint sources of contamination may be impacting the shallow ground water. In Mellette County, it appears that only point-source contamination is impacting the shallow ground water. However, this investigation covered only small areas in Todd and Mellette Counties. In order to adequately assess the ground-water quality in these counties, a much more extensive investigation must be undertaken. In particular, in Mellette County, the isolated surficial terrace deposits need to be identified and the extent of the deposits need to be mapped. This information would aid in understanding the hydrogeology of many areas in Mellette County.

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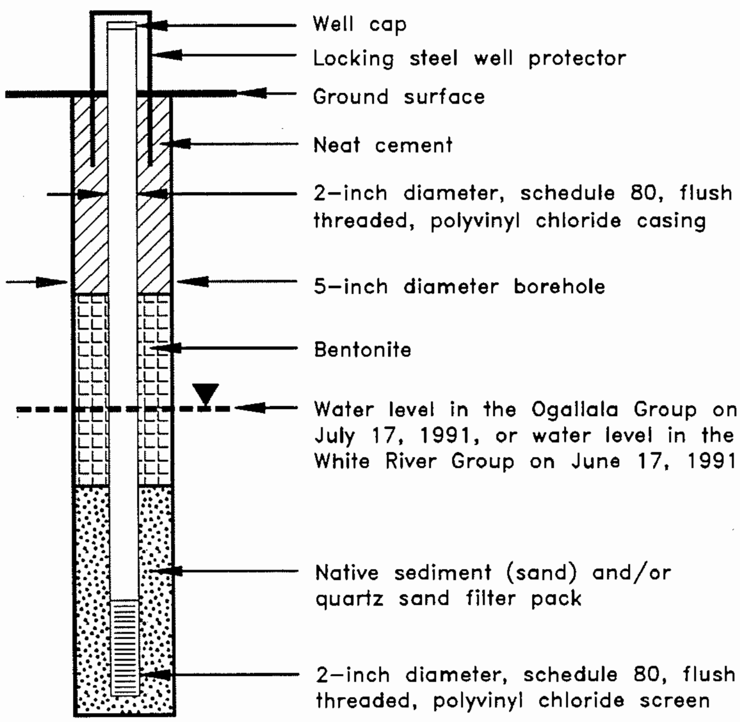
Appendix

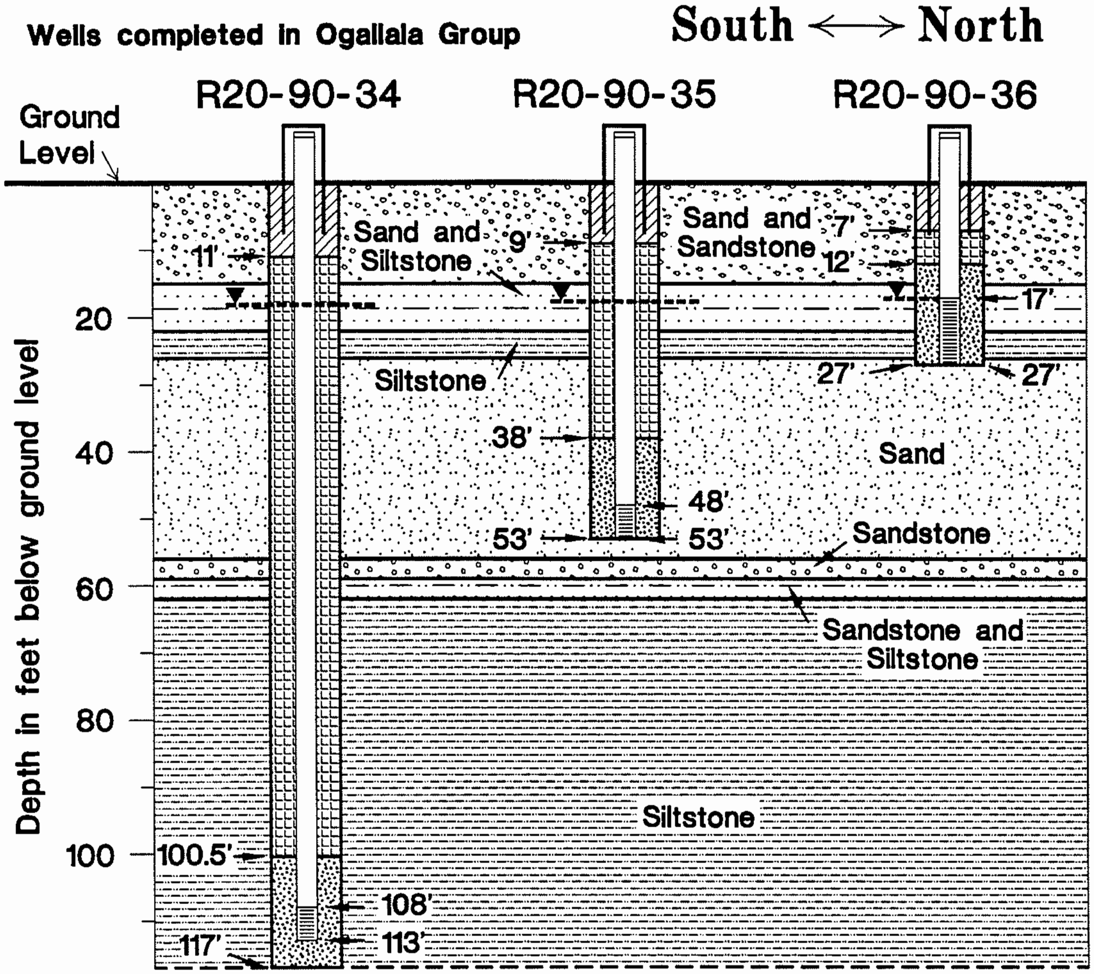
Monitoring well construction diagrams and hydrostratigraphic cross sections for nested monitoring well sites.

Explanation of patterns and symbols on well–construction diagrams.

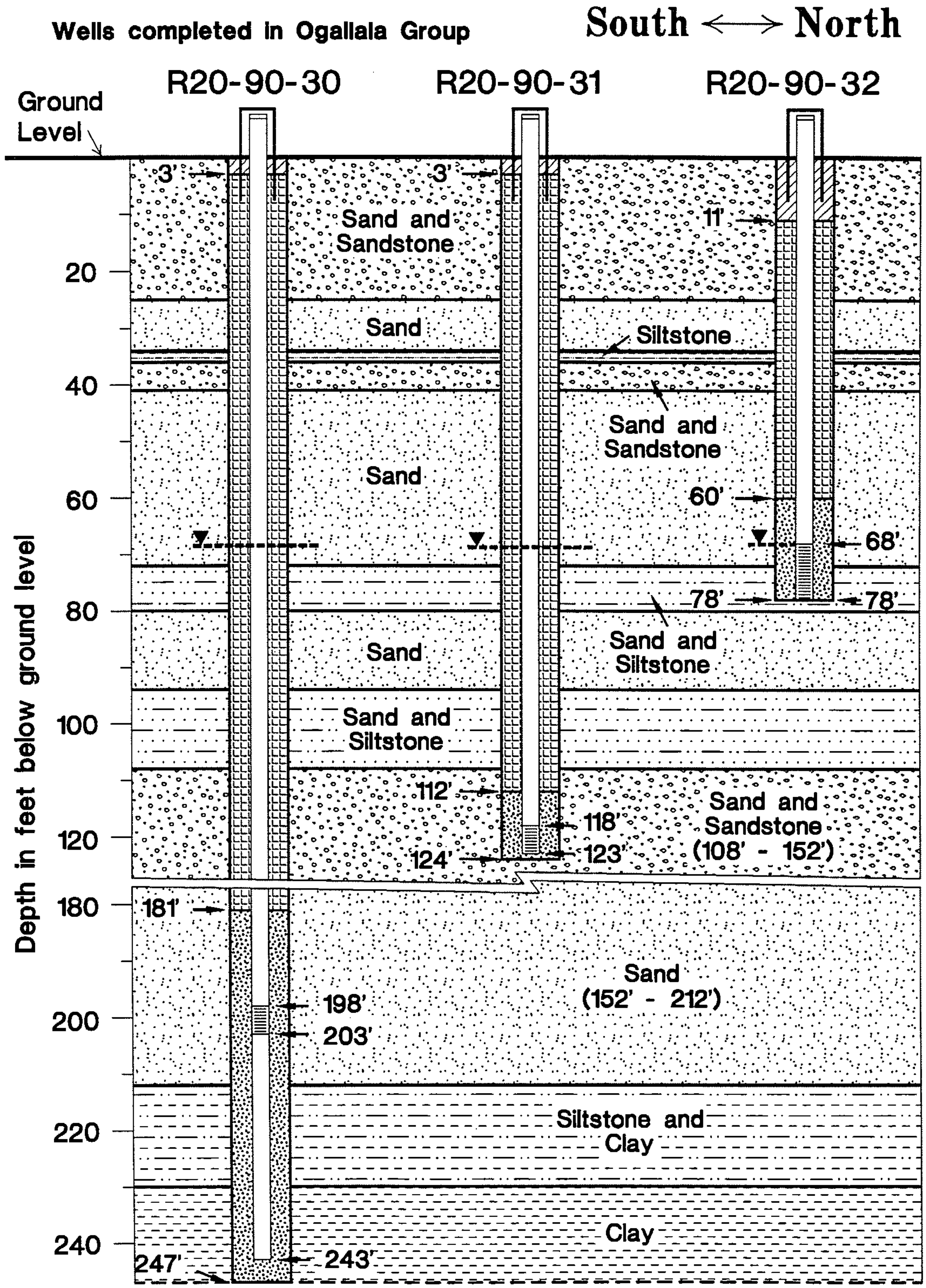


NW SW SW NW sec. 4, T. 35 N., R. 29 W.

Wells completed in Ogallala Group

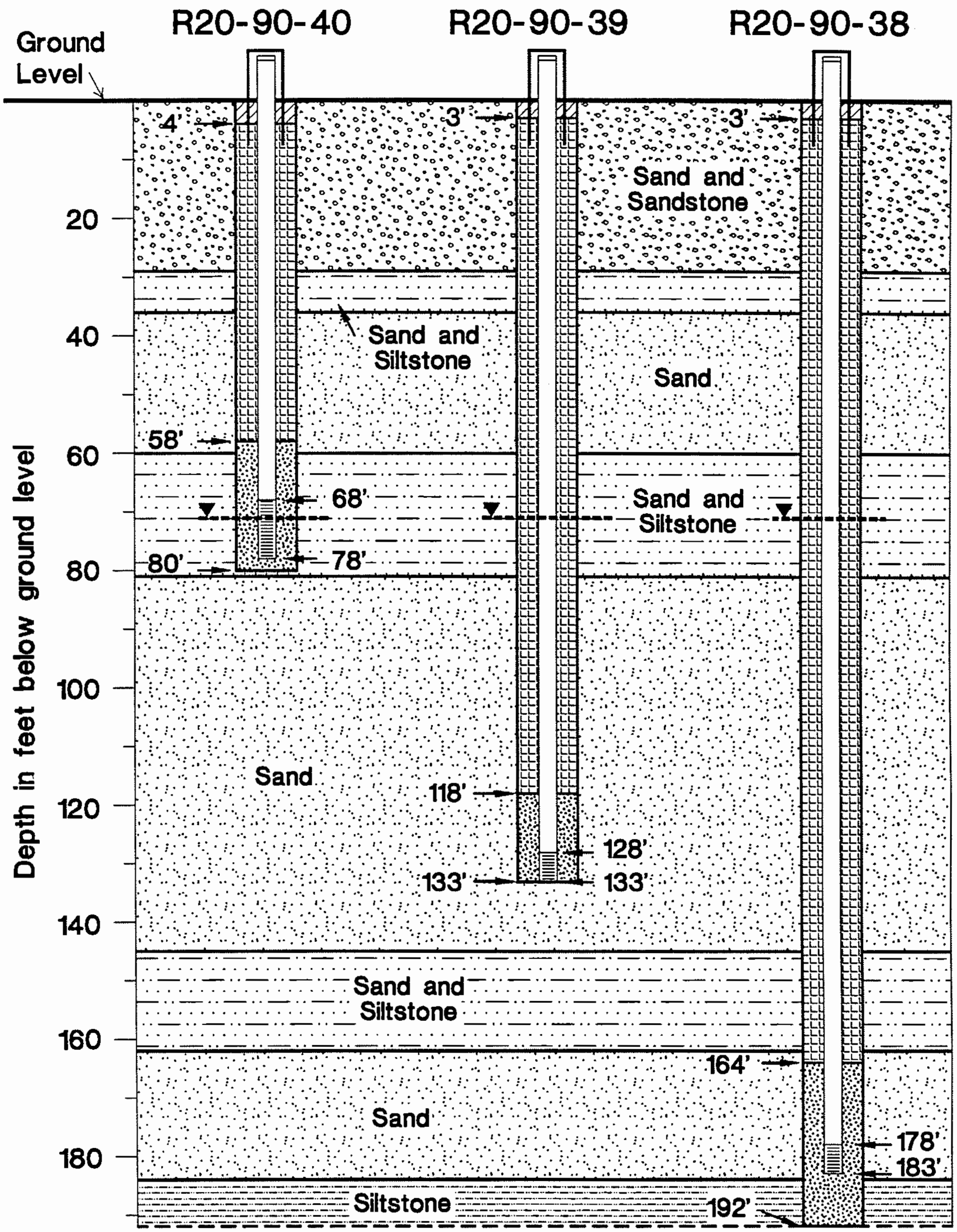


SE SE NE NE sec. 17, T. 36 N., R. 29 W.



SW NW NW SW sec. 27, T. 37 N., R. 29 W.

Wells completed in Ogallala Group South ⟷ North



SW NE NW NE sec. 9, T. 40 N., R. 28 W.

Wells completed in White River Group South ⟷ North