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**DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES  
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**DIVISION OF GEOLOGICAL SURVEY  
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**Open-File Report 64-UR**

**INVESTIGATION OF THE BASAL OUTWASH  
IN THE DOLTON VICINITY**

**by**

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## CONTENTS

	Page
<b>INTRODUCTION</b> .....	1
<b>METHODS</b> .....	1
Drilling .....	1
Well construction .....	1
Well development and sampling .....	1
<b>RESULTS OF INVESTIGATION</b> .....	3
Geology .....	3
Bedrock .....	3
Glacial deposits .....	3
Basal-outwash aquifer .....	3
Hydrology .....	12
Bedrock water bearing units .....	12
Basal-outwash aquifer .....	12
Comparison of water quality in the basal-outwash aquifer with the present water source for the rural-water systems .....	12
<b>SUMMARY AND RECOMMENDATIONS</b> .....	19
<b>REFERENCES</b> .....	20

## FIGURES

1. Locations of cross sections, test holes, and observation wells .....	2
2. Cross section A-A' .....	5
3. Cross section B-B' .....	6
4. Cross section C-C' .....	7
5. Cross section D-D' .....	8

<b>FIGURES -- continued.</b>	<b>Page</b>
6. Cross section E-E' .....	9
7. Configuration and geology of the bedrock surface .....	10
8. Approximate areal extent and thickness of the basal-outwash aquifer .....	11
9. Water-sample locations .....	14
10. Distribution of sulfates, dissolved solids, and hardness in the basal-outwash aquifer .....	16
11. Distribution of iron and manganese in the basal-outwash aquifer .....	17

### **TABLES**

1. Description of geologic units .....	4
2. Static-water levels .....	13
3. Results of analyses of water from the basal-outwash aquifer for selected trace metals and radionuclides .....	15
4. Comparison of the average water quality for the basal-outwash aquifer with the present source for the Hanson Rural Water System and the TM Rural Water District .....	18

### **APPENDICES**

A. Logs of test holes and observation wells .....	21
B. Compilation of available water-quality analyses for the major constituents in the basal-outwash aquifer .....	33

## INTRODUCTION

The Hanson Rural Water System and the TM Rural Water District are currently pumping water from a confined, buried outwash body of glacial origin known as the Dolton aquifer. After pumping began by the Hanson Rural Water System and TM Rural Water District, a dramatic decline in water levels has been recorded in observation wells completed in the Dolton aquifer (Barari, Cowman, and Iles, 1989). This decline in water levels prompted the systems' request of the South Dakota Geological Survey to delineate the areal extent and define the water quality of a deeper aquifer described earlier by Holly and others (in preparation) as the "basal-outwash aquifer."

The purpose of this investigation was to examine the basal-outwash aquifer as a potential water source for the two rural water systems. The results of the investigation, conducted by the South Dakota Geological Survey, are presented in this report. The investigation was financed by the South Dakota Geological Survey, the Hanson Rural Water System, and the TM Rural Water District.

## METHODS

### Drilling

Twelve test holes and eight observation wells were completed for this investigation (fig. 1, app. A). Drilling was accomplished by using a rotary drill rig with a bit diameter of 5½ inches. Samples were collected from the drill cuttings at 10-foot intervals and a lithologic log was written. A geophysical log of the hole was then made to determine at what depth aquifer material might be present. The lithologic and the geophysical logs were then used jointly to determine the suitability of the test hole for well construction.

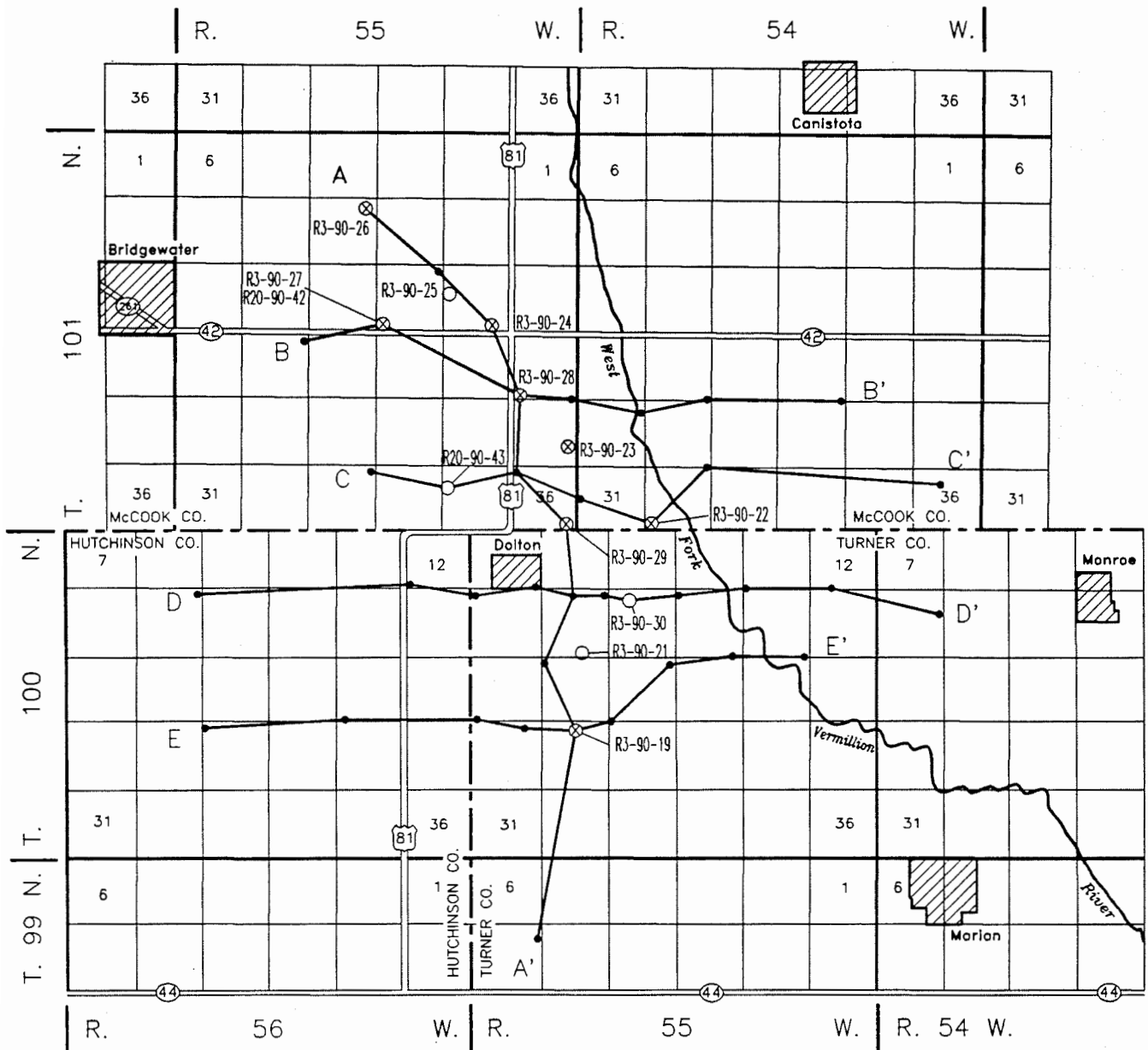
### Well Construction

Observation wells were constructed using 2-inch diameter, schedule 80, threaded, polyvinyl chloride (PVC) casing and screen. Screen length, well depth, and other well construction information are given in appendix A. Filter pack was placed through a tremie line to a depth no less than 3 feet above the top of the screen. Bentonite grout was then placed in the remaining annular space from the top of the filter pack to a depth no less than 20 feet below ground surface. A cement grout was placed from at least 20 feet below land surface to ground level. At this point a locking steel well protector was installed.

### Well Development and Sampling

All wells for this study were developed using compressed air. Wells were pumped until the water temperature and conductivity had stabilized and the well water was clear.

Sampling procedures were consistent with an unpublished manual entitled *South Dakota Geological Survey Water Sampling Manual*. A minimum of 3 well volumes of water were removed before sampling occurred and the samples were collected using a clean teflon bailer.



R3-90-19 Observation well completed for this project. Letters and numbers denote well identification.

R3-90-30 Test hole drilled for this project. Letters and numbers denote test-hole identification.

• Test hole or well not drilled for this project but used in the construction of cross sections A-A' through E-E'. Logs of test holes and wells are on file at the South Dakota Geological Survey.



Figure 1. Locations of cross sections, test holes, and observation wells.

## RESULTS OF INVESTIGATION

### Geology

The geology of the Dolton area can be divided into glacial deposits and bedrock. Table 1 shows the geologic unit or formation names, their relative ages, and provides a brief description of each unit known to be present in the study area. Five cross sections (figs. 2, 3, 4, 5, and 6) show the relative positions of the different units. Cross-section locations are shown in figure 1.

### Bedrock

Bedrock in the study area can be divided into three separate ages. These are: (1) Cretaceous sediments, which include the Niobrara Formation, Carlile Shale, Greenhorn Limestone, Graneros Shale, and the Dakota Formation, (2) pre-Cretaceous(?) sediment which is the quartzite wash, and (3) Precambrian sediment which is the Sioux Quartzite (table 1).

A bedrock valley traverses the study area from roughly the northwest to the south. The channel is broad and gently sloped in the area north of Dolton and becomes very narrow and steeply sloped in the area just south of Dolton (fig. 7). The dominant bedrock along the valley floor is the Precambrian Sioux Quartzite (fig. 7) with pre-Cretaceous(?) quartzite wash and Cretaceous sediments also being present along the valley floor (figs. 3, 5, and 6).

### Glacial Deposits

Glacial deposits consist primarily of till and outwash. Till is a heterogeneous mixture of clay, silt, sand, gravel, and boulders in a predominantly fine grained matrix of clay and silt. Outwash consists mainly of sand and gravel with minor amounts of clay and silt. Two major outwash bodies have been recognized in the study area; one is known informally as the Dolton aquifer and the other has been termed the basal-outwash aquifer (Holly and others, in preparation). Although both of these outwash bodies were encountered in drilling for this project, only the basal-outwash aquifer will be discussed below.

### BASAL-OUTWASH AQUIFER

The location of the basal-outwash aquifer roughly coincides with the location of the bedrock valley shown in figure 7. Sands and gravels which comprise the basal-outwash aquifer have a variable thickness ranging from over 113 feet in the southern part of the study area to less than 15 feet in the northern half of the study area (fig. 8). Overlying the basal-outwash aquifer is unweathered till (figs. 2 through 6). Bedrock is commonly encountered immediately below the basal-outwash aquifer.

TABLE 1. Description of geologic units.

Geologic age from youngest to oldest	Geologic unit or Formation Name	Designation used on the cross sections	Description <sup>1</sup>
Quaternary undifferentiated	Till	Qtw or Qtu	Heterogeneous mixture of clay, silt, sand, pebbles, and boulders.
	Outwash	Qow, Qowd, or Qowb	Mixture of sand and gravel with minor amounts of silt and clay.
	Lacustrine	Qls	Predominantly silt with some fine sand; formed as lake sediments.
Cretaceous	Niobrara Formation	Kn	Light to medium blue gray marl and white to cream colored limestone calcareous, fossiliferous; weathers white to dark yellowish-orange.
	Carlisle Shale	Kc	Medium to dark gray bentonitic shale; fossiliferous; weathers light gray to orange.
pre-Cretaceous?	Dakota Formation	Kd	Interbedded sands, siltstones, and shales.
	Quartzite wash	pKw	Pink to white; lightly cemented; fine to medium grained, well rounded quartz sand.
Precambrian	Sioux Quartzite	pEs	Pink to red; extremely hard, fine to medium grained, well rounded quartz sand, silica cemented orthoquartzite; sometimes conglomeric and jointed.

<sup>1</sup> From Christensen (1989).

# Figure 2. Cross section A - A'

Well or test hole. Upper letters and numbers are the location and, where present, the lower letters and numbers are the well identifier. All logs are on file at the South Dakota Geological Survey. See figure 1 for cross-section locations. See appendix A for location explanation.

100N-55W-29ABBB  
R3-90-19

100N-55W-17BAA  
R3-90-29  
101N-55W-36DDD  
101N-55W-36BBB 1  
MC-83J  
101N-55W-24CCC  
R3-90-28  
101N-55W-14CDD  
R3-90-24  
101N-55W-15AAA  
R3-90-26  
101N-55W-09AAA

100N-55W-20BBB  
R3-90-19  
100N-55W-29ABBB  
R3-90-19  
99N-55W-07AAA

100N-55W-29ABBB  
R3-90-19

Qtw ..... weathered till  
Qtu ..... unweathered till  
Qls ..... lake sediments  
Qow ..... undifferentiated outwash  
Qowd ..... outwash, Dolton aquifer  
Qowb ..... outwash, basal-outwash aquifer

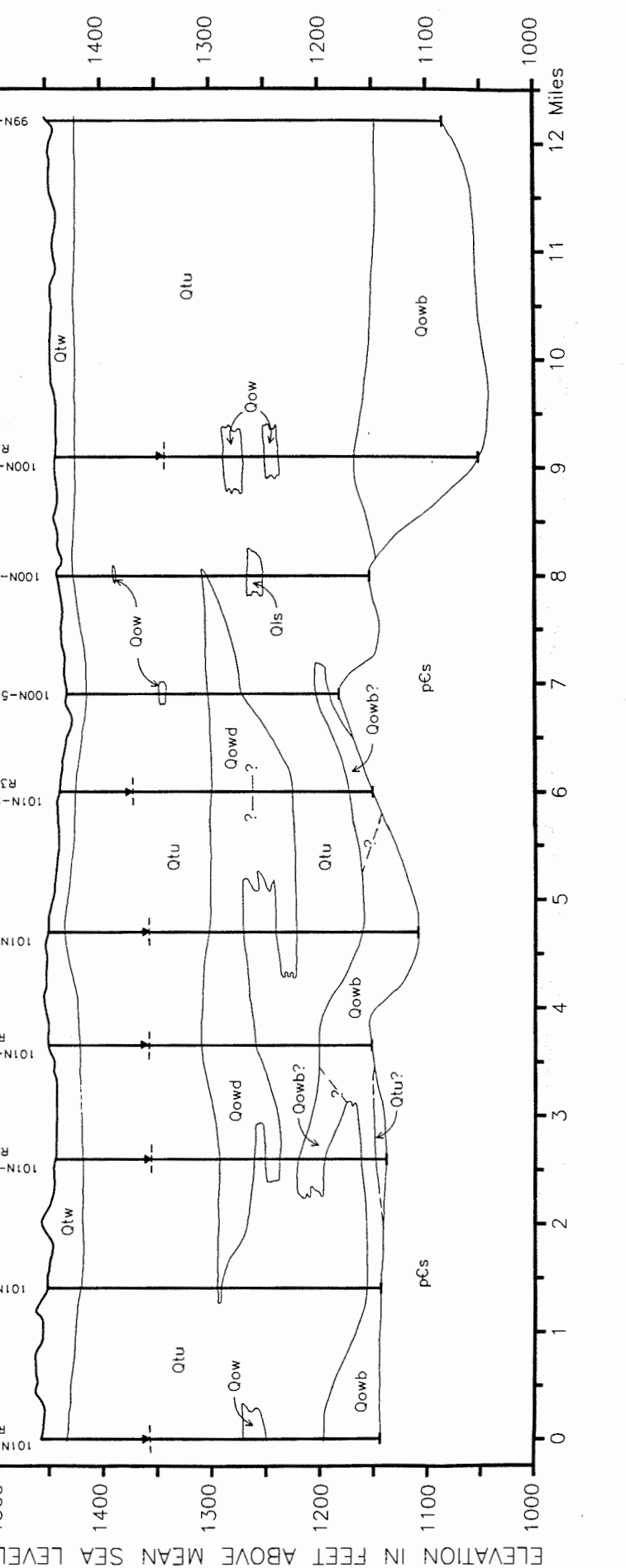
pCs ..... Sioux Quartzite

Geologic contact. Dashed where approximate.  
Static-water level. See table 2 for explanation of water-level data.

Vertical exaggeration = 50X

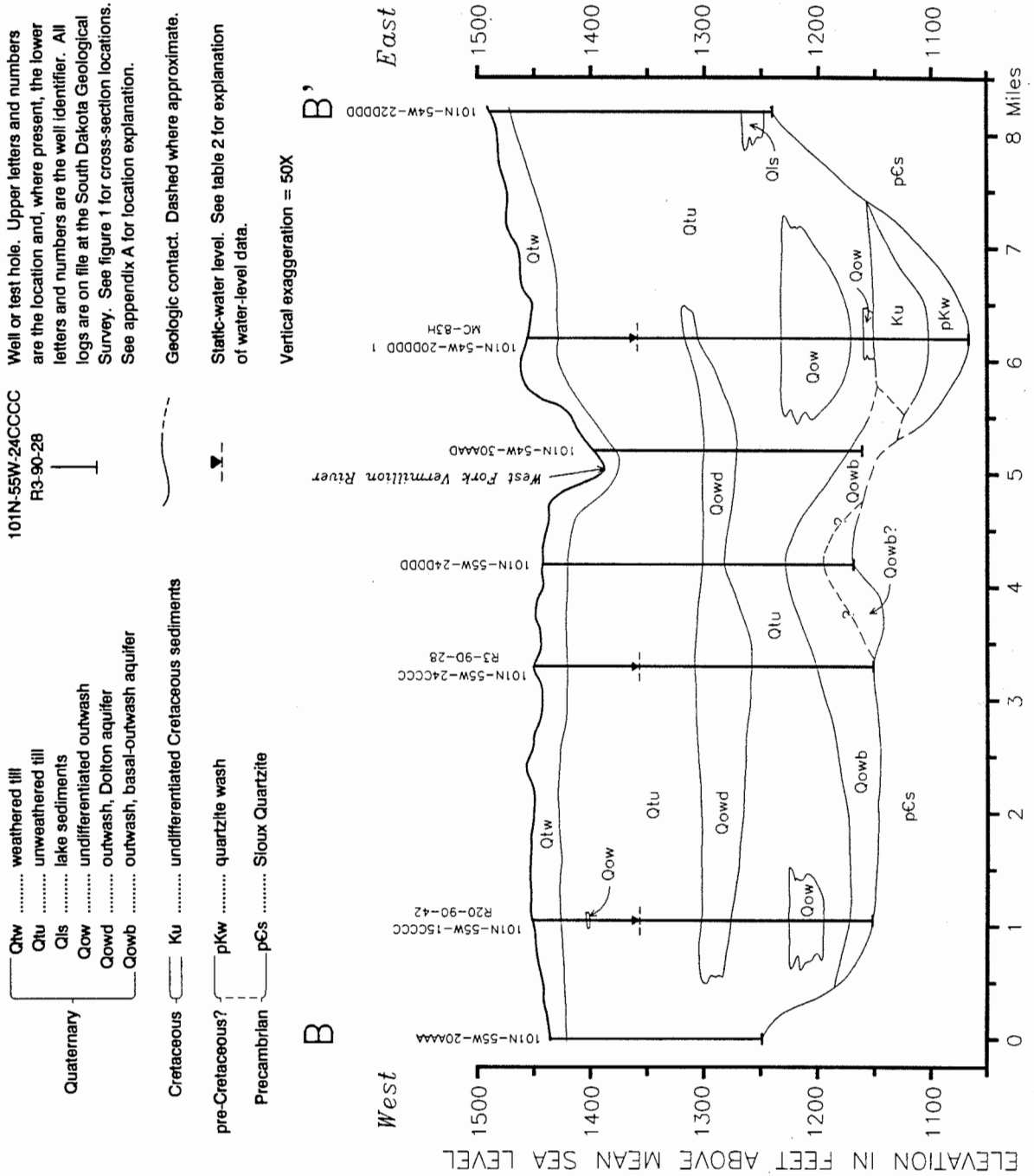
North  
1500  
1400  
1300  
1200  
1100  
1000

ELEVATION IN FEET ABOVE MEAN SEA LEVEL





# Figure 3. Cross section B - B'.



# Figure 4. Cross section C - C'

101N-54W-32CCCC 1 Well or test hole. Upper letters and numbers are the location and, where present, the lower letters and numbers are the well identifier. All logs are on file at the South Dakota Geological Survey. See figure 1 for cross-section locations. See appendix A for location explanation.

101N-54W-32CCCC 1  
 R3-90-22

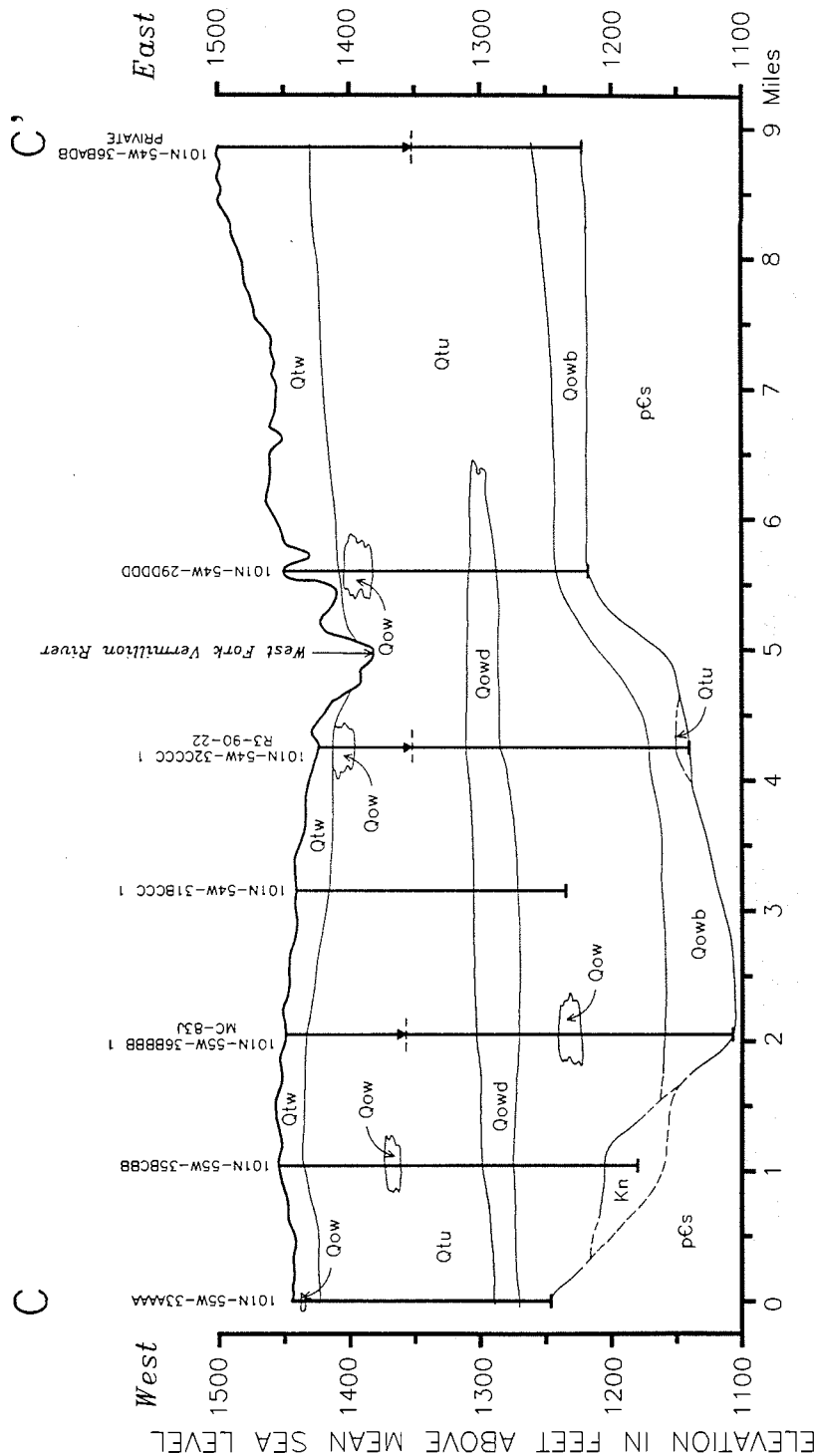
Quaternary  
 Qtw ..... weathered till  
 Qtu ..... unweathered till  
 Qow ..... undifferentiated outwash  
 Qowd ..... outwash, Dolton aquifer  
 Qowb ..... outwash, basal-outwash aquifer

Cretaceous  
 Kn ..... Niobrara Formation

Precambrian  
 pCs ..... Sioux Quartzite

Geologic contact. Dashed where approximate.  
 Static-water level. See table 2 for explanation of water-level data.

Vertical exaggeration = 50X



# Figure 5. Cross section D - D'

100N-55W-07DDDD Well or test hole. Upper letters and numbers are the location and, where present, the lower letters and numbers are the well identifier. All logs are on file at the South Dakota Geological Survey. See figure 1 for cross-section locations. See appendix A for location explanation.

100N-55W-07DDDD TU-83A

100N-55W-18BBB 100N-55W-168AB 100N-55W-17AAA 100N-55W-17BAA 100N-55W-07DDD TU-83A 100N-55W-18BBB 100N-56W-12CCC 100N-55W-12DCC 100N-54W-18ADA

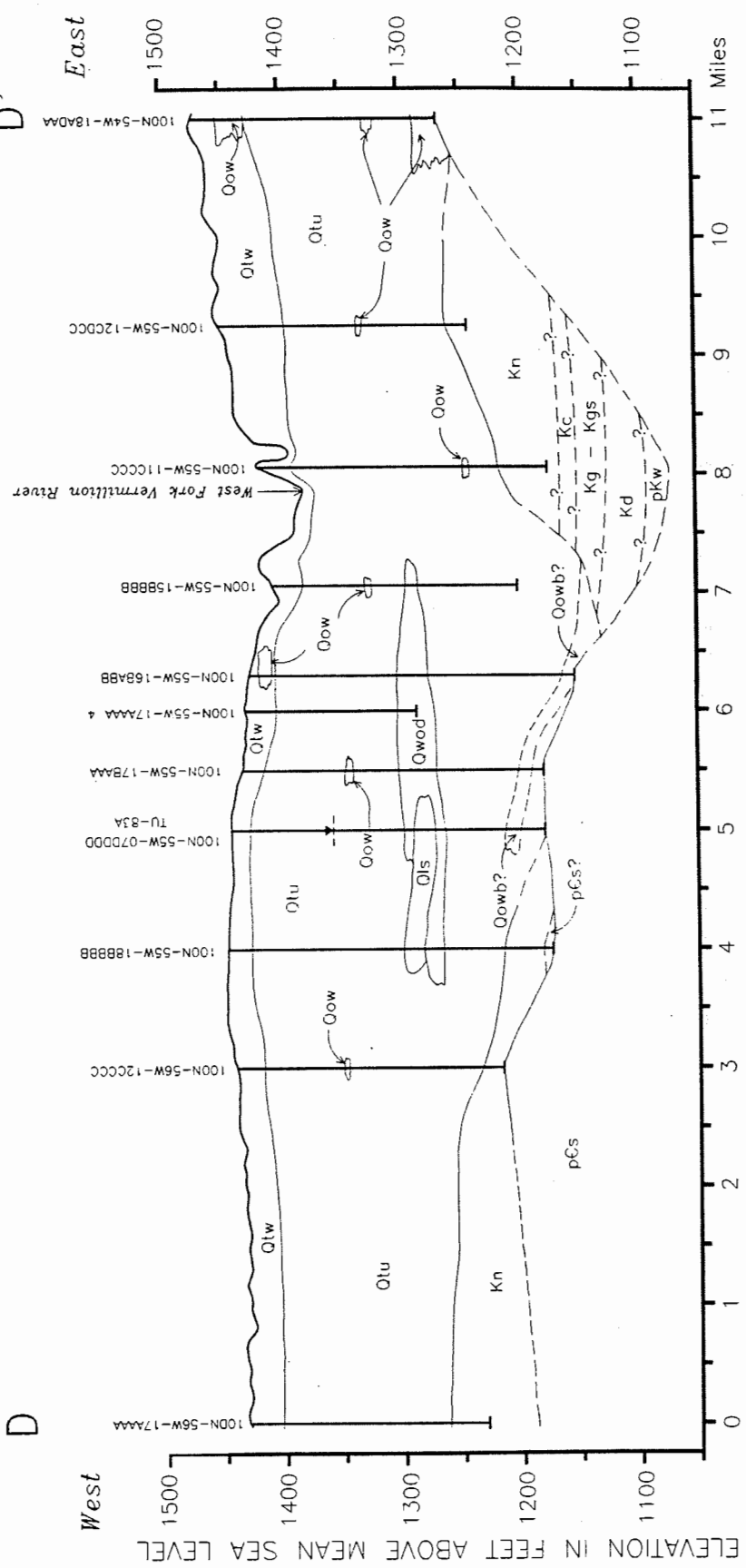
100N-56W-17AAA

- Qtw ..... weathered till
- Qtu ..... unweathered till
- Qls ..... lake sediments
- Qow ..... undifferentiated outwash
- Qowd ..... outwash, Dolton aquifer
- Qowb ..... outwash, basal-outwash aquifer

- Kn ..... Niobrara Formation
- Kc ..... Carlile Shale
- Kg - Kgs ..... Greenhorn Limestone and Graneros Shale
- Kd ..... Dakota Formation

- pkw ..... quartzite wash
- pCs ..... Sioux Quartzite

Geologic contact. Dashed where approximate.  
 Static-water level. See table 2 for explanation of water-level data.  
 Vertical exaggeration = 50X



West 1500 1400 1300 1200 1100 East 1500 1400 1300 1200 1100 Miles 0 1 2 3 4 5 6 7 8 9 10 11

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

# Figure 6. Cross section E - E'

100N-55W-29ABBB Well or test hole. Upper letters and numbers are the location and, where present, the lower letters and numbers are the well identifier. All logs are on file at the South Dakota Geological Survey. See figure 1 for cross-section locations. See appendix A for location explanation.

R3-90-19

100N-55W-21CCC

R3-90-19

100N-55W-29ABBB

TU-82A

100N-55W-30ABB

100N-55W-19CCC

100N-56W-23CCD

100N-56W-26888

100N-55W-14DD2

TU-83F

100N-55W-15DDC

100N-55W-21AAA

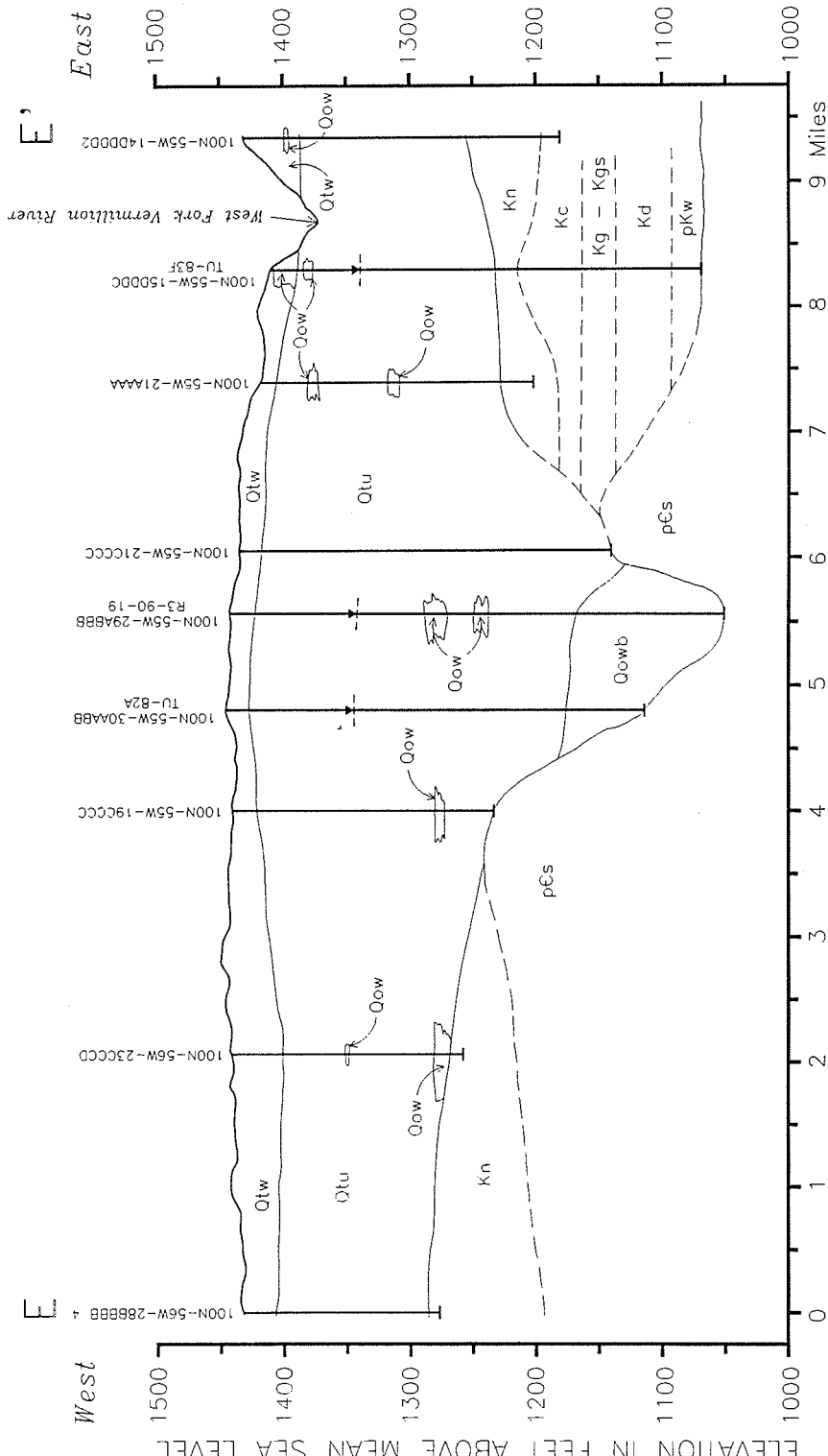
100N-55W-14DD2

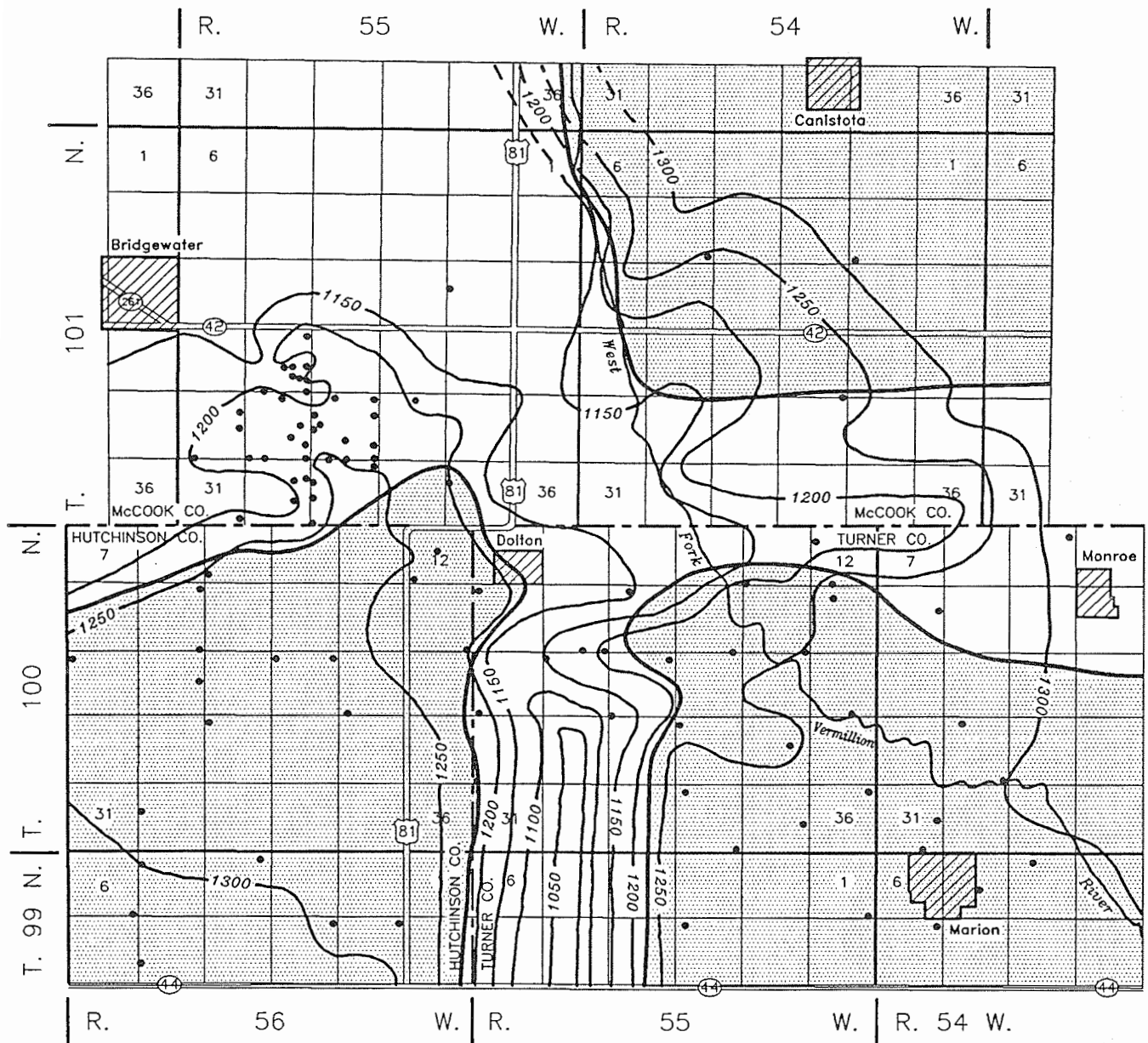
Geologic contact. Dashed where approximate.

Static-water level. See table 2 for explanation of water-level data.

Vertical exaggeration = 50X

- Qtw ..... weathered till
- Qtu ..... unweathered till
- Qow ..... undifferentiated outwash
- Qowb ..... outwash, basal-outwash aquifer
- Kn ..... Niobrara Formation
- Kc ..... Carlile Shale
- Kg - Kgs ..... Greenhorn Limestone and Graneros Shale
- Kd ..... Dakota Formation
- pKw ..... quartzite wash
- pCs ..... Sioux Quartzite





• Test hole or well used for determining bedrock type and elevation. Logs of test holes and wells are on file at the South Dakota Geological Survey.

□ Approximate area in which the Sioux Quartzite is the first bedrock encountered.

▨ Approximate area in which the Niobrara Formation or undifferentiated Cretaceous sediments are the first bedrock encountered.

—1300— Contour line; Number denotes elevation in feet above mean sea level for the bedrock surface. Contour interval equals 50 feet.

— Approximate contact between Cretaceous sediments and the Sioux Quartzite.

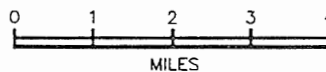
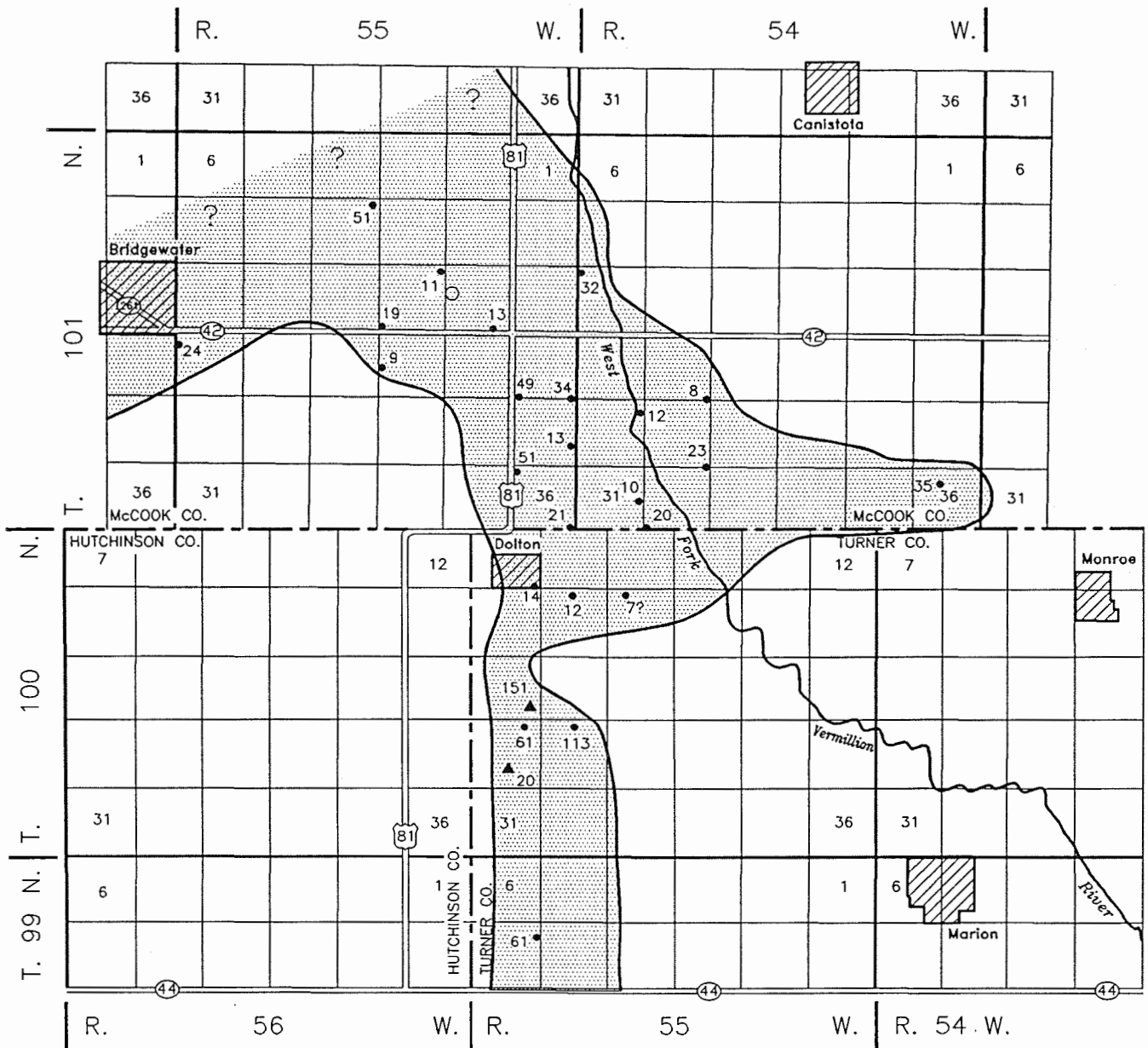


Figure 7. Configuration and geology of the bedrock surface.



61 • Test hole or well where basal aquifer material is present. Number denotes thickness in feet.

○ Test hole in which no basal aquifer material was encountered.

20 ▲ Private well completed in the basal aquifer material. Number denotes thickness in feet.

□ Approximate areal extent of the basal-outwash aquifer.

— Approximate boundary of the basal-outwash aquifer.

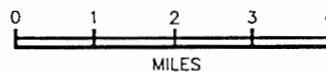


Figure 8. Approximate areal extent and thickness of the basal-outwash aquifer.

## Hydrology

### Bedrock Water Bearing Units

The Niobrara Formation, Dakota Formation, quartzite wash, and Sioux Quartzite all have the potential for yielding water. Very little is known about the quality of water or the directions of water movement in these units. Figures 2 through 6 show that these bedrock units can be in direct contact with the basal-outwash aquifer. These units may influence the quality of water, direction of groundwater movement, and quantity of water available in the basal-outwash aquifer. Data are not available to define the impact, if any, of the bedrock on the basal-outwash aquifer.

### Basal-Outwash Aquifer

Measured water levels in observation wells show that the basal-outwash aquifer is under confined conditions. Approximate static water level elevations are shown in table 2 for wells completed in the basal-outwash aquifer and are based on an approximation of ground-surface elevation using 7.5 minute topographic quadrangle maps. Within the limitations of the available data it can only be said that the water levels in two observation wells south of Dolton appear to be lower than the water levels to the north of Dolton (figs. 2 and 9; table 2).

Water quality in the basal-outwash aquifer is variable but generally has high dissolved solids. Nine water samples were collected for general chemical analysis for this study. Analytical results for these samples collected in 1990 are presented in table 3 and appendix B along with other available data for the basal-outwash aquifer. Figure 9 shows the sample locations and figures 10 and 11 show the distribution of sulfates, dissolved solids, hardness, iron, and manganese in the basal-outwash aquifer. Sulfates vary in concentration from 252 milligrams per liter (mg/L) to 635 mg/L with an average of 451 mg/L. Dissolved-solids concentrations range from 736 mg/L to 1,350 mg/L with an average of 1,043 mg/L. Hardness concentrations range from 190 mg/L to 661 mg/L and average 511 mg/L. Concentrations of iron range from <0.05 mg/L to 3.71 mg/L, and manganese ranges from 0.30 mg/L to 1.60 mg/L.

Two additional water samples were collected for radionuclides and selected trace metals (table 3). Test results show no amounts of gross alpha, radium 226, or inorganic contaminants that exceed the maximum contaminant limits (U.S. Environmental Protection Agency, 1985a).

### Comparison of Water Quality in the Basal-Outwash Aquifer with the Present Water Source for the Rural-Water Systems

Hanson Rural Water System and TM Rural Water District presently obtain their water from the Dolton aquifer. Water-quality data obtained from the Hanson and TM systems are presented in table 4. Also presented in table 4 are the average concentrations of various parameters for the basal-outwash aquifer.

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**TABLE 2. Static-water levels.**

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Well Name	Location <sup>1</sup>	Depth to water <sup>2</sup>	Water-level elevation <sup>3</sup>	Date measured
R3-90-19	100N-55W-29ABBB	102.30	1342	07-11-90
R3-90-22	101N-54W-32CCCC	71.94	1352	07-11-90
R3-90-23	101N-55W-25DADA	85.34	1355	07-12-90
R3-90-24	101N-55W-14DCDD	90.07	1355	07-31-90
R3-90-26	101N-55W-09AAAB	102.77	1356	07-31-90
R3-90-28	101N-55W-24CCCC	95.57	1356	07-30-90
R3-90-29	101N-55W-36DDDD	66.24	1372	07-30-90
R20-90-42	101N-55W-15CCCC	97.57	1356	09-06-90
MC-83J	101N-55W-36BBBB	95.71	1356	07-31-90
MC-83H	101N-54W-20DDDD	102.10	1357	04-24-90
TU-83A	100N-55-07DDDD	93.50	1352	02-14-90
TU-82A	100N-55W-30AABB	102.60	1344	11-21-89

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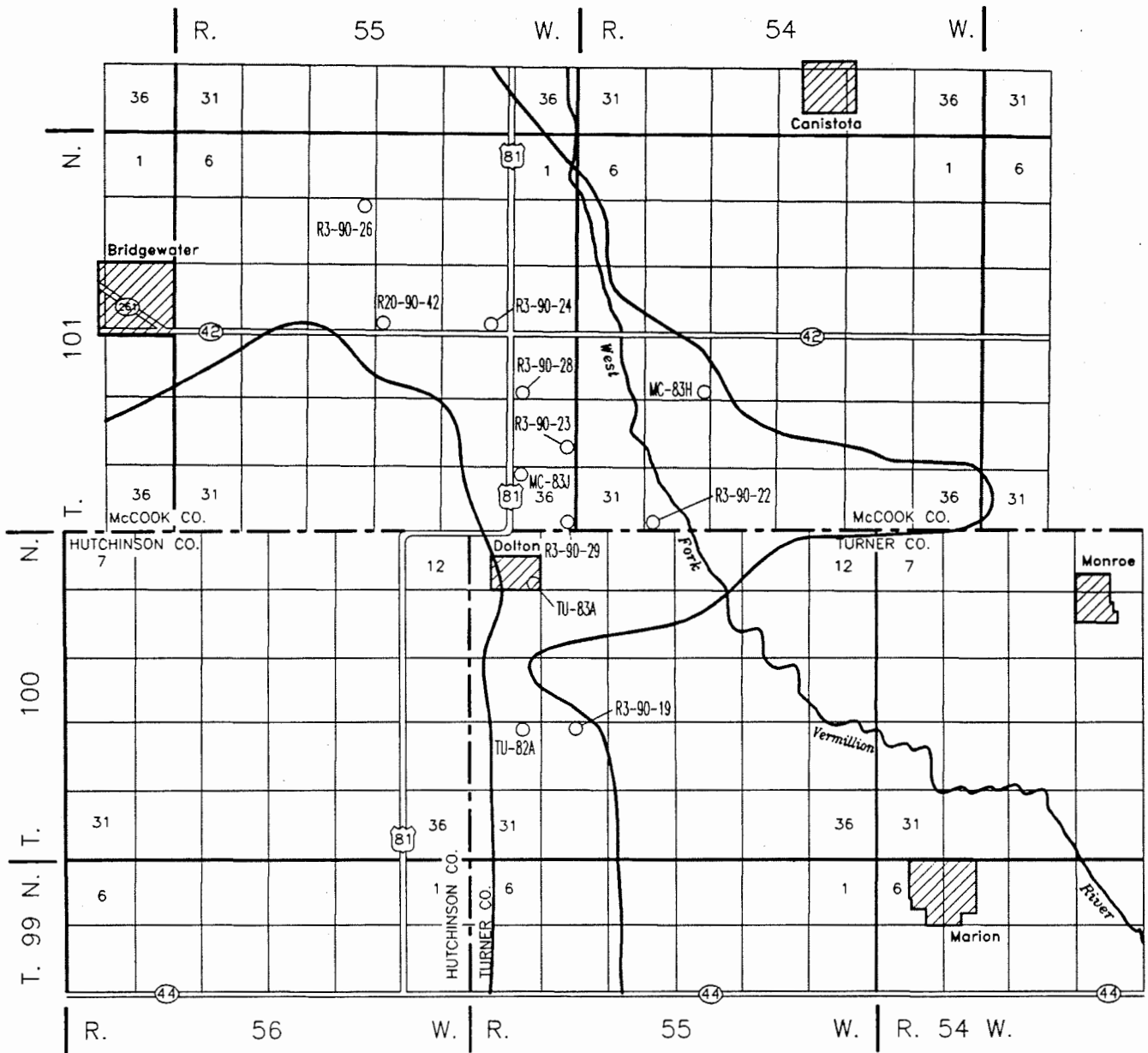
<sup>1</sup> See appendix A for explanation of location format.

<sup>2</sup> Depth to water measured in feet below casing top.

<sup>3</sup> Water-level elevations are in feet above mean sea level and are based on an estimation of land-surface elevation from U.S. Geological Survey 7.5 minute series topographic maps for the Bridgewater East (1964), Canistota (1964), Dolton (1970), and Marion (1970) quadrangles. Elevations are accurate to within plus or minus 5 feet.

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R3-90-19  
○ Observation well sampled for water-quality analysis. Numbers and letters are the well identification.

— Approximate boundary of the basal-outwash aquifer.

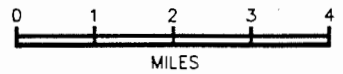


Figure 9. Water-sample locations.

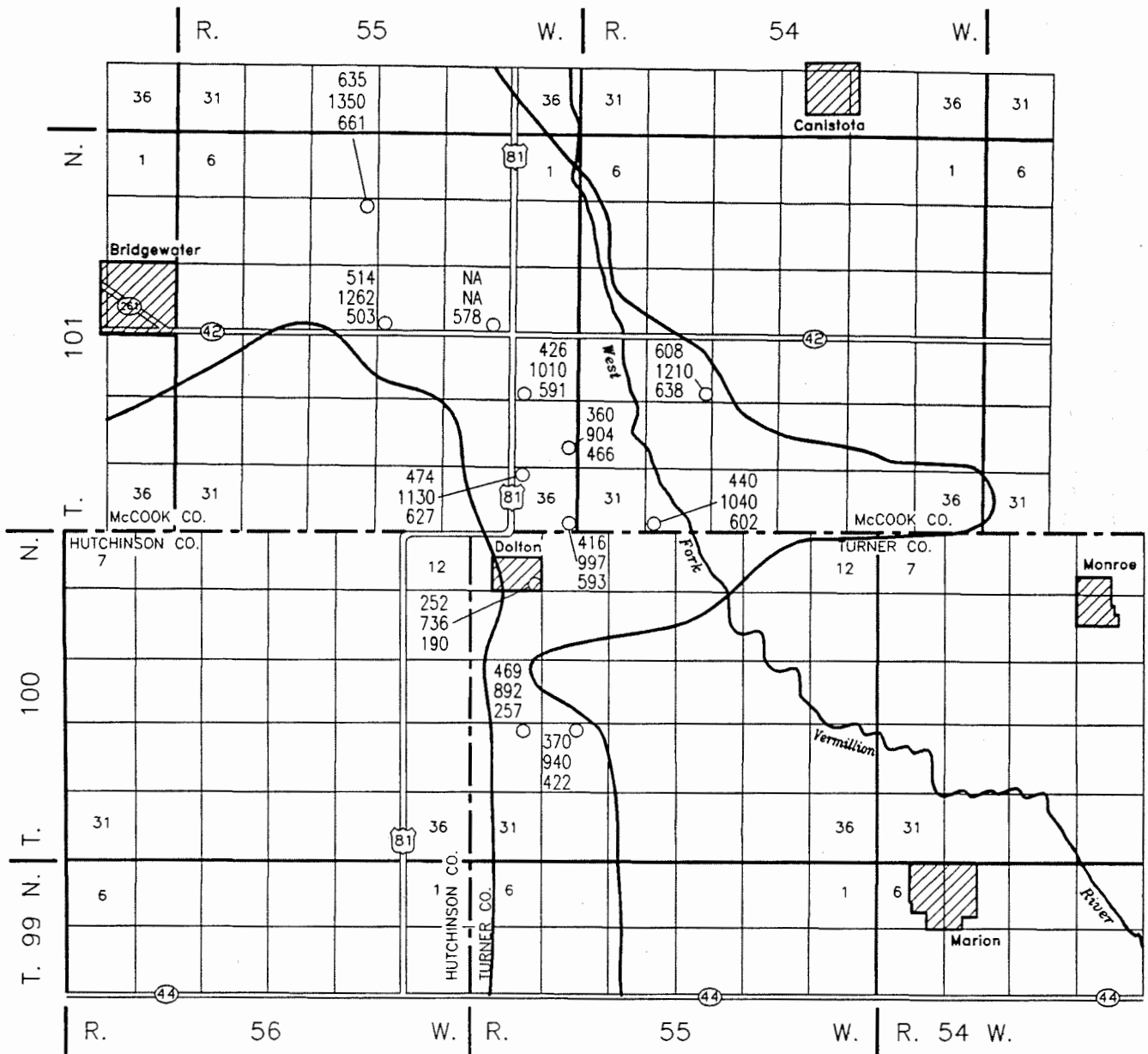
**TABLE 3. Results of analyses of water from the basal-outwash aquifer for selected trace metals and radionuclides.**

Parameter	Maximum Limit <sup>1</sup>	Units <sup>2</sup>	Well identification and sample collection date	
			(R20-90-42) 09-06-90	(R3-90-19) 09-06-90
Arsenic	50	ug/L	3.4	-----
Barium	1000	ug/L	53	-----
Cadmium	10	ug/L	<1.0	-----
Chromium	50	ug/L	<1.0	-----
Lead	50	ug/L	<1.0	-----
Mercury	2	ug/L	<0.2	-----
Selenium	10	ug/L	<1.0	-----
Silver	50	ug/L	<1.0	-----
Gross Alpha	15	pCi/L	0.8 ± 8.7	0.0 ± 6.6
Radium 226	5	pCi/L	0.2 ± 0.2	0.6 ± 0.3

<sup>1</sup> U.S. Environmental Protection Agency (1985a).

<sup>2</sup> ug/L = micrograms per liter, pCi/L = picocuries per liter.

Analytical data are from the State Health Laboratory, Pierre, South Dakota.



370  
940 ○  
422

Observation well. Upper number is concentration of sulfates, middle number is dissolved solids, and the lower number is hardness, given in milligrams per liter. NA = not available.

See appendix B for water-quality analyses.

— Approximate boundary of the basal-outwash aquifer.

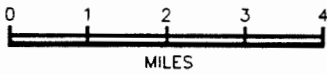
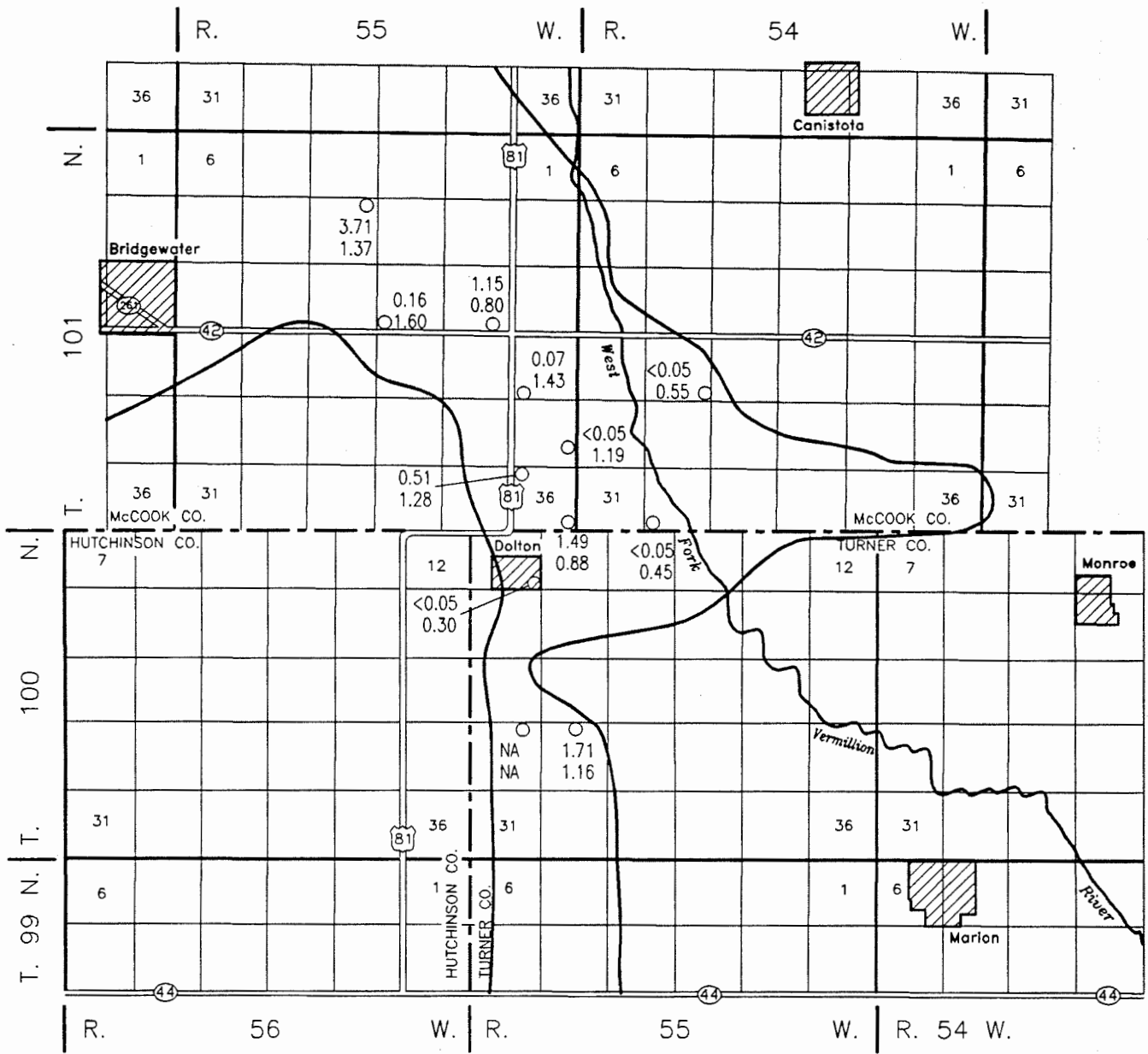


Figure 10. Distribution of sulfates, dissolved solids, and hardness in the basal-outwash aquifer.



1.71 ○  
 1.16 ○  
 ○  
 ———  
 Approximate boundary of the basal aquifer.

See appendix B for water-quality analyses.

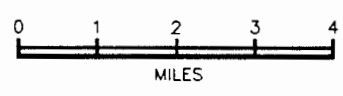


Figure 11. Distribution of iron and manganese in the basal-outwash aquifer.

**TABLE 4. Comparison of the average water quality for the basal-outwash aquifer with the present source for the Hanson Rural Water System and the TM Rural Water District.**

Water source	Date sampled	Conduc- tivity (mmhos) <sup>2</sup>	Concentration in milligram per liter <sup>1</sup>													Hard- ness
			Alk-T	HCO <sub>3</sub>	Ca	Cl	F	Fe	K	Mg	Mn	Na	NO <sub>3</sub> -N	SO <sub>4</sub>	DS	
<b>BASAL-OUTWASH AQUIFER<sup>5</sup></b>																
Average water quality	----- <sup>8</sup>	1399	327	379	136	14	0.44	0.81	12	43	1.00	128	0.18	451	1043	511
<b>DOLTON AQUIFER</b>																
Hanson Rural Water System																
Well 1																
Location: 101N-55W-28BCCA <sup>7</sup>	11-09-88	1296	557	679	33	18	0.36	0.98	9	10	<0.05	272	<0.04	136	828	124
TM Rural Water District																
Well 1																
Location: 100N-55W-08DDDD <sup>7</sup>	12-06-86	853	443	540	23	27	0.53	1.18 <sup>8</sup>	7	6	0.09 <sup>8</sup>	188	<0.01 <sup>8</sup>	<10	639 <sup>8</sup>	101 <sup>8</sup>

<sup>1</sup> Alk-T - total alkalinity; HCO<sub>3</sub> - bicarbonate; Ca - calcium; Cl - chloride; F - fluoride; Fe - iron; K - potassium; Mg - magnesium; Mn - manganese; Na - sodium; NO<sub>3</sub>-N - nitrate nitrogen; SO<sub>4</sub> - sulfate; DS - dissolved solids; Hardness - hardness as calcium carbonate. mmhos - micromhos.

<sup>2</sup> mmhos - micromhos.

<sup>3</sup> U.S. Environmental Protection Agency (1985b).

<sup>4</sup> U.S. Environmental Protection Agency (1985a).

<sup>5</sup> Where parameters were below the detection limit, one half of the detection limit was used to calculate the average. There were 10 to 12 samples used to calculate the averages, depending on the available data.

<sup>6</sup> See appendix B for individual analyses.

<sup>7</sup> See appendix A for explanation of location format.

<sup>8</sup> Concentration taken from analysis of a water sample collected on 02-09-88.

A comparison between the quality of water in the Dolton aquifer and the basal-outwash aquifer shows that water in the basal-outwash aquifer is inferior to the quality of the Dolton aquifer. The basal-outwash aquifer has a sulfate concentration which is more than 3 times, a dissolved-solids concentration which is 1.3 times, and a hardness concentration which is more than 4 times the concentration in the Dolton aquifer.

## SUMMARY AND RECOMMENDATIONS

The basal-outwash aquifer is under confined conditions and contains water of inferior quality compared to the Dolton aquifer. Water in the basal-outwash aquifer was not found to violate any of the national interim primary drinking water regulations set forth by the U. S. Environmental Protection Agency. The quantity of water which could be obtained from the basal-outwash aquifer cannot be accurately predicted with the available data, but the thickness of the aquifer in some areas suggests that usable quantities of water might be obtained as a supplemental water source for the two rural water systems. An irrigation well located in sec. 19, T. 100 N., R. 55 W., and completed in the basal-outwash aquifer, is reported to have produced approximately 1,500 gallons of water per minute over a pumping period of 24 hours. Although the quantity of water needed by the rural water systems might be obtained, several points are unknown about the basal-outwash aquifer:

1. Although the areal extent and thickness are generally known, exact boundaries and thicknesses are not known for all areas.
2. The directions of ground-water movement are not known within the aquifer which prohibits speculation on the natural recharge to and discharge from the aquifer.
3. Very little is known about the potential impact of the bedrock aquifers on the basal-outwash aquifer because:
  - a. The water levels in the bedrock aquifer are not sufficiently documented to determine directions of ground-water movement in them, and
  - b. the quality of water in the bedrock aquifers is not sufficiently documented.
4. The quality of water in the basal-outwash aquifer is generally known as represented in table 4. The quality which might be obtained over a long-term basis from high capacity production wells cannot be reliably predicted with the available data.

Based on thickness and water quality of the basal-outwash aquifer, two areas may warrant further investigation. One area is about 1 to 2 miles north of the town of Dolton and the other is about 2 miles south of Dolton (figs. 8 and 10).

If the decision is made by the Hanson Rural Water System or the TM Rural Water District to pursue an area in the basal-outwash aquifer for development, it is recommended that the following tasks be completed or considered before the final production wells and water distribution systems are installed.

1. Site specific hydrogeologic exploration should be undertaken to better determine aquifer thickness and lithology, water levels in the aquifer, and quality of water in the aquifer.
2. The potential impact of the bedrock aquifers on the quantity and quality of water in the basal-outwash aquifer should be examined further.
3. The suitability of using water from the basal-outwash aquifer for blending with water from the Dolton aquifer should be examined.
4. An aquifer test should be performed to allow predictions of water yield from the basal-outwash aquifer.
5. The Department of Environment and Natural (Division of Water Rights) Resources should be contacted regarding a water-right permit.

## REFERENCES

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- U.S. Environmental Protection Agency, 1985a, *National interim primary drinking water regulations-maximum contaminant levels for inorganic chemicals*: Code of Federal Regulations, Title 40, Part 141, Sections 141.11, and 141.15.
- U.S. Environmental Protection Agency, 1985b, *National secondary drinking water regulations-secondary maximum contaminant levels*: Code of Federal Regulations, Title 40, Part 143, Section 143.3.

## APPENDIX A

### Logs of Test Holes and Observation Wells

#### LEGAL LOCATION and LOCATION

The logs are listed by smallest township number, then the smallest range number, the smallest section number and then by quarter section. NE = A; NW = B; SW = C; SE = D. A comparison of LEGAL LOCATION and LOCATION is as follows. A LEGAL LOCATION of NW $\frac{1}{4}$ SE $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 29 T. 100 N., R. 55 W. is the same as a LOCATION of 100N-55W-29CADB. In one LOCATION, the smallest quarter section is followed by the number 1 which indicates that more than one log may exist for that particular location.

#### LATITUDE and LONGITUDE

The format is DD.MMSS where D is degrees, M is minutes, and S is seconds.

#### DRILLING COMPANY

SDGS is an abbreviation for South Dakota Geological Survey.

#### TOTAL DRILL HOLE DEPTH, SCREEN LENGTH, TOTAL CASING AND SCREEN and CASING STICK-UP

The numbers are presented in feet.

#### SCREEN TYPE and CASING TYPE

PVC is an abbreviation for polyvinyl chloride. MFG. is an abbreviation for manufactured and indicates a product that is commercially available. SLOT is the size, in inches, of the openings on the screen. SCH. is an abbreviation for schedule and refers to casing thickness.

#### CASING TOP ELEVATION and GROUND SURFACE ELEVATION

The numbers are presented in feet above mean sea level. I - the elevation was determined using a surveying instrument. T - the elevation was estimated from a 7.5 minute series topographic map.

#### CASING DIAMETER

The numbers are presented in inches.



County: TURNER  
 Legal Location: NW NW NE NW sec. 16, T. 100 N., R. 55 W.  
 Latitude: 43.2915  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 07-11-1990  
 Ground Surface Elevation: 1426.00 T  
 Total Drill Hole Depth: 273  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential: X  
 Natural Gamma: X  
 Samples:

Location: 100N-55W-16BABB  
 Longitude: 97.2114

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-30

Single Point Resistivity: X  
 Extra:

0	-	2	Topsoil
2	-	8	Clay, tan-brown, silty, sandy, very gravelly; oxidized (till)
8	-	18	Gravel, orange-brown, medium to coarse; oxidized
18	-	123	Clay, gray, silty, sandy, gravelly; unoxidized, slightly calcareous (till)
123	-	148	Sand and gravel, brown to gray, fine sand, medium gravel; many shale clasts, mainly quartz and carbonates, some lignitic coal fragments
148	-	262	Clay, gray, silty, sandy, pebbly; unoxidized, slightly calcareous, driller reports faster penetration, much gravel in cuttings, gravel lense from 215 to 220 feet (till)
262	-	272	Boulders(?); driller reports gravelly clay, but drills like cobbles and clay
272	-	273	Quartzite; hard layer; could not penetrate, many pink quartzite chips received in cuttings (Sioux Quartzite)

\* \* \* \*

County: TURNER  
 Legal Location: SE SW SW SE sec. 17, T. 100 N., R. 55 W.  
 Latitude: 43.2823  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 06-19-1990  
 Ground Surface Elevation: 1434.00 T  
 Total Drill Hole Depth: 270  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential: X  
 Natural Gamma: X  
 Samples:

Location: 100N-55W-17DCCD  
 Longitude: 97.2204

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-21

Single Point Resistivity: X  
 Extra:

0	-	2	Topsoil
2	-	35	Gravel, orange-brown, medium to coarse; some silt and clay (outwash terrace)
35	-	138	Clay, gray, silty, sandy, pebbly; unoxidized, becomes calcareous at 70 feet (till)
138	-	145	Sand and gravel, light-tan to brown, fine sand, medium gravel; mainly quartz, carbonates and shale clasts
145	-	156	Clay, gray, silty, sandy, pebbly; unoxidized (till)
156	-	162	Sand or gravel(?); E-Log indicates sand, but none was reported, this interval

based on E-Log interpretation

162 - 191	Clay, gray, silty, sandy, pebbly; much gravel, unoxidized (till)
191 - 198	Clay, gray, silty, sandy, very gravelly; unoxidized, calcareous (till)
198 - 218	Clay, gray, silty; very little sand, no pebbles (lacustrine?)
218 - 242	Clay, gray, silty, sandy, pebbly, gravelly; unoxidized, calcareous, E-Log indicates sand from 225 to 231 feet, but no cutting received (till)
242 - 269	Clay, gray, very sandy, very gravelly; much black crystalline rock fragments in cuttings, driller reports black hard layer from 247 to 266 feet, E-Log shows interbedded layers of sand and clay, but had no return (till?)
269 - 270	Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: TURNER  
 Legal Location: NW NW NW NE sec. 29, T. 100 N., R. 55 W.  
 Latitude: 43.2731  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 06-18-1990  
 Ground Surface Elevation: 1442.00 T  
 Total Drill Hole Depth: 389  
 Water Rights Well:  
 Other Well Name:  
 Basin: VERMILLION  
 Management Unit:  
 Screen Type: PVC, MFG., SLOT .020  
 Casing Type: PVC  
 Casing Top Elevation: 1444.00 T  
 Casing Stick-up: 1.88  
 Well Maintenance Date:  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential: X  
 Natural Gamma: X  
 Samples:

Location: 100N-55W-29ABBB

Longitude: 97.2207

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-19  
 SDGS Well Name: R3-90-19

Aquifer:

Screen Length: 5.0  
 Casing Diameter: 2.0

Total Casing and Screen: 380.0

Single Point Resistivity: X  
 Extra:

Well screened from 378 to 373 feet. Filter pack from 378 to 368 feet. Bentonite grout from 368 to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Static water level: 102.30 feet on 07-11-1990; measured from casing top.

0 - 18	Clay, orange-brown, silty, sandy, pebbly; oxidized (till)
18 - 154	Clay, gray, silty, sandy, pebbly; slightly calcareous, more sand content at 140 feet (till)
154 - 172	Sand, gray to gray-brown, medium to fine; mainly quartz, carbonate, and shale fragments with some igneous rock fragments, many black crystalline rock clasts
172 - 192	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, interbedded clays and sand layers
192 - 204	Gravel, tan-gray, medium to coarse; mainly subrounded quartz, carbonate, and shale clasts with some igneous rock fragments and black crystalline rock clasts

204	-	214	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, driller reports sand, but is more likely a very sandy clay (till)
214	-	275	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
275	-	300	Sand and gravel, brown to brown-gray, fine sand, fine to medium gravel; mainly quartz, carbonates, and shale clasts, some igneous rock fragments and black crystalline rock clasts
300	-	364	Sand, gray, fine; mainly quartz, some coal, many shale clasts
364	-	388	Gravel, brown to gray-brown, medium to coarse; mainly quartz and carbonates, many shale clasts, some igneous rock fragments, could be lightly cemented(?)
388	-	389	Quartzite; hard layer, could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK  
 Legal Location: SW SW SW SW sec. 32, T. 101 N., R. 54 W.  
 Latitude: 43.3001  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 06-20-1990  
 Ground Surface Elevation: 1422.00 T  
 Total Drill Hole Depth: 301.  
 Water Rights Well:  
 Other Well Name:  
 Basin: VERMILLION  
 Management Unit:  
 Screen Type: PVC, MFG., SLOT .020  
 Casing Type: PVC  
 Casing Top Elevation: 1424.00 T  
 Casing Stick-up: 1.67  
 Well Maintenance Date:  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential: X  
 Natural Gamma: X  
 Samples:

Location: 101N-54W-32CCCC 1  
 Longitude: 97.2052

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-22  
 SDGS Well Name: R3-90-22

Aquifer:

Screen Length: 15.0  
 Casing Diameter: 2.0

Total Casing and Screen: 298.0

Single Point Resistivity: X  
 Extra:

Well screened from 296 to 281 feet. Filter pack from 296 to 255 feet. Bentonite grout from 255 feet to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Static water level: 71.94 feet on 07-11-1990; measured from casing top.

0	-	2	Topsoil
2	-	6	Clay, olive-tan, silty
6	-	9	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
9	-	46	Sand, gray, fine to medium; many shale pebbles, mostly quartz and carbonates
46	-	132	Clay, gray, silty, very sandy, pebbly; unoxidized, slightly calcareous (till)
132	-	158	Sand and gravel, tan-gray, fine to medium sand, medium gravel; many shale pebbles, mostly quartz and carbonates, much lignitic coal
158	-	198	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
198	-	227	Clay, gray, silty, sandy, pebbly, gravelly; unoxidized, calcareous, E-Log shows

interbedded clays and gravels  
 227 - 271 Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)  
 271 - 291 Sand or gravel; poor return, E-Log indicated sand or gravel  
 291 - 300 Clay, black; looks organic (Split Rock Creek Formation?)  
 300 - 301 Quartzite; hard rock; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK	Location: 101N-55W-09AAAB
Legal Location: NW NE NE NE sec. 09, T. 101 N., R. 55 W.	
Latitude: 43.3421	Longitude: 97.2546
Land Owner:	
Project: BURIED AQ. TM-HANSON	
Drilling Company: SDGS	
Driller: G. JENSEN	Driller's Log:
Geologist: L. SCHULZ	Geologist's Log: X
Date Drilled: 06-27-1990	Drilling Method: ROTARY
Ground Surface Elevation: 1457.00 T	
Total Drill Hole Depth: 313	Test Hole Number: R3-90-26
Water Rights Well:	SDGS Well Name: R3-90-26
Other Well Name:	
Basin: JAMES	Aquifer:
Management Unit:	
Screen Type: PVC, MFG., SLOT .020	Screen Length: 5.0
Casing Type: PVC	Casing Diameter: 2.0
Casing Top Elevation: 1459.00 T	
Casing Stick-up: 2.19	Total Casing and Screen: 311.0
Well Maintenance Date:	
USGS Hydrological Unit Code: 10160011	
Electric Log Information:	
Spontaneous Potential: X	Single Point Resistivity: X
Natural Gamma: X	Extra:
Samples:	

Well screened from 309 to 304 feet. Filter pack from 309 to 304 feet. Bentonite grout from 304 to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Static water level: 102.77 feet on 07-31-1990; measured from casing top.

0 - 2 Topsoil  
 2 - 23 Clay, tan-brown, silty, sandy, pebbly; oxidized (till)  
 23 - 186 Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, sand lense from 59 to 64 feet (till)  
 186 - 207 Sand, gray, fine to medium; many shale clasts, mainly quartz and carbonates, some lignitic coal fragments  
 207 - 261 Clay, gray, silty, sandy, pebbly, gravelly; calcareous (till)  
 261 - 312 Sand and gravel, gray to gray-brown, fine to medium sand, medium gravel; many shale clasts, mostly quartz and carbonates, some lignitic coal fragments  
 312 - 313 Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK  
Legal Location: SW NW SW NW sec. 14, T. 101 N., R. 55 W.  
Latitude: 43.3308  
Land Owner:  
Project: BURIED AQ. TM-HANSON  
Drilling Company: SDGS  
Driller: G. JENSEN  
Geologist: L. SCHULZ  
Date Drilled: 06-26-1990  
Ground Surface Elevation: 1461.00 T  
Total Drill Hole Depth: 317  
USGS Hydrological Unit Code: 10170102  
Electric Log Information:  
Spontaneous Potential: X  
Natural Gamma: X  
Samples:

0	-	2	Topsoil
2	-	32	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
32	-	159	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, gravel lenses from 63 to 65 feet and from 87 to 90 feet (till)
159	-	219	Sand and gravel, gray to brown, fine sand, medium gravel; many shale clasts, mainly quartz and carbonates, some lignitic coal fragments; becoming more coarse with depth
219	-	316	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, some gravel
316	-	317	Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK  
Legal Location: SE SE SW SE sec. 14, T. 101 N., R. 55 W.  
Latitude: 43.3237  
Land Owner:  
Project: BURIED AQ. TM-HANSON  
Drilling Company: SDGS  
Driller: G. JENSEN  
Geologist: L. SCHULZ  
Date Drilled: 06-26-1990  
Ground Surface Elevation: 1443.00 T  
Total Drill Hole Depth: 305  
Water Rights Well:  
Other Well Name:  
Basin: VERMILLION  
Management Unit:  
Screen Type: PVC, MFG., SLOT .020  
Casing Type: PVC  
Casing Top Elevation: 1445.00 T  
Casing Stick-up: 1.46  
Well Maintenance Date:  
USGS Hydrological Unit Code: 10170102  
Electric Log Information:  
Spontaneous Potential: X  
Natural Gamma: X  
Samples:

Location: 101N-55W-14BCBC  
Longitude: 97.2427  
Driller's Log:  
Geologist's Log: X  
Drilling Method: ROTARY  
Test Hole Number: R3-90-25  
Single Point Resistivity: X  
Extra:

Location: 101N-55W-14DCDD  
Longitude: 97.2334  
Driller's Log:  
Geologist's Log: X  
Drilling Method: ROTARY  
Test Hole Number: R3-90-24  
SDGS Well Name: R3-90-24  
Aquifer:  
Screen Length: 5.0  
Casing Diameter: 2.0  
Total Casing and Screen: 295.0  
Single Point Resistivity: X  
Extra:

Well screened from 294 to 289 feet. Filter pack from 294 to 268 feet. Bentonite grout from 274 feet to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Water level: 90.07 feet on 07-31-1990; measured from casing top.

0	-	2	Topsoil
2	-	24	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
24	-	151	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
151	-	183	Sand and gravel, tan-brown, medium sand, medium gravel; many shale pebbles, mainly quartz and carbonates, some lignitic coal, some coarse gravel with depth
183	-	193	Clay, gray, silty, sandy, pebbly, gravelly; unoxidized, calcareous (till)
193	-	205	Sand and gravel, gray to brown-gray, fine sand, medium gravel; much clay, many shale clasts, mainly quartz and carbonates
205	-	224	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
224	-	249	Sand, brown-gray, fine; much clay, some gravel, poor return
249	-	282	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
282	-	295	Sand and gravel, gray to brown, fine sand, medium gravel; many shale clasts, mainly quartz and carbonates, some lignitic coal fragments
295	-	304	Clay(?); drilled smooth, no return, E-Log indicates possible clay(?)
304	-	305	Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK

Legal Location: NW SW SW SW sec. 15, T. 101 N., R. 55 W.

Latitude: 43.3241

Land Owner:

Project: BURIED AQ. TM-HANSON

Drilling Company: SDGS

Driller: G. JENSEN

Geologist: L. SCHULZ

Date Drilled: 07-09-1990

Ground Surface Elevation: 1452.00 T

Total Drill Hole Depth: 301

USGS Hydrological Unit Code: 10160011

Electric Log Information:

Spontaneous Potential: X

Natural Gamma: X

Samples:

Location: 101N-55W-15CCCB

Longitude: 97.2539

Driller's Log:

Geologist's Log: X

Drilling Method: ROTARY

Test Hole Number: R3-90-27

Single Point Resistivity: X

Extra:

0	-	2	Topsoil
2	-	25	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
25	-	50	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
50	-	55	Sand, medium
55	-	74	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
74	-	86	Gravel, brown; mainly quartz and carbonates
86	-	152	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
152	-	177	Sand, brown to gray, fine to medium; many shale clasts, mostly quartz and carbonates, some lignitic coal fragments
177	-	236	Clay, gray, silty, very sandy, gravelly; unoxidized, calcareous (till)
236	-	263	Sand and gravel, brown to gray, fine to medium sand, medium gravel; mainly quartz and carbonates, some shale clasts, some lignitic coal fragments
263	-	284	Clay, gray, silty, sandy, pebbly; unoxidized, much sand and gravel in cuttings, E-Log indicates interbedded clays and sands (till)

284 - 300 Sand, brown to gray, medium; many shale pebbles, mostly quartz and carbonates, much lignitic coal  
 300 - 301 Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK	Location: 101N-55W-15CCCC
Legal Location: SW SW SW SW sec. 15, T. 101 N., R. 55 W.	
Latitude: 43.3237	Longitude: 97.2539
Land Owner:	
Project: BURIED AQ. TM-HANSON	
Drilling Company: SDGS	
Driller: D. IVERSON	Driller's Log:
Geologist: L. SCHULZ	Geologist's Log: X
Date Drilled: 08-13-1990	Drilling Method: ROTARY
Ground Surface Elevation: 1452.00 T	
Total Drill Hole Depth: 300	Test Hole Number: R20-90-42
Water Rights Well:	SDGS Well Name: R20-90-42
Other Well Name:	
Basin: JAMES	Aquifer:
Management Unit:	
Screen Type: PVC, MFG., SLOT .020	Screen Length: 5.0
Casing Type: PVC	Casing Diameter: 2.0
Casing Top Elevation: 1454.00 T	
Casing Stick-up: 2.00	Total Casing and Screen: 302.0
Well Maintenance Date:	
USGS Hydrological Unit Code: 10160011	
Electric Log Information:	
Spontaneous Potential:	Single Point Resistivity:
Natural Gamma:	Extra:
Samples:	

Well screened from 300 to 295 feet. Filter pack from 300 feet to 271 feet. Bentonite grout from 287 feet to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Water level: 97.57 feet on 09-06-1990; measured from casing top.

0 - 1	Topsoil
1 - 16	Clay, olive-brown, silty, sandy, pebbly; oxidized (till)
16 - 25	Clay, brown to gray-brown, silty, sandy, pebbly; some brown and gray mottling
25 - 49	Clay, gray, silty, sandy, pebbly; unoxidized, slightly calcareous, more sand content from 45 to 47 feet (till)
49 - 51	Sand and gravel, gray to white, fine sand, medium gravel; some coal
51 - 58	Clay, gray, silty, sandy, pebbly; unoxidized, slightly calcareous (till)
58 - 150	Clay, gray, silty, sandy, very gravelly; unoxidized, slightly calcareous, very calcareous at 64 feet, gravel lenses from 68 to 70 feet, rock at 125 feet (till)
150 - 175	Sand, gray to white, fine to medium; many shale clasts, mainly quartz and carbonates, a few lignitic coal fragments
175 - 227	Clay, gray, silty, very sandy, very gravelly; unoxidized, calcareous, becoming almost entirely silt at approximately 200 feet (till)
227 - 242	Sand, gray to white, fine; mainly well- rounded quartz grains, some clay(?), could be organic(?), rocks at 236 feet
242 - 257	Sand, gray-brown to white, fine to medium; many shale clasts, mainly quartz, some carbonates, some coal, rocks from 255 to 257 feet

257 - 280 Clay, gray, silty, sandy, gravelly; unoxidized, calcareous, driller reports rocks from 257 to 267 feet (till)  
 280 - 299 Sand, tan-brown to white, fine to medium; many shale clasts, mainly quartz, some carbonates, some coal  
 299 - 300 Quartzite; hard layer; could not penetrate, depth matches E-Log for R3-90-27, actually no return (Sioux Quartzite)

\* \* \* \* \*

County: MCCOOK  
 Legal Location: SW SW SW SW sec. 24, T. 101 N., R. 55 W.  
 Latitude: 43.3145  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 07-10-1990  
 Ground Surface Elevation: 1450.00 T  
 Total Drill Hole Depth: 299  
 Water Rights Well:  
 Other Well Name:  
 Basin: VERMILLION  
 Management Unit:  
 Screen Type: PVC, MFG., SLOT .020  
 Casing Type: PVC  
 Casing Top Elevation: 1452.00 T  
 Casing Stick-up: 1.96  
 Well Maintenance Date:  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential: X  
 Natural Gamma: X  
 Samples:

Location: 101N-55W-24CCCC  
 Longitude: 97.3313

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-28  
 SDGS Well Name: R3-90-28

Aquifer:

Screen Length: 5.0  
 Casing Diameter: 2.0

Total Casing and Screen: 293.0

Single Point Resistivity: X  
 Extra:

Well screened from 281 to 276 feet. 10 feet of blank casing below the screen. Filter pack from 297 to 268 feet. Bentonite grout from 268 to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Water level: 95.57 feet on 07-31-1990; measured from casing top.

0 - 2 Topsoil  
 2 - 28 Clay, tan-brown, silty, sandy, pebbly; oxidized (till)  
 28 - 142 Clay, gray, silty, sandy, pebbly; unoxidized, calcareous at 60 feet (till)  
 142 - 191 Sand and gravel, fine sand, medium gravel; many shale clasts, mainly quartz and carbonates  
 191 - 249 Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, much gravel in cuttings (till)  
 249 - 298 Gravel, brown to gray, medium; much clay, mainly quartz and carbonates, many lignitic coal fragments  
 298 - 299 Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \* \*



County: MCCOOK  
 Legal Location: NE SE NE SE sec. 25, T. 101 N., R. 55 W.  
 Latitude: 43.3111  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 06-25-1990  
 Ground Surface Elevation: 1437.00 T  
 Total Drill Hole Depth: 295  
 Water Rights Well:  
 Other Well Name:  
 Basin: VERMILLION  
 Management Unit:  
 Screen Type: PVC, MFG., SLOT .020  
 Casing Type: PVC  
 Casing Top Elevation: 1440.00 T  
 Casing Stick-up: 2.50  
 Well Maintenance Date:  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
   Spontaneous Potential: X  
   Natural Gamma: X  
   Samples:

Location: 101N-55W-25DADA  
 Longitude: 97.2205

Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY

Test Hole Number: R3-90-23  
 SDGS Well Name: R3-90-23

Aquifer:

Screen Length: 5.0  
 Casing Diameter: 2.0

Total Casing and Screen: 289.0

Single Point Resistivity: X  
 Extra:

Well screened from 287 to 282 feet. Filter pack from 291 to 270 feet. Bentonite grout from 270 feet to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Water level: 85.34 feet on 07-12-1990; measured from casing top.

0	-	2	Topsoil
2	-	22	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
22	-	38	Clay, gray-brown, silty, sandy, pebbly; partially oxidized, unoxidized at 24 feet (till)
38	-	50	Gravel, brown, fine to medium; many shale pebbles, some fine sand, mostly quartz and carbonates, much lignitic coal
50	-	78	Clay, olive-gray, silty, sandy, pebbly; unoxidized, slightly calcareous, rock at 62 feet (till)
78	-	91	Sand, gray, fine; many shale clasts, mostly quartz and carbonates, much lignitic coal
91	-	145	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
145	-	164	Sand and gravel, gray-brown, fine sand, medium gravel; many shale pebbles, mostly quartz and carbonates, much lignitic coal
164	-	178	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, more sand and gravel content with depth (till)
178	-	192	Clay, gray, silty; little sand, no pebbles (lacustrine?)
192	-	281	Clay, gray, silty, sandy, pebbly, gravelly; unoxidized, calcareous (till)
281	-	294	Gravel, brown to gray, medium; many shale pebbles, mostly quartz and carbonates, some lignitic coal fragments
294	-	295	Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

\* \* \* \*

County: MCCOOK  
 Legal Location: NW NW SW NW sec. 35, T. 101 N., R. 55 W.  
 Latitude: 43.3038  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: D. IVERSON  
 Geologist: L. SCHULZ  
 Date Drilled: 08-15-1990  
 Ground Surface Elevation: 1454.00 T  
 Total Drill Hole Depth: 274  
 USGS Hydrological Unit Code: 10170102  
 Electric Log Information:  
 Spontaneous Potential:  
 Natural Gamma: X  
 Samples:

Location: 101N-55W-35BCBB  
 Longitude: 97.2427  
  
 Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY  
  
 Test Hole Number: R20-90-43  
  
 Single Point Resistivity: X  
 Extra:

0	-	1	Topsoil
1	-	17	Clay, tan-brown, silty, sandy, pebbly; slightly calcareous, oxidized (till)
17	-	80	Clay, gray, silty, very sandy, pebbly; unoxidized, calcareous (till)
80	-	92	Sand and clay, gray, fine sand, silty; some gravel
92	-	155	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, more gravel content at 118 feet, rock at 124 feet (till)
155	-	178	Sand, brown to gray, fine to medium; many shale clasts, mainly quartz, some carbonates, much coal
178	-	242	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, many chalk pebbles, much wood at 187 feet (till)
242	-	245	Boulders
245	-	248	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous (till)
248	-	274	Clay and siltstone, dark-brown to black, silty clay; greasy clay; hard, friable siltstone, interval is noncalcareous shales and calcareous siltstones (Niobrara Formation)

\* \* \* \*

County: MCCOOK  
 Legal Location: SE SE SE SE sec. 36, T. 101 N., R. 55 W.  
 Latitude: 43.3001  
 Land Owner:  
 Project: BURIED AQ. TM-HANSON  
 Drilling Company: SDGS  
 Driller: G. JENSEN  
 Geologist: L. SCHULZ  
 Date Drilled: 07-10-1990  
 Ground Surface Elevation: 1436.00 T  
 Total Drill Hole Depth: 286  
 Water Rights Well:  
 Other Well Name:  
 Basin: VERMILLION  
 Management Unit:  
 Screen Type: PVC, MFG., SLOT .020  
 Casing Type: PVC  
 Casing Top Elevation: 1438.00 T  
 Casing Stick-up: 2.14  
 Well Maintenance Date:

Location: 101N-55W-36DDDD  
 Longitude: 97.2206  
  
 Driller's Log:  
 Geologist's Log: X  
 Drilling Method: ROTARY  
  
 Test Hole Number: R3-90-29  
 SDGS Well Name: R3-90-29  
  
 Aquifer:  
  
 Screen Length: 2.0  
 Casing Diameter: 2.0  
  
 Total Casing and Screen: 284.0

USGS Hydrological Unit Code: 10170102

Electric Log Information:

Spontaneous Potential: X

Natural Gamma: X

Samples:

Single Point Resistivity: X

Extra:

Well screened from 282 to 277 feet. Filter pack from 282 feet to 268 feet. Bentonite grout from 268 to 20 feet. Neat cement grout from 20 feet to land surface. One steel well protector and lock installed. Water level: 66.24 Feet on 07-30-1990; measured from casing top.

0	-	2	Topsoil
2	-	12	Clay, tan-brown, silty, sandy, pebbly; oxidized (till)
12	-	138	Clay, gray, silty, sandy, pebbly; unoxidized, calcareous, sand stringer at 74 feet, some gravel starting at 120 feet (till)
138	-	213	Sand and gravel, tan-brown to gray, fine sand, medium gravel; many shale clasts, mainly quartz and carbonates
213	-	264	Clay, gray, silty, sandy, pebbly, very gravelly; unoxidized, calcareous (till)
264	-	285	Gravel; poor return, many rocks, E-Log indicates sand or gravel, driller reports large cobbles
285	-	286	Quartzite; hard layer; could not penetrate, many pink quartzite chips (Sioux Quartzite)

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Appendix B. Compilation of available water-quality analyses for the major constituents in the basal-outwash aquifer.

Well	Location <sup>2</sup>	Date sampled	Conduc- tivity <sup>3</sup> (mmhos)	Concentration in milligram per liter <sup>1</sup>													Hard- ness
				Alk-T	HCO <sub>3</sub>	Ca	CL	F	Fe	K	Mg	Mn	Na	NO <sub>3</sub> -N	SO <sub>4</sub>	DS	
TU-83A	100N-55W-070DDD	06-24-83	1190	---	---	---	250 <sup>4</sup>	2.4 <sup>5</sup>	0.3	--	--	0.05 <sup>4</sup>	---	10 <sup>5</sup>	250 <sup>4</sup>	500 <sup>4</sup>	---
R3-90-19 <sup>6</sup>	100N-55W-29A88B	07-11-90	1330	339	413	113	12	0.47	1.71	13	34	1.16	145	<0.04	370	940	422
TU-82A	100N-55W-30A88B	08-31-84	1150	---	185	80	12	----	----	14	35	----	136	0.86	469	892	257
MC-83H	101N-54W-200DDD 1	08-25-83	1590	250	305	160	20	0.32	<0.05	11	58	0.55	130	<0.05	608	1210	638
R3-90-22 <sup>6</sup>	101N-54W-32CCCC 1	07-11-90	1380	324	395	162	9	0.49	<0.05	12	48	0.45	90	<0.04	440	1040	602
R3-90-26 <sup>6</sup>	101N-55W-09A88B	07-31-90	1750	356	434	179	12	0.34	3.71	12	52	1.37	167	<0.04	635	1350	661
R3-90-24 <sup>6</sup>	101N-55W-140CDD	07-31-90	----	326	397	154	--	----	1.15	12	47	0.80	127	----	---	----	578
R20-90-42 <sup>6</sup>	101N-55W-15CCCC	09-06-90	1620	309	377	118	22	0.36	0.16	14	51	1.60	138	<0.1	514	1262	503
R3-90-28 <sup>6</sup>	101N-55W-24CCCC	07-30-90	1350	358	436	161	11	0.39	0.07	11	46	1.43	97	<0.04	426	1010	591
R3-90-23	101N-55W-250ADA	07-12-90	1260	322	393	124	12	0.57	<0.05	14	38	1.19	109	<0.04	360	904	466
MC-83J	101N-55W-36888B	07-31-90	1450	348	424	172	10	0.38	0.51	11	48	1.28	108	<0.04	474	1130	627
R3-90-29 <sup>6</sup>	101N-55W-360DDD	07-30-90	1320	338	412	160	9	0.32	1.49	11	47	0.88	87	<0.04	416	997	593

<sup>1</sup> Alk-T - total alkalinity; HCO<sub>3</sub> - bicarbonate; Ca - calcium; CL - chloride; F - fluoride; Fe - iron; K - potassium; Mg - magnesium; Mn - manganese; Na - sodium; NO<sub>3</sub>-N - nitrate nitrogen; SO<sub>4</sub> - sulfate; DS - dissolved solids; Hardness - hardness as calcium carbonate.

<sup>2</sup> See appendix A for explanation of locations.

<sup>3</sup> mmhos - micromhos.

<sup>4</sup> U.S. Environmental Protection Agency (1985b).

<sup>5</sup> U.S. Environmental Protection Agency (1985a).

<sup>6</sup> Drilled and sampled for the current study.