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Information Pamphlet No. 40

MAJOR AQUIFERS IN BROOKINGS COUNTY, SOUTH DAKOTA

by

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DEFINITIONS OF TERMS

(Accepted for use by the South Dakota Geological Survey)

Aquifer.--A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Basement rock.--A general term for granite, quartzite, and other dense, impermeable rocks that are considered to be the base of the hydrologic system.

Bedrock.--A general term for the rock, usually consolidated, that underlies soil, sand, clay, or other unconsolidated material. In Brookings County, the uppermost bedrock is shale or chalk.

Confined aquifer.--An aquifer containing water under pressure significantly higher than atmospheric. Its upper limit is the bottom of a bed that has a hydraulic conductivity distinctly lower than that of the material in which the confined water is present.

Dissolved solids.--The sum of all dissolved material in water, expressed as the weight (milligrams) of solute per unit volume (liter) of water.

Glacial aquifer.--As used in this report, an aquifer consisting mainly of unconsolidated sand and gravel deposited as outwash from a glacier.

Glacial outwash.--Stratified, unconsolidated rock material (usually sand and gravel) that has been washed, sorted, and deposited by water from melting glacial ice.

Hardness.--A physical-chemical characteristic of water, caused mainly by calcium and magnesium, that is recognized by reduced lathering ability of soap and formation of scale in boilers and pipes. Hardness is expressed as an equivalent concentration of calcium carbonate and is classified by the U.S. Geological Survey as follows:

DESCRIPTION	MILLIGRAMS PER LITER	GRAINS PER GALLON
Soft	0- 60	0- 3.4
Moderately hard	61-120	3.5- 7.0
Hard	121-180	7.1-10.5
Very hard	More than 180	More than 10.5

Milligram per liter (mg/L).--A unit expressing the concentration of chemical constituents in solution as mass (milligrams) of

solute per unit volume (liter) of water. One milligram per liter is approximately equal to one part per million.

Properly constructed well.--A well constructed to transmit the maximum amount of water from an aquifer without excessive drawdown of water level at the well. Such a well usually is installed with a well screen or perforated casing and gravel pack opposite the aquifer. It also is developed in such a manner as to remove drilling mud and other fine-grained material from the aquifer adjacent to the well screen or perforations.

Saline water.--As used in this report, water that contains more than 1,000 mg/L of dissolved solids. Much water in Brookings County aquifers is slightly saline, with concentrations of dissolved solids less than 3,000 mg/L.

Till.--An unsorted, unstratified mixture of clay, silt, sand, gravel, and boulders deposited by a glacier.

CONVERSION FACTORS

The inch-pound units used in this report may be converted to metric (International System) units by the following conversion factors:

MULTIPLY INCH-POUND UNIT	BY	TO OBTAIN METRIC UNIT
acre-foot	1233	cubic meter
foot (ft)	0.3048	meter
gallons per minute (gal/min)	0.06309	liter per second
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

ABSTRACT

Five major glacial aquifers and two major bedrock aquifers underlie the 809-square-mile (mi^2) area of Brookings County, east-central South Dakota. Glacial aquifers of outwash sand and gravel lie at depths ranging from land surface to as much as 700 feet. Sandstone bedrock aquifers lie at depths of 630 to 1,040 feet below land surface. The reported yields of wells in glacial aquifers range from 2 to 1,800 gallons per minute. Yields for bedrock aquifers are estimated to range from 2 to 100 gallons per minute.

Water from the glacial aquifers generally is very hard, hardness concentrations being larger than 180 milligrams per liter and as much as 1,800 milligrams per liter as calcium carbonate. The water is fresh to slightly saline (dissolved solids exceed 1,000 milligrams per liter). Water from the bedrock aquifers is slightly saline and soft to very hard. Hardness concentrations range from 58 milligrams per liter to as much as 190 milligrams per liter as calcium carbonate. Water from many of the aquifers is marginal to unsuitable for use in irrigation, depending on drainage because of large concentrations of dissolved solids, especially sodium.

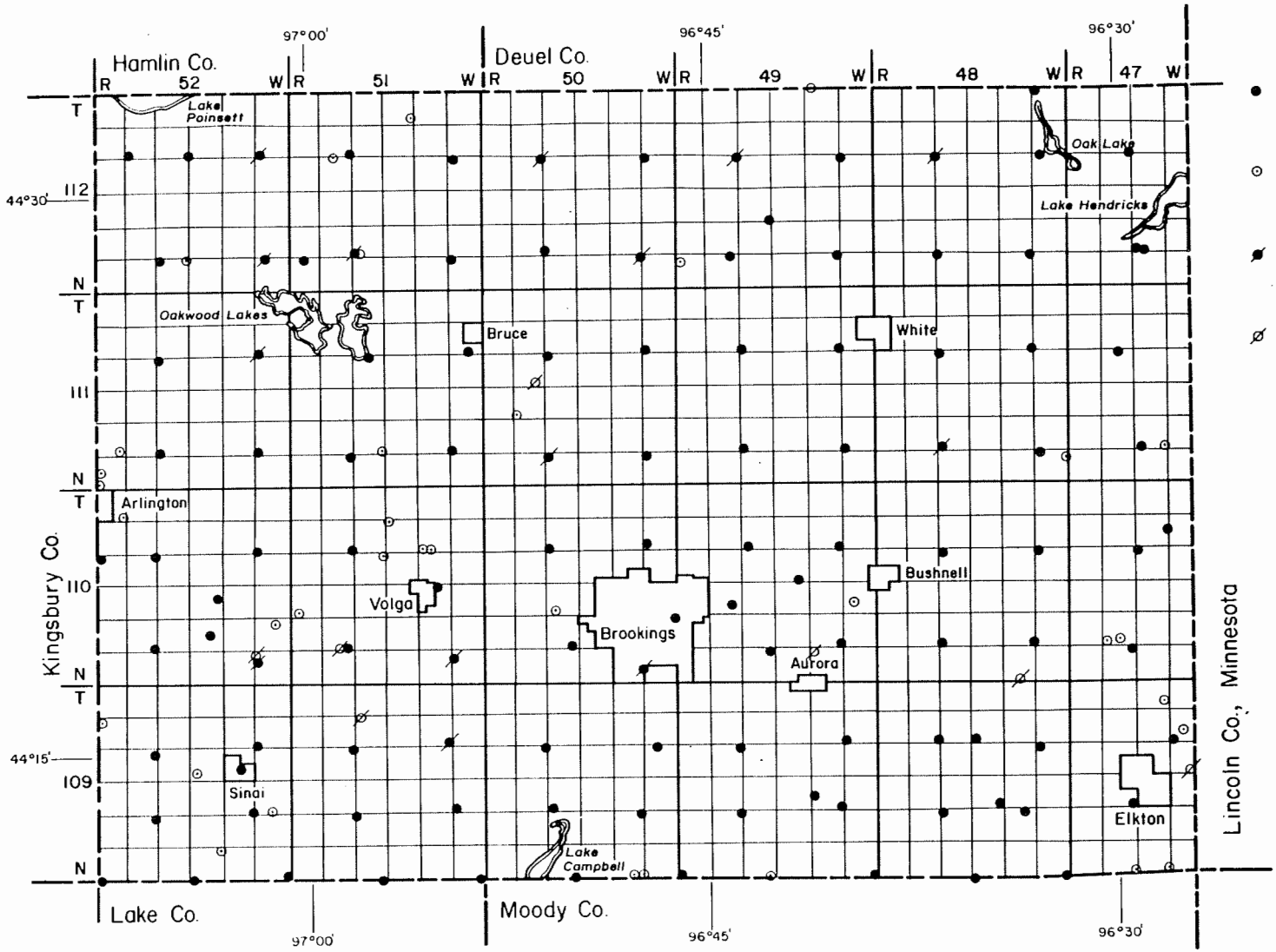
INTRODUCTION

This information pamphlet is one of a series of reports on water-resources studies of South Dakota counties. It is designed to acquaint the reader with the general distribution, quantity, and quality of ground water available from the major aquifers in Brookings County. Information in this pamphlet is based on data collected by the U.S. Geological Survey and the South Dakota Geological Survey during 1982-86. These data were obtained from examination and interpretation of geologic, electric, and drillers' logs of test holes and wells drilled in Brookings County (fig. 1). Many test holes less than 50 ft deep have been drilled prior to and during this study but are too numerous to show in figure 1.

Copies of this publication and other county reports may be obtained from the South Dakota Geological Survey as they become available. Persons wishing additional information about the hydrology and geology may contact the U.S. Geological Survey in Huron, South Dakota, and the South Dakota Geological Survey in Vermillion, South Dakota.

GLACIAL AQUIFERS

Five major glacial aquifers underlie the 809 mi^2 area of Brookings County in east-central South Dakota (table 1). The aquifers, in order of increasing depth, are named Big Sioux, Rutland, Ramona, Howard, and Altamont. The aquifers are composed



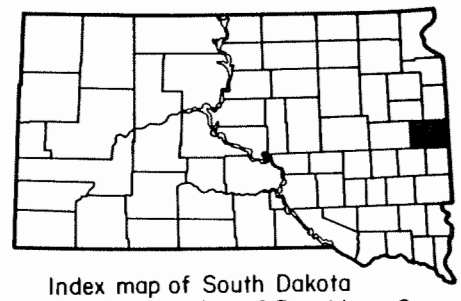
Explanation

- ● Test hole or well drilled into bedrock.
- ⊙ Test hole or well not drilled into bedrock.
- ◉ Observation well drilled into bedrock.
- ⌀ Observation well not drilled into bedrock.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized township

0 1 2 3 4 5 6 7 8 9 10 Mi.



Index map of South Dakota showing location of Brookings Co.

Figure 1. Location of test holes and wells for which geologic, electric, or drillers logs are available (excluding test holes in the Big Sioux aquifer).

Table 1.--Summary of hydrologic characteristics of the major aquifers

Aquifer name	Areal extent (square miles)	Maximum thickness (feet)	Average thickness (feet)	Range in depth to top of aquifer (feet below land surface)	Range of water level (feet below or above (+) land surface)	Estimated amount of water in storage (acre-feet)	Range of reported and estimated well yields (gallons per minute)	Suitable for irrigation
				GLACIAL AQUIFERS				
Big Sioux	470	93	30	0-212	0-120	1,900,000	2-1,300	Yes.
Rutland	250	48	15	23-432	+2-212	400,000	2-1,800	Yes.
Ramona	130	42	20	51-282	10-144	330,000	2-200	Marginal to unsuitable.
Howard	350	135	30	161-438	5-150	1,200,000	2-500	Marginal to unsuitable.
Altamont	305	305	30	345-700	65-420	1,200,000	2-1,000	No.
				BEDROCK AQUIFERS				
Codell	590	125	80	630-785	140-300	6,000,000	2-100	No.
Dakota	270	125	50	990-1,040	200-700	1,700,000	2-20	No.

mainly of water-yielding sand and gravel deposits that are as much as 93 ft thick.

The sand and gravel aquifers were deposited as glacial outwash from melting of a thick continental ice sheet that covered the area. Commonly, a layer of sand and gravel was deposited in front of the advancing ice sheet and then covered by 20 to 50 ft of relatively impermeable glacial till. Later, as the ice sheet melted and receded, another layer of sand and gravel was deposited on top of the till. This sequence was repeated several times. Consequently, the buried glacial aquifers are composed of one or more layers of sand and gravel that can be covered by a maximum of about 700 ft of till and overlying aquifers. Aquifer thickness shown in figures 2-5 of this report are cumulative thicknesses of all sand and gravel layers that compose the aquifer. The thickness also can include a few feet of unsaturated sand and gravel that lies above the water table in the unconfined aquifer.

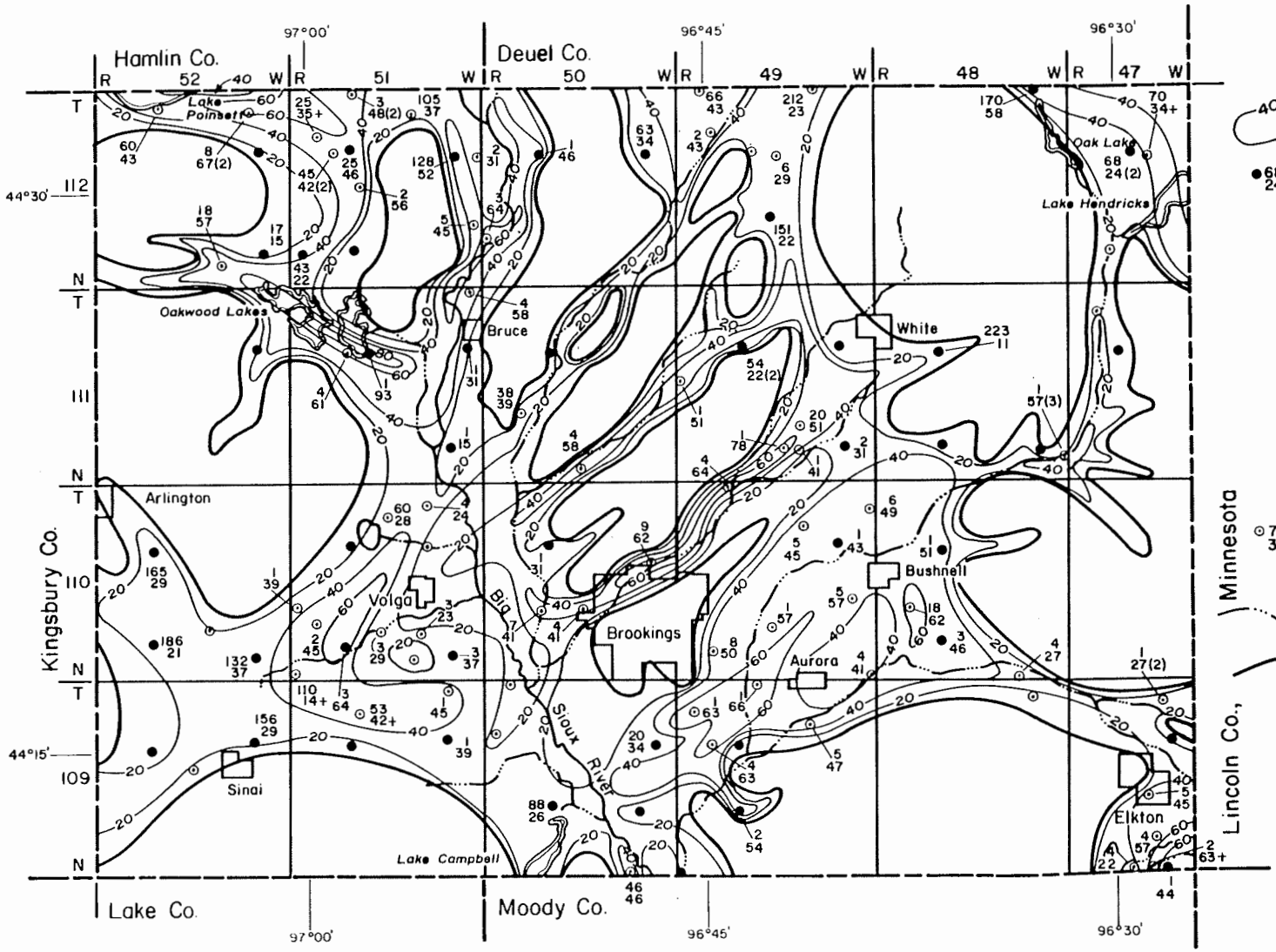
Big Sioux Aquifer

The Big Sioux aquifer underlies an area of 470 mi^2, more than one-half of Brookings County. Depths to the top of the aquifer range from land surface to 212 ft. The aquifer stores an estimated 1,900,000 acre-ft of water (table 1). The thickness of sand and gravel that composes the aquifer averages 30 ft but exceeds 40 ft south and east of Brookings, within some valleys north of Brookings, and locally in the northwestern part of the county (fig. 2). Reported yields from wells in the aquifer (table 1) are as much as 1,300 gal/min in areas where the saturated thickness of sand and gravel exceeds 20 ft. Generally, yields for wells less than 500 gal/min are due to (1) a large percent of clay or fine sand in the aquifer, (2) partial dewatering of the aquifer by intensive pumping, and/or (3) the discontinuous nature of the aquifer where it is composed of thin layers. Water in the aquifer is unconfined. Water levels in wells range from land surface in wetlands to 120 ft below land surface under hills.

Water from the aquifer is fresh to slightly saline (see "saline" in Definition of Terms) and is a calcium bicarbonate type. Concentrations of dissolved solids range from 300 to 2,200 mg/L. Hardness of the water ranges from 400 to 1,640 mg/L. Generally, the water is suitable for use in irrigation because it has relatively small concentrations of dissolved solids. However, water with concentrations of dissolved solids larger than about 1,800 mg/L would be unsuitable for irrigating clayey, poorly permeable soil.

Rutland Aquifer

The Rutland aquifer underlies an area of 250 mi^2 in the south-central and eastern parts of the county. Depths from land surface to the top of the aquifer range from 23 ft in the



Explanation

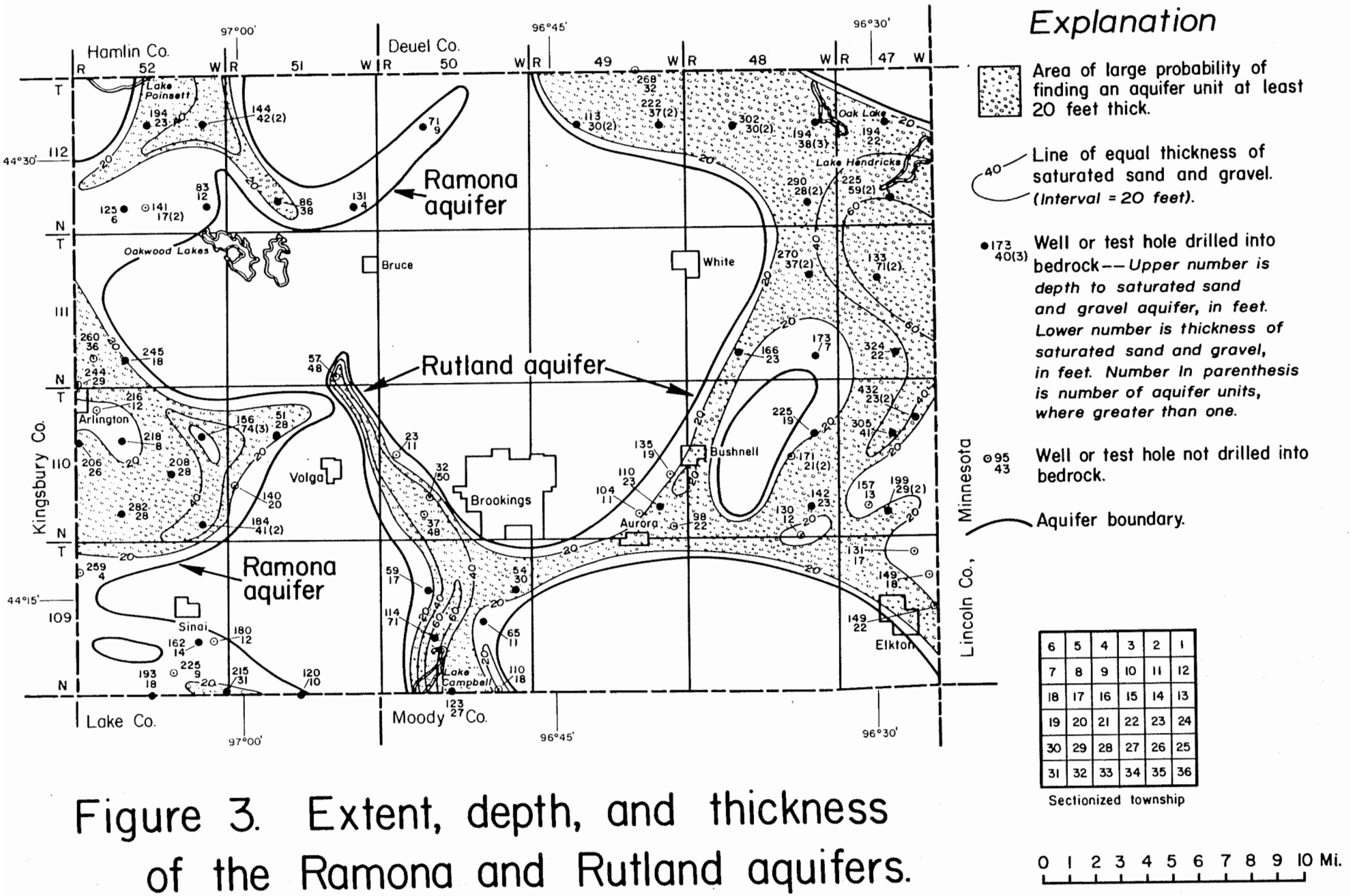
- Line of equal thickness of sand and gravel. (*Interval = 20 feet*).
- Well or test hole drilled into bedrock--*Numbers are for holes that penetrate more than 20 feet of aquifer. Upper number is depth, in feet, to sand and gravel. Lower number is thickness, in feet, of sand and gravel, including the unsaturated zone. A plus (+) indicates thickness greater than shown. Number in parenthesis is number of aquifer units, where greater than one.*
- Well or test hole not drilled into bedrock.
- Intermittent stream.
- Aquifer boundary.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized township

0 1 2 3 4 5 6 7 8 9 10 Mi.

Figure 2. Extent, depth, and thickness of the Big Sioux aquifer.



6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Sectionized township

0 1 2 3 4 5 6 7 8 9 10 Mi.

Figure 3. Extent, depth, and thickness of the Ramona and Rutland aquifers.

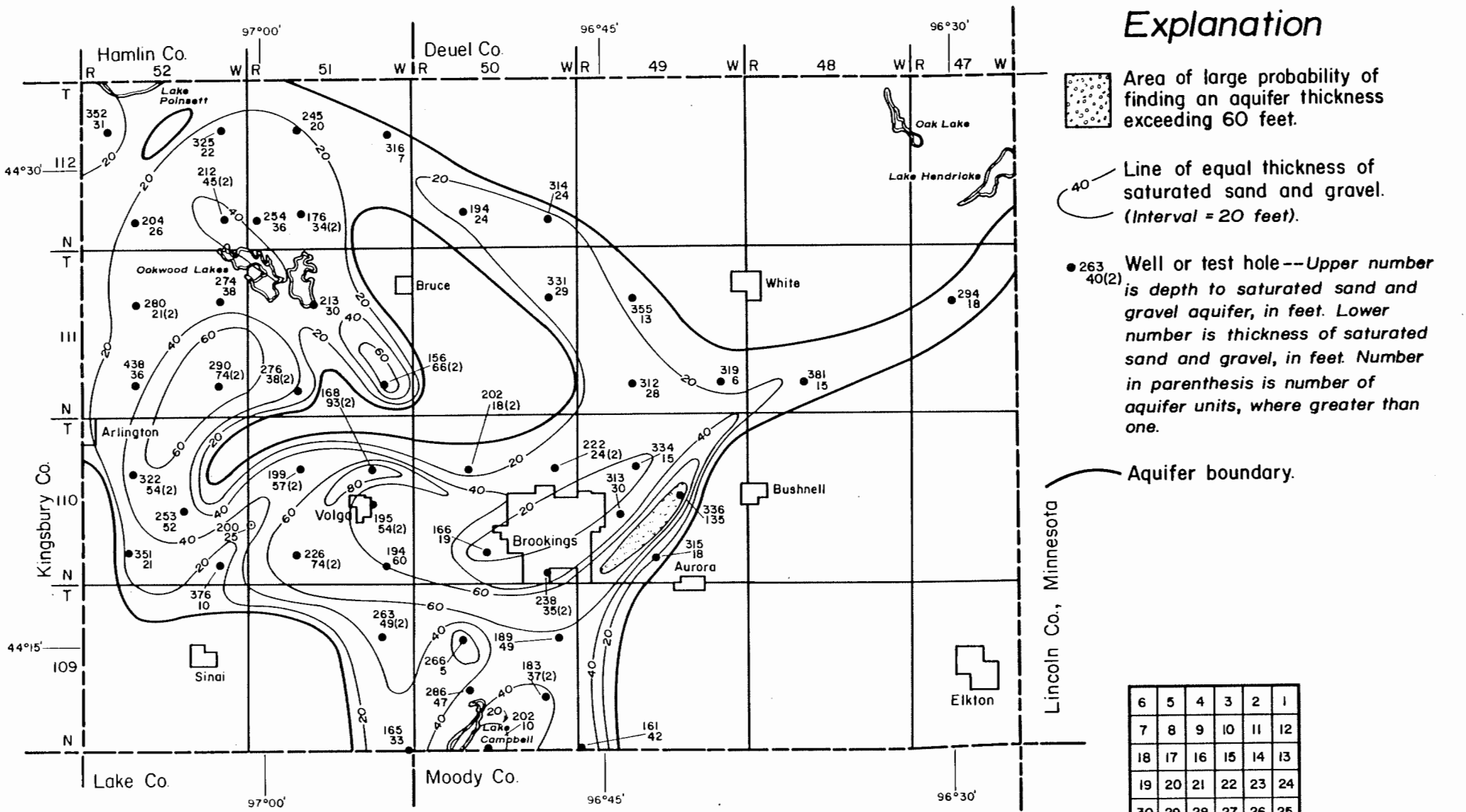


Figure 4. Extent, depth, and thickness of the Howard aquifer.

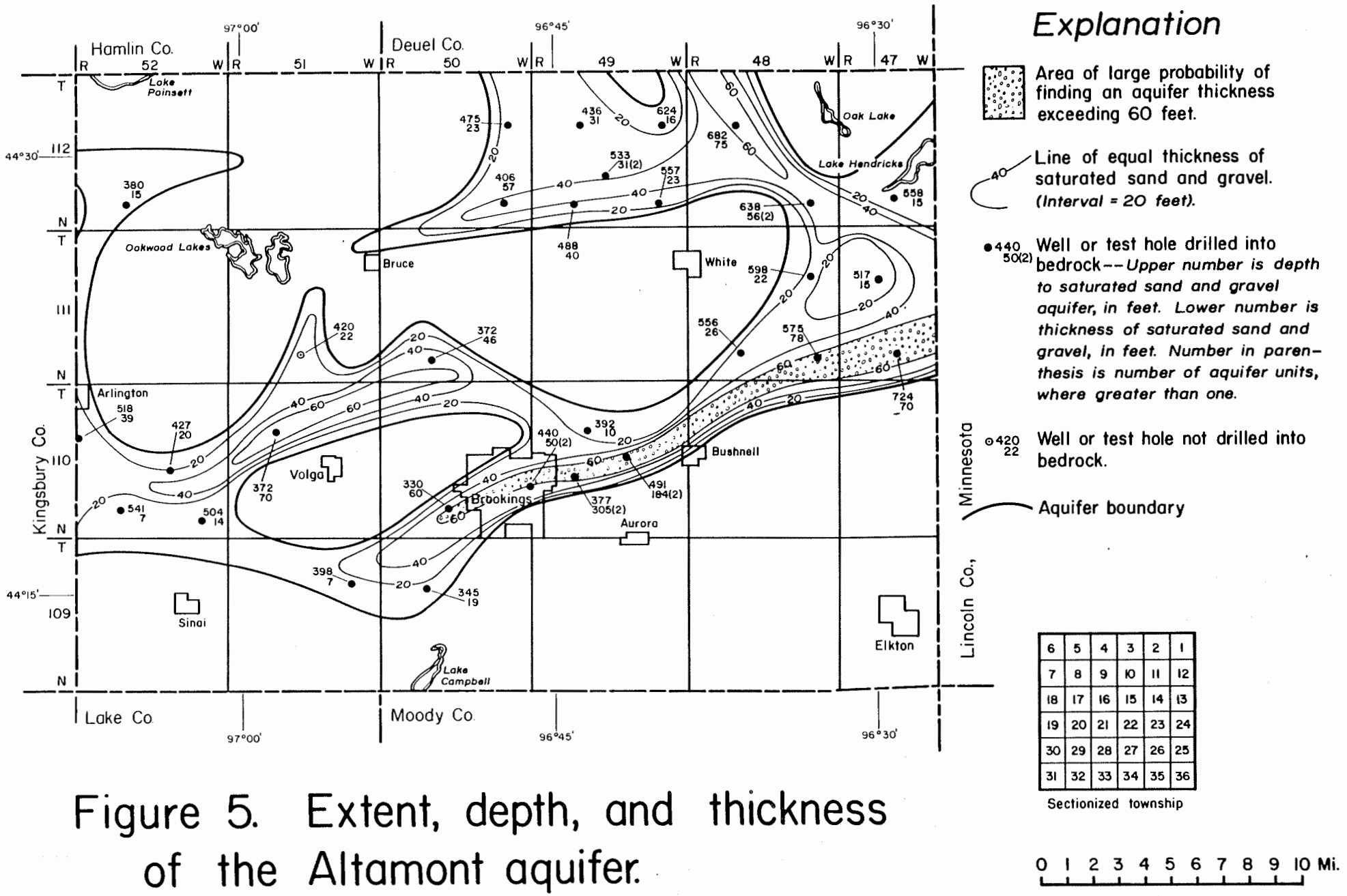


Figure 5. Extent, depth, and thickness of the Altamont aquifer.

south-central to 432 ft in the east-central part of the county (fig. 3). The aquifer averages about 15 ft in thickness and has a maximum thickness of 48 ft in an area 3 mi southwest of Brookings. Although the maximum yield reported for one well in the aquifer was 1,800 gal/min, the maximum yield probably would not exceed 500 gal/min in areas where the aquifer thickness is less than 20 ft.

Water in the aquifer is confined under till and, locally, wells flow in Township 109 N., R. 50 W. Water levels range from 2 ft above land surface 6 mi south of the City of Brookings to 212 ft below land surface 17 mi northeast of Brookings.

Water from the aquifer is fresh to slightly saline and is a calcium-magnesium bicarbonate-sulfate type or a calcium sulfate type. Concentrations of dissolved solids range from 400 to 2,400 mg/L. Hardness of the water ranges from 300 to 1,300 mg/L. Generally, the water is suitable for use in irrigation because of its relatively small concentrations of dissolved solids.

Ramona Aquifer

The Ramona aquifer underlies an area of 130 mi^2 along the western side of the county. Depths from land surface to the top of the aquifer range from 51 to 282 ft (**fig. 3**). The thickness of the aquifer averages about 20 ft. Maximum yields of properly constructed wells are estimated to be as large as 200 gal/min in a few areas where the thickness of sand and gravel exceeds 20 ft. Reported yields are lower than yields from other glacial aquifers (table 1), because much of the aquifer contains poorly permeable fine sand. Water in the aquifer is confined under till, but wells do not flow. Water levels in wells range from 10 ft below land surface in the northwestern part to 144 ft below land surface in the southwestern part of the county.

Water from the aquifer is slightly saline and is a calcium-sulfate type. Concentrations of dissolved solids range from 1,400 to 2,600 mg/L. Hardness of the water ranges from 600 to 1,800 mg/L. Much of the water is marginal to unsuitable for use in irrigation because of relatively large concentrations of dissolved solids.

Howard Aquifer

The Howard aquifer underlies an area of 350 mi^2 in the county. Depths from land surface to the top of the aquifer range from 161 ft in Township 109 North, Range 49 West, to 438 ft in Township 111 North, Range 52 West (fig. 4). The aquifer averages 30 ft in thickness but is as much as 135 ft thick locally. Maximum yields of properly constructed wells may be as much as 500 gal/min in areas where the aquifer thickness exceeds 20 ft and the aquifer consists mostly of coarse sand and gravel. In many areas, the

aquifer is interbedded with sandy clay (till) that yields relatively little water to wells. Water in the aquifer is confined under till, but water levels are not high enough for wells to flow. Water levels in wells range from 5 ft below land surface 2 mi southeast of the town of Volga to a depth of about 150 ft under hills 5 mi west of Volga.

Water from the aquifer is slightly saline and is a calcium-sulfate type. Concentrations of dissolved solids range from 1,800 to 3,400 mg/L. Hardness of the water ranges from 1,100 to 1,800 mg/L. The water is marginal to unsuitable for use in irrigation because of relatively large concentrations of dissolved solids.

Altamont Aquifer

The Altamont aquifer underlies an area of 305 mi^2 in the county. Depths to the top of the aquifer from land surface range from about 345 ft southwest of Brookings to about 700 ft in the northeast (fig. 5). The aquifer averages 30 ft in thickness and locally is as much as 305 ft thick. Maximum yields of properly constructed wells may be as much as 1,000 gal/min where the aquifer thickness exceeds 20 ft and the aquifer consists mostly of coarse sand and gravel. A yield of 224 gal/min is obtained with a 30-horsepower submersible pump from the old municipal well at Arlington, one-half mile west of Brookings County in Township 110 North, Range 53 West, Section 1. This 617-ft well has 22 ft of 10-inch screen in 31 ft of very coarse sand and gravel. Drawdown of the water level is 11 ft below the static level of 220 ft below land surface. Much larger yields can be obtained at Arlington with greater drawdown by installing wells and pumps of larger capacity. Pumping lifts could be as large as 500 ft in the northeastern part of Brookings County. Water in the aquifer is confined under till. Water levels range from 65 ft below land surface 4 mi northwest of the City of Brookings to 420 ft below land surface in the northeastern part of the county.

Few wells have been completed in the aquifer because of the large depths required for wells and the availability of shallower aquifers. Water from two wells in the aquifer is slightly saline and is a sodium sulfate type. Concentrations of dissolved solids for the 2 wells were about 2,100 mg/L, and hardnesses of the water were 80 and 400 mg/L. The water is unsuitable for use in irrigation because of its large concentrations of sodium.

BEDROCK AQUIFERS

Two bedrock aquifers, which are named the Codell and Dakota aquifers, underlie the western and northern parts of the county. Depths from land surface to the top of the aquifers range from 630 ft in the west to as much as 1,040 ft in the northeast. Both aquifers consist mostly of fine-grained, cemented sandstone. Well yields from bedrock aquifers generally are much less than from

glacial aquifers, because the sandstone is less permeable than sand and gravel. Very few wells have been completed in the aquifers because of large well depths and the availability of shallower aquifers.

Codell Aquifer

The Codell aquifer underlies an area of 590 mi^2 in the western and northern parts of the county. Depths from land surface to the top of the aquifer range from 630 to 785 ft. The thickness of the sandstone aquifer is estimated to average about 80 ft but is as much as 125 ft in western Brookings County. Yields of wells are estimated to range from 2 to 20 gal/min. Larger yields of as much as 100 gal/min could be obtained where the aquifer is thicker than 80 ft and contains medium-grained sand. The aquifer is confined beneath 300 to 400 ft of relatively impermeable shale. Water levels are estimated to range below land surface from 140 ft in western Brookings County to 300 ft in the northeastern part of the county.

Water from 2 wells in the aquifer is slightly saline and is a sodium sulfate type. Concentrations of dissolved solids from the 2 wells were 1,730 and 1,890 mg/L. Hardness of the water was about 190 mg/L. The water is unsuitable for irrigation because of its large concentration of sodium.

Dakota Aquifer

The Dakota aquifer underlies an area of 270 mi^2 in the northwestern and extreme northern parts of the county. Depths from land surface to the top of the aquifer range from 990 ft in the northwestern part to 1,040 ft in the northeastern part of the county. Sparse data indicate that the aquifer probably is absent in most of the central and southeast parts of the county. The thickness of the sandstone aquifer averages 50 ft but locally may be as much as 125 ft. The aquifer is underlain by basement rock (quartzite) that yields little water to wells. Yields of wells in the Dakota aquifer are estimated to range from 2 to 20 gal/min. The aquifer is confined by and separated from the overlying Codell by 300 to 600 ft of shale. Water levels are estimated to range from 200 ft below land surface in the west to 700 ft below land surface in the northeastern part of the county.

Water from the aquifer is slightly saline and is a sodium sulfate type. Concentration of dissolved solids at one site was 3,280 mg/L. Hardness of the water was 58 mg/L. The water is unsuitable for irrigation because of its large concentrations of sodium. Fluoride concentrations also exceed the recommended limit of 1.5 mg/L for drinking water set by the U.S. Environmental Protection Agency.

LOCATING SITES FOR LARGE-CAPACITY WELLS IN GLACIAL AQUIFERS

The best possibilities for obtaining wells in glacial aquifers capable of supplying more than 500 gal/min are in the areas where the aquifers are more than 20 ft. thick. Before wells are constructed, test holes commonly are drilled to determine the thickness of the aquifer and to provide samples for determining the grain size of the aquifer material. Grain-size information helps in the selection of the proper slot size and length of screen to be used in the construction of a well. Controlled pumping of the well for at least a day indicates the yield of the aquifer at that locality and provides a representative water sample for chemical analysis. Measurement of the drawdown and recovery of water level in the pumping well and in an observation well provides information that is useful for estimating the yield of a well during longer pumping periods. If the well is to be used for irrigation, knowledge of the type of soil, subsoil, and topography also are important in selecting the most suitable irrigation system. Increased ground-water development from shallow glacial aquifers, especially near lakes and in stream valleys, may lower lake levels and decrease streamflow.