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GEOLOGICAL SURVEY
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Information Pamphlet No. 41

MAJOR AQUIFERS IN KINGSBURY COUNTY, SOUTH DAKOTA

by

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United States Department of the Interior

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South Dakota Geological Survey,
Kingsbury County, and the
East Dakota Water Development District

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DEFINITIONS OF TERMS

(Approved 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 Kingsbury 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 occurs.

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 Kingsbury 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

Four major glacial aquifers and two major bedrock aquifers underlie the 858-square-mile area of Kingsbury County, east-central South Dakota. Glacial aquifers of outwash sand and gravel lie at depths ranging from land surface to about 600 feet. Sandstone bedrock aquifers lie at depths of 320 to 1,300 feet below land surface. The reported yields of wells in glacial aquifers range from 2 to 1,000 gallons per minute. Yields for bedrock aquifers are estimated to range from 2 to 100 gallons per minute.

Water from 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 bedrock aquifers is slightly saline and soft to very hard. Hardness concentrations range from 2 to 200 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 Kingsbury County. Information in this pamphlet is based on well data (fig. 1) collected by the U.S. Geological Survey and the South Dakota Geological Survey from 1982 to 1986.

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, or the South Dakota Geological Survey in Vermillion, South Dakota.

GLACIAL AQUIFERS

Four major glacial aquifers underlie more than one-half of the 858-mi^2 area of Kingsbury County in east-central South Dakota (table 1). The aquifers, in order of increasing depth, are named Vermillion East Fork, Ramona, Howard, and Altamont. The aquifers are composed of water-yielding sand and gravel deposits that are as much as 75 ft thick.

The sand and gravel aquifers were deposited as glacial outwash from melting of a thick continental ice sheet that covered the

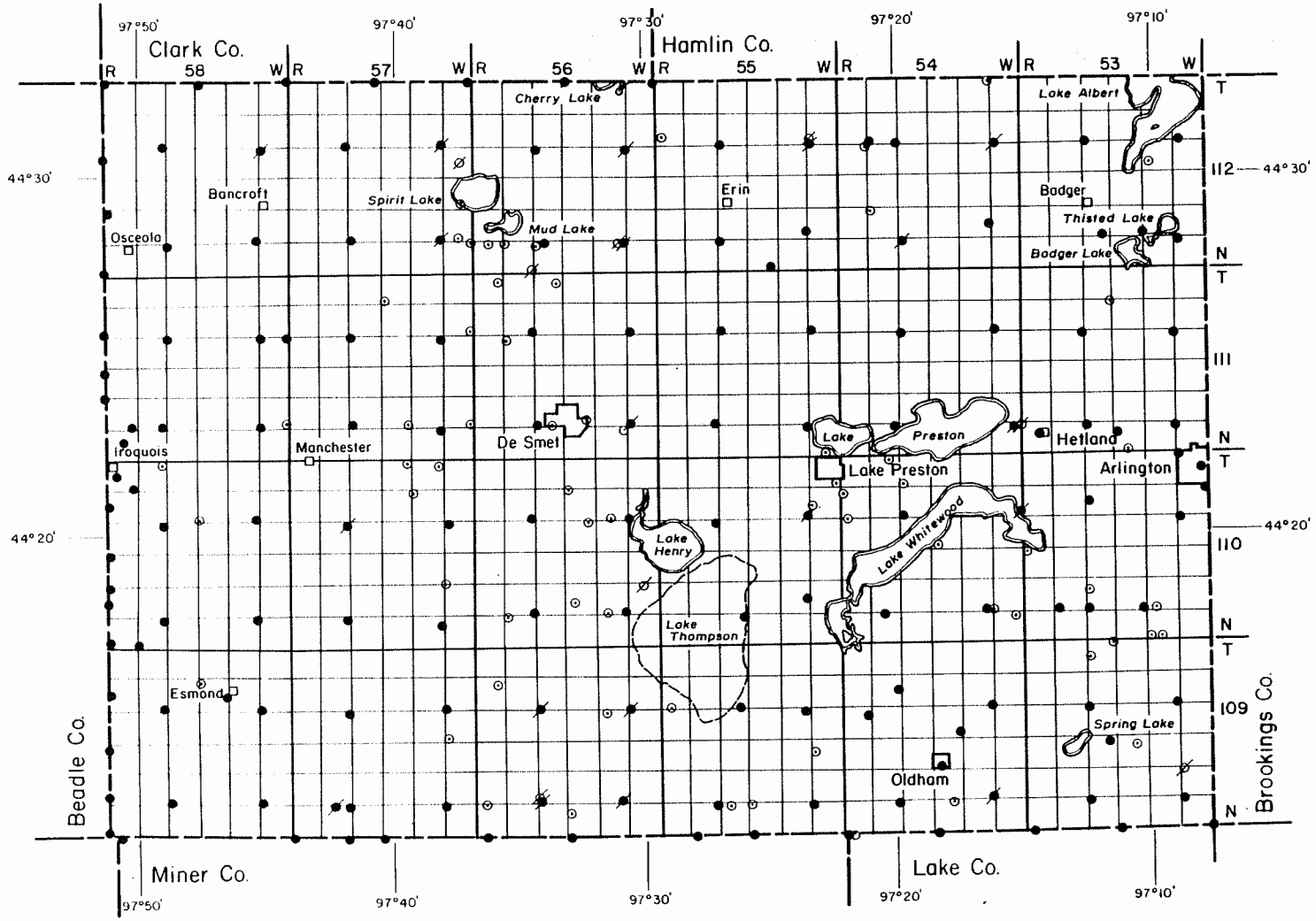
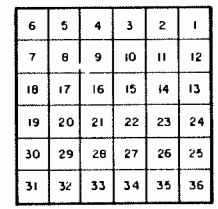
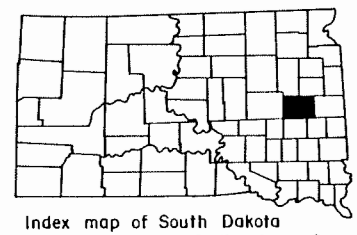


Figure 1. Location of test holes and wells for which geologic, electric or driller logs are available.



Sectionized township



Index map of South Dakota showing location of Kingsbury Co.

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.

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				
Vermillion East Fork	94	70	25	0-120	0-74	300,000	100-1,000	Yes.
Ramona	250	52	20	21-279	30-140	640,000	2-500	Marginal to unsuitable.
Howard	485	75	25	140-420	30-200	1,500,000	10-1,000	Marginal.
Altamont	75	[1/] 54	25	446-588	40-220	130,000	10-1,000	No.
				BEDROCK AQUIFERS				
Codell	858	170	80	320-900	100-340	8,800,000	2-100	No.
Dakota	840	500	300	770-1,300	10-360	32,000,000	2-100	No.

[1/] Composite thickness of two units.

area. Commonly, a layer of sand and gravel was deposited in front of the advancing ice sheet and then covered by 50 to 150 ft of relatively impermeable glacial till. Later, as the ice sheet melted and receded, another layer of sand and gravel could be 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 600 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.

Vermillion East Fork Aquifer

The Vermillion East Fork aquifer underlies an area of 94 mi^2 in Kingsbury County. Depths to the top of the aquifer range from land surface to 120 ft. The aquifer stores an estimated 300,000 acre-ft of water (table 1). The thickness of sand and gravel that compose the aquifer averages 25 ft but exceeds 40 ft between the city of De Smet and Spirit Lake (fig. 2). Near Spirit Lake the aquifer extends to depths below 50 ft and is composed of three units that locally are hydraulically connected to each other and to Spirit Lake. Reported yields from wells in the aquifer (table 1) are as much as 1,000 gal/min in areas where the saturated thickness of sand and gravel exceeds 20 ft. Yields may be much less 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 except for some confined units near Spirit Lake and at De Smet that are overlain by till deposits. Water levels in wells range from land surface in wetlands to 74 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 500 to 2,700 mg/L. Hardness of the water ranges from 100 to 1,700 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.

Minor Aquifers

Several minor aquifers are found at depths ranging from 9 to 268 ft below land surface (fig. 2). Minor aquifers in the eastern one-half of the county, westward extensions of the Big Sioux aquifer, locally have thicknesses greater than 20 ft. These sites

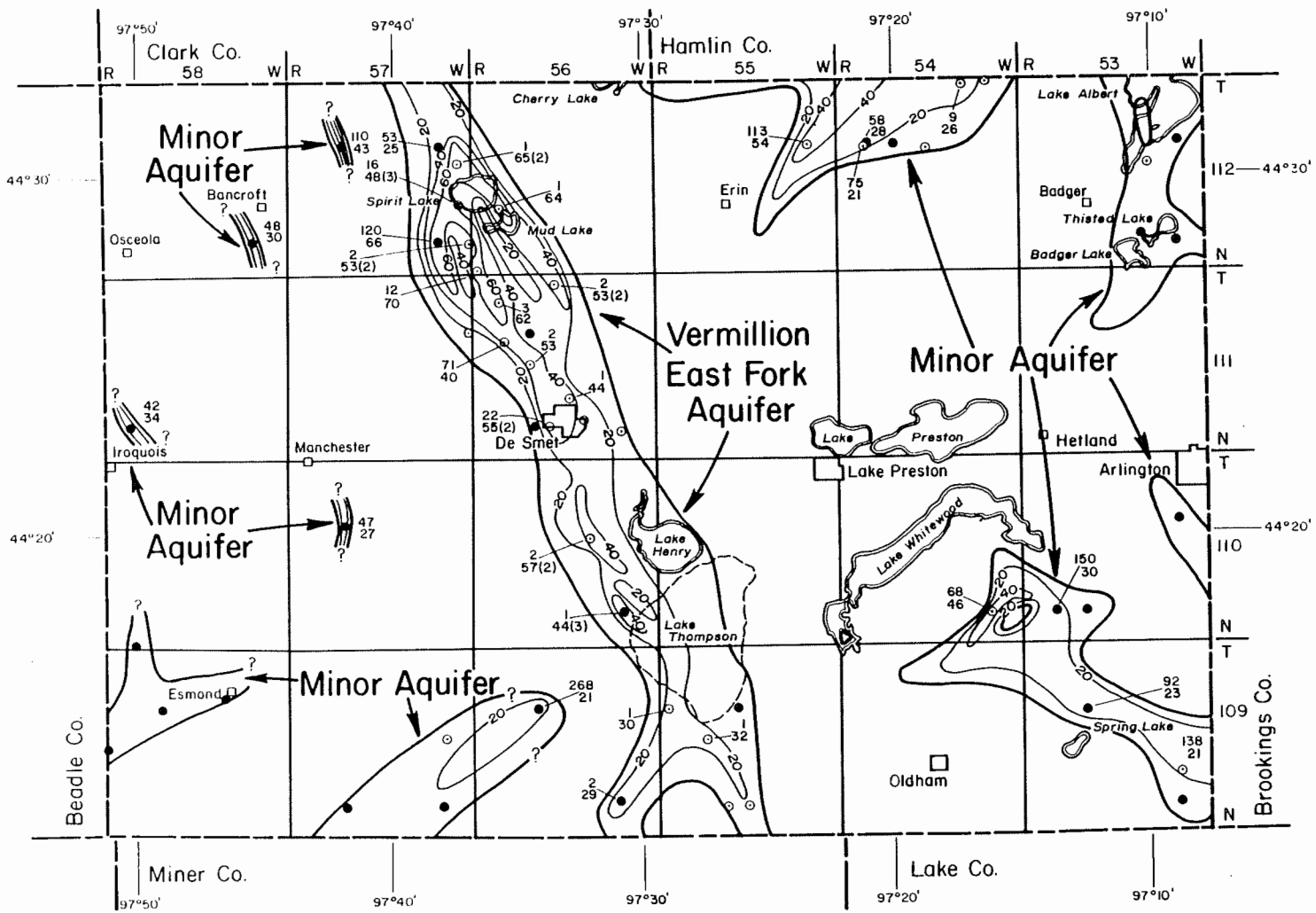


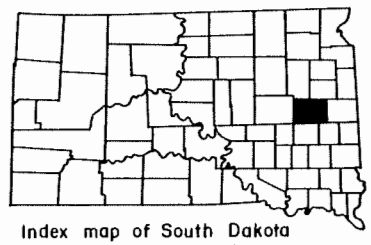
Figure 2. Extent, depth, and thickness of the Vermillion East Fork and minor aquifers.

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

N

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



Index map of South Dakota showing location of Kingsbury Co.

Explanation

40 — Line of equal thickness of sand and gravel. *(Interval = 20 feet.)*

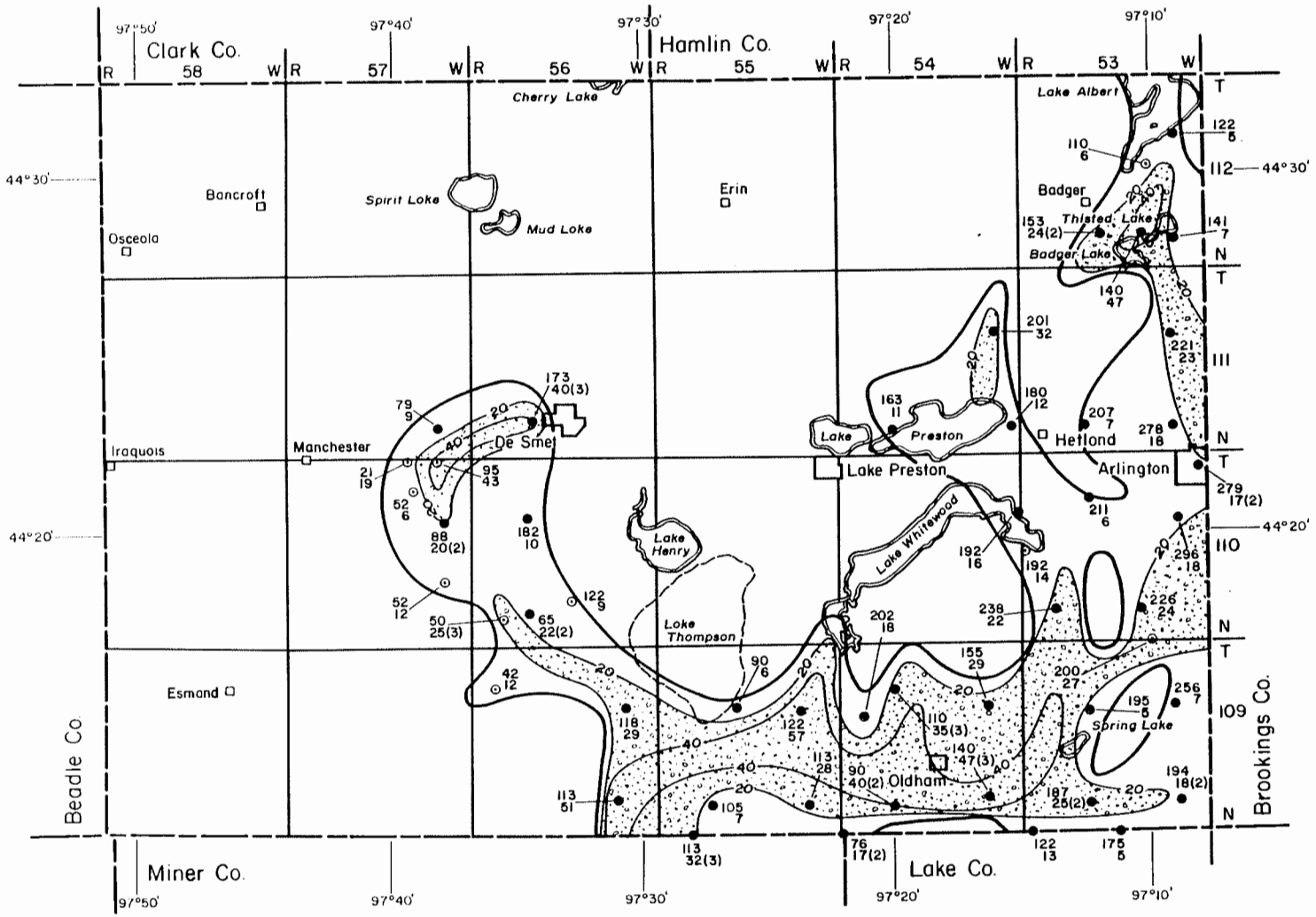
⊙ 1/32 Well or test hole not drilled into bedrock.

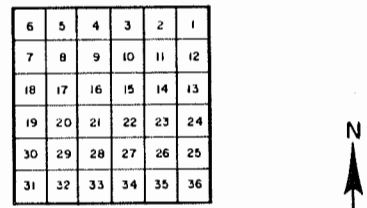
● 1/44(3) Well or test hole drilled into bedrock--*Numbers are for holes that penetrate more than 20 feet of aquifer. Upper number is depth, in feet, to sand and gravel. Lower number is thickness, in feet, of sand and gravel, including the unsaturated zone. Number in parenthesis is number of aquifer units where greater than one.*

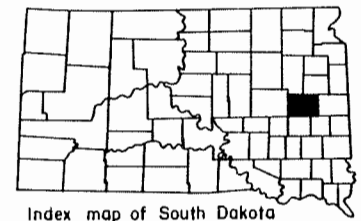
Aquifer boundary

? Aquifer boundary inferred

Figure 3. Extent, depth, and thickness of the Ramona aquifer.






Index map of South Dakota showing location of Kingsbury Co.

Explanation

Area of high probability of finding an aquifer unit at least 20 feet thick.

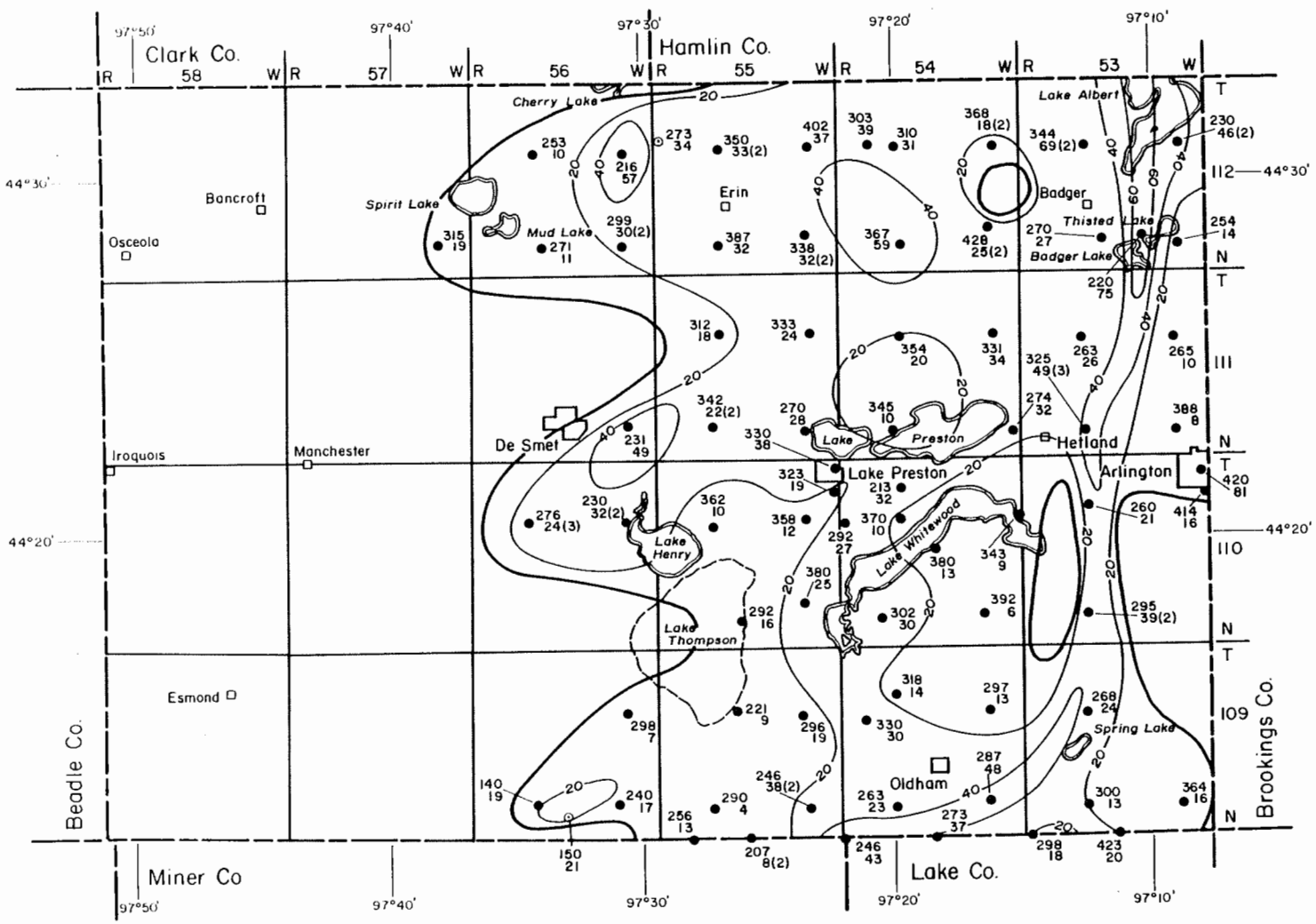
40 — Line of equal thickness of saturated sand and gravel. *(Interval = 20 feet.)*

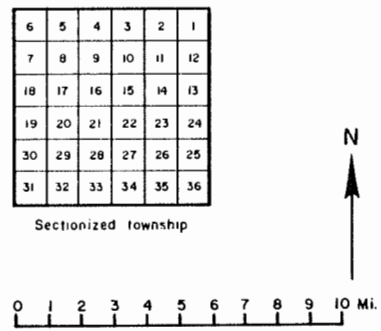
● 173 / 40(3) Well or test hole--*Upper number is depth to saturated sand and gravel aquifer, in feet. Lower number is thickness of saturated sand and gravel, in feet.*

⊙ 95 / 43 *Open circle indicates well or test hole not drilled into bedrock; thus, aquifer thickness may be greater than shown. Number in parenthesis is number of aquifer units where greater than one.*

Aquifer boundary

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





Index map of South Dakota showing location of Kingsbury Co.

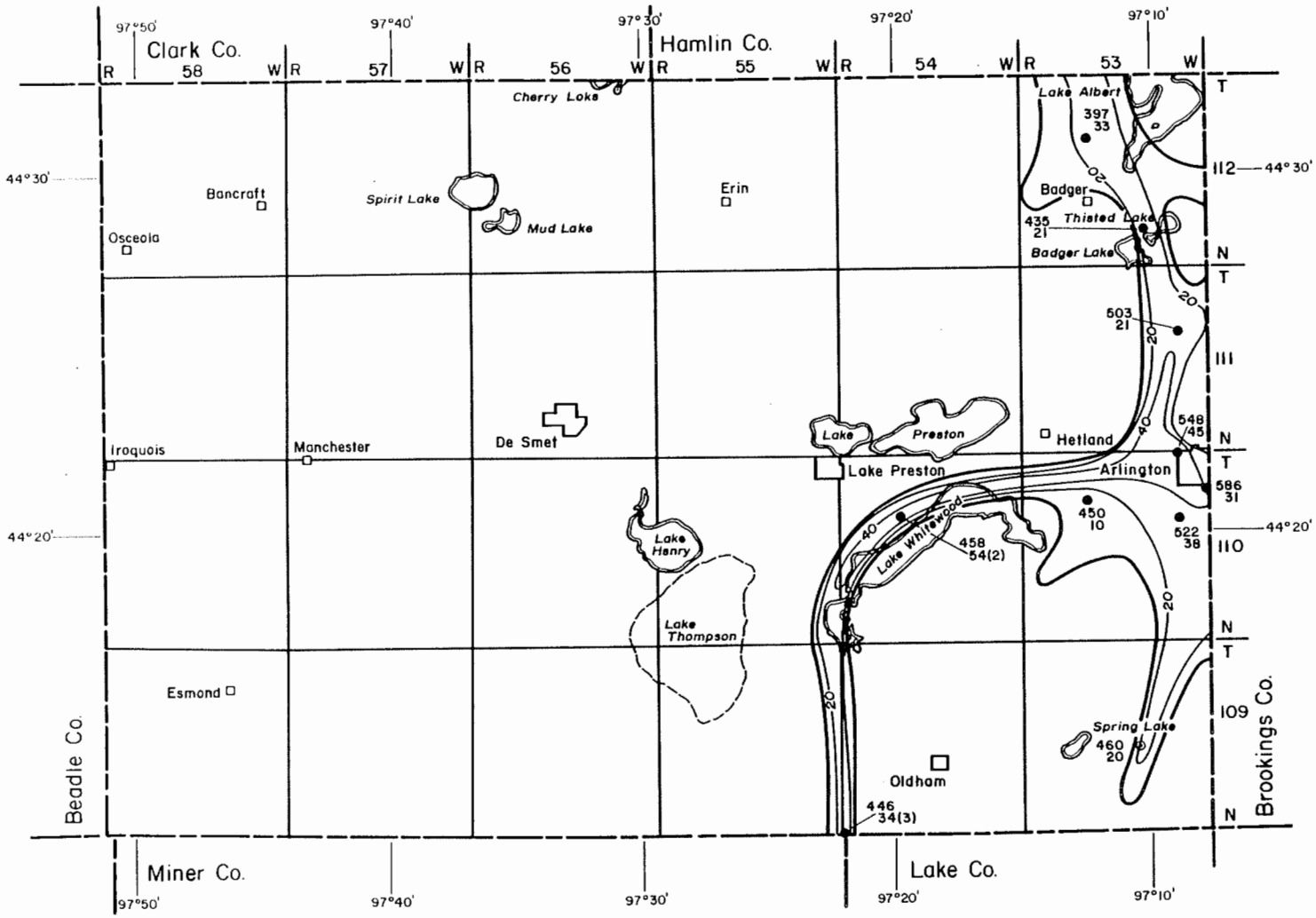
Explanation

40 — Line of equal thickness of saturated sand and gravel. *(Interval = 20 feet.)*

325 / 49(3) — Well or test hole--*Upper number is depth to saturated sand and gravel aquifer, in feet. Lower number is thickness of saturated sand and gravel, in feet. Number in parenthesis is number of aquifer units where greater than one.*

Aquifer boundary

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

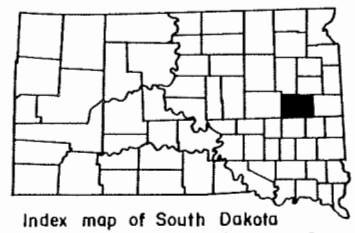


6	5	4	3	2	1	
7	8	9	10	11	12	
18	17	16	15	14	13	
19	20	21	22	23	24	
30	29	28	27	26	25	
31	32	33	34	35	36	

Sectionized township

N

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



Index map of South Dakota showing location of Kingsbury Co.

Explanation

40 — Line of equal thickness of saturated sand and gravel. *(Interval = 20 feet.)*

458/54(2) — Well or test hole -- *Upper number is depth to saturated sand and gravel aquifer, in feet. Lower number is thickness of saturated sand and gravel, in feet.*

460/20 — *Open circle indicates well or test hole not drilled into bedrock; thus, aquifer thickness may be greater than shown. Number in parenthesis is number of aquifer units where greater than one.*

Aquifer boundary

of greater thickness probably are not very extensive, widths being less than a few hundred feet. Minor aquifers have not been tested to determine if they can supply water to large-capacity wells.

Ramona Aquifer

The Ramona aquifer underlies an area of 250 mi^2 in the southern and eastern half of the county. Depths from land surface to the top of the aquifer range from 21 ft 3 mi east of Manchester to 296 ft near Arlington (fig. 3). The aquifer sand and gravel averages 20 ft in thickness and has a cumulative thickness that exceeds 40 ft in several areas. Maximum yields of properly constructed wells may reach 500 gal/min in areas where the thickness of sand and gravel exceeds 20 ft. Yields from wells in most of the aquifer should be lower than 500 gal/min because the aquifer generally is thin and contains poorly permeable, fine, silty sand. 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 30 ft below land surface in Range 57 West to 140 ft below land surface in Range 53 West.

Water from the aquifer is slightly saline and is a calcium sulfate type. Concentrations of dissolved solids range from 1,700 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 485 mi^2 in the eastern part of the county. Depths from land surface to the top of the aquifer range from 140 ft 6 mi southwest of Lake Thompson to 430 ft in the east at Arlington (fig. 4). The aquifer sand and gravel averages 25 ft in thickness but is more than 60 ft thick locally in the northeastern corner of the county. Maximum yields of properly constructed wells may be as much as 1,000 gal/min in areas where the aquifer thickness exceeds 20 ft, and the aquifer consists mostly of coarse sand and gravel. The Howard aquifer is confined beneath till, and water levels in wells range from 30 ft below land surface in the west to 200 ft in the east.

Water from the aquifer is slightly saline and is a calcium sulfate type. Concentrations of dissolved solids range from 1,800 to 2,800 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 depending on soil-drainage conditions. Water with concentrations of dissolved solids large than about 1,800 mg/L would be unsuitable for irrigating clayey, poorly permeable soil.

Altamont Aquifer

The Altamont aquifer underlies an area of 75 mi^2 along narrow bands that are 1 to 3 mi wide. Depths from land surface to the top of the aquifer range from 446 ft a few miles west of the city of Oldham to 588 ft at the city of Arlington (fig. 5). The aquifer sand and gravel averages about 25 ft in thickness and has a maximum thickness of 54 ft (composed of two separate layers) near Lake Whitewood.

Maximum yields of properly constructed wells may be as large 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. 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. Well yields would be less than 100 gal/min along the narrow reaches of the aquifer west of Arlington because the aquifer there is mostly poorly permeable, fine, silty sand. The Altamont aquifer is confined and aquifer water levels range from about 40 ft below land surface 4 mi north of Arlington to 220 ft below land surface at Arlington.

Few wells have been completed in the aquifer because of its limited extent, the large depths required for wells, and the availability of shallower aquifers. Water from 2 wells in the aquifer is slightly saline and is a sodium sulfate type. Concentrations of dissolved solids for the two wells were about 2,100 mg/L, and hardnesses of the water were 80 to 400 mg/L. The water probably 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 most of the county. Depths from land surface to the top of the aquifers range from 320 ft in the west to as much as 1,300 ft in the east and north-central areas. Both the Codell and Dakota aquifers consist mostly of fine-grained, cemented sandstone. Well yields generally are much less than from glacial aquifers because the sandstone is less permeable than the sand and gravel of glacial aquifers.

Codell Aquifer

The Codell aquifer underlies most of the county at depths ranging from 320 ft below land surface in the west to 900 ft below land surface in the east. The thickness of the aquifer averages about 80 ft but is greater than 100 ft in the Iroquois

and Lake Preston areas. 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 200 to 300 ft of relatively impermeable shale. Water levels in wells range from about 100 ft below land surface in the west to 340 ft below land surface in eastern Kingsbury County.

Water from the aquifer is slightly saline and is a sodium sulfate type. Concentrations of dissolved solids range from 1,700 to 2,100 mg/L. Hardness of the water ranges from 50 to 200 mg/L. The water is unsuitable for irrigation because of its large concentration of sodium.

Dakota Aquifer

The Dakota aquifer underlies most of the county at depths ranging from 770 ft below land surface in the west to 1,300 ft below land surface in the north-central part of the county. The aquifer is absent locally in the southeastern part of the county. The Dakota averages 300 ft in thickness but may be as much as 500 ft thick in the northern part of the county. The aquifer is underlain by basement rock that yields little or no water to wells. Yields of wells in the Dakota aquifer are estimated to range from 2 to 100 gal/min. The aquifer is confined by and separated from the overlying Codell by 200 ft of shale. Water levels in wells are estimated to range from 10 ft below land surface in the west to 360 ft below land surface in the eastern part of the county.

Water from the aquifer is slightly saline and is a sodium sulfate type. Concentrations of dissolved solids range from 2,100 to 2,300 mg/L. Hardness of the water ranges from 2 to 40 mg/L. The water is unsuitable for irrigation because of its large concentration 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, especially near lakes and in stream valleys, may lower lake levels and decrease streamflow.