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MAJOR AQUIFERS IN HUGHES COUNTY, SOUTH DAKOTA

by

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CONTENTS

ILLUSTRATIONS

TABLE

ABSTRACT

Large volumes of slightly saline ground water are stored in six major aquifers in Hughes County in central South Dakota. Three glacial aquifers of outwash sand and gravel store nearly one million acre-feet of water underlying an area of 220 square miles. The aquifers can yield as much as 1,000 gallons per minute of water to wells at depths of 300 feet. Water from glacial aquifers generally is suitable for most uses. The hardness of the water ranges from 137 to 3,700 milligrams per liter and averages 700 or 800 milligrams per liter for each aquifer. The water may contain excessive concentrations of iron and manganese. Concentrations of iron generally exceed 0.3 milligrams per liter and concentrations of manganese generally exceed 0.05 milligrams per liter.

Three bedrock aquifers store more than 100 million acre-feet of water in sandstone and limestone that underlie the entire County. These aquifers can yield more than 50 gallons per minute of water to flowing artesian wells at depths of from 800 to 2,600 feet. Shut-in pressures at the surface increase with well depth and can exceed 400 pounds per square inch in the Minnelusa-Madison aquifer. Water from the Dakota aquifer has a hardness that averages 230 milligrams per liter, but the hardness of water from the deeper bedrock aquifers averages about 1,400 milligrams per liter. The water also may contain excessive concentrations of iron and manganese, similar to water from glacial aquifers. Water from bedrock is either unsuitable or marginal for use in irrigation. Bedrock aquifers are a large geothermal resource. The temperature of water from the aquifers increases with increasing depth from 23 to 40 degrees Celsius.

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 occurrence, quantity, and quality of ground water available from the major aquifers in Hughes County. A comprehensive report to be published later will contain additional information on the hydrology and geology of the area. Information in this report is based on data collected by the U.S. Geological Survey and the South Dakota Geological Survey during 1980-83.

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 of Hughes County may contact the U.S. Geological Survey in Huron or the South Dakota Geological Survey in Vermillion.

The inch-pound of measurement used in this report may be converted to metric units by the following conversion factors:

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter (m3)
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	0.063	liter per second (L/s)
mile (mi)	1.609	kilometer (km)
square mile (mi2)	2.590	square kilometer (km2)
pound per square inch (lb/in2)	6.895	kilopascal (kPa)

DEFINITIONS OF TERMS

Alluvium: As used in this report, a general term for unconsolidated detrital material such as clay, silt, sand, or gravel deposited during the post-glacial period by a stream.

Aquifer: A 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.

Artesian aquifer: An aquifer in which the water level in a tightly cased well completed in the aquifer stands above the top of the aquifer.

Artesian well: A well completed in an artesian aquifer. Water in the well rises above the top of an artesian aquifer, but need not reach or rise above the land surface.

Basement rock: A general term for granite, quartzite, and other dense, impermeable metamorphic or igneous rocks that are the base of the hydrologic system.

Bedrock: A general term for the rock, usually consolidated, that in Hughes County crops out or underlies soil, sand, clay or other unconsolidated material.

Fresh water: Water containing less than 1,000 milligrams per liter of dissolved solids.

Glacial aquifer: An aquifer composed of materials derived from a glacier. In Hughes County, glacial aquifers consist mainly of unconsolidated sand and gravel deposited as glacial outwash.

Ground water: That part of subsurface water that is in the saturated zone.

Hardness: Dissolved calcium and magnesium salts that decrease the lathering ability of soap and form scale in boilers and pipes. Hardness is reported as calcium carbonate and is classified by the U.S. Geological Survey as follows:

Description	Milligrams per liter (mg/L)	Grains per gallon (gpg)
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

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada. The datum was formerly termed "Mean Sea Level."

Outwash: A general term for silt, clay, sand, gravel, or boulders that have been washed, sorted, and subsequently deposited by water from melting glacier ice. In South Dakota, sand and gravel are the major constituents of outwash.

Permeability: A measure of the capacity of a porous material to transmit a fluid.

Properly constructed well: A well constructed and developed to admit a maximum amount of water from an aquifer without excessive loss of hydraulic head at the well. This generally requires installing a well screen or perforated casing, and installing a gravel pack opposite the water-yielding interval of the aquifer. It may require developing the well to remove drilling mud and other fine-grained material from the aquifer adjacent to the well.

Saline water: Water containing more than 1,000 milligrams per liter of dissolved solids; slightly saline 1,000 to 3,000 milligrams per liter, moderately saline 3,000 to 10,000 milligrams per liter.

Saturated zone: Zone in which all voids are ideally filled with water under pressure greater than atmospheric. The water table is the upper limit of this zone.

Shut-in pressure: The hydrostatic pressure measured at the land surface when the flow of an artesian well is stopped.

Till: An unsorted, unstratified mixture of clay, silt, sand, gravel, and boulders deposited by a glacier. In South Dakota, clay and silt are the major constituents of till.

Water table: That surface of a water body at which the pressure is atmospheric. Generally this is the upper surface of the zone of saturation.

OCCURRENCE AND QUALITY OF WATER IN MAJOR AQUIFERS

Large quantities of slightly saline ground water are stored in aquifers underlying Hughes County, an area of 784 square miles in central South Dakota. There are three major glacial aquifers and three major bedrock aquifers in the area (table 1). The glacial aquifers, composed of outwash sand and gravel, underlie about 30 percent of the study area at depths ranging from a few feet to 300 ft below land surface. Major bedrock aquifers, composed of sandstone, siltstone, shale, limestone, and dolomite, underlie the entire County at depths ranging from 800 ft to 2,600 ft. Bedrock aquifers extend beyond the central part of South Dakota.

The hardness of water from glacial aquifers ranges from 137 to 3,700 mg/L. The hardness of water from bedrock aquifers ranges from 50 to 1,600 mg/L.

Glacial Aquifers

Most of the sand and gravel of the glacial aquifers in central South Dakota was deposited as outwash when a thick ice sheet melted in the area. Huge quantities of meltwater carved deep, wide channels in bedrock. Later, as the velocity and volume of the water began to decrease, sand and gravel was deposited in the channels. Till was deposited on top of the sand and gravel when the ice sheet readvanced into the area. When the ice sheet melted, sand and gravel was deposited by meltwater at shallow depths along the Missouri River and its tributaries. Alluvium subsequently deposited on top of the outwash is considered, for the purpose of this report, to be part of the glacial aquifers.

Gray Goose Aquifer

The Gray Goose glacial aquifer underlies an area of about 120 square miles in western Hughes County (fig. 1). The aquifer may yield as much as 800 gal/min of water to properly constructed wells drilled to depths ranging from 80 to 300 ft. The thickness of sand and gravel deposits exceeds 40 ft in many areas (fig. 2). The thickness averages about 40 ft and ranges from 8 to 84 ft (table 1). Most of the aquifer is under water-table conditions. The depth to water in wells ranges from about 15 ft in T. 112 N., R. 80 W., to 250 ft in T. 112 N., R. 78 W.

TABLE 1. Summary of hydrologic characteristics of major aquifers.

Major aquifer name	Areal extent (square miles)	Maximum thickness (ft)	Average thickness (ft)	Range of depth below land surface (ft)	Range of water level above(+) or below land surface (ft)	Estimated amount of water in storage * (acre-feet)	Range of reported well yields gallons per minute)	Suitable for irrigation
				GLACIAL AQUIFERS				
Gray Goose	120 **	84	40	0 to 300	15 to 250	610,000	10 to 800	Yes, locally no
Missouri River	55 **	111	30	0 to 160	4 to 100	210,000	10 to 1,000	Yes.
Highmore/ Blunt	45 **	45	20	15 to 120	9 to 30	110,000	10 to 500	Do.
				BEDROCK AQUIFERS				
Dakota	784 **	430	300	800 to 1,800	+230 to 230	30 million	2 to 1,600	No.
Sundance	784 **	140	130	1,200 to 2,000	+470 to +200	13 million	20 to 60	May be marginal
Minnelusa/ Madison	784 **	1,200	600	1,800 to 2,600	+1,120 to +310	60 million	50 to 500	Do.

* Not entirely recoverable through wells.

** Extends beyond the study area of 784 square miles.

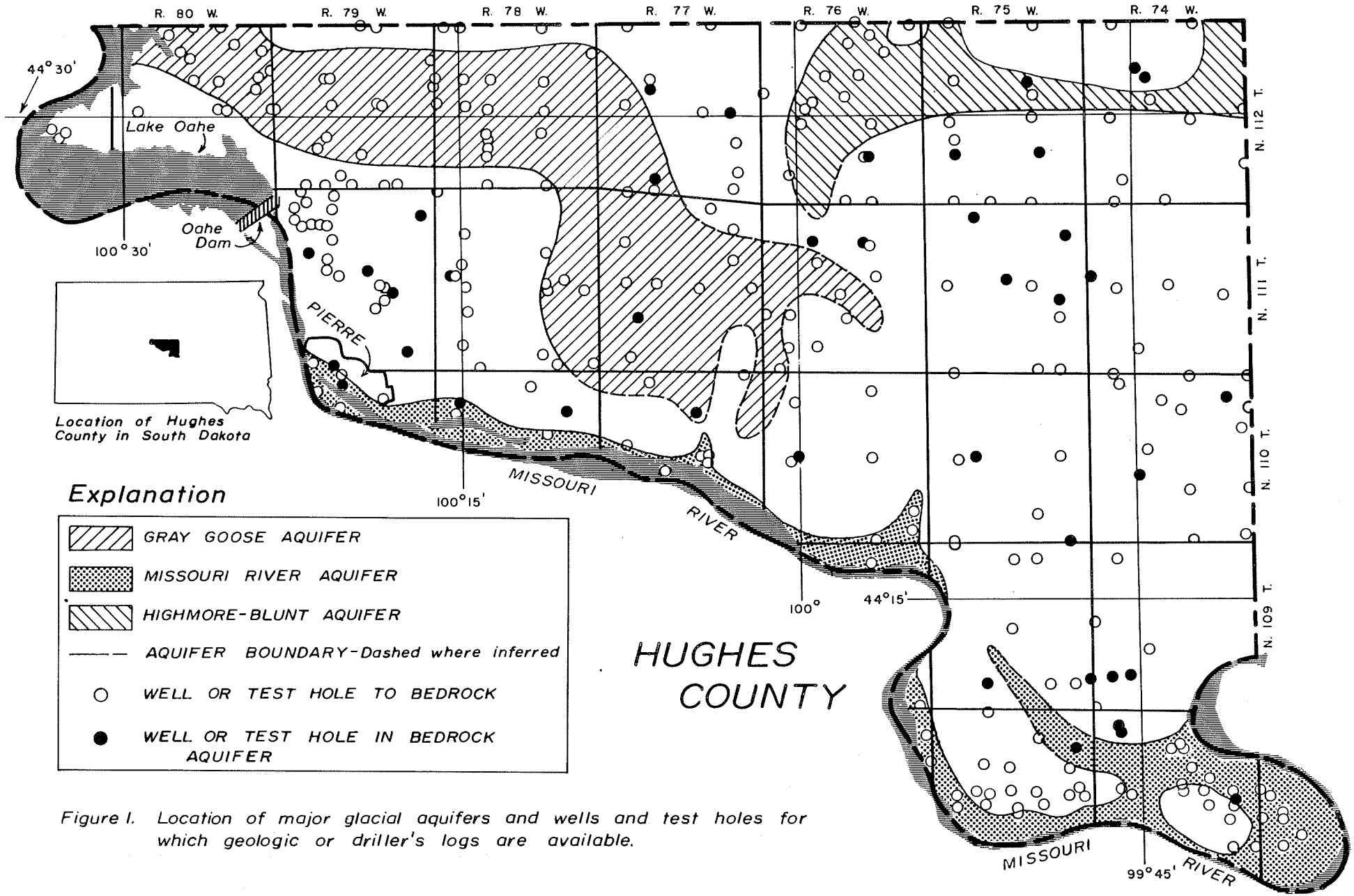

Figure 1. Location of major glacial aquifers and wells and test holes for which geologic or driller's logs are available.

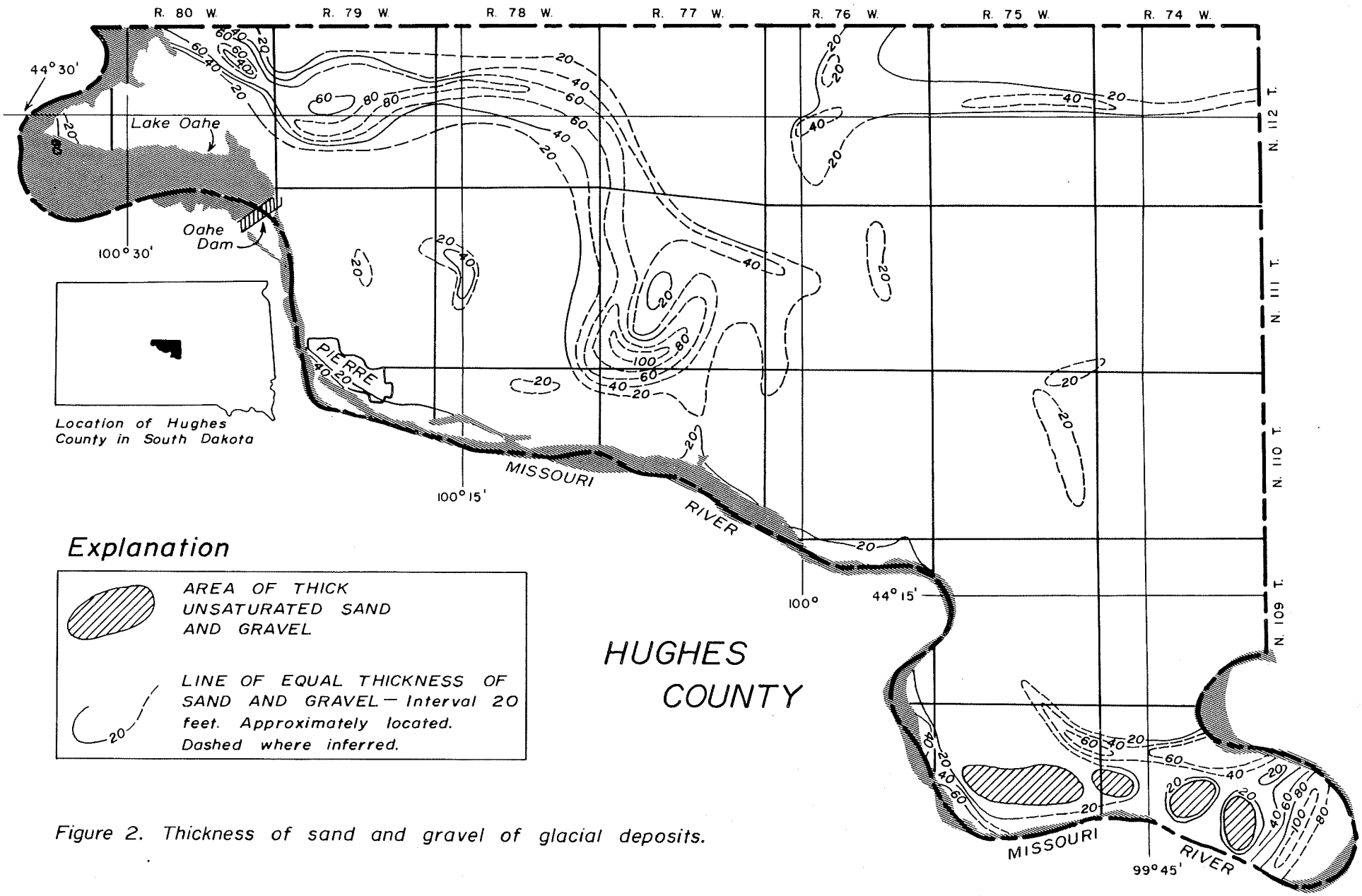

Figure 2. Thickness of sand and gravel of glacial deposits.

Water in the Gray Goose aquifer generally is slightly saline and of the calcium sulfate type. Concentrations of dissolved solids average 1,800 mg/L and range from 540 to 5,000 mg/L. Hardness averages 700 mg/L and ranges from 137 to 3,700 mg/L. The water generally contains excessive concentrations of iron and manganese. Concentrations of dissolved iron in excess of 0.3 mg/L and concentrations of dissolved manganese in excess of 0.05 mg/L cause staining of laundry, utensils, and fixtures, promote growth of certain kinds of bacteria, and are objectionable for food and beverage processing. The temperature of the water ranges from 11 degrees to 13 degrees C. The water generally is suitable for domestic, livestock, municipal, industrial, and irrigation use.

Missouri River Aquifer

The Missouri River glacial aquifer (fig. 1) underlies an area about 55 square miles in Hughes County beneath the flood plain of the Missouri River valley from Oahe Dam downstream to the southeastern border of the County. The area in the flood plain outside of the County is not mapped. The aquifer may yield as much as 1,000 gal/min of water to properly constructed wells at depths to 160 ft. Aquifer thickness averages about 30 ft and ranges from 2 to 111 ft (table 1). The water in the aquifer is under water-table conditions and the upper 10 to 20 ft may not be saturated in some areas. Terrace deposits beyond the aquifer in T. 108 N., R. 74 and 75 W. (fig. 2) contain sand and gravel that is more than 100 ft thick locally. These deposits are unsaturated, except for the lower few feet, and probably can yield no more than a few gallons per minute to a well. The depth to water in wells ranges from 4 to 30 ft except in the deeply buried part of the aquifer (sec. 12, T. 108 N., R. 75 W.) where the depth to water may be as great as 100 ft.

The aquifer generally contains fresh to slightly saline water of the calcium-sodium sulfate-bicarbonate type. Concentrations of dissolved solids average 1,900 mg/L and range from 470 to 4,400 mg/L. Hardness averages 800 mg/L and ranges from 220 to 2,200 mg/L. The water may contain excessive concentrations of manganese. The temperature of the water ranges from 11 degrees to 13 degrees C. The water generally is suitable for municipal, industrial, domestic, livestock, and irrigation use.

Highmore-Blunt Aquifer

The Highmore-Blunt glacial aquifer (fig. 1) underlies an area of about 45 square miles in the northeastern part of the County. The aquifer may yield as much as 500 gal/min of water to properly constructed wells completed at depths to 120 ft. Aquifer thickness averages about 20 ft and ranges from 2 to 45 ft (table 1). The upper part of the aquifer is either unsaturated or under water-table conditions but the lower part is confined beneath poorly permeable, clayey till and is under artesian conditions. The depth to water in wells ranges from 9 to 30 ft.

The aquifer generally contains fresh to slightly saline water of the calcium bicarbonate type. Concentrations of dissolved solids average 1,800 mg/L and range from 540 to 6,000 mg/L. Hardness averages 700 mg/L and ranges from 380 to 1,640 mg/L. Concentrations of iron and manganese generally exceed 0.3 to 0.5 mg/L, respectively, and have the undesirable effects as discussed previously for the Gray Goose aquifer. Temperature of the water ranges from 9 degrees to 11 degrees C. The water generally is suitable for municipal, industrial, domestic, livestock, and irrigation use.

Bedrock Aquifers

Dakota Aquifer

The Dakota aquifer, fine- to medium-grained sandstone interbedded with shale in the Cretaceous Dakota Formation, underlies and extends beyond the study area. The aquifer generally yields 2 to 500 gal/min of water to properly developed pumped or flowing artesian wells completed at depths ranging from 800 to 1,800 ft below land surface. However, a well at the State Capitol in Pierre, is reported to flow about 1,600 gal/min. The unusually large yield of this old well appears to be related to its original large yield of gas. A rapid drop in gas pressure probably caused fracturing of the sandstone formation, greatly increasing its permeability and consequently the yield of the well. Aquifer thickness averages 300 ft and ranges from 240 to 430 ft. Artesian pressure in the Dakota aquifer is sufficient to raise water levels above an altitude of 1,700 ft above sea level (National Geodetic Vertical Datum of 1929). This can produce shut-in pressures at the land surface of about 100 pounds per square inch at low elevations in valleys. Wells do not flow in upland areas where water levels can be more than 200 ft below land surface.

Water in the Dakota aquifer generally is slightly saline and of the sodium chloride type. Concentrations of dissolved solids average 2,100 mg/L and range from 1,200 to 3,500 mg/L. Hardness averages 230 mg/L and ranges from 50 to 580 mg/L. The water may contain concentrations of iron in excess of 0.3 mg/L that cause problems discussed previously for the Gray Goose aquifer. The aquifer is a large geothermal resource, and the temperature of the water ranges from 23 degrees to 35 degrees C. The water generally is suitable for domestic, livestock, municipal, and industrial use but is unsuitable for irrigating crops because of its high concentrations of sodium, boron, and dissolved solids.

Sundance Aquifer

The Sundance aquifer, fine- to medium-grained sandstone, siltstone, and shale in the Cretaceous Inyan Kara Formation and the Jurassic Sundance Formation, underlies and extends beyond the study area, 400 to 500 ft below the top of the Dakota aquifer. The aquifer is recharged by flow from the underlying Minnelusa

aquifer. It yields 20 to 60 gal/min of water to properly developed, high-pressure, flowing artesian wells at depths ranging from 1,200 to 2,000 ft below land surface. Aquifer thickness averages 130 ft and ranges from 80 to 180 ft. Shut-in pressures for wells completed in the Sundance aquifer range from 86 to 200 pounds per square inch at land surface.

Water in the Sundance aquifer is slightly saline and of the calcium sulfate type. Concentrations of dissolved solids average 1,960 mg/L and range from 1,900 to 2,300 mg/L. Hardness averages 1,400 mg/L and ranges from 633 to 1,540 mg/L. The water may contain excessive concentrations of iron and manganese. The aquifer is a large geothermal resource, with the temperature of the water ranging from 26 degrees to 41 degrees C. The water generally is suitable for domestic, livestock, and municipal use. The water probably is unsuitable for irrigating slow-draining soil because of its high concentrations of dissolved solids.

Minnelusa-Madison Aquifer

The Minnelusa-Madison aquifer, mostly sandstone, limestone and dolomite in the upper Paleozoic Minnelusa Formation and Madison Limestone, underlies and extends beyond the study area, 500 to 600 ft below the top of the Dakota. In the northern part of the County, the aquifer also includes about 600 ft of dolomite and sandstone that lie between the Madison and the relatively impermeable quartzite or granite basement rock that is the base of the hydrologic system. The aquifer yields 50 to 500 gal/min of water to properly developed, high-pressure, flowing artesian wells drilled to depths ranging from 1,800 to 2,600 ft. Aquifer thickness probably averages about 600 ft and ranges from 70 ft in the southeast to 1,200 ft in the northwest part of the County. Shut-in pressures for wells completed in the Minnelusa-Madison aquifer range from 134 to 485 pounds per square inch at land surface. The maximum pressure, measured in a 2,176-ft well at Pierre, may not be obtained in other areas of the County.

Water in the Minnelusa-Madison aquifer is slightly saline and of the calcium sulfate type. Concentrations of dissolved solids average 2,030 mg/L and range from 1,870 to 2,240 mg/L. Hardness averages 1,270 mg/L and ranges from 1,060 to 1,595 mg/L. Excessive concentrations of iron and manganese may be a problem, as discussed previously for the Gray Goose aquifer. The aquifer is an enormous geothermal reservoir, the temperature of the water ranging from 27 degrees to 49 degrees C. The water generally is suitable for domestic, livestock, and municipal use. The water probably is unsuitable for irrigating slow-draining soil because of its high concentrations of dissolved solids.

AVAILABILITY OF GROUND WATER FOR IRRIGATION

The best possibilities for obtaining wells capable of supplying yields sufficient for irrigation are in the areas where the

aquifers have a saturated thickness greater than 20 ft. Before irrigation wells are constructed, a test hole should be drilled at the selected location to determine the saturated thickness of the aquifer and to provide samples for determining the grain size of the aquifer material. This information will help in the selection of the proper slot size and length of screen to be used in the construction of a test well. Controlled pumping of the test well can show the yield of the aquifer at that locality and provide a water sample for chemical analysis. A knowledge of the type of soil and subsoil and the topography are important in determining the suitability of the land for irrigation, and in selecting the most suitable irrigation system.