STATE OF SOUTH DAKOTA
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STATE GEOLOGICAL SURVEY
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REPORT OF INVESTIGATIONS

No. 84

GEOLOGY AND SHALLOW GROUND WATER RESOURCES OF THE BROOKINGS AREA BROOKINGS COUNTY, SOUTH DAKOTA

by

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Union Building
University of South Dakota
Vermillion, South Dakota
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CONTENTS PAGE

ILLUSTRATIONS

TABLE PAGE

ERRATA

Pages ii and iv...Table 5 should be listed on page "42" not "36".

Page 8...Line 1, "Stage" not "State".

Page 25...Last column under "Name", line 12 should be "Fine" not "Find"

Page 27...Table "11" not "1".

Pages 42-62...Table "5" not "12".

Page 29...Table 12, "Percent in Millimeters" should be "Percent in Number".

GEOLOGY AND SHALLOW GROUND WATER RESOURCES OF THE BROOKINGS AREA

BROOKINGS COUNTY, SOUTH DAKOTA

By

K. Y. Lee

ABSTRACT

The surficial deposits of the Brookings area comprise chiefly drift of three subdivisions of the Wisconsin, the Iowan, Tazewell and Cary. The pebble fractions of the Iowan and Tazewell tills have only slight differences in percentage of the different rock types, but the Tazewell till is comparatively less oxidized, and somewhat fissile and blocky. The Cary drift is characterized by a remarkable end moraine, a distinctive lithologic composition, and by less leaching than the Iowan and Tazewell.

Outwash deposits of sand and gravel are ideal water-bearing sediments, and are good material for road and building construction. The quantity of sand and gravel is about 4,734,000,000 cubic yards, of which 30 percent is in the Big Sioux Valley. The total storage capacity of shallow ground water in the outwash deposits is approximately 1,066,000 acre-feet, and the Big Sioux outwash occupies 30 percent. The amount of ground water in the outwash deposits during the summer of 1957 was about 364,000 acre-feet, 40 percent of which was stored in the Big Sioux outwash. This ground water is generally satisfactory for human consumption, but water derived directly from sand lenses in the glacial tills is high in nitrate, sulfate, and iron.

INTRODUCTION

Purpose and Scope

This report is based on a geologic investigation of the Brookings area, as part of a program of mapping the geology of the Big Sioux River area. Field work was accomplished during the summer of 1957. The purpose of investigation was a detailed study of the economic geology of the glacial drift, with special emphasis on 1) the availability, movement, storage capacity, and quantity of the shallow ground water in the outwash sediments, for possible development of irrigation, and 2) the physical properties of the outwash sediments for possible use in road and building construction.

General Description of the Area

The Brookings area includes parts of four 15-minute quadrangles near the eastern border of the state (fig. 1), and is named for the city of Brookings. The Brookings area includes 380 square miles, of which the water-bearing glacial outwash sand and gravel occupies about 40 percent.

U. S. Highways 14 and 77 cross the area eastward and southward, and intersect in the city of Brookings. State Highway 30 passes eastward from U. S. 77 in the northern part of the area, and a well-developed network of gravel roads serves most of this area. The mainlines of the Chicago and North Western, and the Chicago, Rock Island, and Pacific railways are major avenues of transportation in the Brookings area.

The Brookings area has a continental climate with extreme summer heat, extreme winter cold, and rapid fluctuations of temperature. A United States Weather Bureau station is located at Brookings, where the average annual precipitation recorded from 1931 to 1956 was 19.55 inches. The mean annual temperature for the same period was 50.1 degrees (fig. 2).

The population of Brookings county is 17,800 (1950 census); it is more populous than counties farther west. Most of the residents of the county are concentrated in the following six towns and cities, all of which are in the area of this report:

Population, 1950 census

Brookings	7764
Volga	578
White	525
Bruce	305
Aurora	202
Bushnell	96

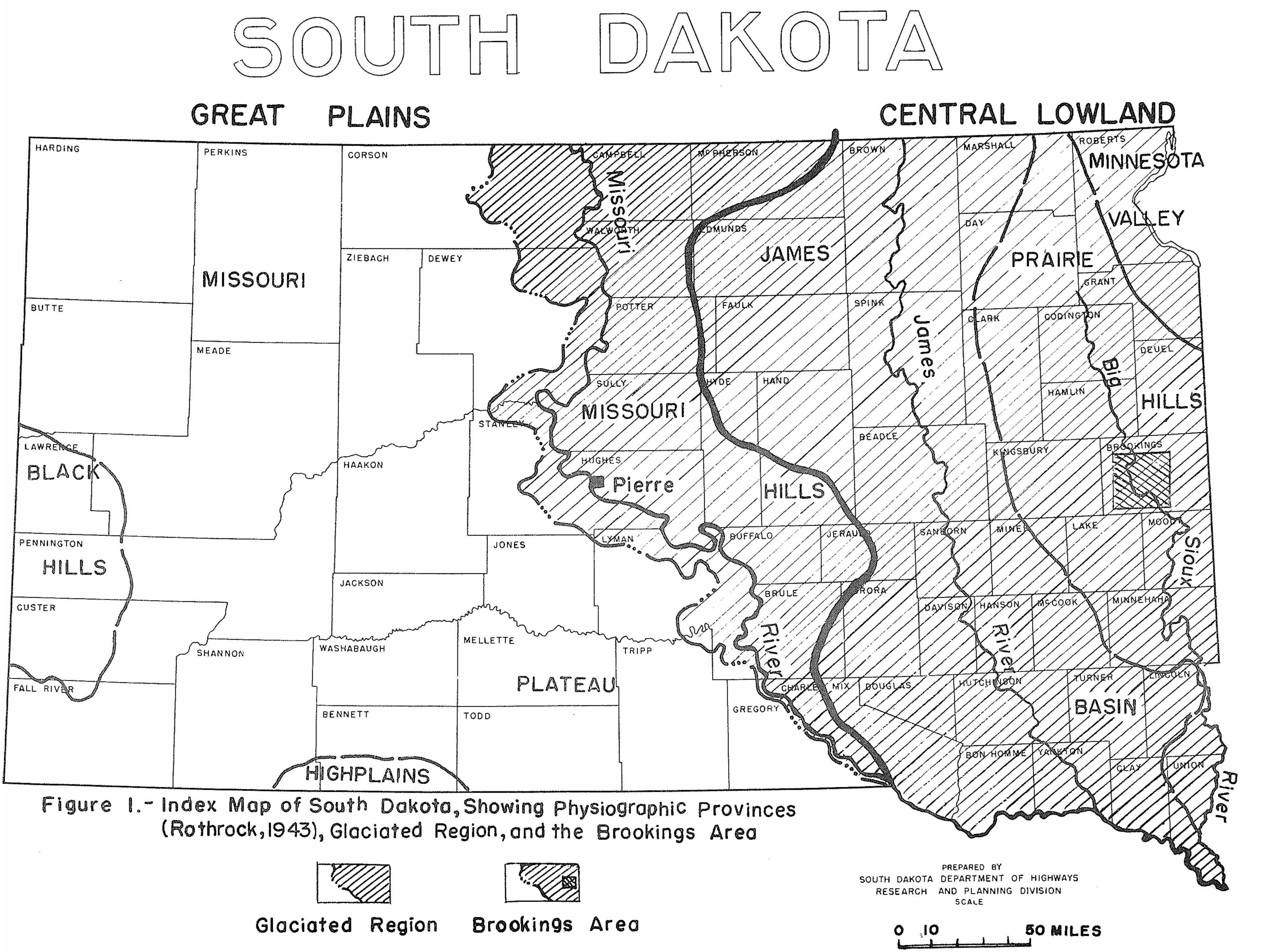

Figure 1.- Index Map of South Dakota, Showing Physiographic Provinces (Rothrock, 1943), Glaciated Region, and the Brookings Area

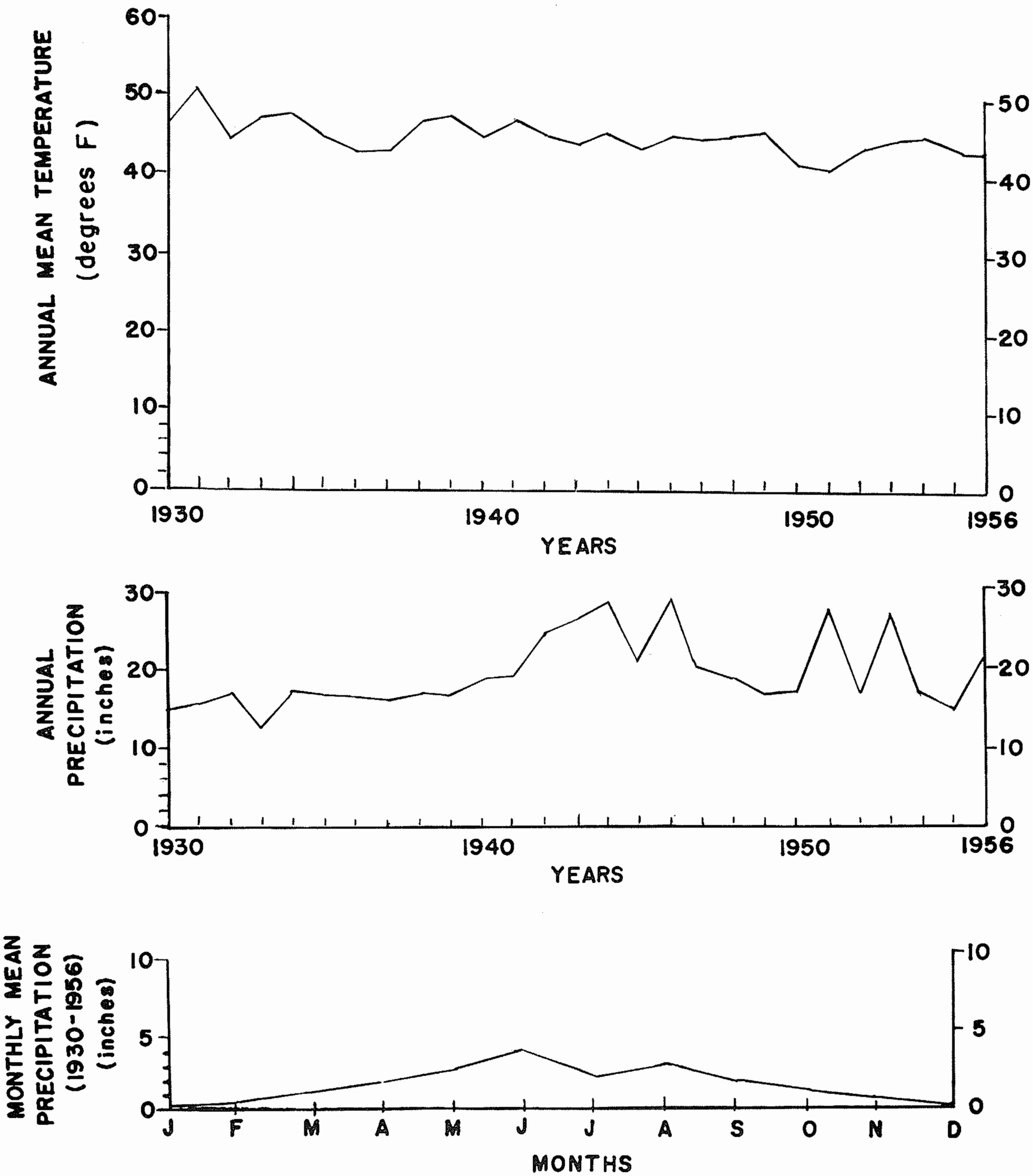

Figure 2.- Climatological Data, 1930 - 1956, at Brookings Weather Station

Farming is the chief occupation. Corn and wheat are the chief crops, and cattle and hogs the common livestock.

The soil is darkish-brown, generally loamy and sandy, and locally calcareous. The topsoil contains much organic material, and is silty especially in the till area. The texture of the topsoil ranges from light to heavy, and it has rather good permeability. The subsoil is gray to brownish-black with scattered caliche, and is less permeable than the topsoil. In the outwash area both topsoil and subsoil are silty and sand-rich, and the permeability is generally greater than that in the till area.

Heavy stands of grass occur along the Big Sioux River and its tributaries. Cottonwood and boxelder trees fringe the Big Sioux River.

Topography and Drainage

The Brookings area lies approximately in the central part of the prairie hills upland (fig. 1). The regional topographic features range from a gently sloping surface of glacial outwash, to an extremely undulating glacial morainal surface with both small and broad depressions. The topography is much dissected by the Big Sioux River and its tributaries. The maximum relief is 245 feet, and altitudes range from 1790 feet in the northeastern part of the area to 1545 feet in the southwestern part.

Ground Moraine

Moraine is an accumulation of drift built by the movement of an ice sheet. According to its topographic expression, moraine is subdivided into ground moraine and end moraine. Ground moraine is relatively widely distributed, thin compared with its areal extent, and usually has a gently undulating surface; end moraine on the other hand, is a ridgelike accumulation of drift built chiefly along the margin of the ice sheet; moraine consists of unsorted and unstratified till with included stratified sand lenses. Outwash is a glacial sediment deposited by meltwater along channels or as sheets on the surface of the moraine during the retreat of the ice sheet.

Drift is defined here as a mechanical mixture of till, gravel, sand or clay transferred by a glacier and deposited by the ice or by meltwater from the ice.

The Cary ground moraine in the western part of the area (Plate 1), is characterized by swells and swales with fairly steep slopes. Closed depressions with ponds and marshes occur near the contact of the Cary ground moraine and end moraine. The surface of the Cary ground moraine with rather gentle slope has been modified somewhat by stream dissection, and the local relief is locally greater than 20 feet.

The Iowan and Tazewell ground moraines consist of low swells and broad gentle depressions, merging in some places into the flat outwash surfaces. The depressions generally form an integrated system drained by the Big Sioux River and its tributaries. The surface of these moraines has an average relief of 10 feet, with a slope of about three degrees.

End Moraine

End moraine is represented by the Cary drift in the western part of the Brookings area, where it occurs as a ridge with steep slopes and many closed depressions. Local relief averages 20 feet at the Oakwood Lakes (northwestern corner of mapped area).

Glacial Outwash

The glacial outwash features of plain, valley train, and terrace are well-developed in the Brookings area. Two Cary outwash plains are recognized, one near Volga, and the other between Aurora and Bushnell (Plate 1). The local relief of the Volga outwash plain averages 4 feet, with a slope of about 5 feet per mile, and the Bushnell-Aurora outwash plain averages 7 feet in local relief, and its slope is about 13 feet per mile. The Bushnell-Aurora outwash plain is thus more dissected than the Volga outwash plain.

Valley trains are confined mainly to the present valley of the Big Sioux River and its tributary valleys. The highest elevation of the Big Sioux Valley train is 1630 feet at the northern border of the area, and the lowest elevation is 1545 feet at the southern border; this valley train has a slope of only 3 feet per mile. The slopes of the valley trains in Deer Creek and Medary Creek (east and southeast of Brookings) average 9 feet per mile, whereas those to the north and northeast average 12 feet per mile.

Outwash terraces occur sporadically along the western flank of the Big Sioux Valley and its tributaries. The surfaces of these terraces are comparatively flat; however, some of them have lost their distinctiveness because of slope wash, and most of the terraces are pocked by several iceblock depressions.

Along the western flank of the Big Sioux Valley northwest of Brookings the terraces are generally 10 feet above the Big Sioux River, but southwest of that city the terraces average 28 feet above the valley.

The terraces along the sides of Six Mile Creek and Deer Creek (northeast of Brookings) are pitted locally with broad depressions, and the local relief averages 7 feet.

A conspicuous kame terrace occurs farther upstream along Six Mile Creek, due west of the city of White. The surface of this terrace drops southwestward from 1758 feet to 1664 feet, and has a slope of 12 feet per mile. This terrace is pitted generally by small depressions, and it grades westward down the valley into valley train.

Brief History of the Main Drainage

The Big Sioux River is interlobate in origin (Flint, 1955, p. 152). It is believed that this river came into existence not later than the beginning of Wisconsin time (Wisconsin is the last of the four glacial stages). The main courses of Deer Creek and Medary Creek had their origin in the Cary (Table 1) end moraine to the northeast, and they transect the Tazewell and Iowan drifts; North Deer Creek, Six Mile Creek, and a creek northwest of Six Mile Creek, on the other hand, head in the Tazewell drift area; therefore the former two creeks came into existence during early Cary time, whereas the latter three probably existed during Tazewell time.

Previous Investigations

During the past sixty years several outstanding geologists have studied this region. First, Todd (1899) published a general account on the topography. About thirty years later, Leverett (1932) reviewed the general glacial features, and in 1945 Searight and Moxon presented the results of a reconnaissance study of the glacial drifts in this region. Flint (1955) included Brookings county in his study of the Pleistocene geology in eastern South Dakota during the summers of 1946 to 1949, and gave a detailed account on the glacial features and their chronology.

Present Investigation

The field geology was mapped mainly by plane-table (1:31,680), and was plotted partly on air photos (1:20,000). The thickness of the glacial outwash and the configuration of the buried surface of the underlying material was determined by electrical resistivity and by auger drill holes. Seventy-six resistivity stations were occupied and 42 test holes were drilled (fig. 3).

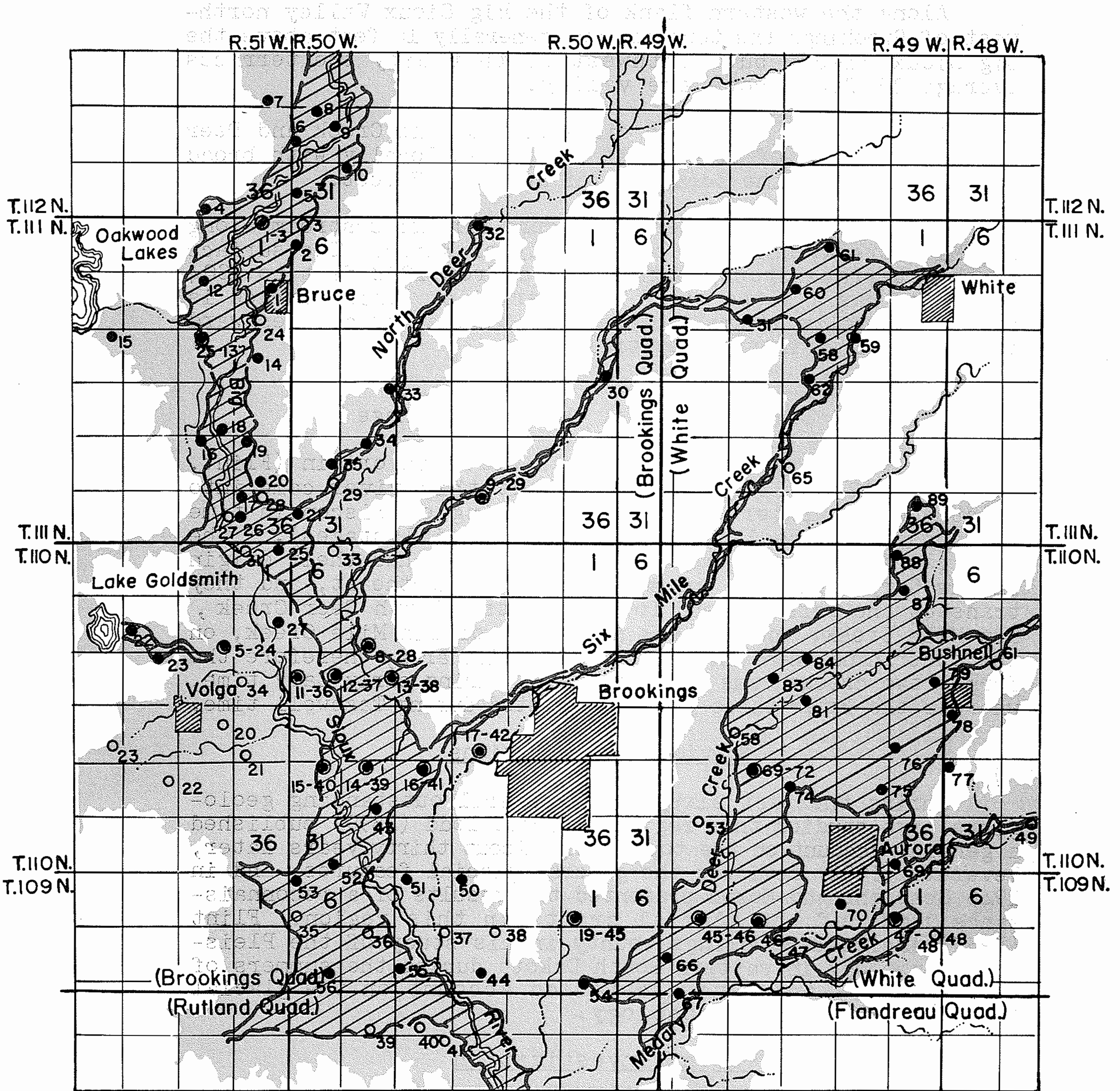

Figure 3.- Map Showing Locations of Resistivity Stations, Test Holes, Outwash (red), and Pre-outwash Channels (blue) in the Brookings Area
(base map by South Dakota Department of Highways)

● 43 Resistivity Station

◉ 16-41 Test Hole And Resistivity Station

○38 Test Hole

0 1 2 3 MILES

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The differentiation of the glacial drift sheet was accomplished by using topographic expression, pebble composition, stratigraphic sequence, and degree of weathering. The most reliable information in the Brookings area was provided by road cuts and stream exposures. A five-foot hand auger was used to determine the depth of leaching on the upland, where the material has been least modified by slope wash.

Water levels in 269 shallow domestic wells were measured by steel tape. Studies of the physical properties and the composition of the glacial drifts were made mainly in the laboratory of the State Geological Survey in Vermillion, and partly in the field work.

Acknowledgments

The geologic work described in this report was done under the supervision of Dr. A. F. Agnew, State Geologist. Daniel Lum, geophysicist, and field assistants and drillers Philip Lidel, Robert Hamill, Richard Von Holdt, and Darrell Buckmeier, provided much factual information. Special thanks is due to Dr. F. C. Westin, South Dakota State College and to the residents of the Brookings area for their cordial cooperation during various phases of this study.

GENERAL GEOLOGY

Surficial Deposits

The surficial deposits consist chiefly of Wisconsin glacial drift of Pleistocene age. Three subdivisions are recognized: Iowan, Tazewell, and Cary (Table 1; Plates 1 and 2). The Wisconsin drift consists of unstratified till, stratified outwash, and glacial lake sediments. Recent alluvial deposits occur along the sides of the Big Sioux River and its tributaries.

Pleistocene Series: Wisconsin Stage: Iowan Substage

General statement.--The Iowan drift consists of till with included stratified lenticular beds of sand and gravel, and outwash. It is well-exposed at a relatively low topographic position in all except the western and southwestern parts of the area. Some rounded rolling till ridges are termed Iowan, however, in the northwestern part of the area secs. 10, 15, and 22, T. 111 N., R. 51 W.

Till.--The Iowan till is gray to brownish- and greenish-gray, and the exposures are mostly oxidized. This till contains scattered pebbles in a clay-rich matrix. The depth of leaching on top of till ranges generally from 1 to 2 feet, and patches of loess up to 3 feet thick locally cap this till. Some white caliche zones are common in the upper part of subsoil developed on this till. The rock fragments of pebble size are 60 percent limestone and dolomite, 29 percent igneous and metamorphic rocks, 9 percent Pierre shale, clay-ironstone, and sandstone, and about 2 percent chert.

The driller's log of a test hole in sec. 30, T. 111 N., R. 48 W. indicated 19 feet of yellowish- to brownish-gray till, underlain by 15 feet of bluish-gray till with water-saturated sand lenses near the base. Next below is five feet of yellowish-to brownish-gray till. The thickness of Iowan till in this area as determined by test drilling ranges from 20 to 113 feet.

Outwash.--The Iowan outwash consists of sand and gravel with silt and clay on top, and occurs along the sides of a small creek a mile and a half northwest of Brookings (secs. 10, 15 and 16, T. 110 N., R. 50 W.). The outwash is divided into valley

Table 1.--Generalized Section of Surficial Geology in the Brookings Area, Brookings County, South Dakota

System	Series	State	Substage*	Lithologic** description	Thickness (feet)
QUATERNARY	Recent			Alluvium: Clay, silt and sand with some gravel	3-15
	PLEISTOCENE	WISCONSIN	CARY	Glacial lake sediments: clay and silt, confined to till area, or near the source of outwash	4-10
				Outwash: Plains, kame terraces, and valley trains; sand and gravel with silt and clay on top	9-185
				Till: Boulder clay with rock fragments, and sand rich matrix. Gray to brownish and greenish gray, when moist; light gray to buff, when dry. Locally with included stratified sand lenses, and patches of loessic material on top	20-45
			TAZEWELL	Outwash: Kame terraces and valley trains; sand and gravel with clay and silt on top	5-105
				Till: Pebble clay with clay-rich matrix; somewhat fissile blocky. Ferruginous sandy till present locally in the upper part. Gray to brownish-gray, when moist, weathered to buff. Stratified sand lenses locally	12-50
			IOWAN	Outwash: Sand and gravel with silt and clay on top	5-38
				Till: Gray to brownish and greenish-gray pebble clay with included stratified sand lenses; local loess	20-113

*Mankato not present

**Alluvial and glacial lake deposits of clay, silt and sand are transmitting agents in recharge of ground water.

Outwash yields water to wells where saturated.

Tills are transmitting agents in upland, and sand lenses yield supplies of water to wells.

Clay is potentially valuable material for ceramic industry.

Sand and gravel are good materials for road and building construction.

train and terrace deposits. The valley train occurs sporadically along the sides of this creek, although the terrace appears only on the southeastern side of this valley. The actual identification of this feature as a terrace is rather difficult, because of mass-wasting. Nevertheless, on the basis of lithology and topographic expression this terrace is tentatively classified as a kame remnant. A kame is an ice-contact feature that consists of ice-contact sand and gravel, and is expressed as low, steep-sided ridges. The thickness of the outwash as determined by the measurement of domestic water wells ranges up to 38 feet.

Tazewell Substage

The Tazewell drift is represented by till and outwash, and is exposed at a higher altitude than the Iowan, and mainly in the northeastern part of the Brookings area. Stratified drift is included locally. The depth of leaching on top of the outwash averages 18 inches. The leached zone grades downward from the base of soil profile into silty clay and fine-grained sand. Locally, pebbles and caliche occur near the base. Fine laminations in the silty sediments are conspicuous, indicating that these sediments were formed by glacial melt-waters with weak current, during the latest stage of ice retreat.

Till.--The Tazewell till is gray to brownish- and yellowish-gray, less oxidized than the Iowan, somewhat fissile and blocky, with bluish-gray streaks and oxidized patches; ferruginous sandy pebble till is usually present in the upper part. A sample collected north of the city of White shows that the rock fragments consist of 66 percent limestone and dolomite, 22 percent igneous and metamorphic rocks, and 12 percent clastic rocks. The exposed thickness of this till ranges from 12 to 50 feet.

Outwash.--The Tazewell outwash is represented by valley train and kame terrace. The outwash was built mainly along several tributary valleys of North Deer Creek, Six Mile Creek, and the creek northwest of Six Mile Creek. Rock fragments comprise 58 percent limestone and dolomite, 24 percent igneous and metamorphic rock types, 16 percent shale, sandstone, and clay-ironstone, and two percent chert. The thickness of the outwash ranges from 5 to 105 feet.

Cary Substage

The Cary drift consists of till with some included stratified sand lenses, outwash, and glacial lake sediments. This drift occupies about half of the Brookings area, and is well-exposed in the western, central, and southeastern portions of this area.

Till.--The Cary till is classified as "Boulder clay" with sand-rich matrix. It belongs to the eastern limb of the James ice lobe, and by topography is the western extension of the Altamount moraine of the Des Moines lobe. This till is exposed only in the western portion of the area, where it is gray to brownish- and greenish-gray with some bluish-gray streaks, and weathers light-gray to buff. It attains an exposed thickness ranging from 20 to 45 feet.

The soil on the Cary is more sandy than that developed on the Iowan and Tazewell tills, and it carried a leached zone up to one foot thick. Loessal materials are locally present near the base of the topsoil in places of low topographic position, and patches of caliche are commonly scattered through the subsoil.

Rock fragments in the till are made up of 37 percent limestone and dolomite, 29 percent igneous and metamorphic rocks, and 31 percent shale, clay-ironstone, some sandstones. The exposed thickness ranges from 5 to 45 feet.

Outwash.--The Cary outwash is subdivided into plain, valley train, and terrace. This outwash occupies 34 percent of the Brookings area, and is well-developed in the Big Sioux Valley, and along the west flank of this valley, and the courses of Deer Creek and Medary Creek.

The outwash plain is confined to the vicinity of Volga on the west, and the area between Aurora and Bushnell on the east. The Volga outwash plain was built by meltwater from the end moraine to the west, whereas the Aurora-Bushnell outwash plain came from the end moraine to the east. Each side of this outwash was built up as fans, which coalesced and migrated toward the respective end moraines, resulting in a receding system of coalescent area on each side of the Big Sioux Valley.

In the western part of the area, several small eskers which are meltwater-deposited sinuous sub-ice ridges of sand and gravel, are near the source of outwash; ice-contact stratified drift appears near the heads of the outwash. The surface of this outwash is generally pitted with steep-sided small depressions, which were made by the melting of masses of buried ice.

The valley train is remarkably displayed along the Big Sioux River and its tributaries, especially in Deer Creek, and part of Medary Creek. The Big Sioux Valley train was derived mainly from upstream, and also from both sides. Four major pre-outwash valleys are present along the western margin of the Brookings area. One originates from the site of Oakwood Lakes, a second leads away from Lake Goldsmith, a third is in sec. 30, T. 110 N., R. 51 W., and a fourth is in sec. 22, T. 109 N., R. 51 W.; they enter the Big Sioux Valley from the west. On the other hand, the present course of Deer Creek and its tributaries were the main spillways of outwash from the east during the Cary ice retreat. Remnants of kame terrace are sporadically present along the sides of Deer Creek on the east, and west side of the Big Sioux Valley.

The Cary outwash consists of sand and gravel with some silt and clay. The coarse gravel is made up of 52 percent limestone and dolomite, 33 percent igneous and metamorphic rocks, and 15 percent sandstone and clay-ironstone. The sand and silt detritus comprises chiefly coarse-grained silt in which quartz constitutes more than 90 percent, with more than 4 percent of accessory minerals (pink feldspar, chert, iron-oxides, tourmaline, hornblende, mica, and aragonite), and 5 percent of rock fragments (granite, schist, slate, limestone, ironstone, shale, and fine-grained sandstone). The thickness of the outwash ranges from 9 to 185 feet.

Glacial Lake Sediments.--The glacial lake sediments are fine-grained clay and silt, which accumulated in temporary lakes in small depressions of the Cary till area, and near the source of the Cary outwash. These depressions were formed probably by pocked ice, and subsequently erosion removed locally the mantling sediments. The thickness of the glacial lake sediments ranges from 4 to 10 feet.

Recent

Alluvial deposits of clay, silt, and sand with some gravel occur along the sides of the Big Sioux River and its tributaries. Fine laminae are more predominant in these sediments than in the glacial outwashes. The thickness of these alluvial deposits range from 3 to 15 feet.

Subsurface Rocks

The subsurface rocks of the Brookings area are inferred on the basis of driller's logs (Erickson, 1954, p. 88-89). The rock formations penetrated by drilling in the adjacent Kingsbury and Hamlin counties to the west and north constitute 182-362 feet of Pierre shale, which overlies 30-138 feet of Niobrara chalk, which is followed below by 184-250 feet of Carlile shale, and 22-35 feet of Greenhorn limestone. Below the Greenhorn limestone are the Graneros shale and the Dakota sandstone, which are more than two hundred feet thick

Although the Pierre shale is not exposed in this area, it is probably present beneath the glacial drift, because of scattered reports that some deep domestic wells near Brookings penetrated shale beneath the glacial drift.

Structure

The surficial deposits of Wisconsin drift and Recent alluvium lie unconformably on the eroded surface of Pierre shale. The structure of the subsurface rock formations is extrapolated from driller's logs in the adjacent counties (Erickson, 1954). The regional structure west of the Brookings area shows a rather broad anticlinal fold whose crest extends approximately through the central part of this area, and plunges about N. 15° W. at 30 feet per mile (Erickson, 1954, p. 51).

The southwestern limb of this anticline turns into a broad synclinal fold at the southwestern corner of Brookings county. This synclinal fold plunges about N. 30° W., and its axis is more or less parallel with that of the anticlinal fold to the northeast.

ECONOMIC GEOLOGY

The Wisconsin glacial drift plays a major role in the economic importance of the Brookings area. Shallow ground water resources, sand and gravel, and clay are the most important potential economic geologic resources.

Shallow Ground Water Resources

General Setting

The shallow ground water resources in the Brookings area are controlled by the mean annual precipitation, the character of the country rock, (see Plates 1 and 2) and the areal topography. The discussion will include the source, the occurrence, the storage capacity of shallow ground water in the outwash deposits, the quality of water, the movement of water, the utilization of water, and suggestions for the future development of irrigation.

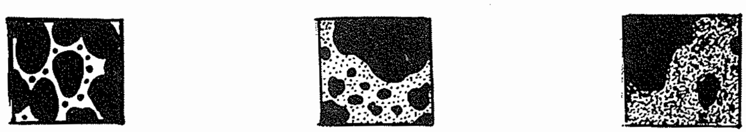
Source

The shallow water is furnished entirely by precipitation in the form of rain or snow. Part of the water is carried away by surface runoff, and is eventually lost to streams; most of the water however, percolates downward through the sandy soil and underlying unsorted tills to the watertable, where it joins the body of shallow ground water in the zone of saturation. The processes of evaporation and transpiration are considered to play subordinate roles in the loss of precipitation in the Brookings area.

Occurrence

The occurrence of shallow ground water is controlled by the physical properties and the distribution of outwash. The physical properties of the outwash are deduced by textural study.

Textural study of sand and gravel is the basis for estimates of the porosity and permeability of these sediments. Porosity is the percentage of interstices in a sediment (fig. 4). High porosity would be represented as a steep curve on Figure 5. Permeability bears no direct relationship to porosity, but is determined by size, shape, and arrangement of the openings in a sediment, and is defined as the capacity for transmitting water under hydraulic head. Well-sorted sediments have a highly uniform particle size. Poorly sorted sediments are generally less permeable than well-sorted sediments, although they may have comparable porosity. A sediment containing very small interstices may be very porous, but it would be difficult to force water through it, whereas a coarser-grained sediment that may have less porosity generally is much more permeable than a fine-grained sediment. The relation of grain size to permeability is well-illustrated by Table 2.



Well - sorted Outwash Sand; High Porosity

Poorly Sorted Outwash Gravel, Sand, Silt; Low Porosity

Unsorted Glacial Till With Much Clay; Very Low Porosity

Figure 4.- Diagram Showing Three Types of Interstices of Glacial Deposits And Their Relation to Porosity

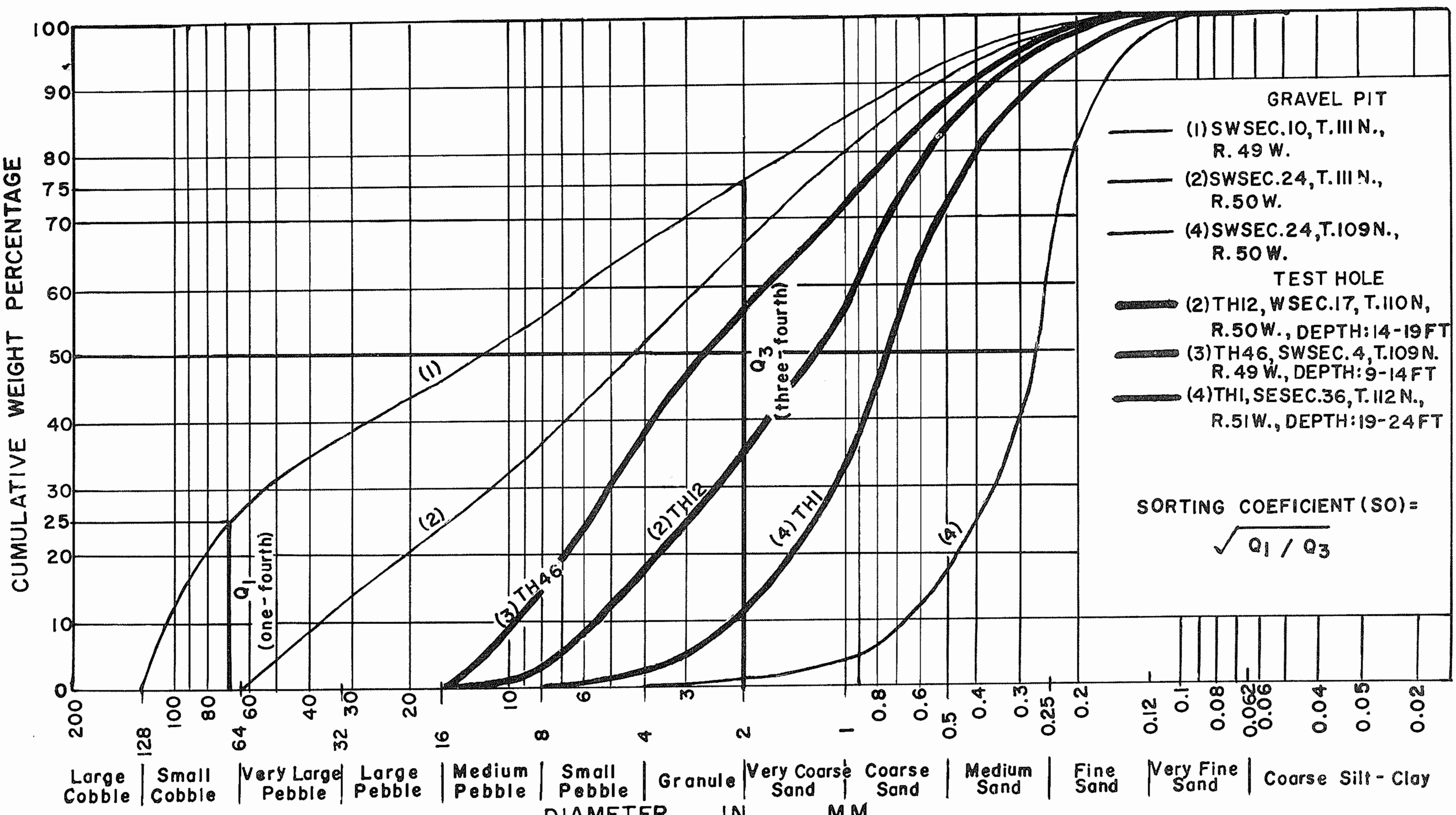


Figure 5. - Cumulative Curves Showing Grain-Size Frequencies of Some Outwash Sediments in the Brookings Area

Table 2.--Relationship of Grain Size to Permeability
(after Foley, 1950, p. 116)

Size of Grain (mm) (percent by weight)								Apparent Sp. Gr.	Porosity percent	Coef. of permeability (gallons per day per sq.ft)
Larger than 2.0	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.125	0.125-0.062	0.062-0.005	Smaller than 0.005			
	0.6	1.0	3.0	5.7	24.7	44.0	21.0	1.62	58.2	0.0002
			2.5	0.9	1.0	45.3	49.3	1.20	55.5	0.2
19.6	24.2	17.4	25.9	8.8	1.3	1.5		1.54	37.0	30
15.4	15.2	20.2	19.5	16.4	7.0	4.5	1.5	1.92	26.3	150
29.7	16.9	18.9	17.1	15.4	1.3	0.4	0.2	1.90	27.1	480
17.9	31.4	32.2	14.0	2.0	0.8	0.4		1.63	31.4	1200
40.4	15.5	22.8	16.5	3.9	0.4	0.3	0.1	1.87	27.2	2600
75.2	8.6	9.4	5.2	0.7	0.2	0.2*		2.06	23.4	4200
68.2	14.8	11.8	4.2	0.4	0.1	0.2*		1.86	25.6	12,800
90.0	7.9	1.0	1.0	0.1	0.1	0.1*			38.0	90,000

*Includes clay

In the Brookings area, the outwash sand and gravel range from well-sorted to poorly sorted, and have an average porosity of about 34 percent. Gravel is rather predominant in the outwash deposits; therefore the passage of fluids is comparatively easy through these sediments.

Ground Water in Transient Storage in the Outwash Deposits

The storage capacity of shallow ground water in outwash deposits is estimated by referring to the sorting coefficient of the outwash, which generally influences the porosity. Local porosity varies greatly; thus the porosity of the outwashes in the Brookings area is averaged for the individual outwashes (Table 3).

Table 3.--Water Storage Capacity of Glacial Outwash in the Brookings Area

Name of Outwash	Reserves of sand and gravel (cubic yards)	Storage Capacity* in Reservoir (acre-feet)	Amt. of Water** in Reservoir (acre-feet) summer, 1957
Big Sioux Valley	1,505,000,000	373,000	157,000
West of the Big Sioux Valley	533,000,000	96,000	26,000
Aurora-Bushnell	725,000,000	138,000	42,000
Medary Creek	282,000,000	70,000	4,000
Deer Creek	899,000,000	223,000	74,000
North Deer Creek	182,000,000	34,000	14,000
Six Mile Creek and Adjacent Creeks	608,000,000	132,000	47,000
TOTAL	4,734,000,000	1,066,000	364,000

*Estimated on the basis of average porosity from cumulative curves (fig. 5).
Big Sioux Valley, 40%
West of the Big Sioux Valley, 27%
Aurora-Bushnell, 30%
Medary Creek, 40 % Deer Creek, 40%
North Deer Creek, 30%
Six Mile Creek and Adjacent creeks, 35%

**Estimated from storage capacity and the average of saturation (measured during the summer of 1957).

The storage capacity data for the glacial outwash in the Brookings area are shown in Table 3. The total storage capacity in the outwash deposits of the Brookings area is about 1,066,000 acre-feet, which is computed directly from the cubic yards of sand and gravel; the Big Sioux outwash contains 30 percent of that amount. During the summer of 1957 the total amount of water stored in the Brookings area was estimated at 364,000 acre-feet, of which 40 percent is stored in the Big Sioux Valley.

Quality of Water

The quality of water is very important in determining its suitability for domestic and irrigational purposes. The quality of the water is discussed on the basis of chemical analyses (Table 4). The most important items concerning use of the water for human consumption include alkalinity, acidity, and purity. Alkalinity is due to the presence of dissolved carbonates of the alkaline earth metals, acidity is due to the presence of acids, and the purity is governed by bacteria and other organic compounds.

Table 4.--Water Analyses of Shallow Wells in the Brookings Area

Sample No.	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11**	12**
Contents	parts per million											
Ca (Calcium)	174.0	104.0	118.0	81.0	80.0	92.0	106.0	84.0	56.0	126.0	153.0	139.00
Mg (Magnesium)	200.0	52.0	52.0	30.0	39.0	43.0	58.0	43.0	33.0	54.0	50.0	64.40
Na (Sodium)	74.0	12.0	28.0	14.0	12.0	26.0	47.0	30.0	7.0	21.0	31.5	1.70
K (Potassium)	3.0	2.0	4.0	4.0	2.0	3.0	85.0	8.0	2.0	3.0		
SO_4 (Sulphate)	415.0	78.0	80.0	75.0	63.0	15.0	323.0	88.0	58.0	268.0	279.0	55.60
N (Nitrate)	122.0	36.0	6.0	11.0	7.0	4.0	6.0				.9	56.00
Cl (Chloride)	180.0	38.0	45.0	8.0	10.0	45.0	13.0	20.0	5.-	5.0	4.8	49.70
Fe (Iron)			0.1-			1.6				7.3	3.5	0.16
SiO_2 (Silica)	26.0	22.0	24.0	26.0	24.0	20.0	24.0	27.0	17.0	23.0		
$CaCO_3$ (Bicarbonate)	200.0	225.0	342.0	185.0	235.0	311.0	255.0	315.0	215.0	277.0	398.0	342.00
$CaCO_3$ (Carbonate)			30.0	10.-	20.0	64.0	40.0	10.-	10.-	10.-		
Hardness ($CaCO_3$)	407.0	475.0	510.0	325.0	361.0	405.0	504.0	385.0	275.0	535.0	595.0	616.00

*Analyst: C. Olson, Head, Station Biochemistry, South Dakota Agricultural Experiment Station, State College, Brookings, South Dakota, 1957

**Analyst: C. D. Dunbar, Division of Sanitary Engineering, South Dakota State Board of Health, Pierre, South Dakota , 1952

1. G.Intermille, sec.2, T.111N., R.51W.
2. W.A. Yule, sec.12, T.111N., R. 49W.
3. C.Churchill, sec.28, T.111N.,R.49W.
4. C.C.Bulen, City of Aurora
5. P.E.Norton, City of Bushnell
6. L.Engel, sec.4, T.110N., R. 49W.
7. E.H. Meyer,sec.12, T.110N.,R.49W.
8. H.J.Clapp, City of Volga
9. P.Skovlund, sec.1, T.111N.,R.51W.
10. City Well No. 1, Brookings
11. City Well No. 2, White
12. City Well No. 1, White

The alkaline waters carry the chief compounds that result in "hardness"; there are two kinds of hardness: temporary and permanent. Temporary hardness is due generally to the presence of calcium and magnesium bicarbonate; it is also known as "carbonate hardness". This hardness can be partially removed by boiling and completely destroyed by judicious addition of lime. Permanent hardness, also called "noncarbonate hardness", is chiefly due to the presence of calcium and magnesium sulfates and chlorides. This hardness is best counteracted chemically, by the use of quicklime or barium carbonate and barium oxide.

Ten samples collected for the chemical analysis show that the principal ions of the water in the Brookings area are bicarbonate, sulfate, calcium, and magnesium; subordinate ions are sodium, potassium, nitrate, chloride, iron, and silica. For human consumption, carbonate hardness should be less than 500 parts per million, iron concentration should be less than 0.3 parts per million, sulfate less than 250 parts per million, and nitrate less than 3 parts per million. According to the above limits, the carbonate hardness of the shallow ground water in this area is entirely satisfactory for human use; however the concentration of sulfate, iron, and nitrate deserve serious consideration. Samples 1, 7, 10, and 11 show sulfate concentration greater than 250 parts per million; this ion may cause a laxative effect on the human body, and also makes poor water for irrigation. Samples 6, 10, and 11 show iron concentration more than 0.3 parts per million; these waters may give rise to red and black water problems. Samples 1, 2, and 4 show nitrate concentration above 10 parts per million, and this nitrate impurity may be important in "blue babies". The best quality water is north of Bruce near the Big Sioux River; it shows below normal alkalinity, acidity and nitrate.

Movement of Water

The movement of shallow ground water depends on the general topography of the ground surface and of the base of the outwash deposits, and on the permeability of the outwash deposits.

The irregularities of the water table are controlled by differences in permeability and thickness of the water-bearing materials, unequal addition to or withdrawals from the transient outwash deposits at different places, and the regional topography. Of these the topographic factor plays a major role in controlling the shape and slope of the water table.

<u>Topographic Factor</u>.--The shape of the water table commonly conforms to the regional topography; therefore a well drilled in a valley will generally find water at a shallower depth than will a well drilled on a nearby divide. As the result of resistivity measurements and drilling (fig. 3), several major pre-

outwash channels were found in the Big Sioux Valley and its tributaries (fig. 3). The base of the outwash deposits apparently has more relief than does the exposed surface of the outwash. The thickness of the outwash averages more than 50 feet. Although the base of the outwash deposits cannot be mapped in detail with the information available, it appears as if this surface is the chief factor in the movement of shallow ground water in the Brookings area. As a whole, the main shallow ground water in the outwash deposits flows along these pre-outwash channels, and eventually drains southeasterly along the present course of the Big Sioux River (fig. 6).

Recharge.--Recharge is the process of adding water to the shallow ground water body in transient storage in the outwash deposits. In the Brookings area, recharge is accomplished mainly by local precipitation, by subsurface percolation from above and laterally, and a small amount from local ponds and swamps. The amount and frequency of recharge however depends on the depth to the water table and the type of material above the water table.

The depth to the water table in the outwash deposits averages 16 feet, which indicates that the process of recharge requires a rather short time; the frequency of recharge is rather high regardless of the local topographic relief.

The topsoil is silty and sandy; thus a considerable amount of recharge by precipitation could be carried out without much difficulty. The subsurface inflows derived directly from stratified sand lenses of the Wisconsin drift, furnish a very large amount of water to the shallow waters in the outwash deposits as is shown by the measurment of domestic water wells along the margins of the outwashes.

Discharge.--Discharge is a process of water loss. In the Brookings area, discharge is accomplished by the shallow ground water movement from the outwash deposits into the main stream channels, by pumping from wells, and by the natural discharge at the surface through the processes of surface runoff, evaporation and transpiration. The first two account for most of the discharge, but the exact amount of discharge from the transient storage in the outwash deposits cannot be computed because of lack of sufficient information. Some of the water may evaporate or be absorbed by vegetation and transpired into the atmosphere.

Recovery.--Recovery is the process whereby the water table returns to its original level after pumping at the well ceases. Generally speaking, if the outwash deposits are saturated with water, the rate of recovery is directly proportional to the permeability of the water-bearing materials. If the water-bearing

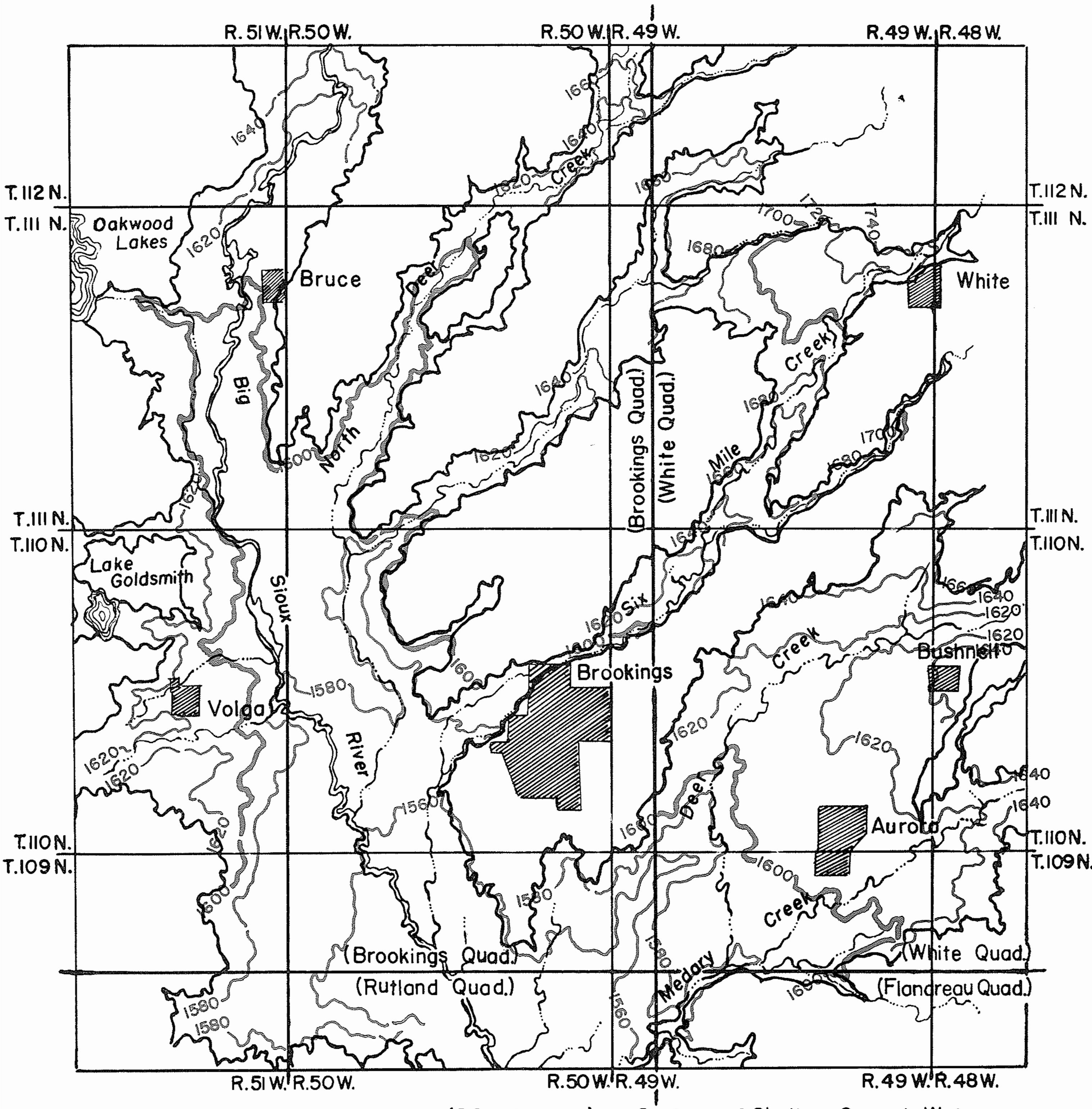


Figure 6.- Map Showing Contours (20 ft Interval) on Surface of Shallow Ground Water, and Outline of Outwash in the Brookings Area (base map by South Dakota Department of Highways)

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materials are of fairly uniform size, the outwash deposits will readily yield large quantities of water to a well with a minimum drawdown_/; if the water-bearing materials are fine or unsorted,

_/Drawdown is the lowering of the water table caused by pumping.

more resistance is offered to the flow of water, thereby decreasing the yield and increasing the drawdown. Thus the drawdown of a well varies inversely with the permeability of the water-bearing material.

This principle is well shown in the Brookings area. Wells in the outwash or in stratified sand lenses in till, were reported in most places to have a comparatively large yield and a slow drawdown, except for the wells in very fine-grained well-sorted sand, which usually offers low yield and rapid drawdown because of the low permeability. As a whole, the outwash consists of a rather high percentage of granule and pebble-size fragments, and thus has good permeability; therefore these materials afford easy passage for fluids.

Use of Water

The water levels in 269 domestic wells were measured (Table 5). These wells are used for domestic, stock, and public supplies. The public supplies are mainly confined to the cities of Brookings and White. In the city of Brookings the water pumpage per month during the summer of 1957 was about 29,000,000 gallons.

Suggestions for the Future Development of Irrigation

The future development of irrigation in this area appears very favorable. However, several factors (Lee, 1956, p. 27-28) concerning such irrigation deserve mention below.

Quality of Water.--As a result of evapo-transpiration and recirculation especially during the dry season, an increase in mineralization of the shallow water will probably accompany irrigation; therefore necessary measures should be taken to counteract it to prevent the excessive concentration of salts in the soil. In order to check these changes of water composition, chemical analysis of water should be carried out regularly during the period of irrigation.

Depth and Location of Wells.--Each well in the reservoir should be drilled at least to the bottom of the outwash in order to keep the maximum height of water in the well. Wells for irrigation should not be located near the till border. As a rule, a greater amount of water can be stored in the lower part of the outwash, owing to rather higher porosity of sand and gravel there. Water in the till near its border is commonly easy to lose to the outwash because of high permeability of the coarse sand and gravel of the outwash. Some fine- to medium-grained sand lenses in the outwash are usually intercalated with the coarse detritus; in these fine lenses a considerable amount of water can be stored for recharge to wells nearby.

During the pumping season, wells in the outwash deposits are usually affected by continuous pumpage according to the principles of recovery. Thus pumpage definitely affects the drawdown of water level in the vicinity of pumping wells. This includes the wells in the till area near the margin of outwash, but it will not have appreciable influence on the water level in wells in the till area several miles away from the outwash.

Character of Soil.--The topsoil developed on the surface of the outwash is generally light in texture, and more silty and sandy than the soil developed on the surface of tills; thus this soil has a rapid to moderate permeability and water can easily percolate downward into the outwash deposits. Therefore it appears advisable that the future development of irrigation in the outwash deposits should be carried out by sprinklers rather than by ditches.

Sand and Gravel

The investigation of sand and gravel included a study of the areal distribution and the physical properties.

Areal Distribution.--Glacial outwash deposits of sand and gravel occupy about 40 percent of the Brookings area, or about 104,000 acres.

Reserves.--The estimated amount of sand and gravel (Plates 1 and 2) in the Brookings area totals 4,734,000,000 cubic yards (Table 6). Areal estimates were computed by the grid method, and the thickness of the sand and gravel in each area was obtained from Tables 7 and 8.

Table 6.--Reserves of Sand and Gravel in the Brookings Area

Outwash	Area (acres) (nearest thousand)	Thickness (feet)	Reserve (cu.yd)	Remarks
Big Sioux Valley	36,000	9-81	1,505,000,000	Valley train
West of the Big Sioux Valley	15,000	3-48	535,000,000	Plain and terraces with some valley train
Aurora-Bushnell	9,000	15-111	725,000,000	Plain
Medary Creek	8,000	6-42	282,000,000	Valley train
Deer Creek	16,000	15-81	899,000,000	Valley train and terraces
North Deer Creek	5,000	6-36	182,000,000	Valley train and terraces
Six Mile Creek & adjacent creeks	15,000	9-57	608,000,000	Valley train and terraces
TOTAL	104,000		4,734,000,000	

Physical Properties.--The physical properties of sand and gravel include texture, composition and structure; texture and composition influence directly the economic importance, and were studied in the laboratory. Structure was investigated in the field in order to determine the source of sand and gravel, and the nature of the transporting medium during deposition.

Texture.--Texture refers to the size of the sedimentary particles, and the mutual relations of the grains. According to the Wentworth's grade limits (Table 9), the textural properties of sand and gravel are determined by size analysis. The size distribution data were arranged as percentages by weight in grade limits (Tables 10 and 11), from which ten samples were selected to make the cumulative curves (fig. 5); points were plotted by adding the weight percentage in succeeding grades, and then drawing a smooth curve through them. The parameters of sand and gravel were computed accordingly from the curve.

The textural parameters of sand and gravel consist of the quartiles, the mean, and the coefficient of sorting. The mean is the median diameter or an average grain size of a clastic sediment, and is controlled generally by the strength of the current that moved the material to the site of deposition. The quartiles are calculated by following the one-fourth (Q1), 25 weight percentage, and three-fourth (Q3), 75 weight percentage lines on the graph to the right until they intersect the cumulative curve and

Table 7.--Thickness of Sand and Gravel in the Brookings Area, as determined by drill holes of the South Dakota Geological Survey

Test Hole Number (Fig. 3)	Altitude above Sea level (feet)				Thickness (feet)	
	Surface	Sand&Gravel Top	Sand&Gravel Bottom	Water table (Summer, 1957)	Sand and gravel	Over-burden
1	1630	1626	1570	1622	56.00	4.00
3	1627	1623	1585	1620	38.00	4.00
5	1598	1590	1570	1588	20.00	8.00
8	1595	1591	1572	1584	19.00	4.00
9	1622	1615	1594	1615	21.00	7.00
11	1590	1583	1564	1583	19.00	7.00
12	1592	1588	1520	1586	68.00	4.00
13	1592	1586	1546	1582	40.00	6.00
14	1583	1581	1552	1571	29.00	2.00
15	1579	1575	1551	1575	24.00	4.00
16	1584	1577	1485*	1577	92.00*	7.00
17	1590	1586	1577	1579	9.00	4.00
19	1571	1570	1547	1562	23.00	1.00
20	1617	1614	1607	----	7.00	3.00
21	1619	1614	1598	1601	16.00	5.00
22	1640	1637	1620	1622	17.00	3.00
23	1645	1641	1626	1629	15.00	4.00
24	1616	1615	1595	1600	20.00	1.00
25	1613	1611	1588	1601	23.00	2.00
27	1599	1592	1585	1592	7.00	7.00
28	1602	1600	1572	1594	28.00	2.00
29	1581	1576	1539	1573	37.00	5.00
31	1595	1589	1557	1589	32.00	6.00
33	1604	1595	1582	1591	13.00	9.00
34	1551	1546	1514	1531	32.00	5.00
35	1564	1556	1487	1556	69.00	8.00
36	1559	1547	1523	1547	24.00	12.00
37	1559	1557	1539	1554	18.00	2.00
38	1560	1558	1545	1554	13.00	2.00
39	1559	1550	1520	1546	30.00	9.00
40	1549	1540	1525	1536	15.00	9.00
41	1547	1539	1522	1539	17.00	8.00
45	1607	1612	1509*	1599	93.00*	5.00
46	1608	1605	1492	1599	113.00*	3.00
47	1615	1610	1539	1607	71.00	5.00
48	1620	1617	1596	1612	21.00	3.00
49	1638	1635	1586	1630	49.00	3.00
53	1616	1606	1541-	1604	65.00+	10.00
58	1623	1618	1573	1615	45.00	5.00
61	1609	1603	1563	1601	40.00	6.00
65	1670	1660	1644	1659	16.00	10.00
69	1620	1614	1558	1612	56.00	6.00
Average Thickness					66.00	5.00

*Thickness of sand and gravel determined by the electric resistivity owing to the shortage of drilling rods.

Table 8.--Thickness of Sand and Gravel in the Brookings Area, as determined by resistivity data of the South Dakota Geological Survey

Station Number (Fig.3)	Altitude above sea level (feet)			Thickness (feet)	
	Surface	Sand & Gravel Top	Sand & Gravel Bottom	Sand & Gravel	Overburden
1	1619	1614	1557	57.00	5.00
2	1623	1618	1585	31.00	5.00
3	1628	1623	1567	56.00	5.00
4	1620	1615	1503	112.00	5.00
5	1623	1620	1574	46.00	3.00
6	1626	1624	1591	33.00	2.00
7	1628	1626	1602	24.00	2.00
8	1629	1626	1576	50.00	3.00
9	1627	1622	1573	49.00	5.00
10	1651	1649	1584	65.00	2.00
12	1619	1614	1528	86.00	5.00
13	1611	1608	1592	16.00	3.00
14	1612	1611	1576	35.00	1.00
15	1625	1620	1611	9.00	5.00
16	1610	1607	1574	33.00	3.00
17	1601	1599	1562	37.00	2.00
18	1607	1606	1558	48.00	1.00
19	1604	1602	1568	34.00	2.00
20	1605	1603	1572	31.00	2.00
21	1605	1601	1570	31.00	4.00
22	1636	1626	1534	95.00	10.00
23	1634	1629	1566	63.00	5.00
24	1598	1595	1578	17.00	3.00
25	1601	1598	1540	58.00	3.00
26	1600	1598	1560	38.00	2.00
27	1594	1591	1569	22.00	3.00
28	1596	1593	1567	26.00	3.00
29	1622	1620	1584	36.00	2.00
30	1649	1644	1614	30.00	5.00
31	1685	1680	1630	50.00	5.00
32	1618	1615	1566	49.00	3.00
33	1595	1590	1562	28.00	5.00
34	1585	1582	1558	24.00	3.00
35	1580	1575	1540	35.00	5.00
36	1591	1585	1559	26.00	6.00
37	1593	1590	1555	35.00	3.00
38	1592	1589	1552	37.00	3.00
39	1584	1582	1550	32.00	2.00
40	1579	1575	1543	32.00	4.00
41	1584	1577	1485	92.00	7.00
42	1590	1586	1576	10.00	4.00
43	1580	1577	1519	58.00	3.00
44	1551	1549	1534	15.00	2.00

Table 8 continued...

Station Number (Fig.3)	Altitude above sea level (feet)			Thickness (feet)	
	Surface	Sand & Gravel Top	Sand & Gravel Bottom	Sand & Gravel	Overburden
45	1574	1573	1542	31.00	1.00
46	1607	1602	1509	93.00	5.00
47	1608	1605	1492	113.00	3.00
48	1615	1610	1539	71.00	5.00
50	1562	1559	1542	17.00	3.00
51	1565	1561	1536	25.00	4.00
52	1563	1554	1506	48.00	9.00
53	1580	1577	1527	50.00	3.00
54	1568	1565	1527	38.00	3.00
55	1555	1544	1514	30.00	11.00
56	1578	1574	1518	56.00	4.00
58	1708	1704	1669	35.00	4.00
59	1745	1743	1653	90.00	2.00
60	1734	1725	1620	105.00	9.00
61	1745	1735	1639	96.00	10.00
62	1689	1680	1618	62.00	9.00
66	1594	1591	1509	82.00	3.00
67	1592	1590	1518	72.00	2.00
69	1631	1625	1530	95.00	6.00
70	1621	1617	1599	18.00	4.00
72	1620	1614	1558	56.00	6.00
74	1637	1633	1597	36.00	4.00
75	1648	1642	1482	160.00	6.00
76	1656	1650	1538	112.00	6.00
77	1669	1660	1628	32.00	9.00
78	1683	1680	1495	185.00	3.00
79	1673	1671	1637	34.00	2.00
81	1634	1630	1523	107.00	4.00
83	1637	1632	1557	75.00	5.00
84	1639	1637	1572	65.00	2.00
87	1702	1699	1613	86.00	3.00
88	1709	1706	1643	63.00	3.00
89	1728	1725	1636	89.00	3.00
Average Thickness				54.00	4.00

Table 9.--Wentworth's Particle Size Classification

Grade Limits		Name
Diameter in Millimeters	Diameter in inches	
Above 256	10	Boulder
256-128	10-5	Large cobble
128-64	5-2.5	Small cobble
64-32	2.5-1.25	Very large pebble
32-16	1.25-0.62	Large pebble
16-8	0.62-0.31	Medium pebble
8-4	0.31-0.15	Small pebble
4-2	0.15-0.078	Granule
2-1	0.078-0.039	Very coarse sand
1-½	0.039-0.019	Coarse sand
½-¼	0.019-0.009	Medium sand
¼-1/8	0.009-0.004	Find sand
1/8-1/16	0.004-0.0024	Very fine sand
Below 1/16	0.0024	Coarse silt and fine clay

Table 10.--Textural Study of Exposed Glacial Outwash Sediments in the Brookings Area

Locality	Sample Number	Weight Percent*- (Diameter in Millimeters)												Total wt. of percent	Textural Parameters			
		128-64	64-32	32-16	16-8	8-4	4-2	2-1	1-1/2	1/2-¼	¼-1/8	1/8-1/16	1/16-		Q1	M	Q3	SO
SW sec. 10, T. 111 N., R. 49 W.	1	27.59	9.79	8.70	9.58	10.12	9.54	8.74	9.44	4.64	1.19	0.40	0.22	99.95	70	11.50	2.05	5.830
SW sec.24, T. 111 N., R. 50 W.	2		11.41	12.10	12.96	14.22	14.93	13.58	11.29	7.48	1.64	0.26	0.08	99.95	15	4.20	1.30	3.316
SE sec.35, T. 111 N., R. 50 W.	3		16.69	10.72	10.51	9.44	9.22	11.14	15.23	12.03	4.20	0.67	0.09	99.94	19	3.30	0.74	5.000
SW sec.24, T. 109 N., R. 50 W.	4						1.24	1.66	13.48	42.29	37.59	3.06	0.59	99.91	0.40	0.26	0.22	1.414
NW sec. 2, T. 110 N., R. 51 W.	5		7.91	12.04	20.15	15.46	8.66	9.73	13.80	9.24	2.72	0.19	0.06	99.96	13	5.20	0.95	3.605
NE sec.23, T. 110 N., R. 51 W.	6				3.79	10.36	15.00	15.80	.39	25.53	7.91	0.20	0.01	99.99	2.35	0.82	0.44	2.236

*Wentworth's Grade Limits Q1, 1st Quartile Q3, 3rd Quartile M, Median

SO, sorting Coefficient ($\sqrt{Q1/Q3}$)

Table 1. Textural Study of Glacial Outwash Sediments

from Test Holes in the Brookings Area

Test Hole No.	Sample No.	Depth	Weight percent - Diameter in millimeters										Total wt. %	Textural Parameters			
			32-16	16-8	8-4	4-2	2-1	1-1/2	½-1/4	¼-1/8	1/8-1/16	1/16-		Q1	M	Q3	SO
61	1	4-9		6.61	25.17	17.24	13.85	17.36	14.29	5.12	0.33	0.03	100.00	4.65	1.90	0.66	2.646
	2	9-14		31.92	27.79	12.00	8.52	10.25	6.83	2.24	0.14	0.04	99.73	9.00	5.60	1.60	2.449
	3	14-19		10.58	38.50	34.22	9.50	3.46	2.63	1.05	0.04	0.01	99.99	6.25	4.00	2.55	1.414
	4	19-24	1.73	7.78	31.71	21.78	18.51	12.36	4.64	1.44	0.01	0.01	99.98	5.40	3.15	1.35	2.000
	5	24-29		8.61	28.19	22.00	22.77	13.55	3.71	0.89	0.01	0.01	99.74	5.50	2.78	1.25	2.000
	6	29-31		0.14	4.95	24.00	34.75	19.83	10.32	4.93	0.58	0.03	99.53	2.20	1.38	0.73	1.732
	7	34-39	2.40	4.72	28.69	25.22	15.79	10.68	7.67	4.17	0.60	0.01	99.95	5.00	2.89	1.10	2.236
	8	39-44		5.35	30.27	29.64	18.18	8.44	4.61	2.72	0.55	0.02	99.78	5.00	3.00	1.45	1.732
14	1	4-5	6.70	11.60	22.71	20.32	15.10	12.70	8.48	2.20	0.01	0.01	99.83	6.60	3.00	1.12	2.449
	2	5-10		4.26	17.86	36.40	20.14	10.94	8.31	1.88	0.20	0.01	100.00	3.80	2.45	1.20	1.732
	3	10-15		0.23	3.79	12.32	16.73	21.41	31.62	13.39	0.37	0.01	99.87	1.40	0.58	0.35	2.000
	4	15-20	5.61	4.72	9.45	12.40	13.81	20.41	24.35	8.82	0.29	0.01	99.86	2.89	0.88	0.42	2.646
	5	20-25		3.60	4.03	5.24	12.40	28.17	32.24	13.41	0.67	0.02	99.75	1.00	0.52	0.35	1.732
	6	25-30				0.36	4.17	26.35	47.65	20.83	0.60	0.02	99.98	0.57	0.37	0.25	1.414
12	1	9-14		0.61	13.02	21.73	22.65	25.34	13.03	3.50	0.11	0.01	100.00	2.65	1.25	0.66	2.000
	2	14-19		2.12	16.12	19.50	19.94	24.64	13.20	4.21	0.26	0.01	100.00	3.00	1.28	0.66	2.236
	3	19-24		1.79	12.89	20.83	20.34	25.79	15.51	2.54	0.07	0.01	99.77	2.79	1.20	0.62	2.236
	4	24-29		2.46	6.57	17.00	20.16	29.11	20.16	4.30	0.10	0.01	99.87	2.09	0.94	0.50	2.000
	5	29-34	8.12	8.40	16.48	14.03	12.97	17.91	15.91	5.75	0.42	0.01	100.00	5.40	1.75	0.55	3.162
	6	34-39		3.96	13.25	26.08	16.56	18.32	15.63	5.76	0.43	0.01	100.00	3.15	1.68	0.56	2.449
	7	39-44		1.01	14.61	23.97	20.18	20.79	14.60	4.42	0.19	0.01	99.78	2.88	1.45	0.62	2.236
	8	44-49			4.69	11.76	22.27	32.61	21.66	6.44	0.33	0.01	99.77	1.55	0.82	0.47	1.732
	9	49-54		1.70	8.10	16.56	17.40	27.15	24.55	4.40	0.17	0.02	99.99	2.10	0.87	0.46	2.236
46	1	3-4		22.23	25.49	11.54	13.99	16.91	7.71	1.77	0.17	0.14	99.95	7.70	3.95	0.98	2.828
	2	4-9		7.70	37.08	25.11	9.17	11.07	7.26	2.03	0.28	0.07	99.77	5.05	3.60	1.40	2.000
	3	9-14		14.45	24.94	16.90	15.59	15.67	8.98	2.95	0.16	0.01	99.65	5.80	2.65	0.88	2.646
	4	14-19		13.26	28.34	27.97	14.40	9.58	4.78	1.39	0.07	0.03	99.82	5.40	3.40	1.60	1.732
	5	19-24		3.25	30.87	25.00	16.15	13.90	8.18	2.25	0.17	0.05	99.82	4.70	2.69	1.00	2.236
	6	24-29		5.83	45.29	23.85	9.94	8.25	4.96	1.47	0.15	0.09	99.83	5.20	4.10	2.00	1.732
	7	29-34		3.50	26.90	34.84	15.58	10.68	6.48	1.76	0.17	0.08	99.99	4.40	2.95	1.40	1.732
	8	34-39		0.46	25.03	37.64	15.64	11.17	7.46	2.30	0.22	0.06	99.98	4.10	2.69	1.15	2.000
	9	39-44		1.41	24.16	38.75	15.88	10.03	7.28	2.22	0.15	0.08	99.96	4.10	2.58	1.30	1.732
	10	44-49		3.37	26.37	32.90	16.20	10.64	7.68	2.41	0.14	0.06	99.77	4.29	2.70	1.20	2.000
	11	49-54		2.83	33.63	40.04	11.67	5.94	4.22	1.36	0.16	0.04	99.89	4.68	3.40	2.10	1.414
	12	54-59		5.95	37.12	35.12	12.34	5.30	3.00	1.00	0.10	0.07	100.00	4.80	3.68	2.22	1.414
	13	59-64		6.12	32.93	37.15	10.40	6.75	4.66	1.27	0.11	0.08	99.47	4.80	3.55	2.10	1.414
	14	64-69		3.76	42.10	39.42	6.45	3.89	3.19	1.00	0.11	0.08	100.00	4.70	3.78	2.60	1.414
	15	69-74		0.76	36.08	48.92	6.90	2.99	2.77	0.99	0.10	0.10	99.61	4.50	3.55	2.55	1.414
	16	74-79		6.84	30.40	37.02	13.19	5.85	4.49	1.82	0.22	0.17	100.00	4.80	3.29	1.90	1.732
1	1	4-9				0.40	4.54	23.64	55.04	15.66	0.70	0.02	100.00	0.51	0.43	0.30	1.414
	2	9-14		2.76	6.07	16.29	15.45	22.43	26.89	9.15	0.90	0.06	100.00	2.00	0.78	0.39	2.236
	3	14-19			6.82	18.53	25.35	28.59	15.24	4.69	0.46	0.01	99.69	2.02	1.02	0.58	1.732
	4	19-24			1.59	9.03	21.71	38.95	20.13	6.95	1.28	0.21	99.76	1.25	0.77	0.46	1.732
	5	24-29		0.84	1.15	7.41	18.36	39.28	26.54	6.15	0.26	0.01	100.00	1.05	0.66	0.43	1.414
	6	29-34		0.82	6.71	17.97	24.92	29.47	15.37	4.52	0.13	0.02	99.93	2.00	1.02	0.58	1.732
	7	34-39			1.66	8.48	30.30	40.14	15.15	4.10	0.07	0.01	99.91	1.28	0.92	0.58	1.414
	8	39-44			0.47	2.65	9.57	53.81	28.80	4.62	0.07	0.01	100.00	0.71	0.55	0.45	1.414
	9	44-49			0.67	6.82	16.72	38.26	30.19	7.16	0.16	0.02	100.00	0.99	0.60	0.42	1.414
	10	49-54		0.26	0.45	4.02	13.92	39.60	30.51	7.77	0.17	0.01	96.71	0.86	0.57	0.37	1.414
	11	54-59			0.18	5.90	12.19	33.89	38.25	9.34	0.12	0.01	99.88	0.84	0.52	0.36	1.414

*Wentworth's Grade Limits Q1, 1st Quartile; Q3, 3rd Quartile; M, Median

SO, Sorting Coefficient ($\sqrt{Q1/Q3}$)

then by dropping lines perpendicular to the size scale below. The coefficient of sorting is defined as the square root of the ratio of the Q1 to the Q3; it is generally an index of the range of conditions present in the transporting fluid--that is, the range of velocities, the degree of turbulence, and to some extent the distance of transportation.

The significance of the degree of sorting is that it indicates the distribution of uniform size present in a sediment, shown by the cumulative curves, and also indicates the percentage of pore space in a sediment. Generally the greater the spread of the curve, the poorer the sorting; poorly sorted sediments are less porous than well-sorted sediments. According to Trask (1932), well-sorted sediments have sorting coefficient (SO) less than 2.5, moderately sorted sediments range from 2.5 to 4.0, and poorly sorted sediments have values larger than 4.0. Samples from the Brookings area show "SO" values of the pebble size detritus that average 4.4, and of sand fraction averaging 1.9; thus the outwash sand and gravel range from well-sorted to poorly sorted. The median diameter of sand and gravel ranges from 0.26 to 11.50, and averages 3.146; this indicates that the principal grain size is granule; therefore these sediments required a moderate transporting medium to move them to the site of deposition.

According to mechanical analysis, the average weight percentage of the grain size fractions of 56 samples of the outwash sand and gravel consists of 0.492 percent cobble, 0.817 percent very large pebble, 1 percent large pebble, 5 percent medium pebble, 18 percent small pebble, 20 percent granule, 15 percent very coarse sand, 19 percent coarse sand, 15 percent medium sand, 5 percent fine sand, 0.322 percent very fine sand, and 0.369 percent coarse silt and clay.

Composition.--The constituents of the coarse detritus (Table 12), ranging from cobble to pebble in size, average 58 percent limestone and dolomite with some chert, 16 percent sandstone, shale and clay-ironstone, and 26 percent igneous and metamorphic rocks. The granule fraction consists chiefly of rock fragments of limestone, dolomite, and igneous and metamorphic rocks. The sand and silt fractions consist mainly of rounded to subangular quartz grains, and a small percentage of rock fragments. Patches and lenticular masses of ferric iron-oxide materials are intercalated sporadically within the masses of sand and gravel.

Structure.--The structure of sand and gravel shows tabular and lenticular cross-bedding in the sand fraction. The majority of the tabular cross-laminated units consist only of the foreset laminae that are sharply truncated at the top, and tangential at the base; thus they were deposited by frequently shifting currents. The coarse gravels are commonly intercalated with silt and sand lenses, in which cut-and-fill structure is well-developed. Imbrication of the flatter pebbles and cobbles is generally present, and shows the direction of current movement.

Table 12.--Lithologic Composition of the Gravel in the Brookings Area

Percent in Millimeters

Sample Number / Location / Rock Type	1 SW sec. 10, T. 111 N., R. 49 W.	2 SW sec. 24, T. 111 N., R. 50 W.	3 SE sec. 35, T. 112 N., R. 50W.	4 NW sec. 2, T. 110 N., R.51 W.	Diameter Range (inches)
Dolomite					
Gray	3.93	3.03	7.59	1.93	0.20-1.80
Brown			1.89		0.20-0.40
Limestone					
Light Gray	7.86	4.76	13.92	5.84	0.20-3.00
Gray	40.17	51.08	29.11	41.55	0.20-1.95
Dark (Black)	2.36	6.92	3.16	2.58	0.20-1.45
Chert	0.78	1.73	3.16		
Calcareous Rocks and Associates	55.10	67.52	58.83	51.90	0.20-3.00
Sandstone					
Gray	1.57				0.20-1.20
Brown			0.63	0.64	0.20
Shale					
Black (Gray)	17.32	3.46	21.51	9.09	0.20-0.85
Clay Ironstone		2.59	0.63	5.19	0.20-0.90
Clastic Rocks and Associates	18.89	6.05	22.77	14.92	0.20-1.20
Igneous					
Granitic	13.38	14.28	11.38	15.58	0.20-2.50
Dioritic		0.86	1.26	2.59	0.20-1.35
Basaltic		0.43	0.63	1.29	0.20-0.70
Metamorphic					
Quartzite		0.86	0.63	0.64	0.20-0.25
Slate	11.81	8.65	3.78	9.74	0.20-0.90
Schist	0.78	1.29	0.63	3.24	0.20-1.65
Gneiss					0.20-1.65
Crystalline Rocks	25.97	26.37	18.31	33.08	
TOTAL PERCENT	99.96	99.94	99.91	99.90	

Economic Value.--The mineral composition of sand and gravel is one of the most important factors in determining the quality and suitability for construction purpose. The constructional uses include chiefly building construction and road making. Because the silt and clay fraction averages less than one percent, the plasticity index of the sand and gravel is low.

The principal mineral constituents of the outwash sand and gravel are about 85 percent quartz, 10 percent limestone, dolomite, igneous and metamorphic rocks, and more than 2 percent accessory detrital silicate minerals; some impurities such as soil, clay, and iron-oxides, occur as sand filler and as coatings on quartz grains.

Quartz is resistant to chemical and physical weathering and pure quartz sand stands a high degree of heat without fusing; however the accessory silicate minerals, hornblende, garnet, mica, and feldspar, serve to increase the fusibility. Generally the fusibility of quartz decreases with the presence of calcite, alkalies and iron oxides. Feldspars are chemically weak, but are physically strong in resisting abrasion. Mica withstands chemical decay, but is weak mechanically. Limestone and dolomite are weak to chemical and physical weathering, whereas igneous and metamorphic rocks are relatively resistant.

According to Condra (1911, p. 149-150), the strongest mortar is made from the pure siliceous coarse sands, if the voids are completely filled. Sharp angular sands produce mortar high in tensile strength. The very coarse and fine siliceous sands are good materials for use as mortar if they contain less than 10 percent by weight of clay or loamy material. In the Brookings area the sands contain about 15 percent impurities and rock fragments, but the silt and clay fraction is less than one percent. The angularity of the sand and gravel ranges from rounded to subangular. As a whole, the outwash sand and gravel are not good material for mortar and concrete paving, but they are generally suitable for the road and building construction.

Clay

Clay serves generally as a very valuable raw material for the ceramic industry. In the Brookings area clay is present in the glacial tills, in the silty materials on top of the outwashes, in the alluvial deposits, and in the loess; clay in the loess is only of minor economic importance.

Glacial tills are composed of about 50 percent clay, which is yellowish-brown, yellowish-gray to gray, and somewhat bluish-gray or greenish-gray; it is silty and sandy. The principal clay mineral is nontronite. The silty materials on top of the outwash are chiefly of gray to brownish-gray; laminated, silty and somewhat sandy clay, with dark-brown soil on top. Alluvial deposits contain rather high percentages of clay, but they are commonly silty and sandy. If this clay is used for brick-making, any drying difficulties that might arise could be overcome by mixing sand with the clay.

SUMMARY

The Brookings area lies approximately in the central part of the Prairie Hills upland of extreme eastern South Dakota, and is much dissected by the Big Sioux drainage.

The surficial deposits of the area consist chiefly of the three oldest subdivisions of the Wisconsin drift: the Iowan, Tazewell and Cary. The pebble fractions of the Iowan and Tazewell tills have only slight differences in percentage of rock types, but the Tazewell till is comparatively less oxidized, and somewhat fissile and blocky. The Cary drift is characterized by a remarkable end moraine, a distinctive lithological composition, and by less leaching.

The glacial deposits lie unconformably on the eroded surface of the gently warped Pierre shale, and are overlain by a thin cover of alluvium.

The Wisconsin drift plays a major role in the potential economic importance of the Brookings area. Clay is considered a potential source material for a ceramic industry. Outwash deposits of sand and gravel are ideal water-bearing sediments, and good material for the road and building construction. The reserve of sand and gravel is about 4,734,000,000 cubic yards, of which 30 percent is in the Big Sioux Valley.

The total storage capacity of shallow ground water in the Brookings area is approximately 1,066,000 acre-feet, and the Big Sioux outwash occupies 30 percent. The amount of water in the outwash deposits during the summer of 1957 was about 364,000 acre-feet, 40 percent of which was stored in the Big Sioux outwash.

Water in the outwash deposits is generally satisfactory for human consumption, but the water derived directly from the sand lenses in the glacial tills should be analyzed in order to determine the concentrations of deleterious nitrate, sulfate, and iron.

The main bodies of shallow ground water flow with moderate hydraulic gradients along the major pre-outwash channels, to the present course of the Big Sioux River.

Irrigation possibilities in the Brookings area are very favorable. However, chemical analysis of water should be carried out regularly to check the changes of chemical composition of water during the period of irrigation. The location of wells in the outwash deposits should be carefully selected, and each well should reach the bottom of the outwash in order to keep the maximum amount of water in the well. The soil is generally silty and sandy, so that future irrigation should perhaps be carried out by sprinklers.

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APPENDIX

Logs of Selected Test Holes in the Outwash Sediments of the Brookings Area

Test Hole 1

Location: SE¼ sec. 1, T. 111 N., R. 51 W.
Elevation (G.L.): 1630 feet
Total Depth: 64 feet
Depth to water: 8 feet

Drillers: Richard Von Holdt and Robert Hamill, Aug. 12, 1957
Sample study and logging: K. Y. Lee, Oct. 5, 1957

Description	Depth (feet)
No sample	0-4
Pleistocene: Wisconsin: Cary Outwash	
Sand, quartz, medium- to coarse-grained, rounded to subrounded, some fragments of shale, slate, and granite, and scattered detrital minerals (pink feldspar, tourmaline, hornblende, mica, and iron-oxides)	4-9
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand, with granules and small pebbles of shale, granite, and slate, detrital minerals (mica, iron-oxides, chert, hornblende, and olivine) are sporadically present	9-14
Sand and gravel, chiefly of rounded quartz; coarse- to very coarse-grained, rather abundant granule and small pebble fragments of slate, schist, granite, limestone, shale, siltstone, sandstone, and chert; a very few accessory minerals (feldspar, tourmaline, and iron-oxides)	14-19
Same as 14-19, but with abundant granules of rock fragments	19-24

Description	Depth (feet)
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained; predominant granules and small pebbles of shale, granite, slate, limestone, schist, chert, and siltstone; accessory detrital minerals (feldspar, tourmaline, hornblende, iron-oxides, and pyrite) fairly common..............................	24-29
Sand and gravel, mainly rounded quartz; medium- to very coarse-grained, scattered rock fragments of limestone, shale, slate, and some granite; accessory detrital minerals (chert, feldspar, mica, iron-oxides, tourmaline, aragonite, and hornblende) rather abundant. Cannel coal..	29-34
Same as 29-34, but with abundant shale fragments.........	34-39
Sand, chiefly rounded quartz, medium- to very coarse-grained; a few fragments of shale, limestone, granite, schist, and cannel coal; accessory minerals (tourmaline, pyrite, iron-oxides, chert, and other detrital minerals) are sporadic.....................	39-44
Same as 39-44...	44-59
Pleistocene: Wisconsin: Iowan? till	
Clay, bluish-gray, silty................................	59-64

Test Hole 12

Location: NE¼ sec. 18, T. 110 N., R. 50 W.

Elevation (G.L.): 1592 feet
Total Depth: 54 feet
Depth to water: 6 feet

Drillers: Richard Von Holdt and Robert Hamill, Aug. 13, 1957
Sample study and logging: K. Y. Lee, Oct. 5, 1957

Description	Depth (feet)
No sample	0-9
Pleistocene: Wisconsin: Cary Outwash	
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand: some granules and small pebbles of shale, limestone, slate, schist, cannel coal, and granite. Accessory detrital minerals (pink feldspar, chert, iron-oxides, and tourmaline) are sporadically present	9-14
Same as 9-14, but with pyrite, and rather abundant chert, tourmaline and ironstone	14-19
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand; some granules and pebbles of limestone, shale, slate, schist, granite, and ironstone. Accessory minerals (chert, pink feldspar, pyrite, tourmaline, and iron-oxides) scattered through	19-24
Sand, chiefly quartz, medium- to very coarse-grained, rounded; some granules and small pebbles of limestone, shale, slate, granite, and ironstone. Feldspar, iron-oxides, tourmaline, and hornblende scattered through	24-29
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand; some granules and small pebbles of limestone, shale, slate, schist, granite and ironstone; accessory detrital minerals (feldspar, tourmaline, iron-oxides and chert) fairly common	29-34

Description	Depth (feet)
Sand and gravel, chiefly subrounded quartz; medium- to very coarse-grained sand, scattered granules and pebbles of limestone, granite, shale, and slate. Chert, feldspar, mica, epidote, pyrite, iron-oxides, tourmaline, and cannel coal are sporadically present	34-39
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand, a fair amount of granules and pebbles of limestone, granite, shale, slate, schist, and sandstone. Accessory detrital minerals (chert, mica, tourmaline, iron-oxides, pyrite, and hornblende) are fairly common	39-44
Sand, chiefly rounded quartz, medium- to very coarse-grained, scattered accessory minerals (feldspar, tourmaline, iron-oxides, mica , pyrite, and others). Rock fragments of granule and pebble size fairly common	44-49
Sand, rounded to subrounded quartz; medium- to very coarse-grained, some granules and pebbles of limestone, slate, and shale. Accessory detrital minerals (pink feldspar, mica, hornblende, tourmaline, chert, and pyrite) scattered through	49-54
No sample	54

Test Hole 14

Location: NW¼ sec. 29, T. 110 N., R. 50 W.
Elevation (G.L.): 1583 feet
Total Depth: 30 feet
Depth to water: 12 feet

Drillers: Richard Von Holdt and Robert Hamill, Aug. 6, 1957
Sample Study and logging: K. Y. Lee, Oct. 6, 1957

Description	Depth (feet)
No sample	0-4
Pleistocene: Wisconsin: Cary Outwash	
Gravel, mainly granules and pebbles of limestone, granite, slate, schist, and some fine-grained sandstone; some coarse- to very coarse-grained sand, rounded to subrounded quartz chiefly; accessory detrital minerals (pink feldspar, chert, hornblende, olivine, mica, and iron-oxides) scattered through	4-5
Sand and gravel, chiefly rounded quartz, coarse- to very coarse-grained sand, some rock fragments and accessory detrital minerals as 4-5	5-10
Sand, chiefly subrounded quartz, fine- to very coarse-grained, rock fragments of shale, siltstone, ironstone, granite, slate, and schist. Accessory detrital minerals (mica, chert, hornblende, augite, tourmaline, feldspar, and iron-oxides) are present	10-15
Sand, chiefly rounded quartz, fine- to coarse-grained, some fragments of limestone, shale, siltstone, slate, granite and cannel coal; scattered detrital minerals of same assemblages as 10-15	15-20
Same as 10-15	20-25
Sand, chiefly subrounded quartz, medium- to coarse-grained, a fair amount of accessory detrital minerals (chert, mica, feldspar, olivine, hornblende, tourmaline, and iron-oxides). Granules of rock fragments and cannel coal are sporadic	25-30
Pleistocene: Wisconsin: Iowan? till	
Clay, bluish-gray, and sandy	30

Test Hole 46

Location: SE¼ sec. 4, T. 109 N., R. 49 W.
Elevation (G.L.): 1608 feet
Total Depth: 79 feet
Depth to water: 9 feet

Drillers: Richard Von Holdt and Robert Hamill, Aug. 21, 1957
Sample study and logging: K. Y. Lee, Oct. 6, 1957

Description	Depth (feet)
No sample	0-3
Pleistocene: Wisconsin: Cary Outwash	
Gravel, chiefly granules and pebbles of limestone, ironstone, granite, slate, and schist; scattered medium- to very coarse-grained sand, rounded quartz chiefly. Accessory detrital minerals (chert, feldspar, aragonite, biotite, iron-oxides, tourmaline, and others) are fairly common	3-4
Same as 3-4, but with rather abundant pebble rock fragments	4-9
Same as 4-9	9-14
Gravel, chiefly granules and pebbles of limestone, granite, slate, siltstone, and ironstone; rather abundant coarse- to very coarse-grained sand, rounded quartz chiefly. Accessory detrital minerals (feldspar, hornblende, mica, olivine, chert, and iron-oxides) are scattered through the mass of sand	14-19
Same as 14-19, but with rather abundant coarse-grained sand, and some dense micaceous siltstone	19-24
Gravel, chiefly granules and pebbles of limestone, shale, ironstone, and slate; some medium- to very coarse-grained sand, containing detrital minerals (feldspar, hornblende, chert, mica, iron-oxides, aragonite, and tourmaline)	24-29
Sand and gravel, chiefly rounded to subangular quartz, medium- to very coarse-grained sand, a fair amount of granule and pebble-size rock fragments, and some accessory detrital minerals, which consist of same assemblages as 24-29	29-34

Description	Depth (feet)
Sand, and gravel, chiefly rounded quartz, medium- to very coarse-grained sand, a fair amount of granules and pebbles of limestone, shale, slate, granite, and sandstone. Accessory detrital minerals (feldspar, hornblende, chert, mica, iron-oxides, and tourmaline) are sporadic	34-39
Same as 34-39, but with rather abundant shale, and ironstone	39-44
Sand and gravel, chiefly rounded quartz; medium- to very coarse-grained sand, a considerable amount of granules and pebbles of limestone, shale, granite, slate, chert, and ironstone, and scattered detrital minerals (feldspar, iron-oxides, hornblende, tourmaline, and others)	44-49
Gravel, granules and pebbles of the same rocks as 44-49; rather abundant coarse- to very coarse-grained sand, rounded quartz chiefly, in which detrital minerals (mica, aragonite, chert, zircon, tourmaline and others) are present	49-54
Same as 49-54	54-59
Gravel, chiefly granules and pebbles of limestone, ironstone, granite, ferrugineous sandstone, slate, and shale; rather abundant medium- to very coarse-grained sand, subrounded quartz chiefly, and accessory detrital minerals (feldspar, chert, mica, hornblende, tourmaline, zircon, and iron-oxides)	59-64
Gravel, same rock types as 59-64; a fair amount of coarse-grained sand, which consists of subrounded quartz with scattered accessory detrital minerals	64-69
Same as 64-69, but with rather abundant feldspar, olivine, and chert	69-74
Sand and gravel, chiefly rounded quartz, coarse- to very coarse-grained sand, rather abundant granules and pebbles of glauconitic shale, granite, limestone, ironstone, chert, slate, and siltstone; accessory detrital minerals (feldspar, mica, aragonite, tourmaline, iron-oxides, and others) scattered through	74-79
No sample	79

Test Hole 61

Location: NE¼ sec. 18, T. 110 N., R. 48 W.
Elevation (G.L.): 1609 feet
Total Depth: 44 feet
Depth to water: 8 feet

Drillers: Richard Von Holdt and Robert Hamill, Aug. 23, 1957
Sample study and logging: K. Y. Lee, Oct. 6, 1957

Description	Depth (feet)
No sample	0-4
Pleistocene: Wisconsin: Cary Outwash	
Sand and gravel, chiefly subrounded quartz; medium- to very coarse-grained sand, a fair amount of granules and pebbles of granite, schist, slate, limestone, and ironstone, and accessory detrital minerals (feldspar, tourmaline, chert, and iron-oxides)	4-9
Gravel, granules and pebbles of limestone, granite, schist, slate, shale, ironstone, and sandstone; a fair amount of medium- to very coarse-grained sand, quartz chiefly, and some accessory detrital minerals	9-14
Same as 9-14, but with rather abundant fine- to medium-grained sandstone	14-19
Gravel and sand, chiefly rounded rock fragments; granule to pebble size, a considerable amount of medium- to very coarse-grained sand, subrounded quartz chiefly, and some accessory detrital minerals	19-24
Sand and gravel, chiefly subrounded quartz, coarse- to very coarse-grained sand, 50 percent rock fragments (granite, slate, schist, limestone, shale, ironstone, sandstone, and chert), and some accessory detrital minerals (mica, feldspar, tourmaline, zircon, hornblende, aragonite, iron-oxides)	24-29
Sand and gravel, chiefly subrounded quartz, fine- to very coarse-grained sand, a fair amount of granules and small pebbles of granite, limestone, shale, slate, schist, sandstone, and ironstone, and some accessory minerals (pyrite, feldspar, tourmaline, hornblende, mica, and iron-oxides)	29-31

Description	Depth (feet)
No sample	31-34
Sand and gravel, chiefly subrounded quartz, fine- to very coarse-grained sand, rather abundant fragments of limestone, shale, siltstone, granite, slate, and ironstone, and some accessory detrital minerals (mica, tourmaline, hornblende, iron-oxides, pyrite, and others)	34-39
Sand and gravel, chiefly subrounded quartz, medium- to very coarse-grained sand, a fair amount of fragments of limestone, slate, cannel coal, granite, siltstone, shale, and sandstone. Accessory detrital minerals (mica, pyrite, chert, tourmaline, and others) scattered through	39-44
Pleistocene: Wisconsin: Iowan? till	
Clay, bluish-gray	44-49

TABLE 12

WELL RECORDS (June-August, 1957)

Dr: Drilled
D: Dug
I: Irrigation

Sp: Sand point
P: Pitcher pump
S: Stock

T: Turbine
J: Jet pump
Pu: Public

H: Hand operated
W: Windmill
C: Cylinder

E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
C. Smith	5-109N-48W	D	32	36	Cement	1632	Sand and Gravel	Outwash	Ep	DoS	14
K. Deen	18-109N-48W	D	60	24	Brick & Wood	1643	Sand and Gravel	Iowan Stratified Drift	Ej	DoS	47
E. W. Leifeman	3-109N-49W	D	18	36	Cement & Rock	1616	Sand and Gravel	Outwash	Ep	S	5
R. Collins	3-109N-49W	D	15	32	Cement & Tile	1618	Sand and Gravel	Outwash	Wp	S	4
H. Wilson	4-109N-49W	Sp	14	$1\frac{1}{4}$		1612	Sand and Gravel	Outwash	Ej	S	6
R. Allison	5-109N-49W	Dr	20	$1\frac{1}{4}$	Steel	1600	Sand and Gravel	Outwash	Ej	Do	10
H. Vandervleit	6-109N-49W	Sp	14	$1\frac{1}{4}$		1576	Sand and Gravel	Outwash	Ej	Do	3
O. Nelson	6-109N-49W	D	14	48	Wood	1603	Sand and Gravel	Outwash	Wp	S	2
H. W. Watson	7-109N-49W	D	12	18	Concrete & Tile	1600	Sand and Gravel	Outwash	Ep	S	4
D. Fabrick	7-109N-49W	D	12	36	Cement, Wood, Tile	1595	Sand and Gravel	Outwash	Hp	DoS	6
A. Allison	8-109N-49W	D	16	24	Tile	1595	Sand and Gravel	Outwash	Ep	Do	9
J. Biggar	8-109N-49W	D	11	24	Steel	1594	Sand and Gravel	Outwash	Ep	DoS	3
M. Biggar	9-109N-49W	D	12	24	Cement & Tile	1592	Sand and Gravel	Outwash	Hp	Do	5

TABLE 12

WELL RECORDS (June-August, 1957)

Dr: Drilled | Sp: Sand point | T: Turbine | H: Hand operated | E: Electric
D: Dug | P: Pitcher pump | J: Jet pump | W: Windmill | Do: Domestic
I: Irrigation | S: Stock | Pu: Public | C: Cylinder

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
M. Andreessen	11-109N-49W	D	10	24	Cement	1609	Sand and Gravel	Outwash	Hp	Do	3
E. Caswell	11-109N-49W	D	51	36	Wood	1611	Sand and Gravel	Outwash	Ep	S	40
C. Deen	13-109N-49W	D	20	30	Cement & Tile	1623	Sand (Gravel)	Iowan Stratified Drift	Ep	DoS	7
J. T. Jensen	14-109N-49W	D	53	24	Cement & Tile	1623	Sand and Gravel	Iowan Stratified Drift	Wp	DoS	26
O. Wantland	14-109N-49W	D	23	24	Cement	1609	Sand and Gravel	Iowan Stratified Drift	Hp	Do	7
R. Myers	15-109N-49W	D	17	36	Cement	1595	Sand and Gravel	Outwash	Ej	DoS	9
S. Maher	15-109N-49W	D	92	18	Cement	1600	Sand (Gravel)	Iowan Stratified Drift	Ep	DoS	85
E. Telkamp	17-109N-49W	D	15	30	Cement	1591	Sand and Gravel	Outwash	Ep	Sd	7
H. Stoltenberg	18-109N-49W	Sp	15	24	Tile	1592	Sand and Gravel	Outwash	Ep	S	6
G. Whitehead	18-109N-49W	D	13	36	Cement & Tile	1589	Sand and Gravel	Outwash	Ep	S	7
E. E. Alexander	18-109N-49W	D	10	36	Wood	1564	Sand and Gravel	Outwash	Wp	S	4
R. Telkamp	19-109N-49W	D	10	4	Steel	1584	Sand and Gravel	Outwash	Ep	Do	8
E. E. Alexander	20-109N-49W	D	14	36	Cement & Tile	1580	Sand and Gravel	Outwash	Wp	S	4
E. Bathe	1-109N-50W	D	30	30	Cement	1578	Sand and Gravel	Outwash	Wp	S	23
J. Hillerud	1-109N-50W	Sp	15	$1\frac{1}{4}$		1574	Sand and Gravel	Outwash	Hp	Do	6

TABLE 12

WELL RECORDS (June-August, 1957)

Dr: Drilled
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S: Stock

T: Turbine
J: Jet pump
Pu: Public

H: Hand operated
W: Windmill
C: Cylinder

E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
C. Opland	3-109N-50W	Sp	15	$1\frac{1}{4}$		1560	Sand and Gravel	Outwash	Ep	Do	7
D. G. Magistad	5-109N-50W	Sp	12	$1\frac{1}{4}$	Concrete	1559	Sand and Gravel	Outwash	Ep	Sd	6
P. Mershon	5-109N-50W	Sp	16	$1\frac{1}{4}$	Wood	1561	Sand and Gravel	Outwash	Ep	DoS	4
F. Schultz	7-109N-50W	Sp	15	$1\frac{1}{4}$	Tile	1565	Sand and Gravel	Outwash	Ep	S	7
G. VanBeek, Jr.	7-109N-50W	Sp	15	$1\frac{1}{4}$		1577	Sand and Gravel	Outwash	Wp	S	5
N. Berkland	8-109N-50W	Sp	13	$1\frac{1}{4}$		1562	Sand and Gravel	Outwash	Ep	Do	8
R. MaCond	9-109N-50W	D	18	18	Concrete	1553	Sand and Gravel	Outwash	Ep	DoS	9
K. James	9-109N-50W	Dr	10	$1\frac{1}{4}$	Steel	1552	Sand and Gravel	Outwash	Ej	DoS	5
H. Sinjem	10-109N-50W	Sp	12	$1\frac{1}{4}$		1554	Sand and Gravel	Outwash	Ej	Do	7
H. Sheldon	10-109N-50W	D	25	32	Concrete	1560	Sand and Gravel	Outwash	Ej	Do	7
A. Vanderwaal	10-109N-50W	Sp	16	$1\frac{1}{4}$	Tile	1557	Sand and Gravel	Outwash	Ej	Do	7
R. Parsley	10-109N-50W	D	30	32	Tile	1555	Sand and Gravel	Outwash	Wp	S	28
D. Christie	11-109N-50W	Sp	19	$1\frac{1}{4}$	Steel & Concrete	1575	Sand and Gravel	Outwash	Ej	Do	9

TABLE 12

WELL RECORDS (June-August, 1957)

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S: Stock

T: Turbine
J: Jet pump
Pu: Public

H: Hand operated
W: Windmill
C: Cylinder

E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
B. K. McMillen	12-109N-50W	D	12	48	Concrete & Tile	1562	Sand and Gravel	Outwash	Wp	S	3
R. Peterson	12-109N-50W	Sp	17	$1\frac{1}{4}$		1574	Sand and Gravel	Outwash	Ej	Do	5
M. F. Sutton	13-109N-50W	Sp	12	$1\frac{1}{4}$		1557	Sand and Gravel	Outwash	Ej	Do	4
L. Vockrodt	13-109N-50W	Dr	26	$1\frac{1}{2}$	Steel	1567	Sand and Gravel	Outwash	Wp	S	19
D. Zemliaska	13-109N-50W	Sp	18	$1\frac{1}{4}$		1564	Sand and Gravel	Outwash	Ej	Do	11
D. Peterson	14-109N-50W	Sp	12	$1\frac{1}{4}$		1556	Sand and Gravel	Outwash	Wp	S	3
R. Heeren	14-109N-50W	D	12	12	Steel	1561	Sand and Gravel	Outwash	Hp	Do	4
S. Billet	15-109N-50W	D	30	36	Concrete	1549	Sand and Gravel	Outwash	Wp	S	22
State College	15-109N-50W	Dr	36	18	Steel	1550	Sand and Gravel	Outwash	Et	I	32
M. Keiper	16-109N-50W	Sp	12	$1\frac{1}{4}$		1556	Sand and Gravel	Outwash	Ej	Do	4
N. Berkland	17-109N-50W	Sp	8	$1\frac{1}{4}$	Steel	1560	Sand and Gravel	Outwash	Hp	Do	4
R. E. Stauffer	17-109N-50W	Sp	28	$1\frac{1}{2}$	Tile	1552	Sand and Gravel	Outwash	Ej	S	29
O. Sween	18-109N-50W	D	35	32	Cement & Wood	1561	Sand and Gravel	Outwash	Ej	S	24

TABLE 12

WELL RECORDS (June-August, 1957)

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S: Stock
T: Turbine
J: Jet pump
Pu: Public
H: Hand operated
W: Windmill
C: Cylinder
E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
C. Tate	18-109N-50W	D	26	32	Cement & Wood	1577	Sand and Gravel	Outwash	Ej	Do	12
G. Borthem	20-109N-50W	Sp	18	$1\frac{1}{4}$	Cement	1571	Sand and Gravel	Outwash	Ej	S	8
V. Stenberg	20-109N-50W	Dr	75	6	Steel	1585	Sand and Gravel	Cary Stratified Drift	Wp	S	27
D. Vandenberg	21-109N-50W	Sp	14	$1\frac{1}{4}$	Tile	1573	Sand and Gravel	Outwash	Ej	S	6
L. Mailey	22-109N-50W	Sp	7	$1\frac{1}{4}$	Steel	1549	Sand and Gravel	Outwash	Ej	S	2
C. Toggstead	22-109N-50W	Sp	9	$1\frac{1}{4}$	Steel	1548	Sand and Gravel	Outwash	Ej	S	3
B. Alexander	23-109N-50W	Sp	17	$1\frac{1}{2}$	Tile	1554	Sand and Gravel	Outwash	Ej	S	9
A. Ponto	23-109N-50W	Sp	13	$1\frac{1}{4}$		1550	Sand and Gravel	Outwash	Ej	S	3
D. Austin	24-109N-50W	Sp	18	$1\frac{1}{2}$		1557	Sand and Gravel	Outwash	Ej	DI	8
T. Martinson	24-109N-50W	Sp	18	$1\frac{1}{4}$	Tile	1559	Sand and Gravel	Outwash	Ej	DI	8
L. Telkamp	24-109N-50W	D	17	32	Tile	1564	Sand and Gravel	Outwash	Ej	Do	5
R. Minor	26-109N-50W	Sp	10	$1\frac{1}{4}$		1547	Sand and Gravel	Outwash	Ej	Do	5
G. E. Hinkley	27-109N-50W	D	12	30	Concrete	1545	Sand and Gravel	Outwash	Ej	Do	7

TABLE 12

WELL RECORDS (June-August, 1957)

Dr: Drilled	Sp: Sand point	T: Turbine	H: Hand operated	E: Electric
D: Dug	P: Pitcher pump	J: Jet pump	W: Windmill	Do: Domestic
I: Irrigation	S: Stock	Pu: Public	C: Cylinder	

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
K. Felter	25-109N-50W	D	23	24	Tile & Concrete	1546	Sand and Gravel	Outwash	Wp	Sd	14
M. Egeberg	1-109N-51W	Sp	12	$1\frac{1}{4}$	Wood	1582	Sand and Gravel	Outwash	Wp	S	4
F. Canten	2-109N-51W	Sp	14	$1\frac{1}{4}$		1622	Sand and Gravel	Outwash	Ej	S	2
A. Wobbema	12-109N-51W	Sp	20	$1\frac{1}{4}$	Tile	1583	Sand and Gravel	Outwash	Ej	Do	7
E. Green	1-109N-51W	Sp	14	$1\frac{1}{4}$		1583	Sand and Gravel	Outwash	Ep	S	3
F. Hallekson	11-109N-51W	D	22	32	Cement Tile, Wood	1553	Sand and Gravel	Outwash	Ej	Do	8
C. Wosje	12-109N-51W	Sp	20	$1\frac{1}{4}$	Wood	1579	Sand and Gravel	Outwash	Wp	S	8
A. Kalsbeek	12-109N-51W	D	15	32	Cement	1584	Sand and Gravel	Outwash	Ej	Do	5
W. Brothers	12-109N-51W	Sp	20	$1\frac{1}{4}$		1581	Sand and Gravel	Outwash	Ej	S	5
D. Sterud	13-109N-51W	D	20	32	Cement & Wood	1590	Sand and Gravel	Outwash	Ej	Do	8
G. Bjerke	14-109N-51W	D	20	32	Cement	1598	Sand and Gravel	Outwash	Ej	Do	1
H. Edmon	14-109N-51W	Sp	23	$1\frac{1}{4}$	Cement	1591	Sand and Gravel	Outwash	Ej	Ps	8
K. Liebsch	23-109N-51W	D	30	24	Steel	1607	Sand and Gravel	Outwash	Ep	S	7

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E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
V. Sween	24-109N-51W	D	26	32	Cement & Steel	1594	Sand and Gravel	Outwash	Ep	S	6
H. Brothers	24-109N-51W	D	30	48	Cement & Wood	1598	Sand and Gravel	Outwash	Ep	S	10
V. Sween	24-109N-51W	D	25	30	Cement & Tile	1580	Sand and Gravel	Outwash	Ep	S	5
C. Johnson	6-110N-48W	D	52	24	Concrete & Wood	1713	Sand and Gravel	Outwash	Ep	DoS	6
M. F. Quinn	6-110N-48W	D	25	36	Concrete & Wood	1698	Sand and Gravel	Outwash	HWp	DoS	4
T. Davis	7-110N-48W	D	20	36	Wood	1620	Sand and Gravel	Outwash	Wp	DoS	4
L. J. Hanneman	7-110N-48W	D	24	36	Cement	1624	Sand and Gravel	Outwash	HWp	S	5
City of Bushnell	18-110N-48W	D	61	36	Cement & Tile	1687	Sand and Gravel	Outwash	Ej	Pu	16
W. Christensen	18-110N-48W	D	56	24	Cement & Tile	1684	Sand and Gravel	Outwash	HEj	DoS	10
G. Davis	18-110N-48W	D	54	36	Steel	1686	Sand and Gravel	Outwash	Ep	Do	9
R. L. Felton	18-110N-48W	D	86	36	Cement	1708	Sand (Gravel)	Iowan Stratified Drift	Ej	DoS	52
T. Framstad	18-110N-48W	D	13	36	Cement	1650	Sand and Gravel	Outwash	Ep	S	5
Mrs. E. Meyer	18-110N-48W	D	48	24	Wood	1715	Sand (Gravel)	Iowan Stratified Drift	HWp	DoS	3

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
D. E. Norton	18-110N-48W	D	54	36	Wood	1690	Sand and Gravel	Outwash	Hp	Do	6
H. W. Friedrich	30-110N-48W	D	65	36	Cement	1667	Sand (Gravel)	Iowan Stratified Drift	Ej	Do	42
W. Friedrich	31-110N-48W	D	25	24	Cement	1642	Sand and Gravel	Outwash	Ej	Do	5
P. E. Griffith	32-110N-48W	D	11	36	Cement	1638	Sand and Gravel	Outwash	Ep	S	2
M. Jensen	32-110N-48W	D	12	36	Tile	1631	Sand and Gravel	Outwash	Ej	DoS	4
L. Engel	4-110N-49W	D	63	24	Cement	1698	Sand (Gravel)	Iowan Stratified Drift	Ep	DoS	31
L. Gorenby	4-110N-49W	D	85	36	Cement	1663	Sand (Gravel)	Iowan Stratified Drift	Ehp	DoS	56
H. Dean	5-110N-49W	Sp	25	$1\frac{1}{4}$	Cement	1640	Sand and Gravel	Outwash	Ec	Do	5
R. Peterson	5-110N-49W	D	81	24	Cement	1653	Sand (Gravel)	Iowan Stratified Drift	Ej	DoS	54
H. Barnett	7-110N-49W	D	16	36	Cement	1631	Sand and Gravel	Outwash	Ej	DoS	6
A. Pullman	7-110N-49W	D	70	36	Wood & Cement	1646	Sand (Gravel)	Iowan Stratified Drift	Ej	DoS	30
R. E. Barnett	8-110N-49W	D	47	24	Cement	1643	Sand (Gravel)	Iowan Stratified Drift	EHPJ	Do	18
H. H. Ruedebusch	9-110N-49W	D	126	24	Cement & Wood	1675	Sand (Gravel)	Iowan Stratified Drift	HWp	DoS	95

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
E. Dupray	10-110N-49W	D	38	24	Cement	1637	Sand and Gravel	Outwash	Ej	Do	25
G. J. Pohlins	10-110N-49W	D	70	24	Tile & Wood	1655	Sand (Gravel)	Iowan Stratified Drift	EHp	Do	30
F. Nullshaum	11-110N-49W	D	19	24	Steel	1646	Sand and Gravel	Outwash	EC	Do	5
E. H. Meyer	12-110N-49W	D	18	36	Tile & Wood	1651	Sand and Gravel	Outwash	Ep	S	6
E. H. Postil	12-110N-49W	D	40	30	Cement Tile, Wood	1696	Sand and Gravel	Outwash	WEJ	DoS	7
W. N. Robbins	13-110N-49W	D	18	30	Cement	1658	Sand and Gravel	Outwash	Wp	S	4
A. D. McKelvey	14-110N-49W	D	102	24	Cement & Wood	1674	Sand (Gravel)	Iowan Stratified Drift	Ej	Do	57
C. Bersch	16-110N-49W	D	19	30	Cement & Tile	1628	Sand and Gravel	Outwash	Ep	DoS	10
M. Larson	16-110N-49W	D	11	24	Cement	1628	Sand and Gravel	Outwash	Ej	Do	2
H. Vanderslins	20-110N-49W	D	13	24	Tile & Cement	1621	Sand and Gravel	Outwash	Wp	DoS	4
C. P. Mans	22-110N-49W	D	33	30	Cement	1643	Sand and Gravel	Outwash	HWp	DoS	7
O. G. Hill	23-110N-49W	D	40	24	Cement	1653	Sand and Gravel	Outwash	Ej	Do	8
H.G. Ostermeier	24-110N-49W	D	59	24	Tile & Cement	1680	Sand and Gravel	Outwash	Wp	DoS	13

TABLE 12

WELL RECORDS (June-August, 1957)

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T: Turbine
J: Jet pump
Pu: Public

H: Hand operated
W: Windmill
C: Cylinder

E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
L. DeGroot	26-110N-49W	D	23	36	Wood & Cement	1635	Sand and Gravel	Outwash	Ep	DoS	6
W. L. Lievan	27-110N-49W	D	33	24	Wood	1631	Sand and Gravel	Outwash	Ep	DoS	16
D. Sanderson	27-110N-49W	D	51	24	Tile & Cement	1650	Sand and Gravel	Outwash	EWp	DoS	13
E.L. Siehemmer	27-110N-49W	D	41	24	Brick & Tile	1640	Sand and Gravel	Outwash	Ep	DoS	10
C. Slocum	28-110N-49W	D	20	36	Tile & Cement	1628	Sand and Gravel	Outwash	Ej	DoS	12
E. Moxon	29-110N-49W	D	14	36	Cement	1618	Sand and Gravel	Outwash	Ej	DoS	8
D. Gilkerson	29-110N-49W	D	12	48	Concrete	1586	Sand and Gravel	Outwash	Ej	DoS	4
R. Morris	29-110N-49W	D	12	30	Tile	1614	Sand and Gravel	Outwash	Ep	Do	5
M. Moxon	29-110N-49W	D	20	36	Cement	1620	Sand and Gravel	Outwash	Ej	Do	11
W. Fichhorst	32-110N-49W	D	20	30	Tile	1581	Sand and Gravel	Outwash	Ej	Do	13
Mrs. E. M. Simkins	32-110N-49W	D	14	24	Cement	1611	Sand and Gravel	Outwash	Ep	DoS	8
M. L. Freeman	33-110N-49W	D	13	30	Cement	1624	Sand and Gravel	Outwash	Ep	DoS	4
N. Jensen	33-110N-49W	D	11	18	Tile	1614	Sand and Gravel	Outwash	Ej	Do	1

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
City of Aurora	35-110N-49W	D	24	36	Cement	1623	Sand and Gravel	Outwash	Ej	Pu	13
A.R. Straight	35-110N-49W	D	11	24	Cement	1625	Sand and Gravel	Outwash	Ej	Do	5
Mrs. D. Thornton	35-110N-49W	D	29	30	Cement	1628	Sand and Gravel	Outwash	Ej	Do	15
C. Davis	36-110N-49W	D	23	24	Cement & Tile	1636	Sand and Gravel	Outwash	Ej	Do	5
L. B. Larson	4-110N-50W	D	14	30	Steel	1608	Sand and Gravel	Outwash	Ewp	DoS	3
J. Hoogwerf	5-110N-50W	Sp	19	$1\frac{1}{4}$		1596	Sand and Gravel	Outwash	Ec	S	10
E. Tofte	5-110N-50W	Sp	12	$1\frac{1}{4}$	Cement & Steel	1603	Sand and Gravel	Outwash	Ej	DoS	3
J. Messerschmidt	6-110N-50W	D	20	24	Tile	1598	Sand and Gravel	Outwash	Ej	Do	10
E. Tofte	8-110N-50W	D	29	30	Cement	1613	Sand and Gravel	Outwash	Ej	Do	23
O. Tufty	8-110N-50W	Sp	20	$1\frac{1}{4}$	Steel	1596	Sand and Gravel	Outwash	Wp	S	7
Mrs. Stern	9-110N-50W	D	27	24	Cement	1616	Sand and Gravel	Outwash	Ej	Do	20
I. C. Hansen	10-110N-50W	D	26	30	Steel & Wood	1623	Sand and Gravel	Outwash	Ej	DoS	3
City of Brookings	13-110N-50W	D	61	36	Cement	1602	Sand and Gravel	Outwash	Et	Pu	45

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
J. Vandenberg	14-110N-50W	D	20	30	Cement & Wood	1596	Sand and Gravel	Outwash	Ej	DoS	9
E. Howell	15-110N-50W	D	30	24	Cement	1597	Sand and Gravel	Outwash	Ej	DoS	21
J. Thompson	16-110N-50W	Sp	10	1¼		1592	Sand and Gravel	Outwash	Ej	Do	4
A. Vostad	16-110N-50W	Sp	30	48	Brick	1613	Sand and Gravel	Outwash	Ej	DoS	5
C. Sorenson	17-110N-50W	D	15	6	Tile & Cement	1589	Sand and Gravel	Outwash	Wp	S	11
K. Christopherson	18-110N-50W	Sp	11	1¼	Tile	1589	Sand and Gravel	Outwash	Wp	S	7
R. Egeberg	19-110N-50W	Sp	10	1¼		1588	Sand and Gravel	Outwash	Hp	Do	8
J. C. Jefferis	19-110N-50W	Sp	7	1¼		1585	Sand and Gravel	Outwash	Ej	Do	3
K. Knutson	20-110N-50W	Sp	10	1¼		1583	Sand and Gravel	Outwash	Ej	Do	4
V. VanMaahen	20-110N-50W	Sp	12	1¼		1589	Sand and Gravel	Outwash	Ej	Do	8
A. Volkers	20-110N-50W	D	10	30	Cement	1587	Sand and Gravel	Outwash	Ec	DoS	4
A. Moore	21-110N-50W	Sp	14	1¼		1587	Sand and Gravel	Outwash	Ej	Do	6
B. Olson	21-110N-50W	D	15	72	Cement	1599	Sand and Gravel	Outwash	Ej	DoS	4

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C: Cylinder
E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
D. Thompson	28-110N-50W	Sp	10	$1\frac{1}{4}$		1584	Sand and Gravel	Outwash			6
O. Egeberg	29-110N-50W	D	10	24	Tile	1584	Sand and Gravel	Outwash	Wp	S	9
A. Wilaby	29-110N-50W	D	10	30	Tile	1582	Sand and Gravel	Outwash	Ej	S	3
F. Callahan	30-110N-50W	Sp	14	$1\frac{1}{4}$		1585	Sand and Gravel	Outwash	Ej	S	5
L. Egeberg	30-110N-50W	Sp	8	$1\frac{1}{4}$		1584	Sand and Gravel	Outwash	Hp	Do	3
M. Ust	32-110N-50W	Sp	18	$1\frac{1}{4}$		1580	Sand and Gravel	Outwash	Ej	Do	7
N. Phillips	33-110N-50W	Sp	18	$1\frac{1}{4}$		1561	Sand and Gravel	Outwash	Ej	Do	9
J. Done	1-110N-51W	Sp	18	$1\frac{1}{4}$		1599	Sand and Gravel	Outwash	Ej	Do	8
C. Peterson	1-110N-51W	Dr	20	$1\frac{1}{4}$	Steel	1595	Sand and Gravel	Outwash	Ec	DoS	14
O. Josenby	2-110N-51W	D	16	30	Tile	1605	Sand and Gravel	Outwash	Ej	DoS	4
H. J. Addison	10-110N-51W	D	22	15	Steel & Brick	1632	Sand and Gravel	Outwash	Wp	Do	6
E. Meyer	10-110N-51W	D	22	18	Steel	1621	Sand and Gravel	Outwash	Wp	DoS	11
J. Wiersma	11-110N-51W	D	23	30	Cement	1622	Sand and Gravel	Outwash	Ej	S	8

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WELL RECORDS (June-August, 1957)

Dr: Drilled   Sp: Sand point   T: Turbine   H: Hand operated   E: Electric
D: Dug   P: Pitcher pump   J: Jet pump   W: Windmill   Do: Domestic
I: Irrigation   S: Stock   Pu: Public   C: Cylinder

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
J. Post	11-110N-51W	Dr	280	4	Steel	1616	Sand (Gravel)	Cary Stratified Drift, Pierre Shale	Ej	DoS	260
O. Brothers	12-110N-51W	Sp	7	$1\frac{1}{4}$	Steel	1593	Sand and Gravel	Outwash	Wp	S	5
L.J. Steuerwald	12-110N-51W	Sp	15	$1\frac{1}{4}$		1591	Sand and Gravel	Outwash	Ej	S	10
L.J. Steuerwald	12-110N-51W	Sp	12	$1\frac{1}{4}$		1594	Sand and Gravel	Outwash	Hp	Do	10
Church of God	13-110N-51W	Sp	10	$1\frac{1}{4}$		1599	Sand and Gravel	Outwash	Ej	Do	4
H. O. Meyer	14-110N-51W	Sp	11	$1\frac{1}{4}$		1617	Sand and Gravel	Outwash	Ej	Do	4
H. Carlson	14-110N-51W	D	18	48	Brick	1624	Sand and Gravel	Outwash	Ej	DoS	7
H. J. Clapp	14-110N-51W	D	14	24	Tile	1628	Sand and Gravel	Outwash	Ec	DPu	1
B. Clapp	14-110N-51W	Sp	14	$1\frac{1}{4}$	Concrete	1627	Sand and Gravel	Outwash	Wp	S	4
J. M. Johnson	14-110N-51W	D	25	30	Wood	1626	Sand and Gravel	Outwash	Ej	DoS	11
G. Vermeulen	15-110N-51W	D	22	24	Steel	1629	Sand and Gravel	Outwash	Ec	Do	6
E. J. Jorenby	21-110N-51W	Sp	18	$1\frac{1}{4}$		1652	Sand and Gravel	Outwash	Ep	Do	4
L. Olson	21-110N-51W	D	30	32	Concrete & Tile	1650	Sand and Gravel	Outwash	Ej	Do	10

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
A. Johnson	22-110N-51W	Sp	15	$1\frac{1}{4}$		1632	Sand and Gravel	Outwash	Hp	Do	4
T. Lien	22-110N-51W	Sp	20	$1\frac{1}{4}$		1631	Sand and Gravel	Outwash	Hp	Do	6
S. Bortelsen	23-110N-51W	D	16	42	Steel	1627	Sand and Gravel	Outwash	Ej	Do	2
T. Carpenter	23-110N-51W	D	18	24	Cement & Tile	1633	Sand and Gravel	Outwash	Ec	Do	3
City of Volga	23-110N-51W	D	22	120	Wood & Brick	1632	Sand and Gravel	Outwash	Ej	Pu	9
F. W. Williams	23-110N-51W	D	18	4	Steel	1633	Sand and Gravel	Outwash	Ej	Do	6
C. Brothers	24-110N-51W	D	26	48	Concrete & Wood	1612	Sand and Gravel	Outwash	Ep	S	8
L. Tenning	24-110N-51W	D	15	36	Wood	1621	Sand and Gravel	Outwash	Ep	S	4
E. G. VanBeek	24-110N-51W	D	15	48	Wood	1622	Sand and Gravel	Outwash	Wp	S	3
J. H. Jorenby	25-110N-51W	D	25	30	Steel, Tile, Wood	1626	Sand and Gravel	Outwash	Ep	Ps	8
M. Karlstad	25-110N-51W	D	18	6	Steel	1616	Sand and Gravel	Outwash	Wp	S	2
E. Hesby	26-110N-51W	D	18	36	Tile	1633	Sand and Gravel	Outwash	Epj	Do	12
H. Karlstad	26-110N-51W	D	18	24	Steel	1632	Sand and Gravel	Outwash	Wp	S	2

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
B. Weber	26-110N-51W	Sp	18	$1\frac{1}{4}$	Tile	1638	Sand and Gravel	Outwash	Ep	Do	2
G. VanMaanen	27-110N-51W	Sp	12	$1\frac{1}{4}$		1633	Sand and Gravel	Outwash	Ep	Do	3
C. McCullow	22-110N-51W	Sp	20	$1\frac{1}{4}$	Concrete	1638	Sand and Gravel	Outwash	Hp	S	4
O. Oines	27-110N-51W	D	30	30	Concrete & Wood	1639	Sand and Gravel	Outwash	Ep	S	14
A. Alexander	28-110N-51W	D	28	12	Steel	1637	Sand and Gravel	Outwash	Wp	DoS	8
H. Houtman	28-110N-51W	D	25	24	Concrete & Tile	1639	Sand and Gravel	Outwash	Ej	Do	5
J. Clapp	29-110N-51W	D	56	32	Concrete & Tile	1676	Sand and Gravel	Outwash	Ejp	DoS	12
W. Mans	29-110N-51W	D	35	32	Concrete & Tile	1671	Sand and Gravel	Outwash	Ejp	DoS	5
R. VanMaanen	32-110N-51W	Sp	40	$1\frac{1}{4}$	Brick, Tile, Concrete	1668	Sand and Gravel	Outwash	Ejp	DoS	8
A.J. Levenkamp	35-110N-51W	Sp	24	$1\frac{1}{4}$		1625	Sand and Gravel	Outwash	Wp	S	17
O. Wattnem	35-110N-51W	D	28	32	Cement	1632	Sand and Gravel	Outwash	Ep	S	12
L. Telkamp	36-110N-51W	Sp	10	$1\frac{1}{4}$		1579	Sand and Gravel	Outwash	Hp	Do	7
G. R. McKnight	1-111N-49W	D	34	36	Wood	1755	Sand and Gravel	Outwash	Ep	Do	16

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds: Character of Material	Principal Water Bearing Beds: Geologic Source	Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
G. W. Peteis	2-111N-49W	D	43	36	Wood & Concrete	1758	Sand and Gravel	Outwash	Ep	DoS	14
R. J. Poss	3-111N-49W	D	39	24	Cement & Steel	1744	Sand and Gravel	Outwash	Hp	Do	7
H. J. Tellingheisen	4-111N-49W	D	26	36	Cement & Wood	1735	Sand and Gravel	Outwash	Ej	Do	2
R. Smidt	7-111N-49W	D	53	30	Cement & Tile	1673	Sand (Gravel)	Iowan Stratified Drift	Wp	DoS	24
Mrs. E. Lutterman	8-111N-49W	D	22	48	Cement & Wood	1671	Sand and Gravel	Outwash	Ehpj	Do	3
M. Thompson	8-111N-49W	D	20	32	Cement & Tile	1688	Sand and Gravel	Outwash	Wp	S	7
L. D. McCuen	9-111N-49W	D	33	24	Cement	1734	Sand and Gravel	Outwash	Ej	Do	5
N. A. Tellinghuisen	10-111N-49W	D	54	24	Cement, Tile, Wood	1740	Sand and Gravel	Outwash	Ewp	DoS	20
L. N. Lucas	11-111N-49W	D	34	48	Wood	1744	Sand and Gravel	Outwash	Ep	DoS	4
W. A. Yule	12-111N-49W	D	14	24	Cement & Tile	1736	Sand and Gravel	Outwash	Ec	Do	2
City of White	12-111N-49W	Dr	112	8	Steel & Cement	1785	Sand (Gravel)	Iowan Stratified Drift	Et	Pu	68
G. T. Hakeman	14-111N-49W	D	18	24	Cement	1703	Sand and Gravel	Outwash	Ep	DoS	8
R. Smidt	15-111N-49W	D	11	24	Cement & Wood	1693	Sand and Gravel	Outwash	Ep	DoS	1

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
N. A. Tellinghuisen	15-111N-49W	D	38	24	Cement	1733	Sand and Gravel	Outwash	Ewp	DoS	28
A. H. Anderson	21-111N-49W	D	51	36	Cement & Wood	1701	Sand (Gravel)	Iowan Stratified Drift	Ep	DoS	35
H. Holler	22-111N-49W	D	58	24	Cement	1716	Sand (Gravel)	Iowan Stratified Drift	Wp	DoS	7
H.E. Landusman	22-111N-49W	D	23	24	Cement	1693	Sand and Gravel	Outwash	Hp	Do	11
J. R. Robbins	25-111N-49W	D	57	24	Concrete & Tile	1730	Sand and Gravel	Outwash	Ewp	DoS	32
W. J. Lang	26-111N-49W	D	40	24	Cement & Steel	1725	Sand and Gravel	Outwash	Ej	DoS	8
M. Langner	26-111N-49W	D	48	24	Cement, Tile, Wood	1707	Sand (Gravel)	Iowan Stratified Drift	Wp	DoS	9
C. Churchill	28-111N-49W	D	73	24	Cement	1683	Sand (Gravel)	Iowan Stratified Drift	Ep	Ps	51
C. L. Culver	28-111N-49W	D	31	48	Cement	1677	Sand and Gravel	Outwash	Wp	DoS	8
A. K. Adams	32-111N-49W	D	54	36	Wood	1673	Sand and Gravel	Outwash	Hp	DoS	39
R. Duff	33-111N-49W	D	27	24	Cement	1680	Sand and Gravel	Outwash	Wp	DoS	4
F. Laabs	35-111N-49W	D	48	36	Cement	1695	Sand (Gravel)	Iowan Stratified Drift	Ej	Do	12
W. Peterson	3-111N-50W	D	17	24	Cement & Tile	1610	Sand and Gravel	Outwash	Ej	Do	7

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Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
L. Thompson	9-111N-50W	D	45	36	Cement	1606	Sand (Gravel)	Iowan Stratified Drift	Hp	Do	16
C. A. Skiner	11-111N-50W	D	44	30	Cement, Tile, Wood	1630	Sand (Gravel)	Iowan Stratified Drift	Ewp	DoS	17
D. Seas	13-111N-50W	D	21	30	Brick & Cement	1661	Sand and Gravel	Outwash	Ej	Do	4
W. Peterson	15-111N-50W	D	23	30	Cement & Tile	1605	Sand and Gravel	Outwash	Ej	Do	8
J. Hegg	20-111N-50W	D	47	30	Cement & Tile	1593	Sand (Gravel)	Iowan Stratified Drift	Ep	DoS	30
O. Peterson	20-111N-50W	D	32	24	Cement	1602	Sand (Gravel)	Iowan Stratified Drift	Ehp	DoS	14
H. Nelson	21-111N-50W	D	18	30	Cement	1598	Sand and Gravel	Outwash	Hp	S	5
H. H. Christensen	23-111N-50W	D	20	36	Cement	1641	Sand and Gravel	Outwash	Ehwp	DoS	2
D. W. Crase	26-111N-50W	D	27	20	Concrete & Tile	1630	Sand and Gravel	Outwash	Ej	Do	15
Mrs. M. Johnson	27-111N-50W	D	12	30	Cement & Tile	1631	Sand and Gravel	Outwash	Wp	DoS	4
T. Odegaard	31-111N-50W	D	20	30	Cement	1599	Sand and Gravel	Outwash	Ec	S	11
E. Tofte	31-111N-50W	D	18	24	Cement	1607	Sand and Gravel	Outwash	Ej	Do	4
L. T. Johnson	32-111N-50W	D	29	32	Cement & Wood	1609	Sand and Gravel	Outwash	Ej	DoS	17

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Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
C. Intverld	33-111N-50W	D	52	24	Cement	1631	Sand and Gravel	Outwash	Ep	S	37
A. Toft	34-111N-50W	D	12	12	Tile	1620	Sand and Gravel	Outwash	Hp	Do	18
S. H. Wilcox	35-111N-50W	D	23	24	Cement & Tile	1634	Sand and Gravel	Outwash	Ejhp	Do	5
E. Cook	1-111N-51W	D	17	$1\frac{1}{4}$	Steel	1627	Sand and Gravel	Outwash	Ec	S	5
O. G. Skort	1-111N-51W	D	12	24	Cement	1618	Sand and Gravel	Outwash	Ej	Do	2
P. Skovlund	1-111N-51W	D	24	8		1623	Sand and Gravel	Outwash	Ej	Do	7
G. Intermill	2-111N-51W	D	58	30	Steel	1631	Sand (Gravel)	Iowan Stratified Drift	Ec	S	35
City of Bruce	12-111N-51W	D	12	144	Cement & Brick	1619	Sand and Gravel	Outwash	Et	Pu	5
D. Mulder	34-111N-51W	D	38	36	Wood	1629	Sand (Gravel)	Cary Stratified Drift	Ej	DoS	8
T. Cor	28-112N-49W	D	19	32	Cement & Tile	1676	Sand and Gravel	Outwash	Ej	DoS	5
A. Watt	32-112N-49W	D	17	32	Cement & Tile	1675	Sand and Gravel	Outwash	Ep	S	7
R. Dries	20-112N-50W	D	38	24	Cement	1658	Sand and Gravel	Outwash	Ej	Do	23
H. Harms	26-112N-50W	D	71	30	Cement	1648	Sand (Gravel)	Iowan Stratified Drift	Ej	Do	51

WELL RECORDS (June-August, 1957)

TABLE 12

Dr: Drilled
D: Dug
I: Irrigation

Sp: Sand point
P: Pitcher pump
S: Stock

T: Turbine
J: Jet pump
Pu: Public

H: Hand operated
W: Windmill
C: Cylinder

E: Electric
Do: Domestic

Owner or Tenant	Location	Type of Well	Depth of Well (ft)	Dia. of Well (in)	Type of Casing	Ground Surface above Sea Level (feet)	Principal Water Bearing Beds		Method of Lift	Use of Water	Depth of Water Summer 1957 (feet)
							Character of Material	Geologic Source			
A. Frykman	29-112N-50W	D	11	24	Cement	1628	Sand and Gravel	Outwash	Hp	S	4
E. B. Apland	30-112N-50W	Sp	18	$1\frac{1}{4}$		1626	Sand and Gravel	Outwash	Ec	Do	8
O. Rust	31-112N-50W	D	16	72	Cement & Steel	1624	Sand and Gravel	Outwash	Wp	Do	10
K. Reed	34-112N-50W	D	62	24	Cement & Wood	1624	Sand (Gravel)	Iowan Stratified Drift	Wp	S	44
Mrs. M. Geringer	25-112N-51W	D	9	48	Cement	1628	Sand and Gravel	Outwash	Ec	S	8
D. Krogh	25-112N-51W	D	40	24	Wood	1653	Sand (Gravel)	Iowan Stratified Drift	Wp	S	12
S. Walters	36-112N-51W	D	9	60	Cement	1623	Sand and Gravel	Outwash	Wp	Do	3