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RECONNAISSANCE OF THE

GEOLOGY AND GROUND-WATER RESOURCES OF SOUTHERN SIOUX COUNTY, NEBRASKA

By Edward Bradley

WITH A SECTION ON THE CHEMICAL QUALITY OF THE GROUND WATER

By F. H. Rainwater

1956

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

HYDROLOGIC INVESTIGATIONS ATLAS HA 6

Compiled as part of the program of the Department of the Interior for development of the Missouri River basin

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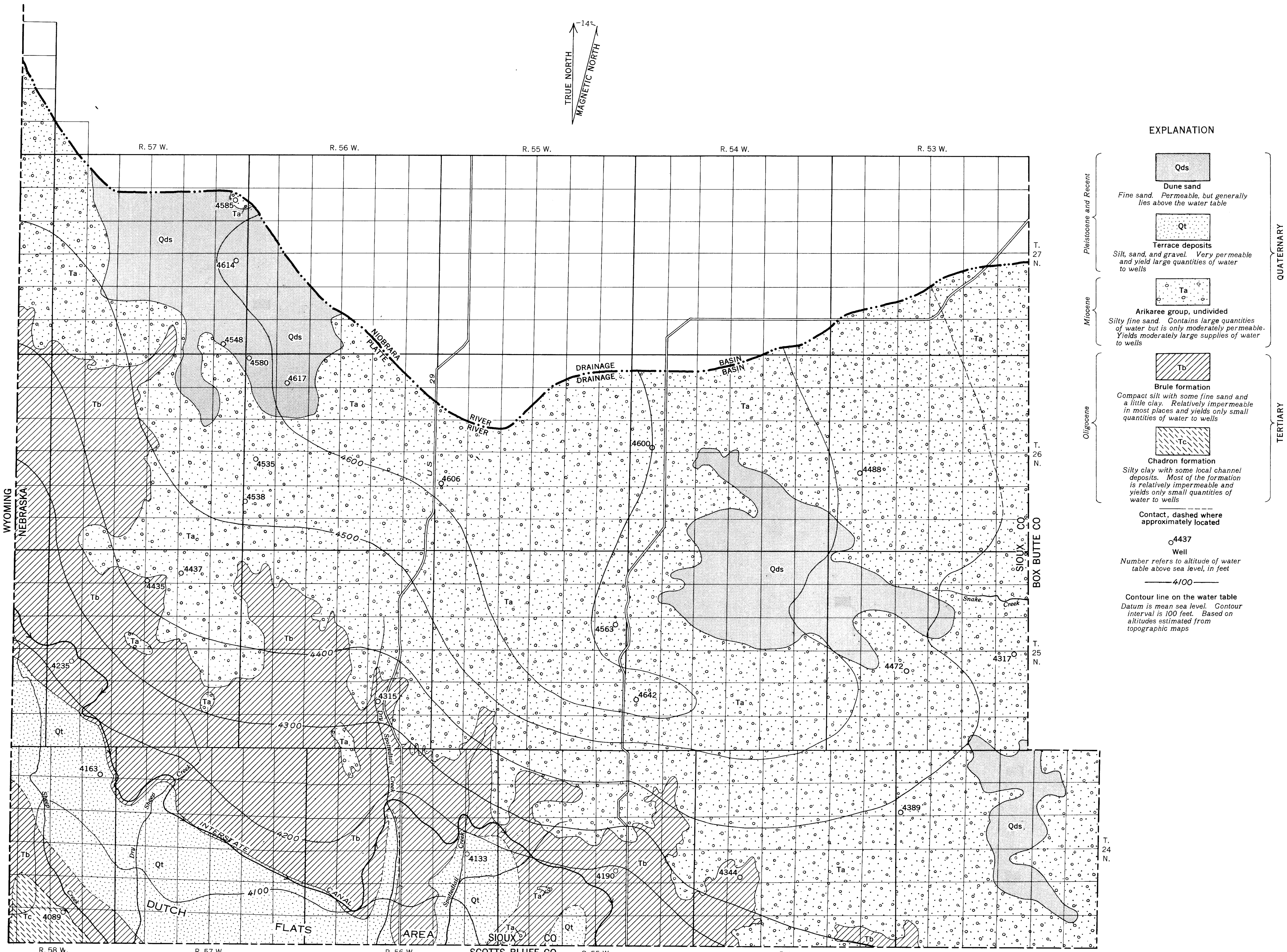

Base map modified from map of Sioux County prepared by the State of Nebraska, Dept. of Roads and Irrigation

MAP OF SOUTHERN SIOUX COUNTY, NEBRASKA, SHOWING AREAL GEOLOGY AND CONTOUR LINES ON THE WATER TABLE, 1952–53

2 0 10 Miles

Geology adapted from geologic map of Sioux County by A. L. Lugn, of the Nebraska Geological Survey, and geologic map of Dutch Flats area by F. N. Visher, of the U. S. Geological Survey

INTRODUCTION

Purpose and Scope of the Investigation

The purpose of this report is to present a résumé of the ground-water resources of southern Sioux County, Nebr., to indicate the present and potential use of ground water in the area, and to call attention to any problem relating to ground-water development. It includes an annotated bibliography of the more important reports pertaining to the ground water and geology of the area; tables of hydrologic data for all large-discharge wells and for some domestic, stock, and unused wells; a compilation of the available geologic information on the water-bearing strata; an evaluation of the occurrence, recharge, and discharge of ground water in the area; and an evaluation of existing hydrologic data in terms of present and potential ground-water uses and problems.

This study is one of several being made by the United States Geological Survey as a part of the program of the Department of the Interior for the development, conservation, and use of the water resources of the Missouri River basin. The investigation was under the immediate supervision of H. M. Babcock, district engineer in charge of ground-water investigations in Wyoming and adjacent areas in Nebraska, and P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin.

Fieldwork was done during June and July 1953. Records were obtained for 28 wells and springs in the area, including all wells of large discharge. Four water samples from wells were collected for chemical analysis. A map showing the areal geology was compiled, largely from existing sources. Maps showing the contour of the water table and the depth to water also were prepared.

Location and Extent of the Area

The area described in this report includes about 600 square miles in southern Sioux County, Nebr. (fig. 1). It is bounded on the north by the topographic divide between the drainage basins of the Niobrara and North Platte Rivers, on the east by Box Butte County, on the south by Scotts Bluff County, and on the west by Goshen County, Wyo. It includes the Sioux County portion of the Dutch Flats area, described in more detail in an earlier report (Babcock and Visher, 1951).

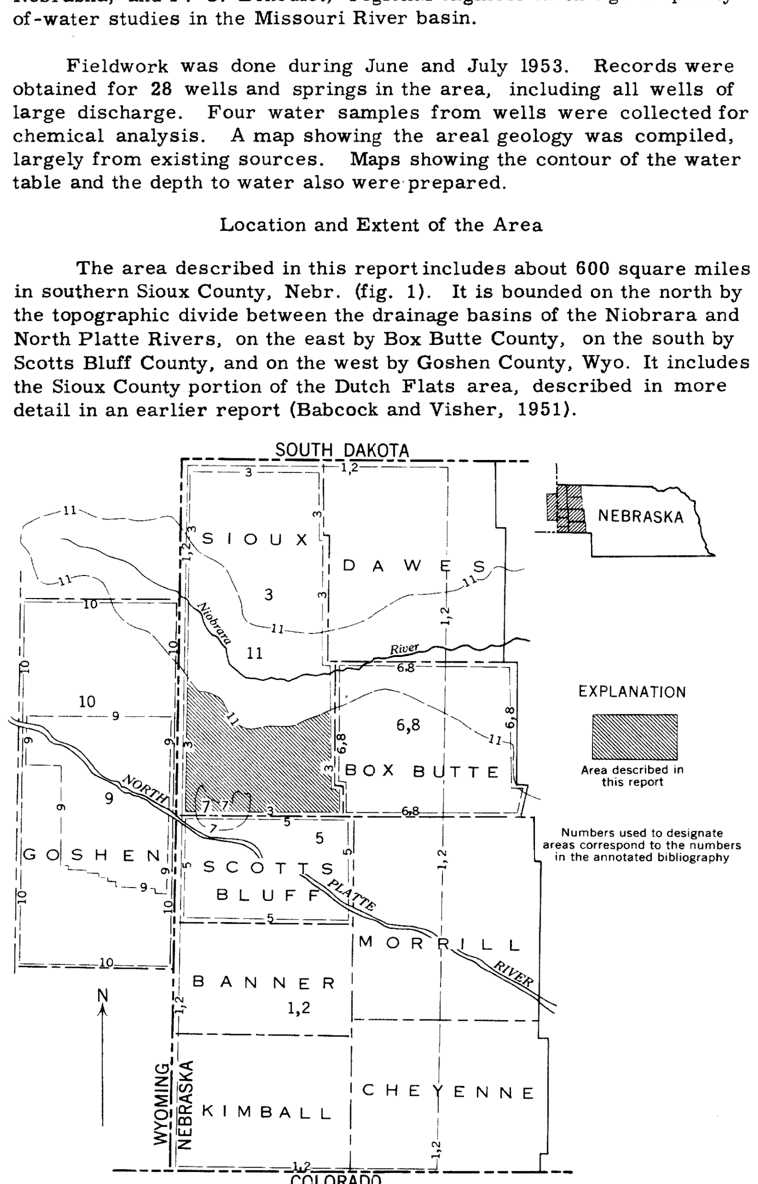

Figure 1. —Index map of western Nebraska and southeastern Wyoming showing area described in this report and other areas nearby in which geologic or ground-water studies have been made.

Well-Numbering System

The wells and springs listed in this report are numbered according to their location within the U. S. Bureau of Land Management survey of the area. The well number shows the location of the well by township, range, section, and position within the section. The first numeral of a well number denotes the township, the second the range, and the third the section in which the well is located. The letters after the section number indicate the location of the well within the section. The first letter denotes the quarter section (160-acre tract) and the second letter the quarter-quarter section (40-acre tract). These subdivisions are designated a, b, c, and d, and the letters are assigned counterclockwise, beginning in the northeast quarter section or quarter-quarter section. A graphical explanation of this method of well numbering is shown in figure 2.

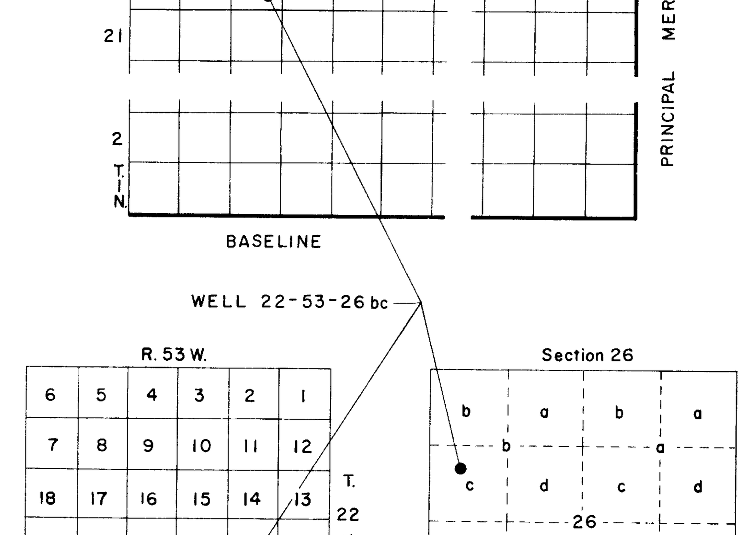

Figure 2. —Sketch showing well-numbering system.

ANNOTATED BIBLIOGRAPHY

A number of reports describing the geology and ground-water resources of areas that include or are adjacent to the report area have been prepared by other investigators and are listed in the following annotated bibliography. The areas covered by these studies are shown in figure 1.

1. Darton, N. H., 1898, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geol. Survey 19th Ann. Rept., pt. 4, p. 719-785, pls. 74-118.

A number of photographs and geologic sections, also a geologic map, accompany the detailed descriptions of the Tertiary and older geologic formations. Brief discussions of the availability of ground water in these formations are presented, and surface-water irrigation from streams is discussed. Maps showing the location of irrigated acreages in 1897 and a generalized depth-to-water map of western Nebraska are included in the report.

2. Darton, N. H., 1903, Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geol. Survey Prof. Paper 17, 69 p., 43 pls.

Except for very slight modifications of and additions to the discussion on the geologic formations, this report is like the one listed above.

3. Cook, H. J., 1915, Notes on the geology of Sioux County, Nebr., and vicinity: Nebr. Geol. Survey, v. 7, pt. 11, p. 59-75.

This report gives a summary of the geological and paleontological discoveries in central Sioux County near Agate, Nebr., up to 1911 and includes a north-south cross section of the county and several photographs illustrating the geology. The origin of the prolific fossil beds in the Arikaree group east of Agate is discussed.

4. Condra, G. E., and Reed, E. C., 1943, The geological section of Nebraska: Nebr. Geol. Survey Bull. 14, 74 p., 25 figs.

The age relations and general lithologic characteristics of the rocks of Nebraska are reviewed; graphic generalized sections indicating geologic groups, formations, and members are accompanied by brief lithologic descriptions; and references and brief discussions of various sections of the geologic column are presented.

5. Wenzel, L. K., Cady, R. C., and Waite, H. A., 1946, Geology and ground-water resources of Scotts Bluff County, Nebr.: U. S. Geol. Survey Water-Supply Paper 943, 150 p., 12 pls.

The Cretaceous, Tertiary, and Quaternary rocks of Scotts Bluff County are described in detail; special attention is paid to the principal water-bearing formations. Nine terraces along the North Platte River valley and various other landforms are discussed. The report describes the occurrence, recharge, and discharge of ground water, and the fluctuations of the water table caused by the infiltration of irrigation water and seepage from canals and ditches. Maps, figures, and tables that illustrate topics discussed in the text and a section on the chemical characteristics of the ground water are included in the report.

6. Cady, R. C., and Scherer, O. J., 1946, Geology and ground-water resources of Box Butte County, Nebr.: U. S. Geol. Survey Water-Supply Paper 969, 120 p., 9 pls.

The report describes the geography, landforms, geology, ground water, fluctuations of the water table, and utilization of ground water in Box Butte County. The Tertiary water-bearing formations are described in detail. Special reference is made to the availability of ground water for irrigation and to the behavior of ground water near pumping wells. The report includes a section on the chemical quality of the ground water, also maps, tables, and figures.

7. Babcock, H. M., and Visher, F. N., 1951, Ground-water conditions in the Dutch Flats area, Scotts Bluff and Sioux Counties, Nebr., with a section on the chemical quality of the ground water, by W. H. Durum: U. S. Geol. Survey Circ. 126, 51 p.

This report describes the geography, geology, and ground-water resources of the Dutch Flats area, of which a part north of the Sioux County line and south of the Interstate Canal lies in the area of the present report. Ground-water recharge from irrigation canals and laterals and from irrigation water applied to the land surface is discussed in detail. The report contains maps showing the geology, contour lines on the water table, depth to water, location of wells, and well records.

8. Nace, R. L., 1953, Ground water for irrigation in Box Butte County, Nebr., with a section on the chemical quality of the water, by W. H. Durum: U. S. Geol. Survey Circ. 166.

This report gives a brief résumé of the topics covered in Water-Supply Paper 969 and also data on the additional irrigation wells that have been installed since the completion of the fieldwork for that paper. The availability of ground water for irrigation in the light of the new data is discussed, and the quality of water from the Ogallala, Marsland, Harrison, and Monroe Creek formations is reported to be generally satisfactory for irrigation. However, because the percent sodium in the water from some formations is variable, the report recommends chemical analysis of all water being considered for use in irrigation.

9. Visher, F. N., Rapp, J. R., and Babcock, H. M., 1954, Geology and ground-water resources of the North Platte Irrigation Project in Goshen County, Wyo., with a section on the chemical quality of the ground water, by W. H. Durum: U. S. Geol. Survey water-supply paper [open-file report].

The report describes the geology of the area and discusses the water-bearing properties of the geologic formations, giving special attention to the alluvium and terrace deposits and the result of laboratory and field tests made to determine the physical and hydrologic properties of the geologic formations. Included are maps showing the geology, contour lines on the water table, depth to water, and the saturated thickness of the water-bearing materials, also tables of water-level measurements, logs of wells and test holes, well records, and the results of chemical analysis of ground-water samples.

10. Rapp, J. R., Visher, F. N., and Littleton, R. T., 1954, Geology and ground-water resources of Goshen County, Wyo., with a section on the chemical quality of the ground water, by W. H. Durum: U. S. Geol. Survey water-supply paper [in preparation].

The report discusses the geologic formations exposed in Goshen County and their water-bearing properties, making special reference to the terrace and alluvial deposits. Recharge, discharge, seepage, and irrigation are discussed in detail. Included in the report are geologic cross sections and maps showing the geology, depth of water, contour lines on the water table, and the saturated thickness of the alluvial deposits along the valley of the North Platte River. The report also includes tables of physical and hydrologic properties of the water-bearing formations, well records, water-level measurements, logs of wells and test holes, and the results of chemical analysis of ground-water samples.

11. Bradley, Edward, 1954, Reconnaissance of the geology and ground-water resources of the upper Niobrara River basin, Nebraska and Wyoming, with a section on the chemical quality of the water, by F. H. Rainwater: U. S. Geol. Survey Water-Supply Paper [in preparation].

The report summarizes the geology, ground-water resources, utilization of ground water, and the chemical quality of the water in the area, and discusses potential future ground-water development and possible problems resulting therefrom. It contains general maps showing the geology, contour lines on the water table, depth to water, and the location of wells. Well records and a number of figures and tables presenting geologic and hydrologic data are included.

GEOGRAPHY

The area described in this report lies within the High Plains section of the Great Plains physiographic province. The highest point in the area is in sec. 17, T. 26 N., R. 55 W., and is about 5,000 feet above sea level; the lowest point, where Spottedtail Creek leaves Sioux County, is about 4,050 feet above sea level. The area consists largely of rolling upland plains, which are covered in a few places by dune sand. In the southernmost part of Sioux County the upland surface is dissected by steep-walled canyons.

The perennial streams in the area are Sheep Creek, which flows south on the western edge of the area; Snake Creek, which flows eastward into Box Butte County from the east-central part of the area; and Spottedtail Creek, which flows southward into Scotts Bluff County from the south-central part of the area. Wind Springs (24-55-1c), Mud Springs (25-53-21cc), and East Springs (27-57-34ab) produce small creeks, but, except during floods, these creeks become dry beyond distances of 1 or 2 miles from the springs. The canyons of Dry Sheep and Dry Spottedtail Creeks and several unnamed creeks in the southern part of the area are dry except during floods.

Cattle raising is the chief means of livelihood in the report area. Sugar beets, potatoes, beans, hay, grains, and other crops are grown in the southwestern part of the area where some land is irrigated. The Interstate Canal flows across the southwestern corner of Sioux County, and most of the cropland south of the canal is irrigated.

There are no towns or cities in the report area. Ranches are several miles apart throughout all but the southwestern irrigated section of the area. Nebraska Highway 29 is a north-south graded dirt road traversing the central part of the area. Parallel to and about 8 miles east of this road is Nebraska Highway 87, which is graveled.

The climate is characterized by relatively low precipitation, high evaporation, and a comparatively wide range in temperature. No climatological stations have been established in the area; however, Scottsbluff, about 10 miles south of the southern boundary, has a U. S. Weather Bureau station. The following is quoted from the report on the Dutch Flats area (Babcock and Visher, 1951, p. 7):

> The normal annual precipitation for 61 years of record at Scottsbluff is 15.6 inches, the highest annual precipitation recorded is 27.5 inches (1915) and the lowest is 9.5 inches (1931). The maximum monthly precipitation occurs during May and the minimum occurs during January, when it usually takes the form of light dry snow. About 48 percent of the annual precipitation is received during April, May, and June, and only about 12 percent is received in November, December, January, and February. The summer rains occur largely as thunderstorms, which are usually sporadic and unevenly distributed. Occasionally these storms are accompanied by high winds and hail that cause considerable damage to crops.
>
> The mean annual temperature is 48.5°F. The growing season is about 150 days. The latest killing frost in the spring and the earliest killing frost in the fall were on April 18 and September 13 in 1949, respectively.

GEOLOGY IN RELATION TO GROUND WATER

The rocks exposed in southern Sioux County include the Chadron and Brule formations and the Arikaree group, all of Tertiary age, and the terrace deposits and dune sand of Quaternary age. The Arikaree group as used in this report includes all sediments of Miocene age in the area; Condra and Reed (1943, p. 11-12) have divided these sediments into the Hemingford and Arikaree groups, but in the present report they are mapped as a single unit called the Arikaree group, undivided. Table 1 shows a generalized geologic section of the rocks that crop out in the report area. The areal distribution of these rocks is shown on plate 1.

Tertiary System

Chadron formation.--The Chadron formation crops out in the southwestern corner of Sioux County. It consists of pale-gray silty clay and is probably less than 100 feet thick. The formation underlies the remainder of the report area at depths ranging from a few feet to several hundred feet. In adjacent areas the formation has been described as a pale-greenish-gray clay that contains local channel deposits of sand and gravel; similar channel deposits possibly underlie parts of the report area. The Chadron formation generally is relatively impermeable, but in the southwestern part of the area it yields water to a few domestic and stock wells. Elsewhere in the report area the Chadron formation has not been developed as an aquifer because sufficient quantities of water are available from overlying strata.

TABLE 1.—*Generalized section of rocks exposed in southern Sioux County, Nebr.*

System	Series	Subdivision	Maximum thickness (feet)	Physical character	Water supply
Quaternary		Dune sand	200 ±	Fine well-rounded buff sand; mainly quartz grains	Generally lies above the water table; serves as infiltration areas for recharge from precipitation
		Terrace deposits	130 ±	Silt, sand, and gravel	Permeable and yields water readily to wells
Tertiary	Miocene	Arikaree group, undivided	600 ±	Silty, fine buff to light-gray sand containing layers of sandstone and zones of tubular concretions	Contains large quantities of water. As the formation is only moderately permeable, wells must penetrate at least 150 ft of saturated material to obtain large quantities of water
	Oligocene	Brule formation	500 ±	Compact pink silt with some fine sand and a little clay; contains many joints and fissures	Relatively impermeable except for large joints and fissures; supplies water to domestic and stock wells
		Chadron formation	100 ±	Pale-gray silty clay possibly containing local channel deposits of sand and gravel	Relatively impermeable; supplies water to a few domestic and stock wells

TABLE 2.—*Analyses of ground water in southern Sioux County, Nebr.*

[Analytical results in parts per million except as indicated]

Well no.	24-55-22db	26-54-18dc [1]	26-56-6bb	27-57-12ac
Geologic source	Brule formation	Arikaree group	Arikaree group	Arikaree group
Well depth (feet)	117	200	126	146
Date of collection	10-7-52	10-7-52	10-7-52	10-7-52
Silica (SiO_2)	55	50	53	55
Iron (Fe), total	.45	.14	.16	.93
Calcium (Ca)	43	47	54	54
Magnesium (Mg)	9.4	7.4	11	11
Sodium (Na)	24	6.1	13	11
Potassium (K)	3.7	3.5	6.0	6.4
Bicarbonate (HCO_3)	198	174	207	212
Carbonate (CO_3)	0	0	0	0
Sulfate (SO_4)	17	3.0	9.0	8.0
Chloride (Cl)	8.0	3.0	2.5	6.0
Fluoride (F)	.4	.3	.5	.6
Nitrate (NO_3)	17	14	28	20
Boron (B)	.06	.02	.05	.06
Dissolved solids				
Sum	276	220	279	277
Residue on evaporation at 180°C	310	258	290	286
Hardness as $CaCO_3$	146	148	178	180
Noncarbonate	0	5	8	6
Specific conductance (micromhos at 25°C)	374	307	385	390
pH	7.7	7.9	8.0	7.8
Percent sodium	26	8	13	11

[1] Composite sample from 7 closely situated wells.

TABLE 3.—*Record of wells and springs in southern Sioux County, Nebr.*

Well no.: See text for explanation of well-numbering system.
Type of well: Dr, drilled; Du, dug; Sp, spring.
Depth of well: Measured depths are given in feet and tenths below land surface; reported depths are given in feet.
Type of casing: N, none; P, metal pipe.
Character of water-bearing material: C, clay; G, gravel; S, sand; Sls, siltstone.
Geologic source: Qt, terrace deposits and (or) alluvium; Ta, Arikaree group; Tb, Brule formation; Tc, Chadron formation.
Method of lift: C, cylinder; N, none; T, turbine.
Type of power: E, electric; F, natural flow; G, gas or gasoline; N, none; W, wind.
Use of water: D, domestic; I, irrigation; N, none; S, stock.
Measuring point: Ls, land surface; Tc, top of casing; Twc, top of well cover.
Height above sea level: Altitudes estimated from topographic maps of the U. S. Geological Survey.
Depth to water: Measured depths are given in feet and hundredths; reported depths are given in feet.
Remarks: A, irrigated area (numeral denotes acres); Ca, sample collected for chemical analysis; D, discharge (numeral denotes reported gallons per minute); F, natural flow (numeral denotes estimated gallons per minute); Gl, garden and lawn irrigation; Gr, group of 7 closely situated wells.

Well no.	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Principal water-bearing beds		Method of lift	Type of power	Use of water	Measuring point			Depth to water below measuring point (feet)	Date of measurement	Remarks
							Character of material	Geologic source				Description	Distance above or below (-) land surface	Height above mean sea level (feet)			
24-53- 7cc	....	....	Dr	212.0	6	P	S	Ta	N	N	N	Tc	0.2	4,590	201.28	6-25-53	
54-20cd	The James Ranch	....	Du	15.0	48	N	Sls	Tb	C	W	S	Twc	3.0	4,350	15.54	6-25-53	
55- 1c	A. E. Springer	....	Sp	.....	..	.	S, Sls	Ta, Tb	N	F	D, S	....	....	4,475	......	....	F-75
22db	....	....	Dr	116.5	6	P	Sls	Tb	C	W	S	Tc	.5	4,285	95	10- 7-52	Ca
56-24bb	....	....	Dr	30.8	6	P	S, G	Qt	C	W	D	Tc	.2	4,145	12.45	6-24-53	
58- 1dc	W. M. Hawkinson	....	Dr	67.0	5	P	S, G	Qt	C	W	D, S	Tc	-5.0	4,202	38.71	7- 3-53	
12ba	do.	....	Dr	310?	5	P	Sls, C?	Tb, Tc?	C	W	S	Tc	1.0	4,210	140.99	6- 5-53	
35ba	....	....	Dr	46.5	5	P	C	Tc	N	N	N	Tc	1.5	4,130	40.74	6- 9-53	
25-53-21ca	J. Henderson	1953	Dr	100	6	P	S	Ta, Qt	T	E	I	Ls	....	4,480	8	1953	D50, Gl, A3
21cc	do.	....	Sp	.....	..	.	S	Qt	N	F	S	..	....	4,470	......	....	F-25
24ab	Earl Henderson	1953	Dr	61	6	P	S	Ta, Qt	T	E	I	Ls	....	4,325	8	1953	D50, Gl, A3.5
54-30ca	....	....	Dr	164.5	6	P	S	Ta	C	W	S	Tc	.5	4,780	137.71	6-24-53	
55-13ab	....	....	Dr	232.5	6	P	S	Ta	C	W	S	Tc	.5	4,770	207.35	6-25-53	
56-26ca	....	....	Dr	81.0	6	P	Sls	Tb	C	W	S	Tc	1.0	4,390	75.11	5-26-53	
57- 2cb	The Prentice Ranch	1953	Dr	274.7	6	P	Sls	Tb	N	N	N	Tc	.3	4,535	97.70	5-15-53	
3cc	do.	1920	Dr	58.0	6	P	Sls	Tb	C	W	S	Tc	1.5	4,485	49.85	5-15-53	
19ac	Everett Heinz	1950	Dr	50	18	P	Sls	Tb	T	G	I	Ls	....	4,250	15	1950	D600, A15
26-53-19da	....	....	Du	91.0	..	.	S	Ta	C	W	S	Twc	0	4,572	84.33	6-24-53	
54-18dc	C. R. Watson	....	Dr	200	6	P	S	Ta	C	W	D, S	Twc	0	4,780	180.50	10- 7-52	Ca, Gr
55-19cc	....	....	Dr	348.0	6	P	S	Ta	C	W	S	Tc	.2	4,935	329.00	5-26-53	
56- 5cd	....	....	Dr	121.0	6	P	S	Ta	C	W	S	Twc	1.0	4,715	98.20	5-26-53	
6bb	The Keimig Ranch	1920	Dr	140	6	P	S	Ta	C	W	D, S	Ls	....	4,685	105	1920	Ca
19ba	Kirk Acton	1920	Dr	255	6	P	S	Ta	C	W	S	Ls	....	4,770	235	1920	
30bc	....	1951	Dr	200	6	P	Sls	Tb	C	W	S	Ls	....	4,585	47	1951	
27-57-12ac	E. M. Hatch	....	Dr	160	6	P	S	Ta	C	W	D	Ls	....	4,730	145	....	Ca
24ab	Hatch & Sons	1952	Dr	203	6	P	S	Ta	C	W	D	Ls	....	4,770	156	1952	
34ab	....	....	Sp	.....	..	.	S	Ta, Qt	N	F	.	...	....	4,530	......	....	F-50
36ca	The Keimig Ranch	1952	Dr	100	6	P	S	Ta	C	W	S	Tc	.2	4,610	61.76	5-15-53	

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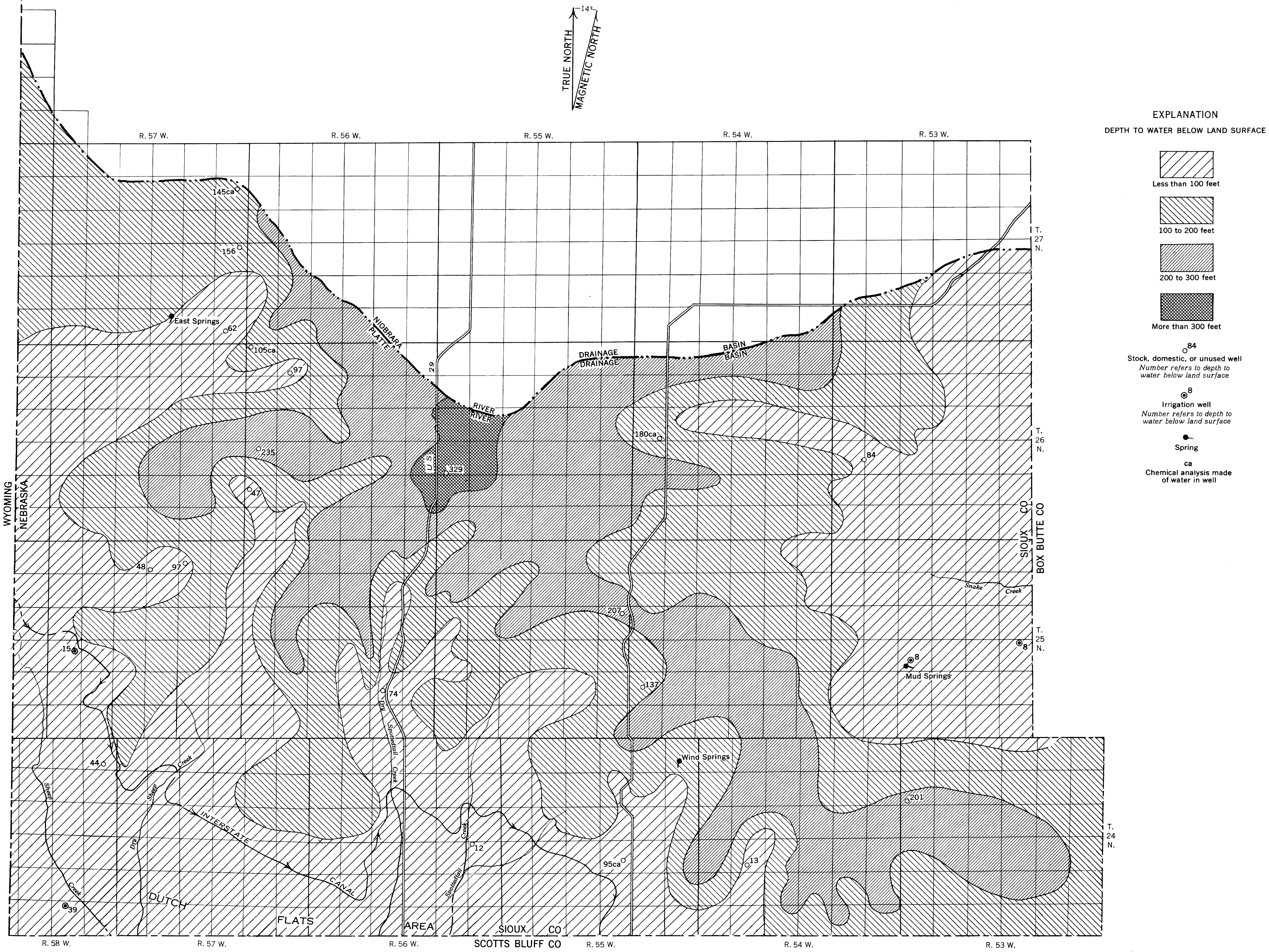

Base map modified from map of Sioux County prepared by the State of Nebraska, Dept. of Roads and Irrigation

MAP OF SOUTHERN SIOUX COUNTY, NEBRASKA, SHOWING LOCATION OF WELLS AND SPRINGS AND DEPTH TO WATER, 1952–53

2 0 10 Miles

Brule formation.--The Brule formation is exposed in the southwestern part of the report area, where its maximum thickness is probably about 500 feet. The formation is a compact pink silt with some fine sand and a little clay. It is generally massive and relatively impermeable, but in some places it contains joints and fissures that readily yield water to wells. Wells that do not encounter such openings generally must be drilled deep into the saturated part of the Brule formation in order to obtain an adequate supply for domestic and stock use. Well 25-57-2cb penetrates 175 feet of the saturated Brule formation and reportedly became dry in 3 hours when pumped at a rate of 4 gpm (gallons per minute). The water-bearing properties of the Brule formation in Scotts Bluff County are discussed in detail by Wenzel, Cady, and Waite (1946, p. 83-86). Some of their discussion was quoted in the report on the Dutch Flats area (Babcock and Visher, 1951, p. 13).

Arikaree group, undivided.--Overlying the Brule formation is the Arikaree group, which consists mainly of silty, fine buff to light-gray sand and contains some sandstone layers and many zones of tubular concretions that are more resistant to erosion than the rest of the formation. In places the Arikaree contains channel deposits of coarse sand, gravel, and cobbles such as are exposed in a vertical cliff in the SW 1/4 sec. 16, T. 25 N., R. 57 W., where a lens of sand, gravel, and cobbles--about 3 or 4 feet thick and about 150 feet wide--lies at the base of the Arikaree group. In southern Sioux County the maximum thickness of the Arikaree group probably is about 600 feet. A brief but more complete lithologic description of the group is given by the writer in his report (1954, in preparation) on the upper Niobrara River basin. Darton (1903) described the Arikaree in detail.

Large quantities of water are available from the saturated part of the Arikaree group. Much of the sandstone is only moderately permeable and wells must penetrate 150 feet or more into saturated material in order to yield large quantities of water; however, sufficient water for domestic and stock uses generally can be obtained by drilling only 15 to 20 feet into the saturated material.

A fragment of sandstone from the Arikaree group was collected near Agate, Nebr., about 12 miles north of the report area, and was analyzed in the hydrologic laboratory of the U. S. Geological Survey at Lincoln, Nebr. The porosity of this fragment was 31.5 percent; the coefficient of permeability was 13 gpd (gallons per day) per square foot; and the specific yield was 15.7 percent. (For definitions, see Stearns, 1927, p. 131, 144-148.)[1] During a study of the geology and ground-water resources of Box Butte County (Cady and Scherer, 1946), a field pumping test was made on an irrigation well that penetrated about 240 feet of the Arikaree group (Harrison and Monroe Creek formations). From this test, the average field coefficient of permeability was determined to be 225 gpd per square foot. This is a more reasonable figure than 13 gpd per square foot for the permeability of sediments of the Arikaree group because it represents the results of testing a considerable thickness of the material rather than a single fragment.

Quaternary System

Terrace deposits.--The terrace deposits, which are present only in the southwestern, or Dutch Flats, part of the area (pl. 1), consist of silt, sand, and gravel. There they range in thickness from a few feet to about 130 feet (Babcock and Visher, 1951, p. 11-12). These deposits are highly permeable and yield large quantities of water to wells. In the Dutch Flats area (Babcock and Visher, 1951, p. 15-16), a pumping test on a well penetrating 48 feet of saturated terrace deposits indicated a coefficient of transmissibility of 112,000 gpd per foot (equivalent to a field coefficient of permeability of 2,330 gpd per square foot). The coefficient of storage (under water-table conditions essentially equal to the specific yield) was determined to be 0.304.

Dune sand.--Part of the upland is mantled by sand dunes, which consist of small well-rounded buff quartz grains. Some of the larger dunes contain a core of sandstone of the Arikaree group. The dune sand is permeable, but in the report area most of it lies above the water table and is not important as a source of water. However, it plays an important role in recharge to the ground-water reservoir because it allows water from precipitation to percolate through it into underlying permeable formations.

[1] Stearns, N. D., 1927, Laboratory tests on the physical properties of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 596-F, p. 121-176.

GROUND WATER

The Water Table

The water table is the upper surface of the zone of saturation where water occurs in an unconfined aquifer. Generally, the water table is higher beneath topographically high areas than beneath adjacent lowlands. The configuration of the water table is shown by contour lines on plate 1. As ground water moves down gradient in a direction perpendicular to contour lines on the water table, the direction of movement in the report area is to the southwest, south, southeast, and east away from the area of greatest elevation on the water table. The average slope of the water table in the report area is about 30 feet per mile. In the moderately permeable sediments of the Arikaree group, the water table slopes about 20 to 30 feet per mile, but in the relatively impermeable Brule formation the slope ranges from about 30 to about 90 feet per mile.

The depth to water in wells is shown on plate 2. Depths reported or measured during this investigation ranged from 8 to 329 feet. Generally, the depth to water is greatest beneath topographically high areas and least beneath lowlands or valleys. In the north-central part of the report area the land surface is high and in some places the depth to water is more than 300 feet. In the valleys of the perennial streams, however, the depth to water generally is less than 25 feet.

In the terrace deposits south of the Interstate Canal the water table is relatively near the land surface. Some old wells cased through the terrace material, however, indicate a deeper water table in the underlying Tertiary formations. This is illustrated by well 24-58-1dc, in which the depth to water is only 44 feet, and nearby well 24-58-12ba, in which the depth to water is 140 feet.

Fluctuations of the water table are caused by changes in the rate of natural recharge and discharge, by changes in barometric pressure, and by pumping from the ground-water reservoir. The position of the water table depends upon the net rate at which water is added to or taken away from the ground-water reservoir. In the greater part of the report area, recharge and discharge generally are in equilibrium and the seasonal fluctuations of the water table are within rather small limits. In the southwestern part of the area, however, recharge due to irrigation has caused a sharp rise in the water level. Before the construction of irrigation canals and laterals, the water table in some places was 50 feet or more below its present position.

Fluctuations of the water table attributable to changes in barometric pressure are described by Cady and Scherer (1946, p. 69-70) in their report on Box Butte County. Throughout the irrigated section of the report area, high recharge from irrigation water causes seasonal water-level fluctuations similar to those described in the Dutch Flats report by Babcock and Visher (1951, p. 26-28). At the present time, however, pumping from the ground-water reservoir has not produced any substantial fluctuations of the water table.

Recharge

Recharge to the ground-water reservoir in the nonirrigated part of the report area is derived from the infiltration of precipitation. In the small irrigated section in southwestern Sioux County, however, most of the relatively large amount of recharge occurs by seepage from irrigation water, and the infiltration of precipitation accounts for only a small part of it.

In the nonirrigated part of the report area the average annual replenishment to the ground-water reservoir probably is only about 1 to 2 inches. The highest rate of recharge from precipitation is in the sand dunes, where the loose, porous sand favors the rapid infiltration and percolation of water.

In the irrigated part of the area recharge results from the infiltration of water applied to the land surface and from seepage from canals and laterals. The following quotation is from a discussion of recharge from irrigation in the Dutch Flats area given in the report by Babcock and Visher (1951, p. 21):

> The gross average rise in water level probably is slightly higher than the 8.3 feet indicated. If the average gross rise in water level is 8.3 feet and the specific yield is 32 percent (determined by the pumping test), the recharge is 2.7 feet of water per acre, or 53,200 acre-feet of water for that part of the area (about 20,000 acres) between Dry Sheep and Dry Spottedtail Creeks. Most of this recharge is by seepage from irrigation canals and irrigated lands, and only a very small part is from direct penetration of precipitation.

Discharge

Ground water is discharged by underflow out of the area, by evaporation and transpiration, by seepage into streams and drains, by springs, and by pumping from wells.

Underflow.--Ground water leaves the area as underflow through the sediments of the Arikaree group along the eastern boundary of the report area. Cady and Scherer (1946, p. 52) computed that about 14 million gallons of water per day, or 15,680 acre-feet per year, cross the 4,350-foot water-table contour line in the western part of Box Butte County. The portion of the western boundary of Box Butte County along which the flow is eastward across the 4,350-foot contour is approximately the same as the eastern boundary of the report area; therefore, the 14 million gpd is approximately the quantity of underflow that leaves the area to the east.

Ground water leaves the area as underflow to the south through the terrace deposits and to a lesser extent through the Brule formation. Because of the relatively large amount of recharge from irrigation water, the quantity of water moving out of the area to the south through the permeable terrace deposits undoubtedly is large, but it cannot be estimated on the basis of available data.

Evaporation and transpiration.--Discharge of ground water by evaporation and transpiration is limited mainly to the flood plains of the perennial streams, to a few marshy areas around springs, and to parts of the irrigated section of the report area where the water table is within a few feet of the land surface. The rate of evaporation and transpiration is greatest during the growing season when temperatures are highest. No determination of the rate of evaporation and transpiration was made during this study, but some idea of the importance of these processes may be obtained from the report on Box Butte County (Cady and Scherer, 1946, p. 60-61), in which some data furnished by W. L. Tolstead, Conservation and Survey Division, University of Nebraska, have been reproduced. According to these data, in northwestern Nebraska where the water table was 3 to 6 feet below the land surface, various common types of vegetation consumed between 2 and 4 feet of ground water between July 9 and September 20, 1937.

Streams and drains.--In the irrigated section of the report area where the water table is relatively high, especially during the growing season, ground water is discharged into streams and drains. A comparatively small quantity of ground water is discharged into Snake Creek in the eastern part of the area. The large flow of Sheep and Spottedtail Creeks and several drains in the southwestern irrigated part of Sioux County is derived almost entirely from ground-water discharge. This discharge is discussed in the report on the Dutch Flats area (Babcock and Visher, 1951, p. 24).

Springs.--Ground water also is discharged in the report area through a few small springs. Three of these springs were visited; their estimated rate of flow is given in table 3. One of the springs, 24-55-1c, is in a canyon and issues from the exposed basal sandstone bed of the moderately permeable Arikaree group, which overlies the relatively impermeable Brule formation. The other two, 25-53-21cc and 27-57-34ab, appear to be depression springs, that is, springs occurring at the intersection of the land surface and the water table.

Wells.--Only a small quantity of ground water in the report area is discharged by wells. Two of the three irrigation wells in the area yield 50 gpm each, and the third, which is a combination irrigation and drainage well, has a maximum yield of 600 gpm. Several irrigation and drainage wells are described in the report on the Dutch Flats area (Babcock and Visher, 1951, p. 25). The remaining wells in the area are wells of small discharge used for domestic and stock purposes.

Potential Ground-Water Development

In parts of southern Sioux County ground-water development for irrigation may be feasible. Pump-irrigation development probably would be most successful in the southwestern, or Dutch Flats, part of the area, which is underlain by terrace deposits. Many irrigation wells are in use in the Dutch Flats area; other wells of comparable discharge probably could be developed from the terrace deposits. These wells could be used to provide supplementary irrigation water and to lower the water table in waterlogged areas. Alleviation of some of the problems resulting from seepage and the establishment of a balanced surface- and ground-water irrigation system in the Dutch Flats area are discussed by Babcock and Visher (1951, p. 37-38).

Limited irrigation-well development may be possible in the rolling upland region underlain by the Arikaree group. In part of the upland the water table is sufficient close to the land surface for pump irrigation to be economically feasible. Because the Arikaree group is only moderately permeable in most places, irrigation wells probably would have to penetrate as much as 150 feet of saturated material to obtain sufficient water. The extent to which pump irrigation can be developed feasibly in the upland probably is not sufficient to utilize all the available ground water.

Wells of large discharge probably cannot be developed from the Brule formation in the report area. In adjacent areas there are large fissures or openings in the Brule formation which supply sufficient quantities of water for pump irrigation. In the report area, however, apparently no wells have penetrated such permeable zones.

Chemical Quality of the Ground Water

By F. H. Rainwater

Data on the chemical quality of ground water in the report area are scanty. In the present investigation analyses were made of 3 samples of water from the Arikaree group and 1 sample from the Brule formation (table 2). The report on the Dutch Flats area (Babcock and Visher, 1951, p. 32) includes analyses of 1 sample from the Brule and 3 from the terrace deposits. The analyses made indicate that the water from the Arikaree group and Brule formation is uniform in chemical composition and suitable for domestic and irrigation use.

The results of the analyses indicate that the water is of the calcium bicarbonate type and contains relatively large quantities of silica. The water is moderately hard, and 2 of the 4 samples analyzed for this report contained larger amounts of iron than is generally recommended for home use. The water is well suited for irrigation because of low percent sodium, low total mineralization, and low boron content. The water from well 24-55-22db, which is in the Brule formation, contained only a small amount of residual carbonate. Residual carbonate is the carbonate and bicarbonate that would remain in solution if the slightly soluble calcium and magnesium carbonates were precipitated--that is, equivalents per million of alkalinity (bicarbonate plus carbonate, if any) minus equivalents per million of calcium and magnesium. The presence of residual carbonate is significant in determining the suitability of water for irrigation[2].

The quality of the water in the deposits south of the Interstate Canal is described in the following passage by Durum in the report on the Dutch Flats area (Babcock and Visher, 1951, p. 2):

> The analytical results of 10 samples of representative ground and surface waters in the Dutch Flats area depict waters that are hard and siliceous, but are moderately low in mineral content. Waters from shallow wells in the seeped area north of Morrill are similar both in concentration and composition to canal and drain waters in the area. All the waters are low in percentage of sodium and are of satisfactory chemical quality for irrigation or domestic use.

CONCLUSIONS

The amount of ground water used in the report area is only a small fraction of the quantity available. The present use of ground water is primarily for stock and domestic needs, but south of the Interstate Canal some ground water is used also for irrigation. In the part of the report area underlain by permeable terrace deposits, additional pump irrigation could be developed to provide supplemental water for irrigation and to lower the water table where it is too close to the land surface. Some irrigation may be feasible in the upland where it is underlain by a sufficient thickness of saturated sediments of the Arikaree group. The quality of the ground water in the area, as indicated by meager data, is suitable for irrigation and domestic uses; no water-quality problems are expected if the use of ground water is expanded

The available hydrologic data are believed to be adequate to satisfy present and anticipated needs for the understanding of the occurrence, availability, movement, recharge, and discharge of ground water. Further and more detailed studies of the ground water in the area are believed to be unnecessary unless unanticipated problems arise, such as an unexpected development and withdrawal of large quantities of ground water. However, annual measurements of the position of the water level in a few selected observation wells is recommended so that the approach of any unexpected problem can be recognized.

[2] Eaton, F. M., 1950, Significance of carbonates in irrigated waters: Soil Sci., v. 69, p. 123-133.