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Geology and Ground- Water Resources of the Upper Niobrara River Basin, Nebraska and Wyoming

Edward Bradley

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By EDWARD BRADLEY

With a section on

CHEMICAL QUALITY OF THE GROUND WATER

By F. H. RAINWATER

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GEOLOGY AND GROUND-WATER RESOURCES OF THE UPPER NIOBRARA RIVER BASIN, NEBRASKA AND WYOMING

By Edward Bradley

ABSTRACT

The upper Niobrara River drainage basin comprises about 6,600 square miles in northwestern Nebraska and east-central Wyoming. The western half consists chiefly of rolling plains broken on either side of the Niobrara River by canyons of intermittent tributary streams; the eastern half is in the Sand Hills region of Nebraska.

Rocks ranging in age from Precambrian to Quaternary are exposed in the area described in this report. The pre-Tertiary rocks crop out only in a small area near Lusk, Wyo., and are not important as a source of water. Most of the area is underlain at considerable depth by the Chadron and Brule formations of Tertiary age, but they are not known to crop out. These rocks are not penetrated by wells because large quantities of water are available from shallower formations.

The Arikaree group and Ogallala formation, both of Tertiary age, consist of fine-grained sand and sandstone, silt, and locally of many layers of limy concretions. These units are the principal aquifers, but they are only moderately permeable; consequently, most wells must penetrate 150 to 200 feet into the zone of saturation to obtain a large yield.

Dune sand, alluvium, and terrace deposits of Quaternary age are probably the most permeable sediments, but the zone of saturation in these deposits is not sufficiently thick to yield large quantities of water; therefore, large-discharge wells must be drilled into the underlying Tertiary rocks.

Ground water moves through the aquifers in an easterly direction toward the perennial streams, probably at a rate of less than 1 foot per day. The slope of the water table generally is about 13 feet per mile; but in that part of the Sand Hills region adjacent to the Niobrara River the slope is 60 to 70 feet per mile. Precipitation is the main source of ground-water recharge. In irrigated parts of the area an appreciable amount of water is added to the zone of saturation by infiltration of water applied to the land. The flow of the Niobrara River and its principal tributaries is derived largely from ground water. The river leaves the area south of Valentine, Nebr., where its average flow probably is about 500,000 acre-feet per year.

The 58 irrigation wells in the area have an average yield of about 770 gpm and an average specific capacity of about 19 gpm per foot of drawdown; they supply about 8,300 acre-feet of water per year to irrigate about 5,500 acres of land. The present quantity of ground water used for irrigation is only a small fraction of the total quantity available. Ground-water withdrawals would have to be increased substantially to produce a noticeable reduction in streamflow. Valleys of the Niobrara River and its tributaries in the western part of the area and the

valleys in the Sand Hills region in the eastern part are particularly favorable for additional development of pump irrigation. However, a more detailed study of the geology and ground-water resources of Sheridan County, Nebr., would be necessary before it could be determined whether recharge to the ground-water reservoir is adequate for the present and estimated future withdrawals of ground water.

The Arikaree group and Ogallala formation of Tertiary age and the unconsolidated deposits of Quaternary age yield water of similar chemical characteristics and concentration. The water is of the calcium bicarbonate type and has high concentrations of silica; it is hard but not excessively so. In the ground-water samples collected in the area the silica content ranged from 46 to 63 ppm and the hardness ranged from 43 to 248 ppm. Because of its low concentration of dissolved minerals, low percent sodium, and low boron content, the water is well suited for irrigation.

Complex surface drainage and ground-water movement in the closed basins of the Sand Hills region contribute to the complexity of water-quality relations there. A cursory survey of the chemical relationship of ground and lake water shows the need for a more detailed study of the local hydrology and water chemistry.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

The purpose of the investigation described in this report was to collect pertinent data on, and to present a general review of, the ground-water resources of the upper Niobrara River basin, and to call attention to problems that may result from present and contemplated ground-water development. The report includes: an annotated bibliography of reports and other data relating to the ground water and geology of the area; records of all irrigation, public supply, and industrial wells and some domestic, stock, and unused wells; available geologic information on the water-bearing strata; a discussion of the occurrence, recharge, and discharge of ground water; an evaluation of present and potential use of ground water for irrigation; and an appraisal of existing hydrologic data together with conclusions and recommendations for further study.

This investigation is one of several being made by the United States Geological Survey as part of the program of the Department of the Interior for the conservation, development, and use of the water resources of the Missouri River basin (fig. 1). The fieldwork was done during the fall and winter of 1952–53 and was under the general supervision of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey; G. H. Taylor, regional engineer in charge of ground-water investigations in the Missouri River basin; and H. M. Babcock, district engineer for Wyoming. The quality-of-water studies were made under the general supervision of S. K. Love, chief of the Quality of Water Branch, and P. C. Benedict, regional engineer in charge of quality-of-water investigations in the Missouri River basin.

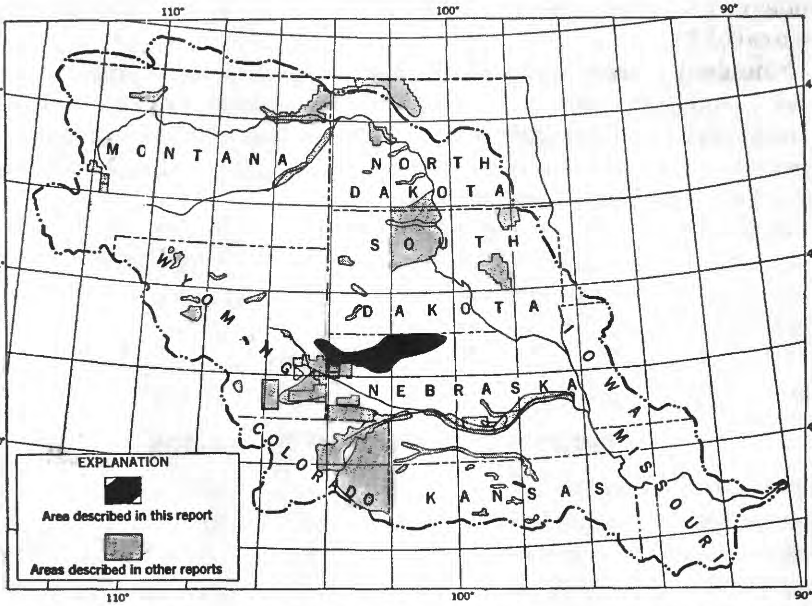

FIGURE 1.—Map of the Missouri River basin showing areas in which ground-water studies have been made nnder the program for the development of the Missouri River basin.

METHODS OF INVESTIGATION

Records were obtained for 191 wells in the area. Information for 20 of these wells was from unpublished records of the U. S. Geological Survey and for 5 wells, from table 14 in a report by Cady and Scherer (1946, p. 90).[1] The other 166 wells were inventoried during the fall and winter of 1952–53. All known irrigation, public-supply, and railroad wells in the area were inventoried; the owners or operators were contacted for information concerning depth, yield, drawdown, type of construction, and use. The depth to water in most of the wells was measured by means of a steel tape. The altitude of the measuring point of 91 of the wells was estimated from available topographic maps; a few of the altitudes had been previously determined by instrumental leveling. Measurements of the depth to water in 25 wells were taken from published and unpublished reports of the U. S. Geological Survey and are reproduced in this report together with a graph of the water-level fluctuations in 6 of the wells. Logs for 7 wells and 12 test holes were secured either from the driller or from the files or publications of the U. S. Geological Survey or the Nebraska Geological Survey. Records of surface-water flow in the Niobrara River basin were obtained from data published by the U. S. Geological Survey. Streamflow in the upper Niobrara River and

[1] In this report the bibliographic references are shown in the annotated bibliography, p. 4–9.

some of its tributaries was estimated where such measurements were unavailable.

Samples of water were collected for chemical analysis from 16 wells and 7 sampling points on streams. In addition, to ascertain the relationship between the quality of lake water and that of adjacent ground water, samples were collected from lakes and adjacent wells at 5 locations in southern Sheridan County.

Outcrops of the principal aquifers were examined at several sites throughout the area; two rock samples were collected and sent to the hydrologic laboratory, Lincoln, Nebr., for determination of permeability, porosity, and specific yield.

The geologic and hydrologic data were plotted on a base map of the area on a scale of 4 miles to the inch. (See pl. 1.)

LITERATURE PERTAINING TO REGION

The area described in this report and adjacent areas in which ground-water studies have been made are shown in figure 2. The reports describing previous investigations and other literature pertaining to the geology or water resources of the region are listed in the following annotated bibliography:

1. Adams, G. I., 1902, Geology and water resources of the Patrick and Goshen Hole quadrangles in eastern Wyoming and western Nebraska: U. S. Geol. Survey Water-Supply Paper 70.

About 25 square miles in the northeastern corner of the Patrick quadrangle is in the upper Niobrara River basin. The report, however, discusses the geology and ground-water resources of the Goshen and Patrick quadrangles without particular reference to that part in the Niobrara River basin.

2. Aughey, Samuel, 1880, Sketches of the physical geography of Nebraska: Omaha, Daily Republican Book and Job Office.

The second part of the book (p. 161–320) discusses the regional geology of Nebraska and makes brief references to its water resources.

3. 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.

The geography, landforms, geology, ground water, fluctuations of the water table, and utilization of ground water in Box Butte County are discussed. The Tertiary water-bearing formations are described in considerable detail. Special reference is made to the availability of ground water for irrigation and to the behavior of ground water near pumped wells. The report includes maps showing the geology, depth to water, contour of the water table, and location of wells and test holes, geologic cross sections, and tables of well records and well logs. It presents an intensive study of the quality of the water and includes 19 analyses of ground water, 3 analyses of surface water, and a discussion of the quality of the ground water.

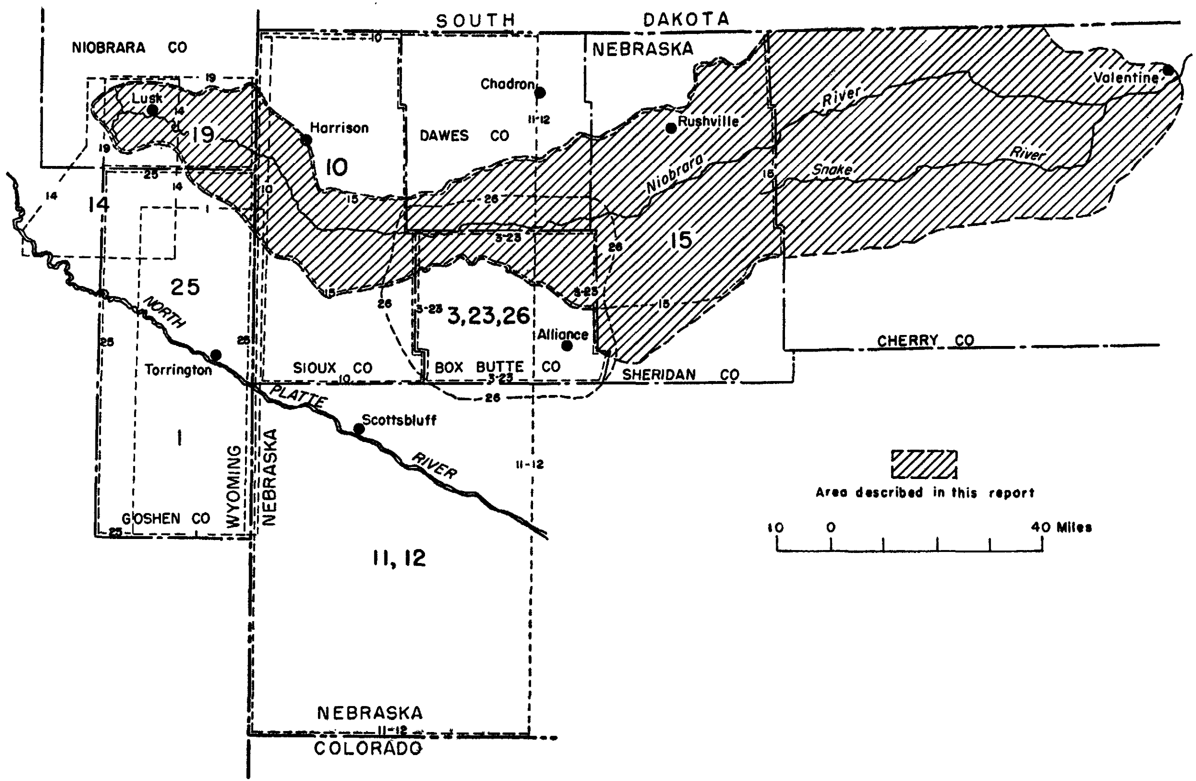

FIGURE 2.—Index map showing area described by this report and adjacent areas in which related geologic and hydrologic studies have been made. Numbers correspond to reports listed under "Literature pertaining to region."

4. Condra, G. E., 1913, The potash industry of Nebraska: Nebr. Bur. Publicity.

The chemical quality of lake water in the Sand Hills region of Nebraska is discussed in relation to the geology of the area. Analyses of lake brines are presented and the origin of the potash is postulated.

5. Condra, G. E., Schramm, E. F., and Lugn, A. L., 1931, Deep wells of Nebraska: Nebr. Geol. Survey Bull., 2d ser., no. 4.

Drilling procedures are discussed and special reference is made to well drilling in Nebraska. Two of the wells for which logs are given are in the upper Niobrara River basin.

6. Condra, G. E., 1932, The ground waters and lakes of the Sand Hill region, Nebraska: Nebr. Irrigation Assoc. Proc.

The water resources of the Sand Hills region of Nebraska are described. The quantity of ground water in storage, the relation of the lakes to ground water, the cycles in lake development, the origin of potash in lake water, and the control of lakes are also discussed.

7. Condra, G. E., and Reed, E. C., 1936, Water-bearing formations of Nebraska: Nebr. Geol. Survey Paper no. 10.

Ground-water regions and the availability of ground water in Nebraska are discussed. Generalized geologic sections and maps also are included.

8. ——— 1943, The geological section of Nebraska: Nebr. Geol. Survey Bull. no. 14.

The age relationship and the general lithologic characteristics of the rocks in Nebraska are reviewed. Graphic generalized sections of the geologic groups, formations, and members are accompanied by a brief lithologic description. References to and brief discussions of sections of the graphic column also are presented. The terminology of Lugn (1939) is used in discussing the Tertiary rocks, which include the principal water-bearing formations of northwestern Nebraska.

9. Condra, G. E., Reed, E. C., and Gordon, E. D., 1950, Correlation of the Pleistocene deposits of Nebraska: Nebr. Geol. Survey Bull. no. 15A.

The correlation of Pleistocene deposits in Nebraska and adjacent areas, based on information obtained in recent years from soil and water studies, is discussed in detail. Also, a short section on fluctuations of the water table during Pleistocene time is included.

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

Geologic and paleontologic discoveries in central Sioux County near Agate, Nebr., before 1911 are summarized. A north-south cross section through the county and several photographs illustrating some of the geology are included. The origin of the prolific fossil beds in the Arikaree group east of Agate is postulated.

11. 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. 727–785.

Photographs, geologic sections, and a geologic map accompany detailed descriptions of the Tertiary and earlier geologic formations. The availability of ground water in these formations is discussed briefly. Surface-water irrigation also is discussed, and maps showing the location of irrigated acreages in 1897 and a general map showing the depth to ground water in western Nebraska are included.

12. 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.

This is the same report as contained in the 19th annual report of the U. S. Geological Survey except for slight modifications and additions to the discussion of the geologic formations.

13. ——— 1905, Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32.

The geology and mineral resources of the central Great Plains, including most of South Dakota, Nebraska, Kansas, eastern Colorado, and eastern Wyoming are discussed in detail, and the geography, geology, and water horizons are described. Deep-well data and well prospects by counties also are presented. Maps and illustrations show the geology, location of deep wells, structure of the Dakota sandstone, depths to this sandstone, artesian pressures, and areas of artesian flow. Pages 270–274 pertain to western and central Nebraska.

14. Denson, N. M., and Botinelly, Theodore, 1949, Geology of the Hartville uplift, eastern Wyoming: U. S. Geol. Survey oil and gas investigations preliminary map 102.

This detailed geologic map also presents cross sections of the area, describes the geologic formations and mineral resources, and discusses oil and gas possibilities.

15. Gwillim, E. C., and others, 1940, Water facilities subarea plan for Niobrara River watershed, Wyoming and Nebraska: U. S. Dept. Agriculture, Bur. Agr. Econ.

This report discusses the geography, land classification, natural vegetation, and hydrology of that part of the Niobrara River basin from the river's headwaters in Wyoming to the Cherry-Sheridan County line in Nebraska. Existing uses of water, water rights, land use, and economic factors are tabulated and discussed. Recommendations for land and water use, including pump irrigation and ground-water control, are given, and cost estimates for surface and ground-water irrigation systems are presented.

16. Hicks, W. B., 1921, The potash resources of Nebraska: U. S. Geol. Survey Bull. 715, p. 125–139.

Analyses of lake brines and a discussion of the origin of the lake potash are presented in this report.

17. Johnson, W. D., 1901, The High Plains and their utilization: U. S. Geol. Survey 21st Ann. Rept., pt. 4c, p. 601–741.

The origin of the Tertiary deposits in the High Plains and the physiography and general lithologic characteristics of these deposits are described. Climate, irrigation possibilities, depressions or basins on the plains, the Meade artesian basin (Kansas), and principles of artesian and other ground water are discussed. Opinions of other writers are reviewed.

18. ——— 1902, The High Plains and their utilization: U. S. Geol. Survey, 22d Ann. Rept., pt. 4c, p. 631–669.

This is the conclusion of the report by Johnson (1901). The occurrence of water in consolidated and unconsolidated formations, the origin and level of ground water in the High Plains, the utilization of ground water for stock raising and irrigation, and methods of well construction are discussed.

19. Knight, S. H., and Morgan, A. M., 1937, Report on the underground water resources of the Niobrara River valley, Niobrara County, Wyo.: Wyo. Geol. Survey. (Mimeographed.)

The topography, drainage, geology, and occurrence of ground water in the area are described, and data pertaining to wells and depth to water are presented. The authors conclude that sufficient water for irrigation can be developed along the valley bottoms from wells 50 to 100 feet deep.

20. Lohman, S. W., 1953, Sand Hills area, Nebraska, *in* Subsurface facilities of water management and patterns of supply—type area studies: The physical and economic foundation of natural resources, no. 4, chap. 5, p. 79–91, U. S. Cong., H. R., Interior and Insular Affairs Comm.

This report discusses the Sand Hills region of Nebraska with special reference to hydrology. The relation between ground water and surface water is explained, and estimates of ground-water recharge are given.

21. Lugn, A. L., 1935, The Pleistocene geology of Nebraska: Nebr. Geol. Survey Bull. 2d ser., no. 10.

Pleistocene geology in Nebraska is discussed in detail, and the Sand Hills region is described briefly.

22. ——— 1939, Classification of the Tertiary system in Nebraska: Geol. Soc. America Bull., v. 50, p. 1245–1276.

Conclusions of the Nebraska Geological Survey on the nomenclature of the Tertiary system in Nebraska are summarized. A table of the Tertiary stratigraphic divisions agreed upon by the State Geological Surveys of Nebraska and Kansas and a geologic map of Nebraska west of the 102d meridian appear in this paper. Frequent references are made to previous works dealing with Tertiary nomenclature in the Great Plains. Four "natural lithologic groups"—Ogallala, Hemingford, Arikaree, and White River—are proposed. A comprehensive list of references accompanies the report.

23. 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.

A brief résumé of the topics covered by Cady and Scherer (1946) is given together with data on irrigation wells installed since the fieldwork was completed. The availability of ground water for irrigation is discussed on the basis of the new data. Water from the Ogallala formation and from the Marsland, Harrison, and Monroe Creek formations (Arikaree group in the present report) is said to be generally satisfactory for irrigation; however, percent sodium in some formations was variable and the report recommended a preliminary examination of water before its use for irrigation.

24. Nebraska State Planning Board, 1936, Report on the water resources of the Niobrara River basin: Water Resources of Nebraska, p. 7, pp. 275–326.

The geology, geography, water resources and their utilization, and related problems in the Niobrara River basin are summarized, and recommendations for future projects are presented.

25. Rapp, J. R., Visher, F. N., and Littleton, R. T., 1956, Geology and ground-water resources of Goshen County, Wyo., with a section on the chemical

quality of the water, by W. H. Durum: U. S. Geol. Survey Water-Supply Paper 1377. (In preparation.)

The geologic formations exposed in Goshen County and their water-bearing properties are described. Special reference is made to the terrace and alluvial deposits. Recharge, discharge, seepage, and irrigation are also discussed. The report includes profile sections, maps showing geology, depth-to-water, ground-water contours, and saturated thickness of the alluvium along the valley of the North Platte River, and tables giving the physical and hydrologic properties of the geologic formations, well records, water-level measurements, logs of wells and test holes, and chemical analyses of the water.

26. Sawyer, C. O., Johannesen, E. W., and others, 1944, Technical information relating to the development of ground water for irrigation in Box Butte County, Nebr., and immediate adjoining areas: Water Facilities Sec., FSA, U. S. Dept. Agriculture.

The feasibility of and problems relating to pump irrigation from ground-water supplies in the area are discussed in relation to the water-facilities program. Brief discussions of the geography, existing ground-water use, available water supply, water rights, and pumping costs are included.

27. Serr, E. F., 3d, 1950, Progress report of investigations of fluvial sediments of the Niobrara River near Cody, Nebr.: U. S. Geol. Survey Circ. 67.

The sediment load of the Niobrara River near Cody is described, and the suspended and bed loads are compared. The methods used in making these comparisons are discussed.

28. Stout, O. V. P., 1904, Reclamation and water storage in Nebraska: U. S. Geol. Survey Water-Supply Paper 93, p. 276–284.

The reclamation and water-storage problems in Nebraska are discussed briefly. Some obstacles to extensive surface-water irrigation in the Niobrara River basin are given on page 284.

29. U. S. Geological Survey, 1942, 1943, 1946–49, Surface water supply of the United States, pt. 6, Missouri River basin: U. S. Geol. Survey Water-Supply Papers 956, 976, 1056, 1086, 1116, and 1146.

These annual publications include measurements of stream discharge in the Niobrara River basin.

30. U. S. Geological Survey, 1947–50, Quality of surface waters of the United States: U. S. Geol. Survey Water-Supply Papers 1102, 1132, 1162, 1187, and 1198.

Included in this series are the results of analyses of samples from the Niobrara and Snake Rivers and tributaries. The chemical quality of the ground water is shown in analyses of the surface water, particularly for base-flow periods.

31. U. S. Geological Survey, 1936–49, Water levels and artesian pressures in observation wells in the United States: U. S. Geol. Survey Water-Supply Papers 817, 840, 845, 886, 908, 938, 946, 988, 1018, 1025, 1073, 1098, 1128, and 1158.

Measurements of the water level and artesian pressure in observation wells in the Niobrara River basin are included in these annual publications.

WELL-NUMBERING SYSTEM

Wells are numbered according to their location within the Bureau of Land Management's 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 indicates the township, the second the range, and the third indicates the section in which the well is located. The lowercased letters after the section number indicate the location of the well within the section. The first letter denotes the quarter section and the second letter the quarter-quarter section (40-acre tract). These subdivisions are lettered *a*, *b*, *c*, and *d* in a counterclockwise direction, beginning in the northeast quarter. Two or more wells within a 40-acre tract are distinguished by adding

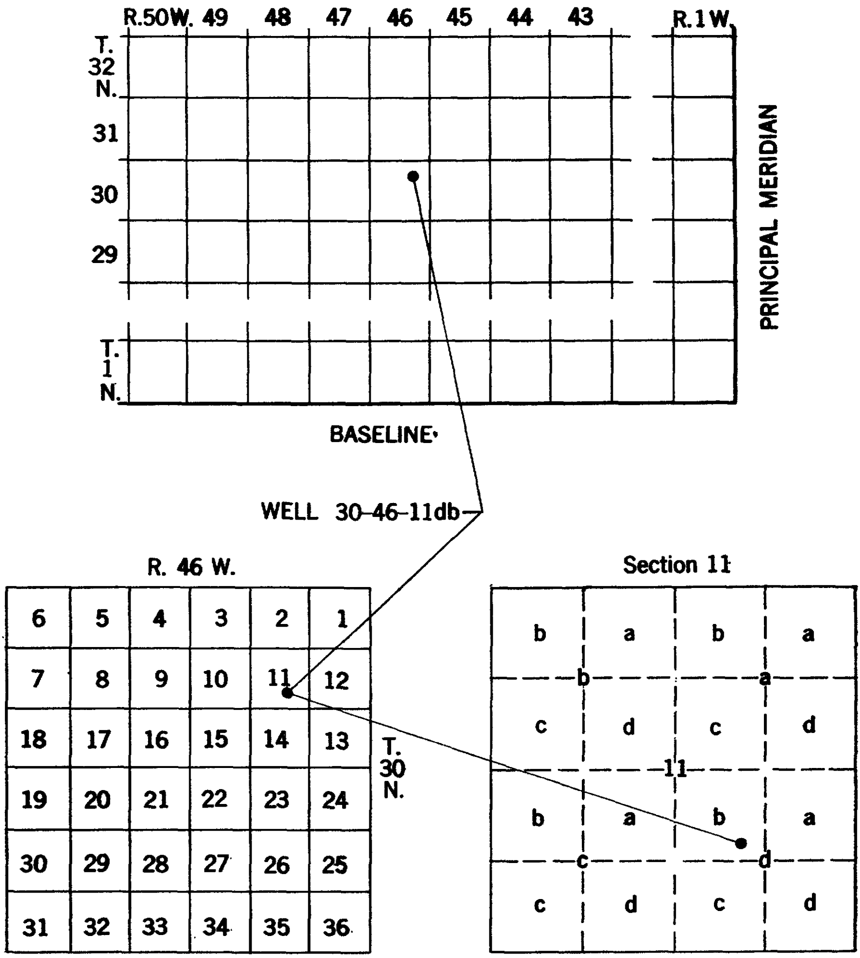

FIGURE 3.—Well-numbering system.

to the well number consecutive numbers beginning with 1. A graphic illustration of this method of well numbering is shown in figure 3.

Test holes and stream-gaging stations also are numbered according to this system.

ACKNOWLEDGMENTS

The residents in the area permitted measurement of and gave information about their wells. Drillers furnished logs and other pertinent information regarding the wells they had drilled; municipal officials contributed information concerning public-supply wells; and officials of the Chicago & North Western Railway System and of the Chicago, Burlington & Quincy Railroad supplied data regarding their wells in the area. E. C. Reed, State geologist of Nebraska, and H. J. Cook, Agate, Nebr., furnished valuable information regarding the geology of and the ground-water development in the area.

GEOGRAPHY

LOCATION AND EXTENT OF AREA

The area described in this report is the upper part of the drainage basin of the eastward-flowing Niobrara River. It extends downstream from near Manville in east-central Wyoming to Valentine in northwestern Nebraska and is about 225 miles long and averages about 25 miles in width. The area, which comprises parts of Goshen and Niobrara Counties, Wyo., and of Sioux, Dawes, Box Butte, Sheridan, and Cherry Counties, Nebr., contains about 6,600 square miles, of which about 6,100 is in Nebraska. (See figs. 1 and 2.)

In southern Sheridan County the topographic divide between the Niobrara River drainage basin and adjacent drainage basins is indistinct and it was difficult to locate the exact position of the divide. Therefore, the southern boundary of the area was arbitrarily extended from sec. 24, T. 26 N., R. 47 W. (northeast of Alliance, Nebr.), south along the Box Butte-Sheridan County line to the Chicago, Burlington & Quincy Railroad, thence southeast along the railroad to Antioch, and northeast in a straight line to the center of sec. 26, T. 27 N., R. 42 W., to include some of the closed basins in southern Sheridan County.

TOPOGRAPHY AND DRAINAGE

Topographically, the area described in this report may be divided roughly into two parts. The western half consists largely of rolling plains which, on either side of the Niobrara River, are broken by canyons of intermittent tributary streams; the eastern half is composed mainly of sand hills. The area from its west end to the

Cherry-Sheridan County line in Nebraska is described by Gwillim and others (1940, p. 8–10) as follows:

The area is located in the High Plains section of the Great Plains physiographic province. The northern divide of the watershed is coincident with the Pine Ridge Escarpment, which forms the topographic boundary between the High Plains section and the unglaciated Missouri Plateau section of the Great Plains. Hat Creek and White River, adjacent drainages on the north, originate in the escarpment and flow northeast away from the Niobrara. The southern divide of the watershed is poorly defined and separates the drainages of the Niobrara and the North Platte. In the southeast part of the area, a barely perceptible divide separates the Niobrara and the Loup Rivers.

Surface expression in the watershed is essentially rolling, although various portions exhibit undulating, gently rolling, roughly rolling, and rough and broken topography. The area north of the river has more relief than the area south of the river. North of the river the uplands rise 250 to 500 feet above the valley floor, whereas south of the river the uplands attain elevations of 200 to 400 feet above the valley floor.

Examples of undulating topography are the Chadron table and similar areas north of the river, and the Box Butte table and similar areas south of the river. Gently rolling and rolling areas occur widespread throughout the area. Roughly rolling and rough and broken areas occur along the drainages, particularly Niobrara River and its principal tributaries. Sandhills occupy large areas in southern Sioux County and in Sheridan County.

In Wyoming, the Niobrara River occupies a broad, shallow, gently concave valley. In Nebraska, the valley is mainly a deep, steep-sided, flat-bottomed trench one-fourth to one mile in width. The stream channel meanders within the confines of the valley walls, dissecting the bottom lands into various sized tracts of meadow land. The stream channel varies in width mainly from 20 to 60 feet. It has cut 5 to 20 feet below the general meadow level. Below the confluence of Pine Creek with the Niobrara River, the river valley becomes a very narrow, steep-walled canyon.

Two large benches are developed along the Niobrara in Sheridan County. These are wide, flat, extensive terraces located 45 and 75 feet above the river. These terraces are known as Mirage Flats.

Sea level elevation at the headwaters of the watershed, in the vicinity of Manville, Wyo., is approximately 5,300 feet. At the Sheridan-Cherry county line, the sea level elevation of the Niobrara River is about 3,400 feet. The stream gradient approaches 10 feet per mile throughout the area. Tributary streams occupy valleys similar in shape and size, but somewhat modified to that of the Niobrara.

There are no defined tributaries entering from the south in Wyoming, and although there is a southern divide, there is no defined drainage pattern. The principal tributary streams of the Niobrara River in the area are L'eau de la Court [Van Tassell] Creek, entering from the north along the Wyoming-Nebraska State line; Whistle Creek, entering from the south in Sioux County; Cottonwood, Pepper, and Sand Canyon Creeks, entering from the north in Dawes County; Box Butte and Dry Creeks, entering from Box Butte County on the South; Pine and Deer Creeks, entering from the south, and Rush and Antelope Creeks entering from the north, in Sheridan County.

In southern Sheridan County, between the drainage areas of the Niobrara and North Platte Rivers, is an area of small closed basins which are surrounded by sand hills. From the Cherry-Sheridan County line to Valentine, Nebr., the Niobrara River basin lies within the Sand Hills region of Nebraska. This is a region of rolling, grass-covered hills of dune sand, and sandy valleys containing many lakes and marshes. The sand dunes stand as high as 250 feet above the valley floors.

Several relatively flat terraces, or benches, separate the Niobrara River and the Sand Hills in western and central Cherry County. These terraces, or benches, range in width from about one-half to about 3 miles, and their height above the river ranges from about 90 feet near the Sheridan-Cherry County line to about 225 feet southwest of Cody, Nebr. The largest terrace, Lavaca Flats, is on the south side of the river in western Cherry County. It is about 2 or 3 miles wide and about 12 miles long, and ranges from about 120 to 140 feet above the river level. A narrow extension of the Lavaca Flats bench extends eastward on the south side of the river to about 9 miles southeast of Merriman and from there 8 miles eastward on the north side of the Niobrara River. About 8 miles southwest of Cody, Nebr., on the south side of the river, the bench forms a relatively flat plain about 6 miles long and about one-half to 3 miles wide and is about 200 to 225 feet above the river level. Eastward along the Niobrara River the bench is increasingly obscure. Additional study will be necessary to determine whether and to what extent these terraces, or benchlands, are underlain by unconsolidated deposits of Quaternary age.

The upper Niobrara River and its principal tributaries flow through narrow canyonlike valleys, which are underlain by little or no alluvium. The altitude of the Niobrara River south of Valentine is about 2,400 feet; the average gradient of the stream in Cherry County west of Valentine is about 9.3 feet per mile. The principal tributaries of the Niobrara River in this section are Leander and Bear Creeks on the north and Medicine, Gordon, and Schlagel Creeks and the Snake River on the south.

CLIMATE

The climate in the upper Niobrara River basin is characterized by low humidity, hot summers, cold winters, and large variations in precipitation from month to month, year to year, and decade to decade. Sudden changes in weather, accompanied by great variations in temperature, are common. Summer storms usually are intensive thundershowers of local extent and many affect only a few square miles. Winter storms commonly occur as widespread blizzards. The normal annual precipitation ranges from 14.48 inches at Lusk, Wyo., to 20.04 inches at Hay Springs, Nebr. Most of the precipitation is received in the spring and summer, but it varies greatly in

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quantity and distribution. Blair [2] reports that precipitation records show the following succession of wet and dry periods in Nebraska:

1876–1892 Wet period with one very dry year.
1893–1901 Dry period with one rather wet year.
1902–1909 Wet period with one rather dry year.
1910–1920 Tendency irregular; most years dry, but 1915 wettest year of record.
1921–1939 Long dry period with only one wet year; especially dry after 1930.

The deficiency and sporadicity of precipitation tend to promote irrigation wherever it is feasible.

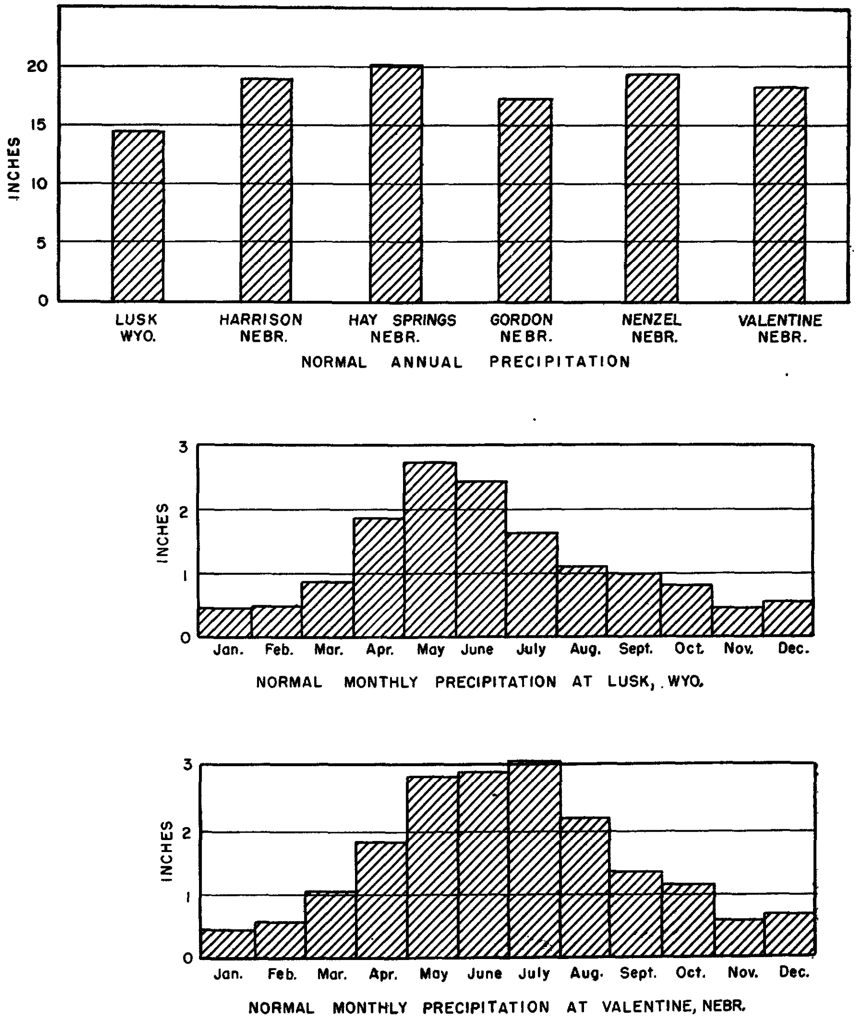

FIGURE 4.—Precipitation at selected stations in the upper Niobrara River basin. (From records of the U. S. Weather Bureau.)

[2] Blair, T. A., 1941, Supplementary climatic notes for Nebraska, *in* Climate and Man: U. S. Dept. Agriculture, 1941 Yearbook of Agriculture, p. 978.

Normal annual precipitation at several stations and normal monthly precipitation at Lusk and Valentine are shown in figure 4. Temperature and frost data are given in table 1.

TABLE 1.—*Temperature and frost data for the upper Niobrara River basin*

[From records of the U. S. Weather Bureau]

Station	Length of record (years)	Temperature				Killing frost, average dates			
		January average (°F)	July average (°F)	Max (°F)	Min (°F)	Length of record (years)	Last in spring	First in fall	Growing season (days)
Wyoming:									
Lusk	40	22.7	68.3	105	−35	40	May 26	Sept. 18	115
Nebraska:									
Harrison	24	20.8	70.9	107	−35	25	May 20	Sept. 25	128
Hay Springs	40	22.0	71.4	108	−41	40	May 15	Sept. 24	132
Gordon	29	20.0	72.1	108	−40	31	May 21	Sept. 21	123
Near Nenzel	22	21.7	74.0	111	−43	22	May 17	Sept. 23	129
Valentine	40	21.2	74.2	110	−38	40	May 4	Oct. 3	152

AGRICULTURE

The principal agricultural product of the upper Niobrara River basin is cattle. Most of the Sand Hills region and much of the rolling upland in Box Butte, Dawes, and Sioux Counties, Nebr., and in Goshen and Niobrara Counties, Wyo., is used for grazing. Such land is unsuited for crops because of the rolling topography and the thin soil. Some parts of the tableland in Box Butte, Dawes, and Sheridan Counties, however, are sufficiently flat and have adequate soil thickness to support such crops as corn, wheat, oats, rye, potatoes, sugar beets, alfalfa, native hay, and sorghum.

Soil and moisture conditions in the bottom lands of the Sand Hills region and the flood plains of streams throughout the area are favorable for crop production. Subirrigated hay thrives in these areas. Table 2 gives the 1940 range and crop acreage as cited by Gwillim and others (1940, p. 46). The relative percentages of rangeland and cropland probably have not changed appreciably since that date. No records were available for Cherry County, but the percentage of rangeland to cropland is probably higher there than in the counties farther west.

TABLE 2.—*Cropland and rangeland acreage in the upper Niobrara River basin, 1940*

State and county	Cropland (acres)	Rangeland (acres)
Wyoming:		
Goshen	9,380	69,691
Niobrara	31,768	255,320
Nebraska:		
Sioux	29,242	380,168
Dawes	76,878	220,177
Box Butte	115,772	104,854
Sheridan	224,476	361,426
Cherry	----------	----------
Total	487,516	1,391,636

GEOLOGIC FORMATIONS AND THEIR RELATION TO GROUND WATER

Rocks ranging from Precambrian to Quaternary are exposed in the upper Niobrara River basin (pl. 1). Rocks of pre-Tertiary age, which crop out only in a small area near Lusk, Wyo., are not differentiated on the map; generally these rocks either are not water bearing or lie too deep to be an economical source of water. Rocks of Tertiary age that crop out are the Arikaree group and Ogallala formation and are the principal sources of ground-water supply. Terrace deposits and alluvium of Quaternary age are confined to such narrow areas that they are not shown on the geologic map. Where present, however, they are tapped by many shallow wells. Dune sand of Quaternary age mantles the upland throughout the entire eastern part of the area and is underlain by the Ogallala formation. In the western part, however, only isolated patches of dune sand are present and are underlain by the Arikaree group. In places the lower part of the dune sand is saturated and is tapped by many wells. The thickness, physical character, and water supply of the formations of Tertiary and Quaternary age are summarized in table 3.

TERTIARY SYSTEM

CHADRON FORMATION

Examination of an exposure of the Chadron formation of Oligocene age, a few miles north of the northern boundary of the Niobrara River basin, shows it to be a light-green silty clay. Locally, the formation contains channels of crossbedded coarse sand, gravel, and boulders mixed with variegated clay. Because so few logs of wells penetrating this formation are available, little is known concerning its thickness or specific nature in the area.

Although the Chadron formation does not crop out in the upper Niobrara River basin, it underlies most of the area at depths ranging from about 400 to 1,200 feet; it has not been developed as an aquifer because large quantities of water are available from shallower formations.

BRULE FORMATION

The Brule formation of Oligocene age consists of compact silt containing small amounts of fine sand and clay. Commonly the upper part is nodular and slightly sandy. Near its base the Brule formation is pale green, but the major part of the formation is pink or flesh colored.

TABLE 3.—*Generalized section of Tertiary and Quaternary rocks in the upper Niobrara River basin*

System	Series	Subdivision	Maximum thickness (feet)	Physical characteristics	Water supply
Quaternary	Recent and Pleistocene	Dune sand	300±	Rounded, well-sorted, very fine to medium sand; predominantly quartz grains.	Most of the dune sand lies above the water table; where saturated it yields water readily to wells.
		Alluvium and terrace deposits	100±	Poorly sorted, rounded sand and fine gravel. Locally contain silt or clay lenses.	Yield water readily to wells; supply many stock and domestic wells and contribute to a few irrigation wells.
Tertiary	Pliocene	Ogallala formation	300±	Fine-grained massive gray and light-greenish-gray sand and silt. Locally contains hard, lime-cemented silt layers. A 3- to 5-foot layer of hard white, lime-cemented material occurs near the middle of the formation.	Yields water readily to wells. Because of its fine texture, about 150–200 feet of saturated material must be penetrated to obtain adequate supplies for irrigation.
	Miocene	Arikaree group (formation in Niobrara County, Wyo.)	500±	Very fine- to medium-grained, moderately cemented, grayish-tan sand, sandstone, and silt. Contains variously shaped concretions of different sizes, usually occurring in layers.	Yields water readily to wells; where sufficient thickness of saturated material is penetrated, it generally supplies adequate water for irrigation.
	Oligocene	Brule formation	600±	Pale-green to pink or flesh-colored compact silt containing small amounts of sand and clay.	Not developed as a source of ground water in this area because sufficient water is available from overlying rocks.
		Chadron formation	100±	Light-green silty clay. Locally contains channels of cross-bedded, coarse sand, gravel, and boulders mixed with variegated clay.	Do.

The Brule formation underlies all but the extreme western part of the area but is not exposed anywhere within the area. It ranges in thickness from a featheredge to about 600 feet, and its thickness probably exceeds 300 feet. Because it generally lies at depths between 300 and 1,200 feet, it has not been developed as an aquifer. In many other places in western Nebraska and eastern Wyoming, the Brule formation yields water to wells from cracks and fissures or from permeable zones, but where such openings are absent the formation is not sufficiently permeable to yield water readily to wells.

ARIKAREE GROUP

The Arikaree group (formation in Niobrara County, Wyo.) as described in this report includes all sediments of Miocene age. Condra and Reed (1943, p. 11–12) have divided these sediments into the Arikaree and Hemingford groups, but in this report these units have not been differentiated and are shown as the Arikaree group on plate 1. Detailed lithologic descriptions of these units and their water-bearing characteristics are given in the report by Cady and Scherer (1946).

The Arikaree is a soft, buff to light-gray fine-grained tuffaceous sandstone. Generally it is massive to poorly bedded but locally it contains lenticular beds of nodular concretions and crossbedding is well developed. Channel and flood-plain deposits are present throughout the group. The lower part of the Arikaree consists of fine-grained, homogeneous, moderately cemented, grayish-tan sand containing layers of potato-shaped and nodular pipy concretions of local origin. These concretions consist of hard, lime-cemented silt and fine sand that is texturally similar to the surrounding matrix. The middle part of the group consists of fine- to medium-grained gray limy sandstone containing a variety of concretionary layers at several levels. Some of these concretions are described by Cady and Scherer (1946, p. 24–25) as follows:

> * * * a 15-foot zone of gray fine-grained, well-sorted sand teems with a great variety of concretionary forms. These include large white vertical root impressions one-half inch in diameter and 3 to 4 inches long, small irregular potato concretions, thin long horizontal root impressions, small pitted and convoluted tabular concretions with many limy stems or roots attached, pipy concretions 8 inches in diameter and 3 to 4 feet long and ornamented by tubercules, knobs, and a few regular tabular concretions. Above this is an 8-foot zone containing pipy and irregular potato and vertical concretions. This is overlain by 4 feet of massive concretions formed by the aggregation of a multitude of root impressions filled with lime, and numerous tabular forms one-quarter-inch thick and 4 inches wide. One foot of massive sand with numerous root impressions is overlain by another concretion 1 to 3 feet thick composed of coalesced lime-filled root impressions. This zone can be traced laterally a few hundred feet, and the concretions become pipy, although they are coalesced into a continuous layer. Ten to twelve feet of these tabular and root concretions are overlain by a zone of giant

pipy concretions, irregular in form, and 4 feet thick by 10 feet wide by 12 feet long. They are alined in a southwest-northeast direction. Over all the western part of the tableland of Box Butte County the giant concretions mark the upper part of the Harrison [sandstone of the Arikaree group]. These concretions occupy a 20-foot zone in which they are scattered discontinuously. The sand is otherwise massive and featureless except for a few root impressions.

The fine- to medium-grained sandstone of the middle part of the Arikaree grades upward into the finer, blocky sandstone layers and beds of limy sandy silt in the upper part of the group. Lime impregnations in the blocky sandstone layers form hard honeycomblike ledges, which stand out in weathered outcrops. Although not so abundant, concretionary layers are present also in the upper part of the Arikaree. Channels, filled with sand and silt, and extensive silty clay deposits are common in the upper part of the group throughout western Nebraska.

The Arikaree group underlies most of the area, and in parts of Box Butte, Dawes, Sheridan, and Sioux Counties it is several hundred feet thick and is saturated with ground water. Generally, satisfactory supplies for domestic and stock wells can be obtained by drilling 15 to 30 feet into the saturated material. Irrigation wells, however, ordinarily must penetrate 150 to 200 feet of saturated material to obtain adequate yields, as the Arikaree is only moderately permeable. In Niobrara County, Wyo., where the Arikaree is considered a formation, it apparently is relatively impermeable, as some irrigation test wells have penetrated a considerable thickness of saturated material and obtained only a small amount of water. In these parts of the area the most successful irrigation wells are those that intersect fissures, a local channel of gravel, or lenses of loose sand in the Arikaree.

OGALLALA FORMATION

The Ogallala formation differs lithologically from sediments of the same age elsewhere in the Great Plains. The lower part of the formation—called the Valentine formation by Lugn (1939)—consists of fine-grained, generally massive gray and light greenish-gray sand and silt, which in places contain pipy concretions. Above this lower part is the Ash Hollow formation of Lugn (1939) which he correlates with the "mortar beds" of the Ogallala elsewhere in the Great Plains province. At the bottom of the Ash Hollow formation of Lugn (1939) is a 3- to 5-foot, hard white lime-cemented layer, or "cap rock" bed. The rest of the Ash Hollow formation of Lugn (1939) consists of gray to buff irregular beds of silt, sand, and, in places, gravel interbedded with hard, lime-cemented silty lenses.

In the NW¼SW¼ sec. 34, T. 33 N., R. 31 W., a distinctive rock layer crops out in the bluffs south of the Niobrara River; for several hundred feet this layer consists of about 2 feet of dark-brown very hard calcareous, thin-bedded shale or argillite overlain by a 1-foot bed of brittle translucent green chert.

In the upper Niobrara River basin the Ogallala formation is almost wholly mantled by dune sand. This dune sand and the sand and silt of the Ogallala are so similar in appearance that generally no differentiation is made by well drillers. Consequently, it was not possible to determine which of these materials is the chief source of water yielded by some of the wells in the Sand Hills region.

The thickness of the Ogallala formation ranges from less than a foot in Sheridan County to about 300 feet in the eastern part of Cherry County. The saturated thickness of the group is not known but throughout most of the eastern part of the area is probably more than 150 feet.

The Ogallala formation is only moderately permeable and, therefore, generally about 150 to 200 feet of saturated material must be penetrated to obtain sufficient water for irrigation. Adequate quantities of water for domestic or stock supplies, however, may be obtained by penetrating from 15 to 30 feet of the saturated material.

In a few places in Cherry County, impermeable lime-cemented layers in the Ogallala prevent or impede the infiltration of water to the regional water table and, as a result, the bodies of perched ground water lie close to the land surface. A few stock wells obtain water from these zones of perched water, but sustained or large withdrawals are not possible because the saturated thickness of these zones is relatively thin.

QUATERNARY SYSTEM

The Quaternary deposits of the upper Niobrara River basin consist of terrace deposits, alluvium, and dune sand. The valley terrace deposits and alluvium are similar in character and consist of poorly sorted sand and some silt and gravel. These materials are finer grained than similar deposits in most of the other major stream valleys in the Great Plains because of the fine-grained texture of the Arikaree group and Ogallala formation, which are the source materials for these deposits.

A narrow terrace about 25 feet above stream level is present in some segments of the Niobrara River valley in eastern Sioux County and western Dawes County. Another terrace, about 40 feet above stream level, is present in parts of eastern Dawes County and western Sheridan County. South of Hay Springs in Sheridan County on the north side of the Niobrara River, a relatively flat-lying surface called the Mirage Flats, which may be a stream terrace, lies about 80 feet above the river. A more detailed discussion of terraces in the Niobrara River valley appears in a report on the geology and ground-water resources of Box Butte County by Cady and Scherer (1946, p. 13–16).

The alluvium in the stream valleys probably is the most permeable material in the area, but it generally is less than 50 feet thick and not more than half a mile wide. Wells in the stream valleys, therefore, must penetrate the Tertiary rocks that underlie the alluvium to obtain a supply sufficient for irrigation. Many stock and domestic wells, however, obtain ample supplies from the alluvium or from terrace deposits.

The dune sand mantles the alluvium and terrace deposits throughout the report area, as well as the Ogallala formation and Arikaree group in part of the area (pl. 1). The sand was derived largely from exposed beds of the Arikaree and Ogallala. Some of the large dunes have cores of Tertiary material, but most of them are true sand dunes. In sec. 19, T. 32 N., R. 32 W., a typical dune-sand deposit consists of medium-grained, well-sorted, well-rounded sand consisting of about 80 to 90 percent quartz grains and 10 to 20 percent multicolored grains of feldspathic and ferromagnesian minerals. The percentage of weight by grain size of two samples of dune sand collected in the area is as follows:

Approximate location	Particle size in millimeters					
	Clay and silt (less than 0.0625)	Sand				
		Very fine (0.0625–0.125)	Fine (0.125–0.25)	Medium (0.25–0.5)	Coarse (0.5–1.0)	Very coarse (1.0–2.0)
U. S. Highway 20 near Cody, Nebr	0.5	10.2	72.6	16.4	0.2	0.1
U. S. Highway 20 near Merriman, Nebr	.6	9.2	66.1	23.7	.4	0

GROUND WATER

OCCURRENCE

The quantity of water contained in a saturated rock depends upon its porosity, which may be expressed quantitatively as the ratio of the aggregate volume of the interstices to the total volume of the rock. The capacity of a rock to yield water to wells or to transmit water in response to the force of gravity, however, is not dependent upon the porosity of the rock or the quantity of water stored in it but on its permeability and storage coefficient.

Permeability refers to the capacity of a water-bearing material to transmit water under pressure. The coefficient of permeability, in Meinzer's units, is defined as the number of gallons of water per day at a temperature of 60°F that percolates through each mile of a water-bearing bed (measured at right angles to the direction of flow) for each foot of thickness of the bed and for each foot per mile of hydraulic gradient. The coefficient of storage, which expresses the amount of water released from storage with a lowering in head in an unconfined aquifer, is about equal to the specific yield, which is defined as the ratio of (1) the volume of water which a rock will yield by gravity, after being saturated, to (2) its own volume. Rock composed of very fine particles, such as a silt or clay, usually has a high porosity and, if saturated, contains a large quantity of water. Because the interstices are small, most of the water in such material adheres to the individual rock particles, and the rock is relatively impermeable. This type of rock does not yield water to wells readily. On the other hand, a rock composed of medium to coarse sand may have only one-half or one-third the porosity of clay, but as only a small part of the water present adheres to the individual sand grains the remainder is free to move through the relatively large interstices. This type of rock, if saturated, readily yields large quantities of water to wells.

In the upper Niobrara River basin, the important water-bearing rocks are the Arikaree group, the Ogallala formation, the terrace deposits, the alluvium, and the dune sand. Fine-grained sand, loosely cemented sandstone, and silt of the Arikaree and Ogallala provide an excellent storage reservoir for vast quantities of ground water. Although these rocks function also as conduits for the movement of water, the rate of movement under natural conditions probably is less than 1 foot per day. The terrace deposits, alluvium, and dune sand are coarser grained than the Arikaree and Ogallala and consequently transmit water more rapidly.

In permeable strata, ground water that is unrestricted by a relatively impermeable overlying confining bed is said to be under water-table conditions. When ground water is confined in an aquifer between relatively impermeable strata, it is under pressure which depends on the difference in altitude between intake and discharge areas and on the loss of head by friction as the water moves. Water so confined is said to be artesian and will rise in a well some distance above the bottom of the overlying confining bed. In the area described in this report almost all ground water is under water-table conditions. Locally, however, ground water in both the Arikaree and the Ogallala is under artesian pressure. Each of two wells, 31–61–4ab and 32–61–32c, flows about 50 gallons per minute (gpm) at the land surface.

HYDROLOGIC PROPERTIES OF THE WATER-BEARING FORMATIONS

Two outcrop samples, one from the Arikaree and one from the Ogallala, were analyzed in the Lincoln hydrologic laboratory of the U. S. Geological Survey. The sample from the Arikaree was collected from the bluffs on the north side of the Niobrara River near Agate, Nebr., near the center of sec. 6, T. 28 N., R. 55 W. This sample consisted of fine sand from near the middle of the Arikaree group (Harrison sandstone) and had a porosity of 31.5 percent, a storage coefficient of 15.7 percent, and a coefficient of permeability of 13 gpd per square foot. The sample of Ogallala was taken from the bluffs along the north side of the Niobrara River in the NE¼SE¼ sec. 22, T. 30 N., R. 44 W., about 11 miles south of Rushville, Nebr. This sample consisted of very fine sand and silt from the lower part of the Ogallala (Lugn's Valentine formation), and had a porosity of 46.6 percent, a storage coefficient of 31.7 percent, and a coefficient of permeability of 2 gpd per square foot. The tests on the sample of the Arikaree were made on a core cut from a consolidated chunk; consequently, the results are more accurate than those for the sample of the Ogallala, which was unconsolidated and had to be repacked.

The analysis of a sample of the Arikaree from Goshen County, Wyo., given in the report by Rapp, Visher, and Littleton (1956), indicates a porosity of 43.3 percent, a storage coefficient of 32.5 percent, and a coefficient of permeability of 69 gpd per square foot.

During a study of the ground-water resources of Box Butte County, Nebr., Cady and Scherer (1946, p. 46) determined by means of a pumping test the field coefficient of permeability (at field temperature rather than at 60°F) of the Arikaree to be 225. This value probably is more representative of the Arikaree than that for the samples cited above. The lithologic characteristics of the Ogallala formation in this area are sufficiently similar to those of the Arikaree group that probably its permeability also is similar to that determined for the Arikaree by Cady and Scherer.

Under water-table conditions, a pumped well withdraws water from the zone of saturation immediately surrounding the well, and the water level in the well is lowered. In the vicinity of the well, the water table assumes a shape similar to that of an inverted cone. The difference between the static (nonpumping) water level and the depth to water in the well when it is pumped is referred to as the drawdown. A discussion of the behavior of the water table in the vicinity of discharging wells is given by Wenzel.[3]

The specific capacity of a well is defined as the number of gallons per minute discharged from a pumped well per foot of drawdown in the well. It is determined by dividing the drawdown (feet) into the yield (gpm). For a well under water-table conditions, values of the specific capacity for different yields and drawdowns are about constant only if the saturated thickness is large in relation to the draw-

[3] Wenzel, L. K., 1942, Methods for determining permeability of water-bearing materials, with special reference to discharging-well methods: U. S. Geol. Survey Water-Supply Paper 887, p. 98–99.

down. Specific capacities of wells indicate the permeability of the aquifer in a general way, although the well construction and development may cause marked differences in the specific capacities of wells in the same aquifer. Table 4 gives average specific capacities of wells in the area by counties and by aquifers.

TABLE 4.—*Average specific capacity of selected irrigation wells in the upper Niobrara River basin*

[Based on reported data]

Location		Geologic source	Number of wells for which computations were made	Average specific capacity (gallons per minute per foot of drawdown)
Nebraska	Box Butte	Arikaree group	5	10
	Cherry	Ogallala formation and dune sand	1	20
		Ogallala formation	3	7
		Arikaree group and Ogallala formation	1	23
	Sheridan	Arikaree group	4	10
		Arikaree group and alluvium	7	33
		Ogallala formation and dune sand	3	12
		Arikaree group and Ogallala formation	1	50
	Sioux	Arikaree group and alluvium	4	12
Wyoming	Niobrara	Arikaree formation	3	11
		Arikaree formation (probably fractured)	2	51

CONFIGURATION OF THE WATER TABLE AND MOVEMENT OF GROUND WATER

The shape and slope of the water table are indicated on plate 1 by contour lines based on the altitude of the water level in the wells; the altitudes were estimated from topographic maps. Ground water moves down gradient in a direction perpendicular to the contour lines. The contour lines indicate that ground water moves generally eastward and is discharged eventually into the Niobara River or one or its principal tributaries. The regional eastward slope of the water table is about 12–14 feet per mile. However, near the Niobrara River in east-central Sheridan County and in Cherry County, the slope of the water table is toward the river and is 60–70 feet per mile. Many local irregularities in the shape of the water table are too small to be shown by the contour lines on plate 1.

In the area of closed basins in southern Sheridan County, the water table is nearly flat. A gentle northward-trending trough in the water table through Tps. 25–28 N., Rs. 44 and 45 W., indicates that here the general movement of ground water is northward toward Pine Creek. (See fig. 9, p. 46.)

The average velocity of ground-water flow in the Arikaree group under the central upland of Box Butte County is computed to be about 75 feet per year, using a permeability of 225 gpd per square foot, an average hydraulic gradient of 14.5 feet per mile, and a porosity of 40 percent. Ground-water velocities throughout most of the Arikaree group and Ogallala formation in this area probably are about the same as in Box Butte County.

The underflow from Wyoming into Nebraska was computed to be about 12 mgd, or about 19 cfs, using an estimated coefficient of permeability of 200, a hydraulic gradient of 20 feet per mile, and a cross-sectional area of saturated material of the Arikaree group 30 miles long and estimated to be 100 feet thick. The coefficient of permeability was estimated by comparing the specific capacity of the irrigation well in Box Butte County on which a pumping test had been run to determine the coefficient of permeability (Cady and Scherer, 1946, p. 46) with the average specific capacity of irrigation wells in Niobrara and Sioux Counties. The hydraulic gradient of the water table and the length of the cross section were taken from plate 1. The saturated thickness of the section was based on data obtained from logs of wells in the area and from information supplied by H. J. Cook (oral communication). The formations underlying the Arikaree group are relatively impermeable and underflow through these units is assumed to be negligible. The overlying alluvium is thin and confined to a narrow valley and is considered to be part of the Arikaree group in the above computation. This estimate of underflow from Wyoming into Nebraska is based on meager data; a more accurate computation would require information obtained from test drilling and pumping tests near the State line.

DEPTH TO WATER

The depth to water in wells in the report area, measured during this investigation, ranges from a few feet to 263 feet. The depth to water in wells is shown on plate 1 by numbers (above the well symbols) and by dashed lines.

Although, in general, the water table is at a higher altitude under upland, or topographically high areas, than it is under adjacent valleys, or topographically low areas, the depth to water is greater beneath upland surfaces than it is beneath valley or lowland areas.

In the valleys of perennial streams, the depth to water ranges from a few feet to about 50 or 60 feet; under the rolling uplands of the western part of the area, the depth to water ranges from about 100 to about 250 feet. In the Sand Hills region, the depth to water is generally not more than 15 or 20 feet in most of the valleys, and the water table intersects the land surface in the many lakes and marshes.

The Niobrara River and its major tributaries in the Sand Hills region are incised into the Ogallala formation, which underlies the dune sand, and drain large quantities of ground water from the surrounding saturated materials. Consequently, the depth to water beneath the bluffs adjacent to the streams is greater than it is farther away from the streams.

Two areas of perched ground water in Box Butte County and one in Cherry County are shown on plate 1. These are areas where the infiltration of water is inhibited by relatively impermeable beds and, consequently, small bodies of water are held at shallow depths below the land surface. Cady and Scherer (1946, p. 49) describe perched water in Box Butte County as follows:

> In the Monroe Creek and Harrison sandstones and the Marsland formation [all are included in the Arikaree group in the present report] the numerous dense concretionary sandstones tend to inhibit the downward seepage of the water that soaks into the ground and passes below the reach of plant roots. It is reported that occasionally a little water is detected in the drilling of wells lying on some of these concretionary zones above the water table. This water, to the extent that it can flow into a well, belongs to a perched zone of saturation and is called perched water. The perched water is believed to flow laterally along the dense zones of impermeable beds and so to bypass them and to reach the water table ultimately. Two localities were discovered where the perched zone of saturation yields enough water to be of practical significance. One area is in the northwestern part of T. 27 N., R. 48 W., and the other is in the southeastern part of T. 28 N., R. 47 W. This perched water exists in a rather thin film of Ogallala sand that overlies the clays of the Box Butte member of the Sheep Creek formation [also included in the Arikaree group in the present report]. The depth of the perched water is about 30 feet or less, depending on the topography at the land surface. A few wells end at this zone and draw the water for small domestic and stock supplies.

WATER-LEVEL FLUCTUATIONS

The principal factors responsible for fluctuations of the water table are variations in the ratio of recharge to discharge and changes in barometric pressure. The gradual rise or decline of water levels extending over long periods of time are generally the result of long-term adjustments between recharge and discharge. Moderately rapid small fluctuations of water levels in wells in upland areas, which are not affected by sudden changes in streamflow, generally can be attributed to changes in atmospheric pressure. The following discussion of water-level fluctuations due to such pressure changes describes this phenomenon as it occurs in this area (Cady and Scherer, 1946, p. 70):

> The exact manner in which the water level in a well fluctuates in response to changes in atmospheric pressure is probably complex. In part, the concretionary zones and tightly cemented layers of sandstone in the Miocene sandstone formations probably aid in segregating the air trapped in interstices at the top of the water table from the free atmosphere, including the air in the well above the water

level. The same effect is obtained if a thick zone of aeration is so damp that changes in air pressure are transmitted through interstices imperfectly. Many wells show a barometric fluctuation where this condition prevails. It is believed that if recharge is occurring on the uplands of Box Butte County, as the evidence indicates, the chief reason for the barometric fluctuations of water level is the moisture in the zone of aeration.

The water levels in some of the wells in areas of shallower water table seem not to exhibit any barometric fluctuations. The hydrographs of these wells are smooth. Other wells in these areas have irregularities that cannot certainly be attributed to changes in atmospheric pressure. It may be noted that during the summer of 1938 the wells in which the water level is deepest show the greatest response to changes in barometric pressure. Where the water level is less than 100 feet, the barometric fluctuations almost disappear.

Hydrographs of selected observation wells in the upper Niobrara River basin are shown in figure 5. The minor fluctuations shown in the hydrographs of wells 27–49–21cb and 31–56–10da are probably due to differences in barometric pressure. The general decline of water levels during the 1930's was due to a prolonged drought, and the subsequent rise of water levels was due to generally above normal precipitation during 1941–52.

The sharp fluctuations of the water levels in wells 31–44–10dd and 34–38–14bc are due largely to local short-term variations in discharge and recharge. These wells are in valley bottom lands where, during the growing season, water levels may be lowered by transpiration from vegetation and rises in water level may result from the rapid infiltration of flood flows.

Water-level fluctuations are caused also by the intermittent pumping of wells. Throughout most of the area, pumping from wells lowers the water table only temporarily; the average annual replenishment during the nonpumping period is usually sufficient to replace the water thus removed. In places, however, movement of ground water through the aquifer is so slow that a continual lowering of the static water level results from the seasonal pumping of irrigation wells. An example of this is the decline of the water level in well 27–49–26cd, an irrigation well in central Box Butte County. On March 29, 1946, the water level in this well was 116 feet below the land surface and by April 2, 1953, it had dropped to 124.5 feet. The water level in observation well 27–49–21cb, which is about 2 miles northwest of this irrigation well, rose more than 1 foot during the same period (fig. 5), which indicates that the regional water table was rising.

RECHARGE

Recharge is the term used to describe the addition of water to the zone of saturation. In the area described in this report, recharge results from the infiltration of precipitation and of water applied to the land for irrigation.

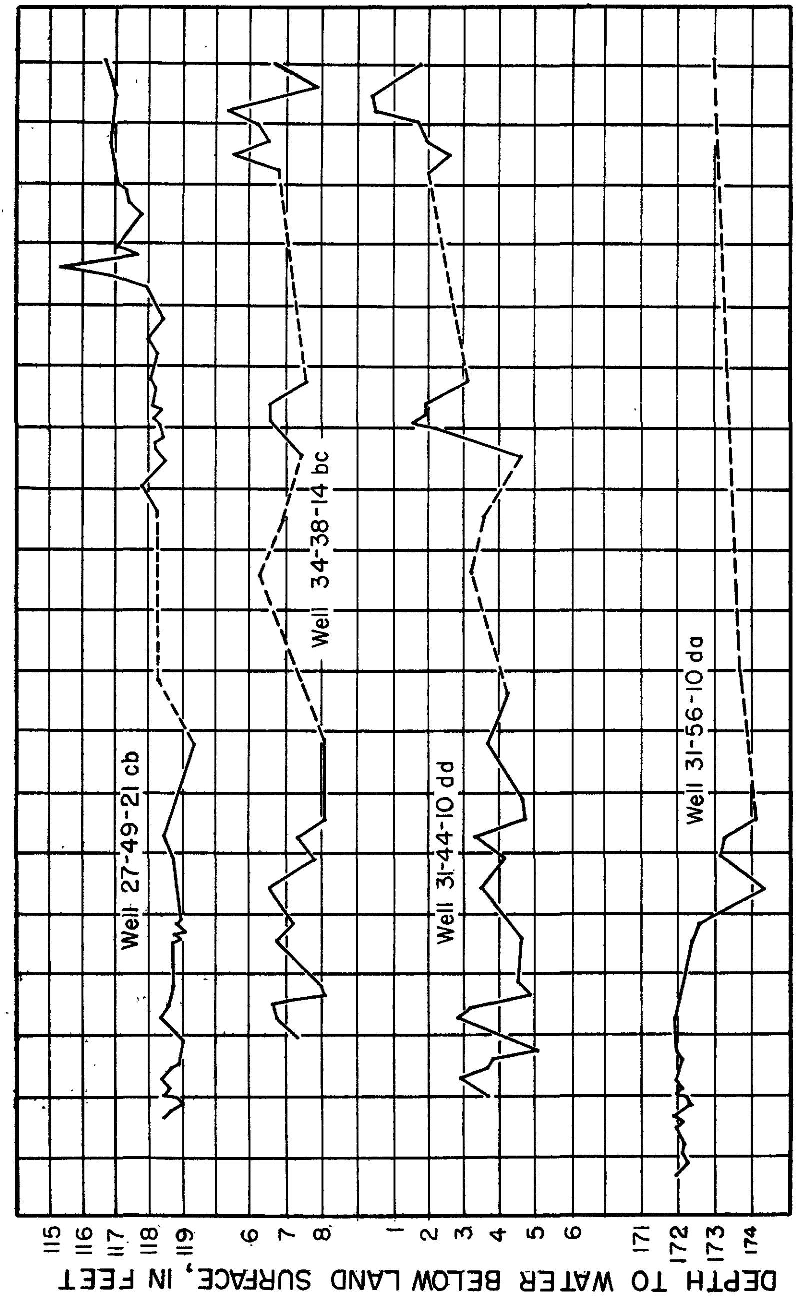

FIGURE 5.—Hydrographs showing water-level fluctuations in wells in the upper Niobrara River basin.

PRECIPITATION

Much of the recharge to the ground-water reservoir is by direct infiltration of precipitation. The amount of this recharge is dependent upon the type and structure of the soil, the topography, the vegetation, the duration and intensity of the precipitation, and the rate of evaporation of moisture from the soil. Much of the surface runoff that accumulates in sandy draws and stream valleys infiltrates through the highly permeable valley fill or alluvium to the ground-water reservoir. Most of the heavy spring and summer rainfall is returned to the atmosphere by evaporation and transpiration, part of it runs off and is discharged by the streams that drain the area, and a part infiltrates to the zone of saturation. During the fall and winter, evaporation and transpiration losses are small, and when the ground is not frozen, a larger proportion of the precipitation reaches the ground-water reservoir.

Sufficient data were not available to determine the total quantity of water recharged to the ground-water reservoir from precipitation. However, it is estimated that the average amount of recharge for the entire area probably is no more than 1 inch a year, which is small compared to the total amount of precipitation. The rate of recharge varies considerably throughout the area with the highest rate occurring in the Sand Hills region. Lohman (1953, p. 88) makes the following observations about the quantity of recharge in the Sand Hills region of Nebraska:

> * * * average yearly recharge to the ground-water reservoir must be in the order of 0.19 cfs per square mile or 2.6 inches mean depth. This is more than 5 times the rate that prevails over much of the High Plains, probably less than 0.5 inch. This mean depth for all the Sand Hills area is an average; actual recharge varies, probably from a fraction of this amount to as much as 5 inches.
>
> As conditions for recharge in the Sand Hills seem to be so nearly ideal, one might expect an even larger rate of recharge; however, the scanty precipitation falls mainly during the growing season when, in large part, it is subject to the preemptive requirements of the dune grasses and meadow grasses. Most of the winter precipitation probably reaches the ground-water reservoir.

Because the figure of 2.6 inches, or about 14 percent of the precipitation, is equivalent to the net amount of ground water annually discharged by the streams that drain the area, it does not include the amount of underflow out of the area, which may be appreciable, nor the amount of evapotranspiration of ground water in the places where the water table is near the land surface. Consequently, the total recharge to the ground-water reservoir is considerably greater than the 14 percent indicated and possibly may be as much as 25 percent of the precipitation.

IRRIGATION

In areas where irrigation water is applied to the land surface, appreciable quantities of recharge result from the infiltration of this

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water. Evidence of such recharge is apparent from the water-level record of well 29–46–11dc (table 11), which is near the center of the Mirage Flats irrigation project, Sheridan County (pl. 1). The water level in this well has risen about 10 feet since water was first applied to the land in 1946, and the water table has risen 5 to 10 feet under most of the Mirage Flats project area since irrigation started. Part of this rise, however, is attributed to a natural rise in the water table, which has occurred in adjacent areas where irrigation has not been practiced.

DISCHARGE

Ground water is discharged from the zone of saturation by evaporation and transpiration, seepage into streams and springs, discharge from wells, and underground movement into adjacent areas.

EVAPORATION AND TRANSPIRATION

Where the zone of capillary water above the water table extends to the land surface, as it does in the lowlands of the Sand Hills region and in the lower parts of the valleys of the Niobrara River and its tributaries, large quantities of ground water are discharged by evapotranspiration. If the zone of capillary water extends near but not to the surface, evaporation is of minor importance and transpiration accounts for most of the ground-water discharge. No evapotranspiration data were obtained during this investigation, but the following from Cady and Scherer (1946, p. 60–61) shows the importance of discharge of ground water by evapotranspiration in northwestern Nebraska:

The discovery through field and experimental investigations of the great amount of water that plants can dispose of through transpiration has been well-nigh revolutionary in the study of hydrology. If the computed amount of water discharged from areas of shallow water table in Box Butte County are of the correct magnitude then about 30 inches of water are evaporated and transpired during a normal year, and about 14 inches of water are evaporated and transpired each year from the upland areas. According to information furnished by W. L. Tolstead, of the Conservation and Survey Division of the University of Nebraska, 4 feet of water was consumed by arrowhead, wildrice, bulrush, and cattail in Cherry County, Nebr., between July 9 and September 20, 1937. A like amount was consumed by swamp grasses and tall meadow grasses during the same period in areas where the water table lay about 3 feet below the land surface. The true prairie grasses in areas where the water table lies at depths of 3 to 6 feet below the surface were estimated by Tolstead to have transpired about one-half as much water in the same period as the other types of vegetation cited. As the water table declines, the grasses obtain and consume less water. These figures cannot be quantitatively applied to Box Butte County, but they illustrate that the lowlands of western Nebraska are tenanted with potent agents for getting rid of water. In addition, the evaporation from water surfaces, as measured at the Box Butte Experiment Farm of the University of Nebraska near Alliance, in May, June, July, August, and September, 1938, was 39.18 inches. It seems, therefore, that the computed losses of water from the areas of shallow water table are not excessive in the light of the above-mentioned information.

STREAMS AND SPRINGS

The flow of the Niobrara River and its principal tributaries consists largely of ground water discharged directly into the stream channels; the greatest ground-water discharge into streams occurs in the Sand Hills region. Streamflow data at several stations along the Niobrara River and some of its tributaries have been taken from records of the U. S. Geological Survey and are shown in table 5. Estimates of the streamflow were made by the writer at several points along these streams where the discharge had not been measured, and because they were made when there was no runoff from precipitation, they represent flow derived from ground water. These estimates are given in table 6.

TABLE 5.—*Measured stream discharge in the upper Niobrara River basin*

Station and location	Runoff by water years (acre-feet)			
	1945–46	1946–47	1947–48	1948–49
Niobrara River above Box Butte Reservoir (29–50–27a)	[1]	30,960	30,450	27,540
Niobrara River below Box Butte Reservoir (29–49–28d)	[1]	10,170	23,070	27,780
Niobrara River near Colclesser (30–44–29)	[1]	[1]	46,480	[1]
Niobrara River near Gordon (31–42–26a)	[2] 69,580	95,440	102,900	109,800
Antelope Creek near Gordon (32–41–13)	[1]	[1]	[3] 1,530	[1]
Bear Creek near Eli (34–35–28c)	[1]	[1]	[3] 6,860	7,310
Niobrara River near Cody (33–34–23ab)	[1]	[1]	194,600	252,100
Snake River near Burge (31–30–20a)	[1]	[4] 41,570	174,700	182,800
Niobrara River near Sparks (34–26–22d) [5]	[2] 491,500	606,800	586,600	623,700

[1] No records available.
[2] 10 months only.
[3] 8 months only.
[4] 3 months only.
[5] Outside report area.

TABLE 6.—*Estimated stream discharge in the upper Niobrara River basin*

Location	Date	Stream	Depth of water at site	Commensurate discharge in cubic feet per second
Bridge on county road, one-quarter mile southwest of Van Tassel (31–60–17ca).	Nov. 13, 1952	Niobrara River		2–3
Bridge on county road (30–56–18ad).	do	do		6–8
Bridge on State Highway 29, at Agate (28–55–6ca).	Apr. 21, 1953	do		11–13
Culvert under county road, 3-foot diameter, 100 yards east of farmhouse (27–54–4ad).	do	Whistle Creek	Water surface 1.3 feet above bottom of culvert pipe.	5–6
In hayfield, 40 yards east of State Highway 87 (28–46–16bb).	Nov. 11, 1952	Box Butte Creek		2–3
Culvert, 3-foot diameter, 100 yards east of farmhouse (28–46–2b).	do	do	Water surface 0.6 foot above bottom of culvert pipe.	3–4
West edge of concrete bridge on county road (29–44–13cc).	Oct. 30, 1952	Pine Creek	Water surface 0.8 foot above concrete base of bridge.	8–10
Wooden bridge on county road near Colclesser (30–44–27cc).	do	do		12–15

Many springs issue from near the bottom of the bluffs that border the flood plain of the Niobrara River. Some of the water from these springs flows into the channel of the river, but most of it evaporates or is transpired before reaching the stream. The quantity of ground water discharged from these springs is small compared to the amount of ground water flowing directly into stream channels.

WELLS

Discharge of ground water from wells is very small compared to discharge by evapotranspiration or discharge through streams. Ground water in the area has been developed for irrigation, public supply, and domestic, stock, and industrial uses.

IRRIGATION

Forty-six wells from which water was pumped for irrigation in 1952, 12 wells not then in use, and 5 wells drilled for irrigation but not equipped with pumps were inventoried; data on these wells are given in table 13. It is believed that the inventory included all irrigation wells in the area. The rate of construction of irrigation wells is shown in figure 6. Two of the wells given in table 13 are not included in figure 6 because the date of construction of one well

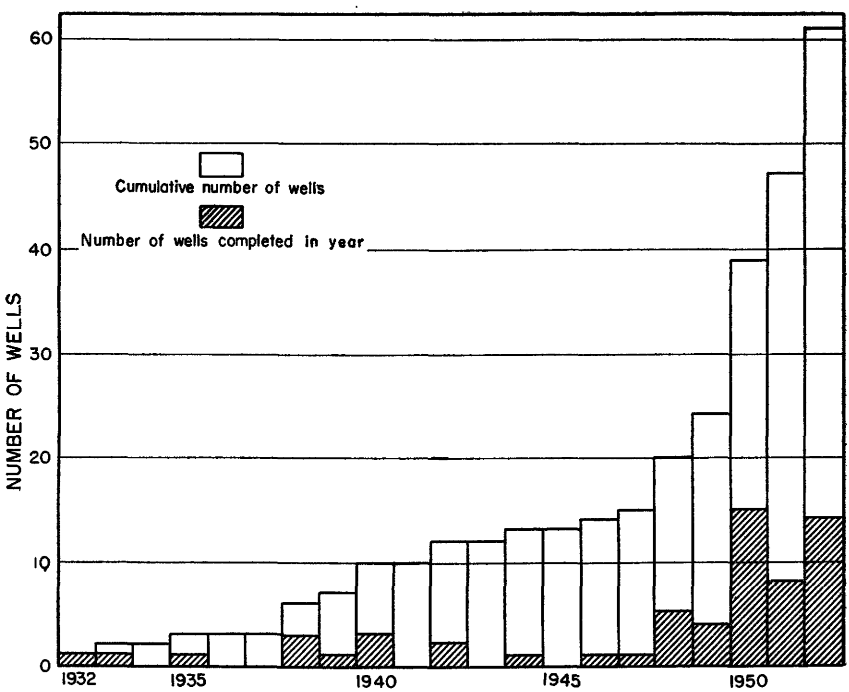

FIGURE 6—Number of irrigation wells constructed in the upper Niobrara River basin, 1932–52.

was unknown and construction of the other had not been completed at the time of the field canvass in 1952.

In north-central Sheridan County 8 irrigation wells have been installed near Gordon and 11 near Hay Springs; in northeastern Box Butte County 11 irrigation wells have been constructed.

The number of irrigation wells is as follows: 11 in Box Butte County, 9 in Cherry County, 2 in Dawes County, 24 in Sheridan County, and 7 in Sioux County, Nebr.; and 10 in Niobrara County, Wyo. Grouped according to their topographic setting, the number of wells is as follows:

Topographic setting	*Number of wells*
Niobrara River valley	5
Valleys of tributaries of the Niobrara River	23
Valleys in the Sand Hills region	12
Benchland along the Niobrara River	1
Flat-lying upland surfaces	10
Rolling plains	12

Of the 63 irrigation wells listed in table 13, 54 were equipped with turbine pumps, 3 with centrifugal pumps, and 1 with a cylinder pump, and 5 were not equipped with pumps. Twelve of the pumps were powered by electric motors and 46 by motors using gasoline, diesel oil, or propane.

The discharges and drawdowns of the irrigation wells are given in the last column in table 13. The smallest yield reported is 60 gpm, and the maximum yield, reported for several wells, is 1,500 gpm. The average discharge of all irrigation wells in the area is about 770 gpm and the average specific capacity is 19 gpm per foot of drawdown. The average specific capacity, according to the geologic source of the water, is shown in table 4 for 34 of the irrigation wells.

About 980 acres in Box Butte County, 600 acres in Cherry County, 190 acres in Dawes County, 2,260 acres in Sheridan County, 160 acres in Sioux County, Nebr., and 230 acres in Niobrara County, Wyo., was irrigated in 1952 by water pumped from 46 wells. The average acreage per well was 97. If the 12 unused wells also had been pumped in 1952, the total acres irrigated from wells would have been about 5,600. It is estimated that about 8,400 acre-feet of water per year, or about 1.5 acre-feet per acre, would be required to irrigate this amount of land.

PUBLIC SUPPLY

Municipal supplies for all the towns and cities in the area are obtained from wells; the total annual withdrawal is about 720 million gallons, or about 2,200 acre-feet. The town well (32–65–1bb) of Manville, Wyo., is 200 feet deep and yields 125 gpm from the

Arikaree formation. The maximum consumption of water at Manville during the hot weather is about 50,000 gpd.

Lusk, Wyo., obtains its water supply from three wells. Well 32–63–7bd is 120 feet deep, penetrates the Arikaree formation and yields 330 gpm; the other two (32–63–8dc1, –8dc2) are each 150 feet deep, draw water from the Arikaree formation and the alluvium, and yield 350 and 250 gpm. The city of Lusk used about 101 million gallons of water in 1951.

Harrison, Nebr., obtains its water supply from two wells tapping the Arikaree. Well 31–56–3cd1 is 274 feet deep and well 31–56–3cd3 is 296 feet deep; they yield 100 and 150 gpm, respectively. Based on daily-consumption data for July and December 1952, the average annual consumption of water for Harrison was estimated to be about 35 million gallons.

Hemingford, Nebr., derives its water supply from wells tapping the Arikaree. Two wells (27–49–7dd1, –7dd2), each capable of yielding about 300 gpm, supply the town during periods of normal consumption, and a third well (27–49–18ca) is used during periods of peak demand. All three wells are reported to be 300 feet deep. The average annual pumpage is estimated to be about 45 million gallons.

Hay Springs, Nebr., obtains its water supply from three wells. One well (31–46–11ba) draws water from the Arikaree exclusively and the other two (31–46–10da, –11bd) tap both the Arikaree and the alluvium in a tributary valley of Rush Creek. The two older wells (31–46–11ba, –11bd) are 150 and 70 feet deep and yield 75 and 50 gpm. The newer well is 288 feet deep and yields 500 gpm. The average annual pumpage for Hay Springs is estimated to be about 65 million gallons.

Rushville, Nebr., procures its water supply from five wells that tap the Arikaree. A battery of 3 wells (32–44–27dc), each 68 feet deep and 18 feet in diameter, were dug at least 30 years ago. The reported maximum yield from these wells is 300 gpm, and they have been pumped "dry" during periods of peak demand. Well 32–44–34dd was drilled in 1939 to a depth of 802 feet, but, after a few years of intermittent pumping, the yield from this well declined from 300 to 125 gpm. Later another well (32–44–34dc) was drilled to a depth of 350 feet, but it yields only 75 gpm. Rushville's average annual pumpage is estimated to be about 75 million gallons.

Gordon, Nebr., derives its water supply from 3 wells, each 150 feet deep, that draw water from the Arikaree and the alluvium in Antelope Creek valley. Well 33–42–25bc1 yields 440 gpm, well 33–42–25bc2 yields 400 gpm, and well 33–42–25dc yields 500 gpm. Average annual pumpage of water is estimated to be 150 million gallons.

Merriman, Nebr., obtains its water supply from well 34–37–17cb, which is 182 feet deep and penetrates the Ogallala formation. The yield from this well is 250 gpm.

Cody, Nebr., procures water from two wells, one (34–33–7db) is 136 feet deep and the other (34–33–7ca) is 150 feet deep. The deeper well is reported to yield 600 gpm. Both wells tap the Ogallala formation.

Valentine, Nebr., derives water from four wells (34–27–31cc, 34–28–36ca, –36da, –36dd) drilled into the Ogallala formation. These wells range in depth from 155 to 163 feet, and their rate of discharge ranges from 300 to 350 gpm. Average annual pumpage at Valentine is about 205 million gallons.

DOMESTIC AND STOCK USE

Stock wells are much more abundant than domestic wells. In the more populous regions, which generally are areas where the ground water is readily accessible, each section of land may have as many as 8 or 10 stock and domestic wells; in the less populous regions, which generally are areas where the depth to water is greater than 100 feet, each township may have only 8 or 10 wells. In the uplands, the domestic and stock wells generally penetrate about 15 to 40 feet of the saturated part of the aquifer, but in the lowlands, where the depth to water is shallow, most of the wells penetrate only about 10 feet below the water table. The domestic and stock wells range in diameter from 2 to 7 inches; however, the majority of the wells are about 6 inches in diameter. Most of the domestic and stock wells are drilled wells, but in the Sand Hills region some are driven or bored.

INDUSTRIAL USE

At present very little ground water is used for industrial purposes in the area. However, before the use of the diesel locomotive, the railroads pumped large quantities of water for steam engines.

The Chicago & North Western Railway System still has wells at several towns in the area. Three of these formerly supplied appreciable quantities of ground water. Well 32–63–8da at Lusk, Wyo., is 38 feet deep, 10 feet in diameter, and obtains water from the alluvium of the Niobrara River. Pumpage at Lusk by the railroad was as much as 140,000 gpd. At Van Tassel, Wyo., the Chicago & North Western Railway System has a well (31–60–17db) that is 97 feet deep and obtains water from the Arikaree formation. Pumpage from this well formerly was between 25,000 and 50,000 gpd. At Hay Springs, Nebr., well 31–46–11ab is 390 feet deep and draws water from the Arikaree. Formerly, about 30,000 gpd was pumped from this well.

The Chicago, Burlington & Quincy Railroad has three wells in the area. The depth of well 27–49–7da at Hemingford, Nebr., is 297 feet; well 29–51–34bc at Marsland, Nebr., is 73 feet; and well 30–51–30bc at Belmont, Nebr., is 412 feet. Each of these wells formerly supplied between 40,000 and 100,000 gpd.

UNDERFLOW FROM THE AREA

An undetermined quantity of ground water is discharged from the upper Niobrara River basin as underflow past the eastern boundary of the area. This underflow moves through the saturated part of the Ogallala formation and dune sand deposits, but more detailed investigation would be required to determine even the approximate quantity of this underflow.

GROUND WATER FOR IRRIGATION

In recent years irrigation by pumping has become increasingly widespread in the Great Plains province because rainfall is sparse and sporadic in distribution. The availability of ground water for irrigation has proved a valuable asset in the upper Niobrara River basin, as well as in the Great Plains as a whole.

Irrigation from wells is comparatively new in the area. The number and distribution of irrigation wells have already been discussed in the section on ground-water discharge. Figure 6 shows that more than half the irrigation wells have been installed since 1949.

In the upper Niobrara River basin, the crops irrigated by water pumped from wells include sugar beets, potatoes, beans, corn, oats, other grains, alfalfa, and hay. In the Sand Hills region in the eastern part of the area, water is pumped mainly to irrigate alfalfa and hay crops. Most of the irrigation is done by the sprinkler method because the land surface is rolling and the topsoil generally is sandy and not suitable for ditch irrigation.

POTENTIAL DEVELOPMENT

In much of the area, sufficient ground water is available for withdrawal from additional irrigation wells. The amount of ground water now used for irrigation is about 8,400 acre-feet per year (a small part of which returns to the water table) and is only a small fraction of the available ground water. The discharge of the Niobrara River south of Gordon, Nebr., which lies downstream from most of the present and proposed pump irrigation, is about 100,000 acre-feet per year and is largely ground-water pickup. The discharge at Valentine, where the river leaves the area, is probably about 5 times as large as it is near Gordon; most of this pickup comes from the Sand Hills region, where the amount of potentially irrigable land is relatively small. The Niobrara River valley and the valleys of some of its tributaries in the western part of the area are particularly favorable for irrigation, because the water table is near the land surface and the alluvium overlying the Arikaree is relatively permeable. However, to obtain a sufficient supply of water for extensive irrigation, the bedrock underlying the alluvium must be penetrated. Successful pump irrigation of forage crops in valleys of the Sand Hills region indicates that further development of ground water is probable in this part of the area. Only the bottom lands of the Sand Hills region can be irrigated profitably because the hills have steep slopes and are very sandy. Local recharge to the ground-water reservoir is more than sufficient to supply water for irrigation of all the bottom lands in the Sand Hills region.

In most of the upland in the western part of the area, ground-water supplies are adequate for pump irrigation, but some factors that tend to discourage this development are: (1) Much of the land surface is rolling and rough; (2) most of the soil is sandy and unsuitable for crop production; and (3) pumping lifts are high. Consequently, it is probable that only a few irrigation wells will be constructed in this part of the area, at least in the near future. In northern Box Butte County, however, the soil and topographic conditions on the relatively flat lying upland are much more favorable for crop production, and a number of irrigation wells have been developed although the pumping lift in a few of the wells is as much as 175 feet. The extension of irrigation in northern Box Butte County and the construction of new wells on the flat-lying uplands in southern Dawes County is possible, but recharge to the ground-water reservoir is slow in these areas and an increased number of irrigation wells could lower the water table until pumping would not be economically feasible. In discussing the mutual interference between wells in Box Butte County, Cady and Scherer (1946, p. 69) indicate that the minimum distance between wells necessary to prevent substantial interference is at least a quarter of a mile.

Another potential area of irrigation by pumping is the benchland along the Niobrara River in Cherry County. Topography, soil, and availability of ground water all favor such development in this area.

EFFECT OF PUMP IRRIGATION ON STREAMFLOW

The present pumping of ground water for irrigation has very little, if any, effect on streamflow. This is particularly true in the eastern part of the area where the amount of water required to irrigate the relatively small area of bottom lands in the Sand Hills region is small in comparison to the amount of water being recharged to the ground-water reservoir. However, a substantial increase in pumping west of the Sand Hills region conceivably could produce a slight but noticeable reduction in the flow of the upper Niobrara River and some of its tributaries.

CHEMICAL QUALITY OF THE WATER

By F. H. Rainwater

The purpose of this section is to describe the quality of the ground water in terms of predominant characteristics and geologic source and to discuss the suitability of the water for domestic and irrigation use. The information herein presented, in conjunction with the foregoing sections, will be helpful in outlining those parts of the upper Niobrara River basin in which more intensive studies of the geologic, hydrologic, and water-quality relations would be desirable before further large-scale development of the water resources. Because surface- and ground-water drainage, which is an important factor in formulating the chemical quality of the water, is different in the upper Niobrara River basin than it is in the area of closed basins, the chemical characteristics of the water in the two areas are discussed separately.

Earlier studies of water quality are cited under "Literature pertaining to region." Samples of water from 16 wells and 7 samples from streams in the upper Niobrara River basin were collected for chemical analysis. The location of each of these sampling points is shown in figure 7. In addition, 5 samples from lakes and 5 samples from adjacent wells in the closed-basins area were collected to ascertain the relationship that exists between the quality of the alkali lake water and the quality of the adjacent ground water.

UPPER NIOBRARA RIVER BASIN

Chemical analyses of the samples of ground water are given in table 7. The water is used primarily for domestic purposes, livestock watering, and irrigation. Although the hardness of water from some of the wells in the upper Niobrara River basin approaches or exceeds 200 parts per million (ppm), it compares favorably with the hardness of many of the water supplies elsewhere in the Great Plains States. Concentrations of chemical constituents did not exceed the limitations established by the U. S. Public Health Service [4] for potable water to be used by interstate carriers.

[4] U. S. Public Health Service, 1946, Drinking water standards: U. S. Public Health Service Repts., v. 61, no. 11, p. 371–384.

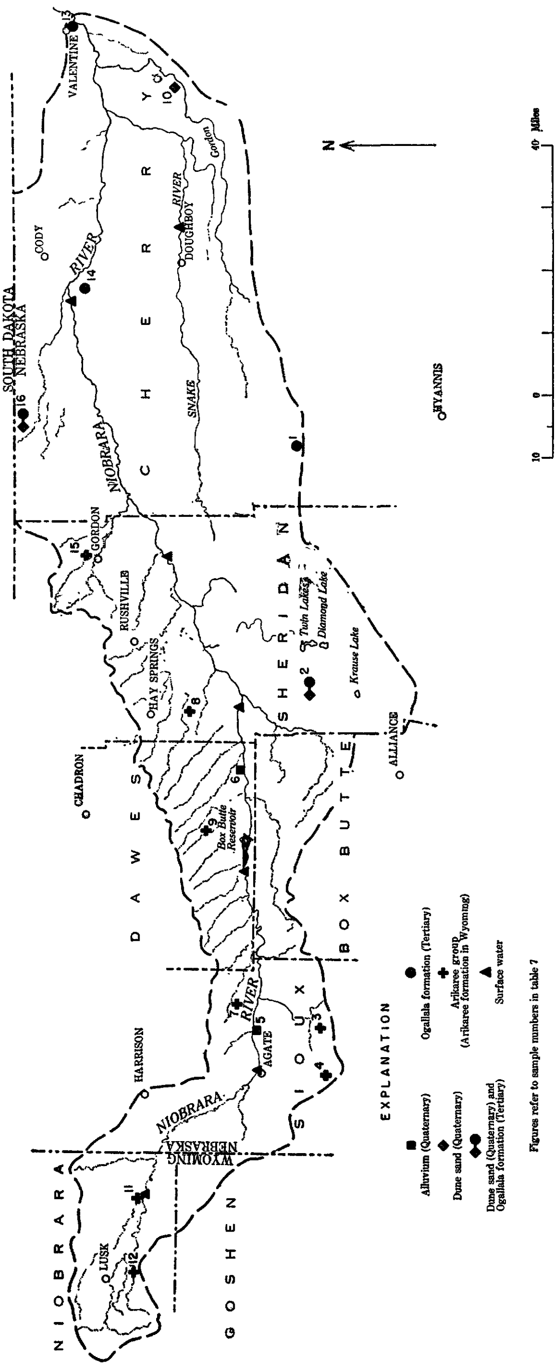

FIGURE 7.—Location and geologic source of water samples collected during this investigation in the upper Niobrara River basin.

Table 7.—*Chemical analyses of ground water in the upper Niobrara River basin*

[Analytical results in parts per million except as indicated]

Sample no.[1]	Well no.	Depth of well (feet)	Date	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
1	27-39-3cd	280	*1952* Oct. 10	51	0.01	28	4.1	8.6	7.9	124	0	8.0	2.5	0.2	3.2	0.04	180	87	0	16	218	8.1
2	27-45-17cb	80	23	54	.14	39	5.7	4.0	9.4	156	0	1.0	2.0	.4	9.7	.01	214	121	0	6	273	7.9
3	27-54-29dc	165	7	46	------	46	7.8	7.2	3.5	165	0	4.0	6.5	1.3	12	.03	238	147	12	9	311	7.9
4	27-56-36dd	------	7	50	.34	54	9.4	7.2	4.6	206	0	8.0	5.0	.3	10	.02	256	173	4	8	355	7.8
5	28-54-6bc2	45	8	50	.37	45	7.4	20	6.8	192	0	19	5.5	.7	18	.04	268	143	0	22	352	8.0
6	29-47-20dd	34	8	46	1.1	76	8.9	19	15	234	0	32	16	.4	50	.06	386	226	34	14	528	8.0
7	29-53-19ba	207	8	55	.17	39	7.2	7.8	4.4	161	0	5.0	5.5	.3	3.6	.02	216	127	0	11	273	8.1
8	30-46-11db	285	*1953* Jan. 11	58	------	44	9.7	24	10	220	0	19	3.5	.3	6.3	.07	302	150	0	24	405	8.0
9	30-49-22bb	200	*1952* Oct. 8	62	------	40	10	10	4.7	183	6	5.0	2.0	1.0	1.4	.08	236	143	0	13	299	8.3
10	31-29-33dd	40	9	63	.24	40	5.4	7.2	5.6	152	0	5.0	11	.1	.6	.02	226	122	0	11	269	7.9
11	31-61-4ab	200	7	54	.01	50	13	10	7.6	214	0	16	5.0	.2	10	.01	276	178	3	10	370	8.1
12	32-63-33bb	206	7	50	.29	73	16	15	6.9	275	0	30	12	.1	12	.06	370	248	22	11	516	8.1
13	33-27-6aa	160	9	47	.02	46	2.2	3.4	3.7	117	0	17	4.0	.2	27	.01	216	124	28	6	257	8.0
14	33-34-17db	212	9	56	.31	24	2.9	4.5	4.9	87	0	4.0	2.0	.2	5.8	.00	152	68	0	12	163	7.6
15	33-41-19ab	280	8	54	.05	51	9.5	15	7.8	214	0	28	3.5	.1	2.9	.04	276	166	0	16	369	8.1
16	35-38-26bb	140	9	52	1.6	12	3.2	5.4	8.3	70	0	3.0	1.0	.2	1.2	.03	138	43	0	18	116	7.5

[1] Numbers refer to sampling sites, fig. 7.

RELATION OF GROUND-WATER QUALITY TO GEOLOGIC SOURCE

The geologic sources of ground water in this area are the Arikaree and Ogallala of Tertiary age and the unconsolidated deposits of Quaternary age. The ground water sampled is, without exception, of the calcium bicarbonate type and is characterized by a high silica content. However, quality patterns are discernible from the ionic concentrations and ratios of the different constituents. Some of the chemical relations of the ground water from different geologic sources are given in table 8. Water from the Arikaree group generally is a little more concentrated and has higher sodium-potassium and lower calcium-magnesium ratios than water from the Ogallala formation. The percentage of chloride in the water from the Arikaree is not so uniform as that from the Ogallala. A wider range in the chemical relationship characterizes water from the Quaternary deposits, as would be anticipated from their greater variety of lithologic types, and from their topographic position which leads in some places to periodic freshening by recharge and in others to concentration by evapotranspiration.

TABLE 8.—*Chemical relationship of ground water from different geologic sources*

[Ratios and concentrations computed from equivalents per million]

Qa Quaternary alluvium
Qds Quaternary dune sand
To Ogallala formation
Ta Arikaree group (Arikaree formation in Niobrara County, Wyo.)

Location	County	Geologic source	Ratio of equivalents per million			Total concentration (cations +anions)
			$\frac{\text{Chloride}}{\text{anions}} \times 10^2$	$\frac{\text{Sodium}}{\text{potassium}}$	$\frac{\text{Calcium}}{\text{magnesium}}$	
28-54- 6bc	Sioux	Qa	4.0	5.1	3.7	7.94
29-47-20dd	Dawes	Qa	7.8	2.2	5.2	11.51
31-29-33dd	Cherry	Qds	10.7	2.2	4.5	5.81
27-45-17cb	Sheridan	To+Qds(?)	2.1	.7	4.1	5.65
35-38-26bb	Cherry	To+Qds	2.4	1.1	2.3	2.57
27-39- 3cd	do	To	3.0	1.9	4.1	4.64
33-27- 6aa	do	To	3.9	1.7	12.8	5.55
33-34-17db	do	To	3.6	1.5	4.7	3.36
33-41-19ab	Sheridan	Ta	2.4	3.3	3.3	8.42
27-54-29dc	Sioux	Ta	5.5	3.4	3.6	6.56
27-56-36dd	do	Ta	4.3	2.6	3.5	7.76
29-53-19ba	do	Ta	5.4	3.1	3.3	5.97
30-46-11db	Sheridan	Ta	2.4	4.0	2.6	8.53
30-49-22bb	Dawes	Ta	1.7	3.6	2.3	6.84
31-61- 4ab	Niobrara	Ta	3.4	2.3	2.4	8.33
32-63-33bb	do	Ta	6.0	3.6	2.8	11.46

The interrelation of ground water and streamflow in the Niobrara River basin affords a reliable means of ascertaining the quality of water in the alluvium and terrace deposits from a long-term study of stream quality. The Niobrara and Snake Rivers are relatively even flowing streams in a region of erratic precipitation. The minimum discharge of the Niobrara River near Cody, Nebr., for the 1949 water year was 187 cubic feet per second (cfs) and the mean discharge was 348 cfs. The constancy of flow is due mainly to the large proportion of ground-water discharge. During periods of high flow, streams carry a combination of direct surface runoff and ground water; however, during periods of low flow, they drain off surplus ground water only. Consequently, the chemical type and total mineral content of stream water in periods of low flow closely resemble those of the adjacent ground water. Table 9 gives the maximum concentrations of the more important constituents in the surface-water samples collected during 1947–51. These records show that the ground water contributed to the stream during the period of sampling did not contain excessive concentrations of dissolved minerals.

TABLE 9.—*Maximum concentration of chemical constituents of surface water in the upper Niobrara River basin*

[Analytical results in parts per million except percent sodium]

Location	Period of record	Number of samples	Dissolved solids	Hardness	Bicarbonate	Percent sodium
Niobrara River near Hay Springs	1949–51	8	320	178	254	42
Niobrara River near Gordon	1947–49	12	250	127	190	32
Antelope Creek near Gordon	1947–48	3	381	217	291	35
Niobrara River near Cody	1948–49	9	215	112	154	35
Snake River near Burge	1947–51	12	192	97	107	47
Gordon Creek near Simeon	1947–48	2	214	108	165	32
Minnechaduza Creek at Valentine	1947–49	7	250	174	204	24
Niobrara River near Sparks	1947–51	15	215	108	156	31

The field investigation included a salinity survey of surface water in the Niobrara River basin during a period when the flow was principally ground water. The results of this survey are shown in figure 8. The diameters of the circles are proportional to the total concentration, and the percentage by weight of the total concentration that consists of silica is shown as a solid segment. The U. S. Geological Survey considers that silica exists almost exclusively in nonionized form and does not appreciably affect the ionic balance between the acids and bases at the pH values of these samples (8.1 to 8.6). The remaining constituents of the dissolved solids are indicated in terms of their reacting-value percentages, which are calculated by dividing each ionized constituent in equivalents per million by the total ionic concentration in equivalents per million. Figure 8 shows that the decrease in total concentration in the downstream direction is accompanied by a decrease in percentage by weight of the ionized constituents and by an increase in the proportion of silica; the relative percentages of the strong and weak acid and base components remain nearly constant. These facts indicate that during the sampling period the ground water and the tributary surface flow received by the

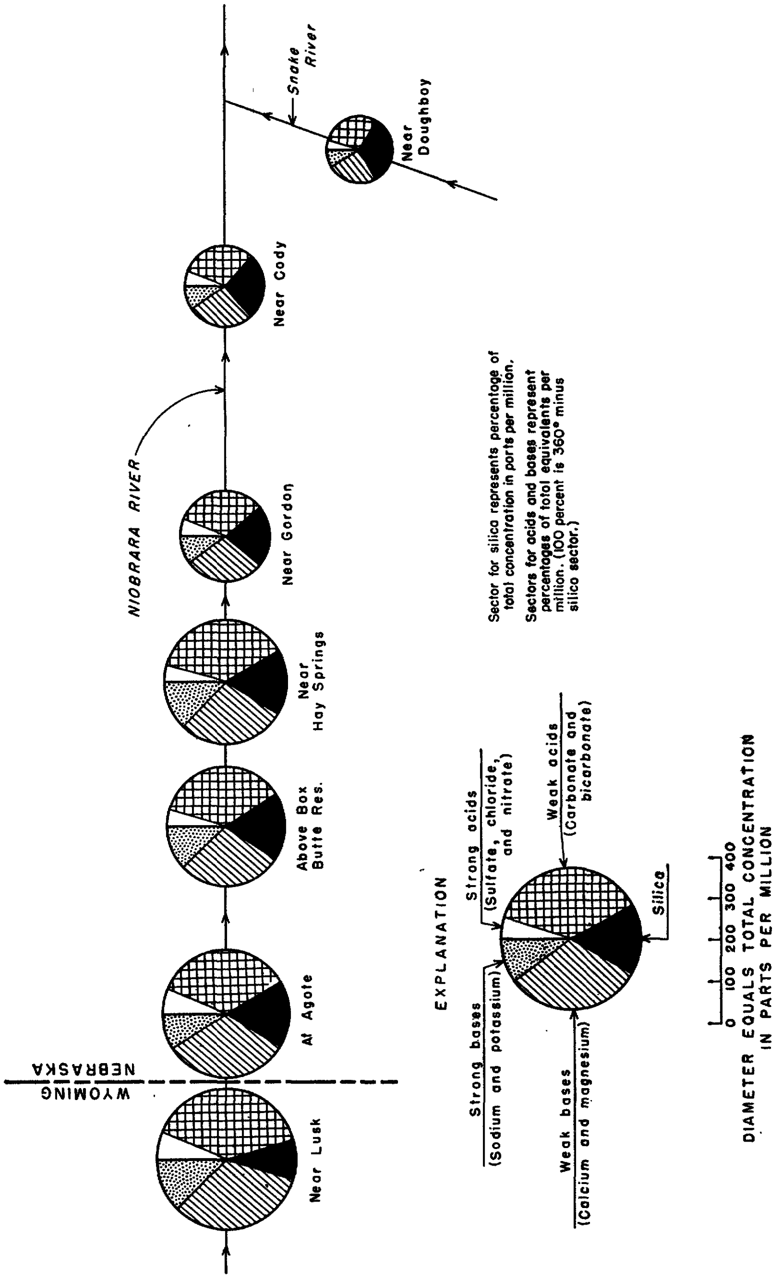

FIGURE 8.—Chemical quality of surface water, upper Niobrara River basin, October 7–9, 1952.

Niobrara River in its upper reaches were more mineralized than those received in its lower reaches.

SUITABILITY OF GROUND WATER FOR IRRIGATION

The interrelations and concentrations of calcium, magnesium, and sodium in water are significant in determining the suitability of the water for irrigation; the reaction of these constituents with the soil affects the soil structure. Poor structure results if the ratio of sodium to calcium and magnesium becomes too large. Wilcox [5] has summarized the results of extensive field investigations by defining the suitability of water for irrigation on the basis of total salinity expressed in equivalents per million (epm) and the chemical ratio of sodium to the sum of the positively charged ions in solution. All the wells sampled yielded water of excellent to good quality for irrigation according to Wilcox's classification. The maximum "residual sodium carbonate" was 0.61 epm, and the total concentration of cations and anions for the same sample was 8.53 epm. Residual carbonate is carbonate in excess of calcium and magnesium, all expressed in equivalents per million. The maximum concentration of boron was 0.08 ppm, which is well below the limit for even the most sensitive crops.

CLOSED-BASINS AREA

During World War I, large quantities of potash were produced from the lake water in the closed-basins area of southern Sheridan County. Because of the high mineral content of the lake water, cattle are watered from wells. Wildfowl shun the more alkaline lakes, many of which are rimmed with heavy deposits of salts. As high concentrations of sodium and potassium carbonates are especially undesirable in irrigation water, the surface expression of these salts in the lakes emphasizes the need for appraising ground-water quality.

Much was written about the closed-basins area during its period of economic importance, and many views and interpretations of the origin of the alkali salts were advanced. Probably the most authoritative was presented by Condra (1918), who wrote as follows:

> Sand Hill lakes are fed principally by underflow. * * * Many of the lakes are ground water exposed in depressions or low places in valleys. * * * The conditions which determine the accumulation of potash in sand hill lakes are about as follows: Comparatively fresh water enters the lakes from the highest point on the surrounding ground water, which usually is to the west. * * * The water entering

[5] Wilcox, L. V., 1948, The quality of water for irrigation use: U. S. Dept. Agriculture Tech. Bull. 962, 40 p.

some lakes, passes out at once. In others it is held back by a sand dam, or by the natural form of the basin. In case the water is retained, the principal loss is through solar evaporation which becomes very heavy in the summer time. * * * The alkali solutions are concentrated by evaporation. * * * Lakes supplied by considerable water, and subject to evaporation for a long period become heavily mineralized. * * * An examination of the materials on the beds of several alkali lakes shows them to be principally fine sand, indurated or cemented by magnesia and alkali compounds. * * * The conclusion is that lakes, after becoming somewhat mineralized, began to precipitate certain compounds. Some of the materials were thrown down before the brine became very strong. Salts of magnesium, calcium and alumina were dropped in a flocculent, colloidal form, making the muck and magnesia layers.

The complex contour of the water table and the location of some of the larger lakes in the closed-basins area are shown in figure 9. As the depth to water in wells adjacent to the lakes is only 5 to 15 feet, it is believed that the lake surfaces are an extension of the water table.

Two or three hardpan layers, separated by a layer of sand, are under most of the lakes, although no hardpan layer extends throughout the closed-basins area. The sand layers are high in alkali content. Condra (1918) concluded that the deeper hardpan layers formed as floors or beds of ancient lakes and that the alkali sands are the result of basin filling. He further concluded that the alkali concentrates probably originated from the weathering of feldspathic and other potash-bearing rocks.

Field investigations in the fall of 1952 included the collection of samples from lakes and adjacent wells at five selected locations in southern Sheridan County (fig. 9). Analyses of the water in these samples are given in table 10 and show that the well water is dilute, is of the calcium bicarbonate type, and has a high silica content. The results show also that the lake water is characterized by more concentrated solutions of sodium and potassium carbonates and bicarbonates than is the well water.

Trilinear diagrams, in which the center diamond represents the chemical classification of the water,[6] are useful in defining the chemical relationship and the changes that take place in water. The grouping and arrangement of the chemical constituents in figure 10 were selected to depict the quality characteristics and reaction patterns that occur in this area. Sodium, potassium, and calcium plus magnesium are used as the bases of the right-hand triangle; and carbonate plus bicarbonate, sulfate plus chloride plus nitrate, and silicate constitute the bases of the left-hand triangle.

[6] Palmer, Chase, 1911, The geochemical interpretation of water analyses: U. S. Geol. Survey Bull. 479, 31 p.

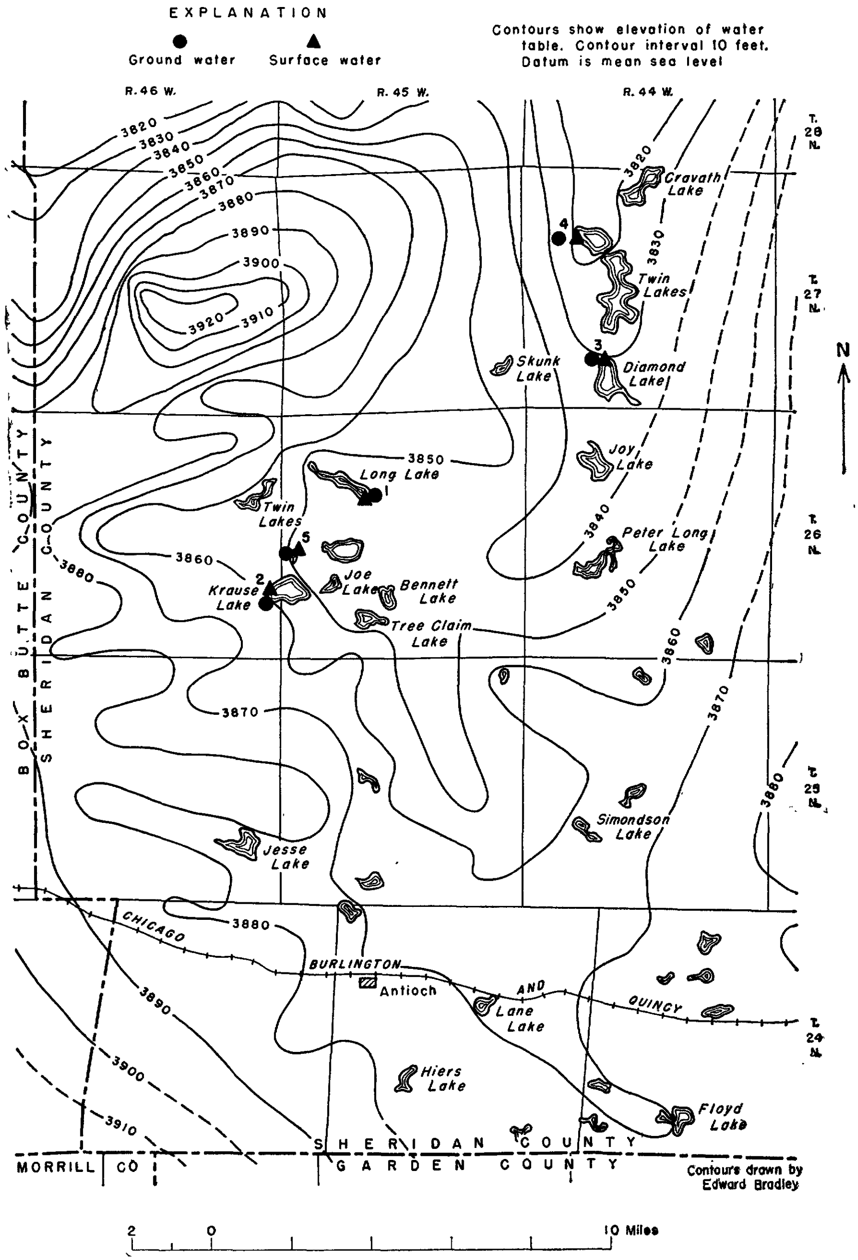

FIGURE 9.—Contour of the water table and sampling points in southwestern Sheridan County, Nebr.

TABLE 10.—*Chemical analyses of water in the closed-basins area in southwestern Sheridan County, Nebr.*

[Analytical results in parts per million except as indicated]

Location no.[1]	Source	Date	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	pH
		1952																			
1	Long Lake	Oct. 10	37	------	------	----	1,100	1,140	1,890	530	965	------	----	------	------	5,490	540	0	------	7,300	9.4
1	Well 26-45-9cb	10	48	------	------	----	5.3	11	146	0	10	------	----	------	------	240	113	0	------	272	7.8
2	Krause Lake	10	12	------	------	----	255	305	900	248	110	------	----	------	------	1,650	396	0	------	2,250	9.3
2	Well 26-46-25db	10	48	------	------	----	28	40	270	0	90	------	----	------	------	846	428	207	------	1,080	7.6
3	Diamond Lake	23	31	------	------	----	444	544	1,200	242	395	------	----	------	------	2,500	250	0	51	3,360	9.2
3	Well 27-44-29db	23	57	0.15	33	4.3	20	21	160	0	27	8.0	0.8	0.3	0.10	254	100	0	26	335	8.1
4	Twin Lakes	23	31	------	------	----	1,730	1,930	2,180	1,190	2,020	------	----	------	------	8,480	73	0	60	11,000	9.7
4	Well 27-44-7dd2	23	47	.23	58	3.8	7.2	9.5	127	0	17	13	.2	62	.03	310	160	56	8	386	7.6
5	An unnamed lake	10	170	------	------	----	89,000	96,600	55,000	137,000	24,700	------	----	------	------	448,000	------	------	------	140,000	10.0
5	Well 26-45-19bc	10	56	------	------	----	29	20	201	0	21	------	----	------	------	280	108	0	------	374	8.0

[1] Numbers refer to sampling sites, fig. 9.

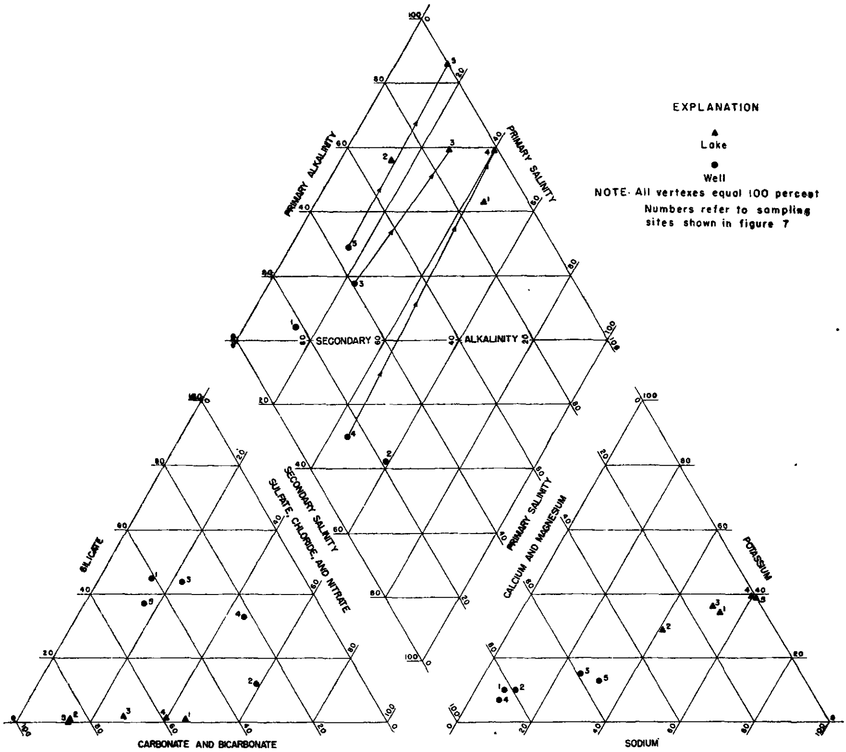

FIGURE 10.—Chemical relationship of water from wells and lakes, southwestern Sheridan County, Nebr.

As the pH approaches 7, the ability of silica (or silicic acid) to form the silicate ion and to take part in chemical reactions, such as precipitation, is considered negligible. However, the quantity of silica in the lakes is much less than would be expected if all silica remained in solution and, at 4 of the 5 sampling sites (table 10), is even less than that in the adjacent ground water. This apparent loss cannot be attributed to insolubility, because the solubility of silica increases as the pH increases and the pH of each lake is higher than that of water in the adjacent well. The decrease of the silica content has been observed in the water of some reservoirs and has been attributed to one-celled plants called diatoms. Diatoms may account for some of the apparent loss of silica in the lakes in the closed-basins area. However, when the salts in these lakes are concentrated by evaporation, the loss of calcium and magnesium is greater than that of carbonate and sulfate. The relationship suggests that calcium and magnesium are removed from solution by reaction with silica. The tendency of hydrated silica to ionize and form hydrogen and silicate ions at a high pH is well known. The writer attributes the major loss of silica in lake water to the ionization of silica to silicate as the pH increased during evaporation and to the subsequent precipitation of insoluble calcium, magnesium, or aluminum silicate. Therefore, in figure 10, silica is considered to be a "potentially ionizable" constituent and, as such, is treated as an anion. Because the hydrogen ions produced in the ionization process neutralize an equivalent part of the bicarbonate, the alkalinity, in equivalents per million, for each analysis was reduced by the amount of silica present (calculated as silicate) to give the carbonate-plus-bicarbonate content.

The straight-line relationship of sodium, potassium, and calcium plus magnesium between the ground and lake waters of varying concentrations shows that, by means of evaporation of ground water and the subsequent precipitation of calcium and magnesium, continuous chemical reactions would result in a water that is low in calcium and magnesium and whose ratio of sodium to potassium would not have changed during the process. Such a reaction is probable even though the calcium-plus-magnesium content of the original water may be several times the sodium and potassium content.

The plots of percentage composition in the left-hand triangle of figure 10 do not result in a straight line, because carbonate, silicate, and sulfate are all capable, to some degree, of forming precipitates with calcium or magnesium.

The difference in chemical character of the well and lake water is shown in the center diagram. Approximately parallel lines between wells 3, 4, and 5 and lakes 3, 4, and 5 suggest similar modes of transition in quality. The lakes show a much higher percentage of primary alkalinity, a lower percentage of secondary alkalinity, and little change in total salinity. Apparently the chemical relationship for locations 3, 4, and 5 does not hold for locations 1 and 2. From this reconnaissance study, it is difficult to determine if the discrepancy represents different types of chemical reactions in the lakes or is due primarily to drainage conditions in the area. Well 2, near Krause Lake, contained about three times as much dissolved solids as did the water in each of the other sampled wells.

This investigation and the work of others show that the water-quality relationship is complex in this area of ephemeral drainage. Alkali sands of ancient lake beds are also a potentially complicating factor in predicting local ground-water quality. The definition of quality characteristics will require additional field and laboratory examination.

CONCLUSIONS

Hydrologic data are sufficient to provide a general picture of the availability of ground water in the upper Niobrara River basin, but more detailed studies should be made in local areas where ground-water problems, such as a rise of the water table necessitating drainage, are probable or where additional ground-water development appears feasible.

Many irrigation wells have been constructed in recent years in Sheridan County between the Niobrara River and the northern boundary of the Niobrara River drainage basin. A more detailed investigation of the ground-water resources and geology of that part of Sheridan County will be required to determine the maximum amount of ground water that can be withdrawn without exceeding the average annual replenishment to the ground-water reservoir. Quantitative data concerning the artificial recharge from irrigation water should be obtained in the Mirage Flats project, and studies should be made to determine whether ground water could be pumped for supplemental irrigation. Because of increased recharge from irrigation water, the area lying northeast of the Mirage Flats project may be favorable for additional ground-water development.

In the upper Niobrara River basin, ground water from the Arikaree group, the Ogallala formation, and the deposits of Quaternary age is similar in concentration and chemical type. Calcium, bicarbonate, and silica are the major constituents in solution. Because the few ground-water samples collected for this investigation are from widely scattered wells and from different geologic sources, it was impossible to correlate the chemical quality with geologic source or hydrologic conditions in the area. However, the analyses of Niobrara River water collected when ground-water inflow comprised the major part of the flow indicate that the ground water contributed in the western part of the area, which is underlain principally by the Arikaree, is more concentrated than that contributed in the eastern part, which is underlain principally by the Ogallala formation.

The hardness of some of the samples approaches or exceeds 200 ppm, but otherwise the water is well suited for domestic use. Because of its low total salt content, low percent sodium, and low boron concentration, the water is of excellent quality for irrigation.

Drainage characteristics in southern Sheridan County and surrounding areas have resulted in the formation of lakes that have high concentrations of sodium and potassium carbonates. The quality of the water from some wells near these lakes in the closed-basins area is comparable to that from wells in the Niobrara River basin, but the water yielded by other wells near the lakes is more highly mineralized. The possibility of obtaining water of inferior quality in some local areas and the presence of alkali sands in ancient lake beds emphasize the advisability of making a more detailed study and an accurate appraisal of the hydrology and water quality of the area before planning future development.

TABLE 11.—*Water-level measurements in wells, in feet below land-surface datum*

Date	Water level	Date	Water level	Date	Water level
BOX BUTTE COUNTY, NEBR.					
26-47-17dd					
Apr. 22, 1946	53.26	Feb. 17, 1947	53.26	Jan. 25, 1950	52.69
May 16	53.21	Mar. 14	53.37	Apr. 5	52.74
24	53.27	May 1	53.46	Aug. 15	62.72
June 3	53.35	27	53.42	Oct. 17	56.72
10	53.30	Aug. 27	53.13	Dec. 18	54.36
17	53.36	Oct. 26	52.89	Feb. 20, 1951	53.64
July 1	53.39	Mar. 26, 1948	52.91	Apr. 18	53.29
22	53.30	July 1	52.21	Sept. 5	61.64
Aug. 5	53.36	Sept. 1	62.29	July 1, 1952	55.98
Sept. 13	53.26	Oct. 27	57.07	Jan. 8, 1953	54.84
Oct. 11	53.18	May 11, 1949	52.32	June 16	56.18
Nov. 7	53.16	July 13	55.12	Sept. 26	65.85
Dec. 17	53.25	Sept. 13	57.84		
Jan. 16, 1947	53.26	Nov. 23, 1949	53.55		
27-47-12da					
Aug. 27, 1934	11.83	Mar. 27, 1936	11.38	Sept. 13, 1949	7.18
Nov. 11	12.09	June 2	10.64	Nov. 23	7.30
Apr. 19, 1935	12.22	July 21	11.33	Jan. 25, 1950	7.48
July 14	10.71	Aug. 28	11.70	Oct. 17	8.91
Sept. 14	10.35	Apr. 2, 1937	12.04	Sept. 5, 1951	8.31
Oct. 22	10.34	June 5, 1946	7.71	July 1, 1952	8.83
Nov. 25	10.21	Oct. 21, 1948	8.98	Jan. 8, 1953	9.69
Dec. 28	10.15	May 11, 1949	7.02	June 16	9.38
Jan. 17, 1936	10.25	July 12	6.92	Sept. 26	9.37
27-47-17db					
Apr. 12, 1946	74.93	Jan. 14, 1953	76.62		
27-47-25dc					
July 29, 1938	29.97	Apr. 12, 1946	27.69	Jan. 8, 1953	29.01
27-49-21cb					
Aug. 14, 1935	118 52	Aug. 24, 1938	119.03	Mar. 13, 1947	118.28
Sept. 14	118.73	Sept. 3	119.03	May 1	118.48
Oct. 22	119.10	21	119.05	27	118.27
Nov. 25	118.96	Oct. 3	118.85	Aug. 26	118.34
Dec. 28	118.58	25	118.98	Oct. 26	118.20
Jan. 17, 1936	118.69	June 7, 1939	118.86	Mar. 27, 1948	118.32
Mar. 27	118.46	Dec. 1	118.79	July 1	118.10
June 2	118.71	Mar. 30, 1940	118.56	Sept. 1	118.29
July 21	118.93	Oct. 20, 1941	119.41	Oct. 21	118.45
Aug. 28	118.99	Nov. 14, 1942	118.41	May 10, 1949	117.99
Nov. 23	119.02	Aug. 16, 1944	118.33	July 11	117 04
Apr. 2, 1937	118.41	Aug. 17, 1945	118.38	Sept. 13	115.45
June 16	118.68	Feb. 27, 1946	118.00	Nov. 22	117.91
Aug. 9	118.75	Mar. 29	118.10	Jan. 25, 1950	117.12
Oct. 14	118.82	June 12	118.50	Aug. 15	117.84
June 23, 1938	118.81	July 11	118.53	Oct. 17	117.49
July 2	118.83	Sept. 13	118.28	Dec. 18	117.46
11	118.89	Oct. 10	118.27	Feb. 19, 1951	117.17
15	118.95	Nov. 12	118.54	Apr. 17	117.13
21	119.06	Dec. 17	118.52	Sept. 6	117.06
Aug. 1	118.80	Jan. 17, 1947	118.45	July 1, 1952	117.11
10	119.17	Feb. 18	118.41	Feb. 5, 1953	116.89
27-49-26cd					
Mar. 29, 1946	115.94	Apr. 2, 1953	124.52		

TABLE 11.—*Water-level measurements in wells, in feet below land-surface datum*—Continued

BOX BUTTE COUNTY, NEBR.—Continued

28-51-6dd

Date	Water level	Date	Water level	Date	Water level
Nov. 25, 1935	2.18	Sept. 21, 1938	3.30	Jan. 17, 1947	2.42
Dec. 28	1.90	Oct. 3	3.46	Feb. 18	1.89
Jan. 17, 1936	1.72	23	3.25	Mar. 13	1.93
Mar. 27	1.67	Dec. 1, 1939	2.81	May 2	2.51
June 2	2.16	Mar. 30, 1940	2.45	June 5	3.17
July 21	3.85	July 20	4.08	Aug. 26	2.99
Sept. 11	3.83	Nov. 1	3.14	Oct. 26	2.32
Nov. 23	2.37	Oct. 20, 1941	2.87	Sept. 1, 1948	3.43
June 16, 1937	2.66	Aug. 22, 1942	3.11	Oct. 21	3.00
Aug. 9	4.00	Nov. 14	2.42	May 10, 1949	1.94
Oct. 14	2.84	Aug. 16, 1944	2.72	July 12	2.74
June 23, 1938	3.65	Aug. 2, 1945	3.15	Sept. 14	2.92
July 2	3.75	Feb. 27, 1946	1.97	Nov. 22	2.41
11	3.73	Apr. 1	2.20	Jan. 24, 1950	1.62
15	3.70	May 15	2.65	Apr. 4	1.70
21	3.43	July 11	3.53	Aug. 15	3.29
Aug. 1	3.70	Sept. 13	2.79	Oct. 17	2.84
10	3.91	Oct. 10	2.42	Dec. 19	2.06
24	3.82	Nov. 13	2.36	Feb. 20, 1951	1.77
Sept. 3	3.20	Dec. 20	2.31	Apr. 18	2.20

28-51-8bc

Date	Water level	Date	Water level	Date	Water level
June 18, 1938	85.57	Aug. 16, 1944	85.20	Sept. 1, 1948	85.41
July 2	85.70	Aug. 17, 1945	85.30	Oct. 21	85.41
11	85.76	Feb. 27, 1946	85.60	May 10, 1949	84.47
21	85.79	Apr. 1	85.03	July 12	84.84
Aug. 1	85.87	May 15	85.14	Sept. 19	85.09
10	85.98	June 12	85.39	Nov. 22	84.80
24	86.04	July 11	85.36	Jan. 24, 1950	84.71
Sept. 3	86.06	Aug. 14	85.63	Apr. 3	84.60
21	86.00	Sept. 13	85.55	Aug. 15	84.10
Oct. 3	86.00	Oct. 10	85.47	Oct. 17	85.05
June 7, 1939	85.80	Nov. 13	85.28	Dec. 18	85.35
Mar. 30, 1940	86.40	Dec. 20	85.17	Sept. 5, 1951	86.06
July 20	85.72	Jan. 17, 1947	85.11	July 1, 1952	84.83
Nov. 1	85.97	Feb. 18	85.04	Feb. 5, 1953	84.73
Oct. 20, 1941	86.04	Mar. 27, 1948	85.38	June 16	84.98
Nov. 14, 1942	85.38	July 1	85.00	Sept. 27	85.45

CHERRY COUNTY, NEBR.

31-29-33ad

Date	Water level	Date	Water level	Date	Water level
Feb. 7, 1951	1.53	July 19, 1951	2.01	Oct. 7, 1952	3.22
June 12	.70	June 26, 1952	2.27	Jan. 5, 1953	2.26

31-30-29ac

Date	Water level	Date	Water level	Date	Water level
Oct. 10, 1950	96.43	Feb. 8, 1951	95.24	May 7, 1952	94.94
Jan. 2, 1951	95.24				

TABLE 11.—*Water-level measurements in wells, in feet below land-surface datum*—Continued

CHERRY COUNTY, NEBR.—Continued

33-27-17cb

[8ab *in* WSP 840, 845, 886, 908, 938, 946, 988, 1018, and 1025]

Date	Water level	Date	Water level	Date	Water level
Jan. 16, 1936	2.23	Nov. 29, 1939	2.31	Oct. 19, 1948	2.32
Mar. 25	2.20	Mar. 29, 1940	1.88	June 5, 1950	2.43
June 1	2.77	July 19	2.53	Jan. 16, 1951	1.61
Sept. 12	3.21	Oct. 31	2.41	May 2	2.21
Nov. 20	2.45	Oct. 18, 1941	2.23	June 12	2.21
Mar. 31, 1937	2.20	May 15, 1943	2.18	July 26	2.69
June 15	2.55	Aug. 1, 1944	2.58	Sept. 12	1.78
Aug. 9	3.38	Aug. 2, 1945	2.14	Dec. 29	1.52
Oct. 13	2.67	Aug. 7, 1946	2.87	Apr. 2, 1952	1.76
July 14, 1938	2.76	Apr. 30, 1947	2.07	June 25	2.32
Oct. 22	2.47	June 6	2.33	Oct. 6	2.40
June 6, 1939	2.37	Oct. 10	2.49		

34-27-31da

Date	Water level	Date	Water level	Date	Water level
Aug. 25, 1934	98.02	Mar. 26, 1936	98.43	Nov. 29, 1939	99.65
Nov. 9	98.12	June 1	98.42	Mar. 29, 1940	99.81
Jan. 2, 1935	98.10	July 18	98.49	July 19	99.80
Feb. 23	98.07	Sept. 12	98.54	Oct. 31	100.05
Apr. 18	98.17	Nov. 20	98.60	Oct. 19, 1941	100.39
June 5	98.19	Mar. 31, 1937	98.70	Aug. 1, 1944	98.69
July 13	98.10	June 15	98.73	May 17, 1945	98.26
Aug. 13	98.27	Aug. 9	98.81	Aug. 2	98.20
Sept. 13	98.13	Oct. 13	98.89	Aug. 7, 1946	98.03
Oct. 21	98.30	July 14, 1938	99.15	Apr. 30, 1947	97.95
Nov. 23	98.35	Oct. 22	99.29	June 6	97.94
Dec. 27	98.32	June 6, 1939	99.42	Oct. 7	97.92
Jan. 16, 1936	98.40				

34-36-12aa (was 1dc)

Date	Water level	Date	Water level	Date	Water level
Dec. 12, 1934	6.68	Mar. 31, 1937	7.11	Aug. 2, 1945	7.01
Jan. 3, 1935	6.67	June 15	6.55	Jan. 22, 1947	7.37
Feb. 24	6.40	Aug. 9	7.70	Feb. 21	7.34
Apr. 18	5.45	Oct. 14	7.88	Mar. 15	7.40
June 6	4.46	July 14, 1938	7.26	Apr. 30	7.20
July 13	5.65	Oct. 22	7.96	June 6	7.09
Aug. 13	6.33	June 6, 1939	8.01	Oct. 7	7.49
Sept. 13	6.69	Nov. 29	8.53	Apr. 21, 1951	7.75
Oct. 21	6.73	Mar. 29, 1940	8.67	July 30	7.24
Nov. 23	6.69	July 19	8.69	Oct. 3	7.75
Dec. 27	6.71	Oct. 31	9.20	Jan. 29, 1952	7.82
Jan. 16, 1936	6.72	Oct. 19, 1941	9.44	Apr. 2	6.68
Mar. 26	6.32	Aug. 23, 1942	6.96	June 24	6.95
June 1	6.47	Mar. 11, 1943	7.82	Oct. 6	7.83
July 18	6.95	May 15	7.94	29	7.83
Sept. 12	7.37	Aug. 1, 1944	6.26	Jan. 14, 1953	7.90
Nov. 20	7.12				

34-38-14bc

[14db *in* WSP 886]

Date	Water level	Date	Water level	Date	Water level
Nov. 20, 1936	7.39	July 19, 1940	8.01	June 6, 1947	6.45
Mar. 31, 1937	6.73	Oct. 31	8.04	Oct. 7	7.45
June 15	6.60	Oct. 19, 1941	8.09	Apr. 21, 1951	6.67
Aug. 9	8.14	Aug. 1, 1944	6.19	July 30	5.36
Oct. 14	7.90	Aug. 2, 1945	6.93	Oct. 3	6.46
July 14, 1938	6.69	Aug. 7, 1946	7.36	Jan. 29, 1952	6.10
Oct. 22	7.21	Jan. 22, 1947	6.64	Apr. 2	5.20
June 6, 1939	6.53	Feb. 21	6.49	June 25	6.25
Nov. 29	7.82	Mar. 15	6.53	Oct. 6	7.43
Mar. 29, 1940	7.28	Apr. 30	6.52	Jan. 14, 1953	6.58

TABLE 11.—*Water-level measurements in wells, in feet below land-surface datum*—Continued

DAWES COUNTY, NEBR.

29-47-2dc

Date	Water level	Date	Water level	Date	Water level
Oct. 4, 1950	80.61	Oct. 3, 1951	80.24	Nov. 12, 1952	79.82
Dec. 28	80.28	Jan. 29, 1952	79.77	Oct. 30, 1953	81.23
May 12, 1951	80.22	Apr. 2	79.65		

SHERIDAN COUNTY, NEBR.

28-46-32adl

Date	Water level	Date	Water level	Date	Water level
Apr. 23, 1946	24.83	Dec. 19, 1946	24.85	June 9, 1947	24.60
Aug. 16	25.33	Jan. 22, 1947	24.89	Jan. 7, 1953	24.88
Nov. 14	24.84	Feb. 21	24.81		

29-45-8bb

Date	Water level	Date	Water level	Date	Water level
May 3, 1950	43.53	July 30, 1951	41.28	Apr. 2, 1952	39.78
Oct. 4	42.33	Oct. 3	40.40	June 25	39.85
May 12, 1951	41.29	Jan. 29, 1952	39.84	Oct. 6	39.36

29-46-4bd

Date	Water level	Date	Water level	Date	Water level
May 2, 1950	63.25	July 30, 1951	62.01	June 25, 1952	60.80
July 19	63.25	Oct. 3	61.03	Oct. 6	59.78
May 12, 1951	62.46	Apr. 2, 1952	60.59		

29-46-4dc

Date	Water level	Date	Water level	Date	Water level
Mar. 20, 1946	[a] 69.00	Dec. 28, 1950	59.70	July 30, 1951	59.64
May 2, 1950	61.34	Apr. 20, 1951	60.28	Oct. 3	58.23
July 19	60.93	May 12	60.28	Jan. 7, 1953	56.55
Oct. 4	59.20				

29-46-11dc

Date	Water level	Date	Water level	Date	Water level
Mar. 7, 1946	[a] 58.00	Apr. 20, 1951	40.57	Apr. 2, 1952	39.54
May 3, 1950	42.50	May 12	40.79	June 25	39.84
July 19	42.12	July 30	40.66	Oct. 6	38.51
Oct. 4	40.29	Oct. 3	39.75	Jan. 7, 1953	38.20
Dec. 28	40.39	Jan. 29, 1952	39.25	Oct. 30	37.71

29-46-24ad

Date	Water level	Date	Water level	Date	Water level
Mar. 7, 1946	[a] 65.00	Oct. 4, 1950	63.10	July 30, 1951	64.23
May 2, 1950	64.32	Dec. 28	63.62	Oct. 3	63.59
July 19	64.46	Apr. 20, 1951	64.23	Jan. 7, 1953	62.99
Aug. 29	63.60	May 12	64.38		

[a] Reported depth.

TABLE 11.—*Water-level measurements in wells, in feet below land-surface datum*—Continued

SHERIDAN COUNTY, NEBR.—Continued

31-44-10dd

Date	Water level	Date	Water level	Date	Water level
Nov. 23, 1935	3.75	Oct. 22, 1938	4.19	Feb. 21, 1947	1.48
Dec. 27	3.53	June 6, 1939	3.44	Mar. 15	1.81
Jan. 16, 1936	3.37	Nov. 29	4.10	Apr. 30	1.85
Mar. 26	2.82	Mar. 29, 1940	3.23	June 6	1.84
June 1	3.67	July 20	4.72	Oct. 7	3.05
July 20	3.77	Nov. 1	4.68	Apr. 21, 1951	1.90
Sept. 12	5.24	Oct. 20, 1941	3.67	July 30	2.54
Nov. 21	4.20	Aug. 23, 1942	4.19	Oct. 3	1.87
Apr. 1, 1937	2.68	Aug. 1, 1944	3.16	Jan. 29, 1952	1.60
June 16	3.20	Aug. 2, 1945	3.47	Apr. 1	.46
Aug. 9	4.88	Aug. 7, 1946	4.55	June 25	.24
Oct. 14	4.50	Jan. 22, 1947	2.17	Jan. 14, 1953	1.74
July 14, 1938	4.55				

31-46-8ad

Date	Water level	Date	Water level	Date	Water level
Nov. 22, 1936	5.27	Nov. 1, 1940	6.20	June 6, 1947	3.16
June 16, 1937	3.80	Oct. 20, 1941	5.21	Oct. 7	3.67
Aug. 9	5.52	Aug. 23, 1942	4.04	Apr. 21, 1951	2.78
Oct. 14	5.60	Aug. 1, 1944	3.83	July 30	3.34
July 14, 1938	5.09	Aug. 2, 1945	4.06	Oct. 3	3.10
Oct. 22	5.65	Aug. 7, 1946	4.36	Jan. 29, 1952	2.09
June 6, 1939	3.91	Jan. 22, 1947	2.94	Apr. 2	2.12
Nov. 29	5.17	Feb. 21	2.79	June 25	2.29
Mar. 29, 1940	4.09	Mar. 15	2.84	Oct. 7	3.82
July 20	6.02	Apr. 30	3.12		

SIOUX COUNTY, NEBR.

29-55-33cc

Date	Water level	Date	Water level	Date	Water level
Aug. 28, 1934	174.41	Dec. 28, 1935	174.66	June 7, 1939	175.28
Nov. 10	174.68	Jan. 17, 1936	174.84	Dec. 1	175.16
Jan. 4, 1935	174.58	Mar. 26	174.61	Mar. 30, 1940	175.03
Feb. 25	174.57	June 2	174.95	July 20	175.08
Apr. 19	174.53	July 20	174.66	Nov. 1	174.94
June 7	174.46	Sept. 11	174.80	Oct. 20, 1941	174.89
July 14	174.53	Nov. 22	174.74	Nov. 15, 1942	174.84
Aug. 14	174.54	Apr. 6, 1937	174.77	June 27, 1946	175.74
Sept. 14	174.71	Oct. 14	174.80	Jan. 6, 1947	175.73
Oct. 22	174.85	July 15, 1938	174.90	May 7	175.80
Nov. 25	174.73	Oct. 22	175.07	Apr. 21, 1953	175.19

31-56-10da

Date	Water level	Date	Water level	Date	Water level
Aug. 26, 1934	171.94	Nov. 25, 1935	172.22	Oct. 14, 1937	172.08
Nov. 10	172.20	Dec. 28	171.90	July 15, 1938	172.35
Jan. 4, 1935	172.03	Jan. 17, 1936	172.09	Oct. 22	172.50
Feb. 25	172.03	Mar. 26	171.89	June 1, 1939	[b] 174.32
Apr. 19	171.96	June 2	172.03	Dec. 1	173.17
June 7	171.85	July 20	172.04	Mar. 30, 1940	173.23
July 14	172.07	Sept. 11	171.91	July 20	[b] 174.14
Aug. 14	171.69	Nov. 22	171.83	Nov. 15, 1942	173.69
Sept. 14	172.00	Apr. 1, 1937	171.84	Feb. 4, 1953	172.91
Oct. 22	172.32	June 16	171.94		

[b] Pumped recently.

LOGS OF WELLS AND TEST HOLES

Logs obtained from well drillers, well owners, files and publications of the Nebraska Geological Survey, and publications of the U. S. Geological Survey are given in the following table. The drill cuttings from the wells were not available for examination; consequently, the logs are presented with the drillers' terminology largely unchanged. Additional information on irrigation and public-supply wells is given in table 13.

TABLE 12.—*Drillers' logs of wells and test holes*

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
CHERRY COUNTY, NEBR.					
27-39-3cd					
[Irrigation well of Floyd Yahney. Altitude, about 3,795 feet. Drilled in 1948]					
Soil	4	4	Sand and clay	100	200
Soil, sandy, clayey	36	40	Sand, hard; and clay	50	250
Sandstone; hard, and sand	60	100	Sand, very fine	30	280
33-40-29bcl					
[Test hole near site of irrigation well of William Roberts. Drilled in 1948]					
Soil	7	7	Sand, hard	8.5	70
Soil, sandy	5	12	Rock layers and soft sand	10	80
Sand	8	20	Clay, sandy, white	6	86
Sand, hard	10	30	Sand	4	90
Sand, soft	10	40	Sand, hard; contains some clay	10	100
Sand, soft; contains some hard sand	10	50	Clay, very sticky, white	10	110
			Rock layers with lenses of sand	95	205
Sand	10	60	Sandstone	21	226
Rock, soft	1.5	61.5	Rock, hard	4	230
35-38-26bb					
[Irrigation well of M. O. Metzger. Altitude, about 3,316 feet. Drilled in 1950]					
Soil	2	2	Sand, quartz, fine to medium; high mafic mineral content	50	140
Sand	48	50			
Sand, quartz, very fine to fine; high mafic mineral content	40	90			
DAWES COUNTY, NEBR.					
29-47-2dcl					
[Test hole near site of irrigation well of Otto Anderson. Drilled in 1950]					
Soil	3	3	Sand	13	110
Clay, sandy	7	10	Sand and quicksand	10	120
Sand	20	30	Clay, sandy	50	170
Sand, soft	10	40	Sand, coarse	10	180
Sand, some clay	20	60	Clay, sandy	40	220
Sand, soft	10	70	Sand	25	245
Sand	25	95	Clay, sandy	20	265
Sand (water)	2	97	Rock layers	35	300

TABLE 12.—*Drillers' logs of wells and test holes*—Continued

DAWES COUNTY, NEBR.—Continued

29-51-34c

[Deep boring on bank of Niobrara River at Marsland. Drilled in 1896. Copied from report by Darton, N. H., 1905, p. 273]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay	5	5	Slate	20	470
Gravel, clay, and sand	40	45	Coal	.5	470.5
Hard rock	6	51	Rock	149.5	620
"Butte" rock	100	151	(?)	130	750
Slate	20	171	Coal	.5	750.5
Rock and slate alternating	79	250	Slate	29.5	780
Coal	.5	250.5	Sandstone, very hard, reddish	20	800
Slate	29.5	280	Sandstone, soft	100	900
Rock	170	450	Sandstone, hard	27	927

SHERIDAN COUNTY, NEBR.

32-42-18cbl

[Test hole near site of irrigation well of Frank Dowd. Drilled in 1944]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Sand, clayey	21	136
Clay, sandy	18	20	Sand, hard, or soft sandstone	6	142
Clay layers, hard (water)	10	30	Clay, sandy, soft	18	160
Clay, hard	10	40	Clay, sandy, red	20	180
Clay, sandy	10	50	Sand, hard	5	185
Clay, sticky	10	60	Sand and rock, hard	2	187
Clay (some water)	5	65	Clay, sandy	3	190
Clay, soft, and sand	5	70	Clay	27	217
Clay and gravel	20	90	Rock	4	221
Clay and sand layers	10	100	Clay	14	235
Sand, very fine	5	105	Rock layers	12	247
Sand, hard, or soft sandstone	5	110	Clay	33	280
Sand, very fine	5	115	Clay and sand layers	70	350

32-44-34da

[Public-supply well of Rushville. Drilled in 1939]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil and sand	20	20	Rock, red; contains layers of very hard rock from 3 to 6 feet apart and from ⅛ to 4 feet thick (yields small quantities of water)	551	646
Clay, sand, and gravel	20	40	Rock, red	104	750
Sand	20	60	Rock, red (good flow of water)	50	800
Sand (water-bearing)	20	80	Siltstone (Brule formation)	15	815
Sand, fine	15	95			

32-44-35bb

[Test hole drilled for city of Rushville]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand	8	8	Clay, white	36	207
Clay, coarse sand	32	40	Caliche	5	212
Gravel and sand	46	86	Sandstone, brown	6	218
Clay, white	4	90	Caliche	72	290
Clay, brown	13	103	Sandstone, brown	5	295
Sandstone, brown	4	107	Sandstone, brown, with layers of caliche	107	402
Clay, brown	11	118	Clay, brown	1	403
Sandstone, brown	5	123			
Clay, brown	48	171			

TABLE 12.—*Drillers' logs of wells and test holes*—Continued

SHERIDAN COUNTY, NEBR.—Continued

33-41-19abl

[Test hole near site of irrigation well of H. C. Wilhite]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	Sandstone, hard and soft layers	21	178
Clay, sandy, brown	19	21	Rock, hard	4	182
Sand, fine, and sandstone	10	31	Sandstone, soft	2	184
Sandstone	2	33	Rock, very hard	1	185
Rock, very soft, white	1	34	Sandstone, moderately soft	7	192
Caliche	6	40	Rock, very hard	2	194
Sand, gravel, and sandstone layers	2	42	Sandstone, soft	28	222
Sand, calcareous, and sandstone	13	55	Rock, very hard	.5	222.5
Sandstone, with hard calcareous rock layers	50	105	Sandstone and hard rock layers	7.5	230
Sand, fine, and calcareous sandstone	23	128	Sand, fine, and soft sandstone layers	13	243
Rock, hard	2	130	Rock, hard	1	244
Sand, fine, and calcareous sandstone	12	142	Sand, fine to medium; contains a few sandstone layers	16	260
Caliche	3	145	Rock	3	263
Sand, fine, and calcareous sandstone layers	12	157	Sand, fine to medium	4	267

33-42-25bcl

[Public-supply well for city of Gordon]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, black	2	2	Sand	1	84
Clay, calcareous, white	5	7	Clay, sandy, red	1	85
Sand, fine, and calcareous sandstone	9	16	Sand	1	86
Caliche	4	20	Clay, sandy, calcareous, red	4	90
Sand, fine, and calcareous sandstone	12	32	Clay, sandy, yellow; contains some sandstone	12	102
Sand and sandstone	9	41	Sand	2	104
Sand, fine, and calcareous sandstone	23	64	Clay, sandy, yellow; contains some sandstone	9	113
Clay, sandy, red; contains some sandstone	19	83	Sand	1	114
			Sandstone, soft, brown	16	130
			Sandstone, hard, brown	8	138

33-42-36d

[Well drilled by Chicago & North Western Railway System. Altitude about 3,556 feet. Copied from a report by Condra, G. E., Schramm, E. F., and Lugn, A. L., 1931, p. 267-268]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil and subsoil	12	12	Sand, gray, water-bearing, considerable supply	2	182
Sand, yellowish, fine	3	15	Silt, clay and some fine sand, yellow to yellowish gray	398	580
Clay, hard, sandy	25	40			
Sandy rock and some clay, some water at 155 feet	140	180			

TABLE 12.—*Drillers' logs of wells and test holes*—Continued

SHERIDAN COUNTY, NEBR.—Continued

33-43-25ca1

[Test hole near site of irrigation well of James Clarke. Drilled in 1947]

	Thickness (feet)	Depth (feet)
Soil	14	14
Gravel, sandy, white; contains some sand	10	24
Sand, with some loose rocks	13	37
Sandstone, fairly hard; sand and clay layers	2	39
Sand and rock layers	11	50
Sandstone	20	70
Sand, fine, hard	17	87
Sandstone, soft	3	90
Sandstone	24	114
Rock, hard	2	116
Sandstone, red, and sand	4	120
Sandstone, dark, and sand	5	125
Sandstone, hard and soft layers	43	168
Rock, hard	5	173
Rock, hard and soft layers, and calcareous clay	17	190
Rock, light layers	20	210
Rock	2	212
Rock and calcareous clay	8	220
Rock and red calcareous clay	7	227
Rock, sandstone, soft	4	231
Sandstone and yellow clay	9	240
Clay, sandy; contains rock layers	20	260
Clay, sandy; contains some rocks	24	284
Clay and gravel	3	287
Sand, hard; contains rock and some clay	11	298
Sand, soft, and gravel	9	307
Clay, sandy, and gravel	11	318
Rock layers, clay	39	357
Clay, soft, gravel, and sand	15	372
Sand, hard, and clay	10	382
Sand, soft, dark, and clay	40	422
Clay, hard	4	426
Rock and clay	1	427
Clay, sticky, some rock	20	447
Sandstone and rock	2	449

SIOUX COUNTY, NEBR.

28-55-15a

[Test hole for oil well of Associated Oil Co. of Wyoming. Altitude, about 4,520 feet. Drilled in 1920-21. Correlated by H. J. Cook and E. F. Schramm from driller's log and cuttings. Copied from report by Condra, G. E., Schramm, E. F., and Lugn, A. L., 1931, p. 266-267]

	Thickness (feet)	Depth (feet)
Quaternary	40	40
Monroe Creek beds	100	140
Brule clay (White River)	570	710
Chadron formation (White River)	100	810
Pierre shale	2,890	3.700
Niobrara	60	3,760
Carlile	277	4,037
Greenhorn	10	4,047
Graneros	520	4,567

28-55-32da

[Irrigation well of Cherry Brothers. Altitude, about 4,570 feet. Drilled in 1951]

	Thickness (feet)	Depth (feet)
Soil	8	8
Limestone	3	11
Sandstone, soft	4	15
Sand and gravel	16	31
Sandstone, soft; contains traces of gravel and sand	13	44
Sand, fine	12	56
Sandstone, soft; contains traces of gravel and sand	33	89
Sandstone, soft; contains traces of gravel	36	125
Sand, fine	10	135
Sand and gravel	5	140
Sandstone, sand, and gravel	8	148
Gravel, coarse, and layers of green shale	11	159
Rock, chalky, hard	1	160
Sand, fine; contains hard limestone beds	14	174

TABLE 12.—*Drillers' logs of wells and test holes*—Continued

SIOUX COUNTY, NEBR.—Continued

31-56-3cd2

[Test hole near site of public-supply well (31-56-3cd3), village of Harrison]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
(?)	193.5	193.5	Sandstone, hard	3	236
Rock	10.5	204	Sandstone	2	238
Sandstone	2	206	Rock	2	240
Rock	1	207	Shale, sandy	3	243
Sandstone	3	210	Sandstone and shale	1	244
Do	8	218	Rock	5	249
Rock	4	222	(?)	28.5	277.5
Shale, sandy	11	233			

32-62-20abl

[Test hole near site of irrigation well of Noel Larson. Drilled in 1951]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, heavy	6	6	Sandstone, soft	17	54
Rock, chalky, soft	2	8	Limestone, hard	2	56
Sand and gravel	2	10	Sandstone, soft	68	124
Limestone, hard	2	12	Limestone, hard	2	126
Sandstone, soft	12	24	Sandstone	10	136
Sand, fine	2	26	Limestone, hard	2	138
Sandstone, soft	10	36	Sandstone, soft; contains streaks of hard limestone	30	168
Limestone, hard	1	37			

32-64-18ba

[Irrigation well of N. V. Lamb. Drilled in 1949]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	6	6	Sandstone, soft, broken	17	70
Sandstone, hard	35	41	Sandstone, hard	15	85
Rock, chalky, hard	12	53			

33-63-25db

[Test hole for oil well]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
White River Group	525	525	Sand, red (Bell sand zone?)	21	909
Conglomerate	255	780	Sand, red and purple (Deadwood formation)	37	946
Limestone and dolomite, gray	55	835	Shale, green and yellow	39	985
Sand, pink	21	856	Shale, metamorphosed, hard, green	243	1,228
Limestone, pink	19	875	Schist, black (Precambrian?)	12	1,240
Sand, pink (basal Pennsylvanian)	13	888			

33-63-30cc

[Test hole for oil well]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
White River group	248	248	Schist and shale, green	65	415
Sand, coarse	40	288	Schist, micaceous, black	35	450
Schist, micaceous, brown	62	350			

TABLE 13.—*Record of wells*

Well No.: See text for explanation of well-numbering system.
Type of well: B, bored; Dn, driven; Dr, drilled; Du, dug.
Depth of well: Measured depths are given in feet and tenths below land surface; reported depths are given in feet.
Type of casing: B, brick; C, concrete; P, iron or steel pipe; S, stone; W, wood.
Geologic source: Qa, alluvium; Qds, dune sand; Ta, Arikaree group (Arikaree formation in Wyoming); Tb, Brule formation; To, Ogallala formation.
Type of pump: C, cylinder; Cf, centrifugal pump; N, none; T, turbine.
Type of power: E, electric motor; F, natural flow; G, butane, diesel, or gasoline engine; H, hand-operated; N, none; W, windmill.
Use of water: C, cemetery irrigation; D, domestic; I, irrigation; N, none; O, observation of water-level fluctuations; P, public supply; R, railroad; S, stock.
Measuring point: Bpb, bottom edge of pump base; Dc, top of discharge column; Em, edge of manhole; Hc, hole in casing; Hpb, hole in pump base; Hph, hole in pump housing; Hspb, hole in side of pump base; Idp, invert of discharge pipe; Ls, land surface; Tc, top of casing; Tcl, top of pipe clamp; Twc, top of well cover.
Altitudes: Altitudes determined by instrumental leveling are given in feet and tenths; altitudes estimated from U. S. Geological Survey topographic maps are given in feet.
Depth to water: Measured depths are given in feet, tenths, and hundredths; reported depths are given in feet.
Average acreage irrigated per year: E, estimated; R, reported.
Remarks: AI, formerly used for irrigation; Bw2, battery of 2 wells (or number indicated); Ca, sample collected for chemical analysis; D, discharge in gallons per minute (E, estimated; R, reported); DD, drawdown in feet (M, measured; all others reported); GI, domestic garden irrigation; L, log of well or nearby test hole given in table of logs; PWT, perched water table; Wd, well destroyed.

Well no.	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (feet)	Type of casing	Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (–) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Average acreage irrigated per year	Remarks
Box Butte County																	
26-47-11db	Kenneth Beckhoff	1950	Dr	253	18	P	Ta	T	G	I	Hpb	1.0	3,909	16.19	Jan. 8, 1953	110R	D350R; DD140
13cb	E. J. Zochol	1950	Dr	175	18	P	Ta	T	G	I	Hph	-1.5	3,936	53.35	do	160R	D450R; DD95
17ca	Robert Detsch	1950	Dr	365	18	P	Ta	T	G	I	Hph	1.0	3,983	35.73	Apr. 2, 1953	160E	D1,120R; DD67
17dd	David R. Lawrence		Dr	129.0	6	P	Ta	C	W	S,O	Tc	.6	3,985.3	55.44	Jan. 8, 1953		
48- 4dd	Kenneth Banks	1948	Dr	293	14	P	Ta	T	G	I	Hpb	.5	4,085	84.83	Feb. 5, 1953	120E	D590R; DD49
27-47-12da	Frank Krejci	1930	Dr	19	6	P	Qa	C	W	S,O	Tc	.6	3,861	12.43	Aug. 27, 1934		
17db	C. R. Fentress	1942	Dr	160	18	P	Ta	T	G	I,O	Hpb	.4	3,962	77.02	Jan. 14, 1953	50E	D300R
25dc	R. A. Kittleman		Du	69	24	P	Ta	C	G	I,O	Twc	.5	3,890	29.51	8, 1953	2E	GI
48- 10cc	E. F. Walters	1950	Dr	293	12	P	Ta	T	G	I	Ls		4,090	100		37R	D200R
49- 7d a	Chicago, Burlington & Quincy Railroad		Dr	297	10	P	Ta	T	G	R	Ls			120			
7dd1	Town of Hemingford	1919	Dr	300	14	P	Ta	T	E	P	Ls			130			D300R
7dd2	do	1952	Dr	300	12	P	Ta	T	E	P	Ls		4,262	125			D300R
12bb	Frank Dee	1952	Dr	300	16	P	Ta	T	G	I	Hpb	.3	4,154	118.75	Feb. 5, 1953	160E	D800R
12cc	do	1950	Dr	300	16	P	Ta	T	G	I	Dc	1.3	4,163	121.98	do	30E	D400R
18aa	Town of Hemingford	1914	Dr	300	14	P	Ta	C	E	P	Ls			130			
21cb	E. S. Wildy	1925	Dr	156	4	P	Ta	N	N	O	Hc	.6	4,230	117.49	Feb. 5, 1953		
26cd	Cecil Vickers	1939	Dr	396	36	P	Ta	T	G	I,O	Hpb	.2	4,010.1	124.72	Apr. 2, 1953	140R	D700R; DD45
28-51- 6d a	J. R. Hughes	1938	Dr	300	6	P	Ta, Qa	Cf	G	I	Twc	.2	4,130	19.11	Sept. 3, 1938	15R	
6dd	Univ. of Nebraska	1935	Dn	11.2	1	P	Qa	N	N	O	Tc	1.55	4,115.3	3.73	Nov. 25, 1935		Wd
8bc	W. T. Gregg		Dr	102	6	P	Ta	N	N	O	Tc	1.4	4,199.2	86.13	Feb. 5, 1953		

TABLE 13.—*Record of wells*—Continued

Well no.	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (feet)	Type of casing	Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Average acreage irrigated per year	Remarks
Cherry County, Nebr.																	
27-39- 3cd	Floyd Yahney	1948	Dr	280	18	P	To	T	G	I	Tc	0	3,795	30	1948	50R	D700R; L; Ca
28-39-31cc	Arthur D. Dille	1950	Dr	286	24	P	To	T	G	I	Ls		3,835	80	1950	60R	D650R
30-33- 9ac	Elmer Barnes	1950	Dr	112	18	P	To	T	G	I	Hpb	.3	3,118	12.86	Oct. 15, 1952	50R	D1,000R; DD50
31-29-33ad	U. S. Bureau of Reclamation	1948	Dn	6.4	3	P	Qds	N	N	O	Tc	1.0	2,915.8	3.26	Jan. 5, 1953		
33dd	Arthur E. Daniels		Dr	40	6	P	Qds	C	W	S	Ls		2,925	10			Ca
31-30-29ac	U. S. Geol. Survey	1950	Dn	105.0	¾	P	To	N	N	O	Tc	1.7	2,954.6	98.13	Oct. 10, 1950		
40- 7bd			Dr	104.0	6	P	To	C	W	S	Tc	1.0		74.74	Oct. 17, 1952		
15ad			Dn	14.0	6	P	Qds	C	W	S	Tc	.2	3,530	13.10	do.		
32-32-36ac			B	33.0	3	P	Qds	C	W	S	Tc	7.1	2,960	20.65	Oct. 15, 1952		
37-27cb	D. J. Noble	1952	Dr	170	8	P	To, Qds(?)	T	G	I	Ls		3,353	18	1952	40E	D240R
39-4d c			Dr	146.0	6	P	To	C	W	S	Tc	2.0	3,420	82.75	Oct. 14, 1952		
27cb	Roy Spangler		Dr	86.0	6	P	Qds, To	C	W	S	Tc	1.0	3,441	12.95	do.		
33-27- 6aa	Valentine Cemetery Association.		Dr	160	6	P	To	T	G	C	Ls		2,585	100			D150R; Ca
17cb	Univ. of Nebraska	1936	Dn	8.5	1	P	Qa	N	N	O	Tc	1.4	2,408.9	3.63	Jan. 16, 1936		
29- 6ad	Paul Reihmar		Dr	164	6	P	To	C	W	S	Tc	1.0	2,815	111.74	Oct. 15, 1952		
17dc	Fred Kruger		B	292	2½	P	To	C	W	D	Ls		2,832	235			
28bc	Albert Bush		Dr	201.0	6	P	To	C	W	S	Tc	1.0	2,691	169.50	Oct. 15, 1952		
30-14cd			Dr	52.0	6	P	Qds, To(?)	C	W	S	Tc	4.0	2,839	19.11	Oct. 16, 1952		PWT
31-23dc	Paul J. Goodwin		Dr	272	6	P	To	C	W	S	Tc	2.0	2,939	226.10	do.		
32-23aa			B	251.0	2½	P	To	N	N	N	Tc	2.0	3,004	189.13	Oct. 15, 1952		
34-17db	H. A. Schneider	1952	Dr	212	18	P	To	T	G	I	Hpb	.4	3,028	72.28	Oct. 9, 1952	160R	D700R; Ca
40-29bc2	William Roberts	1948	Dr	333	18	P	To	T	G	I	Tc	0		51.63	Oct. 3, 1952	160E	D800R; DD35; L
34-27-31cc	City of Valentine	1926	Dr	163	28	P	To	T	E	P	Ls		2,582	96			D350R; DD59
31da	Univ. of Nebraska		Dr	127.5	2	P	To	N	N	O	Em	.7	2,575	98.72	Aug. 25, 1934		
28-36ca	City of Valentine	1947	Dr	155	28	P	To	T	E	P	Ls		2,594	98			D360R; DD31
36da	do.	1932	Dr	159	28	P	To	T	E	P	Ls		2,588	93			D300R; DD59
36dd	do.	1951	Dr	157	28	P	To	T	E	P	Ls		2,587	97			D350R
32-18dd		1942	B	160	2½	P	To	C	W	S	Ls		3,161	100	1942		
33- 7ca	Town of Cody	1942	Dr	150	8	P	To, Qds(?)	T	E	P	Ls		3,108	35			D600R
7db	do.	1930	Dr	136	8	P	To, Qds(?)	T	E	P	Ls		3,120	38			

34-36db			Dr	132.0	6	P	To	C	W	S	Tc	1.0	3,115	126.31	Oct. 29, 1952		
36-12aa	Univ. of Nebraska	1936	Dn	21.1	1	P	Qds	N	N	O	Tc	1.6	3,202	9.43	do		
37-17cb	Town of Merriman	1935	Dr	182	8	P	To	T	E	P	Ls		3,285	20			D250R
18da	Jack Larson	1950	Dr	180	6	P	To,Qa	T	E	I	Ls		3,270	5	1950	25E	D60R
38-14bc	Univ. of Nebraska	1936	Dn	17.3	1	P	Qa	N	N	O	Tc	2.3	3,312	9.69	Nov. 20, 1936		
20dd	Ed Belsky	1950	Dr	150	8	P	To,Qds	T	E	I	Ls		3,345	15	1950	20E	D90R; DD35
39-17ba		1952	Dr	86.0	6	P	To,Qds	C	W	S	Tc	.3	3,423	8.90	Oct. 17, 1952		
31db	Chicago & North Western Railway System.		Dr	100	6	P	To,Qds	C	W	R	Ls		3,438	15			
35-38-26bb	M. O. Metzger	1950	Dr	140	12	P	To,Qds	T	G	I	Ls		3,316	10	1950	40E	D190R; Ca; L

Dawes County, Nebr.

29-47-2dc2	Otto Anderson	1950	Dr	265	16	P	Ta	T	G	I, O	Bpb	0		79.82	Nov. 12, 1952	80R	D1,000R; DD15; L
20dd	Duane Wildy		Dr	34.0	6	P	Qa	C	W	D	Tc	0	3,850	26.25	Oct. 8, 1952		Ca
48-15cb	W. M. Montag	1946	Dr	132	18	P	Ta	T	G	I	Tc	−.5	3,950	42.15	Nov. 12, 1952	110R	D1,200R
51-34bc	Chicago, Burlington & Quincy Railroad.		Dr	73	144	S	Ta	C	W	R	Em	−10.0	4,147	42.79	Feb. 5, 1953		
52-27ad	Mr. Hoffman		Dr	235.0	6	P	Ta	C	W	S	Tcl	1.0	4,421	195.53	do		
34dc			Dr	91.0	6	P	Ta	C	W	S	Tc	1.0	4,240	62.77	do		
30-47-17ba			Dr	200.0	7	P	Ta	C	N	S	Tc	.5		156.32	Nov. 7, 1952		
49-22bb	Joseph Strumpf	1929	Dr	200	6	P	Ta	C	W	D	Ls			163	1929		Ca
50- 2ac	Earl F. Reed	1944	Dr	200	6	P	Ta	C	W	D	Ls			153	1944		
51-30ac			Dr	179.0	6	P	Ta	N	N	N	Tc	1.5		168.20	Feb. 5, 1953		
30bc	Chicago, Burlington & Quincy Railroad.		Dr	412	12	P	Ta, Tb(?)	T	G	R	Ls			130			
36bc	C. E. Hale	1930	Dr	165	6	P	Ta	C	W	D	Ls			100	1930		
31-48-28bb			Dr	254.0	6	P	Ta	C	W	S	Twc	0		231.10	Nov. 7, 1952		
49-28da	H. Deans		Dr	280	6	P	Ta	C	W	D	Ls			225	1925		

Sheridan County, Nebr.

24-46-6bd	Philo Sturgeon	1952	Dr	102	18	P	To,Qds	N	N	I	Tc	0.8	3,900	7.33	Jan. 8, 1953		D1,000R; DD46
25-46-26cb	F. S. Jesse	1950	Dr	113	14	P	To,Qds	T	G	I	Tc	0	3,895	14.32	do	70R	D650R; DD23
26-45- 9cb			Dr	30	6	P	Qds	C	W	S	Ls		3,855	10	1952		Ca
19bc			Dr	25	6	P	Qds	C	W	S	Ls			8	1952		Ca
46- 2ac	Robert Messersmith	1951	Dr	143	18	P	To,Qds	T	G	I	Hpb	1.5	3,902	19.46	Jan. 8, 1953	80R	D460R; DD120
25db			Dr	40	6	P	Qds	C	W	D, S	Ls		3,876	12	1952		Ca
27-44- 7dd1	Twin Lakes Gun Club		Dr	69.0	6	P	Qds,To(?)	N	N	N	Tc	2.0	3,857	14.67	Oct. 23, 1952		
7dd2			Dr	70	6	P	Qds,To(?)	C	W	S	Ls		3,857	15			Ca
29db			Dr	20	6	P	Qds	C	W	S	Ls		3,835	7			Ca
45-17cb	Hans Jaeger		Dr	80	6	P	To,Qds(?)	C	W	D	Ls		3,886	8			Ca
46- 5cc	Joe Krejci	1936	Dr	35.0	6	P	Qds,To(?)	C	W	S	Twc	1.0	3,843	25.02	Nov. 11, 1952		
28-42-30bd	Don Forney	1952	Dr	200	16	P	To,Qds	T	G	I	Hspb	1.5	3,894	7.28	Oct. 23, 1952	110R	D800R; DD120
45-10- bc			Dr	100.0	6	P	To	C	W	S	Tc	2.0	3,872	82.48	Nov. 6, 1952		
29cb	Levi H. Hahn	1910	Dr	88.0	8	W	To	C	W	D	Ls		3,910	54	1910		

TABLE 13.—*Record of wells*—Continued

Well no.	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (feet)	Type of casing	Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Average acreage irrigated per year	Remarks
Sheridan County, Nebr.—Continued																	
46-32ad1	Hans Jaeger		Dr	49.5	4	P	To,Qds(?)	N	N	O	Tc	2.0	3,850	26.88	Jan. 7, 1953		
32ad2	do	1937	Dr	276	16	P	To,Ta(?)	C	W	S	Twc	.8	3,849	25.50	Apr. 23, 1946		D800R; AI
32ad3	do		Dr	160	16	P	To,Ta(?)	N	N	N	Twc	2.0	3,852	33.45	Jan. 7, 1953		
29-42- 2ca			Dr	65.0	6	P	To,Qds(?)	C	W	S	Tc	2.0		26.26	Oct. 30, 1952		
44- 7ac	Charles Lecher	1945	Dr	270	6	P	To	C	W	S	Tc	.3		200.00	do		
13ab	Dell Britt	1939	Dr	140	4	P	To	C	W	S	Tc	1.0	3,810	105.95	Nov. 6, 1952		
18bc			Dr	275.0	4½	P	To	C	W	S	Tc	2.0	3,913	217.86	do		
45- 8bb		1926	Dr	80	5	P	Ta	C	W	D,S	Twc	.5		44.03	May 3, 1950		
46- 4bd	Alfred Deans		Dr	92	6	P	Ta	C	E	S,O	Tc	.7		63.95	May 2, 1950		
4dc	G. Glenn	1946	Dr		6	P	Ta	C	H	D,S,O	Tc	−5.3	3,833	56.04	do		
11dc	Andrew Young	1946	Dr	93	6	P	Ta	C	H	D,O	Tc	.5	3,786	38.70	Jan. 7, 1953		
24ad	K. Pyle	1946	Dr	95	6	P	Ta	C	W	S,O	Tc	.5	3,780	64.09	Oct. 3, 1951		
30cc	Tom Hughes	1938	Dr	204	18	P	Ta,Qa	T	G	I	Tc	1.1	3,813	28.80	May 16, 1946		D1,500R; DD21
30-42-12cd	Joe Swanson	1949	B	130	4	P	To	C	W	S	Ls			60	1949		
43-32aa	Ed Kearns	1950	Dr	120	6	P	To	C	W	D,S	Tc	1.0		66.20	Oct. 30, 1952		
44-11bb			Dr	180.0	6	P	To	C	W	S	Twc	1.0		134.30	Nov. 6, 1952		
32ab			Dr		4½	P	To	C	W	S	Tc	1.0		94.40	do		
45- 8cb1	W. A. Christians	1933	Dr	80	18	P	Ta,Qa(?)	T	G	I	Ls			22	1950	80E	D1,500R; DD37
8cb2	do	1942	Dr	80	18	P	Ta,Qa(?)	T	G	I	Hpb	.2		22.30	Nov. 12, 1952	80E	D1,500R; DD38
8da	do	1940	Dr	80	18	P	Ta,Qa(?)	T	G	I	Tc	−.2		14.74	do	80E	D1,000R
20ab	Milton Burrows	1949	Dr	138	18	P	Ta,Qa(?)	T	G	I	Hpb	0		34.43	do	130R	D1,000–1,200R; DD65
46- 4cc	Dan Peters	1940	Dr	80	18	P	Ta	T	G	I	Hpb	0		32.65	do	25R	D500R; DD40
11bb	Lewis Mendenhall	1938	Dr	80	18	P	Ta	T	G	I	Ls			37	1938	150R	D1,250 R
11db	do	1951	Dr	285	16	P	Ta	T	G	I	Tc	0		31.29	Sept. 24, 1952	120R	D700E; Ca
31-41-6bb			Dr	127.0	6	P	To	N	N	N	Tc	0		118.90	Oct. 23, 1952		
43- 9cc	Anton Roffers	1927	Dr	250	4	P	To,Ta(?)	C	W	D	Ls			200	1927		
44- 1cb	Charles Plants		Dr	47.0	6	P	Qa,Ta(?)	C	W	S	Tc	1.5		40.12	Nov. 6, 1952		
10dd	Univ. of Nebraska	1935	Dn	12.3	1	P	Qa	N	N	O	Tc	1.1		4.85	Nov. 23, 1935		
45-25ad	Elmer Prokop	1951	Dr	99	18	P	Ta	T	G	I	Ls			45	1951	160R	D600R; DD50
46- 8ad	Univ. of Nebraska	1936	Dn	17	1	P	Qa	N	N	O	Tc	3.0		8.27	Nov. 22, 1936		
10ad	Town of Hay Springs	1948	Dr	288	16	P	Ta,Qa	T	E	P	Hpb	2.0		21.47	Nov. 11, 1952		D500R

11ab	Chicago & North Western Railway System.		Dr	390	10	P	Ta	T	G	R	Ls			25			
11ba	Town of Hay Springs	1885	Du-Dr	150	12	P	Ta	T	E	P	Ls			30			D75R
11bd	do	1940	Dr	70	12	P	Ta,Qa	T	E	P	Ls			20			D50R
17dd	Erwin Blonien	1952	Dr	65	18	P	Ta,Qa	T	G	I	Hpb	.2		1.10	Nov. 12, 1952		D400R
18aa	Max Kutschara	1950	Dr	425	18	P	Ta	T	G	I	Hspb	.2		30.86	Oct. 31, 1952	160E	D600R; DD18
33ca	Guy Alcorn	1940	Dr	60	18	P	Ta(?)	T	G	I	Hpb	0		17.70	Nov. 12, 1952	40R	D400R; DD38
32-42-18cb2	Frank Dowd	1944	Dr	286	24	P	To,Ta	T	G	I	Tc	0		43.03	Sept. 24, 1952	150R	D750R; DD15; L
43-26ab	John Schuster	1948?	Dr	240	16	P	To,Ta(?)	T	G	I	Bpb	0		66.84	Oct. 17, 1952	150R	D700R
26ca	do	1949?	Dr	265	16	P	To,Ta(?)	T	G	I	Hpb	.3		63.10	Sept. 23, 1952	60R	D650R
44- 3cc			Dr	128.0	6	P	Ta	C	W	S	Twc	.5		77.08	Nov. 11, 1952		
27dc	City of Rushville		Du	68.0	216	B	Ta	T	E	P	Em	0		36.46	Nov. 6, 1952		Bw3; D300R
34da	do	1939	Dr	803	24	P	Ta	T	E	P	Ls			60	1939		D300R; L
34dc	do		Dr	350	15	P	Ta	T	E	P	Ls			60			D75R
45-35cc			Dr	26.0	6	P	Qa,Ta(?)	C	W	S	Tc	1.5		14.08	Nov. 11, 1952		
33-41- 1cd	Hugh Goodfellow	1950	Dr	286	18	P	Ta	T	G	I	Hpb	.2		26.48	Oct. 22, 1952	160E	D600R
7cc	Fred Schmidt	1951	Dr	290	12	P	Ta	T	E	I	Hpb	.2		49.18	Jan. 14, 1953	80R	D380R; DD71.5M
19ab2	H. C. Wilhite	1948	Dr	280	18	P	Ta	T	E	I	Tc	.2		30.72	Oct. 23, 1952	150E	D600R; L; Ca
33-42-10ad	J. L. Martin	1950	Dr	230	8	P	Ta	T	E	I	Ls			47	1950	100E	D460R
25bc1	City of Gordon	1930	Dr	150	18	P	Ta, Qa	T	E	P	Ls			15			D440R;L
25bc2	do	1936	Dr	150	18	P	Ta,Qa	T	E	P	Ls			15			D400R
25dc	do	1947	Dr	150	18	P	Ta,Qa	T	E	P	Ls			9			D500R;DD68
43-25ca2	James-Clarke	1947	Dr	420	18	P	Ta	T	E	I	Hc	.5		17.00		120E	D500R;DD130;L

Sioux County, Nebr.

27-53- 2da			Dr	123.0	6	P	Ta	C	W	S	Tc	1.0	4,557	116.08	Feb. 6, 1953		
15ca			Dr	155.0	6	P	Ta	C	W	S	Tc	2.0	4,543	141.47	do		
54-29dc			Dr	165	6	P	Ta	C	W	D,S	Tc	0	4,700	161.22	Oct. 7, 1952		Ca
55- 5aa		1953	Dr	155+	18	P	Ta,Qa(?)	N	N	I	Twc	.6	4,576	66.39	Apr. 21, 1953		
56-36dd	Jos. Sanford	1908	Dr	225	6	P	Ta	C	W	D	Ls		4,840	178	1908		Ca
28-53- 7ac	Fred Davison	1952	Dr	175	18	P	Qa,Ta	T	E	I	Hpb	1.0	4,281	18.18	Oct. 1, 1952		D825R
54- 5db	Frank Harris	1952	Dr	173	18	P	Qa,Ta	T	E	I	Hpb	1.0	4,351	37.61	do		D800R;DD75
6bc1	Clarke Hickey	1952	Dr	131	18	P	Qa,Ta	T	E	I	Hpb	2.0	4,392	40.19	Feb. 6, 1953		D1,400R
6bc2	do		Dr	45	6	P	Qa	C	W	S	Ls			35			Ca
55-32da	Cherry Bros.	1951	Dr	174	18	P	Ta,Qa(?)	T	E	I	Hpb	1.0	4,571	50.20	Feb. 4, 1953		D1,500R;DD110;L
33cc	do	1952	Dr	165	18	P	Ta,Qa(?)	T	G	I	Hpb	.2	4,565	48.34	do	160R	D1,500R; DD107
35ca	Tom McKnight	1952	Dr	159	18	P	Ta,Qa(?)	T	G	I	Hpb	.3	4,555	70.10	do		D710R;DD70
56- 3cc			Dr	166.0	6	P	Ta	C	W	S	Twc	0	4,618	135.52	Nov. 14, 1952		
57- 9db	Frank Parsons		Dr	125.0	6	P	Ta	C	W	S	Tc	0	4,665	84.08	do		
29-53-19ba	Guy Yohe		Dr	207	6	P	Ta	C	W	D,S	Tc	1.0	4,539	172.28	Oct. 8, 1952		Ca
54-17bc		1939	Dr	34.0	6	P	Qa,Ta(?)	N	N	N	Tc	2.0	4,486	29.09	Feb. 6, 1953		
55- 6cc			Dr	188.0	8	P	Ta	N	N	N	Tc	1.0		157.92	Nov. 14, 1952		
33cc	H. J. Cook	1914	Dr	200	6	P	Ta	N	N	O	Hpb	.35	4,605	175.54	Apr. 21, 1953		
57-13ab			Dr	212.0	6	P	Ta	C	W	S	Tc	0	4,720	167.09	Nov. 14, 1952		
30-56- 3ac	Charles Mack	1915	Du	90	6	P	Ta	C	W	S	Tc	.5		73.20	do		
57-21aa	John Tangen	1910	Dr	100	6	P	Ta	C	W	D,S	Ls			60	1910		
34ad	Hebner Ranch		Dr	203.0	6	P	Ta	C	W	S	Tc	0		158.03	Nov. 13, 1952		

TABLE 13.—*Record of wells*—Continued

Well no.	Owner or tenant	Year drilled	Type of well	Depth of well (feet)	Diameter of well (feet)	Type of casing	Geologic source	Type of pump	Type of power	Use of water	Measuring point: Description	Measuring point: Distance above or below (−) land surface (feet)	Measuring point: Height above mean sea level (feet)	Depth to water level below measuring point (feet)	Date of measurement	Average acreage irrigated per year	Remarks
Sioux County, Nebr.—Continued																	
31-56-3cd1	Village of Harrison	1933	Dr	274	10	P	Ta	T	E	P	Tc	−7.0	------	133	1933	------	D100R
3cd3	do	1944	Dr	296	10	P	Ta	T	E	P	Ls	------	------	142	1944	------	D150R; L
3db	do	1910	Dr	315	8	P	Ta	C	G	N	Idp	−7.0	------	177.98	Nov. 13, 1952	------	D20R
10da	Cemetery Assn. of Harrison.	------	Dr	243.0	8	P	Ta	C	W	C,O	Tc	.5	------	173.41	Feb. 4, 1953	------	
32-57-27da?	------	------	Dr	240.0	6	P	Ta	C	W	S	Tc	0	------	205.50	Nov. 13, 1952	------	
Goshen County, Wyo.																	
29-60-22bc	Bruce Parson	------	Dr	187.0	6	P	Ta	C	W	S	Tc	0.3	4,814.4	178.55	Nov. 18, 1949	------	
30-60-6ab	Carl Dallam	1910	Dr	235	6	P	Ta	C	W	S	Tc	.2	4,915.6	190.39	Nov. 8, 1949	------	
34bd	H. H. Petersen	------	Dr	186	6	P	Ta	C	W	D,S	Hpb	.3	4,785.4	146.01	Nov. 9, 1949	------	
61-28bb	H. M. Petersen	------	Dr	------	6	P	Ta	N	N	N	Tc	1.4	4,954.8	213.66	Oct. 11, 1949	------	
62-2ac	A. M. Henderson	------	Dr	------	7	P	Ta	C	W	S	Hpb	.4	4,973.6	167.15	Aug. 24, 1950	------	

Niobrara County, Wyo.

31-60-17db	Chicago & North Western Railway System.	------	Dr	97	12	C	Ta	T	E	R	Tc	−9.3	--------	16.67	Nov. 4, 1952	-------	
61- 4ab	John Christian	1932	Dr	200	8	P	Ta	Cf	G,F	I	Ls	------	--------		--------------	-------	D150E; Bw2; Ca
32-60-17ba	------------------	------	Dr	210?	6	P	Ta	C	W	S	Tc	.5	--------	184.16	Nov. 4, 1952	-------	
61- 32c	John Christian	1935	Dr	200	8	P	Ta	Cf	G,F	I	Ls	------	--------	------	--------------	-------	D500E; Bw3
62-17cd	Ralph Larson	1952	Dr	125	18	P	Ta	T	E	I	Ls	------	--------	14	--------------	80R	D1,000R; DD45 L
20ab2	Noel Larson	1952	Dr	150	18	P	Ta	N	N	I	Tc	.5	--------	20.13	Oct. 28, 1952	-------	
63- 2cc	J. W. Christian	1951	Dr	200	24	P	Ta	N	N	I	Tc	1.0	--------	44.92	Aug. 20, 1952	-------	D700R; DD85
7bd	Town of Lusk	------	Dr	120	16	P	Ta,Qa	T	E	P	Ls	------	--------	40	--------------	-------	D330R
8da	Chicago & North Western Railway System.	------	Du	38	120	B	Qa	T	E	R	Tc	1.0	--------	23.00	Nov. 4, 1952	-------	
8dc1	Town of Lusk	1950	Dr	150	16	P	Ta,Qa	T	E	P	Ls	------	--------	35	--------------	-------	D350R
8dc2	do	1946	Dr	150	16	P	Ta,Qa	T	E	P	Ls	------	--------	32	--------------	-------	D250R
11ac	J. W. Christian	1951	Dr	200	24	P	Ta	N	N	I	Hc	0	--------	45.22	Aug. 20, 1952	-------	
11bb	do	1952	Dr	300	24	P	Ta	T	G	I	Tc	1.0	--------	44.42	do	-------	D400R
11bd	do	1951	Dr	205	24	P	Ta	T	G	I	Tc	1.0	--------	43.34	do	-------	
33bb	Earl Quigley	1949	Dr	205	18	P	Ta	T	G	I	Hpb	1.1	--------	39.00	Aug. 30, 1950	50-60R	D350E; DD98; 5M; Ca
64-18ba	N. V. Lamb	1949	Dr	85	22	P	Ta	T	E	I	Hpb	.8	--------	63.04	Feb. 2, 1952	95R	D1,000R; DD14; L
65- 1bb	Town of Manville	------	Dr	200	8	P	Ta	Cf	E	P	Ls	------	--------	39	--------------	-------	D125R; DD4
6cc	Delia Grant	------	Dr	170.0	6	P	Ta	C	E	D	Bpb	0	--------	136.33	Oct. 23, 1952	-------	
33-61-22ba	Harlan Lohr	------	Dr	287.0	8?	P	Ta	C	W	D	Twc	1.0	--------	234.05	Nov. 4, 1952	-------	

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