Geology and Ground Water Resources of the Egbert-Pine Bluffs Carpenter Area Laramie County Wyoming

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GEOLOGY AND GROUND-WATER RESOURCES OF THE EGBERT-PINE BLUFFS-CARPENTER AREA, LARAMIE COUNTY, WYOMING

By JOHN R. RAPP, DONALD A. WARNER, and ARTHUR M. MORGAN

ABSTRACT

This report describes the geography, geology, and ground-water resources of the Egbert-Pine Bluffs-Carpenter area in Laramie County, Wyo. The area comprises about 380 square miles of the High Plains and consists essentially of an upland dissected by Lodgepole and Crow Creeks. Farming and livestock raising are the principal occupations. Ground water is the principal mineral resource. The climate is semiarid, the average annual precipitation being about 16 inches.

The rocks exposed are of Tertiary, Pleistocene, and Recent age. A map showing the areas of outcrop of the rock formations is included in the report. The Brule formation, of Oligocene age, crops out in the lowland parts of the area, and the Arikaree and Ogallala formations, of Miocene and Pliocene age, respectively, cap the upland area. The Pleistocene formations are deposits of sand and gravel, which are present in the form of terraces. The Recent deposits are alluvial sediments in the stream valleys.

The report contains a map showing the shape and slope of the water table by means of contour lines. This map shows that the ground water moves eastward through the area, and the water table has an average gradient of about 35 feet to the mile.

The ground-water reservoir is recharged by subsurface inflow from the west, by seepage from streams, and in part by precipitation. Ground water is discharged from the ground-water reservoir by surface and subsurface outflow to the east and south, by evaporation and transpiration, and through wells.

Most of the wells in the area are drilled, but a few are dug. Ground water was used to irrigate about 9,800 acres in 1949. The areas most favorable for additional development are the terrace lands east of Carpenter and the terraces in the Lodgepole Creek valley. The principal water-bearing beds are the Brule formation and the Pleistocene gravel deposits. Caution should be used in developing additional ground-water supplies for irrigation from the Brule formation in the Pine Bluffs lowland.

The chemical quality of the water is such that the water is satisfactory for most uses, although it is generally hard.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

A program of ground-water investigation was begun in Wyoming in November 1940 by the Wyoming State Planning and Water Conservation Board in cooperation with the Geological Survey, U. S. Department of the Interior. The cooperation was transferred from the State Planning and Water Conservation Board to the Wyoming State engineer on July 1, 1945, as the result of a curtailment of activities by the planning board. The initial project in this program was the investigation of the geology and ground-water resources of the Lodgepole Creek valley and the adjacent uplands in the southeastern part of Laramie County. The area was designated the Egbert-Pine Bluffs area, after the two principal towns. In 1943 the area surrounding Carpenter was included, and it has since been known as the Egbert-Pine Bluffs-Carpenter area. The investigation was begun by T. W. Robinson, of the Ground Water Branch of the Geological Survey, in November 1940 and was continued by the following Survey personnel: F. C. Foley, from June 1941 through July 1942; A. M. Morgan, from August 1942 through December 1945, assisted by J. B. Graham until early 1944 and by D. A. Warner from September through December 1945; and Mr. Warner from January through December 1946 and intermittently to March 1949. The investigation was completed in December 1949 by J. R. Rapp, who spent several weeks in the field remapping the geology. Since January 1946 the investigation has been under the supervision of S. W. Lohman, district geologist in charge of ground-water investigations in Colorado and Wyoming. The investigation is under the general supervision of A. N. Sayre, chief, Ground Water Branch, Water Resources Division, U. S. Geological Survey.

Plates 1 and 2, the chapters on geologic formations and their water-bearing properties, and the summary of geologic history were prepared by Mr. Rapp. The remainder of the text and illustrations was prepared by Messrs. Rapp and Warner, who adapted considerable material from an earlier progress report by Morgan.

The area was selected by the Wyoming State Planning and Water Conservation Board, and the details as to the scope of the project were worked out in conferences between L. C. Bishop, State engineer, Earl Lloyd, engineer-secretary of the board, and the several Federal geologists.

Ground water is the principal natural resource in the Egbert-Pine Bluffs-Carpenter area because nearly all the domestic, stock, industrial, irrigation, and public supplies are obtained from wells. There is, therefore, an acute need for understanding the origin, movement, and availability of this important resource in order to facilitate its proper development.

LOCATION AND EXTENT OF THE AREA

The Egbert-Pine Bluffs-Carpenter area (fig. 1), which is in the High Plains in southeastern Laramie County, is bounded on the east by the Wyoming-Nebraska State line, on the south by the Wyoming-Colorado State line, on the west by the range line between Rs. 63 and 64 W., and on the north by the north line of T. 15 N., Rs. 60 and 61 W. The area contains seven complete townships and parts of seven other townships; it comprises about 380 square miles.

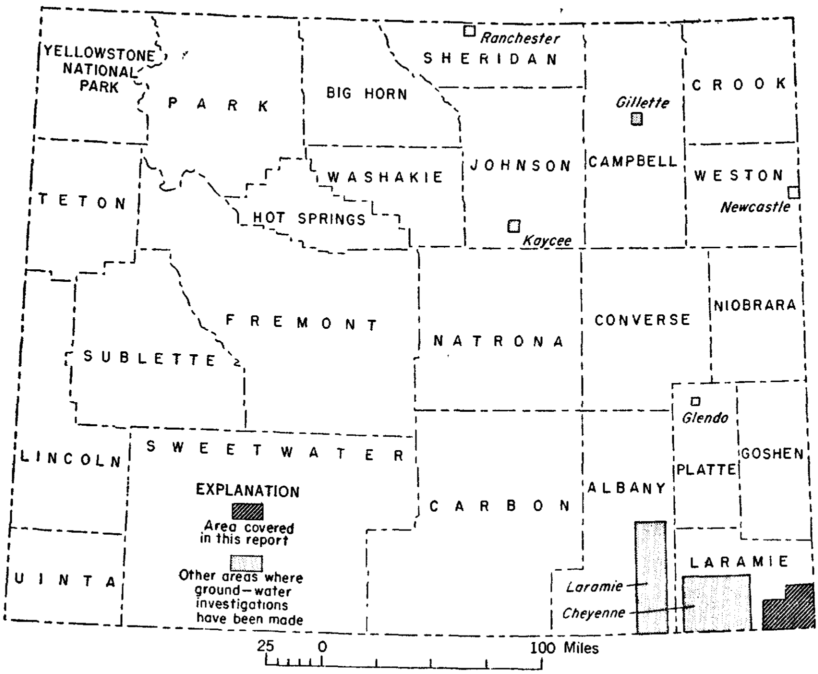

FIGURE 1.—Index map of Wyoming showing area covered by this report and other areas in which cooperative ground-water investigations have been made.

PREVIOUS INVESTIGATIONS

Several studies have been made of the geology or ground-water resources of all or part of the area under consideration. These studies are listed below in chronological order.

Darton (1905) made a reconnaissance survey of the geology and ground-water resources of the central Great Plains, including the Egbert-Pine Bluffs-Carpenter area. In 1915 Meinzer (1917) made a brief field investigation of the Lodgepole valley. In 1936 Knight and

Morgan[1] prepared a report in which they discussed the geology and occurrence of ground water in the Egbert-Pine Bluffs area, and in a report issued in 1938, Burleigh, Gwillim, Dunnewald, and Pearson[2] discussed the geology, the occurrence of ground water, and the economic aspects of pump irrigation in the same area. In January 1943, a preliminary report on the geology and underground water of the Egbert-Pine Bluffs area, by Morgan, Graham, Robinson, and Foley,[3] was issued by cooperating State and Federal agencies. The data in this earlier unpublished report are included in the present report.

METHODS OF INVESTIGATION

Records of about 224 wells were obtained during the investigation, and the water levels in about 175 of these wells were measured with a steel tape. Periodic water-level measurements were made in selected observation wells. Reported depths and water levels of the other wells were obtained from land owners and tenants, many of whom supplied information concerning the yield and drawdown of wells.

Thirty-four samples of ground water were collected in this area and analyzed by the laboratory of the Quality of Water Branch of the U. S. Geological Survey in Lincoln, Nebr.

Thirty-four test holes, aggregating 2,351 feet of drilling, were put down in the summer of 1943 in the Egbert-Pine Bluffs part of the area. Samples of the cuttings were collected and studied by Morgan and Graham. Additional logs of wells drilled in the area were obtained from well owners and drillers.

During the course of the investigation the geology of the area was studied and mapped, with particular emphasis on the extensive terraces underlain by gravel in the Pine Bluffs and Carpenter areas. The geology as shown on plate 1 is based primarily on original field work by Rapp, but some data are included from field notes by Warner and Morgan.

Field data were recorded on enlarged sections of the Laramie County map prepared by the Wyoming State Highway Department. The roads and drainage were checked and modified by field observation and by examining aerial photographs. The locations of wells shown on plate 2 were obtained by means of an odometer and are believed accurate to 0.1 mile. The wells are numbered serially. They are grouped by townships, and in table 9 locations are given to

[1] Knight, S. H., and Morgan, A. M., 1936 Report on underground water possibilities of the Egbert-Pine Bluffs region. [Manuscript report in files of Wyoming Geological Survey.]

[2] Burleigh, H. P., Gwillim, H. C., Dunnewald, T. J., and Pearson, H. W., 1938 Report on irrigation by recovery of ground waters in the Egbert-Pine Bluffs area: Wyoming Dept. Agr., Bur. Agr. Economics, Div. Land Economics. [Manuscript report.]

[3] Morgan, A. M., Graham, J. B., Robinson, T. W., and Foley, F. C., 1943 Preliminary report on the geology and underground water of the Egbert-Pine Bluffs area, Wyoming: U. S. Geol. Survey. [Manuscript report.]

10-acre tracts. For each well shown on plate 2 the number above the line corresponds with the number of the well in table 9, and the number below the line is the depth to the water table below the land surface. Parentheses around the upper number indicate that an analysis of the water from that well is given in table 7.

ACKNOWLEDGMENTS

The writers are indebted to the many residents in the area who supplied information about their wells and permitted test drilling on their land. Thanks are extended to Leslie L. Canfield, driller of Fort Morgan, Colo., and to the W. G. Dunlap Co. of Lexington, Nebr., who supplied logs of test holes they drilled in the Carpenter area.

The manuscript was reviewed critically by L. C. Bishop, State engineer of Wyoming, and by Earl Lloyd, deputy State engineer and engineer-secretary of the Wyoming State Planning and Water Conservation Board.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

All the area described herein lies in the Great Plains physiographic province. The altitude of the highest point, on the upland at the west edge of the area, is about 5,700 feet and that of the lowest point, where Lodgepole Creek leaves Wyoming and enters Nebraska, is about 5,000 feet; the total relief, therefore, is about 700 feet.

The eastern, northern, and western parts of the area consist of broad, relatively flat uplands into which the streams have cut flat-floored, relatively steep-walled valleys. The north-central part is a gently undulating lowland that comprises the valley of Lodgepole Creek between Egbert and the Wyoming-Nebraska State line and the lower parts of the valleys of Muddy Creek, Spring Creek, and Chevington Draw. The lowland belt north of Lodgepole Creek is 6 to 8 miles wide, and to the south in the valley of Muddy Creek it is 1½ to 3½ miles wide. The total relief of the lowland belt is about 150 feet.

In the vicinity of Carpenter there are three distinct topographic features. A broad, flat terrace extends eastward for about 12 miles from Carpenter to the valley of a southern tributary of Muddy Creek. Directly west of Carpenter is a low gently undulating embayment underlain by thin remnants of terrace deposits and by the Brule formation (pl. 1). Along the western edge of the embayment a pediment cut on the Brule rises toward a steep escarpment cut into the Brule and overlying Arikaree and Ogallala formations.

The most prominent topographic feature in the area is the Pine Bluffs escarpment, which extends north and south from Pine Bluffs. The escarpment faces westward and rises abruptly about 200 feet above the floor of the adjacent lowland. The west side of the lowland belt is bounded in places by a lower, less sharply defined eastward-facing escarpment, but in most places the boundary is marked by a gentle slope from the valley to the upland.

Lodgepole Creek has cut a valley about 3 miles wide through the Pine Bluffs escarpment near the town of Pine Bluffs. East of the Wyoming-Nebraska line the beds of the Ogallala formation that cap the escarpment on either side of the valley approach stream level, and at Bushnell, Nebr., 8 miles east of the State line, they dip beneath the stream.

The streams that drain the Egbert-Pine Bluffs-Carpenter area are tributary to the South Platte River. The principal stream, Lodgepole Creek, heads in the Laramie Mountains northwest of Cheyenne, Wyo., and flows eastward across Laramie County. It is an intermittent stream from a point a short distance northwest of Egbert to its junction with Muddy Creek, but it has a perennial flow west of Egbert and from the junction with Muddy Creek eastward into Nebraska. The valley of Lodgepole Creek has a relatively constant average gradient of about 25 feet to the mile through the area, calculated on the basis of the length of the valley in the area and not on the length of the stream channel.

Lodgepole Creek has three principal tributaries in the Egbert-Pine Bluffs area. Muddy Creek, which drains much of the land south of Lodgepole Creek, heads on the plains in the south-central part of Laramie County and flows east-southeastward to the NE¼ sec. 18, T. 13 N., R. 60 W., where it turns abruptly northward to join Lodgepole Creek. It is normally dry in its upper reaches but usually has a small flow through Rs. 61 and 62 W. From the west line of R. 60 W. to the boundary between secs. 16 and 17, T. 14 N., R. 60 W., the channel is dry except for a short stretch of open water upstream from the bridge on U. S. No. 30. From the boundary between secs. 16 and 17, T. 14 N., R. 60 W., to the junction with Lodgepole Creek the stream has a small perennial flow. An unnamed tributary of Muddy Creek that heads in the southwestern part of T. 12 N., R. 60 W., is normally dry, but it is joined by a number of small arroyos from the west, several of which have short stretches of perennial flow in the lower parts of their courses.

Most of the Egbert-Pine Bluffs area lying north of Lodgepole Creek is drained by Chevington Draw and Spring Creek. Chevington Draw heads on the plains northwest of Cheyenne and extends east-southeastward to sec. 30, T. 15 N., R. 60 W. It drains a large tract west of the Egbert-Pine Bluffs area but flows only after heavy rains. Occasional floods on Chevington Draw are reported to have caused damage in the town of Pine Bluffs on the south side of Lodgepole Creek. The draw occupies a relatively deep, well-defined valley several miles northwest of the branch line of the Union Pacific Railroad to Yoder, Wyo., but where it crosses the railroad the channel is almost undistinguishable and is broken by a number of small playas.

Spring Creek is a small perennial stream that heads in the lowlands of the Egbert-Pine Bluffs area in the northeastern part of T. 14 N., R. 61 W., and flows eastward to its junction with Lodgepole Creek. An arroyo that heads on the plains about 15 miles west-northwest of Jonas opens on to the lowlands about 2 miles north of Jonas and a few miles west of the head of Spring Creek. Flood waters from this stream appear to run off through Spring Creek; however, there is no distinguishable channel between the mouth of the arroyo and the head of Spring Creek.

A dry steep-sided valley extends west from Egbert to a point a few miles west of Hillsdale, where it ends. The main line of the Union Pacific Railroad follows the valley.

The Carpenter area is drained by Crow Creek and some unnamed tributaries of the South Platte River. Crow Creek is an intermittent stream throughout most of its course but is perennial where it enters the western part of the area and as far downstream as sec. 25, T. 13 N., R. 63 W. It is dry throughout the rest of its course in the Carpenter area except after heavy rains and in the early spring.

The principal tributary of Crow Creek in the Carpenter area is Porter Draw, which heads in the uplands southwest of Cheyenne and extends east-southeastward to its junction with Crow Creek at Hereford, Colo., about 2 miles south of the Wyoming-Colorado State line. Porter Draw also is an intermittent stream throughout most of its course, but it has a small perennial flow through its lower part in the Carpenter area.

POPULATION

Most of the Egbert-Pine Bluffs-Carpenter area consists of grazing and farm land and hence is sparsely settled. It has a population of about 2,000. According to the records of the U. S. Census Bureau for 1950, the population of the principal towns was as follows: Pine Bluffs, 846; Burns, 216; Carpenter, 114; and Hillsdale, 164.

TRANSPORTATION

The area is served by the Union Pacific and the Chicago, Burlington & Quincy Railroads and U. S. No. 30. Several graveled county roads traverse the area, some of which are improved and kept open throughout the year. Gravel or dirt roads are found on nearly every section line, and, although such roads become temporarily impassable at times during the year owing to snow or rain, they generally are in good condition.

AGRICULTURE

The principal crops in the Egbert-Pine Bluffs area are potatoes, alfalfa, beets, and corn, whereas wheat and hay are the principal crops in the Carpenter area. According to the information furnished to the Office of the State engineer by the irrigators, a total of 8,600

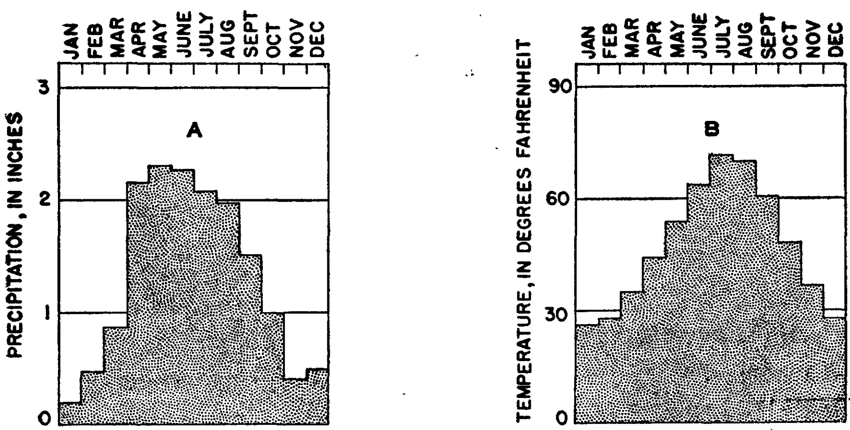

FIGURE 2.—*A*, Normal monthly precipitation at Pine Bluffs; *B*, Normal monthly temperature at Pine Bluffs.

acres in the Egbert-Pine Bluffs area and 1,200 acres in the Carpenter area were irrigated in 1949, mainly by ground water. In the uplands, where irrigation is not practiced, the principal products are livestock, wheat, and corn.

MINERAL RESOURCES

The principal mineral resource is ground water. Deposits of sand and gravel cover large parts of the area, and several gravel pits have supplied sand and gravel for road metal. No large pits are in operation, but many of the local residents use the sand and gravel in concrete aggregate for foundations.

CLIMATE

The climate is semiarid. There is scant to moderate precipitation and moderately high average wind velocity. The summer days are generally hot, but, owing to the movement of wind and the low humidity, the nights are relatively cool. The mean annual temperature at Pine Bluffs is 47° F.; the normal monthly temperature is shown in figure 2. The mean annual precipitation at Pine Bluffs is 15.68 inches, about two-thirds of which falls during April, May, June, July, and August (fig. 2).

GEOLOGY

SUMMARY OF STRATIGRAPHY

The rocks that crop out are sedimentary and range in age from Tertiary to Recent. The areal extent of these formations is shown on plate 1. A generalized section of the rocks exposed is given in table 1.

TABLE 1.—*Generalized section of the geologic formations exposed in the Egbert-Pine Bluffs-Carpenter area*

System	Series	Formation	Physical character	Thickness (feet)	Water supply
Quaternary.	Recent	Alluvium	Coarse sand and gravel containing beds and lenses of silt and clay.	0–85	Yields adequate water for stock, domestic, and—in some places—irrigation supplies.
		—Unconformity—			
	Pleistocene	Younger terrace deposits.	Sand and gravel containing a few thin beds of silt and clay.	10–60	Thicker deposits in Lodgepole valley yield adequate quantities of water for irrigation.
		—Unconformity—			
		Older terrace deposits.	Sand and gravel containing a few thin beds of silt and clay.	30–150	Yields large quantities of water for irrigation in the Carpenter area.
		—Unconformity—			
Tertiary.	Pliocene	Ogallala formation.	Beds of clay, silt, sand, sandstone, gravel, and algal limestone containing flint, chalcedony, and agate.	0–70	Yields adequate water supply to domestic and stock wells.
		—Unconformity—			
	Miocene	Arikaree sandstone.	Massive to poorly bedded fine-grained loose to moderately cemented sand containing layers of well-cemented sandstone.	0–80	Not known to yield water to wells in the area; however, in nearby areas yields sufficient water for stock and domestic purposes.
		—Unconformity—			
	Oligocene	Brule formation.	Massive fissured bentonitic siltstone that locally may be sandy or argillaceous. Contains joints and fissures and reworked zones of Brule pebbles.	±300	Yields large quantities of water to irrigation wells from fissures or zones of fracturing or pebbles beneath a cover of saturated gravel; otherwise, yields adequate water for domestic and stock purposes.

SUMMARY OF GEOLOGIC HISTORY

PALEOZOIC AND MESOZOIC ERAS

Sedimentary rocks of Paleozoic and Mesozoic age underlie the area but do not crop out. In adjacent areas to the south, west, and north these sedimentary rocks either are exposed or have been penetrated by drilling. Data obtained from studies in those areas constitute the basis of the following brief discussion of the pre-Tertiary geologic history of the area.

Pre-Cambrian rocks are directly overlain by Pennsylvanian strata, indicating that during early Paleozoic time this area was a land surface, or at least that any pre-Pennsylvanian rocks that were present were eroded away. Near the end of the Paleozoic era the Pennsylvanian sea advanced and shore-line conditions prevailed. The era ended with a widespread emergence of the land, resulting in the formation of shallow basins and low plains with wide mud flats. The climate was arid.

In early Mesozoic time, during the Triassic period, the gypsum and gypsiferous red clay and sand of the Chugwater formation were laid down under prevailingly arid climatic conditions. Local shallow basins and extensive mud flats predominated. Triassic time ended with extensive uplift which, although not causing local deformation, resulted in general planation and, in some places, deep channeling. Encroachment by the sea again took place, and sands and clays were deposited in a sea during Sundance time. Marine conditions gave way to continental conditions, and fresh-water sands and clays were laid down during Morrison time. The abundance of dinosaur remains and carbonaceous matter in the Morrison formation indicates that a humid climate prevailed. At the beginning of Lower Cretaceous time there was some uplift, after which near-shore sediments were deposited. Then the sea advanced, and during the remainder of Lower Cretaceous and most of Upper Cretaceous time thousands of feet of marine clay and sand were deposited. The sea began to retreat in the latter part of Fox Hills time, and a considerable thickness of sand was laid down on the great series of marine clay and sand. Marine conditions recurred locally during the middle of Lance time, and the Cretaceous period ended with extensive mountain making and the consequent deposition of continental sediments.

TERTIARY PERIOD

During Tertiary time repeated uplift and erosion of the Rocky Mountains caused recurrent deposition of material by streams. The Brule formation, which in part is derived from volcanic ash, was deposited during a period of relative quiescence in the area. The large amount of volcanic ash deposited during the Oligocene epoch indicates that extensive volcanism occurred, though at considerable distances from this area. The uniformity of the Brule formation is indicative of large-scale deposition in a broad basin which at times contained water.

The overlying Arikaree sandstone consists mainly of fine-grained sand, suggesting that it was laid down by streams during the relatively quiet times of the Miocene epoch. The beds of volcanic ash in the area show that sporadic volcanism took place during this epoch. The sources of the ash probably were at considerable distances from the area. Active erosion of the Arikaree sandstone and the subsequent deposition of the coarser stream-laid deposits of the Ogallala formation indicate that some rejuvenation of streams by uplift of areas to the west took place during Pliocene time. The algal limestone, which occurs locally at the top of the Ogallala formation, indicates that near the end of the Pliocene epoch fresh-water limestones were deposited in lakes.

QUATERNARY PERIOD

Streams that had been rejuvenated as a result of uplift at the close of the Tertiary period were enlarged by the increased supply of water during the Pleistocene epoch of the Quaternary period. The underlying Tertiary rocks were deeply eroded, and the process of cutting and filling of channels was so widespread that gravel and sand were deposited in sheetlike beds. The principal streams eroded deeply into the bedrock, cutting and building terraces along the channels and finally, in Recent time, depositing the alluvium that now underlies the flood plains (pl. 3).

GROUND WATER

PRINCIPLES OF OCCURRENCE

The following discussion of the occurrence of ground water has been adapted in part from Meinzer's report (1923a), to which the reader is referred for a more detailed treatment of the subject.

The rocks that form the outer crust of the earth generally contain numerous open spaces called voids or interstices, which may contain air, natural gas, oil, or water. The amount of water that may be stored in a rock depends upon the volume of the rock that is occupied by open spaces, that is, the porosity of the rock. A rock is said to be saturated when all its interstices are filled with water or other liquid. The porosity of a rock determines only the amount of water a rock can hold, not the amount it may yield to wells. The amount of water a rock will yield to a well depends on its permeability. The permeability of a rock is its capacity for transmitting water under pressure and is measured by the rate at which it will transmit water through

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a given cross section under a given difference of head per unit of distance. Deposits such as silt or clay may have a high porosity but, because the openings are very small, will transmit water very slowly. Well-sorted sand or gravel, which contains large openings that are freely interconnected, however, will transmit water readily. Part of the water in any deposit is not available to wells because it is held against the force of gravity by molecular attraction, that is, by cohesion of the molecules of the water and by their adhesion to the walls of the pores. Essentially all the water in a saturated clay may thus be prevented from draining into a well.

Below a certain level the permeable rocks generally are saturated with water and are said to be in the zone of saturation. The upper surface of the zone of saturation is called the water table. The rocks above the zone of saturation are in the zone of aeration, which normally consists of three parts: the belt of soil water, the intermediate or vadose zone, and the capillary fringe.

The belt of soil water lies just below the land surface and contains water held by molecular attraction. The soil zone generally must be saturated before appreciable amounts of water can percolate down to the water table. The thickness of the moist zone is dependent upon the character and thickness of the soil and upon the precipitation.

The intermediate or vadose zone lies between the belt of soil water and the capillary fringe. The larger interstices in the rocks in this zone generally are filled with air; however, when the zone of aeration is saturated (at least locally) the intermediate zone contains water moving downward from the belt of soil water to the water table. Water that is drawn into the smaller interstices in the capillary fringe by molecular attraction may become nearly or entirely stationary. The intermediate zone may be entirely absent in places, such as river valleys where the water table is near the surface, or it may be quite thick, as in the upland or interstream segments of the Brule formation in the Egbert-Pine Bluffs-Carpenter area.

The capillary fringe lies directly above the water table and is formed by water rising from the zone of saturation by capillary action. The water in the capillary fringe is not available to wells; they must penetrate the zone of saturation before water will enter them. The water in the fringe, however, is available to plant roots where they can reach it. The capillary fringe is of negligible thickness in coarse sand or gravel but may be several feet thick in fine-grained sediments.

THE WATER TABLE AND MOVEMENT OF GROUND WATER

The water table is defined as the upper surface of the zone of saturation, except where that surface is formed by an impermeable body (Meinzer, 1923b, p. 30). The water table also may be considered as the boundary between the zone of saturation and the zone of aeration. The water table is not a static, plane surface but generally has many irregularities owing to differences in thickness and permeability of the water-bearing materials, and normally it fluctuates up and down in response to local differences in the gain or loss of water.

Plate 1 shows the shape and position of the water table by contour lines. These represent lines of equal altitude on the water table and are based on the measured altitude of the water surface in many wells. The direction of movement of ground water generally is at right angles to the contour lines in the direction of the downward slope. Throughout most of the area the general movement of ground water is eastward, but the slope and direction of movement are variable from one part of the area to another. The average slope of the water table in the area is about 25 to 30 feet to the mile.

Irregularities in the shape and slope of the water table, shown on plate 1, may be caused largely by discharge of ground water into streams, recharge of the ground-water reservoir by precipitation or by intermittent streams, local differences in the thickness and permeability of the deposits, and the pumping of large amounts of water from wells for irrigation.

IRREGULARITIES CAUSED BY DISCHARGE OF GROUND WATER INTO STREAMS

Along Spring Creek and the lower stretches of Lodgepole and Muddy Creeks that have perennial flow the contour lines generally bend slightly upstream, indicating that a trough in the water table underlies that part of the valley. Within the trough the ground water moves toward the streams from both sides and is discharged into the channels of the streams. A similar condition exists along several of the tributaries of Muddy Creek.

IRREGULARITIES CAUSED BY RECHARGE FROM STREAMS

Ephemeral streams are streams that flow only after rains. Their channels lie above the water table and are dry most of the time. During periods of flow much of the water seeps into the stream bed and thence downward to the ground-water reservoir. Streams that lose water to the water table are influent. Lodgepole Creek, from Egbert to the head of the lower flowing stretch of the stream, and Crow Creek are excellent examples of influent streams. Along these streams the water-table contours have a pronounced downstream bulge, indicating a ridge on the water table below each stream. Such ridges or mounds indicate that recharge to the ground-water reservoir is greater along the streams than in the interstream areas.

IRREGULARITIES CAUSED BY DIFFERENCES IN THICKNESS AND PERMEABILITY OF THE DEPOSITS

The east-west trough in the water table just north of Carpenter coincides with coarse-grained channel deposits, the location of which is known from well logs, test holes, and outcrops of gravel. The trough is due to the higher permeability of the deposits, which permits water to flow more readily at a lower gradient. A pronounced north-south trough in the water table occurs just west from the Pine Bluffs escarpment in the southeastern part of the area. This trough results, in part, from heavy pumping for irrigation from wells along Muddy Creek below the bend in the creek, but it is due largely to the presence of a thicker or more permeable zone in the Brule formation along the north-south axis of Muddy Creek which allows the water to drain rapidly northward.

The pronounced flattening of the water table in the area southeast of Carpenter in T. 12 N., R. 62 W., is caused by an increase in the thickness and permeability of the sand and gravel underlying the area. The steepness of the slope of the water table throughout the rest of the area is caused by the relatively low permeability of the Ogallala and Brule formations.

IRREGULARITIES CAUSED BY PUMPING

The several troughs in the water table, between which ridges remain, in the area just northwest of Pine Bluffs are caused mainly by the pumping of large quantities of water for irrigation. In that area the water-table fluctuations are greatest, and the ridges and troughs are most pronounced during the pumping season.

FLUCTUATIONS OF THE WATER TABLE

The water table in any area does not remain static but fluctuates much like the level of a surface reservoir. If the inflow to the ground-water reservoir exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow, the water table will decline. During a period of dry years the water table declines, but in subsequent wet years it rises. The decline during dry years does not necessarily mean there has been an excessive withdrawal of water from the ground-water reservoir but may indicate only that less recharge was received during the years of deficient precipitation. Such a decline in water level may be accelerated, however, if the discharge of ground water is increased by pumping for irrigation or other purposes or by increased evapotranspiration, or by both.

The fluctuations of the water table in the Egbert-Pine Bluffs-Carpenter area were determined by observing the water levels in selected observation wells. Water levels have been measured periodically in the Egbert-Pine Bluffs area since November 1940 and in the

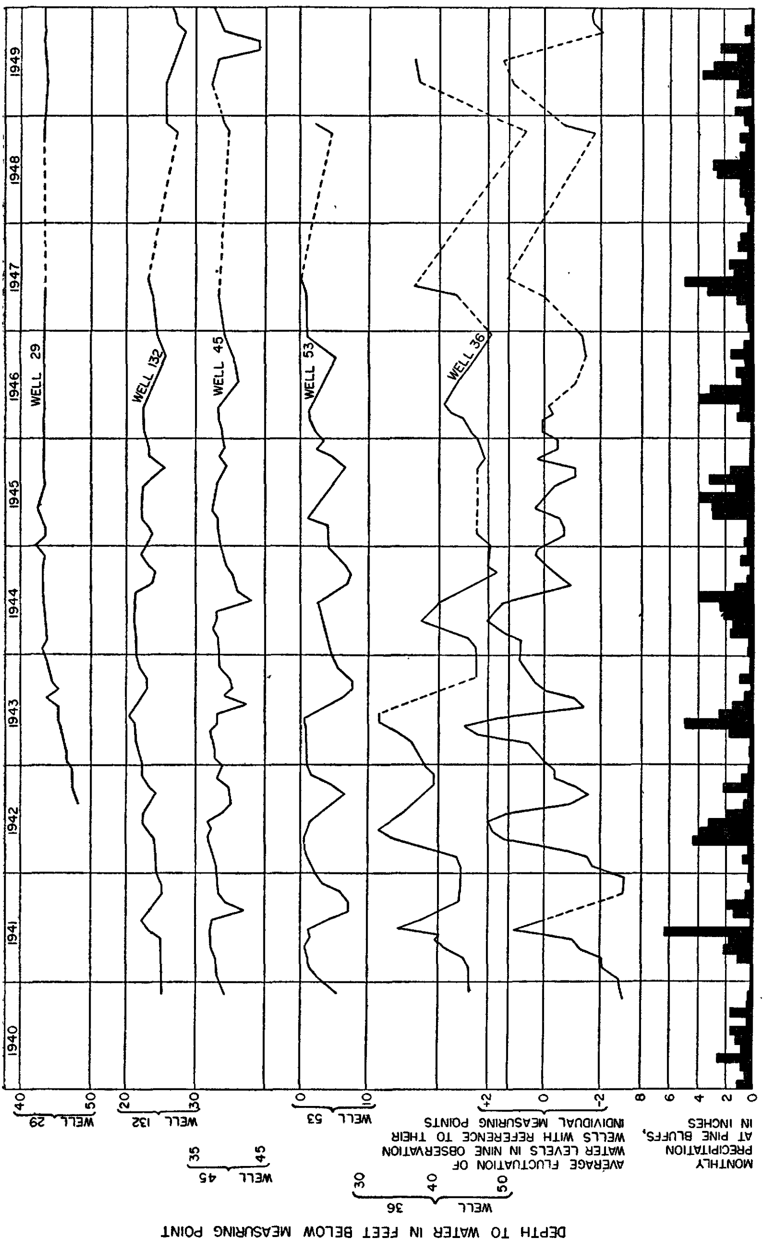

FIGURE 3.—Hydrographs showing fluctuation of water levels.

Carpenter area since September 1942 by members of the Geological Survey. Hydrographs showing fluctuations of water levels in five observation wells in the Egbert-Pine Bluffs-Carpenter area are given in figure 3, which includes also a composite graph showing average fluctuations in these (except well 53) and five other wells. The fluctuations were plotted by using depths to water below measuring points.

Water-level measurements made during the years 1940–48 have been published in annual water-level reports of the U. S. Geological Survey (Water-Supply Papers 910, 940, 948, 990, 1020, 1027, 1075, 1100, and 1130). The measurements for 1949 and subsequent years will be published in ensuing reports of this series.

FLUCTUATIONS CAUSED BY TRANSPIRATION

Hydrographs show different patterns of fluctuation in the observation wells in the area. Well 53 (fig. 3) is typical of wells in which the water level declines during the growing season because of the transpiration of ground water by plants. The water levels generally fluctuate as a result of transpiration along the stream channels where the water level is near the surface. The water level in well 53 declines each year beginning in March, April, or May; the decline persists until September or October, when the water level begins a more or less steady rise and reaches its peak in March, April, or May.

FLUCTUATIONS CAUSED BY PRECIPITATION

In this area normal or moderate precipitation generally does not cause fluctuations of the water table of more than 0.5 foot. Intense or sustained precipitation causes a marked rise in water levels in wells penetrating the Brule formation and the Pleistocene deposits. This is shown by the hydrograph of well 132 (fig. 3), in which the water level remains relatively constant during the year except for a sharp increase beginning in April and May in the years when there is increased precipitation, followed by a slow decline starting in June or July. These water-level rises correspond closely to the heaviest periods of precipitation in each year.

FLUCTUATIONS CAUSED BY SEEPAGE FROM STREAMS

The hydrograph of well 36 (fig. 3) illustrates a third type of fluctuation, where seepage from an intermittent stream appears to be the controlling factor. The hydrograph indicates that the water level rose during the early spring of each year and began to decline in May. The rise of the water level in the well corresponds to the lengthening of the stretch of perennial flow of Muddy Creek, and the decline of the water level corresponds to the retreat of the lower end of the stretch of perennial flow as increased transpiration along

Muddy Creek becomes effective. The hydrograph of this well also shows the effects of heavy precipitation in early spring. The five wells for which individual hydrographs are given in figure 3 obtain water from the Brule formation, and their hydrographs show fluctuations typical of the wells in that formation. In all the wells in the area the general pattern of fluctuation follows one or a combination of two of the types illustrated.

FLUCTUATIONS CAUSED BY PUMPING

The water levels in wells adjacent to pumped irrigation wells fluctuate in accordance with the periods of pumping. The amount of fluctuation depends to a large extent upon the distance between the observation well and the pumped well, the fluctuation being greater in the immediate vicinity of the pumped well.

The fluctuation of the water table in the area of irrigation development is seasonal, the water table generally reaching its highest stage in the spring and early summer and its lowest stage in the fall. The water table in the area of heavy pumping fluctuates as much as 10 feet annually. The hydrograph of well 45 (fig. 3) shows the fluctuations caused by pumping. Also, over a period of time, there may be an over-all lowering of the water table in areas of considerable development. Hydrographs of wells 36, 45, and 132 show a slight decline for the period of record. These wells are in local areas of considerable development and therefore are affected by relatively heavy pumping from nearby wells. Thus the over-all increase in the development of these local areas has modified somewhat the raising of the water table in them by the generally annual increase in precipitation from 1941–49. (See fig. 4, graph *B*.)

FLUCTUATIONS IN THE UPLAND AREAS

The ground-water levels in the upland areas, where there is no pumping for irrigation, are characterized by only a slight seasonal fluctuation. This is illustrated by the hydrograph of well 29 (fig. 3). Recharge to the area near well 29 is from precipitation; hence fluctuations in this well should reflect variations in precipitation. By comparing the hydrograph of well 29 and the graph showing the cumulative departure from normal in precipitation (fig. 4, graph *B*), the upward trend in the water-level curve from 1942–45 is seen to result from a progressive increase in precipitation, and the more-or-less flattening of the curve (1945–49) indicates a period in which relatively even, normal precipitation occurred. In the upland area only very small amounts of water are withdrawn annually for domestic and stock use, whereas in the irrigated areas large amounts of water are withdrawn for irrigation.

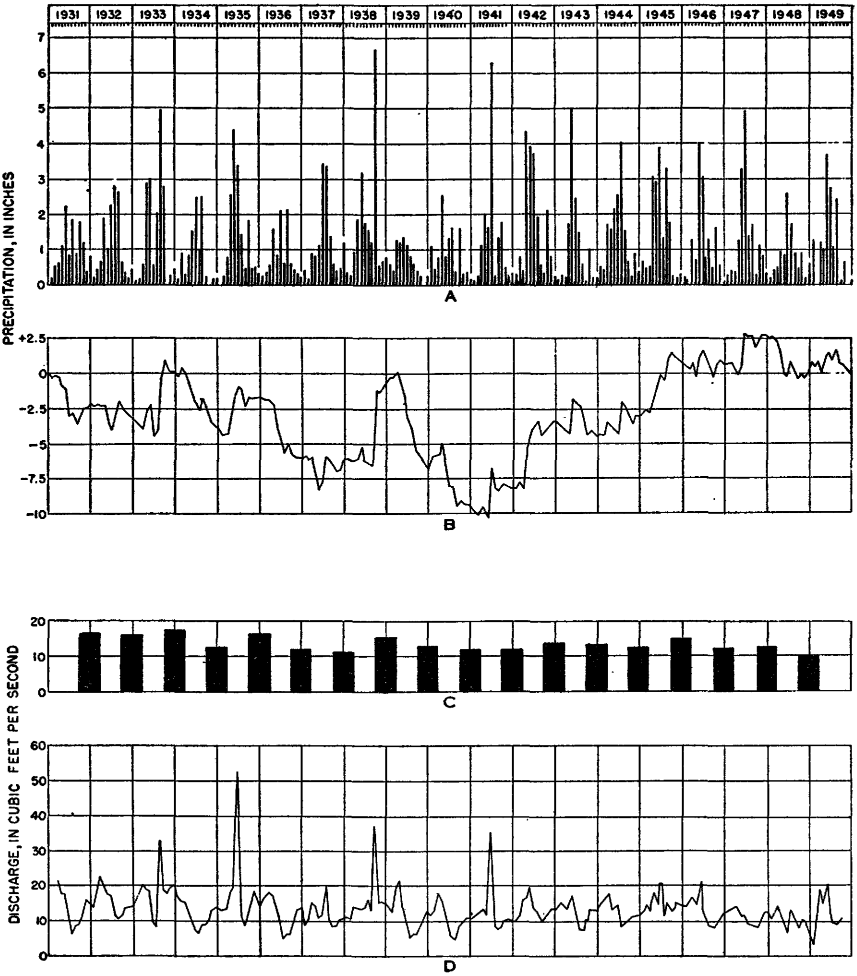

FIGURE 4.—Graphs showing (*A*) monthly precipitation and (*B*) cumulative departure from normal precipitation at Pine Bluffs, Wyo., and (*C*) mean winter flow and (*D*) mean discharge of Lodgepole Creek at Bushnell, Nebr.

GROUND-WATER RECHARGE

Recharge is the addition of water to the ground-water reservoir, and, other things being equal, the average recharge is equal to the total average discharge; thus in nature a ground-water reservoir is in approximate balance or equilibrium. Discharge from wells is an artificial discharge superimposed upon a previous system which has been in equilibrium and causes the system to become unbalanced. Before the system can reach a new equilibrium water levels must fall throughout the aquifer enough to increase the natural recharge or decrease the natural discharge, or both, by an amount equal to the amount discharged by the wells. Until this new equilibrium can be established, water must be taken from storage in the aquifer.

Recharge in the Egbert-Pine Bluffs-Carpenter area is derived mainly from three sources: Subsurface inflow from the west, seepage from streams entering the area from the west, and precipitation within the area.

SUBSURFACE INFLOW FROM THE WEST

Subsurface inflow from the west contributes a part of the recharge to the Ogallala and Arikaree formations in the Egbert-Pine Bluffs-Carpenter area (pl. 1). In the interstream areas west of the Pine Bluffs lowland and west of the Carpenter area it is thought that some water from the Ogallala and Arikaree formations in turn moves directly into the Brule formation.

RECHARGE FROM STREAMS

Seepage from streams entering the Egbert-Pine Bluffs lowlands from the west and seepage from Crow Creek as it enters the Carpenter area from the west are important sources of recharge to the area. Lodgepole and Muddy Creeks have perennial flows near the points where they emerge from the upland plains onto the lowland belt in the Egbert-Pine Bluffs area. The perennial flows of these creeks are maintained by ground water discharged from the beds overlying the Brule formation to the west. Crow Creek also has a perennial flow in the western part of the Carpenter area, maintained principally by ground-water discharge from the Ogallala formation. The water table in the valley bottoms along the stretches of perennial flow is near the surface; hence during the summer considerable ground water is discharged by evaporation from the soil and by transpiration from plants. During the winter transpiration ceases and evaporation is at a minimum; consequently the quantity of ground-water discharge into the channels of the streams increases. The perennial flows of Lodgepole and Muddy Creeks that reach the Brule formation disappear into its weathered and creviced parts. The small perennial flow of Crow Creek disappears into the older Quaternary terrace deposits at the head of the Crow Creek embayment. Lodgepole Creek has a perennial flow of 1 to 5 cfs, all of which disappears near Egbert. The normal winter flow of Muddy Creek is estimated at about 5 cfs, but during the summer the quantity of water contributed by the perennial flow of Muddy Creek probably is about 1 cfs. In years of normal stream flow the average rate of contribution of water to the Brule formation in the Egbert-Pine Bluffs-Carpenter area is believed to be about 6 cfs. Crow Creek is estimated to have an average winter flow of about 10 cfs, and it is believed that a yearly average of about 5 cfs is contributed as recharge to the gravel in the

Carpenter area. Therefore the average annual recharge from stream flow to the Brule formation and the gravel in the area is about 8,000 acre-feet.

RECHARGE FROM PRECIPITATION

Recharge from precipitation is the major contributing factor to the over-all recharge of the area. Some of this water runs off into the streams, some is held by the soil and is evaporated later at the surface or is transpired by plants, and some percolates downward to the water table—particularly during long, moderately heavy rains.

In the area east of Carpenter underlain by the older terrace deposits surface runoff is at a minimum, and no pronounced channels are developed on the land surface. That there is little surface runoff even after moderately heavy rains indicates that rainfall penetration to the ground-water reservoir through the porous and permeable terrace deposits is relatively high.

During periods of intense precipitation in late spring or early summer in the Egbert-Pine Bluffs area, major contributions of water are made to the ground-water reservoir, both by rainfall penetration and by seepage from streams. It is difficult to distinguish the relative effects of recharge from direct precipitation and recharge from streams during these periods, as both take place at the same time.

During the period of record in the Egbert-Pine Bluffs-Carpenter area the water levels have fluctuated in response to the amount and concentration of the precipitation. There was a net rise of 0.47 foot in the water levels in five representative wells in the Brule formation in the Pine Bluffs lowlands from 1940 through 1945 (table 2, wells 36, 111, 117, 132, and 171). In the Carpenter area there was a net rise of 1.37 feet in the water table for the period 1944–49 (table 2, wells 7, 29, and 45). From December 1946 to December 1949 the water levels in eight wells in the Egbert-Pine Bluffs-Carpenter area declined an average of about 0.6 foot, but there has been an average net rise of about 1.3 feet since 1940. (See table 2.) The general rise in the water levels prior to January 1, 1947, was caused primarily by the heavy precipitation, which was 3.89 inches above the normal for the period 1931–49. The decline in water levels from January 1, 1947, through December 1, 1949, was caused primarily by the low precipitation, which was 5.09 inches below normal during this period.

TABLE 2.—*Water levels in observation wells in the Egbert-Pine Bluffs-Carpenter area*

December water levels below measuring point, in feet

Well no.	1940	1941	1942	1943	1944	1945	1946	1948	1949
7			--------	--------	33.68	33.17	33.32	32.55	31.60
29	--------	--------	47.30	43.78	43.47	43.39	43.37	43.28	43.18
36	49.29	43.72	42.28	45.59	[1] 47.23	45.95	47.34	--------	--------
45	[1] 40.30	39.51	39.05	38.67	39.30	39.17	39.64	39.56	38.30
111	--------	--------	--------	29.41	29.86	35.38	36.84	[2] 39.15	38.63
117	--------	--------	--------	23.82	23.95	23.69	23.66	[2] 24.57	24.24
132	25.45	24.88	22.53	21.88	23.05	23.05	24.94	25.78	27.00
171	30.62	30.05	28.74	29.10	29.54	29.84	30.42	30.98	31.76
193	--------	--------	--------	--------	--------	56.24	57.86	55.03	59.51

Rise (+) or decline (−) in water level, in feet

Well no.	1940 to 1941	1941 to 1942	1942 to 1943	1943 to 1944	1944 to 1945	1945 to 1946	1946 to 1948	1948 to 1949	1940 to 1949
7			--------	--------	+0.51	−0.15	−0.23	+0.95	--------
29	--------	--------	+3.52	+0.31	+.08	+.02	+.09	+.10	--------
36	+5.57	+1.44	−2.31	−1.64	+1.28	−1.39	--------	--------	--------
45	+.79	+.46	+.38	−.63	+.13	−.47	+.08	+.26	--------
111	--------	--------	--------	−.45	−5.52	−1.46	−2.31	+.52	--------
117	--------	--------	--------	−.13	+.26	+.03	−.91	+.33	--------
132	+.57	+2.35	+.65	−1.17	0	−1.89	−.84	−1.22	--------
171	+.57	+1.21	−.36	−.44	−.30	−.58	−.56	−.78	--------
193	--------	--------	--------	--------	--------	−1.62	+2.83	−4.48	--------
Average net change	+1.87	+1.36	+.38	−.59	−.45	−.63	−.12	−.54	+1.28

[1] Interpolated measurement.
[2] Measurement for October 12, 1948.

During 1941 and 1942 there were two periods of excessive precipitation accompanied by a general rise in water levels in the wells penetrating the Brule formation in the Egbert-Pine Bluffs area. The first of these periods occurred in June 1941 after a rainy period in which 5.56 inches of rain fell at Pine Bluffs. The following year the water levels rose again in response to a rainy period in May and June when the precipitation at Pine Bluffs amounted to 5.78 inches. The water levels rose throughout the entire lowland area, but the largest rises were recorded in wells near the normally dry stretches of Chevington Draw and Muddy Creek after floods in these streams. In 1943 and 1944 there were no comparable periods of intense precipitation or rises in water level. Moderately heavy rains on June 20, 1945, were accompanied by a moderate rise in water levels. During 1946 there were no periods of intense precipitation in the late spring and early summer; hence the water levels did not rise.

During 1947 the water levels showed a moderate rise in response to relatively intense precipitation in May and June. No measurements were made in the spring of 1948, and it is not known to what extent the water levels fluctuated. There were no periods of intense precipitation in the late spring and early summer of 1949, and the water levels did not rise appreciably.

Based on recharge from precipitation of 0.83 inch annually, calculated for the Cheyenne area by Littleton and Foley (personal communication), the total recharge from precipitation in the area (380 square miles) is about 16,800 acre-feet per year. This value of 0.83 inch for the Cheyenne area is considered to be applicable to the area covered by this report because the two areas are adjacent and similar.

CONCLUSIONS

Intensive precipitation in the late spring produces the principal recharge to the ground-water reservoir in this area. In all the years but 1940, 1944, and 1948 the precipitation at Pine Bluffs was above normal during May and June, and, although the rains were scattered, the recharge resulting from this precipitation apparently is reflected in the water-level fluctuations in 1941, 1942, 1943, and 1947 as shown in the hydrographs in figure 3. Intense rains or repeated rains of moderate intensity are effective in recharging the Brule formation. Scattered light rains, although they may produce above-normal monthly precipitation, are less effective in recharging the ground-water reservoir.

In the Carpenter area the main sources of recharge are rainfall penetration and seepage from Crow Creek. The amount of water contributed by rainfall penetration alone was not determined but is believed to be relatively high. Crow Creek contributes about 3,600 acre-feet of water annually to the Carpenter area, but it is not known how much of this water crosses the Wyoming-Colorado State line into Colorado as underflow in the stream channel. The total amount of recharge available to the Carpenter area from both main sources is estimated at about 6,000 acre-feet per year.

It has not been practicable to measure directly the amount of recharge from each of the several sources, particularly recharge from rainfall penetration and seepage from flash floods. Normally the quantity of recharge to the ground-water reservoir is balanced by an equivalent quantity of water that is discharged from the reservoir, plus or minus the net change in storage; therefore, by measuring the total quantity of water discharged from an aquifer it is possible to approximate the amount of recharge. (See the following section.)

GROUND-WATER DISCHARGE

Water is discharged from the ground-water reservoirs in the Egbert-Pine Bluffs-Carpenter area through transpiration and evaporation, seepage into streams, springs, wells, and underflow that leaves the area. The relation between discharge and recharge and the added effect of discharge from wells upon the previously existing natural hydraulic system are discussed on pages 17–19. The principal types of discharge in this area are discussed below.

DISCHARGE BY TRANSPIRATION AND EVAPORATION

Water may be taken into the roots of plants directly from the zone of saturation and may be discharged by plants through the process known as transpiration (Meinzer, 1923b, p. 48). The depth from which plants commonly lift ground water ranges from a few feet for most plants to more than 100 feet for some desert plants.

The discharge of ground water by transpiration and evaporation in the Egbert-Pine Bluffs-Carpenter area is limited primarily to the valley floors adjacent to the stretches of perennial flow of the streams where the water table is relatively near the surface. The amount of water discharged through these processes probably is very small in areas where the water table lies at depths greater than 20 feet. The effect upon the water table of discharge by transpiration from the ground-water reservoir is discussed on page 16.

DISCHARGE FROM SPRINGS

A small quantity of ground water is discharged through springs from the strata of post-Brule age. Most of the few springs in the area are along the western edge of the Pine Bluffs lowland. These springs issue at the contact between the Brule formation and overlying beds and hence are known as contact springs.

DISCHARGE FROM WELLS

According to the data supplied to the Wyoming State engineer's office by the irrigators and town officials in this area, about 14,500 acre-feet of water was pumped in 1947 for irrigation and public supply, but it is believed that this figure is in excess of the actual amount and that about 10,000 acre-feet would be more nearly accurate. An estimated total of 15,000 acre-feet was pumped in 1949. Most of the rural residents of the area derive their supplies of domestic and stock water from wells, but the amount of discharge for these purposes is thought to be about 100 acre-feet.

DISCHARGE BY UNDERFLOW FROM THE AREA

A large quantity of water leaves the Egbert-Pine Bluffs area by moving eastward into Nebraska beneath the valley of Lodgepole Creek. The valley of Lodgepole Creek decreases in width from about 3 miles at the State line to about 0.6 mile at Bushnell, 10 miles east of Pine Bluffs, where the top of the Brule formation passes beneath the "mortar beds" of the Ogallala formation in the floor of the valley. Additional water is discharged from the Brule and the alluvium as the width of the valley decreases.

Several measurements of the flow of Lodgepole Creek near the State line in 1895, 1904, and 1915 were given by Meinzer (1917, p. 45), and since March 1, 1931, the Geological Survey has maintained a gaging station on Lodgepole Creek near Bushnell. Except for flash floods, all the flow of Lodgepole Creek above the gaging station at Bushnell is derived from ground-water discharge.

The flow of Lodgepole Creek near the State line reported by Meinzer was 3.5 cfs in August 1895, 4.3 cfs on May 2, 1904, and 6.09 cfs on September 21, 1915. These measurements of the stream flow do not represent the total ground-water discharge upstream from the State line because they were made in the summer when a considerable quantity of ground water was being transpired and evaporated from the valley floor.

The mean discharge of Lodgepole Creek near Bushnell for each month from March 1931 through September 1949 is given in table 3 and is shown graphically in figure 4.

TABLE 3.—*Mean discharge of Lodgepole Creek at Bushnell, Nebr.,*[1] *in cubic feet per second*

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average monthly
1931	------	------	------	------	------	21.2	17.7	17.8	9.3	6.0	8.4	9.1	--------
1931–32	11.9	16	15	14	18	22.8	20.6	17.7	17.0	11.7	10.0	11.2	15.2
1932–33	13.6	13.7	13.9	26	17.6	20.6	19.0	18.6	9.4	8.2	34.3	18.4	17.9
1933–34	17.5	19.1	20	17	15.9	15.4	13.6	9.8	7.8	6.5	9.1	9.1	13.4
1934–35	10.6	13.4	13.9	13.2	13.4	13.5	12.8	20.1	52.4	12.3	8.6	11.1	16.6
1935–36	14.9	18.5	13.4	16.2	17.0	18.1	17.3	13.6	10.1	4.24	5.94	6.44	12.9
1936–37	9.48	13.3	13.3	8.37	11.1	15.8	14.4	10.9	11.9	19.8	11.0	8.08	12.3
1937–38	8.71	10.1	10.4	11.0	10.6	14.2	13.9	13.4	13.4	16.2	13.0	38.0	14.4
1938–39	15.1	15.6	15.5	13.5	12.6	19.1	21.5	13.3	8.35	5.21	6.35	6.25	12.7
1939–40	8.88	11.0	12.8	11.3	13.2	18.0	15.5	12.0	7.46	5.33	4.85	8.60	10.7
1940–41	9.96	10.6	10.7	11.2	12.6	13.4	13.4	10.9	35.8	8.73	7.43	8.02	12.7
1941–42	10.3	10.8	10.6	9.74	11.8	15.9	16.2	20.0	14.1	12.9	10.3	10.9	12.8
1942–43	11.5	13.0	13.6	13.2	15.3	13.6	16.0	17.7	13.0	9.9	8.0	7.8	12.7
1943–44	10.5	13.0	12.8	12.0	15.1	16.6	17.7	13.5	13.7	14.3	8.5	9.3	13.1
1944–45	10.5	10.9	11.1	12.6	14.3	12.5	17.4	14.9	20.6	11.4	15.1	12.7	13.7
1945–46	14.8	14.5	14.0	14.0	15.1	16.3	14.0	20.7	11.8	8.74	8.16	8.08	13.4
1946–47	9.32	11.1	12.3	12.6	13.3	13.5	14.0	11.5	11.8	9.92	9.1	8.51	11.4
1947–48	10.2	12.4	12.8	10.8	12.6	14.9	12.1	9.53	6.89	13.0	11.2	8.06	11.2
1948–49	10.13	9.58	5.74	3.0	8.12	19.46	15.2	19.86	13.7	9.91	9.36	10.4	11.2
Average	11.55	13.14	12.82	12.76	13.76	16.57	15.91	15.04	15.18	10.26	10.46	11.05	--------

[1] Surface Water Supply of the United States, part 6, Missouri River basin: U. S. Geol. Survey Water-Supply Paper 716, 1931, p. 247; 731, 1932, p. 239; 746, 1933, p. 193; 761, 1934, p. 254; 786, 1935, p. 263; 806, 1936, p. 274; 826, 1937, p. 27; 856, 1938, p. 306; 876, 1939, p. 329; 896, 1940, p. 352; 926, 1941, p. 362; 956, 1942, p. 356; 976, 1943, p. 353; 1006, 1944, p. 351; 1036, 1945, p. 350; 1056, 1946, p. 441; 1947, 1948, and 1949 from unpublished records of U. S. Geol. Survey. Area of drainage basin above gaging station, 1,090 square miles.

The discharge of Lodgepole Creek generally varies widely in the summer owing to storm runoff, but it also varies seasonally owing to changes in the rate at which ground water is discharged into the stream. The sustained flow is least during the summer when considerable ground water is being transpired and evaporated and greatest in the winter when such draft ceases or is greatly reduced. The summer flow is reduced also by the pumping of large amounts of water for irrigation in the Egbert-Pine Bluffs area. Because transpiration and evaporation, direct runoff, and withdrawal by wells are neglible during the winter, the winter discharge of the stream approximates the average annual rate of ground-water discharge from the area above the gaging station. The mean daily discharge during the winter, October 1 through March 31, is given in table 4 and is shown graphically in figure 4.

As shown in figure 4, the winter discharge has varied from year to year, depending mainly upon the amount and intensity of the precipitation during the preceding summer. The correspondence between the variation in mean winter discharge of the stream and the amount of precipitation received during the preceding summer is shown by comparing graphs *B* and *C*, figure 4. The winter flow of Lodgepole Creek was relatively high when the preceding year was average, except for heavy summer precipitation, whereas the winter flow was relatively low after summers in which there were no heavy or sustained rains. The graphs also show a declining trend in the flow that affects both the relatively high and relatively low stages of the stream. The downward trend in the winter flow probably results in part from the sustained period of deficient precipitation (graph *B*) but also results in part from the fact that pumping in the Pine Bluffs area increased from an estimated 1,300 acre-feet in 1936 to an estimated 15,500 acre-feet in 1949.

TABLE 4.—*Mean annual discharge of Lodgepole Creek at Bushnell, Nebr., from October 1 through March 31 for the years 1931–49*

Year	*Cubic feet per second*	*Year*	*Cubic feet per second*
1931–32	16.3	1942–43	13.4
1932–33	[1] 15.7	1943–44	13.3
1933–34	17.2	1944–45	11.9
1934–35	12.8	1945–46	14.8
1935–36	16.2	1946–47	12.0
1936–37	11.7	1947–48	12.3
1937–38	10.7	1948–49	9.6
1938–39	15.1	1949–50	10.4
1939–40	12.5		
1940–41	11.3	Average	12.9
1941–42	11.4		

[1] The estimated discharge for January 1932, based on one measurement, is believed to be too high and was not used in determining the mean daily discharge.

The variation in mean daily winter flow from year to year indicates a rather rapid adjustment between the recharge and discharge of ground water. As the large variations in recharge occur during relatively short periods of the summer and seem to reach approximate equilibrium with the natural discharge by winter, it appears probable that the adjustment between pumping and natural discharge also is made in a rather short time and, hence, that the natural discharge has been reduced by pumping. The probability that increased pumping has reduced the natural discharge from the aquifer is supported by the fact that the flow was less in the winter of 1944–45 than in the winter of 1943–44.

Although much of the ground water in the Brule formation is discharged above Bushnell, three irrigation wells in sec. 33, T. 14 N., R. 57 W., near the gaging station indicate that there is considerable underflow past the station. One well penetrated 80 feet of alluvium consisting largely of gravel; the other two were drilled through the Ogallala formation and yielded water from fissures in the underlying Brule formation. All three wells have yields of 1,000 gpm or more and have high specific capacities indicating a relatively high transmissibility.

The transmissibility of the aquifers beneath the valley at Bushnell appears to be roughly equal to that of the aquifers beneath the valley at the State line, but the width of the valley at Bushnell is considerably less. Assuming equal coefficients of transmissibility and equal gradients, the ratio of the underflow at Bushnell to that at the State line should be about the same as the ratio between the widths of the valley at the two points. The valley is about 3 miles wide at the State line and about 0.6 mile wide at Bushnell; therefore the underflow at Bushnell should be about one-fifth as great as that at the State line. The remaining four-fifths would discharge into the creek or would be discharged by evapotranspiration and wells in the stretch between the two points. In view of the fact that evapotranspiration and pumping may be considered negligible during the winter, the flow at the Bushnell gaging station for the winter months should represent the flow at the State line plus four-fifths of the underflow at the State line. From the increase in flow between the State line and the Bushnell gaging station, it is estimated that the underflow at Bushnell amounts to about 1.5 cfs.

It is thought that the underflow at Bushnell is relatively constant from year to year, as the water table in the narrow valley above the gaging station is relatively stable owing to the proximity of the stream. Pumping, however, has increased greatly since 1938, and the natural discharge into Lodgepole Creek varies widely from year to year. The total ground-water discharge from the area above Bushnell is the sum of the underflow at Bushnell, the flow of Lodgepole Creek at the gaging station, and the amount of ground water used for irrigation. These are tabulated in table 5.

TABLE 5.—*Estimated discharge in the Egbert-Pine Bluffs area for the years 1941–49*

Year	Acreage irrigated	Average mean winter discharge of Lodgepole Creek at Bushnell (cubic feet per second)	Estimated underflow at Bushnell (cubic feet per second)	Estimated total surface and subsurface discharge		Estimated consumptive use of ground water, at 0.75 acre-foot per acre (acre-feet per year)	Estimated total discharge (acre-feet per year) [1]
				Cubic feet per second	Acre-feet per year		
1941	5,225	11.35	1.5	12.85	9,200	3,900	13,100
1942	[2] 5,600	12.40	1.5	13.90	10,000	4,200	14,200
1943	[2] 5,900	13.35	1.5	14.85	10,700	4,400	15,100
1944	[2] 6,300	12.6	1.5	14.1	10,200	4,700	14,900
1945	[2] 6,800	13.35	1.5	14.85	10,700	5,100	15,800
1946	[2] 7,300	13.40	1.5	14.90	10,800	5,500	16,300
1947	8,000	12.3	1.5	13.8	10,000	6,000	16,000
1948	8,300	9.55	1.5	11.05	8,000	6,200	14,200
1949	8,600	10.36	1.5	11.86	8,600	6,400	15,000

[1] Estimated discharge equals average mean winter discharge plus underflow at Bushnell plus estimated consumptive use of water.
[2] Estimated.

On the basis of the relation between discharge and recharge, (recharge is equal to the discharge plus or minus the change in ground-water storage) it is possible to set up a ground-water equation if sufficient data are available. In the Egbert-Pine Bluffs-Carpenter area not enough measurements were made to provide sufficient data for the ground-water equation; however, an approximate evaluation can be made on the basis of computations involving both measured and estimated data.

Recharge from stream flow is about 8,000 acre-feet per year for the entire area. (See section on "Recharge from streams," p. 20.) Recharge from precipitation is about 16,800 acre-feet. (See p. 22.) Therefore, the total recharge to the area is about 24,800 acre-feet per year. The average annual discharge from only the Egbert-Pine Bluffs area is about 15,000 acre-feet. (See table 5.) No estimate was made for the discharge from either the much smaller Carpenter area or evapotranspiration by native vegetation.

The increase in ground-water storage for the entire area was about 51,000 acre-feet over a 9-year period, based on an average net rise of 1.3 feet and a specific yield of an estimated 0.15. Then recharge to the entire area R would be equal to the discharge from the Egbert-Pine Bluffs area (D_e, average for 9 years) plus the discharge from the Carpenter area D_c plus the evapotranspiration along streams E_t plus the over-all change in storage (S, average for 9 years).

$$R=D_e+D_c+E_t+S$$

$$24,800=15,000+D_c+E_t+5,700$$

$$4,100=D_c+E_t$$

As neither D_c nor E_t is known, it is estimated that about half the amount is discharged in each manner. Therefore, about 2,000 acre-feet is discharged by stream and underflow from the Carpenter area per year, and about 2,100 acre-feet is discharged from the entire area by evapotranspiration per year.

RECOVERY OF GROUND WATER

SPRINGS

Some ground water is recovered in this area through small springs and seeps. The springs have very small yields, and most of the water discharged from them is not used beneficially.

The springs and seeps are caused by water percolating from permeable material along outcrops of the water table. Springs and seeps of two types are found in the Egbert-Pine Bluffs-Carpenter area: Depression springs and seeps, from which the water issues at the surface because the land surface is below the water table; and contact springs, from which the water issues at the surface because its downward percolation is retarded or prevented by a relatively impermeable bed. Depression springs and seeps are found in the alluvium in the major stream valleys, and contact springs are found at places where terrace gravel or the Ogallala and Arikaree formations overlie the Brule formation.

WELLS

In the Egbert-Pine Bluffs-Carpenter area there is but one flowing artesian well. In general water from wells is recovered by the use of pumps. When a well is pumped, the water table near the well declines and takes the form of an inverted cone, called the cone of depression. The cone of depression may extend for great distances laterally from the pumped well. The difference between the static water level and the pumping water level in the well, which is at the apex of the cone of depression, is called the drawdown of the well. The higher the rate at which a given well is pumped, the greater the drawdown and, also, the larger the cone of depression. At the start of pumping, the water level in a well lowers very rapidly and then more slowly until, if conditions are favorable, it becomes almost stationary or declines very slowly. At the completion of pumping, the water level rises rapidly in the well for a time and then more slowly until it approaches its original level.

Dug wells.—Wells excavated by means of picks, shovels, spades, or power-digging machinery are called dug wells. Dug wells generally are more than 2 feet in diameter, and in this area they generally are not more than 50 feet deep. Few new wells are dug at the present time, but many of the early wells were dug by hand.

Drilled wells.—A drilled well is excavated by means of a percussion or a rotary drill. This type of well is the most common and is particularly suitable in the upland areas where the depth to the water-bearing formations is considerable. The drilled domestic and stock wells generally are 4, 5, or 6 inches in diameter, and the drilled irrigation wells generally are 12 to 24 inches in diameter. All the drilled wells, with the exception of a few in the Brule formation, are cased either with galvanized iron or steel. Most of the wells are cased to the bottom, but many of the wells in the Brule formation are cased only through the overlying unconsolidated material.

Methods of lift.—Windmill-operated lift or force pumps are in general use on domestic and stock wells. The pump cylinders are placed either below or just above the water table. Force pumps are used more generally to raise the water to elevated tanks or into houses. Centrifugal and turbine pumps are used exclusively on the irrigation and municipal wells and generally are powered by electric motors.

UTILIZATION OF WATER

Data obtained on 203 wells are listed in table 9, which includes records of most of the irrigation and public-supply wells but only a small proportion of the domestic and stock wells.

DOMESTIC AND STOCK SUPPLIES

Domestic water is obtained principally from drilled or dug wells. Most of the domestic wells are pumped either by hand or by windmills, but where electric power is available many wells have been equipped with electric motors. Water for stock is obtained mainly from drilled domestic wells but is obtained in part from reservoirs or small streams. The ground water in this area generally is adequate both in quantity and quality for domestic and stock use.

PUBLIC SUPPLIES

Burns and Pine Bluffs are the only towns that have municipal water supplies. The residents of Arcola, Carpenter, Egbert, and Hillsdale obtain their water from individual wells.

Burns.—The town of Burns in the western part of the area obtains its municipal water supply from two drilled wells. Well 164 is used, and 165 is maintained on a stand-by basis. Well 164 has a reported depth of 254 feet and a static water level about 70 feet below the surface. It is equipped with a 4-inch turbine pump powered by an electric motor. The average daily rate of consumption is reported to be about 20,000 gallons.

The water is pumped into an elevated 35,000-gallon steel tank. The supply from well 164 is not sufficient for unrestricted use, and another well will be drilled in the near future so that residents may irrigate small gardens. The water is of good chemical quality and is suitable for ordinary uses. (See analysis 164, table 7.) According to the Wyoming State Board of Health the water because of its low bacterial content is safe for domestic use without chlorination or other treatment.

Pine Bluffs.—The municipal water supply for Pine Bluffs is derived from well 120, which is drilled into the Brule formation. The well is 125 feet deep and has a static water level of about 25 feet. It is equipped with a centrifugal pump powered by a 50-horsepower electric motor and yields 500 gpm with a 6-foot drawdown, which is reported to remain relatively constant even after long periods of pumping.

The water is pumped into a 216,000-gallon concrete tank situated about 100 feet above the well on the bluff south of town. The estimated average daily consumption is about 60,000 gallons. The supply has proved adequate during the 8 years the well has been in operation. The water is hard but is suitable without treatment for most uses. (See analysis 120 in table 7.)

IRRIGATION SUPPLIES

The investigation of the Egbert-Pine Bluffs-Carpenter area was devoted mainly to a study of the present and potential supplies of ground water available for irrigation. The following discussion of the irrigation supplies deals only with those parts of the area which are now being irrigated.

The first attempts at irrigation were made in the late 1920's, but it was not until the drought years in the middle 1930's that much progress was made. In the summer of 1942 there were approximately 75 wells in the Egbert-Pine Bluffs area equipped to pump water for irrigation, and by the end of 1946 there were about 125 wells. It is estimated that about 210 wells will be in operation at the start of the 1950 irrigation season.

Yield of irrigation wells.—The yields of irrigation wells in the Egbert-Pine Bluffs-Carpenter area range from 250 to 2,000 gpm. Most wells yield about 500 to 1,200 gpm; a well that yields less than 300 gpm is not considered wholly successful. The yields of some of the irrigation wells given in the table of well records were reported by the owners, some were measured by the Rural Electrification Administration, and a few were measured by F. C. Foley, of the Geological Survey. A Parshall flume was used by the Rural Electrification Administration and by Foley to measure discharges. A steel tape was used to measure the drawdowns.

Many of the irrigation plants consist of a battery of two or more wells. The wells in a battery are drilled to about the same depth below the water table and are then connected below the surface by use of an off-center bit; however, only one well of the battery is equipped with a pump. This type of irrigation plant has proved successful in the vicinity of Pine Bluffs where the Brule formation is exposed or lies beneath a thin cover of gravel that has an insufficient saturated thickness to supply adequate amounts of water to porous zones or fissures in the Brule. Local conditions, however, determine whether one or several wells are drilled to obtain an adequate irrigation supply at a given locality. Well 130 in the Brule formation near Pine Bluffs reportedly yields 2,000 gpm, the largest yield in the entire area. The use of a battery of several wells generally increases the aggregate yield, but in places it is more feasible to drill several widely spaced wells and equip each with a pump. In the part of the area underlain by the Brule formation, however, the risk and expense involved in drilling several widely spaced wells may be too great for the increased yield that would be obtained, and a battery of wells generally is satisfactory. In those parts of the Egbert-Pine Bluffs-Carpenter area where the irrigation supplies are obtained from terrace deposits of sand and gravel, one well of large diameter—18 to 36 inches—generally supplies sufficient water.

The measured drawdowns in irrigation wells in this area range from only 4.3 feet in well 33, which yields 1,105 gpm from the Brule formation, to 54.3 feet in well 3, which yields 780 gpm, also from the Brule formation. The drawdowns increase during long periods of continuous pumping. Many of the wells in the Brule formation fail after several weeks of continuous pumping, but they recover in a short time and may be pumped repeatedly during the irrigation season. Three to 5 miles southwest of the town of Pine Bluffs wells 33, 132, 136, 141, and 142 have notably high specific capacities. (See table 6 and pl. 2.) In this area overlying saturated gravels supply water to interconnected fractures in the Brule formation, which in turn yield water to penetrating wells. The yield, drawdown, and specific capacity (yield per unit of drawdown generally expressed as gallons a minute per foot of drawdown) for the wells that were tested are given in table 6.

Depth and diameter of irrigation wells.—The depths and diameters of the irrigation wells are given in table 9 and are summarized below.

Irrigation wells in the Egbert-Pine Bluffs part of the area that penetrate the Brule formation range in depth from about 35 to about 125 feet, but most of them are 75 to 100 feet deep. The depths of the wells apparently is a minor factor in determining the yield. (See table 6.) The wells that penetrate the entire thickness of the younger terrace deposits range in depth from a few feet to 75 feet. Nearly all the irrigation wells in the area are equipped with galvanized-iron casing, which generally ranges in diameter from 14 to 30 inches. A few of the wells of very large diameter, however, are cribbed with rock or concrete. Several of the wells in the Brule formation are uncased, and even after several years of use the walls have not caved.

TABLE 6.—*Depth, yield, drawdown, and specific capacity of irrigation wells tested in the Egbert-Pine Bluffs-Carpenter area*

No. on plate 2 and table 9	Depth (feet)	Yield (gallons a minute)	Drawdown (feet)	Specific capacity (gallons a minute per foot of drawdown)
1	100	685	26.8	25.6
3	110	780	54.3	14.4
33	88.2	1,105	4.3	257.0
35	98	600	15.1	39.7
45	110	476	31.8	15.0
112	73.3	732	36.0	20.3
120	125	500	6	83.3
121	91.1	1,400	14.79	94.7
124	100	422	42.2	10.0
132	96	1,465	11.8	124.2
136	78	1,355	9.8	138.3
137	100	1,200	13	92.3
138	82.2	507	8.9	57.0
141	80	1,000	6	166.7
142	41.3	1,105	7.5	147.3
149	95	490	12	40.8
151	85.5	600	35	17.1
163	91	360	15	24.0
166	90	1,600	20	80.0
172	95	805	11.9	67.6
199	95	585	13	45.0

Types of pumps and pump power.—Nearly all the irrigation wells in this area are equipped with turbine pumps, but two wells are equipped with centrifugal pumps. The pumps generally are powered by electric motors, ranging from 10 to 30 horsepower, but a few are powered by tractors or stationary gasoline engines, and eight are powered by diesel engines. It is believed that, as the power network of the Rural Electrification Administration is expanded, many existing wells will be converted to the use of electric power, and an additional incentive will be provided for the drilling of many additional wells.

Most of the turbine pumps in the area are 8 or 10 inches in diameter, but a few are 14 inches in diameter.

Construction of irrigation wells.—Most of the irrigation wells in the Egbert-Pine Bluffs area were put down by boring machines commonly referred to as "horse and bucket rigs." This type of drilling rig is used widely throughout the area for reasons of economy, and many of the irrigators of the larger tracts own and operate their own rigs. The horse and bucket rig is used principally where the Brule formation is penetrated throughout the full depth of the wells, as such wells generally do not cave and hence require no casing. This type of rig is not well suited for drilling in unconsolidated deposits that require casing because the rotating mechanism gets in the way, making it difficult to force the casing down the hole. Several drillers have been successful in putting down wells in the younger terrace deposits with this type of rig, however, and, although the walls of the hole have a tendency to cave, the gravel generally is consolidated sufficiently to remain standing for a short time. After the hole is drilled, casing is inserted to prevent caving. The casing is then perforated below the water table.

Cable-tool drilling rigs also are used throughout the area. A few of the newer wells have been drilled with hydraulic-rotary rigs; this type of drilling rig has been used very successfully in the Carpenter area.

A few of the wells in this area have been gravel-packed. Gravel packing a well may be advantageous if the water-bearing beds contain much fine material as the gravel keeps the fine material from entering the well and provides easy passage for the water as it approaches the screen. Care should be exercised in choosing the proper type of gravel; screened pea-size gravel is usually considered the most satisfactory for the conditions generally prevailing in this area. If the water-bearing bed includes much coarse gravel, little if any advantage will be gained from gravel packing because the fine sand will be pumped out and the coarse gravel will be left to form an effective natural packing.

POSSIBILITIES OF FURTHER DEVELOPMENT OF IRRIGATION SUPPLIES FROM WELLS

General considerations.—The amount of water that can be withdrawn from a ground-water reservoir without causing excessive permanent lowering of the water table depends on the capacity of the reservoir and on the amount of recharge to it. If water is withdrawn from the reservoir faster than it is added by recharge, the water levels will decline, and eventually the reservoir will be depleted. The amount of water that can be withdrawn annually over a long period of years without causing depletion of the available supply may be called the safe yield of the reservoir. The feasibility of developing additional water supplies for irrigation from wells in the Egbert-Pine Bluffs-Carpenter area is dependent upon the safe yield of the ground-water reservoir, which in turn is governed by geologic, hydrologic, and economic factors. For the purpose of more detailed consideration of the problem the Egbert-Pine Bluffs area and the Carpenter area are discussed separately.

Egbert-Pine Bluffs area.—The ground-water conditions in this area indicate that additional development of irrigation wells is possible; however, the behavior of the water table should be watched carefully to prevent overdevelopment of local areas. The development of irrigation with water from wells generally results in a decline in the water table, but a decline of water levels during a period of development is not necessarily a sign of overdevelopment as long as the decline is not so great as to indicate the approach of pumping lifts beyond the economic limit or to indicate failure of the supply. A decline in the water levels is very important to owners of irrigation wells, however, because the cost of lifting water to the surface increases in proportion to the pumping lift. It is generally not possible to state the limit of economic pumping lift because it depends on many factors, including the cost of fuel or power for operating the pump, efficiency of the pump, kind and price of crops being irrigated, and the individual irrigator's skill and management.

Periodic measurements of the depth to the water levels have been made in this area since 1940 and are being continued. The water levels have fluctuated annually in response to pumping and recharge. (See section on "Ground-water recharge," p. 18.) The water levels in the area of development rose an average of about 1 foot from 1940 through December 1949. This average net rise of water levels indicates that not all the available ground water in the area was utilized. Also, any flow in Lodgepole Creek (except storm runoff) shows an excess of ground water and further indicates that not all available ground water has been utilized in the past. Barring legal considerations and extreme drought conditions, additional pump irrigation can be developed, but close watch should be kept on water levels to avoid overdeveloping local areas.

The possibility of development of irrigation supplies in the upland areas adjacent to the Pine Bluffs lowland is remote. The Ogallala formation underlying these areas is mainly a tight sandstone having a low permeability, which precludes the withdrawal of large amounts of water for irrigation; moreover, the depth to water level is more than 100 feet, and the opportunity for recharge to the sandstone is negligible. As these areas are bounded by escarpments on the west and the beds of the formation dip to the east, direct rainfall penetration is the sole source of recharge and would be insufficient for the support of a large irrigation development.

Carpenter area.—The coarse terrace deposits extending southeastward from Carpenter offer good possibilities for the development of additional ground-water supplies for irrigation. In places these deposits have an estimated saturated thickness of as much as 70 feet. As their greater thicknesses occur in channels cut in the relatively impermeable Brule formation, test drilling is needed to determine the location of the most favorable sites for irrigation wells. West of Carpenter the deposits thin progressively toward pediments cut on the Brule formation.

The terrace deposits underlying the area east of Carpenter range in thickness from a few feet at the edges to as much as 120 feet. These deposits consist of gravel admixed with sand and clay or beds of poorly sorted gravel containing beds and lenses of sand and clay; therefore the average permeability generally is relatively low. A few irrigation wells have proved unsuccessful, whereas others within a short distance have been highly successful. Apparently there are zones or channels of higher permeability, and a well must penetrate such a zone in order to yield sufficient water for irrigation. For this reason it is advisable that one or more test holes be drilled before the drilling of an irrigation well.

It is estimated that the amount of water available for recharge in the Carpenter area is about 6,000 acre-feet annually. (See p. 22.) Recharge is primarily from rainfall penetration, and this figure is based upon present climatic conditions. It is quite possible that the figure of 6,000 acre-feet annually may prove to be in error. Before a more exact determination can be made, test holes should be drilled across the area, and pumping tests should be conducted to determine the thickness, character, and permeability of the material.

No successful irrigation wells have been drilled in that part of the Carpenter area where the Brule formation is exposed. Several wells have been drilled and tested but have not yielded sufficient water for irrigation. Permeable zones are present in places in the upper part of the formation, but owing to the lack of a saturated cover of coarse materials there is no great source of recharge for these zones.

QUALITY OF GROUND WATER

Samples of water from 34 typical wells in the Egbert-Pine Bluffs-Carpenter area have been analyzed in the laboratory of the U. S. Geological Survey at Lincoln, Nebr., the results of which are given in table 7. The analyses show only the chemical character of the waters and not their sanitary condition.

CHEMICAL CONSTITUENTS IN RELATION TO USE

The following discussion of the chemical constituents of ground water has been adapted in part from publications of the U. S. Geological Survey.

TABLE 7.—*Analyses of water from typical wells in the Egbert-Pine Bluffs-Carpenter area*

[Dissolved constituents given in parts per million [1]; reacting values, in italics, given in equivalents per million [2]]

No. on pl. 2	Location	Depth (feet)	Geologic formation	Date of collection	Temperature (F)	Specific conductance (micromhos)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolves solids	Hardness as $CaCO_3$			Percent sodium
																			Total	Carbonate	Noncarbonate	
	T. 12 N., R. 60 W.																					
2	SE¼SW¼SW¼ sec. 5	130	Terrace deposits	Sept. 23, 1947	50	463	55	0.00	28 *1.40*	11 *.90*	50 *2.16*	182 *2.98*	40 *.83*	17 *.48*	0.8 *.04*	7.5 *.12*	0.10	293	115	115	0	48
	T. 12 N., R. 62 W.																					
23	NW¼NW¼SW¼ sec. 9	145	do	Nov. 20, 1948	51	(3)	42	.02	50 *2.50*	8.5 *.70*	14 *.54*	170 *2.79*	12 *.25*	18 *.51*	1.2 *.06*	3.2 *.05*	.01	234	160	139	21	12
	T. 13 N., R. 60 W.																					
36	NW¼NW¼SW¼ sec. 8	77.5	Brule	Sept. 26, 1947	52	554	57	.00	66 *3.29*	15 *1.23*	34 *1.46*	302 *4.95*	34 *.71*	11 *.31*	.2 *.01*	.6 *.01*		378	226	226	0	24
39	SE¼SE¼NW¼ sec. 17	80	do	Oct. 7	52	365	66	.16	32 *1.60*	11 *.90*	34 *1.46*	172 *2.82*	32 *.67*	9.0 *.25*	.5 *.03*	11 *.19*		274	125	125	0	37
	T. 13 N., R. 61 W.																					
52	SE¼SE¼NW¼ sec. 11	60	do	Sept. 23	50	433	60	.02	60 *2.99*	15 *1.23*	15 *.66*	248 *4.06*	28 *.54*	7.0 *.20*	.8 *.04*	.0 *.0*		305	211	203	8	17
54	SE¼SE¼SW¼ sec. 15	125	do	Sept. 26	52	462	64	.10	36 *1.80*	13 *1.07*	54 *2.34*	222 *3.64*	63 *1.31*	8.0 *.23*	.6 *.03*	.0 *.0*		333	143	143	0	47
63	NW¼NW¼NE¼ sec. 29	85	do	Oct. 17	52	335	53	.02	39 *1.95*	12 *.99*	18 *.76*	176 *2.88*	30 *.62*	4.0 *.11*	.8 *.04*	2.1 *.03*		238	147	144	3	24
64	NW¼NW¼SW¼ sec. 30	83	Terrace deposits	Sept. 26	53	335	47	.02	45 *2.25*	11 *.90*	10 *.46*	163 *2.67*	29 *.60*	9.0 *.25*	.8 *.04*	2.2 *.04*		234	158	134	24	16
	T. 13 N., R. 62 W.																					
88	SE¼SE¼NE¼ sec. 28	80	do	Oct. 7	52	486	51	.02	68 *3.39*	13 *1.07*	16 *.69*	202 *3.31*	42 *.87*	16 *.45*	.6 *.03*	30 *.48*		358	223	166	57	13
93	SW¼SW¼NW¼ sec. 32	65	do	do	52	387	55	.02	50 *2.50*	13 *1.07*	10 *.43*	186 *3.05*	29 *.60*	6.0 *.17*	.8 *.04*	8.0 *.13*		266	178	153	25	14
	T. 14 N., R. 60 W.																					
113	NE¼NW¼NW¼ sec. 8	80	Brule	Sept. 23	52	338	66	.02	35 *1.75*	14 *1.15*	23 *.98*	176 *2.89*	33 *.69*	8.0 *.23*	.6 *.03*	3.0 *.05*		251	145	144	1	28
114	SW¼SW¼NW¼ sec. 8	80	do	do	53	333	61	.10	42 *2.10*	7 *.58*	26 *1.13*	188 *3.08*	26 *.54*	2.0 *.06*	.6 *.03*	5.5 *.09*		250	134	134	0	30
117	SW¼NW¼ sec. 11	85	Alluvium	Oct. 7	51	423	55	.10	53 *2.64*	10 *.82*	33 *1.43*	222 *3.64*	44 *.92*	8.0 *.23*	.6 *.03*	5.5 *.09*		302	173	173	0	29
120	NW¼NW¼SE¼ sec. 15	125	Brule	Sept. 25	54	(3)	53	.00	68 *3.39*	14 *1.15*	31.4 *1.22*	270 *4.42*	41 *.85*	14 *.40*	.8 *.04*	5.0 *.08*		354	227	221	6	17

121	SE¼SE¼SW¼ sec. 16	91.1	Alluvium	Sept. 23	53	306	65	.16	34	7.5	26	154	28	5.0	.4	11		230	116	116	0	33
									1.70	*.62*	*1.13*	*2.52*	*.58*	*.14*	*.02*	*.18*						
122	NW¼NW¼NE¼ sec. 17	70	Brule	do	52	349	65	.16	39	12	26	189	30	7.0	.8	2.9		266	147	147	0	28
									1.95	*.99*	*1.14*	*3.16*	*.63*	*.20*	*.04*	*.05*						
125	NW¼NW¼NE¼ sec. 19	110	Terrace deposits	do	52	337	55	.01	42	4.4	24	189	8.6	5.0	.6	2.1		242	123	123	0	29
									2.10	*.36*	*1.02*	*3.10*	*.18*	*.14*	*.03*	*.03*						
132	NW¼NW¼NW¼ sec. 28	96	Brule	Oct. 7	52	445	56	.00	58	12	29	218	51	12	.2	10		327	194	194	0	25
									2.89	*.99*	*1.26*	*3.57*	*1.06*	*.34*	*.01*	*.16*						
136	SW¼NW¼NW¼ sec. 29	78	do	Sept. 25	52	369	52	.01	48	4.6	25	194	21	6.0	.6	3.0		261	139	139	0	28
									2.40	*.38*	*1.09*	*3.18*	*.44*	*.17*	*.03*	*.05*						
137	SE¼NW¼SW¼ sec. 29	105	do	Oct. 7	53	370	62	.16	40	10	32	188	37	6.0	.6	9.5		270	141	141	0	33
									2.00	*.82*	*1.39*	*3.08*	*.77*	*.17*	*.03*	*.15*						
142	NW¼NW¼SE¼ sec. 32	45	do	do	50	552	57	.16	68	17	42	320	44	10	.8	10		374	244	244	0	27
									3.39	*1.48*	*1.80*	*5.24*	*.92*	*.28*	*.04*	*.19*						
	T. 14 N., R. 61 W.																					
148	NW¼SW¼NW¼ sec. 18	45	Arikaree	Sept. 25	53	474	36	.05	26	7.4	67	208	26	12	.8	30		301	95	95	0	60
									1.30	*.61*	*2.91*	*3.41*	*.54*	*.34*	*.04*	*.48*						
149	NW¼NW¼NW¼ sec. 21	95	Brule	do	53	365	46	.06	52	10	18	198	37	4.0	.9	1.8		226	171	162	9	19
									2.60	*.82*	*.79*	*3.24*	*.77*	*.11*	*.05*	*.03*						
159	NW¼SW¼SW¼ sec. 27	100	do	Sept. 24	52	444	60	.05	23	8.7	53	154	42	18	.8	15		288	93	93	0	56
									1.15	*.72*	*2.33*	*2.52*	*.87*	*.51*	*.04*	*.24*						
	T. 14 N., R. 62 W.																					
164	NW¼NW¼SE¼ sec. 7	254	do	Sept. 26	54	(3)	55	.00	59	12	14	184	22	16	.6	40	.10	294	196	151	45	8
									2.94	*.99*	*.51*	*3.02*	*.46*	*.45*	*.03*	*.64*						
166	NW¼NW¼SE¼ sec. 11	90	do	Sept. 25	53	466	48	.05	66	12	12	255	21	4.0	.8	2.5	.17	283	214	209	5	11
									3.29	*.99*	*.53*	*4.18*	*.44*	*.11*	*.04*	*.04*						
172	NW¼NW¼NW¼ sec. 24	95	do	do	53	363	63	.20	35	10	33	188	27	4.4	.8	13		274	128	128	0	36
									1.75	*.82*	*1.45*	*3.08*	*.56*	*.12*	*.04*	*.21*						
	T. 14 N., R. 63 W.																					
179	NW¼NW¼NW¼ sec. 20	80	Ogallala	Sept. 23	52	421	55	.20	53	13	9.2	185	21	16	.6	10	.11	270	186	152	34	10
									2.64	*1.07*	*.40*	*3.03*	*.44*	*.45*	*.03*	*.16*						
	T. 15 N., R. 60 W.																					
185	NE¼NE¼NE¼ sec. 4	108	do	Sept. 25	52	456	59	.07	52	16	22	168	47	34	.4	10		336	196	138	58	20
									2.60	*1.32*	*.96*	*2.75*	*.98*	*.96*	*.02*	*.16*						
190	NW¼SE¼SW¼ sec. 20	108	Brule	July 24	52	313	57	.05	44	7.9	1.1	144	15	4.5	.4	4.5	.10	214	142	118	24	2
									2.20	*.65*	*.05*	*2.36*	*.31*	*.13*	*.02*	*.07*						
192	NW¼NW¼SW¼ sec. 28	96	do	Sept. 24	53	310	28	.05	37	5.9	21	160	11	6.0	.2	12		258	117	117	0	28
									1.85	*.48*	*.89*	*2.62*	*.23*	*.17*	*.01*	*.19*						
194	SW¼SE¼NW¼ sec. 29	108	do	do	52	313	26	.05	36	8.3	14	152	12	6.0	.2	11		256	124	124	0	20
									1.80	*.68*	*.62*	*2.49*	*2.5*	*.17*	*.01*	*.18*						
200	NE¼SW¼NW¼ sec. 34	80	do	Oct. 6	50	305	62	.16	35	8.5	19	142	27	7.0	.4	11		230	122	116	6	25
									1.75	*.70*	*.84*	*2.33*	*.56*	*.20*	*.02*	*.18*						
	T. 15 N., R. 61 W.																					
203	SE¼SE¼NE¼ sec. 28	100	do	Sept. 25	56	314	64	.02	37	10	15	169	20	2.0	.6	3.4		232	133	133	0	24
									1.85	*.82*	*.66*	*2.77*	*.42*	*.06*	*.03*	*.06*						

[1] 1 ppm is equivalent to 1 pound of substance per million pounds of water or 8.33 pounds per million gallons of water.

[2] An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

[3] Chemical analysis not on file.

Dissolved solids.—The residue left after a natural water has evaporated consists of rock materials, with which may be included some organic material and some water of crystallization. Waters containing less than 500 ppm of dissolved solids generally are satisfactory for domestic use, except for the difficulties that may result from hardness, excessive corrosiveness, or excessive content of iron and other minor constituents. Waters containing more than 1,000 ppm of dissolved solids generally are not satisfactory, for they are likely to contain enough of certain mineral constituents to produce a noticeable taste or to make the water unsuitable in some other respect.

The waters sampled from this area ranged in concentration of dissolved solids from 214 to 378 ppm.

Hardness.—The hardness of water, which is the property that generally receives the most attention, is most commonly recognized by its effect when soap is used with the water in washing. Calcium and magnesium cause virtually all the hardness in ordinary waters and also are the active agents in the formation of the greater part of the scale in steam boilers and in other vessels in which water is heated or evaporated.

In addition to the total hardness, the table of analyses indicates also the carbonate and noncarbonate hardness. Carbonate hardness is caused by calcium and magnesium bicarbonate; it can be removed almost entirely by boiling and is sometimes referred to as temporary hardness. Noncarbonate hardness generally is caused by sulfate or chloride of calcium and magnesium; it cannot be removed by boiling and is sometimes referred to as permanent hardness. There is no difference between carbonate and noncarbonate hardness with reference to use with soap. In general the noncarbonate hardness forms harder scale in steam boilers.

Water having a hardness of less than 50 ppm generally is rated as soft, and treatment for the removal of its hardness generally is not necessary. Hardness between 50 and 150 ppm does not seriously interfere with the use of water for most purposes, but it does increase the consumption of soap, and its removal by a softening process is profitable for laundries and sometimes for other industries. Hardness of more than 150 ppm can be noticed, and if the hardness is greater than 200 ppm it is generally advisable to treat the water for removal of the excess hardness.

All the waters analyzed from this area may be considered moderately hard to hard. The hardness ranged from 93 to 244 ppm. The noncarbonate hardness of the samples analyzed ranged from 0 to 58 ppm. However, 19 of the 34 samples showed no noncarbonate hardness.

Iron.—Iron, next to hardness, is the constituent of natural water that generally receives the most attention. If a water contains much more than 0.3 ppm of iron the excess may precipitate and settle as a reddish sediment and may stain clothes and fixtures. The amount of iron in most of the samples collected from this area ranged from less than 0.01 to 0.2 ppm.

Fluoride.—It is desirable to know the quantity of fluoride present in waters that are likely to be used by children. Fluoride in water has been shown to be associated with the dental defect called "mottled enamel," which may appear on the teeth of children who drink water containing excess amounts of fluoride during the period of formation of the permanent teeth. A concentration of less than 1.5 ppm of fluoride in water has been shown either to reduce or prevent entirely the development of tooth decay in children. The fluoride concentration of the waters analyzed ranged from 0.2 to 1.2 ppm.

Water for irrigation.—The usefulness of water for irrigation is thought to depend principally on the concentration of soluble salts and the proportion of sodium. It is exceedingly difficult to appraise the quality of water for irrigation, and no single criterion, such as total salinity or chloride content, should be used. A few of the variables that enter into the evaluation of an irrigation water are the type of crop; soil type, including subsurface drainage; climatic conditions; and relative proportion of irrigation water to rainfall. The following table, adapted from one given by Scofield (1935, p. 286), however, indicates in a general way how the concentration of various salts affect the quality of irrigation waters.

The samples of water from wells producing from the Brule formation, the terrace deposits, and the alluvium, which are the sources of water for the irrigation wells in this area, showed concentrations of dissolved solids low enough to cause little or no damage to soils or crops. Also, the chloride, sulfate, and sodium concentrations in the samples from these formations generally are below the limits considered to be harmful.

TABLE 8.—*Suitability of water for irrigation as determined by concentration of certain mineral constituents*

Classes of water	Total dissolved solids (parts per million)	Sodium (percent of total bases)	Concentration (milligram equivalents)		Boron (parts per million)[1]
			Chloride	Sulfate	
Excellent	Less than 175	Less than 20	Less than 4	Less than 4	Less than 1.00
Good	175–525	20–40	4–7	4–7	1.00–2.00
Permissible	525–1,400	40–60	7–12	7–12	2.00–3.00
Doubtful	1,400–2,100	60–80	12–20	12–20	3.00–3.75
Unsuitable	More than 2,100	More than 80	More than 20	More than 20	More than 3.75

[1] Listed for tolerant crops. This column was taken from table 8 of a report by Wilcox (1948).

SANITARY CONDITIONS

The analyses of water given in table 7 show only its chemical character, not its sanitary quality. Most of the population is dependent upon private water supplies from wells, and the development of a water supply safe from pollution is the responsibility of the individual and the well driller. It is obvious that a well should be located where surface water cannot enter it; moreover a well should be constructed in such a manner that all surface water is sealed off. Drainage from cesspools, privies, or barnyards is especially dangerous. Generally speaking, dug wells are more subject to pollution from surface water than drilled wells, mainly because they usually are not properly sealed at the top.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

TERTIARY SYSTEM

Sediments that are Oligocene in age and younger are exposed in the Egbert-Pine Bluffs-Carpenter area. No wells have completely penetrated the Brule formation; so specific details of the older sediments underlying the area are not known. Identification of the Brule formation of Oligocene age, the Arikaree sandstone of Miocene age, and the Ogallala formation of Pliocene age was made purely on the basis of physical and lithologic character, stratigraphic position, and the relations with exposures of these formations in adjacent areas. No fossils were collected from the formations.

BRULE FORMATION

Character.—In the Egbert-Pine Bluffs-Carpenter area the Brule formation is a moderately hard bentonitic siltstone, which is compact and brittle and locally may be sandy or argillaceous. No mechanical analyses were made of the material, but in appearance it is similar to that in the Scotts Bluff area, Nebraska, as described by Wenzel, Cady, and Waite (1946, pp. 66–70). Fresh fractures show the material to be buff to flesh-colored, but it is light pink to almost white on weathered surfaces. The Brule typically weathers into cubical blocks and slabs. Extensive erosion of outcrops produces miniature badlands in places.

The Brule formation generally is massive. It has regular bedding planes, but these are indistinct and difficult to trace. However, a somewhat layered appearance is caused by zones that stand out because they are more resistant to erosion than the bulk of the formation, owing to cementation by calcium carbonate. These zones are not persistent but grade laterally into massive beds of the Brule. Lenticular beds of volcanic ash and sandstone also occur locally in the formation. Zones of loose material are found in places at the top. They range in thickness from 2 to 15 feet and contain rounded pebbles of reworked siltstone from the Brule. These zones, however, occur only where there is a protective cover of younger deposits. They probably are younger than Brule in age but, for the purposes of this report, are included in the Brule formation. Long, thin veins of calcite occur in places on badland surfaces of the Brule.

Superficially the Brule formation is cut by systems of joints, both vertical and along bedding planes. These joints generally are narrow, ranging in width from a feather edge to several inches. The joint systems are most prominent on badland surfaces, but in places they occur near the top of the formation beneath a cover of younger deposits. In addition there are fissures that penetrate the formation to unknown depths and possibly extend completely through it. Surface traces of these fissures, some of which are a mile or more in length, are easily seen on aerial photographs but are difficult to detect and follow on the ground. Some of these fissures and joints are filled with materials derived from overlying sediments, the wall rock, or both, but some are believed to be open.

Distribution and thickness.—The Brule formation is exposed in the lowland areas and in the lower slopes of the escarpments. The lowland exposures are mainly along the lower valleys of Crow and Lodgepole Creeks and their main tributaries where the younger Tertiary and Quaternary deposits have been removed by erosion. In the extreme north-central part of the area in secs. 6 and 7, T. 15 N., R. 60 W., and in secs. 1, 2, 10, 11, and 12, T. 15 N., R. 61 W., an exposure of the Brule rises some 70 feet above that in any other part of the area, including the escarpments along which the contact of the Brule formation with overlying younger formations is exposed. No structure is discernible, and this area is believed to be an erosional high. The total thickness of the Brule is not known because the formation has not been completely penetrated by drilling. It is at least 334 feet thick, however, because near the town of Pine Bluffs about 150 feet is exposed on the face of the escarpment, and test hole 1, in sec. 14, T. 14 N., R. 60 W., penetrated the Brule to a depth of 184 feet.

Water supply.—The Brule formation is the principal aquifer in the area adjacent to the town of Pine Bluffs. As the Brule is primarily a siltstone, generally low permeability is to be expected. However, locally the permeability of the formation is increased by porous zones of reworked Brule and by jointing and fissures. These zones are good sources of ground water for irrigation where they are overlain by deposits of saturated gravel. Water percolates downward through overlying materials into these permeable fractured zones or into interconnecting joints which in turn transmit the water to the larger fissures. It is evident from the sustained yields of wells producing from the fissures that the network of interconnecting joints and fissures is of considerable extent. Where the formation is lacking in these permeable zones and fissures it will yield at best only meager amounts of water to wells, even though it might be overlain by deposits of saturated gravel.

In the area west of Carpenter where the Brule is exposed or lies near the surface many wells have been drilled in an attempt to develop enough water for irrigation, but all these wells have been unsatisfactory. There are permeable zones in places in the upper part of the formation, but they are not well developed and where not at the surface are covered by a relatively thin mantle of gravel which is not saturated. The Brule, therefore, yields water in quantities sufficient only for domestic and stock needs throughout most of this area.

Water from the Brule formation generally is hard but can be used for most domestic and stock needs and for irrigation. The concentration of dissolved solids in the 23 water samples from the Brule ranged from 214 to 388 ppm, and the hardness ranged from 93 to 261 parts. The amounts of sodium, chloride, and fluoride are within the safe limits for ordinary uses.

ARIKAREE SANDSTONE

The Arikaree sandstone consists mainly of loosely to moderately cemented fine-grained gray to brown sand interbedded with lenses of very hard, tough brownish to dark-gray sandstone. The layers of sandstone are concretionary and generally consist of long irregular cylindrical masses. They were described by Darton (1903, pp. 23–29) as pipy concretions. Some of these pipes attain a thickness of 2 or 3 feet and a length of about 10 feet. They are alined in a general northwest-southeast direction in the Egbert-Pine Bluffs-Carpenter area. The pipes are the result of the cementation of sand by calcium carbonate deposited by ground water. A few beds of volcanic ash are found in the upper part of the formation.

The Arikaree sandstone forms bluffs along Lodgepole Creek northwest of Egbert and a belt that extends from Hillsdale eastward to Egbert and then northward almost to the northwestern border of the area. It is also exposed in two other escarpments in the area. In the escarpment west of Carpenter it occupies a zone 30 feet thick that disappears to the north and east beneath a cover of younger sediments. In the escarpment north of the town of Pine Bluffs it is about 10 feet thick and northward is covered by younger deposits. Over the area in general, however, the Arikaree ranges in thickness from a knife edge to about 70 feet.

The Arikaree sandstone yields enough water for stock and domestic uses. Although its saturated thickness may be as much as 70 feet, sufficient water for irrigation is not obtainable, owing to the relatively low permeability of the formation.

The analysis of a sample of water from well 148 indicates that water from the Arikaree is of moderately good quality and is suitable for most uses. The total hardness of this sample was 95 ppm.

OGALLALA FORMATION

The Ogallala formation, which is the youngest Tertiary formation in the area, overlies the Arikaree sandstone in parts of the area, but where the Arikaree is absent the Ogallala lies unconformably on the Brule formation. The Ogallala consists of sand and silt containing lenses of clay and gravel deposited as detritus from the Laramie Mountains. It may be loose, loosely consolidated, or tightly cemented by calcium carbonate to form masses that resemble concrete. Locally these are called "mortar beds" and are the prominant beds of the formation in this area. In general the materials contained in the Ogallala are poorly sorted, and the beds are discontinuous. The lower part of the formation is characteristically a fine-grained sand containing many lenticular mortar beds. Zones of pebbles of reworked Arikaree sandstone and claystone occur in places in it. These pebbles range in diameter from about ¼ inch to about 2 inches. Along Crow Creek, in the NE¼NW¼NW¼ sec. 15, T. 13 N., R. 63 W., is an outcrop of gray resistant sandstone of the Ogallala formation containing geodelike nodules composed mainly of calcium and magnesium carbonate, in part silicified and containing centers of agate, opal, and quartz. Layers of buff and pink unconsolidated silt and clay, which occur in places throughout the formation, contain widely scattered crystalline pebbles that range from about ¼ inch to as much as 5 inches in diameter. Above the mortar beds are thin beds of gravel, sand, and silt, which, although in many places aggregating only 10 to 50 feet in thickness, are widely exposed and form the surface of most of the uplands. Interbedded layers of buff to red unconsolidated clay occur in places. The highest part of the escarpment south of the town of Pine Bluffs is capped by algal limestone, which ranges in thickness from 6 inches to 2 feet. The limestone is white but contains red and brown bands. The escarpment north of the town is capped by a material resembling mortar beds. In the upper part of these beds are thin zones of flint, chalcedony, and agate.

The Ogallala formation crops out or underlies large areas in Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas, and New Mexico. In the Egbert-Pine Bluffs-Carpenter area it makes up the greater part of the escarpments and caps other upland areas. The

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best exposures are in the escarpments south of the town of Pine Bluffs. Mortar beds are exposed in the areas lying north of Carpenter and south of Burns. Where present the formation has an average thickness of about 90 feet. It is 50 to 150 feet thick in the Pine Bluffs escarpment.

The formation yields sufficient water for stock and domestic uses. Quantities of water large enough to supply irrigation wells are not available from the Ogallala because of its low permeability, even though the saturated thickness is as much as 50 feet in places. A few fissures, similar to those described as being typical of the Brule formation, are thought to penetrate the Ogallala, but their effect on the occurrence and availability of ground water is not known.

The water from the Ogallala formation is satisfactory in quality for most domestic and stock uses although it is hard. The hardness of two samples from this formation showed 186 and 196 ppm.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Older terrace deposits.—The principal topographic and geologic feature in the area just east of Carpenter is a large undissected flat terrace. The terrace is underlain by deposits of sand and gravel that were laid down in a valley previously cut into the Tertiary formations. No fossils have been found to classify these deposits as Pleistocene in age, but it is believed that they are Pleistocene rather than Tertiary because they occupy a channel that was cut through the Ogallala and Arikaree formations and perhaps as much as 100 feet into the underlying Brule formation.

From the Wyoming-Colorado State line the terrace extends northward 3 to 6 miles into Wyoming and roughly an equal distance into Colorado. The boundaries of the terrace are shown topographically by a slight break in slope in both Wyoming and Colorado. The sediments that underlie this terrace are similar to the younger terrace deposits of Lodgepole Creek except that the older terrace deposits contain a greater proportion of fragments of weathered granite. The older terrace deposits range in thickness from a few feet at the edges to about 150 feet in the deepest part of the old valley.

The older terrace deposits constitute the principal aquifer in the Carpenter area. They generally supply sufficient water for domestic and stock wells and contain highly permeable channels that yield large quantities of water to irrigation wells. In several areas where the deposits of gravel are at the surface the lack of a soil cover makes necessary the use of large amounts of water to irrigate crops properly because the loss of water in ditches is excessive. The yields of irrigation wells producing from the terrace gravel range from a few hundred to 1,500 gpm. The water is hard but is of satisfactory quality for most domestic and stock uses and for irrigation. The dissolved solids in water from wells 23, 88, and 93 ranged from 234 to 358 ppm and the total hardness from 160 to 233 ppm.

Younger terrace deposits.—Terrace deposits are present in the valleys of Lodgepole and Crow Creeks and have been observed at several levels in other valleys throughout the area. The larger terraces in the valleys of Lodgepole and Crow Creeks are shown on plate 1. These deposits consist of coarse sand and gravel containing thin beds of clay. The gravel is composed mainly of fragments of weathered granite carried into the area from the Laramie Mountains to the west, but it contains, also, fragments of other igneous rocks. The terrace deposits in the Lodgepole valley generally are poorly sorted, but in some places they contain channel deposits that are coarse enough to yield sufficient water for irrigation wells.

The terraces in the Lodgepole valley lie about 60 feet above the valley floor, and the deposits are about 60 to 70 feet thick. They yield water in sufficient quantity for irrigation, stock, and domestic wells. The water generally is hard, but it can be used for most purposes. The concentration of fluoride, boron, and sodium is low enough for the water to be satisfactory for domestic, stock, and irrigation uses.

The terrace deposits along Crow Creek in the Carpenter area are not extensive enough or thick enough to supply water for irrigation. The present course of Crow Creek through this area apparently is of relatively recent origin, and important terraces have not yet been developed.

Water from the younger terrace deposits is hard. Chemical analysis of water from well 125 showed a content of dissolved solids of 242 ppm and a total hardness of 123 ppm.

PLEISTOCENE AND RECENT SERIES

Alluvium.—All the stream valleys and many of the dry washes and upland valleys in this area are underlain by alluvial deposits. The larger deposits of alluvium in the valleys of Lodgepole and Crow Creeks and along their principal tributaries are shown on plate 1, but the alluvium along the minor streams is not shown because it is only of local extent and is not highly important as a source of ground water. Some of these deposits may be of late Pleistocene age, but most of them probably are of Recent age.

The alluvium consists mainly of sand and gravel but also contains a few beds of clay and silt. It is composed mostly of granitic material and has fewer fragments of other types of igneous rock than do the terrace deposits. The particles composing the gravel range in diameter from a fraction of an inch to as much as 6 inches. The grains and pebbles less than 1 inch in diameter are mainly granite, but the larger pebbles and cobbles are quartzite, quartz, schist, and gneiss. Fragments of siltstone from the Brule formation occur in the deeper valley fill near Pine Bluffs, but near the surface they have weathered to silt and clay. The alluvium in areas immediately adjacent to the uplands contains a large proportion of sand, silt, and clay weathered from the Brule, Arikaree, and Ogallala formations.

The test holes drilled in the Pine Bluffs lowland (pl. 3) in 1943 encountered a relatively deep buried valley filled with sand, gravel, and clay. The gravel in the valley fill is very similar to the terrace gravel except that at depth it contains fragments derived from the Brule formation. The westward extent of this buried valley was not determined, but as far west as the line of test holes *B–B′* it is 107 feet deep. (See pl. 1 and log of test hole 16.) Thick beds of buried gravel are reported in several wells in the valley of Muddy Creek and in the lowland south of the Creek. From the evidence available, the writer believes that these buried valleys are about the same age, but Muddy Creek and its southern tributary drained into something other than the contemporaneous Lodgepole Creek.

The alluvium in the Egbert-Pine Bluffs area ranges in thickness from a feather edge to about 85 feet. In the Carpenter area it is generally not more than about 15 feet thick and is composed of about the same materials as the alluvium in Lodgepole Creek valley. In the valleys it is as much as 1.5 miles wide.

The alluvium in the valley of Crow Creek supplies sufficient water for stock and domestic use, but no wells have yielded enough water for irrigation. At several localities in the Lodgepole valley it yields water in quantities sufficient for irrigation. The water in the alluvium throughout the area is of suitable quality for domestic, stock, and irrigation purposes. (See analyses 117 and 121, table 7.)

WELL RECORDS

Information pertaining to water wells in the Egbert-Pine Bluffs-Carpenter area is tabulated in table 9. The numbers in the first column correspond to the well numbers on the map (pl. 2) and in the tables of analyses (table 7). The numbers in the first column that are in parentheses indicate wells from which samples of water were taken for analysis. The wells are listed in order by townships from south to north and by ranges from east to west. Within a township the wells are listed in the order of the sections. The measured depths to water level are given to the nearest 0.01 foot, whereas reported depths are given only to the nearest foot and are subject to error.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*

Well no.	Location	Owner or tenant	Type of well [1]	Depth of well (feet) [2]	Diameter of well (inches)	Type of casing [3]	Depth to which well is cased (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic formation
	T. 12 N., R. 60 W.								
1	NE¼NE¼NW¼ sec. 5	Olive M. Young	Dr	100	20	GI	20	Siltstone	Brule.
(2)	SE¼SW¼SW¼ sec. 5	W. T. Young	Dr	118	18	N		do	Do.
3	NW¼NW¼SE¼ sec. 6	Clyde Stevens	Dr	110	20	GI	100	do	Do.
4	SE¼SE¼SE¼ sec. 6	do	Dr	125	18	S	20	do	Do.
	T. 12 N., R. 61 W.								
5	SW¼SW¼SE¼ sec. 1	Union Pacific R. R.	Dr	159.0	5	GI		Sand and gravel	Terrace deposits.
6	NE¼NE¼NW¼ sec. 2	William Herman	Dr	62.0	5	GI		do	Do.
7	NE¼NW¼NE¼ sec. 3	Harry E. Anderson	Dr	110	24	GI	110	do	Do.
8	NW¼NW¼NW¼ sec. 7	Gerald Thompson	Dr	50	3.5	S	50	Sand	Do.
9	NW¼NW¼NE¼ sec. 8	Henry Hodges	Dr	49	6	S	49	do	Do.
10	SE¼SE¼NE¼ sec. 8	John Bauman	Dr	70	6	S	70	Sand and gravel	Do
11	SW¼SW¼SE¼ sec. 10	J. L. McDonald	Dr	53.0	6	GI	53	do	Do.
12	NW¼SE¼NW¼ sec. 18	John Bauman	Dr	95	16	GI	95	do	Do.
13	SE¼SE¼SE¼ sec. 18	do	Dr	150	20	GI	150	do	Do.
	T. 12 N., R. 62 W.								
14	NW¼NW¼NE¼ sec. 1	Carl Jennings	Dr	114	18	GI		do	Do.
15	NW¼NW¼NE¼ sec. 2	Odd White	Dr	56.5	6	GI	56.5	do	Do.
16	SW¼SW¼NW¼ sec. 2	George Phillips	Dr	104	56	S	104	do	Do.
17	SE¼SE¼NW¼ sec. 2	George Bours	Dr	85	32	GI	85	do	Do.
18	SW¼NW¼NW¼ sec. 3	C. G. DeMuth	Dr	92	18	GI	92	do	Do.
19	SE¼SE¼NE¼ sec. 5	Ray True	Dr					do	Do.
20	NW¼NE¼NE¼ sec. 6	William Flamme	Dr	78.0	3	GI		do	Do.
21	NE¼NE¼NE¼ sec. 8	Bank of Carpenter	Dr	64.0	5	GI	64	do	Do.
22	NE¼NW¼NE¼ sec. 9	D. A. Bunnell	Dr	66.0	5	GI	66	do	Do.
(23)	NW¼NW¼SW¼ sec. 9	P. M. Ragland	Dr	145	60	GI	145	do	Do.
24	NW¼NW¼NW¼ sec. 11	Carl Jennings	Dr	113.0	18	S	113	do	Do.
25	NW¼NW¼SW¼ sec. 12	Charles Smith	Dr	54	6	GI	54	do	Do.
26	NW¼NW¼NE¼ sec. 13	R. D. Smith	Dr	32.0	8	GI	32	do	Do.
27	NW¼SW¼NW¼ sec. 14	G. H. Pema	Dr	40.0	6	GI	40	do	Do.
28	NW¼NW¼NW¼ sec. 15	Lebertas Noyer	Dr	50	6	GI	50	do	Do

	T. 12 N., T. 63 W.								
29	NE¼NE¼NW¼ sec. 3	R. L. Gasserant	D	49.0	96	N	-	Siltstone	Brule.
30	NE¼NE¼SE¼ sec. 3	Wyoming Farm Loan Board	Dr	49.0	6	GI	-	do	Do.
31	NW¼NW¼SE¼ sec. 7	F. E. Bollan	Dr	75.0	24	GI	75	do	Do.
32	SW¼NE¼SE¼ sec. 12	Otis Breedon	Dr	14.0	4	GI	14	do	Do.
	T. 13 N., R. 60 W.								
33	NW¼SW¼NE¼ sec. 5	Herbert Campbell	Dr	88.2	24	GI	30	do	Do.
34	SE¼NE¼SE¼ sec. 5	do	Dr	120	24	GI	36	do	Do.
35	NW¼NW¼NW¼ sec. 8	do	Dr	98	24	GI	40	do	Do.
(36)	NW¼NW¼SW¼ sec. 8	do	Dr	77.5	20	GI	-	do	Do.
37	SE¼NE¼SW¼ sec. 8	do	Dr	97.2	14	N	-	do	Do.
38	SE¼SE¼NE¼ sec. 17	Moritz brothers	Dr	130	26	S	-	do	Do.
(39)	SE¼SE¼NW¼ sec. 17	do	Dr	80	23	N	-	do	Do.
40	SW¼SW¼NE¼ sec. 18	Ray Larsen	Dr	85	26	Cn	26	do	Do.
41	SE¼NE¼SE¼ sec. 18	do	Dr	100	18	S	30	do	Do.
42	SW¼NW¼NW¼ sec. 20	Moritz brothers	Dr	110	40	Cn	10	do	Do.
43	SW¼NW¼SW¼ sec. 21	do	Dr	114.0	5	GI	-	do	Do.
44	NE¼NE¼SW¼ sec. 30	Myles Gardner	Dr	96	20	GI	15	do	Do.
45	NE¼NW¼NE¼ sec. 31	Olive M. Young	Dr	110	20	GI	15	do	Do.
46	NW¼NW¼NE¼ sec. 31	Max Thelen	Dr	104	32	S	18	Gravel	Terrace deposits.
47	SE¼SE¼SE¼ sec. 31	Olive M. Young	Dr	85	18	-	-	Siltstone	Brule.
48	SE¼SE¼SW¼ sec. 32	do	Dr	130.6	20	GI	20	do	Do.
49	NW¼NE¼NW¼ sec. 34	Not known	Dr	284	5	GI	-	do	Do.
	T. 13 N., R. 61 W.								
50	NE¼SE¼SW¼ sec. 3	James Dolan	Dr	58	-	GI	-	do	Do.
51	NW¼NW¼SE¼ sec. 5	J. D. Wasson	Dr	72	6.5	GI	-	do	Do.
(52)	SE¼SE¼NW¼ sec. 11	Edna I. Dolan	Dr	60	60	S	60	do	Do.
53	NW¼SW¼SW¼ sec. 12	Thomas Kelly	Dr	57.5	20	GI	-	do	Do.
(54)	SE¼SE¼SW¼ sec. 15	Jesse Stuart	Dr	125	6	GI	-	do	Do.
55	SE¼SW¼SE¼ sec. 16	C. L. Butler	Dr	80.5	8	N	-	do	Do.
56	SW¼SW¼NW¼ sec. 17	do	Dr	88	6	GI	88	do	Do.
57	SW¼SW¼NW¼ sec. 18	Mr. Johnson	Dr	85.5	6	GI	-	do	Do.
58	NW¼NW¼NE¼ sec. 20	G. H. Plamback	Dr	40	18	GI	15	do	Do.
59	SW¼NW¼SW¼ sec. 22	Gertrude Evans	Dr	56.5	36	R	36	do	Do.
60	NE¼NE¼NE¼ sec. 24	Leona G. White	Dr	24.5	5	GI	-	do	Do.
61	NW¼SW¼SE¼ sec. 25	Myles Gardner	Dr	96	18	S	-	Gravel	Alluvium.
62	NE¼SW¼NW¼ sec. 28	R. L. Gall	Dr	114	5	S	114	Siltstone	Brule.
(63)	NW¼NW¼NE¼ sec. 29	Park Chamberlain	Dr	85	6	GI	85	do	Do.
(64)	NW¼NW¼SW¼ sec. 30	Claude E. Hardy	Dr	83	5	GI	83	Gravel	Terrace deposits.
65	SW¼SE¼SE¼ sec. 31	Max Thelen	Dr	60	5	GI	60	do	Do.
66	SE¼SE¼SE¼ sec. 31	O. M. Young	Dr	85	20	GI	-	do	Do.
67	SE¼SE¼SW¼ sec. 32	Robert Morris	Dr	90	6	GI	90	Sand	Do.
68	NW¼NW¼SW¼ sec. 34	do	D	90	6	GI	90	Gravel	Do.

See footnotes at end of table.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*—Continued

Well no.	Location	Owner or tenant	Type of well [1]	Depth of well (feet) [2]	Diameter of well (inches)	Type of casing [3]	Depth to which well is cased (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic formation
	T. 13 N., R. 62 W.								
69	SW¼NW¼SW¼ sec. 2	Robert Brady	Dr	82	6	S	82	Sand	Terrace deposits.
70	NW¼NW¼SW¼ sec. 4	William Kranz	Dr	90	6	GI	90	do	Do.
71	NE¼NE¼NE¼ sec. 6	A. H. Black	Dr	40	6	GI	40	do	Do.
72	NE¼NE¼SE¼ sec. 6	Ernest Wagner	Dr	75.3	6	GI	75.3	do	Do.
73	NE¼NE¼NE¼ sec. 7	Leonard Rochlitz	Dr	75	6	GI		do	Do.
74	SW¼SW¼SE¼ sec. 9	Adolph Schliski	Dr	110	5	GI	110	Sand and gravel	Do.
75	SE¼NE¼NE¼ sec. 12	Mrs. Ron Middleton	Dr	52	6	GI	52	do	Do.
76	NW¼NW¼NW¼ sec. 14	T. H. Evans	Dr	80	6	GI	80	do	Do.
77	NW¼NW¼SE¼ sec. 15	Richart Kent	Dr	75	6	S	75	do	Do.
78	SW¼SW¼SW¼ sec. 16	do	Dr	69.3	5	GI	69.3	do	Do.
79	NW¼NW¼SW¼ sec. 17	do	Dr	90	4	GI	90	do	Do.
80	NE¼NE¼NE¼ sec. 20	Not known	Dr	59.5	4.5	GI		do	Do.
81	SW¼SW¼SW¼ sec. 20	Edward Jacobson	Dr	75	6	GI	75	do	Do.
82	SW¼SW¼SW¼ sec. 21	Union Pacific R. R.	Dr	67.0	4	GI	67	do	Do.
83	SW¼SW¼SW¼ sec. 23	Walter Kent	Dr	100	5	GI	100	do	Do.
84	NE¼NW¼NE¼ sec. 24	L. M. Wilkowski	Dr	60	5	GI	60	do	Do.
85	NW¼NE¼NW¼ sec. 25	Harold Vaughan	Dr	97	18	S	70	do	Do.
86	NW¼NW¼NW¼ sec. 25	do	Dr	102	18	GI	102	do	Do.
87	SW¼SW¼NW¼ sec. 26	Gilbert Troutman	Dr	100	5	GI	100	do	Do.
(88)	SE¼SE¼NE¼ sec. 28	Elmer Cloyd	Dr	60.0	5	GI	60	do	Do.
89	SW¼SW¼NW¼ sec. 29	W. H. Chamberlain	Dr	67.0	5	GI	67	do	Do.
90	SW¼SW¼SW¼ sec. 29	O. R. McComas	Dr	67.0	5	GI	67	do	Do.
91	SW¼SW¼NW¼ sec. 30	James H. Carnes	Dr	61.0	5	GI	61	do	Do.
92	SW¼NE¼SW¼ sec. 31	Carpenter General Store	Dr	80	5	GI	80	do	Do.
(93)	SW¼SW¼NW¼ sec. 32	R. E. Kane	Dr	65	6	GI	65	do	Do.
94	NW¼NW¼NW¼ sec. 33	Carrol Cloyd	Dr		4.5	GI		do	Do.
95	SW¼SW¼SW¼ sec. 33	M. A. Little	Dr	115	4.5	GI	80	do	Do.
	T. 13 N., R. 63 W.								
96	NW¼NW¼SW¼ sec. 4	James L. Bailey	Dr	113.0	5	GI		Sand	Do.
97	SE¼SE¼SE¼ sec. 4	H. P. Dipner	Dr	700	6	GI	30	do	Do.
98	NW¼SW¼NW¼ sec. 5	W. A. McDowell	Dr	85	6	S	85	do	Do.
99	SW¼SW¼NE¼ sec. 8	Emil Gustafson	Dr	75.0	4.5	GI		Sand and gravel	Do.
100	NE¼NE¼NE¼ sec. 10	William Dittmer	Dr	82.0	5	GI		do	Do.
101	SW¼SW¼SW¼ sec. 12	A. R. Mittan	Dr	100	6	GI	100	do	Do.
102	SE¼SE¼SE¼ sec. 13	Harold Cozad	Dr	80	6	GI	80	do	Do.
103	SW¼SW¼SE¼ sec. 14	R. V. Kent	Dr	49	4	GI		do	Do.
104	NE¼NE¼NE¼ sec. 20	C. E. Montgomery	Dr	54	6	GI	54	do	Do.

105	NE¼NW¼NW¼ sec. 22	R. V. Kent	Dr	64.0	5	GI		Siltstone	Brule.
106	SW¼NE¼SW¼ sec. 26	Edward Oline	Dr	57.0	5	GI		do	Do.
107	NE¼NE¼NE¼ sec. 30	Ward Evans	Dr	125	6	GI	125	Sandstone	Arikaree.
108	SW¼NW¼SW¼ sec. 33	D. A. Bunnell	Dr	131.0	24	S	8	Siltstone	Brule.
	T. 14 N., R. 60 W.								
109	NW¼NW¼NE¼ sec. 4	C. G. Wisroth	Dr	73	18	GI	20	do	Do.
110	NE¼NW¼SE¼ sec. 4	H. L. Wisroth	Dr	70	18	GI	24	do	Do.
111	NE¼SW¼NE¼ sec. 5	C. G. Wisroth	Dr	80	18	GI	20	do	Do.
112	NW¼NW¼SE¼ sec. 6	H. L. Wisroth	Dr	73.3	18	GI	24	do	Do.
(113)	NE¼NW¼NW¼ sec. 8	C. G. Wisroth	Dr	80	18	GI	25	do	Do.
(114)	SW¼SW¼NW¼ sec. 8	Henry Wisroth	Dr	80	100	GI		do	Do.
115	SW¼NE¼NW¼ sec. 10	M. L. Larson	Dr	72	36	GI	72	Sand and gravel	Alluvium.
116	SW¼SW¼SE¼ sec. 10	Mrs. Ellison	Dr	92	24	GI	92	Siltstone	Brule.
(117)	SW¼SW¼NW¼ sec. 11	M. L. Larson	Dr	60	24	GI	60	Sand and gravel	Alluvium.
118	SW¼NW¼NW¼ sec. 14	E. G. Sanders	DD	62	60 by 72 to 24	Cn	32	Siltstone	Brule.
119	SW¼SW¼NW¼ sec. 15	C. C. Gross	DD	100	72 to 36	Cn	29	do	Do.
(120)	NW¼NW¼SE¼ sec. 15	City of Pine Bluffs	Dr	125	20	GI	20	do	Do.
(121)	SE¼SE¼SW¼ sec. 16	C. C. Gross	D	91.1	60 to 24	Cn	26	Sand and gravel	Alluvium.
(122)	NW¼NW¼NE¼ sec. 17	do	Dr	80	18	GI	25	Siltstone	Brule.
123	SW¼SW¼SW¼ sec. 17	do	Dr	68.3	24	N		Sand and gravel	Terrace deposits.
124	NW¼SW¼SE¼ sec. 17	do	Dr	100	36	GI	100	do	Do.
(125)	NW¼NW¼NE¼ sec. 19	Olive M. Young	Dr	110	20	GI	20	do	Do.
126	SE¼SE¼NW¼ sec. 19	Dale C. Bowers	Dr	100	18	GI	100	do	Do.
127	NE¼SW¼NE¼ sec. 20	Carl Fornstrom	Dr	90	20	GI	24	do	Do.
128	NW¼NW¼SW¼ sec. 20	C. F. Paullin	Dr	80	20	N		do	Do.
129	NW¼SW¼NW¼ sec. 21	Carl Fornstrom	Dr	83	18	GI	25	Siltstone	Brule.
130	SW¼SW¼SW¼ sec. 21	Anna L. B. Foster	Dr	93	20	S	25	do	Do.
131	NE¼NE¼NW¼ sec. 26	Ronald Haines	D	145	72	Cn	145	Sandstone	Ogallala.
(132)	NW¼NW¼NW¼ sec. 28	Herbert Campbell	Dr	96	20	GI	20	Siltstone	Brule.
133	SW¼SW¼SW¼ sec. 28	Elmer Glantz	Dr	84	18	S	40	do	Do.
134	NW¼NW¼SE¼ sec. 28	Mable Soule	Dr	106	22	GI	35	do	Do.
135	NE¼SW¼SE¼ sec. 28	Herbert Campbell	Dr	65	60	S	65	Gravel	Alluvium.
(136)	SW¼NW¼NW¼ sec. 29	C. F. Paullin	Dr	78	22	GI	28	Siltstone	Brule.
(137)	SE¼NW¼SW¼ sec. 29	Herbert Campbell	Dr	100	18	GI	6	do	Do.
138	NW¼SW¼NW¼ sec. 30	Robert Morris	Dr	82.2	22	GI	17	do	Do.
139	SW¼NW¼SW¼ sec. 30	do	Dr	93	18	GI		do	Do.
140	SW¼NW¼SE¼ sec. 30	do	Dr	78.3	18	GI	12	do	Do.
141	NE¼NW¼NE¼ sec. 32	Herbert Campbell	Dr	80	18	S	15	do	Do.
(142)	NW¼NW¼SE¼ sec. 32	do	Dr	41.3	60	Cn	20	do	Do.
143	SE¼SE¼SE¼ sec. 32	do	D	37	72	Cn	7	do	Do.

See footnotes at end of table.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*—Continued

Well no.	Location	Owner or tenant	Type of well [1]	Depth of well (feet) [2]	Diameter of well (inches)	Type of casing [3]	Depth to which well is cased (feet)	Principal water-bearing bed: Character of material	Principal water-bearing bed: Geologic formation
	T. 14 N., R. 61 W.								
144	NE¼NE¼SW¼ sec. 2	Carl Bogic	Dr	94.2	24	GI		Siltstone	Brule.
145	SW¼SE¼SW¼ sec. 9	L. F. Brillhart	Dr	110	18	GI		do	Do.
146	NW¼NW¼NE¼ sec. 14	H. R. Eggrs	Dr	70	4.5	GI		do	Do.
147	SW¼SW¼NW¼ sec. 16	L. F. Brillhart	Dr	116	18	GI	10	do	Do.
(148)	NW¼SW¼NW¼ sec. 18	Bert Tucker	Dr	45	5	GI	17	Sandstone	Arikaree.
(149)	NW¼NW¼NW¼ sec. 21	C. E. Kaser	Dr	95	18	GI	30	Siltstone	Brule.
150	SW¼NW¼NW¼ sec. 21	do	Dr	97.2	18	GI	10	do	Do.
151	NE¼NE¼SW¼ sec. 21	do	DD	85.5	21	GI	35	do	Do.
152	SW¼SW¼NE¼ sec. 23	Walter Brown	Dr	125	21	GI	27	do	Do.
153	SW¼NW¼NW¼ sec. 23	John C. Prosser	Dr	100	18	GI	100	do	Do.
154	NW¼SW¼SE¼ sec. 23	J. W. Minnick	Dr	105	23	GI	40	do	Do.
155	SW¼SW¼NW¼ sec. 25	C. B. Brown	Dr	120	18	GI		do	Do.
156	SE¼SE¼SW¼ sec. 25	do	Dr	100	18	GI		do	Do.
157	SW¼SW¼NW¼ sec. 26	Walter Brown	Dr	125	24	GI	20	do	Do.
158	SW¼SW¼SW¼ sec. 26	Andrew C. Floy	Dr	87	18	GI	9	do	Do.
(159)	NW¼SW¼SW¼ sec. 27	Jay Brown	Dr	80	20	GI		do	Do.
160	SW¼NW¼SE¼ sec. 28	do	Dr	90	20	GI		do	Do.
161	NW¼NW¼NW¼ sec. 29	G. E. Cook	Dr	27.5	6	GI	27.5	do	Do.
162	SW¼SW¼NE¼ sec. 32	Thomas Suchomel	Dr	100	18	N		do	Do.
163	SW¼NW¼NE¼ sec. 35	do	Dr	91.0	20	N		do	Do.
	T. 14 N., R. 62 W.								
(164)	NW¼NW¼SE¼ sec. 7	Town of Burns	Dr	254	6			Sandstone	Arikaree.
165	do	do	Dr	150	6			do	Do.
(166)	NW¼NW¼SE¼ sec. 11	C. E. Kaser	Dr	90	18	S	18	Siltstone	Brule.
167	NE¼NE¼NE¼ sec. 12	R. G. Anderson	Dr	140	6	GI		do	Do.
168	SW¼SE¼SW¼ sec. 12	C. E. Kaser	Dr	20.3	8	GI	20	Gravel	Alluvium.
169	SW¼SW¼SE¼ sec. 19	Joe Lagerway	Dr	70.6	4	GI	30	Sandstone	Ogallala.
170	NW¼NW¼NW¼ sec. 22	J. W. Minnick	Dr	120	4	GI		do	Arikaree.
171	SE¼NE¼NE¼ sec. 24	Union Pacific R. R.	D	36.5	192	R	36.5	Siltstone	Brule.
(172)	NW¼NW¼NW¼ sec. 24	L. A. Miller	DD	95	96	R	35	do	Do.
173	SW¼NW¼SE¼ sec. 36	J. M. Bastain	Dr	17	6	GI	17	Gravel	Alluvium.

	T. 14 N., R. 63 W.								
174	NW¼NW¼NW¼ sec. 8	C. A. Erickson	Dr	98	6	GI	98	Sandstone	Ogallala.
175	NE¼NE¼SE¼ sec. 10	A. B. Schauf	Dr	96	6	GI	96	do	Do.
176	SE¼SE¼SW¼ sec. 12	Vernon McDowell	Dr	63	5	GI	63	do	Do.
177	NE¼NE¼NE¼ sec. 18	Robert Gibson	Dr	83.7	6	GI	40	do	Do.
178	NW¼SW¼NW¼ sec. 18	Mr. Burkett	Dr	120	6	GI		do	Do.
(179)	NW¼NW¼NW¼ sec. 20	Elmer Gibson	Dr	112	6	GI	12	do	Do.
180	SW¼SW¼SE¼ sec. 20	Arthur G. Gillett	Dr	98.6	5	GI		do	Do.
181	SE¼SE¼SE¼ sec. 22	do	Dr	100	6	GI	100	do	Do.
182	NE¼SE¼SE¼ sec. 26	J. M. Bastain	Dr	53.5	6	GI		do	Do.
183	SE¼SE¼SW¼ sec. 32	W. H. Miller	Dr	80	6	GI	80	do	Do.
184	NE¼NE¼SE¼ sec. 34	Lorena F. G. Noyes	Dr	110.2	3	GI		do	Do.
	T. 15 N., R. 60 W.								
(185)	NE¼NE¼NE¼ sec. 4	John Marquardt	Dr	108	6	GI	108	Sand	Do.
186	SW¼SW¼SE¼ sec. 7	Hazel Sundin	Dr	100	18	N		Siltstone	Brule.
187	NW¼NW¼SW¼ sec. 8	Victor Sundin	Dr	149	20	N		do	Do.
188	NE¼NE¼SW¼ sec. 18	Lee Wymer	Dr	96	18	GI		do	Do.
189	NW¼NW¼SW¼ sec. 20	W. T. Young	Dr	108	21	GI	20	do	Do.
(190)	NW¼SE¼SW¼ sec. 20	do	Dr	108	21	GI	20	do	Do.
191	NW¼NW¼NW¼ sec. 22	M. L. Larson	Dr	136	6	GI		Sandstone	Ogallala.
(192)	NW¼NW¼SW¼ sec. 28	Edward Macy	Dr	100	18	GI	20	Siltstone	Brule.
193	SE¼NW¼NW¼ sec. 29	W. T. Young	Dr	108	21	GI	20	do	Do.
(194)	SW¼SE¼NW¼ sec. 29	do	Dr	108	21	GI	20	do	Do.
195	SW¼NW¼SW¼ sec. 30	Mary A. Simpson	D	48	36	R	48	do	Do.
196	NW¼NW¼NE¼ sec. 32	W. T. Young	Dr	120	22	GI	20	do	Do.
197	NW¼NW¼SW¼ sec. 32	C. S. Macy	Dr	96	18	GI	24	do	Do.
198	NE¼NE¼SW¼ sec. 33	Fred Prosser	Dr	85	18	GI	15	do	Do.
199	NW¼NW¼NW¼ sec. 34	Glenn Macy	Dr	95	18	N		do	Do.
(200)	NE¼SW¼NW¼ sec. 34	do	D	95	36	Cn		do	Do.
	T. 15 N., R. 61 W.								
201	NE¼SE¼SE¼ sec. 4	R. O. Stansbury	Dr	95	6	S	95	Sandstone	Do.
202	NE¼NE¼SE¼ sec. 24	John Wymer	Dr	120	6	S	120	Siltstone	Do.
(203)	SE¼SE¼NE¼ sec. 28	Mark Floy	Dr	100	6	GI	100	do	Do.

See footnotes at end of table.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*—Continued

Well no.	Location	Owner or tenant	Method of lift [4]	Use of water [5]	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Depth to water level below measuring point (feet) [6]	Date of measurement	Remarks (Yield given in gallons a minute, drawdown in feet)
	T. 12 N., R. 60 W.								
1	NE¼NE¼NW¼ sec. 5	Olive M. Young	T, E	I	Land surface	0	60	Oct. 10, 1947	Yield 685; drawdown 26.8.
(2)	SE¼SW¼SW¼ sec. 5	W. T. Young	T, E	I, O	do	0	54	Oct. 14, 1947	Battery of four wells.
3	NW¼NW¼SE¼ sec. 6	Clyde Stevens	T, E	I	Concrete floor in pump house	+.6	20.24	July 9, 1941	Yield 780; drawdown 54.3.
4	SE¼SE¼SE¼ sec. 6	do	T, E	I	do	+.5	19.14	July 18, 1936	Reported yield 900; drawdown 20.
	T. 12 N., R. 61 W.								
5	SW¼SW¼SE¼ sec. 1	Union Pacific R. R.	Cy, H	D, O	Top of casing, west side	+.4	63.83	Sept. 2, 1942	Unused well.
6	NE¼NE¼NW¼ sec. 2	William Herman	N	O	Top of casing	+.8	55.46	Nov. 24, 1940	Abandoned.
7	NE¼NW¼NE¼ sec. 3	Harry E. Anderson	T, E	I, O	Hole in pump base	+.3	32.90	Sept. 15, 1947	Reported yield 400.
8	NW¼NW¼NW¼ sec. 7	Gerald Thompson	T, E	D, S	Land surface	0	35	June 10, 1947	
9	NW¼NW¼NE¼ sec. 8	Henry Hodges	Cy, W	D, S	do	0	22	Dec. 20, 1945	
10	SE¼SE¼NE¼ sec. 8	John Bauman	Cy, W	D, S	do	0	40	Oct. 7, 1947	
11	SW¼SW¼SE¼ sec. 10	J. L. McDonald	Cy, W	D, S, O	Bottom of pump base	+1.0	39.05	Sept. 2, 1942	
12	NW¼SE¼NW¼ sec. 18	John Bauman	T, G	I	Land surface		24.0	June 1, 1940	Reported yield 500.
13	SE¼SE¼SE¼ sec. 18	do	T, Tr	I	do		24	Oct. 8, 1947	Reported yield 1,700; drawdown 38.
	T. 12 N., R. 62 W.								
14	NW¼NW¼NE¼ sec. 1	Carl Jennings	T, E	I	do		54	Dec. 15, 1947	Reported yield 1,400.
15	NW¼NW¼NE¼ sec. 2	Odd White	N	O	Top of casing, south side	+.7	54.44	Nov. 28, 1940	Abandoned.
16	SW¼SW¼NW¼ sec. 2	George Phillips	T, E	I	Hole in pump base	+1.7	61.08	Mar. 15, 1946	Reported yield 970.
17	SE¼SE¼NW¼ sec. 2	George Bours	T, Tr	I	Lower lip of discharge pipe	+7.4	60.48	do	Reported yield 800.
18	SW¼NW¼NW¼ sec. 3	C. G. DeMuth	T, E	I	do	+9.5	64.46	Oct. 6, 1947	Reported yield 700.
19	SE¼SE¼NE¼ sec. 5	Ray True	Cy, W	S	Top of casing	+1.0	65.87	do	
20	NW¼NE¼NE¼ sec. 6	William Flamme	Cy, W	S, O	do	+.1	58.59	Apr. 25, 1945	Abandoned.
21	NE¼NE¼NE¼ sec 8	Bank of Carpenter	Cy, W	S, O	do	+.5	54.06	May 8, 1945	Do.
22	NE¼NW¼NE¼ sec. 9	D. A. Bunnell	Cy, W	S, O	Bottom of pump base	+1.4	51.96	Sept. 15, 1947	
(23)	NW¼NW¼SW¼ sec. 9	P. M. Ragland	T, E	I	Lower lip of discharge pipe	+9.4	57.11	Mar. 15, 1946	Reported yield 1,350.
24	NW¼NW¼NW¼ sec. 11	Carl Jennings	T, E	I	Hole in pump base	+.9	54.43	Mar. 11, 1946	Reported yield 1,050; drawdown 14.5.
25	NW¼NW¼SW¼ sec. 12	Charles Smith	Cy, E	D, S	Land surface	0	44	Oct. 7, 1947	
26	NW¼NW¼NE¼ sec. 13	R. D. Smith	Cy, W	S, O	Top of casing, south side	+.8	25.69	Sept. 2, 1942	
27	NW¼SW¼NW¼ sec. 14	G. H. Pema	Cy, W	D, S	Land surface	0	30	Oct. 8, 1947	
28	NW¼NW¼NW¼ sec. 15	Lebertas Noyer	Cy, G	D, S	Top of casing, east side	0	40.28	do	

	T. 12 N., R. 63 W.								
29	NE¼NE¼NW¼ sec. 3	R. L. Gasserant	N	O	Edge of wooden frame, north side.	+.4	48.32	Aug. 28, 1942	Unsuccessful irrigation well.
30	NE¼NE¼SE¼ sec. 3	Wyoming Farm Loan Board.	Cy, W	D, O	Top of casing	+0.3	34.54	Aug. 21, 1942	
31	NW¼NW¼SE¼ sec. 7	F. E. Bollan	N	O	do	0	1.25	Aug. 28, 1942	
32	SW¼NE¼SE¼ sec. 12	Otis Breeden	N	O	do	+1.2	8.91	Sept. 2, 1942	
	T. 13 N., R. 60 W.								
33	NW¼SW¼NE¼ sec. 5	Herbert Campbell	T, E	I	Top of pump base	+.1	25.90	July 8, 1941	Yield 1,105; drawdown 4.3.
34	SE¼NE¼SE¼ sec. 5	do	T, E	I	Land surface	0	24	do	
35	NW¼NW¼NW¼ sec. 8	do	T, E	I	Top of pump base, east side	+.5	42.41	June 6, 1941	Yield 600; drawdown 15.1.
(36)	NW¼NW¼SW¼ sec. 8	do	T, E	I, O	Lower lip of discharge pipe		36.42	June 27, 1947	
37	SE¼NE¼SW¼ sec. 8	do	T, E	I	Top of 2- by 4-inch wedge, west side.	−.5	78.20	Jan. 9, 1943	
38	SE¼SE¼NE¼ sec. 17	Moritz brothers	T, E	I	Land surface	0	61.0	Feb. 10, 1947	Reported yield 800.
(39)	SE¼SE¼NW¼ sec. 17	do	T, E	I	Hole in pump base	+.3	32.83	Mar. 13, 1946	Reported yield 1,500; drawdown 2.
40	SW¼SW¼NE¼ sec. 18	Ray Larsen	T, E	I	do	+1.0	27.28	Mar. 14, 1946	Reported yield 1,378; drawdown 10.
41	SE¼NE¼SE¼ sec. 18	do	T, E	I	Top of casing	+.7	38.14	Mar. 13, 1946	Reported yield 750; drawdown 20. Gravel from 18 to 23 feet.
42	SW¼NW¼NW¼ sec. 20	Moritz brothers	T, E	I	Land surface	0	39.70	Mar. 15, 1946	Reported yield 600.
43	SW¼NW¼SW¼ sec. 21	do	Cy	S	Hole in steel cover	+.8	76.72	Jan. 9, 1943	Abandoned.
44	NE¼NE¼SW¼ sec. 30	Myles Gardner	T, E	I	Land surface	0	42.31	Mar. 18, 1946	Reported yield 675; drawdown 45.
45	NE¼NW¼NE¼ sec. 31	Olive M. Young	T, E	I	do	0	60	Sept. 15, 1947	Yield 476; drawdown 31.8.
46	NW¼NW¼NE¼ sec. 31	Max Thelen	T, G	I	do	0	40	Nov. 3, 1947	
47	SE¼SE¼SE¼ sec. 31	Olive M. Young	T, E	I, O	Top of oil-drum cover	+1.5	22.14	Sept. 15, 1947	
48	SE¼SE¼SW¼ sec. 32	do	T, G	I	Land surface	0	56	July 15, 1947	Reported yield 600.
49	NW¼NE¼NW¼ sec. 34	Not known	Cy, W	S, O	Bottom of pump base	+1.0	163.84	Jan. 6, 1943	
	T. 13 N., R. 61 W.								
50	NE¼SE¼SW¼ sec. 3	James Dolan	T, E	I, O	Top of casing	0	19.90	Nov. 28, 1940	
51	NW¼NW¼SE¼ sec. 5	J. D. Wasson	N	O	do	+.5	9.87	Nov. 24, 1940	Abandoned.
(52)	SE¼SE¼NW¼ sec. 11	Edna I. Dolan	T, E	I	Land surface				Well flows.
53	NW¼SW¼SW¼ sec. 12	Thomas Kelly	T, E	I, O	Top of casing	−.3	5.35	Nov. 22, 1940	
(54)	SE¼SE¼SW¼ sec. 15	Jesse Stuart	Cy, W	D, S	Land surface	0	90	Sept. 26, 1947	
55	SE¼SW¼SE¼ sec. 16	C. L. Butler	N	O	Top of iron rod at well	0	40.31	Nov. 30, 1940	Well caved and abandoned.
56	SW¼SW¼NW¼ sec. 17	do	Cy, W	D, S	Top of casing	+1.0	52.14	Oct. 14, 1947	
57	SW¼SW¼NW¼ sec. 18	Mr. Johnson	N	O	do	+.3	48.74	Nov. 22, 1940	
58	NW¼NW¼NE¼ sec. 20	G. H. Plamback	Cy, G	D, S	Land surface	0	30	Oct. 8, 1947	
59	SW¼NW¼SW¼ sec. 22	Gertrude Evans	Cy, H	O	Top of concrete curb at bench mark.	+1.2	47.10	Nov. 24, 1940	
60	NE¼NE¼NE¼ sec. 24	Leona G. White	N	O	Top of casing	+.2	13.75	Nov. 20, 1940	
61	NW¼SW¼SE¼ sec. 25	Myles Gardner	T, E	I	Land surface	0	18	Dec. 20, 1947	Reported yield 800.
62	NE¼SW¼NW¼ sec. 28	R. L. Gall	Cy, W	D, S	do	0	64	Oct. 7, 1947	
(63)	NW¼NW¼NE¼ sec. 29	Park Chamberlain	Cy, W	S	Top of casing	+.6	60.14	Oct. 8, 1947	
(64)	NW¼NW¼SW¼ sec. 30	Claude E. Hardy	Cy, E	D, S	Land surface	0	65	Sept. 26, 1947	
65	SW¼SE¼SE¼ sec. 31	Max Thelen	Cy, W	S, O	Top of casing	+.6	46.05	Sept. 2, 1942	
66	SE¼SE¼SE¼ sec. 31	O. M. Young	T, E	I	Land surface	0	50	Sept. 26, 1947	Reported yield 800.
67	SE¼SE¼SW¼ sec. 32	Robert Morris	Cy, W	D, S	Top of casing	+.8	30.95	Oct. 8, 1947	Well not in use.
68	NW¼NW¼SW¼ sec. 34	do	N	O	do	+.8	36.25	Dec. 20, 1945	

See footnotes at end of table.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*—Continued

Well no.	Location	Owner or tenant	Method of lift [4]	Use of water [5]	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Depth to water level below measuring point (feet) [6]	Date of measurement	Remarks (Yield given in gallons a minute, drawdown in feet)
	T. 13 N., R. 62 W.								
69	SW¼NW¼SW¼ sec. 2	Robert Brady	Cy, W	D, S	Land surface	0	60	Oct. 9, 1947	
70	NW¼NW¼SW¼ sec. 4	William Kranz	Cy, W	D, S	do	0	62	Oct. 8, 1947	
71	NE¼NE¼NE¼ sec. 6	A. H. Black	Cy, W	D, S	do	0	30	do	
72	NE¼NE¼SE¼ sec. 6	Ernest Wagner	Cy, W	D, S	Top of casing	+1.1	72.50	Oct. 9, 1947	
73	NE¼NE¼NE¼ sec. 7	Leonard Rochlitz	Cy, W	S	Land surface	0	65	Oct. 7, 1947	
74	SW¼SW¼SE¼ sec. 9	Adolph Schliski	Cy, W	D, S	do	0	90	do	
75	SE¼NE¼NE¼ sec. 12	Mrs. Ron Middleton	Cy, W	D, S	do	0	40	do	
76	NW¼NW¼NW¼ sec. 14	T. H. Evans	Cy, W	S	Top of casing, north side	+.4	63.77	do	
77	NW¼NW¼SE¼ sec. 15	Richard Kent	Cy, W	S	Top of casing	+.8	60.40	do	
78	SW¼SW¼SW¼ sec. 16	do	Cy, W	D, O	do	+1.0	57.64	Sept. 1, 1942	
79	NW¼NW¼SW¼ sec. 17	do	Cy, E	D, S	Hole in pump platform, north side.	+.3	59.99	Nov. 7, 1947	
80	NE¼NE¼NE¼ sec. 20	Not known	Cy	D, S, O	Base of pump	+.2	55.53	June 19, 1941	
81	SW¼SW¼SW¼ sec. 20	Edward Jacobson	T, E	D	Land surface	0	60	Oct. 6, 1947	
82	SW¼SW¼SW¼ sec. 21	Union Pacific R. R.	Cy, W	O	Top of casing, west side	+.5	44.66	Sept. 1, 1942	
83	SW¼SW¼SW¼ sec. 23	Walter Kent	Cy, E	D, S	Land surface	0	55	Oct. 7, 1947	
84	NE¼NW¼NE¼ sec. 24	L. M. Wilkowski	Cy, W	S, O	Top of block below pump base	+1.6	55.30	Sept. 2, 1942	
85	NW¼NE¼NW¼ sec. 25	Harold Vaughan	T, E	I	Land surface	0	70	Jan. 15, 1948	Reported yield 600.
86	NW¼NW¼NW¼ sec. 25	do	T, G	I	Lower lip of discharge pipe	+20.0	92.69	Oct. 8, 1947	Reported yield 500.
87	SW¼SW¼NW¼ sec. 26	Gilbert Troutman	Cy, W	D, S	Top of casing		50	do	
(88)	SE¼SE¼NE¼ sec. 28	Elmer Cloyd	Cy, W	D, S, O	do	+.2	52.48	Sept. 1, 1942	Abandoned.
89	SW¼SW¼NW¼ sec. 29	W. H. Chamberlain	Cy, H	D, O	do	+.6	48.11	Aug. 21, 1942	Abandoned.
90	SW¼SW¼SW¼ sec. 29	O. R. McComas	Cy, W	D, S	do	+.5	56.20	Oct. 6, 1947	
91	SW¼SW¼NW¼ sec. 30	James H. Carnes	Cy, W	D, I, O	Top of casing, west side	+.5	44.47	Aug. 21, 1942	Irrigates small garden.
92	SW¼NE¼SW¼ sec. 31	Carpenter General Store.	Cy, H	D, O	Top of casing	+.3	60.0	do	Abandoned.
(93)	SW¼SW¼NW¼ sec. 32	R. E. Kane	Cy, W	D, S	Land surface	0	33	Oct. 7, 1947	
94	NW¼NW¼NW¼ sec. 33	Carrol Cloyd	Cy, W	S	Edge of pump base	+1.2	54.75	Oct. 6, 1945	
95	SW¼SW¼SW¼ sec. 33	M. A. Little	Cy, W	D, S	Top of casing	+.9	72.60	Oct. 6, 1947	
	T. 13 N., R. 63 W.								
96	NW¼NW¼SW¼ sec. 4	James L. Bailey	Cy, W	S	Bottom edge of pump base	+.5	85.79	Sept. 1, 1942	
97	SE¼SE¼SE¼ sec. 4	H. P. Dipner	Cy, W	D, S	Land surface	0	93	Oct. 10, 1947	
98	NW¼SW¼NW¼ sec. 5	W. A. McDowell	Cy, W	S	do	0	70	Oct. 14, 1947	
99	SW¼SW¼NE¼ sec. 8	Emil Gustafson	Cy, H	D, O	Top of casing	+1.2	71.41	Aug. 21, 1942	Unused well.

100	NE¼NE¼NE¼ sec. 10	William Dittmer	Cy, W	O	Top of casing, south side	0	67.59	Sept. 1, 1942	Do.
101	SW¼SW¼SW¼ sec. 12	A. R. Mittan	Cy, W	D, S	Land surface	0	60	Oct. 14, 1947	
102	SE¼SE¼SE¼ sec. 13	Harold Cozad	Cy, W	D, S	Top of casing	0	60.30	Oct. 9, 1947	
103	SW¼SW¼SE¼ sec. 14	R. V. Kent	N	O	Top of casing, west side	0	38.28	Mar. 21, 1942	Do.
104	NE¼NE¼NE¼ sec. 20	C. E. Montgomery	Cy, W	D, S	Land surface	0	50	Oct. 10, 1947	
105	NE¼NW¼NW¼ sec. 22	R. V. Kent	Cy, W	S, O	Top of casing	+1.2	57.89	Aug. 28, 1942	
106	SW¼NE¼SW¼ sec. 26	Edward Oline	Cy, W	I, S, O	do		50.64	do	
107	NE¼NE¼NE¼ sec. 30	Ward Evans	Cy, W	D, S	Land surface	0	90	Oct. 10, 1947	
108	SW¼NW¼SW¼ sec. 33	D. A. Bunnell	N	I, O	Edge of steel cover, west side	+1.0	49.75	Aug. 21, 1942	
	T. 14 N., R. 60 W.								
109	NW¼NW¼NE¼ sec. 4	C. G. Wisroth	T, E	I	Top of casing	0	40.25	Dec. 11, 1945	Reported yield 500; drawdown 20.
110	NE¼NW¼SE¼ sec. 4	H. L. Wisroth	T, E	I	do	0	30.13	Dec. 7, 1945	Reported yield 750; drawdown 27.
111	NE¼SW¼NE¼ sec. 5	C. G. Wisroth	T, Tr	I	do	−.6	27.65	do	Reported yield 800.
112	NW¼NW¼SE¼ sec. 6	H. L. Wisroth	T, E	I	do	+.1	30.13	do	Yield 732; drawdown 36.
(113)	NE¼NW¼NW¼ sec. 8	C. G. Wisroth	T, E	I	do	0	20	June 2, 1947	Reported yield 800.
(114)	SW¼SW¼NW¼ sec. 8	Henry Wisroth	T, G	I	do	0	40	Dec. 30, 1947	Reported yield 900.
115	SW¼NE¼NW¼ sec. 10	M. L. Larson	T, E	I	Lower lip of discharge pipe	+5.7	24.72	Dec. 4, 1945	Yield 1,000.
116	SW¼SW¼SE¼ sec. 10	Mrs. Ellison	T	I, O	Timber at pump base, east side.	+.4	15.38	June 26, 1947	
(117)	SW¼SW¼NW¼ sec. 11	M. L. Larson	T, E	I, O	Lower lip of discharge pipe	+8.3	22.67	do	Yield 1,000.
118	SW¼NW¼NW¼ sec. 14	E. G. Sanders	T, E	I, O	Land surface	0	30.48	do	Reported yield 400.
119	SW¼SW¼NW¼ sec. 15	C. C. Gross	T, D	I	Top of concrete casing	−3.0	5.95	Dec. 11, 1945	Reported yield 1,250.
(120)	NW¼NW¼SE¼ sec. 15	City of Pine Bluffs	T, E	P	Land surface	0	25	do	Yield 500; drawdown 6.
(121)	SE¼SE¼SW¼ sec. 16	C. C. Gross	T, E	I	Top of casing	−5.5	8.89	June 26, 1947	Yield 1,400; drawdown 14.79.
(122)	NW¼NW¼NE¼ sec. 17	do	T, E	I	Lower lip of discharge pipe	+5.8	31.62	Dec. 7, 1945	Reported yield 1,400.
123	SW¼SW¼SW¼ sec. 17	do	N	N	Top of casing	−.8	54.50	July 9, 1946	Unsuccessful irrigation well.
124	NW¼SW¼SE¼ sec. 17	do	T, E	I	Edge of casing	0	50.80	Dec. 7, 1945	Yield 422; drawdown 42.2.
(125)	NW¼NW¼NE¼ sec. 19	Olive M. Young	T, E	I	do	0	60.44	Dec. 20, 1945	Reported yield 475.
126	SE¼SE¼NW¼ sec. 19	Dale C. Bowers	T, E	I	do	0	29.0	June 8, 1942	Reported yield 1,500.
127	NE¼SW¼NE¼ sec. 20	Carl Fornstrom	T, E	I	Edge of south side of pump base.	0	25.32	Dec. 13, 1945	Twelve feet of gravel.
128	NW¼NW¼SW¼ sec. 20	C. F. Paullin	N		Edge of plank over well	−.4	46.69	June 26, 1947	
129	NW¼SW¼NW¼ sec. 21	Carl Fornstrom	T, E	I	Land surface	0	23.0	May 20, 1945	
130	SW¼SW¼SW¼ sec. 21	Anna L. B. Foster	T, E	I	Edge of casing	+.3	21.43	Dec. 13, 1945	Reported yield 2,000.
131	NE¼NE¼NW¼ sec. 26	Ronald Haines	Cy, W	D, S	Top of concrete curbing	+2.0	131.23	Dec. 30, 1942	
(132)	NW¼NW¼NW¼ sec. 28	Herbert Campbell	T, E	I, O	Hole in east side of pump base	+.8	23.11	June 26, 1947	Yield 1,465; drawdown 11.8.
133	SW¼SW¼SW¼ sec. 28	Elmer Glantz	T, G	I	Land surface	0	10	Mar. 11, 1946	
134	NW¼NW¼SE¼ sec. 28	Mable Soule	T, D	I	North side of pump base	+4.0	56.65	Jan. 9, 1943	
135	NE¼SW¼SE¼ sec. 28	Herbert Campbell	T, E	D, S, I	Land surface	0	34	Mar. 11, 1946	Pump in basement of house.
(136)	SW¼NW¼NW¼ sec. 29	C. F. Paullin	T, E	I, O	Hole in north side of pump base.	+2.6	50.38	June 26, 1947	Yield 1,355; drawdown 9.8.
(137)	SE¼NW¼SW¼ sec. 29	Herbert Campbell	T, E	I	Land surface	0	52.37	Mar. 11, 1946	Yield 1,200; drawdown 13.
138	NW¼SW¼NW¼ sec. 30	Robert Morris	T, E	I, O	Top of plank, south of pump	+.5	55.85	July 8, 1941	Yield 507; drawdown 8.9.
139	SW¼NW¼SW¼ sec. 30	do	N	N	Land surface	0	29.85	Nov. 25, 1940	Well caved.
140	SW¼NW¼SE¼ sec. 30	do	T, E	I	Hole in pump base	+.2	55.88	Mar. 12, 1946	
141	NE¼NW¼NE¼ sec. 32	Herbert Campbell	T, E	I	Top of casing	0	31.0	Mar. 11, 1946	Yield 1,000; drawdown 6.
(142)	NW¼NW¼SE¼ sec. 32	do	T, E	I	Top of pump base	+.9	21.98	Mar. 12, 1946	Yield 1,105; drawdown 7.5.
143	SE¼SE¼SE¼ sec. 32	do	T, E	I	Edge of plank in pump-house floor.	+.8	26.56	June 26, 1947	

See footnotes at end of table.

TABLE 9.—*Record of wells in the Egbert-Pine Bluffs-Carpenter area*—Continued

Well no.	Location	Owner or tenant	Method of lift [4]	Use of water [5]	Measuring point: Description	Measuring point: Distance above (+) or below (−) land surface (feet)	Depth to water level below measuring point (feet) [6]	Date of measurement	Remarks (Yield given in gallons a minute, drawdown in feet)
	T. 14 N., R. 61 W.								
144	NE¼NE¼SW¼ sec. 2	Carl Bogic	T, Tr	I, O	Top of timber over well at bench mark.	+.6	27.38	June 26, 1947	
145	SW¼SE¼SW¼ sec. 9	L. F. Brillhart	T, Tr	I	Concrete collar on pumped well.	0	54.16	Feb. 12, 1946	Yield 400. Battery of 3 wells.
146	NW¼NW¼NE¼ sec. 14	H. R. Eggrs	N	O	Top of casing, southeast side	+.7	58.34	June 26, 1947	Abandoned.
147	SW¼SW¼NW¼ sec. 16	L. F. Brillhart	T, Tr	I	Concrete collar of well	0	60.69	Feb. 12, 1946	Battery of 8 wells.
(148)	NW¼SW¼NW¼ sec. 18	Bert Tucker	Cy, W	D, S, O	Pump curb	+1.0	28.0	Oct. 7, 1947	
(149)	NW¼NW¼NW¼ sec. 21	C. E. Kaser	T, E	I, S	Edge of well collar	+1.0	52.12	Feb. 12, 1946	Yield 490; drawdown 12.
150	SW¼NW¼NW¼ sec. 21	do	N	O	Edge of casing	0	44.71	Apr. 29, 1947	
151	NE¼NE¼SW¼ sec. 21	do	T, E	I, O	Edge of plank, south side of pump.	0	31.20	Dec. 20, 1945	Yield 600; drawdown 35.0.
152	SW¼SW¼NE¼ sec. 23	Walter Brown	T, E	I	Land surface	0	56	Dec. 19, 1945	Battery of wells.
153	SW¼NW¼NW¼ sec. 23	John C. Prosser	T, G	I	do	0	53.0	Nov. 1, 1947	Reported yield 500.
154	NW¼SW¼SE¼ sec. 23	J. W. Minnick	T, Tr	I	Hole in pump base	+.7	63.12	Dec. 19, 1945	Forty feet of gravel at top of well.
155	SW¼SW¼NW¼ sec. 25	C. B. Brown	T, E	I	Land surface	0	42	Sept. 23, 1947	
156	SE¼SE¼SW¼ sec. 25	do	N	I	do	0	35	Feb. 1, 1940	
157	SW¼SW¼NW¼ sec. 26	Walter Brown	T, E	I	Top of casing, south well	+3.3	21.08	Dec. 19, 1945	Battery of 3 wells.
158	SW¼SW¼SW¼ sec. 26	Andrew C. Floy	T, Tr	I	Land surface	0	34	Sept. 23, 1947	
(159)	NW¼SW¼SW¼ sec. 27	Jay Brown	N	I	do	0	31	Dec. 22, 1947	
160	SW¼NW¼SE¼ sec. 28	do	C, G	I	do	0	36.12	Dec. 19, 1945	Reported yield 900.
161	NW¼NW¼NW¼ sec. 29	G. E. Cook	N	O	Top of casing	+1.3	25.95	May 2, 1947	
162	SW¼SW¼NE¼ sec. 32	Thomas Suchomel	T, E	I	Edge of plank, south of pump	+.3	48.83	Mar. 13, 1946	Battery of 4 wells.
163	SW¼NW¼NE¼ sec. 35	do	T, E	I	Top of concrete pump base	+.2	49.30	Aug. 14, 1941	Yield 360; drawdown 15.
	T. 14 N., R. 62 W.								
(164)	NW¼NW¼SE¼ sec. 7	Town of Burns	T, E	P	Land surface	0	70	Nov. 30, 1948	
165	do	do	N	P	do	0	100	do	
(166)	NW¼NW¼SE¼ sec. 11	C. E. Kaser	T, E	I	Lower lip of discharge pipe	+7.5	30.77	Feb. 12, 1946	Reported yield 1,600; drawdown 20.
167	NE¼NE¼NE¼ sec. 12	R. G. Anderson	Cy, W	D, S	Top of casing	+.7	120.30	Oct. 13, 1947	
168	SW¼SE¼SW¼ sec. 12	C. E. Kaser	N	O	do	0	4.28	June 27, 1947	
169	SW¼SW¼SE¼ sec. 19	Joe Lagerway	Cy, G	D	do	+.4	63.0	Oct. 13, 1947	
170	NW¼NW¼NW¼ sec. 22	J. W. Minnick	N	O	do	+.3	95.51	June 27, 1947	

171	SE¼NE¼NE¼ sec. 24	Union Pacific R. R.	C, G	R, O	Top of well platform	+.5	30.42	Dec. 16, 1946	
(172)	NW¼NW¼NW¼ sec. 24	L. A. Miller	T, E	I	Top of casing	+.6	46.91	Nov. 25, 1945	Yield 805; drawdown 11.9.
173	SW¼NW¼SE¼ sec. 36	J. M. Bastain	N	O	Top of concrete floor	+.8	8.87	Oct. 5, 1946	
	T. 14 N., R. 63 W.								
174	NW¼NW¼NW¼ sec. 8	C. A. Erickson	Cy, W	D, S	Land surface	0	80	June 20, 1947	
175	NE¼NE¼SE¼ sec. 10	A. B. Schauf	Cy, W	D, S	do	0	80	do	
176	SE¼SE¼SW¼ sec. 12	Vernon McDowell	Cy, W	O	Top of casing	+.9	62.23	July 8, 1948	
177	NE¼NE¼NE¼ sec. 18	Robert Gibson	Cy, W	D, S	Land surface	0	50	June 20, 1947	
178	NW¼SW¼NW¼ sec. 18	Mr. Burkett	Cy, W	D, S	do	0	85	do	
(179)	NW¼NW¼NW¼ sec. 20	Elmer Gibson	Cy, W	D, S	do	0	80	do	
180	SW¼SW¼SE¼ sec. 20	Arthur G. Gillett	N	O	Top of casing, west side	+.6	79.79	Mar. 7, 1946	
181	SE¼SE¼SE¼ sec. 22	do	Cy, W	D, S	Land surface	0	60	Oct. 10, 1947	
182	NE¼SE¼SE¼ sec. 26	J. M. Bastain	Cy, W	D, S	Top of casing	+.6	42.53	do	
183	SE¼SE¼SW¼ sec. 32	W. H. Miller	Cy, W	D, S	do	+.7	46.58	do	
184	NE¼NE¼SE¼ sec. 34	Lorena F. G. Noyes	Cy, W	O	do	+1.0	97.76	Sept. 15, 1947	
	T. 15 N., R. 60 W.								
(185)	NE¼NE¼NE¼ sec. 4	John Marquardt	Cy, E	D, S	Land surface	0	50	Sept. 25, 1947	
186	SW¼SW¼SE¼ sec. 7	Hazel Sundin	N	N	do	0	50.0	Nov. 9, 1947	
187	NW¼NW¼SW¼ sec. 8	Victor Sundin	N	O	Iron peg in well wall	-.2	87.98	Nov. 20, 1940	Reported yield 250.
188	NE¼NE¼SW¼ sec. 18	Lee Wymer	T, Tr	I	Top of casing, west side	0	40.50	Dec. 7, 1945	Reported yield 750.
189	NW¼NW¼SW¼ sec. 20	W. T. Young	T, E	I	Hole in northeast side of pump base.	+.8	63.62	Dec. 5, 1945	Reported yield 850.
(190)	NW¼SE¼SW¼ sec. 20	do	T, E	I	Top of casing, east side	+2.0	63.57	do	Reported yield 500; drawdown 5.
191	NW¼NW¼NW¼ sec. 22	M. L. Larson	Cy, W	S	Top of casing, south side	+1.2	121.51	Dec. 30, 1942	
(192)	NW¼NW¼SW¼ sec. 28	Edward Macy	T, E	I	Lubricating hole in pump base	+1.5	54.48	Dec. 5, 1945	Reported yield 615.
193	SE¼NW¼NW¼ sec. 29	W. T. Young	T, E	I	Hole in north side of pump base.	+1.2	60.58	do	Reported yield 600; drawdown 13.
(194)	SW¼SE¼NW¼ sec. 29	do	T, E	I	Hole in pump base	+1.2	59.26	do	Reported yield 450; drawdown 26.
195	SW¼NW¼SW¼ sec. 30	Mary A. Simpson	N	O	Timber at bench mark over well.	0	45.04	June 26, 1947	
196	NW¼NW¼NE¼ sec. 32	W. T. Young	N	O	Top of casing, east side	0	48.54	Dec. 31, 1947	
197	NW¼NW¼SW¼ sec. 32	C. S. Macy	T, Tr	I	Edge of plank, northeast side of pump.	0	57.57	Dec. 11, 1945	Twenty-four feet of sand and gravel at top of well. Reported yield 800.
198	NE¼NE¼SW¼ sec. 33	Fred Prosser	T, Tr	I	Top of casing, west side	+1.4	50.86	Oct. 14, 1947	Reported yield 800.
199	NW¼NW¼NW¼ sec. 34	Glenn Macy	T, E	I	Lower lip of discharge pipe	+11.6	66.89	Dec. 5, 1945	Yield 585; drawdown 13.
(200)	NE¼SW¼NW¼ sec. 34	do	Cy, W	S, O	Top of plank platform	+.8	69.83	June 26, 1947	
	T. 15 N., R. 61 W.								
201	NE¼SE¼SE¼ sec. 4	R. O. Stansbury	Cy, W	D, S	Top of casing	+.9	82.58	Oct. 13, 1947	Abandoned.
202	NE¼NE¼SE¼ sec. 24	John Wymer	Cy, W	D, S	do	+.2	78.10	do	
(203)	SE¼SE¼NE¼ sec. 28	Mark Floy	Cy, W	D, S	Land surface	0	60	Sept. 25, 1947	

[1] Dr, Drilled; D, dug; DD, dug and drilled.
[2] Measured depths given in feet and tenths of feet; reported depths given in feet.
[3] Cn, Concrete; GI, galvanized iron; N, none; R, rock; S, steel.
[4] C, Centrifugal; Cy, cylinder; N, none; T, turbine. Power: D, diesel; E, electric motor; G, gasoline motor; H, hand; N, none; Tr, tractor; W, wind.
[5] D, Domestic; I, irrigation; N, none; O, observation; P, public supply; R, railroad; S, stock.
[6] Measured water levels given in feet and in tenths and hundredths of feet; reported water levels given in feet.

LOGS OF TEST HOLES

Logs of 41 test holes put down in the area are given on the following pages. The sample logs (1–34) were compiled from studies of samples obtained from test holes drilled for the Wyoming State Planning and Water Conservation Board in 1943. The driller's logs (35–41) are from test holes drilled by L. L. Canfield, of Fort Morgan, Colo., in locating sites for irrigation wells.

Sample logs

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
1. SW¼SW¼SW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,039 feet					
Alluvium:			Brule formation—Continued		
Sand, medium to coarse, to medium gravel	11	11	Clay, brittle, buff; contains small geodes. Layer of white clay or ash at 45 feet	5	45
Sand, medium	1	12	Clay, brittle, buff	35	80
Gravel, coarse	4	16	Clay, buff	64	144
Brule formation:			Sandstone, impure	1	145
Clay, brittle, buff	24	40	Clay, buff	39	184
2. SW¼NW¼SW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,027 feet					
Alluvium:			Alluvium—Continued		
Soil and gravel	4	4	Gravel, coarse	3	13
Gravel, coarse	5	9	Brule formation: Clay, brittle, jointed	27	40
Sand, medium	1	10			
3. NW¼NW¼SW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,022 feet					
Alluvium: Gravel	13	13	Brule formation: Clay, buff	7	20
4. SW¼SW¼NW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,021 feet					
Alluvium:			Alluvium—Continued		
Gravel, medium to coarse	8	8	Sand, fine to medium, some gravel; contains fragments of clay	10	60
Sand to gravel, fine	1	9	Gravel and sand; contains fragments of clay	5	65
Gravel, fine to sand	4	13	Gravel and sand; contains buff clay	10	75
Sand, medium to coarse, and gravel	2	15	Gravel	2	77
Gravel, medium, and coarse sand; contains fragments of clay	5	20	Sand, impure; largely reworked Brule formation	1	78
Gravel, coarse; contains fragments of clay	4	24	Gravel; contains thin layer impure sand	2	80
Gravel, coarse	3	27	Gravel; contains rounded fragments of clay	5	85
Gravel, medium	2	29	Brule formation:		
Gravel and sand; medium to coarse	2	31	Gravel, consisting of rounded fragments of clay (reworked Brule formation)	5	90
Gravel, coarse	2	33	Clay, buff	10	100
Gravel and sand	3	36			
Sand, fine to medium	4	40			
Sand and gravel	3	43			
Sand, fine to medium	1	44			
Sand, fine to medium, and gravel	6	50			
5. SW¼NW¼NW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,020 feet					
Soil	2	2	Alluvium—Continued		
Alluvium:			Sand and clay	5	25
Clay, buff	1	3	Brule formation: Clay, buff; contains pellets brown clayey sand	15	40
Gravel, coarse	7	10			
Gravel and sand	10	20			

Sample logs—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
6. NW¼NW¼NW¼ sec. 11, T. 14 N., R. 60 W. Altitude, 5,018 feet					
Alluvium:			Alluvium—Continued		
Sand and gravel	10	10	Clay and sand	3	19
Gravel, coarse	2	12	Brule formation: Clay, hard, brittle	21	40
Gravel, coarse, clean	3	15			
Clay, gray	1	16			
7. NW¼NW¼SW¼ sec. 2, T. 14 N., R. 60 W. Altitude, 5,064 feet					
Terrace deposits:			Brule formation:		
Clay, sandy (reworked Brule formation)	5	5	Clay, fractured, buff and orange	5	27
Sand, fine, and clay	2	7	Clay, buff	8	35
Gravel, coarse, and sand	3	10	Clay, buff and orange	5	40
Gravel, coarse	2	12	Clay, buff	2	42
Clay and gravel	2	14	Sandstone, fine, clayey, buff	1	43
Gravel; contains some pellets of clay	2	16	Sandstone, fine, clayey, buff; contains interbedded buff clay	4	47
Gravel and some clay	2	18	Clay, buff, and pellets of sandstone	3	50
Gravel, coarse, clean, and medium to coarse sand (lost drilling water)	1	19	Clay, orange	5	55
Sand, fine to medium	1	20	Clay, buff; interbedded with orange clay and fine sandstone	27	82
Sand, medium, white	2	22			
8. NW¼NE¼NE¼ sec. 3, T. 14 N., R. 60 W. Altitude, 5,076 feet					
Brule formation:			Brule formation—Continued		
Clay, brittle, buff	18	18	Sandstone; interbedded with orange clay	1	47
Clay, buff and orange	11	29	Sandstone and clay	3	50
Clay, orange	2	31	Clay, buff	1	51
Clay, buff	1	32	Clay, buff and orange	3	54
Clay, buff and orange	2	34	Clay, brittle, fissile, orange	2	56
Clay, jointed, buff (lost water at 35 feet)	1	35	Clay, buff	3	59
Clay, buff and orange	5	40	Sandstone, brown; interbedded with buff clay	4	63
Clay, brittle, buff	1	41	Clay, buff	3	66
Sandstone, fine, brown	2	43	Clay, brown and orange	3	69
Sandstone, fine, and brown clay	3	46	Clay, orange	1	70
9. NW¼NW¼NE¼ sec. 21, T. 14 N., R. 60 W. Altitude, 5,059 feet					
Alluvium: Gravel and sand	10	10	Brule formation: Clay, hard, buff	30	40
10. NE¼NW¼NE¼ sec. 21, T. 14 N., R. 60 W. Altitude, 5,063 feet					
Soil	1.4	1.4	Alluvium—Continued		
Alluvium:			Clay, muddy (reworked Brule formation)	42	69
Clay	2.6	4	Brule formation:		
Gravel	9	13	Clay, hard, buff	1	70
Gravel and sand	2.5	15.5	Clay, hard, jointed, buff, and some rounded pellets interbedded with sandstone	4	74
Sand and gravel	1.5	17	Clay, buff, and sandstone	7	81
Sand	5	22	Clay, buff	21	102
Sand and gravel	2.5	24.5			
Sand and gravel; contains reworked buff clay	2.5	27			
11. NW¼NE¼NE¼ sec 21, T. 14 N., R. 60 W. Altitude, 5,065 feet					
Alluvium:			Brule formation:		
Gravel	6	6	Clay, brittle, buff (lost water at 23 feet)	2	22
Clay, gray	2	8	Clay, jointed, buff	13	35
Gravel, coarse	4	12			
Gravel, coarse; interbedded with medium to coarse sand, contains a few fragments of Brule formation	8	20			

Sample logs—Continued

12. NW¼SW¼NW¼ sec.29, T. 14 N., R. 60 W. Altitude, 5,120 feet

	Thickness (feet)	Depth (feet)
Soil and sand	6	6
Alluvium: Gravel, coarse, and sand	13	19
Brule formation:		
Clay, hard, angular, buff (lost drilling water at 83 feet)	64	83
Clay, hard, buff	21	104

13. SW¼NW¼SW¼ sec. 20, T. 14 N., R. 60 W. Altitude, 5,113 feet

	Thickness (feet)	Depth (feet)
Soil and clay	5	5
Alluvium:		
Gravel and sand	12	17
Clay, hard, buff	9	26
Alluvium—Continued		
Clay, buff, sand, and gravel	9	35
Gravel	3	38
Brule formation: Clay, buff	24	62

14. SW¼SW¼NW¼ sec. 20, T. 14 N., R. 60 W. Altitude, 5,134 feet

	Thickness (feet)	Depth (feet)
Soil and sand	2	2
Terrace deposits:		
Gravel, coarse, and sand; contains some clay at 20 feet	18	20
Gravel and clay	3	23
Terrace deposits—Continued		
Clay, sandy, gray; interbedded with sand and coarse gravel	6	29
Brule formation: Clay, hard, brittle, buff	33	62

15. SE¼SE¼SE¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,129 feet

	Thickness (feet)	Depth (feet)
Soil and sand	5	5
Terrace deposits:		
Gravel, coarse, and sand	5	10
Gravel	3	13
Sand, fine to medium	1	14
Gravel and coarse sand	3	17
Gravel, clean, well-sorted	3	20
Gravel, coarse, and sand	7	27
Clay, soft, sticky, brown	9	36
Clay, sandy, gray and brown	4	40
Clay, sandy, gray	2	42
Clay, sandy, gray; contains some interbedded sand and gravel	11	53
Gravel and sand	2	55
Terrace deposits—Continued		
Gravel and sand; contains gray and brown clay	6	61
Sand and gravel; contains some brown clay	5	66
Sand and gravel	2	68
Brule formation:		
Clay, brittle, jointed, buff	17	85
Clay, buff, and pink gravel	3	88
Clay, sandy, buff	2	90
Sandstone, micaceous	5	95
Sandstone, clayey, soft, and buff clay	3	98
Clay, buff, and some sandstone	5	103

16. NE¼SE¼SE¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,126 feet

	Thickness (feet)	Depth (feet)
Terrace deposits:		
Dirt and white clay	5	5
Gravel, coarse	35	40
Clay	10	50
Sand, fine	20	70
Clay	3	73
Sand and clay	4	77
Clay, soft, and some gravel	4	81
Clay, soft, and sand	4	85
Clay, soft	5	90
Terrace deposits—Continued		
Clay, and fine gravel	4	94
Sand, and some clay	6	100
Gravel, coarse, pink, and gray sandy clay	2	102
Gravel, coarse; contains pellets of clay	5	107
Brule formation:		
Clay, jointed, buff	17	124

17. SE¼NE¼SE¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,125 feet

	Thickness (feet)	Depth (feet)
Soil	3	3
Terrace deposits:		
Clay, gray	2	5
Gravel and sand	5	10
Clay, green	2	12
Gravel, coarse, and coarse sand	8	20
Gravel, coarse	9	29
Clay, gray	3	32
Clay, brown	8	40
Clay, sandy, gray and buff	10	50
Brule formation:		
Clay, hard, buff	11	61
Clay, hard, buff; contains pipe concretions lined with crystals	4	65
Clay, hard, buff	17	82
Clay, hard, buff; contains pipe concretions lined with crystals	8	90
Clay, hard, buff	13	103

Sample logs—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
18. SE¼SE¼NE¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,125 feet					
Soil	2.5	2.5	Terrace deposits—Continued		
Terrace deposits:			Gravel and sand	6	34
Clay, gray	4.5	7	Clay, gray	4	38
Clay and gravel	2	9	Clay, brown and gray	7	45
Gravel, coarse	11	20	Brule formation: Clay, hard, buff	55	100
Clay, gray	8	28			
19. SE¼SE¼SE¼ sec. 7, T. 14 N., R. 60 W. Altitude, 5,084 feet					
Soil and gravel	4	4	Brule formatian—Continued		
Alluvium: Clay	2	6			
Brule formation:					
Clay, jointed, buff	12	18	Clay, sandy, dendritic, buff; contains crystal-lined tubular concretions	20	40
Clay, sandy, buff; contains black flecks of mica	2	20			
20. NE¼NE¼SE¼ sec. 7, T. 14 N., R. 60 W. Altitude, 5,067 feet					
Alluvium:			Brule formation—Continued		
Clay, gray	6	6			
Gravel; contains rounded fragments of clay	4	10	Clay, sandy, buff, speckled with black mica	4	19
Gravel; contains fragments of clay	2	12	Clay, jointed, buff; contains stains of iron oxide on joint planes	1	20
Brule formation:			Clay, water-marked, buff	17	37
Clay, buff	3	15	Clay, brittle, buff	24	61
21. SW¼NW¼NW¼ sec. 32, T. 15 N., R. 60 W. Altitude, 5,120 feet					
Soil and dirty sand	12	12	Terrace deposits—Continued		
Terrace deposits:			Gravel and sand	4	18
Clay, gray, and gravel	2	14	Brule formation: Clay, hard, buff	6	24
22. SW¼SW¼SW¼ sec. 20, T. 15 N., R. 60 W. Altitude, 5,137 feet					
Soil and sand	3	3	Brule formation—Continued		
Terrace deposits: Gravel	12	15			
Brule formation:			Clay, buff and orange; contains dendritic markings	15	60
Clay, buff and orange	5	20	Sandstone, with black mica	10	70
Clay, buff and orange; contains black dendritic stains	20	40	Clay, buff, and sandstone	5	75
Clay, buff	5	45	Clay, buff (lost water at 103 feet)	28	103
23. NW¼NW¼NW¼ sec. 17, T. 14 N., R. 61 W. Altitude, 5,235 feet					
Soil, sandy, black	8	8	Brule formation: Clay, hard, buff, with soft matrix	26	41
Alluvium: Gravel	7	15			
24. NW¼SW¼SW¼ sec. 21, T. 14 N., R. 61 W. Altitude, 5,229 feet					
Alluvium: Gravel and sand	11	11	Brule formation: Clay, hard, buff	9	20
25. NW¼NW¼SW¼ sec. 21, T. 14 N., R. 61 W. Altitude, 5,238 feet					
Soil and sand	2	2	Brule formation—Continued		
Alluvium: Gravel	14	16	Clay, sandy, buff and brown	15	83
Brule formation:			Clay, brittle, buff	12	95
Clay, blocky, buff; fragments have rounded edges	24	40	Clay, buff and cream, and buff and brown sandstone	9	104
Clay, blocky, buff; fragments have rounded edges (lost water at 68 feet)	28	68			

Sample logs—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
26. NW¼NW¼SW¼ sec. 21, T. 14 N., R 61 W. Altitude, 5,259 feet					
Soil	2	2	Brule formation: Clay, buff	3	20
Terrace deposits: Gravel and sand	15	17			
27. NW¼SW¼NW¼ sec. 21, T. 14 N., R. 61 W. Altitude, 5,251 feet					
Soil, sandy	2	2	Brule formation—Continued		
Terrace deposits:			Clay, blocky, buff; fragments have rounded edges	2	29
Sand; contains some clay and gravel	7	9	Clay, hard, brittle, buff	21	50
Gravel, and some fragments of clay	2	11	Clay, blocky, buff; fragments have rounded edges	1	51
Brule formation:			Clay, soft, buff	1	52
Clay, hard, buff	16	27			
28. NW¼SW¼SW¼ sec. 16, T. 14 N., R. 61 W. Altitude, 5,285 feet					
Soil	3	3	Terrace deposits—Continued		
Terrace deposits:			Sand and fragments of clay	2	17
Sand and gravel	7	10	Brule formation: Clay, sandy, dark	3	20
Gravel and sand	5	15			
29. NW¼NW¼NW¼ sec. 16, T. 14 N., R. 61 W. Altitude, 5,241 feet					
Soil and sand	7	7	Brule formation—Continued		
Terrace deposits: Gravel and clay	5	12	Clay, sandy, dark-brown, having dendritic markings	10	45
Brule formation:			Clay, brittle, buff	17	62
Clay, sandy, dark-brown	23	35			
30. SW¼NW¼NW¼ sec. 19, T. 14 N., R. 61 W. Altitude, 5,280 feet					
Soil	5	5	Brule formation—Continued		
Alluvium: Gravel	10	15	Clay, brittle, buff	53	88
Arikaree sandstone: Siltstone, buff and gray	15	30	Clay, buff and orange (losing water)	4	92
Brule formation:					
Clay, buff and yellow	4	34	Clay, dendritic, buff and orange	3	95
Clay, blocky, buff; fragments have rounded edges	1	35	Clay, orange and buff	5	100
31. NW¼SW¼SW¼ sec. 18, T. 14 N., R. 61 W. Altitude, 5,288 feet					
Alluvium: Gravel, coarse, and sand	17	17	Brule formation: Clay, blocky, buff; some fragments rounded	12	75
Arikaree sandstone: Sandstone, fine, clayey, gray-brown	46	63			
32. NW¼NW¼SW¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,286 feet					
Alluvium: Gravel	8	8	Arikaree sandstone—Continued		
Arikaree sandstone:			Sandstone, fine, cemented, white	2	12
Sandstone, fine, gray, and buff hard clay	2	10	Clay, iron-stained, buff	2	14
			Sandstone, fine, dark-brown	6	20

Sample logs—Continued

33. NW¼NW¼NW¼ sec. 18, T. 14 N., R. 60 W. Altitude, 5,291 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Arikaree sandstone—Continued		
Soil, sand, and boulders	3	3	Sandstone, cemented, white and brown	7	72
Gravel	9	12	Sand, medium, loose; contains layers of cemented sandstone and buff clay	3	75
Arikaree sandstone:			Sand, medium to coarse, loose, and some clay	5	80
Sandstone, soft, brown	4	16	Sand, medium to coarse, loose	2	82
Clay, brittle, buff, having iron stains on joint surfaces	4	20	Sand, fine to coarse; contains thin beds of green and buff clay (lost water)	3	85
Sandstone, fine, buff and brown	9	29	Sandstone, fine, cemented, brown and white	5	90
Sand, medium to coarse; contains fragments of hornblende (lost water)	8	37	Sand, fine, loose	5	95
Sandstone, hard, dark; contains hornblende and quartz	6	43	Brule formation:		
Sand, coarse, loose	7	50	Siltstone (volcanic ash?), soft, brown and white	10	105
Sand, coarse, loose, and gravel	5	55	Clay, silty, brown	5	110
Sand, coarse, loose, and clay	4	59	Siltstone, brown	8	118
Clay, hard, brittle, buff	1	60			
Clay, hard, buff; interbedded with sandstone	5	65			

34. SW¼SW¼SW¼ sec. 7, T. 14 N., R. 61 W. Altitude, 5,305 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil, gravelly	6	6	Arikaree sandstone: Sandstone, brittle, brown, and some clay	69	81
Alluvium: Gravel and sand	6	12	Brule formation: Clay	20	101

Driller's logs

35. NW¼NW¼NE¼ sec. 2, T. 12 N., R. 62 W., drilled on March 18, 1942

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	3	3	Terrace deposits—Continued	7	63
Terrace deposits:			Sand and clay	6	69
Gravel and sand	17	20	Gravel, dirty	7	76
Gravel and strips of clay	16	36	Sand, fine, and gravel	5	81
Gravel and sand	6	42	Sand and clay	19	100
Gravel (water level 50 feet)	14	56	Brule formation: Hardpan		

36. NW¼NW¼SW¼ sec. 3, T. 12 N., R. 62 W., drilled for D. A. Bunnell on August 13, 1941

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	3	3	Terrace deposits—Continued		
Terrace deposits:			Gravel (dry)	6	42
Gravel (dry)	15	18	Gravel (water)	13	55
Clay	3	21	Magnesia and clay	10	65
Gravel (dry)	14	35	Brule formation: Clay, brown	75	140
Clay	1	36			

37. NW¼NW¼NW¼ sec. 5, T. 12 N., R. 62 W., drilled on April 20, 1942

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	4	4	Terrace deposits—Continued		
Terrace deposits:			Clay	12	85
Gravel	33	37	Gravel	4	89
Clay	3	40	Clay	3	92
Gravel	18	58	Sand, fine	5	97
Clay	11	69	Gravel	2	99
Sand and gravel	4	73	Brule formation: Clay	16	115

38. SE¼SE¼NW¼ sec. 8, T. 12 N., R. 62 W., drilled on March 10, 1942

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil	4	4	Terrace deposits—Continued		
Terrace deposits:			Sand, fine	4	64
Gravel	16	20	Clay	16	80
Clay	4	24	Gravel and clay, interbedded	14	94
Gravel	21	45	Sandstone, soft	6	100
Gravel (lost water)	15	60	Brule formation: Hardpan	20	120

Driller's logs—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
39. NE¼NE¼SW¼ sec. 32, T. 13 N., R. 61 W., drilled on February 5, 1941					
Topsoil	4	4	Terrace deposits—Continued		
Terrace deposits:			Hardpan	8	98
Clay and sand	4	8	Gravel, dirty	4	102
Gravel	14	22	Hardpan	10	112
Clay	18	40	Gravel, solid, clean	8	120
Clay	46	86	Brule formation: Hardpan	10	130
Gravel	4	90			
40. SW¼SW¼NW¼ sec. 33, T. 13 N., R. 62 W., drilled on March 3, 1942					
Topsoil	3	3	Terrace deposits—Continued		
Terrace deposits:			Sandstone	5	40
Gravel	7	10	Sand, fine, and clay	6	46
Clay	2	12	Brule formation: Hardpan	74	120
Gravel	23	35			
41. NW¼NW¼SE¼ sec. 34, T. 13 N., R. 62 W., drilled on December 14, 1941					
Topsoil	4	4	Terrace deposits—Continued		
Terrace deposits:			Gravel, clean	6	44
Gravel, dirty	21	25	Gravel and sand, fine	12	56
Gravel and strips of magnesia	13	38	Brule formation: Hardpan	24	80

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