Reconnaissance of Geology and Ground Water in the Lower Grand River Valley South Dakota

By P. C. TYCHSEN *and* R. C. VORHIS

With a section on
CHEMICAL QUALITY OF THE GROUND WATER

By E. R. JOCHENS

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By P. C. Tychsen and R. C. Vorhis

WITH A SECTION ON THE CHEMICAL QUALITY OF THE GROUND WATER

By E. R. Jochens

ABSTRACT

The area described in this report is the flood plain of the Grand River and the bordering benchlands in Perkins and Corson Counties, S. Dak., from a point about 6 miles west of the town of Shadehill to the confluence of the Grand and Missouri Rivers near Mobridge.

The exposed bedrock formations include the Pierre shale, the Fox Hills sandstone, and the Hell Creek formation of Late Cretaceous age, and the Ludlow member of the Fort Union formation of Tertiary (Paleocene) age. Some stringers of the Cannonball formation probably interfinger with beds of the Ludlow member but none of the former was identified during the field investigations. The Pierre shale is exposed from the mouth of the Grand River to approximately the center of the area. Although a few wells in the area obtain water from this formation, it is not generally considered to be a source of supply. The Fox Hills sandstone, the Hell Creek formation, and the Ludlow member of the Fort Union formation are exposed successively upstream and, where saturated, yield small to moderate quantities of water to wells.

Unconsolidated deposits of silt, sand, and gravel occur in several physiographic positions; they underlie the high benchland on both sides of the river, the poorly defined terraces along the river, and the flood plain throughout its entire length. Possibly all these unconsolidated deposits are water bearing; however, where the deposits on the benchland and in the terraces are dissected by streams, they probably contain little or no water.

The average depth to ground water along the lower Grand River valley is about 17 feet. Probably, the flow of ground water in the bottom lands is nearly parallel to and slightly toward the surface stream. The measurements of the water level in observation wells for the period 1946–48 indicate that the fluctuations of the water table are small.

The results of analyses of 13 samples of ground water from the alluvium and the Hell Creek formation show that the suitability of the ground water for use varies because of the considerable range in mineralization and composition. Dissolved solids ranged from 343 to 4,250 parts per million (ppm), hardness from 11 to 1,130 ppm, and percentage of sodium from 25 to 98. Concentrations of some of the individual constituents exceed standards of the United States Public Health Service. The water is moderately hard and contains undesirable amounts of iron and moderate to large amounts of dissolved solids. In general, the water quality ranges from excellent to unsuitable for irrigation use. The result of the mixing of the ground water with recharge water from Shadehill Reservoir cannot be predicted on the basis of available data.

The geologic and hydrologic data in this report were obtained from earlier reports and from field observations during the period 1946–48. The report includes a geologic map and tabulated well records.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

An extensive program of ground-water investigations was begun in 1945 by the Geological Survey as a part of the program of the United States Department of the Interior for the development of the Missouri River basin. This report is based on an investigation of the ground-water resources of the Grand River valley, which was begun in May 1946 and was continued at intervals through 1948. The results of chemical analyses of water samples collected from the Grand River in 1949 are also included in this report.

The immediate objectives of the investigation were to obtain information on the ground-water conditions in the vicinity of the proposed Shadehill Reservoir, canals, and irrigated areas of the lower Grand River valley, and to study the relation of these ground-water conditions to the domestic and stock-water supplies and to possible future drainage problems. The data collected in the study can be used later to determine the extent and nature of changes in ground-water levels and ground-water quality after the application of irrigation water.

This investigation was made under the general supervision of A. N. Sayre, chief of the Ground Water Branch, U. S. Geological Survey, and G. H. Taylor, regional engineer in charge of ground-water studies under the Missouri River basin development program. G. A. LaRocque, district engineer for North and South Dakota, supervised the field studies and the preparation of the report.

The quality-of-water study was made under the general supervision of S. K. Love, chief of the Quality of Water Branch, and P. C. Benedict, regional engineer in charge of quality-of-water studies in the Missouri River basin. Ground-water samples were collected by P. C. Tychsen in 1947 and R. C. Vorhis in 1948.

LOCATION AND EXTENT OF THE AREA

The drainage basin of the Grand River is in northwestern South Dakota and southwestern North Dakota. The basin is 25 to 60 miles across and has an area of approximately 5,700 square miles. The part of the Grand River basin covered by this investigation (see fig. 1) is 500 square miles of the main valley in South Dakota, extending west along the Grand River from its confluence with the Missouri River near Mobridge, S. Dak., to the site of the Shadehill Reservoir, about 6 miles west of Shadehill. The area lies between parallels 45°30′ and 46°00′ north latitude and between meridians

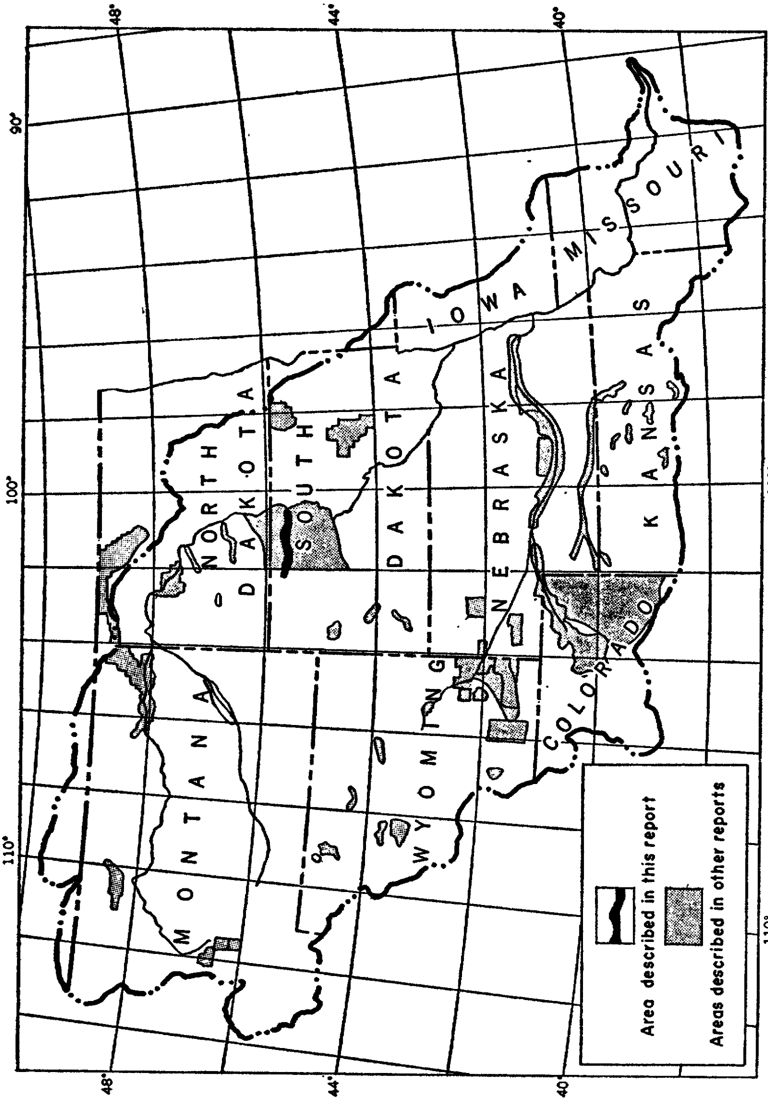

FIGURE 1.—Map of the Missouri River basin showing areas in which ground-water studies have been made under the program for the development of the Missouri River basin.

100°20′ and 102°30′ west longitude and consists mainly of the flood plain of the Grand River and the bordering benchlands.

PREVIOUS INVESTIGATIONS

No detailed study of the ground-water resources of any part of the Grand River valley had been made previously. Darton (1905 and 1909),[1] however, included some geologic and ground-water information pertaining to the Grand River basin in papers that described the geology and ground-water resources of much larger areas. He reviewed the previous geologic work in northwestern South Dakota (1909, p. 27–32) and included in his report a structural map of the Dakota sandstone as well as a generalized geologic map of South Dakota.

Most reports on the geology of parts of the area pertain primarily to the lignite resources (Calvert and others, 1914; Hares, 1928; Searight, 1930; Willis, 1885; and Winchester and others, 1916). Little mention is made of ground-water supplies in these reports.

Ward (1925) described the geologic structure of western South Dakota. Morgan and Petsch (1945) drafted a structure-contour map of Corson County. Winchester and others (1916, p. 37) published a structural map of Perkins and Harding Counties, S. Dak. Searight (1937) described the lithology and stratigraphy of the Pierre shale, and Gries (1942) discussed its economic possibilities.

The locations and logs of deep borings in western South Dakota are given in a paper by Baker (1947), but none are in the immediate area of this report.

The logs of test holes drilled by the United States Bureau of Reclamation in 1946 in the vicinity of the Shadehill dam site, sec. 25, T. 21 N., R. 15 E., have been used to supplement surface investigations. Geologic maps of the area, prepared by Calvert and others (1914, pl. 1) and by Winchester and others (1916, pl. 2) were consulted freely to supplement the geologic field investigations.

WELL-NUMBERING SYSTEM

The well numbers in this report show the location of the wells according to the United States Bureau of Land Management's survey of the area. The component parts of a well number are the township, range, and section numbers and two lower-cased letters which indicate, respectively, the quarter section and quarter-quarter section. The quarter section and quarter-quarter section are designated by a, b, c, and d, the letters being assigned counterclockwise beginning in the northeast quarter. Where two or more wells are located within a 40-acre tract, the wells are numbered serially according to the order in which they were inventoried.

The well-numbering system is illustrated in figure 2.

[1] See list of references at end of report.

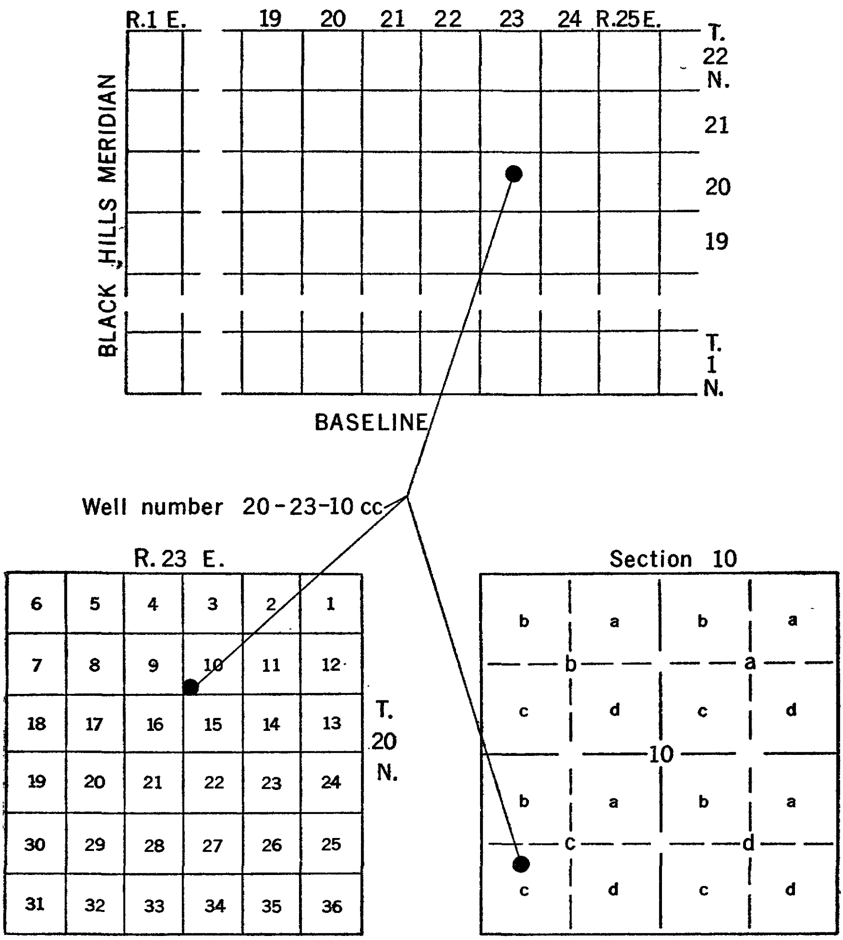

FIGURE 2.—Sketch showing well-numbering system.

GEOGRAPHY

TOPOGRAPHY AND DRAINAGE

The Grand River valley is in the Missouri Plateau section of the Great Plains province. It is characterized by a gently rolling topography, locally incised by deeply eroded valleys. The monotony of the prairies on both sides of the Grand River valley is broken by numerous buttes, which are capped by resistant sandstone beds, usually of the Fox Hills sandstone or the Ludlow member of the Fort Union formation. Badlands, formed by the erosion of the softer Pierre shale and Hell Creek formation, are common along the Grand River and tributary streams.

Wide terraces, 10 to 100 feet above the stream, parallel the Grand River in much of its course. They are incised locally by the deep, narrow valleys of tributary creeks. The highest terrace, mantled by colluvium, has a gentle slope toward the river, because of the greater deposition of colluvium near the heel of the terrace. The flood plain is covered with a growth of cottonwood, elm, and boxelder.

The elevation of the floor of the Grand River valley ranges from 2,400 feet above sea level in the northeast part of T. 21 N., R. 13 E., to about 1,540 feet at the confluence of the Grand and Missouri Rivers near Mobridge. The slope of the river bed is about 3 feet to the mile.

From runoff studies, the Bureau of Reclamation (1942, p. 4) concluded:

> Approximately 3.1 percent of the average annual precipitation over the basin runs off in the Grand River. The run-off, as is characteristic of the streams in this portion of the Great Plains area, occurs as flash floods following intense summer rain storms, or results from general spring rains which sometimes occur before the ground has thawed. Thus, a large portion of the run-off occurs during a few days' time at unpredictable intervals. No base flow is maintained, as portions of the river may be dry following extended dry periods.

Shallow depressions, which when dry are covered with white alkaline deposits, are common in the upland areas underlain by the Hell Creek formation. These depressions retain water for some time after periods of prolonged rainfall.

CLIMATE

The climate of the Grand River basin is semiarid and is characterized by slight to moderate precipitation and by a moderately high average wind velocity. The summer days are generally hot, though they are somewhat tempered by generally low relative humidity and by the wind. The winter is characterized by severe cold periods and a continuous light snow cover. Extremes of temperature commonly range from 110° F in the summer to −30° F in the winter. In general, the hottest months are July and August and the coldest months are December and January.

The mean monthly precipitation, based on records of 20 years or more at the nearby towns of McIntosh, McLaughlin, Mobridge, and Lemmon, is indicated below:

Mean monthly precipitation, in inches, at stations in the lower Grand River basin

[Based on records of the U. S. Weather Bureau]

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
0.47	0.53	0.84	1.45	2.16	3.27	1.83	1.68	1.17	0.92	0.41	0.42	15.15

POPULATION

The population of the Grand River basin was about 21,000 in 1930 but had decreased to 17,000 in 1940 (U. S. Bur. Reclamation, 1942, p. 15). Numerous abandoned farmhouses throughout the area are evidence of this decrease.

According to the 1950 census, the population of the principal towns near the area was as follows: Mobridge, 3,753; McIntosh, 628; McLaughlin, 713; and Lemmon, 2,760. In 1950, the population of Corson County was 6,168, and that of Perkins County was 6,776. The villages of Little Eagle and Bull Head are Indian communities, and numerous farms along the lower Grand River valley are operated by Indians.

TRANSPORTATION

The Grand River basin, in the vicinity of the area studied, is served by the Chicago, Milwaukee, St. Paul, & Pacific Railroad, which crosses the area in an east-west direction through Mobridge, McLaughlin, Walker, McIntosh, and Lemmon. U. S. Highway 12 roughly parallels the railroad and passes through the same towns. South Dakota Route 8 extends in an east-west direction along the southern part of the basin and passes through Mobridge, Trail City, Timber Lake, Isabel, Meadow, and Bison. South Dakota Routes 73 and 65, which extend south from Lemmon through Shadehill and from McIntosh to Isabel, respectively, are the main north-south roads within the area. Graded dirt roads that cross the area are generally impassable in wet weather.

AGRICULTURE, INDUSTRY, AND NATURAL RESOURCES

Agriculture is the chief occupation in the Grand River valley. Livestock raising and the growing of wheat, barley, oats, rye, and flax constitute the main types of agricultural activity. Coal mining is the only industry and chiefly supplies local needs.

The Pierre shale, which is exposed extensively along the lower Grand River valley, contains natural gas, aluminum, gypsum, manganese, and possibly oil. However, the character of the deposits and the costs of production preclude their exploitation in this area at present.

SUMMARY OF GEOLOGIC STRUCTURE AND STRATIGRAPHY

The area is underlain by stratified rocks of Cretaceous and Tertiary age which strike about N. 65° E. and dip about N. 25° W. (Morgan and Petsch, 1945, p. 43, Corson County; Winchester and others, 1916, p. 37, Perkins County). In and along the Grand River valley these rocks are mantled by terrace deposits, colluvium, and alluvium of Quaternary age.

In sec. 19, T. 20 N., R. 20 E., two normal faults are exposed in the left bank of the Grand River. One has a displacement of more than 50 feet, and the other has a displacement of 5 feet. The larger fault strikes N. 25° E. In the immediate vicinity of the Grand River valley, its trace is covered by gravel that is younger than that of the highest

Quaternary terrace. The fault trace may be exposed in the uplands, but no search was made for it there.

The formations exposed along the Grand River valley in Corson and Perkins Counties are of sedimentary origin. Their areal extent is shown on the geologic map (pl. 1). The water-bearing formations are the Fox Hills sandstone and the Hell Creek formation of Late Cretaceous age, the Ludlow member of the Fort Union formation of Tertiary (Paleocene) age, and the alluvium of Quaternary age. The Pierre shale of Late Cretaceous age is generally too impervious to yield ground water; it is exposed in most of the eastern part of the area.

The Niobrara formation (locally known as chalkstone), the Benton shale, and the Dakota sandstone, which are of Late Cretaceous age, lie successively beneath the Pierre shale but are not exposed in the Grand River valley. Of these, the Dakota sandstone contains the most abundant supplies of ground water, but in the Grand River valley the formation lies too far beneath the land surface to be of much value for water supply; the depth to the sandstone was estimated by Darton (1909, p. 138) to be at least 2,500 feet at the boundary line between Perkins and Corson counties.

The White River formation of Tertiary (Oligocene) age formerly mantled the uplands in the western part of the area of this investigation. Now eroded from the uplands, it is represented in the area by pebbles of felsite porphyry, typical of the formation in North Dakota, which are found in the alluvium of the Grand River and its southward-flowing tributaries.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

PIERRE SHALE

The Pierre shale is exposed at the surface over a large part of the lower Grand River basin. It crops out along both sides of the Grand River valley westward from the confluence of the Grand and Missouri Rivers to the eastern half of T. 20 N., R. 22 E. (See pl. 1.)

Along the Grand River the upper part of the exposed Pierre shale is dark gray and bluish and is composed of fossiliferous plastic clay and shale. The beds are generally uniform in composition but contain small calcareous concretions and local beds of fine sand. Numerous gypsum crystals, which are from half an inch to 2 inches long, are present on weathered surfaces; in sunlight, they give the shale a lustrous sheen. The gypsum is particularly noticeable in the roadcuts along U. S. Highway 12 in secs. 22 and 23, T. 20 N., R. 28 E.

Numerous small, barren, dome-shaped hills, typical of badlands, are a common feature in outcrop areas of the shale. The surface of the shale is deeply cracked and weathers to light gray or brown to a depth of 5 to 20 feet below the land surface. A large part of the soil in the outcrop area is derived locally from the wash material of the adjacent slopes or from alluvium, which also is derived from the Pierre shale. These soils are comparatively heavy in texture and generally are too infertile and alkaline to be used for agriculture.

In Harding County, west of the area of investigation, Baker (1947, pls. 1 and 2) found the thickness of the Pierre shale to be 1,730 feet in one well and 1,780 feet in another well. In Potter County, 40 miles south of the mouth of the Grand River, the Pierre shale is reported to be 790 feet thick. No wells are known to penetrate the entire thickness of the Pierre shale in either Perkins or Corson County.

The Pierre shale has a low permeability and specific yield [2] and, therefore, yields little or no water to wells. Openings along bedding planes and joints contain small quantities of ground water, which is generally too highly mineralized for domestic use. Throughout the eastern part of the Grand River valley, where the shale is overlain by river alluvium, ground water occurs in the alluvium but not in the underlying impervious shale.

FOX HILLS SANDSTONE

The Fox Hills sandstone, which overlies the Pierre shale, is exposed on the upland areas throughout most of the lower Grand River basin. The maximum width of the outcrop is about 36 miles in R. 23 E., where it is interrupted by only a narrow tongue of the Pierre shale along the Grand River valley. The outcrop is progressively narrower toward the west; it is restricted to the valley wall on both sides of the Grand River from T. 20 N., R. 22 E., to the center of T. 20 N., R. 19 E., where it passes underneath the overlying Hell Creek formation.

In the exposures along the Grand River valley, the Fox Hills sandstone is typically a massive buff-colored sandstone and some sandy shale. It contains numerous limonitic tubes of *Halymenites major*. The sandy shale occurs most commonly at the base of the formation and grades upward into a relatively pure sandstone. The upper part of the formation is a fine-grained fossiliferous sandstone which is loosely cemented and interbedded with clayey sand.

The Fox Hills sandstone is conformable with the underlying Pierre shale. The contact generally is gradational, the transitional beds being about 50 feet thick. Locally, however, as in secs. 34 and 35, T. 21 N., R. 23 E., the contact between the typical buff-to-brown Fox Hills sandstone and the underlying typical dark-gray Pierre shale is well defined. In this locality, 60 feet of massive buff-colored sandstone is underlain by 70 feet of exposed Pierre shale. According to Searight (1930, p. 11), the thickness of the Fox Hills sandstone in the Grand River basin ranges from 25 to 350 feet; the greatest thickness is in the

[2] Specific yield is defined as the ratio of (1) the volume of water yielded by gravity to (2) the volume of the saturated material.

eastern part of the area. Sandy soil generally characterizes the areas underlain by the sandstone.

The Fox Hills sandstone is the most fossiliferous formation in the area. The junior author collected the following specimens in T. 20 N., R. 20 E., from the upper part of the formation:

Cardium (*Granocardium*) *speciosum*? Meek and Hayden.
Halymenites major Lesquereux.
Lunatia occidentalis Meek and Hayden.
Lunatia subcrassa Meek and Hayden.
Tellina equilateralis Meek and Hayden.
Gastropod operculi.
Shark? tooth.
Unidentified pelecypod.
Otoliths (sagittae) of fish.

Calvert and others (1914, p. 13) state:

> At many localities there is at or near the top of the Fox Hills an oyster-shell "breccia" which apparently fills previously eroded channels, as observed at the top of the formation in sec. 22, T. 21 N., R. 25 E., the S½NW¼ sec. 30, T. 20 N., R. 23 E., and the E½ sec. 26, T. 16 N., R. 20 E.

This "breccia" also occurs at the southwest corner of SE¼, sec. 25, T. 20 N., R. 22 E.

The most interesting specimens were the otoliths, or ear stones, of fish. The specimens found are sagittae, the larger of the two otoliths found in the ears of most fish. These were identified as such by D. H. Dunkle of the National Museum. No descriptions could be found in the literature of exactly comparable structures but, according to Mr. Dunkle, "certain gross features suggest affinity with such primitive teleostean groups (which include most living fishes) as the chirocentrids, the salmonoids, and the elopids. Unfortunately, knowledge of the fish fauna in the Fox Hills sandstone is limited to a few isolated scales (three types), and apparently the otoliths of even common Upper Cretaceous fishes remain unknown." Otoliths have received only scant attention and that mainly in Europe where some Tertiary and Recent otoliths have been described. Otoliths in pre-Tertiary formations have been found only rarely and consequently have received practically no study.

The Fox Hills sandstone contains considerable ground water, even in the eastern part of the area where its base is above the local drainage level. Recharge of this supply is almost wholly from precipitation within the area. Abundant supplies of generally hard water are reported by the owners of shallow wells that tap this formation.

HELL CREEK FORMATION

The Hell Creek formation of Late Cretaceous age (formerly called the Hell Creek member of the Lance formation) is exposed on both sides of the floor of the Grand River valley, from the center of T. 20 N., R. 19 E., to the junction of the North and South Forks of the Grand River. It is exposed in the valley of the North Fork, northwestward from the confluence for a few miles, and in the valley of the South Fork, west-southwestward past the Perkins County line.

The Hell Creek formation consists of thin, alternating light- and dark-gray beds of clay, shale, silt, and sandstone. Beds of lignite and nodules or concretions of manganese and iron carbonate are present. Erosion of the formation results in the concentration of numerous concretions on the lower lying flat plains. Their considerable number gives the impression that they are relatively more abundant in the formation than is actually the case.

The composition of the alluvium and of the underlying Hell Creek formation is indicated by the following log of one of several test holes that were drilled by the U. S. Bureau of Reclamation at the Shadehill dam site in the SE¼ sec. 25, T. 21. N., R. 15 E.:

Log of test hole in SE¼ sec. 25, T. 21 N., R. 15 E., approximately 640 feet east of east bank of the Grand River.

[Altitude of land surface is 2,212.1 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Silt, sandy fine-grained, loose	20	20
Hell Creek formation:		
Sand, silty, fine-grained; contains carbonaceous material	27	47
Clay, sandy, gray	9	56
Sand, soft, silty	15	71
Clay and silt, interbedded	61	132
Sand, fine; with some silt	25	157
Silt, sandy, light-gray	3	160
Clay, silty, gray	14	174
Sand, silty; grading downward to cleaner sand	9. 3	183. 3

Badlands consisting of sharply divided valleys, gullies, and dome-shaped hills are typically formed in the soft strata of the Hell Creek formation. Many of the dome-shaped hills are capped by clay that was baked into brick-red erosion-resistant masses (pseudoscoria) by the burning of lignite beds. Where the Hell Creek formation borders the valley bottom, the slope between the bottom land and the top of the bluffs is generally steep to precipitous, in contrast to the gently rolling topography typical of areas not subject to rapid erosion.

The contact between the Hell Creek formation and the underlying Fox Hills sandstone is apparently conformable; a sharp line of contact separating the two formations is not present in the area. The top of the Fox Hills sandstone was considered to be above the highest stratigraphic level at which specimens of *Halymenites major* occur, and the base of the Hell Creek formation was considered to be below the lowest level at which manganese and iron carbonate nodules are present and also below the strata forming the typical Hell Creek badlands. The thickness of the Hell Creek formation is about 700 feet (Calvert and others, 1914, p. 17).

No fossils were found in the Hell Creek formation during the course of the investigation. However, fossils of land vertebrates have been found in this formation in the Marmarth area in southwestern North Dakota (Hares, 1928, p. 23–24). Similar fossils were found in the Grand River basin in T. 21 N., R. 22 E., by Calvert and others (1914, p. 22). Winchester and others (1916, p. 19) reported that dinosaur remains were collected from the Hell Creek formation in Perkins County. These fossils indicate that the Hell Creek formation is a continental deposit, and it is thereby distinguished from the Fox Hills sandstone, which is a marine or brackish-water deposit.

The loosely cemented sandstones of the Hell Creek formation yield adequate supplies of ground water to shallow wells within the area. The water is reported to be softer than that in the Fox Hills sandstone. In sec. 25, T. 21 N., R. 15 E., test holes of the U. S. Bureau of Reclamation encountered flowing artesian water in the Hell Creek formation at depths of 124 to 189 feet below the land surface. The flows from various test holes ranged from 0.5 to 10 pgm and issued from sand overlain by clay and shale.

FORT UNION FORMATION (LUDLOW MEMBER)

The Ludlow member of the Fort Union formation of Paleocene age is composed of sandstone, shale, and lignite. The occurrence of lignite beds in the Ludlow member distinguishes it from the underlying Hell Creek formation. In northeastern Perkins County and in Corson County no lignite beds are present, but the carbonaceous layers and partings are believed to be their equivalent.

In the vicinity of the Shadehill dam site the Ludlow member crops out 25 feet above stream level. A geologic map of Perkins County (Winchester and others, 1916, pl. 2) does not indicate any exposure of the Ludlow member northeast of the junction of the North and South Forks of the Grand River. However, excavations made since that map was prepared have exposed sandstones containing many carbonaceous layers typical of the Ludlow member; therefore, the member probably extends farther north of the Grand River in northeastern Perkins County than Winchester indicated. Intricate folding of the beds in one exposure is probably the result of differential compaction of organic sediments and of slumping along valley walls.

The Cannonball formation, which interfingers with the Ludlow member, undoubtedly is present in the area; however, because no identifying fossils were found by the writers, the two units could not be readily distinguished. The geologic map of Winchester and others (1916, pl. 2) shows the Cannonball formation cropping out north of Shadehill.

Quartzite boulders are present at many places both in the Grand River valley and on the surrounding uplands. Most of these boulders probably have been let down a considerable vertical distance owing to erosion of the underlying fine-grained sedimentary rocks. Winchester and others (1916, p. 30) described these boulders as follows:

> * * * The rock on fresh exposure is of a grayish-white to bluish-gray color and is very soft, but on weathering it becomes well indurated and in many places highly polished by wind action. It is composed largely of fine subangular pieces of quartz. The rock in places is perforated with impressions of roots and stems, but nothing identifiable was found.

Winchester and others stated further that quartzite is present in the Fox Hills sandstone, the Fort Union formation, and the White River formation; therefore, little stratigraphic significance can be attached to the presence of these boulders. Northwest of Shadehill in the SW¼ sec. 15, T. 21 N., R. 15 E., a small butte is capped by quartzite boulders so numerous as to suggest that they are at or near the level of the original bed. The original bed may have been a bed of the Ludlow member, which is exposed in the butte and its immediate vicinity. A few other buttes also are capped by boulders.

The Ludlow member has no pronounced physiographic expression; this probably is due to the lack of uniformity of cementation. When struck with a hammer a sandstone layer in one place may be hard enough to cause the hammer to ring, but a few feet away it may give only a dull thud.

The soil formed on the Ludlow member is well drained and is free from alkali.

In the report area the Ludlow member is generally above the water table and, hence, it has no importance as a source of ground water.

GLACIAL DEPOSITS

Granitic glacial boulders are scattered throughout the eastern part of Corson County. They range from a few inches to several feet in diameter, but they do not form bedded deposits and are not a source of ground water.

TERRACE DEPOSITS

The origin of the terrace deposits is related to the physiographic development of the area, including the continental glaciations that blocked the Grand River valley at least once during Pleistocene time. In the Grand River valley two earlier major river stages are distinguishable; many younger but less distinct terraces also are present along the river.

A gravel deposit that may be of Miocene, Pliocene, or early Pleistocene age occurs in the vicinity of the Hager gravel pit in the NE¼SW¼ sec. 20, T. 21 N., R. 17 E., at an altitude of about 2,350 feet above sea level and about 215 feet above the level of the Grand River. The gravel apparently was deposited by a stream of considerable size and competence and is composed of pebbles of sandstone, quartz, quartzite, felsite porphyry, petrified wood, pseudoscoria, and jasper. This gravel deposit probably is a remnant of a much more extensive terrace deposit.

A broad, level terrace borders the Grand River and extends up most of the tributary streams. This terrace, which is about 90 feet above the Grand River at Shadehill, is the principal irrigable area of the valley. The terrace is underlain by several feet of fine sand and silt, except along the edge of the terrace where the fine-grained deposits have been removed by erosion. Underlying the fine-grained deposits is gravel composed of pebbles and fragments of sandstone, limestone, chert, quartzite, felsite porphyry, petrified wood, jasper, and pseudoscoria. The gravel is generally thin but locally is as much as 20 feet thick.

The gravel along the North Fork of the Grand River, Lodge Pole Creek, Thunder Hawk Creek, and a south-flowing stream half a mile west of the Perkins-Corson County line contains felsite porphyry that probably was derived from conglomerate in the White River formation. Pebbles of felsite porphyry were found also atop a butte near the Perkins-Corson County line in the vicinity of U. S. Highway 12. This indicates that the White River formation may have covered much of southwestern North Dakota and northwestern South Dakota.

The downstream slope of the terrace along the Grand River valley is about 6 feet to the mile. Hares (1928, p. 8) reported the same slope for terraces that are underlain by similar gravel and are at a similar elevation in the valley of the Little Missouri River. Further study and correlation of the terraces in these two valleys should lead to a more complete understanding of the physiographic history of the area.

The age of the principal terrace deposits is not definitely known but is thought to be Iowan. The coarseness of these deposits and the fact that they overlie soft bedrock formations suggest that a stream of great carrying power was formed by the release of a large volume of water within a relatively short time. One of the early Pleistocene glaciers may have blocked the Grand River and caused water to back up much of the length of the valley; then, when the ice melted, the water may have been released more or less suddenly. The rapid release of a large volume of water would account for the broad cut in the bedrock on which the gravel was deposited and for the great transporting power of the stream. The silt and fine sand that overlie the gravel would then have been deposited as the streamflow returned to normal.

The gravel is locally water bearing. Test holes were drilled by the U. S. Bureau of Reclamation in T. 21 N., R. 16 E., and T. 20 N., R. 19 E., in which water was encountered in the gravel within 8 to 20 feet of the land surface. Some test holes near the edge of the terrace, however, were dry at a depth of 24 feet.

Smaller remnants of younger, lower lying terraces also are present along the Grand River valley. Apparently they are the result of stream meandering. Because their deposits are usually fair to good sources of ground water, they are of considerable local importance.

ALLUVIUM

The bottom land, which comprises small areas that are separated by sharp bends of the river or by bluffs, is underlain by alluvium. The surface soil of the bottom land is gray, fine-textured silty or loamy sand which grades downward to coarse sand and gravel. The general character of the alluvium is shown by the following four sections, which were measured along the banks of the Grand River:

Measured sections of alluvium on banks of the Grand River, North Dakota

	Thickness (feet)
Section in NE¼ sec. 20, T. 20, N., R. 19 E., along dry creek bed.	
Alluvium:	
Surface soil, silty, fine-textured; alternating light and dark strata	4.9
Sand, fine-grained, thin-bedded; grades downward to coarse gravel	3
Sand, medium-grained, blue; with water	3
Total exposed	10.9
Section in S½ sec. 22, T. 20 N., R. 21 E.	
Alluvium:	
Sand, fine-grained, silty, buff	13
Gravel, coarse, lenticular	3
Fox Hills sandstone:	
Sand and clay, gray; contains large sandstone concretion	15
Total exposed	31

Measured sections of alluvium on banks of the Grand River, North Dakota—Con.

	Thickness (feet)
Section in SE¼ sec. 35, T. 21 N., R. 23 E., along north side of river.	
Alluvium:	
Sand, fine-grained to silty	10
Clay; contains numerous gravel lenses; grades from a sandy clay at top to a purer clay toward bottom of section	22
Total exposed	32
Section in W½ sec. 10, T. 20 N., R. 25 E., on east side of river.	
Alluvium:	
Clay, sandy, dark; surface cracked owing to drying	6
Gravel, fine, with sand matrix	1
Sand, fine-grained, crossbedded; contains numerous pebbles as much as ½ inch in diameter	3
Talus	------------
Total exposed	10

Where the valley bottom is bordered by the Pierre shale, the alluvium generally contains a relatively high percentage of clay that has been washed down from the uplands; the upper part of the alluvium on the east side of the river in secs. 9 and 10, T. 20 N., R. 25 E., consists of a thick deposit of clay that overlies sand and gravel lenses.

The logs of test holes drilled in 1948 by the U. S. Bureau of Reclamation at the site of the Shadehill dam in the SE¼ sec. 25, T. 21 N., R. 15 E., indicates that the thickness of the alluvium ranges from about 2 to 20 feet. The thinnest deposits generally are beneath the river bed and near the valley walls, where the alluvium thins to a featheredge. (See pl. 2.) The logs show that the alluvium consists of sandy silt which grades downward to a mixture of sand and gravel. Some clay is interbedded with the gravel deposits. Sandstone of the Hell Creek formation underlies the alluvium in the western part of the report area.

Wells dug in the alluvium usually yield adequate supplies of ground water for domestic and stock use. The water is generally hard but is reported to be satisfactory for domestic use.

GROUND WATER

Factors that affect the availability, quantity, and occurrence of ground water in the Grand River valley include the type and permeability of the soil and the permeability, structure, thickness, and lateral extent of the underlying rock formations which constitute the underground reservoir. Water from rain and snow is transmitted freely to the ground-water reservoir by the sandy soil that generally overlies the Fox Hills sandstone and the silty or sandy soil of the alluvium. The soils formed on the other exposed formations are less permeable.

Except for the Pierre shale, which is almost impermeable, all the formations exposed in the area, where saturated, yield water to wells. The general movement of the ground water is from the uplands toward the Grand River, where the water discharges into the stream or joins the underflow in the alluvium.

The alluvium that underlies the valley floor is the principal ground-water reservoir. It is recharged by water percolating from the bedrock, by the river when it is at a high stage, and by precipitation. During periods of low precipitation and runoff, the alluvium discharges ground water into the river.

DEPTH TO GROUND WATER

The slope of the water table toward the Grand River is less than that of the corresponding land surface, and the relief of the water table generally is much less than that of the land surface. Accordingly, in the topographically low areas—such as coulees and the valleys of intermittent streams—the depth to ground water is comparatively slight. In the upland area the depth to the water table is greater.

The average measured or reported depth of 38 upland wells penetrating bedrock (see table 4) is 101 feet, and, in the summer of 1946, the average depth to water in 46 wells on the upland was 30 feet. The average depth of 45 wells drilled in or to the base of the valley alluvium was 38 feet, and the average depth to water in 48 wells in the alluvium was 17.0 feet. Many owners of shallow wells reported that the water level in the wells correlates closely with the rise and fall of the river level. The zone of saturation in the alluvium is directly connected with the river, but the water table rises gradually to the valley borders.

The U. S. Bureau of Reclamation drilled numerous test holes at the proposed dam site in sec. 25, T. 21 N., R. 15 E. (pl. 2), and the depth to water in them was measured. In that area, according to the measurements, the water table in the alluvium along the valley bottom is generally 2 or 3 feet above the top of the underlying Hell Creek formation—that is, the zone of saturation in the alluvium is 2 or 3 feet thick. The top of the artesian zone in the Hell Creek formation was encountered at a depth of 140 feet beneath the surface of the bottom land.

FLUCTUATIONS OF THE WATER TABLE

Periodic measurements of the water level in 30 wells (table 3) show that the water table fluctuates in response to recharge to and discharge from the zone of saturation. When recharge to the ground-water reservoir exceeds discharge, the water table rises accordingly; and when recharge is less than the discharge, the water table declines.

Ground-water recharge in the area is caused by the underflow of ground water into the area from the region of higher altitude to the west, by seepage from the Grand River and its tributaries, and by precipitation that infiltrates to the water table. The recharge from precipitation is especially significant in the areas underlain by the porous Fox Hills sandstone and the alluvium.

Ground water is discharged by withdrawal of water from wells, underflow of ground water out of the report area into adjacent areas of lower altitude, and evapotranspiration.

UTILIZATION

Of the 131 wells inventoried in the report area during this investigation, 72 are used as a source of supply for domestic and stock needs. Most of the other wells are on abandoned farms and no use is made of the water in them. Little ground water is used for irrigation. (See table 4.)

The water supply in the villages of Bull Head, Little Eagle, and Wakpala is obtained from shallow-dug wells. Practically all the water from these wells is used for domestic and livestock needs. Many Indian families that live along the lower Grand River use the river water and prefer it to ground water for domestic purposes.

The large number of abandoned wells and farms indicates that the amount of pumping in the past was greater than it is at present; however, it was never very great. The amount of precipitation within the area is the most important factor in the determination of the quantity of available water, but at the present or probable future rate of utilization, the ground-water supply is not likely to be depleted.

Irrigation with impounded Grand River water, if practicable, would increase and stabilize crops and stock raising in the Grand River Basin. However, the soils of the lower Grand River valley are derived from wash material of the Pierre shale, which causes them to be comparatively heavy in texture; when such areas are irrigated, suitable drainage generally must be provided if waterlogging and concentration of alkaline salts in the soil are to be prevented.

CHEMICAL QUALITY OF THE WATER

By E. R. Jochens

A reconnaissance of the chemical quality of ground water in the Grand River valley was made during May 1947 and October 1948. In addition to providing general information on the present chemical character of water in wells in the area, the results of the investigation will be useful for comparison with the ground-water quality after irrigation from the Shadehill Reservoir is begun.

Thirteen ground-water samples were collected for chemical analysis. The results of the analyses are listed in table 1, and the locations of sampling points are shown in plate 1. The samples were obtained from shallow wells that tap the alluvium or deposits of the Hell Creek formation; no samples were obtained from wells tapping other formations in the area. Most of the samples were collected in the vicinity of Shadehill, because in this area experimental irrigation farming will be conducted. The samples contained variable amounts of dissolved mineral substance; most of them represented water of the sodium bicarbonate type. Objectionable quantities of certain mineral constituents were found in most of the samples.

DOMESTIC USE

Ground water contains variable amounts of dissolved minerals. When present in even small amounts, some of these minerals are objectionable in water to be used in the home and may affect the health of the consumer; others are desirable in limited amounts. In either case, the cost of the water is increased.

The optimum content of fluoride in drinking water, for both health and appearance of the consumer's teeth, is very close to 1.0 ppm. When the fluoride content exceeds about 1.5 ppm, the tooth enamel of young children may become mottled and unsightly (Dean, 1936); when it is less than about 1.0 ppm, their teeth may decay more rapidly (Dean, 1938).

Nitrate in water often indicates pollution by sewage or other organic matter. Infants who are fed water that contains excessive amounts of nitrate may develop the condition of cyanosis or "blueness." Comly (1945), Waring (1949), and Bosch and others (1950) have written articles on the occurrence of cyanosis in relation to nitrate in water. Maxcy (1950, p. 271), recommended that, pending further study, water from private sources that has a nitrate content (as NO_3) greater than 45 ppm should be regarded unsafe for infant feeding.

Iron and manganese are objectionable because, if present in sufficient quantities, they may stain porcelain, enameled fixtures, or clothing or other fabrics. Iron may also cause the water to be turbid and to have an unpleasant taste.

Considerable amounts of the scale- and hardness-forming constituents (calcium and magnesium) in water may cause much expense and trouble in the home. Scale formation reduces flow in hot water pipes, and of course leads to increased consumption of soap. Water having a hardness (as $CaCO_3$) of more than 120 ppm is considered hard, and domestic users may find it desirable to soften such water.

TABLE 1.—*Chemical analyses of representative waters in the lower Grand River valley, S. Dak*

[Analyses in parts per million except as indicated]

Well number	Date of collection	Depth (feet)	Temperature (° F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Percentage of sodium	Specific conductance (micromhos at 25°C)	pH
Corson County																						
20-18-1cc	10- 7-48	30	54	15	1.2	32	8.0	214	3.2	394	22	202	9.0	0.8	19	0.15	732	113	0	79	991	8.6
1dc2	5-14-47	62	46	13	.12	38	10	73	13	314	0	37	7.3	.4	4.0	.24	343	136	0	51	578	7.6
24bb2	10- 7-48	80	50	14	1.0	4.0	.3	459	4.0	711	17	330	68	1.7	2.1	.80	1,260	11	0	98	1,780	8.2
20-28-35bd	5-12-47	19	45	8	2.0	73	22	91	18	265	24	153	30	.4	40	.11	597	273	16	40	908	8.5
21-24-24ca	5-13-47	25.8	48	11	.80	99	39	257	12	519	0	514	13	.4	2.0	.24	1,210	407	0	57	1,740	7.9
Perkins County																						
21-15-24da	10- 6-48	100+	48	15	14	56	34	59	19	338	0	98	14	0.4	58	0.21	514	280	3	30	806	7.7
21-16-18da	10- 7-48	19	54	23	.15	70	15	38	6.8	216	0	52	18	.5	100	.21	434	236	59	25	649	8.1
19bb	5-15-47	87	49	12	.10	15	3.1	202	10	393	0	156	9.8	.6	2.0	.45	598	50	0	87	972	7.8
19bb	10- 6-48	87	48	12	3.6	14	2.0	208	1.6	403	0	158	9.0	.6	1.5	.36	630	43	0	91	882	7.6
19cd	10- 6-48	25	50	10	.65	6.0	.3	375		652	20	174	54	2.0	2.2	1.1	968	16	0	98	1,520	8.4
19dal	5-15-47	16	48	17	2.1	28	11	420	.0	562	24	497	13	1.0	.0	.65	1,290	116	0	89	1,910	8.6
20bb	10- 7-48	------	52	11	24	222	140	945	14	842	0	2,460	37	.2	.6	.00	4,250	1,130	440	64	4,850	7.7
21bcl	10- 8-48	32	53	14	.35	46	37	463	7.2	376	10	832	45	.4	2.9	.26	1,650	267	0	78	2,340	8.3
Grand River at Shadehill, S. Dak.																						
Weighted average for 1947 water year [1]	------	------	------	12	0.05	27	11	126	18	243	------	198	2.8	0.2	1.1	0.22	524	113	0	67	826	------
Weighted average for 1948 water year [1]	------	------	------	12	.04	29	13	253	8.1	380	------	349	7.0	.3	1.9	.31	869	126	0	80	1,250	------
Weighted average for 1949 water year [1]	------	------	------	10	.22	21	7.8	80	6.6	165	------	125	2.0	.3	2.6	.20	344	85	0	65	518	------

[1] Weighted averages calculated on basis of streamflow.

In addition to limitation for nitrate (Maxcy, 1950, p. 271) and the general criterion for hardness, useful standards for drinking-water requirements are given by the U. S. Public Health Service (1946). These standards are mandatory for public carriers in interstate commerce. Some people accustomed to drinking water that has appreciable mineral content may find less mineralized water, which conforms with this standard, to be unpalatable. Maximum recommended concentrations of certain individual constituents and the analytical results of samples from the lower Grand River valley are given in table 2. Because only a few samples were analyzed, only general statements can be made as to the ground-water quality. The data in the table indicate that much of the water is moderately hard and contains excessive amounts of iron and moderate to large amounts of mineral solids.

TABLE 2.—*Comparison of concentration of several constituents in water from wells and suggested limits of concentration*

[Analyses in parts per million. Figures indicated by an asterisk (*) exceed suggested limits]

Well location	Iron (Fe)	Magnesium (Mg)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$
20-18-1cc	*1.2	8.0	202	9.0	0.8	19	*732	113
1dc2	.12	10	37	7.3	.4	4.0	343	*136
24bb2	*1.0	.3	*330	68	*1.7	2.1	*1,260	11
28-35bd	*2.0	22	153	30	.4	40	597	*273
21-24-24ca	*.80	39	*514	13	.4	2.0	*1,210	*407
15-24da	*14	34	98	14	.4	*58	*514	*280
16-18da	.15	15	52	18	.5	*100	434	*236
19bb (1947)	.10	3.1	156	9.8	.6	2.0	*598	50
19bb (1948)	*3.6	2.0	158	9.0	.6	1.5	*630	43
19cd	*.65	.3	174	54	*2.0	2.2	*968	16
19dal	*2.1	11	*497	13	1.0	.0	*1,290	116
20bb	*24	*140	*2,460	37	.2	.6	*4,250	*1,130
21bcl	*.35	37	*832	45	.4	2.9	1,650	*267
Limits suggested by U. S. Public Health Service except as indicated	[1] 0.3	125	250	250	1.5	[2] 45	[3] 500	[4] 120

[1] Iron plus manganese.
[2] See Maxcy, 1950.
[3] 1,000 permitted if better water is not available.
[4] Generally accepted figure but not standard.

IRRIGATION USE

Little ground water in the Grand River valley is used at present for irrigation. The samples of ground water, however, as well as the water in the Grand River at Shadehill, were rated for use as irrigation supplies by a graphic method of classification proposed by Wilcox (1948). (See fig. 3.) This classification is somewhat arbitrary because, in addition to the quality of the ground water, the soil composition, permeability and drainage, irrigation practices, and crop tolerances also must be taken into consideration.

All five classes of irrigation water are represented by the ground-water samples collected in the lower Grand River valley (fig. 3).

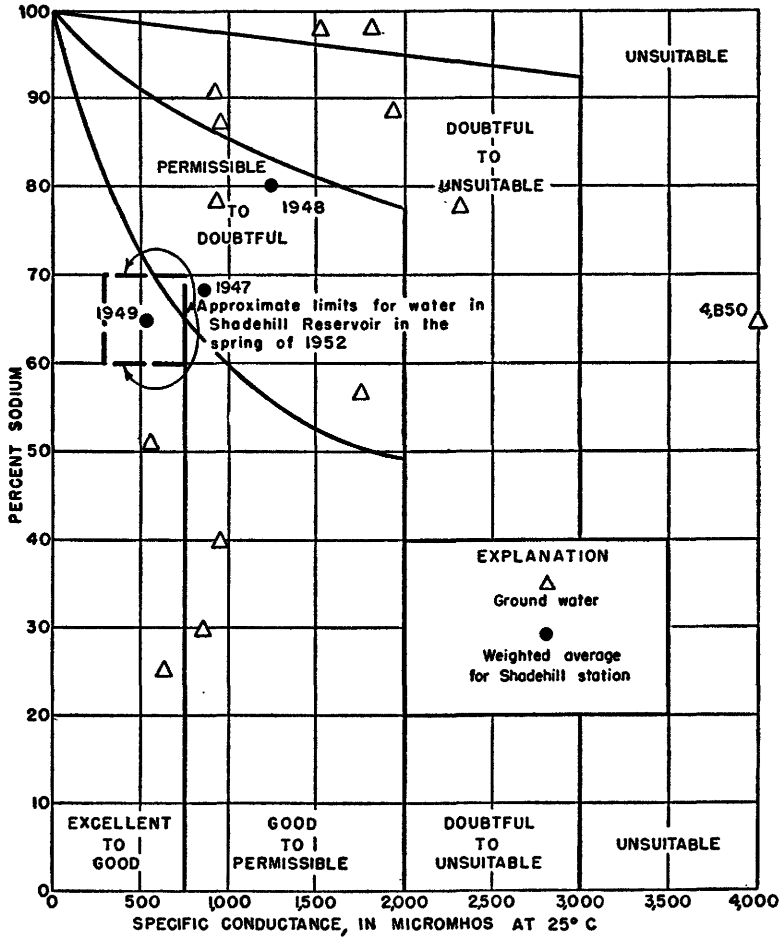

FIGURE 3.—Classification of water in the lower Grand River valley for irrigation (after Wilcox).

Of all the water-bearing rocks in the area, however, only the alluvium is likely to yield enough water for irrigation, and that only in areas where it is thickest and most permeable. No specific information was obtained in this study as to the maximum yields available from wells. The river water varies from "excellent to good" to "permissible to doubtful" for irrigation.

It is difficult to estimate the probable quality of the ground water after irrigation with water from the Shadehill Reservoir is begun. Ground water sampled in 1947 and 1948 was very different in average quality from water in the reservoir in 1952. Well 21–16–19bb was sampled in 1947 and 1948, and the results of the analysis show changes in water quality. Water in the alluvium probably varies in quality with changes in the quality and stage of the Grand River.

The tolerance of various plants to boron has been studied by Scofield (1936) and Eaton (1935). Although ground water sampled in the lower Grand River valley generally contained low concentrations of boron, several samples contained boron in concentrations that could affect sensitive crops if the water was used for irrigation. Semitolerant crops, however, would not be affected. Boron probably will not be present in the water in Shadehill Reservoir in amounts that will affect even the most sensitive crops.

TABLE 3.—*Measurements of the water level in observation wells, in feet below land surface datum*

Date	Water level	Date	Water level	Date	Water level
CORSON COUNTY					
19-26-2ba					
Oct. 25, 1946	25.63	Oct. 16, 1947	24.21	Aug. 4, 1948	24.92
May 13, 1947	25.85	May 11, 1948	23.17	Oct. 8, 1948	25.77
July 17, 1947	24.06				
19-29-10bc					
Nov. 6, 1946	5.02	Oct. 16, 1947	5.06	Aug. 4, 1948	5.09
May 12, 1947	5.35	May 11, 1948	5.01	Oct. 8, 1948	5.48
July 15, 1947	5.12				
20-18-1dcl					
Sept. 27, 1946	23.45	Sept. 16, 1947	23.18	Aug. 5, 1948	22.92
May 14, 1947	23.59	May 12, 1948	22.87	Sept. 7, 1948	22.96
July 16, 1947	23.15				
20-18-3ba					
Oct. 1, 1946	40.58	July 16, 1947	40.96	Oct. 16, 1947	40.84
May 14, 1947	41.13				
20-18-4bc					
Sept. 30, 1946	28.28	Oct. 16, 1947	28.13	Aug. 11, 1948	27.14
May 14, 1947	28.74	May 12, 1948	27.34	Oct. 7, 1948	26.96
July 16, 1947	28.38	Aug. 5, 1948	27.29		
20-18-12ab					
Sept. 27, 1946	19.45	Oct. 16, 1947	18.31	Aug. 5, 1948	18.61
May 14, 1947	19.17	May 12, 1948	18.60	Oct. 7, 1948	18.74
July 16, 1947	18.24				
20-18-14aal					
Sept. 27, 1946	31.43		28.55	Aug. 5, 1948	28.86
May 14, 1947	29.96	May 12, 1948	29.00	Oct. 7, 1948	29.11
July 16, 1947	29.49				

TABLE 3.—*Measurements of the water level in observation wells, in feet below land surface datum*—Continued

Date	Water level	Date	Water level	Date	Water level
CORSON COUNTY—Continued					
20-18-24bbl					
Sept. 27, 1946	15.9	----------	----------	Aug. 11, 1948	15.86
May 14, 1947	14.72	May 12, 1948	15.14	Oct. 7, 1948	16.20
July 16, 1947	14.56				
20-19-17bc					
June 8, 1948	9.5	Aug. 11, 1948	9.47	Nov. 24, 1948	9.69
June 24, 1948	9.4	Oct. 7, 1948	9.54		
20-19-18ba					
Sept. 27, 1946	5.75	Oct. 16, 1947	5.56	Aug. 5, 1948	6.12
May 14, 1947	5.62	May 12, 1948	5.19	Oct. 7, 1948	6.34
July 16, 1947	5.47				
20-21-16aa					
June 21, 1946	13.63	July 16, 1947	12.27	Aug. 5, 1948	13.38
Oct. 17, 1946	13.38	----------	----------	Oct. 8, 1948	13.40
May 13, 1947	13.19	May 12, 1948	13.65		
20-26-34dc					
Apr. 30, 1946	13.36	July 17, 1947	10.42	Aug. 4, 1948	11.20
Oct. 25, 1946	13.52	----------	----------	Oct. 8, 1948	11.68
May 13, 1947	10.89	May 11, 1948	10.68		
20-28-11cb					
Nov. 1, 1946	29.80	Oct. 16, 1947	29.47	Aug. 4, 1948	29.24
May 12, 1947	29.49	May 11, 1948	29.12	Oct. 8, 1948	29.71
July 17, 1947	29.32				
21-18-34dd					
Sept. 30, 1946	32.68	Oct. 16, 1947	32.52	Aug. 5, 1948	31.66
May 14, 1947	32.56	May 12, 1948	31.62	Oct. 7, 1948	31.47
July 16, 1947	32.46				
21-23-35db					
Oct. 22, 1946	15.20	Oct. 16, 1947	14.88	Aug. 4, 1948	15.41
May 13, 1947	14.77	May 11, 1948	15.20	Oct. 8, 1948	15.66
July 15, 1947	14.79				
21-23-36cb					
June 19, 1946	13.60	July 15, 1947	13.24	Aug. 4, 1948	13.96
Oct. 22, 1946	13.85	Oct. 16, 1947	13.52	Oct. 8, 1948	14.16
May 13, 1947	13.14	May 11, 1948	13.62		
21-24-23ad					
Oct. 23, 1946	17.74	Oct. 16, 1947	17.11	Aug. 4, 1948	17.45
May 13, 1947	16.59	May 11, 1948	16.86	Oct. 8, 1948	18.13
July 15, 1947	16.59				

TABLE 3.—*Measurements of the water level in observation wells, in feet below land surface datum*—Continued

Date	Water level	Date	Water level	Date	Water level
CORSON COUNTY—Continued					
21-24-24ca					
Apr. 30, 1946	22.71	July 15, 1947	22.38	Aug. 4, 1948	22.58
Oct. 23, 1946	22.75	Oct. 16, 1947	22.45	Oct. 8, 1948	23.49
May 13, 1947	21.79	May 11, 1948	21.90		
21-24-25aa					
Apr. 30, 1946	15.25	Oct. 16, 1947	14.38	Aug. 4, 1948	15.07
Oct. 23, 1946	15.58	May 11, 1948	14.50	Oct. 8, 1948	15.54
July 15, 1947	14.24				
PERKINS COUNTY					
21-15-9dc					
Oct. 15, 1946	9.50	Oct. 17, 1947	4.70	Aug. 10, 1948	6.57
May 15, 1947	8.32	May 13, 1948	6.80	Oct. 6, 1948	8.26
July 16, 1947	5.57				
21-16-15cd					
Oct. 15, 1946	19.8	Oct. 17, 1947	17.94	Aug. 10, 1948	18.47
May 15, 1947	17.64	May 14, 1948	16.73	Oct. 7, 1948	19.49
July 16, 1947	17.39	June 2, 1948	16.82		
21-16-19ca					
Oct. 12, 1946	8.88	May 15, 1947	7.98	Oct. 17, 1947	8.07
21-16-19da1					
Oct. 12, 1946	10.47	Oct. 17, 1947	9.33	June 2, 1948	9.79
May 15, 1947	10.20	May 13, 1948	9.77	Aug. 11, 1948	10.10
July 16, 1947	9.55				
21-16-19dd1					
Oct. 20, 1946	8.61	Oct. 29, 1947	6.97	Apr. 5, 1948	7.05
Apr. 17, 1947	7.64	Nov. 13, 1947	7.29	Apr. 28, 1948	7.45
May 22, 1947	7.30	Dec. 18, 1947	7.42	Aug. 10, 1948	7.81
June 3, 1947	7.30	Jan. 6, 1948	7.57	Oct. 7, 1948	7.95
Sept. 17, 1947	7.46	Feb. 16, 1948	7.63	Nov. 24, 1948	7.58
Oct. 7, 1947	7.61				
21-16-21bc1					
Oct. 15, 1946	28.80	Oct. 17, 1947	27.73	Aug. 10, 1948	28.48
May 15, 1947	28.25	May 14, 1948	28.29	Oct. 8, 1948	28.59
July 16, 1947	27.59	June 2, 1948	28.44		
21-16-21bc2					
Oct. 15, 1946	11.8	May 14, 1948	11.55	Aug. 10, 1948	11.73
May 15, 1947	11.4	June 2, 1948	11.66	Oct. 8, 1948	11.78

TABLE 3.—*Measurements of the water level in observation wells, in feet below land surface datum*—Continued

Date	Water level	Date	Water level	Date	Water level
PERKINS COUNTY—Continued					
21-16-24dcc					
June 1, 1948	13.58	Oct. 22, 1948	13.8	Nov. 23, 1948	13.78
21-16-24ddd					
May 28, 1948	13.5	Aug. 11, 1948	12.08	Nov. 23, 1948	12.55
June 2, 1948	11.95	Oct. 22, 1948	Dry		
21-16-29ba					
Oct. 12, 1946	13.96	Oct. 17, 1947	12.40	Aug. 10, 1948	14.14
May 15, 1947	12.58	May 13, 1948	13.49	Oct. 6, 1948	14.22
July 16, 1947	11.98				
21-17-19cb					
June 2, 1948	7.16	Oct. 22, 1948	9.40	Nov. 23, 1948	10.23
Aug. 11, 1948	8.09				

TABLE 4.—*Record of wells*

Well number: See description of well-numbering system in text.
Type of well: B, bored; Dn, driven; Dr, drilled; Du, dug.
Depth of well: Measured depths are given in feet and tenths; reported depths are given in feet.
Type of casing: C, concrete, brick, or stone; P, metal pipe; T, tile; W, wood.
Character of water-bearing material: C, clay; G, gravel; S, sand.
Method of lift: Cy, cylinder; F, natural flow.
Type of power: E, electric; G, gasoline engine; H, hand; W, windmill.
Use of water: D, domestic; I, irrigation; N, little or no use; O, observation; S, stock.
Description of measuring point: Bp, base of pump; Hp, hole in pump base; L, land surface; Tca, top of casing; Tco, top of cover; Tcu, top of curb; Tp, top of pump.
Altitude of measuring point: Altitudes determined by spirit leveling are given in feet and tenths; altitudes interpolated from topographic maps or determined by Paulin altimeter are given in feet.
Depth to water: Measured depths are given in feet, tenths, and hundredths; reported depths are given in feet.
Chemical analysis: C, results of chemical analysis given in table 1.

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Character of water-bearing material	Method of lift and type of power	Use of water	Measuring point			Depth to water level below measuring point (feet)	Date of measurement	Chemical analysis
									Description	Height above land surface (feet)	Altitude above mean sea-level datum (feet)			
Corson County														
19-20- 4aa	W. Hayes	Dn	16	2	P		Cy, H	D, S	L		2,090	12		
22- 2cc		B		24	W		Cy, W, H	D, S	Bp	1.6	2,160	40.7	6-20-46	
6cb	L. A. Mader	Du	40	48	C		Cy, W, H	D, S	Bp	.7	2,142	30.43 30.73	10-22-46 10-22-46	
26- 2ba		Du		48	W		Cy, H	O	Tcu	.9	1,704	26.53	10-25-46	
3dd		Du	19.4	48	W			N	Tcu	1.0	1,700	Dry	10-25-46	
4aa		Du	26.1	48	P		Cy, H	D, S	Bp	.0	1,696	21.51 21.80	4-30-46 10-25-46	
5aa		Du	16.0	36	W		Cy, H	D, S	Bp	1.5	1,690	13.37	11- 6-46	
5ac		Du, Dn	16.0	24, 6	P, W		Cy, H	D, S	Bp	1.5	1,700	11.08	11- 6-46	
16ac		Du	25	48	W			N	Tcu	1.7	1,780	21.89	10-25-46	
27- 1aa	J. Arberly	Dr	20			S, G		N	L		1,679	12.16		
28- 5ba		Du	13.4	48	C		Cy, H	N	Tcu	.9	1,600	Dry	4-29-46	
29- 3db	H. Kurt	B	27	24	W	S, G	Cy, H	D, S	Bp	.4	1,805	19.72	10-31-46	
10bc		Du	15	48	C, P		H	D, O	Tca	.0	1,620	5.02	11- 6-46	
10dd	Redhorse	Du	14.0	36	C	S, G	Cy, H	D, S	Tca	1.2	1,700	8.42	10-31-46	
14da	L. Gunnar	B	32	24	C	G	Cy, H	S	L		1,590	10		
30- 6dc		Du		36	W		Cy, W	D, S	Tca	1.9	1,650	9.90	10-31-46	
20-17-12ab	Lyman	Du	50	48	C		Cy, H, W	D, S	Tco	.2	2,122	7.88	9-24-46	
18-1ab	C. Fish	Du	42	40	C		Cy, H, W	D, S	Bp	1.4	2,220	38.76	9-30-46	

TABLE 4.—*Record of wells*—Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Character of water-bearing material	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Altitude above mean sea-level datum (feet)	Depth to water level below measuring point (feet)	Date of measurement	Chemical analysis
Corson County—Continued														
1cc		Dr	30		P		Cy, H	D			2,192			C
1dc1	C. Sands	Du	34.0	36	C		Cy, H	O	Bp	1.0	2,200	24.45	9-27-46	
1dc2	do	Dr	62	6	P			N			2,200			
2cc		Dr	200	6	P		Cy, W	D, S			2,190			C
3ba		Dr	100+	6	P			O	Tco	.6	2,188	41.18	10-1-46	
4bc	R. Montgomery	Du	90	48	W		Cy, H, W	O	Bp	1.0	2,205	29.28	9-30-46	
5db	do	Du					Cy, H	S	Bp	.0	2,207	30.3	10-1-46	
10dd	E. H. Will	Du	24	60	W		Cy, W	D	Tcu	.75	2,110	12.48	10-1-46	
11aa		Dr		6	P		Cy, H, W	N	Bp	.6	2,190	16.05	9-27-46	
12ab		Du	25.0	36	C		Cy, H, W	O	Tca	.0	2,192	19.45	9-27-46	
13bb		Dr		12	P		Cy, G	S	Bp	.6	2,180	41.8	9-27-46	
14aa1		Du	36.0	36	C		Cy, H	O	Bp	.3	2,099	31.73	9-27-46	
14aa2		Dr	33.2	4	P			N	Tca	1.0	2,100	Dry		
17ad		Dr		4	P		Cy, W	N	Tca	3.5	2,152	7.5	10-1-46	
24bb1	H. Lyman	Du	24	36	C	S, G		O	Tco	.4	2,070	16.3	9-27-46	
24bb2	do	Dr	80	6	P		Cy, W	D, S, I						C
24bc		Dr	200	4	P		Cy, W	N	Hp	2.5	2,146	6.4	9-27-46	
19-5bc		Du		48	W		Cy, H, W	S	Bp	.5	2,157	3.35	9-27-46	
7dd	U. S. Bureau of Reclamation	B	22	12		S		N	L		2,185.3	18		
8db	do	B	24	12		S		N	L		2,183.2	20		
14ac	A. Tomac	Dr	300	6	P			N	Tco	.4	2,210	Dry at 100.6	9-26-46	
17aa		Du	38	48	C		Cy, H, W	D, S	Bp	1.5	2,175	17		
17baa	U. S. Bureau of Reclamation	B	18	12		S, G		N	L		2,177.1	13		
17bbb	do	B	18	12		G		N	L		2,177.8	13		
17bc	do	B	24	12,4	P	S		O	L		2,172.2	9.5	6-8-48	
17dbb	do	B	15	12		S		N	L		2,171.4			
17dbc	do	B	24	12				N	L		2,166.3	Dry		
18aab	do	B	16	12		S		N	L		2,177.8	10		
18ba		Dr	32.0	4	P		Cy, H	O	Tca	1.0	2,170	6.75	9-27-46	
20bd		B	4	2		S		N	L		2,044	2.5	10-2-46	
20-3dd		Dr	70				Cy, W	N	Hp	2.4	2,200	24.83 24.92	6-22-46 10-17-46	
18ac	J. S. Burns	Dr	219	6	P		Cy, G, H	S	L		2,155	37.0	9-24-46	
18ca		Du	12.7	48	C				Tco	1.3	2,164	9.25	9-26-46	

20cc		B	22	24	C		Cy, G	S	Bp	1.4	2,060	19.86	6-22-46	
												20.14	6-26-46	
28cb		Dr		2	P		Cy, H, W	N	Bp	.3	2,130	63.0	6-22-46	
												76.3	9-27-46	
30ba		Dr	130	6	P		Cy, G, W	D, S	L		2,103	30		
21-16aa		Du	24.4	36, 1	C, P		Cy, H	D, O	Tca	.5	2,030	14.13	6-21-46	
20ba		Du	45	30, 1	C, P		Cy, H	D, S	Tca	.7	1,972	41.04	10-21-46	
20cb	Yellow Ears	Du	23	24	C	S	Cy, H	D	Tcu	1.6	1,940	16.68	10-22-46	
21dd	J. F. Horse	B	83	6	C	S	Cy, H	D	L		1,865	19		
22da		Du	21.2	24, 1	C	S	Cy, H	D, S	Tca	.9	1,980	18.27	10-21-46	
22-11bb	Community well	Du	16.0	48		S		N	L		1,950	12.8	6-19-46	
												9.60	10-18-46	
												9.45	5-13-47	
												10.84	7-15-47	
18cd	A. W. Quietly	Dr	197	6	P		Cy, H	D, S			1,970			
19cc	H. T. Twito	Du	34	24	W		Cy, G	S	Tco	.6	1,845	18.2	6-20-46	
												25.40	10-22-46	
23-9cc	E. Larson	Du	37.0	36	C, P		H	D	Tca	.2	2,010	33.25	10-22-46	
10cc	P. Emmons	Du	15	24		S		N	L					
25-6dd	B. Crow	Dr	24	3	P	G	Cy, H	D	L		1,750	18		
10bc	W. Temple	Du		24	P	S		D	Tca	.7	1,728	2.39	10-23-46	
26-32cd		Du	20.1	36	P	S	Cy, H	D	Bp	.4	1,690	Dry	11- 4-46	
34dc		Du	16.4	48	W	S		O	L		1,662	13.36	4-30-46	
27-21da	W. Middlemoon	Du		48	P	S	Cy, H	N	Tca	1.0	1,650	25.93	4-20-46	
36bd		Du	26.9	48	C			N	Tca	.6	1,600	26.35	4-29-46	
28-11cb		B	38.5	18	W			O	Tcu	.0	1,980	29.80	11- 1-46	
25da	H. M. Sherwood	Du	35.0	36, 3	C, P	S	Cy, W	D, S	L		1,605	18		
35bd	J. Corken	Du	19	36	W	S	Cy, H	D	Hp	.7	1,596	14.55	11- 1-46	O
												13.10	5-12-47	
												12.91	7-17-47	
29-19ba	E. Riekr	Du	35.0	48	C		Cy, H	D, S	Bp	.0	1,774	4.70	11- 1-46	
32cc	W. Strongheart	Du	23.0		C	S	Cy, H	D, S	L		1,590	20		
21-18-28cc		B	72	20	W		Cy, H	D, S	L		2,252	68		
34dd		Du	37	60	C		Cy, H, W	O	Tcu	.9	2,209	33.58	9-30-46	
21-26db		Du	91.1	24	W			N	L		2,160	55.90	6-21-46	
												53.50	10-21-46	
23-33cc	L. Middleboro	Du	28.5	24	C		Cy, H	D	Tca	.7	2,000	20.41	6-19-46	
												20.05	10-23-46	
35db		Du	32.5	24	P	S		O	Tca	.5	1,820	15.70	10-22-46	
36cb	J. R. Shamble	B	18.9	24	P	S	Cy, W, H	D, O	Tca	.5	1,818	14.1	6-19-46	
24-15da		Du		36	C	S	Cy, H	D, S	Tca	.3	1,800	20.98	10-23-46	
23ad	L. Shooter	Du	30.0	48	C	S		O	Tcu	.6		18.34	10-23-46	
24ca	Community well	Du	25.8	36	P		H	D, O	Tca	1.5		24.21	4-30-46	O
24db	J. Redfish	Du	25.0	48	W		Cy, H	N	L			21.71	4-30-46	
												22.02	10-23-46	
25aa		Du	15.9	48	C		Cy, H	O	Bp	.3		15.55	4-30-46	

TABLE 4.—*Record of wells*—Continued

Well number	Owner or tenant	Type of well	Depth of well (feet)	Diameter of well (inches)	Type of casing	Character of water-bearing material	Method of lift and type of power	Use of water	Measuring point: Description	Measuring point: Height above land surface (feet)	Measuring point: Altitude above mean sea-level datum (feet)	Depth to water level below measuring point (feet)	Date of measurement	Chemical analysis
Perkins County														
14–15dd	School	Dr		4	P		Cy, H	D	Bp	0.5	2,575	37.52	10–14–46	
15–5ad	D. Benite	Dr	150	6	P		Cy, W	D, S	L		2,328	35		
9dc				4	P		Cy, H	O	Hp	2.6	2,314	12.1	10–15–46	
20cd	Burdick	Dr	168	6	P	C	Cy, H, W	D, S	Bp	1.0	2,430	73.05	10–14–46	
22bb	A. E. Sandwick	Dr	15	6	P			N	Tca	.2	2,224	12		
23cc	School	Dr	68	5	P		Cy, H	N	Bp	.6	2,238	19.8	10–14–46	
23dd	Mosely	Dr	285	6	P		Cy, W	D, S						
24da	R. Ham	Dr	100+	5	P		Cy, H, W	D, S	Bp	1.3	2,285	61.38	10–14–46	C
25aa	R. Merriman	Dr	160	4	P		Cy, W	D, S	Tp	3.0	2,232	36.90	10–12–46	
25cd		Du		36	C		Cy, W	N	Tca	.2	2,212	18.60	10–12–46	
27aa1	E. Sandwick	Du	18	30		G		N	L		2,224	14		
27aa2	do		191				F	N						
34cc		Dr	200	6	P		Cy, W	D, S	L		2,238	20		
16–8ab	King	Du	15.0	48	W			S	Tcu	1.65	2,285	9.20	10–16–46	
14dd		Dr	190	6	P		Cy, W	D, S	L		2,280	60		
15cd	R. Ham	B	24.5	17	P		Cy, H	S, O	Tca	.8	2,205	20.6	10–15–46	
18da	J. Stanley	Du	19.0	36	P	G	Cy, H	D, I	Tco	.3	2,276	17.41	6– 2–48	C
19ad	Walker & Summers	Dr	81.5	4	P	S	Cy, E	D			2,282	50	6– 2–48	
19bb	E. Burns	Dr	87	6	P		Cy, H	D, S	L		2,286	15.20	6– 2–48	C
												13.42	10– 6–48	
19ca		Du	15	24	P		Cy, H	O	Bp	.0	2,208	8.88	10–12–46	
19cd	R. Merriman	Dr	25.0	4, 1½	P	G	Cy, H	D, S			2,209	13.78	10–12–46	C
												13.66	6– 2–48	
												13.67	8–10–48	
												13.96	10– 6–48	
19da1	O. Weinkauf	Dr	16	6	P	G	Cy, H	D, O	Tca	.1	2,208	10.57	10–12–46	C
19da2	F. Gossman	Dr		5	P		Cy, H	D			2,215			
19da3	do	Dr		5	P		Cy, G	I			2,215			
19da4	C. Barnett	Dr		2			Cy, H	D			2,208			
21–16–19dd1		Du	12.0	15	P			O	Tca	.5	2,201.6	9.11	10–20–46	
19dd2	R. W. Hager	Du	12		T	G	Cy, H	D			2,203			
20bb	School						Cy, H	D	Hp	.7	2,280	43.84	6– 3–48	C
												44.01	8–10–48	
												44.32	10– 7–48	

21bc1	C. Lutz	Dr	32	6	P		Cy, H	D, O	Bp	0.3	2,212	29.10	10-15-46	C
21bc2	do	Du		60			Cy, H	S, O	Tco	.5	2,201	11.8	10-15-46	
23cd	J. Sullivan	Du		48	W	S	Cy, H	D, S	Bp	.1	2,185	11.20	10-15-46	
24ad		Dr	100+	6	P		Cy, G, W	D, S	Bp	.3	2,270	86.43	10-12-46	
24bcc	U. S. Bureau of Reclamation	B	24	12				N	L		2,246.4	Dry	6- -48	
24bdd	do	B	21	12				N	L		2,249.6	20	6- -48	
24dcc	do	B	24	12,4	P	S		O	L		2,244.7	13.58	6-1-48	
24ddd	do	B	24	12,1	P	S		O			2,235.7	13.5	5-28-48	
25abc	do	B	24	12				N			2,236.9	Dry	5- -48	
29ba	Barnett	Du	17.0	30	W	S	H	D, O	Tcu	1.3	2,212	15.26	10-12-46	
17-17dd	School	Dr	100+	6	P		Cy, H	D	Hp	1.3	2,341	77.95	10-15-46	
19cb	U. S. Bureau of Reclamation	B	24	12,4	P	S		O	L		2,242.0	7.16	6-2-48	
19cc		Du		24			Cy, H	N	Tp	2.79	2,206	12.23	10-12-46	
24cd	M. Femrite		57.3					D, S	Tco	.6	2,260	36.8	9-24-46	
25ab	T. Femrite	Dr	102	6	P		Cy, G, W	D, S	Bp		2,258	19		
28cc		Du	14.0	24	W		Cy, H	D, S	Bp	.3	2,232	13.28	10-16-46	
30bc	U. S. Bureau of Reclamation	B	20	12				N	L		2,168.8	Dry	6- -48	

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