STATE OF SOUTH DAKOTA
Sigurd Anderson, Governor

STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

NO. 71

ARTESIAN CONDITIONS
IN
SOUTHEASTERN SOUTH DAKOTA

by

Raymond C. Barkley

University of South Dakota
Vermillion, South Dakota
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ARTESIAN CONDITIONS

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INTRODUCTION

Location and Area

The region treated in this report ties in southeastern South Dakota, including Douglas, Bon Homme, Hutchinson, Yankton, Turner, Lincoln, Clay and Union Counties. The northern boundary of the area is parallel 43° 30' north latitude and its southern boundary is the Missouri River. It lies between meridians 97° 30' and 99° 30' west longitude, the Big Sioux River being its eastern limit and the Missouri River its western limit. The area is 138 miles long and 60 miles wide, a total of approximately 2046 square miles.

Purpose of Investigation

The purpose of this investigation was to determine the static level of the artesian water, or height above sea level to which the artesian water would rise; and the rate and amount of decline of this water level in the past fifty years.

Another purpose of this report was to investigate the stratigraphy and structure of the area.

Previous Investigations

The first investigation of artesian water in the region covered by this report was made by E. S. Nettleton[2], an engineer working for the U.S. Department of Agriculture. He made a general investigation to determine the depths, pressures and flows of artesian wells in North and South Dakota during 1890 and 1891.

A more comprehensive study of the artesian basin in South Dakota was made for the United States Geological Survey by N. H. Darton[8] in 1896. Darton's preliminary report investigated the location of water-bearing beds and the limits of the territory in which artesian flows were expected in South Dakota and adjoining states. J. E. Todd[6d] made several investigations of the geology and underground water resources in this region covered by the present report. In 1909 Darton[1] wrote a second report for the United States Geological Survey on "Geology and Underground Conditions of South Dakota". He investigated the geologic conditions bearing on the occurrence of artesian waters.

Their previous investigations have made it possible to record the changes in head or water pressure during the past 60 years.

Method of Investigation

This survey was made by a two-man party consisting of C. Eugene Harrington as engineer and the author as geologist.

An altimeter was used to determine the elevation above sea level of each well site, with levels carried from precise level bench marks near each well. A pressure gauge was used to determine the pressure on any well that was in sufficiently good condition. The rate of flow was determined by observing the time required to fill a gallon measure.

A well was measured every three to six miles to determine the gradient of the water level. Wherever possible, pressures were taken on wells that had good casings to obtain the water level. In certain parts of the area where there were no flowing wells, information was acquired from pumped artesian wells.

Acknowledgments

The author greatly appreciates the cooperation and information given by the well drillers and farmers to help make this report possible.

MESOZOIC SECTION

Pierre Formation

Character

The Pierre formation consists of a grey clay varying from light to dark with numerous bentonite beds and concretions scattered throughout.

Bentonite is a finely divided, altered volcanic ash that settled at various times during the geologic past in shallow interior seas. The volcanic ash was altered to bentonite by action of salt water.

The concretions are composed of hard limestone and iron carbonate, which vary from two to twelve inches in thickness.

In certain parts of the Pierre the bentonites are very numerous. An example of this condition can be seen along the highway on the west side of Missouri at Wheeler Bridge where a section was measured by E. P. Rothrock May, 1932.

Succession of Beds in the Pierre Formation
Measured in Road Cut of Highway 18
West Side of Wheeler Bridge
Sec. 18, T. 96 N., R. 67 W.
Gregory County, S. Dak.

Shale -	50 ft.
Zone of calcareous shale which weathers buff, and is continuous in this region- - - - -	60 ft.
Dark shales -	70 ft.
Bentonite streaks in dark shales- - - - - - - - - -	
Shales which are noticeably light grey when dry - - - - - - - - - - - - - - - - - -	60 ft.
Oligonite concretions 3 to 4 inches in diameter seem to correspond to the manganese zone at Chamberlain -	
Brown sticky clay - - - - - - - - - - - - - - - - - -	40 ft.
Blue-grey, shaly chalk- - - - - - - - - - - - - - - -	7 ft.

Blue-black fissile shale - - - - - - - - - - - -	25 ft.
8 bentonite streaks in zone of black shale - -	6 ft.
Black shale rather fissile on outcrop - - - - - -	30 ft.

The concretions are composed of hard limestone and iron carbonate, which vary from two to twelve inches in thickness.

Distribution

The Pierre formation extends over the western part of the area thinning to the east and appearing along the bluffs of the Missouri Valley. East of Yankton its surface has been eroded away with only outliers outcropping on top of Turkey Ridge. Its eastern limit may be traced from Yankton to the northwestern part of Hutchinson County, and lies roughly along the James Valley.

Distinguishing and Drilling Characteristics

Since the Pierre is a soft, plastic clay that contains numerous bentonites in certain zones and layers of concretions, the formation drills easily but the bentonites and concretions that occur in certain zones may cause some trouble. The bentonites have the property of absorbing large quantities of water causing heaving and swelling which might close the hole. The bentonites are useful in rotary drilling as they make their own drilling mud, saving the driller the expense and trouble of using prepared muds. The concretions that occur in layers are very hard and may cause some trouble in drilling if the well happens to encounter a large one.

Fossils

The most common fossils found in the Pierre are clam shells of the genus Inoceramus, identified by heavy corrugations of the shell. Micro-fossils of the order, Foraminifera, too small to detect without visual aid, can be identified under the microscope. Marine reptile bones can sometimes be found in certain horizons of the Pierre.

Thickness

The Pierre formation varies greatly in thickness in the region between the James and Missouri Rivers in Charles Mix, Douglas, Bon Homme and Yankton Counties. Because it is the topmost of the bedrock formations, it has been subject to much erosion. The maximum thickness is in the western part of the area where 160 feet is recorded at Armour. Near Yankton, 40 feet is outcropping; east of Yankton no Pierre is evident except for a thin veneer capping Turkey Ridge.

The following thicknesses of the Pierre were encountered in wells of the counties listed.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	135 ft.
Sec. 17, T. 100 N., R. 68 W.	40 ft.
Douglas County	
Armour City Well	165 ft.
Bon Homme County	
Scotland City Well	15 ft.

Niobrara Formation

Character

The Niobrara is composed of a dark grey to blue chalk and marl. Under the microscope the chalk has a speckled appearance due to the micro-fossils which are made up of white calcite.

In Kansas the Niobrara has been divided into two members on the basis of lithology. The upper part, called the Smoky Hill Member, is softer and contains numerous bentonites. The lower part, called the Fort Hays Member, is almost a limestone and has fewer bentonite seams. In this area the upper part of the Niobrara is made up of a marl which grades into a chalk in the lower part.

Distribution

The chalk is a conspicuous feature in the bluffs along the Missouri River above Yankton and can easily be seen because it weathers to a buff color at the surface. It underlies the drift along the James River Valley as far north as Letcher, westward beyond Plankinton, and eastward to the Big Sioux River in Hutchinson, Turner, Lincoln, Yankton, Clay and Union Counties, except in the higher part of Turkey Ridge where it is capped by a small outlying area of the Pierre. In northern Turner and Lincoln Counties it abuts against the Sioux Ridge.[1]

Distinguishing and Drilling Characteristics

Weathered chalk appears buff or white, but unweathered or fresh chalk is a blue color, and it is often mistaken for clay or shale. When a drop of acid is placed on the chalk, it will bubble or effervesce briskly, while the clay will not react to the acid.

The Niobrara grades from a marl to a hard homogeneous chalk, making a firm foundation on which to set casing. It does not cave easily and it can be left uncased longer than shaly formations.

Fossils

The most numerous fossils found in the Niobrara are micro-fossils called Foraminifera and Ostracods. Other prevalent fossils found are small, deep cup-shaped oysters (Ostrea congesta) usually found in clusters. Teeth of sharks, fish scales and fish bones are abundant throughout the formation. Reptile bones are occasionally found.

Thickness

In Charles Mix, Douglas and Bon Homme Counties the Niobrara averages from 120 to 140 feet in thickness. In Hutchinson, Turner, Yankton, Lincoln and Union Counties it varies from 40 to 100 feet.

The following thicknesses of the Niobrara were encountered in the wells of the counties listed.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	120 ft.
Sec. 17, T. 100 N., R. 68 W.	120 ft.
Pickstown Well	147 ft.
Douglas County	
Armour City Well	72 ft.
Hutchinson County	
Sec. 23, T. 100 N., R. 60 W.	50 ft.
Turner County	
Sec. 25, T. 98 N., R. 54 W.	110 ft.
Viborg City Well	100 ft.
Bon Homme County	
Scotland City Well	40 ft.
Tyndall City Well	100 ft.

Carlile Formation

Character

The Carlile formation consists of dark grey and bluish grey clay. Calcareous concretions are more or less abundant throughout the deposit occurring mainly at two horizons, 50 and 60 feet below the top of the formation. The size of the concretions vary from 2 to 36 inches in thickness. A considerable amount of iron pyrite and gypsum is abundant in the Carlile. A section of the Missouri River bluffs at old site of the Vermillion Ferry shows the following beds.[6a]

Succession of Beds in the Carlile Formation
Missouri River Bluffs at Old Site of Vermillion Ferry
Sec. 29, T. 32 N., R. 4 E.
Dixon County, Nebraska

Quaternary	
Loess	30 ft.
Rust-colored sand and granite boulders	3 ft.

Carlile Shale (upper half)

Drab shale -	12 ft.
Irregular, coarse-grained, dark colored limestone, much of it conglomeratic at base- -	1 ft.
Drab shale with small concretions at base- -	5 ft.
Dark shale with large concretions at base- -	4 ft.
Dark shale with large concretions at base- -	15 ft.
Shale with an occasional small concretion- -	55 ft.
White bentonite clay - - - - - - - - - - - - - -	2 in.
Dark shale -	6 ft.

Distribution

The Carlile outcrops mainly along the bluffs of the Missouri River and Brule Creek, where it is overlain by loess or drift and lies conformably on the Greenhorn.

Codell Sandstone Member

A horizon of sandstone near the top of the Carlile is persistent over most of the area. This sandstone is called the Codell member of the Carlile. The Codell consists of a fine quartz sand with some of the grains frosted or etched. It is present over most of the area except in the northwestern part of Charles Mix County where it grades into a clay. The Codell is generally known as the "tubular sand" and produces a great amount of water for farm wells.

The thickness of the Codell varies from 30 to 50 feet over most of the area.

Distinguishing and Drilling Characteristics

In the stratigraphic section, the Carlile lies conformably between the Niobrara and the Greenhorn. In most areas the Codell lies immediately under the Niobrara and the first sign of sand indicates the contact. In other areas, however, a shale parting reaching a maximum thickness of 15 to 20 feet separates the Codell from the Niobrara.

The Carlile is a dark colored, soft, plastic clay that contains layers of concretions in the upper part of the formation. It drills easily, but hard concretions that occur in certain zones may cause some drilling trouble. The Carlile can also be used as a drilling mud because it consists of a soft plastic clay and contains scattered bentonites.

Fossils

Fossils are very abundant in the formation, especially in the upper part. Fish remains are common throughout the formation, some layers being composed entirely of fish teeth and bones. Other common fossils found are Inoceramus shells, previously described, and fossil oyster shells called Ostrea congesta.

Thickness

In the western part of the area the Carlile varies from 250 to 270 feet, and in the eastern area it ranges from 200 to 215 feet.

The following thicknesses of the Carlile have been encountered in wells of the area.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	260 ft.
Sec. 17, T. 100 N., R. 68 W.	270 ft.
Pickstown Well	230 ft.
Sec. 7, T. 96 N., R. 64 W.	30 ft.
Douglas County	
Armour City Well	230 ft.
Hutchinson County	
Sec. 23, T. 100 N., R. 60 W.	210 ft.
Turner County	
Sec. 25, T. 98 N., R. 54 W.	220 ft.
Viborg City Well	65 ft.

Lincoln County

Worthing City Well	220 ft.
Canton City Well	110 ft.

Bon Homme County

Scotland City Well	195 ft.
Tyndall City Well	230 ft.

Yankton County

C., M., St. Paul and P. RR	35 ft.

Union County

Sec. 33, T. 94 N., R. 49 W.	150 ft.

Greenhorn Formation

Character

The Greenhorn is a fossiliferous chalk and limestone with an admixture of clay that occurs in thin but distinctive beds. It consists of a lower member of bluish grey chalk containing thin seams of black shale and a few bentonites; a medial member of hard, shelly, thin bedded limestone containing numerous Inoceramus prisms separated by partings of clay; and a top member of light blue-grey chalk.

Succession of Beds in the Greenhorn Formation
Measured at Quarry 12.3 miles S.E. of Westfield
Near Highway 12
Plymouth County, Iowa

3'	Highly weathered, soft, buff and light blue-grey chalk.
8.7'	Slabby thin-bedded, white ls. Beds vary from ¼" to about 1" in thickness. Contains abundant Inoceramus fragments and has iron staining on surface.
4.5'	Very hard, massive, white ls. Contains abundant Inoceramus fragments and has iron staining on surface.
3.72'	Highly weathered, soft, buff and light blue-grey chalk. Contains a 1" seam of bentonite 2.45' below top. Much limonite mixed with bentonite.
.4'	Black, slabby, calcareous shale.
.3'	Chalk as above.
.5'	Shale as above.
3.14'	Chalk as above.
	Base of quarry.

Distribution

South of Burbank along the Missouri River bluffs in Nebraska, it is exposed at numerous points giving rise to many prominent cliffs that cap the softer shale of the Graneros formation. The Greenhorn lies beneath most of the area covered by this report except where it is wedged out against the quartzite in the northern part of Hutchinson, Turner and Lincoln Counties.

Distinguishing and Drilling Characteristics

The Greenhorn lies conformably under the Carlile shale and conformably over the Graneros shale. It can be recognized by numerous casts of Inoceramus shells. It is probably the hardest formation to drill through before reaching the artesian horizon. The driller can easily recognize this formation by the "feel of the bit".

Fossils

The Greenhorn is a shelly limestone that consists mostly of Inoceramus shells. Besides Inoceramus, the formation contains fish fragments, shark teeth, fish scales and foraminifera.

Thickness

This thickness of the Greenhorn varies from 15 to 50 feet. In northwestern Charles Mix County, 50 feet was logged in a well; at Canton and Worthing in Lincoln County 50 feet was logged in each respective well. The Greenhorn appears to thin toward the east, except where it thickens again at Canton and Worthing.

The following thicknesses of the Greenhorn were encountered in the following wells.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	55 ft.
Sec. 17, T. 100 N., R. 68 W.	30 ft.
Pickstown City Well	32 ft.
Sec. 7, T. 96 N., R. 68 W.	30 ft.
Douglas County	
Armour City Well	37 ft.
Bon Homme County	
Scotland City Well	20 ft.
Tyndall City Well	55 ft.
Yankton County	
C., M., St. Paul and P. RR	30 ft.
Union County	
Sec. 33, T. 94 N., R. 49 W.	30 ft.
Turner County	
Viborg City Well	15 ft.
Lincoln County	
Worthing City Well	50 ft.
Canton City Well	55 ft.

Graneros Formation

Character

The Graneros consists mainly of fine grained, dark-colored shale, which is sandy at the base. Concretions of iron carbonate varying from two to six inches in thickness occur at different horizons, and pyrite is abundant throughout the shale. In the vicinity of Ponca, Nebraska, near the base of the formation, there is a thin seam of lignite.

Succession of Beds in the Graneros Formation
Measured at Old Mill Site above Rock Creek
On the Big Sioux River
Plymouth County, Iowa[6a]

Graneros Shale	
Dark-colored shale	80 ft.
Sandstone and shale	20 ft.
Sandy shale	5 ft.

Distribution

The Graneros outcrops at short intervals along the base of the Missouri River Bluffs on the Nebraska side, as far north as Ponca. It appears extensively along the bluffs and large tributary valleys of the Bix Sioux River from the mouth of Joy Creek north to Westfield on the Iowa side.[7] The Graneros underlies most of the area except where it wedges out against the quartzite in the northern part of Hutchinson, Turner and Lincoln Counties.

Distinguishing and Drilling Characteristics

The Graneros lies conformably between the Greenhorn and the Dakota. The Graneros is easy to drill except for concretions and a hard layer between the Dakota and the Graneros which the drillers call the cap rock. The Graneros, like the Pierre and the Carlile, can be used as a drilling mud because it consists of a soft plastic clay.

Fossils

Few fossils are found in this formation with the exception of some large reptile bones.[6a]

Thickness

The formation varies considerably in thickness from one area to another. Two hundred feet of shale logged at Yankton is the thickest section in the entire area. Thirty feet of Graneros, logged at Tyndall in Bon Homme County, is the thinnest section in the area.

The following thicknesses of the Graneros were encountered in the following wells.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	85 ft.
Sec. 17, T. 100 N., R. 68 W.	120 ft.
Sec. 4, T. 95 N., R. 65 W.	170 ft.
Sec. 7, T. 96 N., R. 64 W.	110 ft.
Douglas County	
Armour City Well	70 ft.
Bon Homme County	
Scotland City Well	45 ft.
Tyndall City Well	30 ft.
Yankton County	
C., M., St. Paul and P. RR	200 ft.
Turner County	
Viborg City Well	60 ft.
Lincoln County	
Canton City Well	95 ft.

Dakota Formation

Character

The Dakota formation is made up of sandstones with some thin interbedded shales, some of the features which are given in the following detailed section.

Succession of Beds in the Dakota Formation
Measured Below the Mouth of Aowa Creek
Dixon County, Nebraska[6a]

Sandstone, soft, porous, rust colored	10 ft.
Clay, dark, with thin sandstone layers	2½ ft.
Sandstone, nodular, rust colored	1 ft.
Clay, dark, sandy at base	1 ft.
Sandstone, with layers of iron concretions	4½ ft.
Sandstone, dark, rust colored, with shaly layers	25 ft.

Distribution

The Dakota underlies most of the area covered except where it is wedged out against the quartzite ridge. It outcrops along the Missouri River bluffs southeast of Ponca and is exposed as far north as the mouth of Rock Creek along the Big Sioux River on the Iowa side. It is more extensively exposed near Sioux City and farther south in Nebraska.

Distinguishing and Drilling Characteristics

The Dakota lies conformably between the Graneros and Fuson formations. The upper part of the sandstone is a stratum generally presenting hard layers termed as cap rock. After the cap rock has been penetrated, the sand can be drilled without much trouble. Drilling with a jetting machine, the water bearing sand can be detected by the familiar "bounce of the bit". The drillers have identified three flows in the Dakota which are separated by thin seams of clay. No accurate information could be found as to the depth at which these different flows were encountered. Since the Dakota varies in thickness, the depth at which these flows are found is not the same over a large area.

Fossils

The formation contains numerous traces of plant life in the form of carbonaceous strata, bits of charcoal, root marks and fragments of leaves. It is a fresh water deposit with a few animal fossils that occur rarely. The Dakota has yielded a large and characteristic flora consisting mostly of dicotyledonous plants, as well as a small molluscan fauna of fresh water types.[6a]

Thickness

The Dakota thickens and thins in the western and eastern part of the area. It ranges from 40 to over 230 feet in thickness. In the northwestern part of Charles Mix County, 160 feet was drilled into the Dakota. At Ponca, Nebraska, a thickness of 230 feet was encountered.

The following thicknesses of the Dakota were encountered in the wells listed below.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	40 ft.
Sec. 17, T. 100 N., R. 68 W.	160 ft.*
Sec. 4, T. 95 N., R. 65 W.	85 ft.*
Sec. 7, T. 96 N., R. 64 W.	80 ft.
Douglas County	
Armour City Well	60 ft.*
Hutchinson County	
Tripp City Well	95 ft.*
Bon Homme County	
Scotland City Well	30 ft.
Tyndall City Well	40 ft.
Yankton County	
C., M., St. Paul and P. RR	80 ft.
Turner County	
Sec. 25, T. 98 N., R. 54 W.	90 ft.
Viborg City Well	70 ft.
Lincoln County	
Worthing City Well	65 ft.*
Canton City Well	45 ft.*
Union County	
La Fleur Oil Test, Jefferson	238 ft.
Elk Point City Well	138 ft.

*Figures followed by an asterisk do not represent the complete thickness of the Dakota.

Fuson Formation

Character

The Fuson formation consists of thin beds of fine grained sandstone and different light colored clays mixed with a great amount of bentonite. The most diagnostic hues of the clays are purple, yellow and red.

Manganese pellets are found in great numbers near the top of the formation, and appear to be persistent from the Black Hills to the eastern part of the state. The manganese pellets vary in color from a light brown to deep purple.

Distribution

The Fuson underlies most of the area except where it is wedged out against the quartzite. It does not outcrop anywhere in the area, but it does outcrop 8 miles southeast of Sioux City, Iowa.

Distinguishing and Drilling Characteristics

The Fuson serves as a good impermeable horizon between the Dakota and Lakota. It is a soft, plastic, bentonitic clay that is easy to drill. The formation can be recognized in the cuttings because of numerous rounded manganese pellets that vary in color. The pellets can easily be mistaken for sand by the driller because of the similar size and shape of the grains. The Fuson is full of bentonite and slacks easily, so it should be cased as soon as possible.

Fossils

No fossils have been found in the Fuson in this area, but pieces of carbonized wood and thin streaks of lignite are commonly found.

Thickness

The Fuson ranges from 50 to 70 feet in Charles Mix and Bon Homme Counties, and it varies from 30 to 130 feet in Yankton, Turner and Union Counties.

The following thicknesses of the Fuson are recorded in the wells of the area.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W.	50 ft.
Sec. 7, T. 96 N., R. 64 W.	50 ft.
Bon Homme County	
Scotland City Well	30 ft.
Tyndall City Well	70 ft.
Yankton County	
C., M., St. Paul and P. RR	40 ft.
Turner County	
Viborg City Well	130 ft.
Union County	
La Fluer Oil Boring, Jefferson	30 ft.

Lakota Formation

Character

The Lakota varies in texture from a grey, fine angular to a coarse, angular, subrounded, unsorted sand.

Distribution

The Lakota underlies most of the area except where it is wedged out against the quartzite ridge. At Elk Point and Jefferson well records show that the Lakota is pinched out by the Paleozoic section. There are insufficient records in the eastern part of the area to determine exactly where the Lakota is missing.

Distinguishing and Drilling Characteristics

The Lakota lies conformably under the Fuson and unconformably on the Sioux Quartzite. In general it is a better water sand than the Dakota because it is coarser grained. The formation has the same drilling characteristics as the Dakota.

Fossils

Carbonized wood and seams of lignite are frequently found throughout the formation. Fossil fern trees called cycadeoids have been found in the Lakota north of Edgemont in the Black Hills region.

Thickness

In Yankton and Bon Homme Counties the Lakota is 100 to 109 feet, and in Turner County it is 75 feet.

The following thicknesses of the Lakota were encountered in the following wells.

Location	Thickness
Charles Mix County	
Sec. 11, T. 99 N., R. 70 W. - - - - - -	50 ft.*
Sec. 7, T. 96 N., R. 64 W.- - - - - - -	230 ft.
Turner County	
Viborg City Well- - - - - - - - - - - - -	75 ft.
Bon Homme County	
Scotland City Well- - - - - - - - - - - -	100 ft.
Tyndall City Well - - - - - - - - - - - -	75 ft.*
Yankton County	
C., M., St. Paul and P. RR. - - - - - -	80 ft.*

Figures followed by an asterisk do not represent a complete thickness of the Lakota.

PALEOZOIC SERIES

Character

The Paleozoic series consist of a group of limestones, shales and sandstones ranging from Ordovician to Cambrian in age. The section contains the following division.

> Paleozoic limestone - probably Ordovician in age
> Decorah-Platteville shale - mid-Ordovician
> St. Peter sandstone - base of middle Ordovician
> Upper-Cambrian - grading from dolomite to glauconitic sand

The following section is a description of the boring at Ponca, Nebraska.[6a]

Hard limestone, variegated colors containing fragments of fossils resembling Macrocheilus near top - 460-500 ft.

White limestone, argillaceous above, brecciated below - - - - - - - - - - - - - - - 515-560 ft.

Gray limestone, very compact, containing part of large trilobite - - - - - - - - - - - - - 560-660 ft.

Compact limestone, with nodules of flint - - 660-698 ft.

These Paleozoic rocks were also encountered in an oil test at Jefferson logged by C. L. Baker.[4]

Succession of Paleozoic Beds
Measured in the La Fleur Oil Test at Jefferson
Sec. 18, T. 90 N., R. 48 W., Union County, S. Dak.

Paleozoic limestone and dolomite with various colors - - - - - - - - - - - - - - - - - - - 390-666 ft.

Decorah-Platteville (mid-Ordovician) shale, grey green, bentonitic, silty, with rhombic magnesian limestone- - - - - - - - - - - - 666-765 ft.

St. Peter Sandstone, all size grains, etched, round to subround - - - - - - - - - - - - - - - 765-825 ft.

Upper Cambrian grading from dolomite to sand with glauconite particles - - - - - - - - - - 825-1027 ft.

Distribution

The Paleozoic series underlies the southeastern corner of the area. Little information has been received in regard to the extent of the Paleozoic section. Two tests at Elk Point and Jefferson indicate the Paleozoic strata extends further north to Canton and as far west as Yankton. This series represents the shoreline of the Paleozoic seas on the edge of the Forest City Basin.

Distinguishing and Drilling Characteristics

The Paleozoic series consists of an alternation of limestone, shale and sandstone. The Paleozoic limestone is very hard and would be harder to drill than the Greenhorn limestone. The Decorah-Platteville shale is bentonitic and probably caves easily. The St. Peter Sandstone is comparable to the Dakota and Lakota for drilling purposes. The upper Cambrian grading from dolomite to sand is also hard rock and, therefore, difficult to drill.

Fossils

A trilobite was found in the limestone taken from the Ponca City boring.

Thickness

In 1898 a deep boring made at Ponca, Nebraska, passed through 238 feet of Paleozoic strata; the well at Elk Point was drilled 15 feet into Paleozoic limestone, and 637 feet of the section was encountered at Jefferson.

PRE-CAMBRIAN SECTION

The pre-Cambrian section, so far as known, consists of pink quartzite called the Sioux Quartzite Formation. Another type of pre-Cambrian rock is white granite which has been encountered in the Jefferson Oil Test.

Sioux Quartzite Formation

Character

The Sioux quartzite is composed of fine, well sorted angular pink quartz grains that are tightly cemented. The rock has a characteristic greasy luster due to the fact that it breaks through the quartz grains instead of around them. This quality of breaking identifies the rock as a quartzite and is a result of the compact cementation of quartz by silica. Although the greater part of the Sioux formation consists of fine-grained quartzite, a number of outcrops show seams and beds of coarse-grained quartzite.[3]

Distribution

The Sioux quartzite forms a subsurface ridge that outcrops near Sioux Falls and extends west of Pierre for some distance. The known exposures that occur in this area are located in northern Turner and Lincoln Counties. The quartzite is exposed in a number of small patches along the East Fork of the Vermillion River. It is also exposed in the northeastern corner of Lincoln County along the Big Sioux River.

Distinguishing and Drilling Characteristics

The quartzite is a very hard formation which is too difficult to drill with the Jetting Machine and the Rotary Rig. The best method of drilling the quartzite is to use a heavy cable tool rig so that the formation can be smashed. Jetting tools will not break the quartzite and rotary tools wear out in a very short time trying to grind it.

Fossils and Age

The age of the Sioux quartzite cannot be determined directly because no fossils have been found in the formation, and the relationship with other formations is obscured by glacial debris. A well in Stanley County encountered the Sioux quartzite directly under the St. Peter sandstone, which is lower middle Ordovician. It is, therefore, older than Ordovician; no other direct evidence is known in South Dakota.

On indirect evidence, the formation is probably pre-Cambrian in age. On the basis of lithology, absence of fossils and gentle structures, the formation has been correlated by some geologists with the Baraboo quartzite in Wisconsin, which is overlain directly and unconformably by upper Cambrian sediments.[3]

Thickness

The thickness of the formation is indeterminable with no known boring going through it. In Charles Mix County, near Wagner, 3787 feet was drilled into the quartzite. In Hutchinson County near Parkston, 1526 feet was drilled into the quartzite.

Pre-Cambrian Granite

Character

The pre-Cambrian granite is composed mainly of quartz, pink feldspar, chlorite and biotite fragments. The granite is defined as a rock that consists predominantly of quartz with smaller percentages of the other constituents.

Distribution

The granite is known to underly the Paleozoic sediments around Jefferson; and the Mesozoic strata around Canton. It has not been proved that granite underlies the Sioux quartzite, but under the assumption that granite is the basement rock, the quartzite probably overlies the granite.

Distinguishing and Drilling Characteristics

Granite is a hard formation and presents the same problems as the Sioux quartzite for drilling with the Jetting Machine and the Rotary Rig.

Thickness

Granite, which forms the crust of continental areas, has no known thickness. It is commonly called the "suitcase formation" by many well drillers because at that horizon all operations cease.

STRUCTURAL CONDITIONS IN SOUTHEASTERN SOUTH DAKOTA

Introduction

In the area covered by this report, gentle folds and flexures are the principle features of the strata. The data obtained was taken from elevations on the surface of the Dakota and plotted as the structure contour map which accompanies this report. The sea level elevations on the Dakota were determined from water well logs by subtracting the depth to the Dakota from surface altitudes of the well curbs.

Sioux Quartzite Ridge

The Sioux quartzite rises abruptly in an escarpment up to 1000 feet in height above a lowland of metamorphic and intrusive rocks to the north. This scarp runs eastward across the state from some point south of Pierre. The quartzite outcrops at the surface near Parker along the Vermillion River and in the northeastern corner of Lincoln County along the Big Sioux River. The quartzite has an irregular surface that slopes gently to the southwest.

Overlaps and Unconformities

During the time of deposition, stratigraphic overlaps were formed near the shore line of the arch.

In the northern part of Hutchinson, Turner and Lincoln Counties, formations of the Cretaceous overlap against the quartzite; this is illustrated in the diagram below.

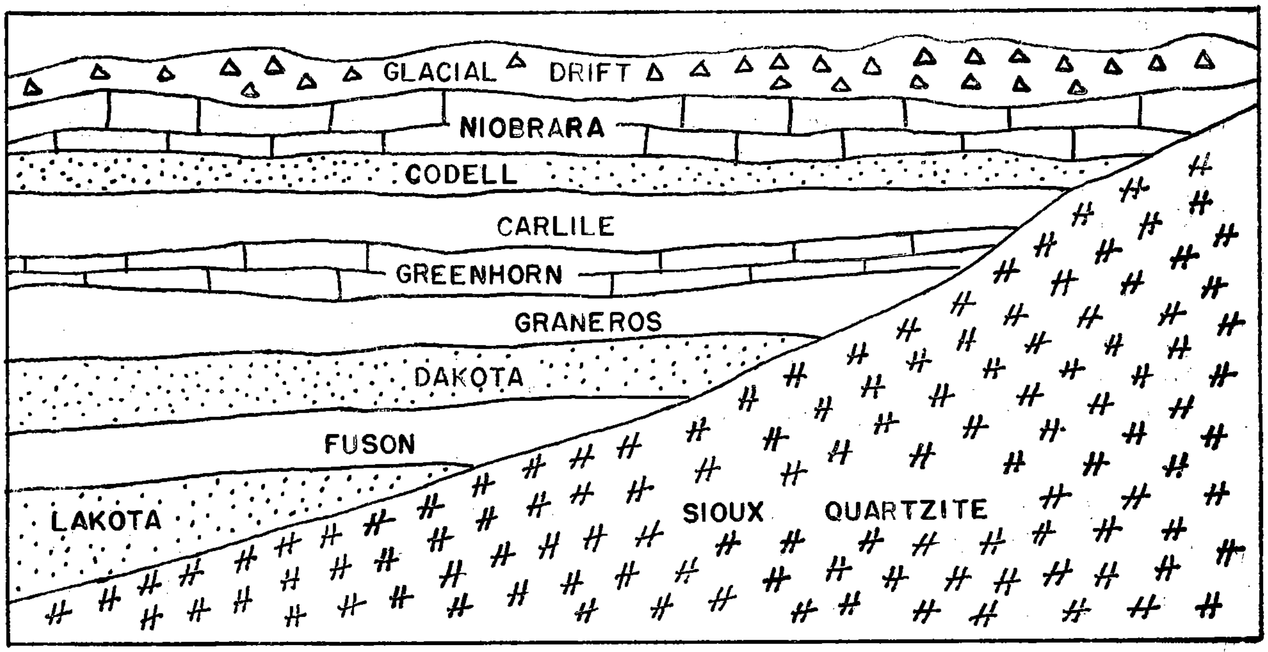


Diagram 1

In the southeastern corner of the area, the Paleozoic group lies unconformably under the Cretaceous series. The information collected from the Jefferson, Ponca and Elk Point tests indicates that the Paleozoic series pinches out to the west between Elk Point, Canton and somewhere in the vicinity of Yankton.

Regional Dips

Two regional dips occur in the area under consideration. In the western part, the Dakota slopes southwest 5 feet per mile from the Sioux quartzite arch to the Missouri River. In the southeastern corner, the Dakota slopes northwest 5 feet to the mile from the mouth of the Bix Sioux River to Viborg. The slope in the southeastern corner is bounded by a trough extending from Yankton to northwest of Viborg and a syncline around Canton in Lincoln County.

Minor Flexures

Although the structure map shows anticlines and synclines, they are extremely gentle, suggesting compaction and settling over an irregular pre-Cambrian surface.

Near Lake Andes, a low fold striking northwest dips 20 feet per mile to the southwest and 5 feet per mile to the northeast. The flexure is approximately 27 miles long and 13 miles wide.

In Douglas County a broad trough separates the regional dip in northern Hutchinson and Turner Counties from the slope extending from Charles Mix to Yankton Counties. The trough forms a crescentic shape 48 miles in length and 12 miles wide.

A long, broad-nosed anticline strikes to the northwest in Hutchinson, Turner, Yankton and Bon Homme Counties. This fold, which is 45 miles long and 16 miles wide, is very gentle with a slope of 3 feet to the mile.

The syncline in Lincoln County plunges to the northeast with the axis passing near Canton. The length of the trough cannot be determined because of insufficient information in Iowa. The width is approximately 17 miles.

Faulting

There may be some faulting in Charles Mix County and Bon Homme County along the Missouri River. This is suggested by warm springs that occur in various places along the Missouri. An analysis of water from these springs shows similarity to water coming from the Dakota. An island with warm springs which was mapped by the Army Engineers in 1889 is located in T. 100 N., R. 71 W. in Charles Mix County. Descriptions and analyses of other warm springs submitted by John Trantina in 1946 are illustrated in Table 3.

Methods of Determining the Static Water Levels in Observation Wells

The pressure head above ground surface in flowing wells was determined by measuring the shut in pressure with a pressure gauge. The pressure gauge connected to a pitot tube is calibrated to measure the pressure in pounds per square inch. The pitot tube is a small tube which is bent at an angle of 90° near the lower end. When the tube is inserted in a pipe line under pressure, the water will rise a distance equal to both pressure and velocity head at the point where the tube is inserted.

Pressure head in a well is expressed as the height in feet of a column of water that can be supported by hydrostatic pressure. It has been proved mathematically that the hydrostatic head is equal to 1 lb./sq. in. X 2.3 ft. For example, a flowing artesian well that measures 8 lbs./sq. in. pressure will support a column of water 18.4 ft. above the ground level. Another way of measuring the hydrostatic head is to connect a hose to the outlet pipe and raise the open end until the water just ceases to flow. The hydrostatic level is obtained by measuring the vertical distance from the end of the hose to the ground.

A standard gallon measure and watch was used to obtain the rate of flow. In some cases where the flow was too great a formula had to be used to calculate the rate of flow.

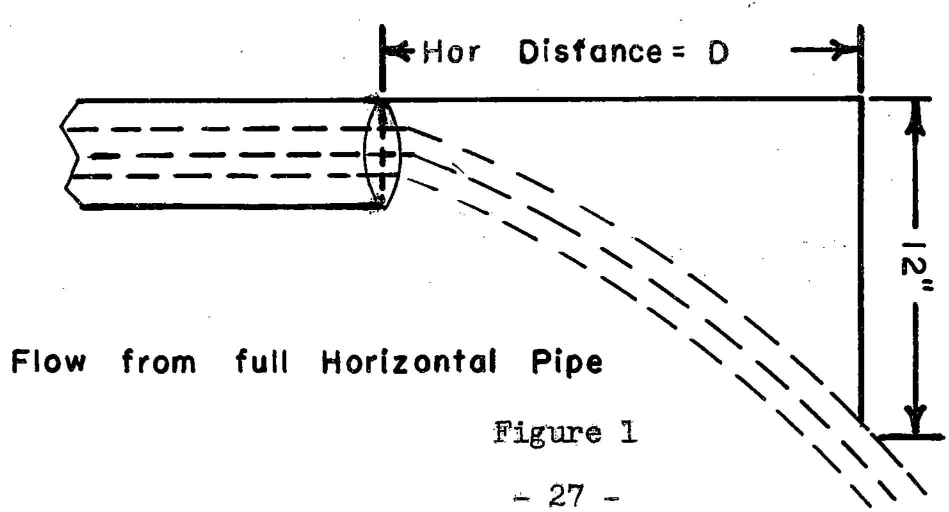


Figure 1

Example: Horizontal Distance = 24"

Diameter of Pipe = 6"

Area of Pipe = 9 X 3.1416 = 28.9 sq. in.

Q = 1.015 X 28.9 X 24 = 696 gal./min.

An altitude above sea level was taken on each well checked in order to study the relation of the static water level in the wells throughout the area. A Paulin Altimeter was used to determine the altitude on each well. The Altimeter is an instrument graduated in feet which depends upon the variation of air pressure with altitude for its operation. The Altimeter is so arranged that the force of air pressure required to bring the disks of the evacuated boxes back to their normal position is exactly recorded when the tendency pointer is brought to its zero position. The Altimeter was checked with known altitudes within short intervals to allow for sudden changes in pressure.

Draw-down

"In any artesian well that is yielding water, whether by pumping or by discharge through artesian pressure, there is invariably a draw-down, or a reduction in pressure of the water in the well. As soon as a well ceases to yield water there is a decrease in the amount of draw-down and an equivalent increase in the pressure is very rapid at first and then continues at a gradually diminishing rate until the normal static pressure of the water is reached. In any well that discharges by artesian pressure, this increase in pressure can be measured by means of a pressure gauge. The length of time required for complete recovery of the pressure will vary according to the permeability of the aquifier and the length of time the well has been yielding water. In some flowing wells the static pressure appears to be reached almost immediately after the well is closed; in others it may require several hours or days. Repeated measurements made in flowing wells after the flow has been shut off indicate that in wells drawing water from the Dakota sandstone recovery is relatively rapid."

Atmospheric Pressure

The difference in pressure and water level can be seen due to atmospheric pressure. A noted change in water level occurs during winter and summer. During winter months the atmospheric pressure is higher causing an increased pressure of the flowing wells. In the summer, the atmospheric pressure is lower causing a decreased pressure of flowing wells.

General Ground-Water Conditions

In southeastern South Dakota there are two main artesian aquifiers. In the order of their depth, they are the Dakota and Lakota sandstones. These artesian aquifiers crop out in wide zones encircling the Black Hills uplift and have a steep outward dip that within short distances carries them far beneath the adjoining plains, where they are buried under a thick body of impermeable shales.[7]

In the vicinity of Sioux City, Iowa, and Dakota City, Nebraska, the Dakota formation outcrops approximately from 1100 to 1150 feet. Examining the structure contour map on top of the Dakota formation, it can be seen that it declines in elevation northwest. An uplift of the Dakota in this area strongly suggests that the Dakota may receive an intake from the Big Sioux and Missouri Rivers, and other streams in the vicinity where it outcrops.

In the outcrop zones of the Black Hills the sandstones receive water, part of which comes from rainfall and part from streams that flow across the outcrops. In general, the direction of movement of this water is outward from the Black Hills eastward across the state. The accompanying maps show the approximate heads of the artesian water in the Dakota and Lakota sandstones in 1951 in the southeastern section of South Dakota. The contour lines show the piezometric surface of the Dakota and Lakota sandstones. The head or piezometric level is the surface to which the water will rise in wells that tap these horizons. The movement of the artesian water is always in the direction that the piezometric surface slopes from higher to lower levels.

Artesian Water in the Codell Sandstone

The Codell receives its head and source of water supply from the Sioux quartzite ridge.

In some instances the water from Codell will flow where the relief of the land is low enough. The greatest amount of flow coming from this horizon occurs along Choteau and Emanuel Creeks in Charles Mix and Bon Homme Counties. In various places along the James River and the Missouri River, the Codell also has enough piezometric head to flow.

The piezometric surface is never very high in the Codell, averaging from one foot to nine feet above the surface in the low areas of the stream valleys.

Artesian Water in the Dakota Sandstone

Differences in Static Level

The importance of measurement on the artesian wells in this state was recognized by Todd[6d] as early as 1898. At that time he recommended in part that "a careful record be kept of the pressure in the various artesian wells." A careful record has not been kept of the artesian pressure, but many of the farmers and well drillers are aware that it has dropped considerably since 1908.

The water enters the Dakota at an altitude of 3,100 to 3,500 feet in the Black Hills and is confined by impermeable shale in its eastward extension to where it outcrops in the southeastern corner of the state near Sioux City.

There is a decrease in altitude to which water will rise 3,200 feet in the Black Hills to about 1,100 feet in the southeastern part of South Dakota. The 2,100-foot loss of head is due to the frictional resistance and other factors that slow up the flow of water.

COMPARISON OF DARTON'S SURVEY IN 1908 TO PRESENT SURVEY IN 1951

DARTON'S SURVEY			PRESENT SURVEY			
LOCATION	DEPTH	HEAD	LOCATION	DEPTH	HEAD	DECLINE SINCE 1908
CHARLES MIX COUNTY T. 94 N., R. 64 W.	651 FT.	273 FT.	CHARLES MIX COUNTY SEC. 5, T. 94 N., R. 64 W.	994 FT.	50.6 FT.	223 FT.
T. 95 N., R. 65 W.	730 FT.	92 FT.	T. 95 N., R. 65 W. PICKSTOWN WELL	854 FT.	25.3 FT.	67 FT.
T. 96 N., R. 65 W.	802 FT.	161 FT.	T. 96 N., R. 65 W.	900 FT.	32.2 FT.	129 FT.
T. 98 N., R. 64 W.	772 FT.	119 FT.	NO REPORTED FLOWS			
T. 98 N., R. 66 W.	950 FT.	69 FT.	" " "			
T. 99 N., R. 69 W.	944 FT.	115 FT.	T. 99 N., R. 69 W. SEC. 32	900 FT.	32.2 FT.	83 FT.
			SEC. 23	900 FT.	92.0 FT.	23 FT.
			SEC. 11	850 FT.	46.0 FT.	69 FT.
T. 100 N., R. 67 W.	875 FT.	200 FT.	T. 100 N., R. 67 W.	750 FT.	9.2 FT.	191 FT.
T. 100 N., R. 70 W.	890 FT.	69 FT.	T. 100 N., R. 70 W.	WILD WELLS -- UNABLE TO DETERMINE HEAD.		
BON HOMME COUNTY T. 92 N., R. 60 W.	885 FT.	69 FT.	BON HOMME COUNTY T. 92 N., R. 60 W.	705 FT.	138 FT.	
T. 93 N., R. 59 W.	646 FT.	103 FT.	T. 93 N., R. 59 W.	---	46 FT.	57 FT.
SPRINGFIELD CITY WELL	620 FT.	197.8 FT.	SPRINGFIELD	620 FT.	92 FT.	105 FT.
MOUTH OF CHOTEAU CREEK	837 FT.	142.6 FT.	MOUTH OF CHOTEAU CREEK SEC. 25, T. 93 N., R. 62 W.	600 FT.	46 FT.	96.6 FT.
YANKTON COUNTY YANKTON CITY WELL	615 FT.	41.4 FT.	YANKTON CITY WELL	615 FT.	23 FT.	18.4 FT.
DOUGLAS COUNTY ARMOUR CITY WELL	757 FT.	126.5 FT.	ARMOUR LAKE WELL	1040 FT.	13.8 FT.	112.7 FT.

TABLE NO. 1

Piezometric Surface

The location and numbers of all artesian wells for which information was collected are shown on the accompanying map and table.

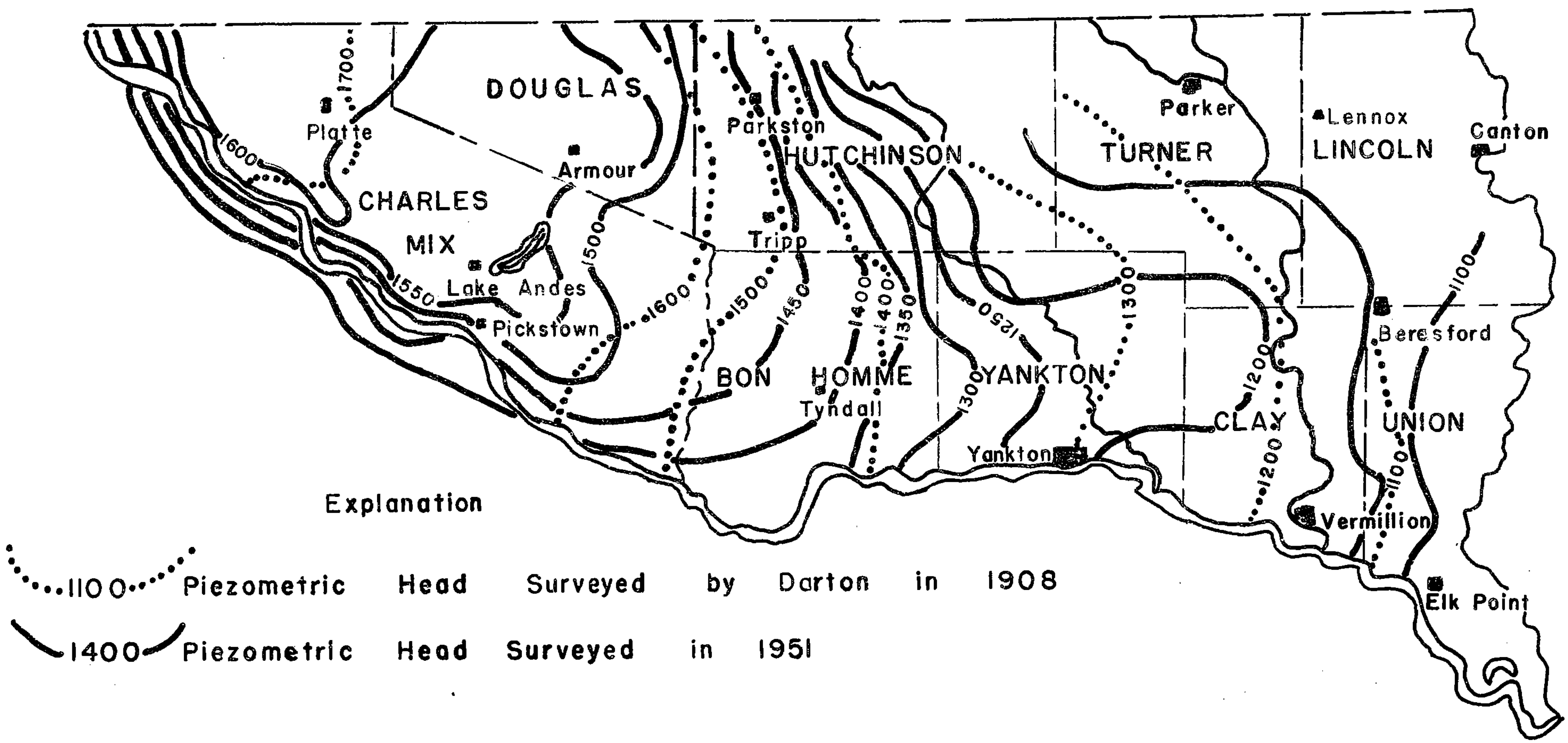
From the contours on the map two prominent slopes may be seen in the piezometric surface. One slopes southwest, 57 feet to the mile, near the Missouri River in Charles Mix County. The reason for such a sharp decline in slope along the river is due to a number of large wells and some leakage, mentioned above. The general gradient of the piezometric surface which is four feet per mile slopes southeast to the James River. The slope steepens across the James River Valley twelve feet per mile and then levels again to two and four feet per mile.

Decline in Head

There has definitely been a decline in the artesian head since the first wells were drilled in the area. It has been greatest near the Missouri River in Charles Mix County. Comparing the present survey to Darton's survey in 1908, the head has decreased as much as 100 feet in the northwestern part of Charles Mix County and 50 feet in the eastern part of the area. The reason for a greater decline in head in Charles Mix County is at least in part because of the larger wells which tap the horizon. The springs in the river mentioned in discussing this structure doubtlessly have helped materially in this decline.

Only two wells located in Springfield and Yankton checked by Darton were checked again by the author in the present survey. A comparison of water levels within an area of six square miles may be seen in Table No. 1.

The largest decline in head occurs where a number of wild wells have been flowing for a number of years. Near Greenwood the water level has dropped approximately 223 feet since 1909, which is the largest fall recorded in the area. The reason for such a big drop is that a well has been flowing tremendously over 50 years in Greenwood in the same horizon. The decline of head at Springfield has been 105 feet, and the city well at Yankton has shown a decline of 18 feet. In



Explanation

1100 Piezometric Head Surveyed by Darton in 1908

1400 Piezometric Head Surveyed in 1951

the vicinity of Yankton several large wells have been flowing for a period of time but have not affected the decline in head to a great extent. This condition is due to different pressures and flows encountered in the Dakota and Lakota formations. Inaccurate and incompetent logs recorded over the past 60 years sometimes do not give accurate information on whether the flows were encountered in the Dakota or Lakota formations.

Artesian Water in the Lakota Sandstone

The Lakota formation is separated from the Dakota by a layer of impermeable shale called the Fuson. A cross-sectional map of the area was made to determine which wells tapped the Dakota and Lakota horizons. All of the known reliable logs of the area were used in the cross-sectional maps to determine the depths and thicknesses of the formations.

In some areas a difference in both pressure and flow are evident in the artesian aquifiers. At present the Lakota has not been tapped as much as the Dakota, so under these conditions the Lakota produces a larger flow and pressure. In compiling his data, Darton did not differentiate between the pressures and flows coming from the two artesian horizons. In this report, an attempt has been made to distinguish the pressures and flows coming from the Dakota and Lakota so that in the future a check can be made on the water level of both horizons.

Temperature of the Artesian Water

In general the temperature of the artesian water from the aquifiers increases northwestward toward the Missouri River. The temperatures range from 55° F. in Yankton County to 90° F. in the northwestern part of Charles Mix County.

A great difference in temperature was noted in northwestern Charles Mix County. Near the river the temperature averaged from 75° F. to 90° F. A short distance from the river the temperatures varied from 60° F. to 65° F.

The highest temperature recorded in the area was 90° F. at a well located in Sec. 16, T. 100 N., R. 71 W., Charles Mix County.

Quality of the Water

During the course of the survey an investigation was made of quality of artesian water.

It was found that the hardness and taste of water varied from one place to another without any particular pattern. This condition is due to the circulation of water in the sandstone. In places where there is good permeability and slope, the water is kept circulating. Where the sandstone is more impermeable and flat lying, the water becomes stagnant because the circulation of water is slowed down considerably.

In the vicinity of Lake Andes the water coming from the Codell is very high in saline matter. An analysis taken of the water showed that it contained 2,057 parts per million of sodium chloride. Water containing 1,000 to 2,500 parts per million of sodium chloride (common salt) has a strong taste but is useable. North of Lake Andes in Charles Mix County and in Douglas County, the Codell produces soft water that is good for farm use.

Around Geddes the Codell water has been mixed with water coming from the Dakota, making it very hard with a strong taste.

The following table shows records of several chemical analyses which have been made from time to time. A comparison of mineral content in parts per million can be made with the standard water analysis Table No. 2.

TABLE NO. 2

WATER ANALYSIS INTERPRETATION

STANDARD WATER

Turbidity	less than 5
Color	less than 6
Odor of H_2S	0
Odor of organisms	0
Lead	less than 1 ppm
Copper	less than 0.2 ppm
Zinc	less than 5 ppm
Magnesium	less than 100 ppm
Iron	less than 0.3 ppm
Sulphate	less than 250 ppm
Chlorides	less than 250 ppm
Total Solids	less than 1,000 ppm

PH VALUES

Above 7 -- water is alkaline
Below 7 -- water is acid

CORROSIVE WATERS

1. Acid waters
2. High CO_2
3. Free $FeSO_4$

	Should not exceed:
Calcium chloride	15 ppm in hard water
Magnesium chloride	10 ppm in soft water
Sodium chloride	
Iron oxide	
Hydrogen sulphide	

TABLE NO. 2 (continued)

SALINITY

Ppm	Nature
400	No taste of salt
500	Slightly brackish taste
1,000-2,500	Strong taste but bearable
3,300	Useable domestically
3,500-5,000	Almost unbearable
5,000 plus	Unfit for human use
6,200	Horses live on it in good condition
7,800	Horses can live on it
9,375	Cattle can live on it
15,625	Sheep can live on it
16,000	Beyond tolerance limit for most grasses

Sea water -- 35,000 ppm

Great Salt Lake --- 250,000 ppm

HARDNESS

CO_3 hardness is "temporary hardness"

SO_4 hardness is "permanent hardness"

Hardness Table (total hardness "soap test")

0 - 15 ppm	extremely soft water
15 - 30 ppm	very soft water
30 - 45 ppm	soft
45 - 90 ppm	moderately soft
90 - 110 ppm	moderately hard
110 - 130 ppm	hard
130 - 170 ppm	very hard
170 - 230 ppm	excessively hard
230 - 500 ppm	too hard for many purposes -- nearly always have to be softened by treatment

Underground Leakage

Defective construction and corrosion are the chief causes of underground leakage of wells. The common failing of wells is due to poor grade of casing and the way it is set to prevent leakage.

Corrosion of the metal casing is the biggest factor resulting in leakage. The amount of corrosive properties found in water varies from one area to another. The casing has lasted over 50 years in some wells. Through the action of high corrosive water, wells 5 to 10 years old were too corroded for further use. Another principal cause of corrosion is an electro-chemical process. Corrosion through electro-chemical process means that charged mineral particles tend to react on the iron. This is especially true where large pressures and flows tend to accelerate this reaction.

The Codell sand is noted for its property of corroding and rusting through the casing at the contact. In some places it also incrusts the screens within a short period of time.

It has been found that copper or brass-lines casing wear much longer against corrosion because these metals are more resistant to chemical actions. Recently, plastic casing has been used for lining wells which should be very suitable against corrosion.

Proper construction of wells can be a prime factor in reducing water loss and pressure decline caused by leaking wells.

Wild Wells

In this area there are a number of "wild wells" which flow unrestricted the year around. For all practical purposes these wells are too large for beneficial use, and some of them are not used at all.

The thickest concentration of wild wells are near the Missouri River. One of the famous wild wells in this area is the Turgeon Well located in Sec. 26, T. 100 N., R. 70 W., in Charles Mix County. It was drilled in 1896 and four or five years later the casing blew out of the well by tremendous pressure. This well has been flowing wild at an estimated 1700 gallons per minute since that time. A big hole has been eroded around the well and the discharge runs into a channel to the Missouri River.

The total waste from these wells, which amounts to a vast amount of water flowing into the Missouri River each year, is not necessary.

If the following act passed by the state Legislature during the session of 1919 was followed, there would be a chance for the pressure of the artesian horizons to build up again. It reads in part as follows:

"Every owner of a well capable of delivering more than twenty-five gallons a minute, shall provide and sustain a valve or valves, capable of controlling the discharge of the well, and only such escape of water shall be allowed as corresponds to the taxes assessed and paid for that year."

Determination of Head at Proposed Well Sites

The altitude to which the water from the Dakota and Lakota sandstones may be expected to rise is shown on the following map by contours of the piezometric surface. This information can be very helpful to the farmer and well driller in the area where the proposed well is to be drilled. The depth at which the water will stand in a non-flowing well may be estimated by subtracting the altitude of the piezometric surface from the altitude of the land surface at the proposed site.

The piezometric map may deviate somewhat from the actual pressure or the level to which the water will rise, especially in localities far from wells on which measurements of head were obtained because interpolation cannot always be exact. It should be remembered that the accompanying map represents the piezometric surface as it was in 1951. Therefore, forecasts made after a few years will have some error until the lowering of pressure through the waters which have been described can be controlled.

TABLE NO. 3

ANALYSES OF SPRINGS AND WELLS ALONG THE MISSOURI RIVER

Submitted by
John Trantina, U. S. Army Engineer Corps

Spring on Island at center line of dam
Coordinates N31818 - E73257
Temperature of water 74° F.
Lab. No. H-9761

	Parts Per Million
Total Dissolved Solids (Residue at 103° C.)	1503
Silica (SiO_2)	15
Iron (Fe)	0.4
Calcium (Ca)	253
Magnesium (Mg)	61
Alkalies as Sodium (Na)	69
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	149
Chloride (Cl)	91
Sulfate (SO_4)	756
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	882

Site "A"
On Kaberna Farm, 5 miles E. of Greenwood, South Dakota, in Sec. 6, T. 93 N., R. 63 W.
Water temperature 70° F. Artesian spring
Lab. No. H-9762

Total Dissolved Solids (Residue at 103° C.)	1480
Silica (SiO_2)	15
Iron (Fe)	0.2
Calcium (Ca)	268
Magnesium (Mg)	51
Alkalies as Sodium (Na)	69
Carbonate (CO_3)	1
Bicarbonate (HCO_3)	191
Chloride (Cl)	89
Sulfate (SO_4)	696
Nitrate (NO_3)	3
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	878

Site "B"
At Rising Hail Indian Colony in Sec. 36, T. 95 N., R. 65 W.
Water temperature 74° F. Artesian well
Lab. No. H-9763

	Parts Per Million
Total Dissolved Solids (Residue at 103° C.)	1775
Silica (SiO_2)	10
Iron (Fe)	0.5
Calcium (Ca)	284
Magnesium (Mg)	63
Alkalies as Sodium (Na)	92
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	188
Chloride (Cl)	106
Sulfate (SO_4)	835
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	967

Site "C"
2200 feet downstream from dam site on right bank of Missouri River. About 300 feet southeast of farm house. Probably in Sec. 17, T. 95 N., R. 65 W. Drilled artesian well.
Water temperature 82° F.
Lab. No. H-9764

Total Dissolved Solids (Residue at 103° C.)	1527
Silica (SiO_2)	15
Iron (Fe)	0.2
Calcium (Ca)	256
Magnesium (Mg)	56
Alkalies as Sodium (Na)	56
Carbonate (CO_3)	3
Bicarbonate (HCO_3)	143
Chloride (Cl)	104
Sulfate (SO_4)	720
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	874

Site "D"
On right bank of Missouri River 5500 feet due south of well at Site "C" and at the head of a coulee. Probably in Sec. 20, T. 95 N., R. 65 W.
Water temperature 82° F. Artesian well
Lab. No. H-9765

	Parts Per Million
Total Dissolved Solids (Residue at 103° C.)	1506
Silica (SiO_2)	16
Iron (Fe)	0.2
Calcium (Ca)	255
Magnesium (Mg)	58
Alkalies as Sodium (Na)	64
Carbonate (CO_3)	8
Bicarbonate (HCO_3)	150
Chloride (Cl)	93
Sulfate (SO_4)	730
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	874

Site "E"
Located 11 miles west and 2½ miles south of Platte, S.D., on the left bank of the Missouri River. About 400 yards south-east of the Turgeon Ranch house.
Water temperature 88° F.
Artesian spring
Lab. No. H-9766

Total Dissolved Solids (Residue at 103° C.)	1672
Silica (SiO_2)	17
Iron (Fe)	0.2
Calcium (Ca)	265
Magnesium (Mg)	63
Alkalies as Sodium (Na)	72
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	172
Chloride (Cl)	127
Sulfate (SO_4)	769
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	919

Site "F"
Located 100 yards northwest of the corner of Sections 25, 26, 35 and 36, in T. 98 N., R. 69 W. Also 8 miles south and 6 miles west of Platte, S. D.
Water temperature 82° F. Artesian well
Lab. No. H-9768

	Parts Per Million
Total Dissolved Solids (Residue at 103° C.)	1554
Silica (SiO_2)	16
Iron (Fe)	0.1
Calcium (Ca)	251
Magnesium (Mg)	59
Alkalies as Sodium (Na)	86
Carbonate (CO_3)	1
Bicarbonate (HCO_3)	122
Chloride (Cl)	103
Sulfate (SO_4)	760
Nitrate (NO_3)	2
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	869

Site "G"
On Willow Island in Missouri River, eight miles south and 7½ miles west of Platte, S. D., in Sec. 34, T. 98 N., R. 69 W.
Water temperature 91° F. Artesian spring
Lab. No. H-9768

Total Dissolved Solids (Residue at 103° C.)	1580
Silica (SiO_2)	15
Iron (Fe)	0.2
Calcium (Ca)	244
Magnesium (Mg)	45
Alkalies as Sodium (Na)	108
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	156
Chloride (Cl)	107
Sulfate (SO_4)	758
Nitrate (NO_3)	0
Total Hardness Expressed as Calcium Carbonate ($CaCO_3$)	793

TABLE NO. 4

ANALYSES OF WATER FROM WELLS IN THE SOUTHEASTERN PART OF S. DAK.
from State Geological Survey Files

County - Union
Location - Beresford
Local Name - City Water, Beresford
Owner - City of Beresford
Date - 1/27/26

	Parts Per Million
Sodium Chloride	132.8
Sodium Sulfate	284.2
Magnesium Sulfate	149.5
Calcium Sulfate	72.6
Iron & Aluminum Oxides	3.6
Silica	9.2
Organic & Volatile Matter	19.1
Calcium Carbonate	243.0
Total Solids	914.0
Total Hardness	420.7

County - Union
Location - Elk Point, S. Dak.
Local Name - City Water, Elk Point
Owner - City of Elk Point
Date - 11/29/25
Depth - 375 feet

Sodium Chloride	78.9
Sodium Sulfate	224.8
Magnesium Sulfate	197.0
Calcium Sulfate	507.1
Calcium Carbonate	196.6
Iron & Aluminum Oxides	4.5
Silica	9.5
Organic & Volatile Matter	49.3
Total Solids	1267.7
Total Hardness	730.0

County - Clay
Location - Vermillion, S. Dak.
Local Name - University Water
Owner - University of South Dakota
Date - 10/22/25
Depth - 440 feet

	Parts Per Million
Sodium Chloride	80.6
Sodium Sulfate	146.0
Magnesium Sulfate	227.8
Calcium Sulfate	606.6
Calcium Carbonate	145.9
Iron & Aluminum Oxides	4.6
Silica	8.0
Organic & Volatile Matter	55.3
Total Solids	1274.8

County - Clay
Location - Wakonda, S. Dak.
Local Name - City Water - Wakonda
Owner - City of Wakonda
Date - 12-31/25
Depth - 550 feet

Sodium Chloride	284.2
Sodium Sulfate	163.4
Magnesium Sulfate	354.6
Calcium Sulfate	899.0
Calcium Carbonate	183.6
Iron & Aluminum Oxides	7.6
Silica	5.8
Organic & Volatile Matter	78.8
Total Solids	1941.0

County - Charles Mix
Local Name - Wagner #2
Date - 3/28/38

Total Solids	1597.0
Silica	7.5
Sulfate (SO)	851.0
Chloride (Cl)	110.0
Calcium (Ca)	289.0
Magnesium (Mg)	56.5
Alkalinity as $CaCO_3$	
Phenolphthalein	None
Methyl Orange	112.0
Hardness as $CaCO_3$	955.0
Iron in Solution	0.1
Manganese	0.2
Fluoride	2.8

County - Charles Mix
Location - Lake Andes, S. Dak.
Local Name - Rest Haven Artesian Well
Date - 3/28/38

	Parts Per Million
Total Solids	1785.0
Silica	9.0
Sulphate (SO_4)	949.0
Chloride (Cl)	148.0
Calcium (Ca)	320.5
Magnesium (Mg)	63.0
Alkalinity as $CaCO_3$	
Phenolphthalein	None
Methyl Orange	122.0
Hardness as $CaCO_3$	1060.0
Iron in Solution	0.1
Manganese	0.2
Fluoride	2.8

County - Bon Homme
Location - Tyndall, S. Dak.
Local Name - Artesian Well

NaCl	243.8
Na_2SO_4	100.2
Na_2CO_3	.....
$MgSO_4$	403.6
$MgCO_3$	.....
$CaSO_4$	1119.9
$CaCO_3$	90.5
SO_4	1192.0
Fl	3.6
Total Solids	2252.0

County - Turner
Location - Viborg, S. Dak.
Local Name - City of Viborg
Date - 10/21/50

Total Solids	1256.0
Chloride (Cl)	91.0
Sulfate (SO_4)	605.0
Silica	11.0
Calcium (Ca)	167.0
Magnesium (Mg)	41.0
Sodium Alkalinity as Na_2O	218.0
Carbonate (CO_3)	None

	Parts Per Million
Bicarbonate (HCO_3)	112.0
Iron (Fe)	1.3
Nitrate (NO_3)	1.2
Total hardness as $CaCO_3$	585.0

County - Lincoln
Location - Canton, S. Dak.
Local Name - City Water, Canton
Owner - City of Canton
Date - 1/10/26
Depth - 315 feet

Sodium Chloride	27.4
Sodium Sulfate	229.2
Sodium Carbonate	271.9
Magnesium Carbonate	45.2
Calcium Carbonate	76.2
Iron & Aluminum Oxides	1.7
Silica	10.6
Organic & Volatile Matter	3.4
Total Solids	665.6
Total Hardness	129.8

County - Lincoln
Location - Canton, S. Dak.
Owner - City of Canton
Date - 10/21/50

Total Solids	705
Chloride (Cl)	33
Sulfate (SO_4)	241
Silica	9
Calcium (Ca)	86
Magnesium (Mg)	30
Sodium Alkalinity as NA_2O	168
Carbonate (CO_3)	None
Bicarbonate (HCO_3)	187
Iron (Fe)	0.8
Nitrate (NO_3)	0.7
Total Hardness as $CaCO_3$	338

County - Lincoln
Location - Worthing, S. Dak.
Owner -
Date - 10/21/50
Depth - 464 feet

	Parts Per Million
Total Solids	465.0
Chloride (Cl)	6.0
Sulfate (SO_4)	84.0
Silica	6.0
Calcium (Ca)	53.0
Magnesium (Mg)	19.0
Sodium Alkalinity as Na_2O	93.0
Carbonate (CO_3)	None
Bicarbonate (HCO_3)	157.0
Iron (Fe)	0.3
Nitrate (NO_3)	0.6
Total Hardness as $CaCO_3$	210.0

TABLE NO. 5

ARTESIAN WELL DATA

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
	Charles Mix County						
1	James Blaha NW¼, Sec. 16, T. 94 N, R. 62 W.		1000' App.	1548'		1528'	
2	Dave Ochinger SW¼, Sec. 34, T. 94 N, R. 62 W.	1926	1160'	1626'		1606'	
3	Tom Kocer NW¼, Sec. 3, T. 94 N, R. 63 W.			1573'		1483'	
4	Ben Berge NW¼, Sec. 27, T. 94 N, R. 63 W.	1906	800'	1455'		1401'	
5	Marty Mission NE¼, Sec. 5, T. 94 N, R. 64 W.	1940	994'	1466'	22 lbs.	1517'	4
6	Ben Owing NW¼, Sec. 10, T. 94 N, R. 64 W.	1932	712'	1429'	10 lbs.	1452'	7
7	Lionel Robertson NE¼, Sec. 21, T. 94 N, R. 64 W.	1934		1374'	4 lbs. App.	1383'	3
8	Lionel Robertson NW¼, Sec. 22, T. 94 N, R. 64 W.	1925		1528'		1510'	
9	Greenwood City Well SW¼, Sec. 26, T. 94 N, R. 64 W.	1946	796'	1391'			
10	Wagner City NW¼, Sec. 4, T. 95 N, R. 63 W.	1900	800'	1450'			

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
11	Duncanson SE$\frac{1}{4}$, Sec. 9, T. 95 N, R. 63 W.	1900	750'	1484'			3
12	Louis Wampal SW$\frac{1}{4}$, Sec. 15, T. 95 N, R. 63 W.	1927	898'	1494'	3 lbs. app.	1501'	1
13	George Kuhlman SW$\frac{1}{4}$, Sec. 15, T. 95 N, R. 64 W.	1914	1250'	1700'		1575'	
14	Frank Rada NW$\frac{1}{4}$, Sec. 21, T. 95 N, R. 64 W.	1896	980'	1641'		1611'	
15	Gene McFarland SW$\frac{1}{4}$, Sec. 24, T. 95 N, R. 64 W.	1923	980'	1636'		1546'	
16	Fred Eggers SW$\frac{1}{4}$, Sec. 25, T. 95 N, R. 64 W.	1931	835'	1507'	4 lbs.	1516'	1$\frac{1}{2}$
17	Pickstown Well SE$\frac{1}{4}$, Sec. 4, T. 95 N, R. 65 W.		854'	1489'	11 lbs.	1514'	60
18	John Pesicka NE$\frac{1}{4}$, Sec. 11, T. 95 N, R. 65 W.	1925	1099'	1780'		1440'	
19	V. E. Kreeger SW$\frac{1}{4}$, Sec. 24, T. 95 N, R. 65 W.	1944	780'	1443'	App. 30 lbs.	1512'	30
20	Harry Strehlo NE$\frac{1}{4}$, Sec. 4, T. 95 N, R. 66 W.	1911	500'	1340'	App. 3 lbs.	1347'	2

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
21	Podzimek NE$\frac{1}{4}$, Sec. 30, T. 96 N, R. 62 W.			1496'			
22	State Fish Hatchery SE$\frac{1}{4}$, Sec. 5, T. 96 N, R. 64 W.	1948		1310'			1100
23	State Fish Hatchery SE$\frac{1}{4}$, Sec. 7, T. 96 N, R. 64 W.	1946	960'	1454'			500
24	Lake Andes City Well NW$\frac{1}{4}$, Sec. 4, T. 96 N, R. 65 W.	1945	900'	1490'			
25	Jim Soulek NW$\frac{1}{4}$, Sec. 18, T. 96 N , R. 65 W.	1947	900'	1508'	14 lbs.	1540'	4
26	Louis Pesicka NW$\frac{1}{4}$, Sec. 27, T. 96 N, R. 65 W.		1100'	1821'			
27	George Svatos SW$\frac{1}{4}$, Sec. 29, T. 96 N, R. 66 W.	1921	800'	1453'	11 lbs.	1478'	2
28	George Svatos NE$\frac{1}{4}$, Sec. 30, T. 96 N, R. 65 W.	1945	631'	1384'	12 lbs. app.	1412'	15
29	Lewis Kubal SW$\frac{1}{4}$, Sec. 27, T. 96 N, R. 66 W.	1937	1000'	1726'		1576'	
30	Louis and Charley Paulis SW$\frac{1}{4}$, Sec. 29, T. 96 N, R. 66 W.	1913	800'	1520'	20 lbs.	1566'	6
31	Herbert Strehlow NW$\frac{1}{4}$, Sec. 31, T. 96 N, R. 66 W.	1921	700'	1442'	20 lbs.	1488'	2
32	Asher Young SW$\frac{1}{4}$, Sec. 10, T. 96 N, R. 67 W.	1925	564'	1344'	1 lb.	1346'	$\frac{1}{2}$

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
33	Exon Estate NE$\frac{1}{4}$, Sec. 1, T. 96 N, R. 68 W.	1921	640'	1330'	12 lbs. app.	1358'	3
34	Paul Witchman SW$\frac{1}{4}$, Sec. 34, T. 97 N, R. 63 W.	1926	650'	1410'	5 lbs.	1422'	3
35	Floyd Strehlow NW$\frac{1}{4}$, Sec. 31, T. 97 N, R. 66 W.	1913		1500'	5 lbs.	1512'	4
36	Charlie Carda SW$\frac{1}{4}$, Sec. 6, T. 97 N, R. 67 W.			1588'	2 lbs.	1593'	1$\frac{1}{2}$
37	Sipp, Emil SE$\frac{1}{4}$, Sec. 9, T. 97 N, R. 67 W.	1930	1015'	1767'		1592	
38	Keegal, John NW$\frac{1}{4}$, Sec. 19, T. 97 N, R. 67 W.	1949	855'	1565'	20 lbs.	1611'	20
39	Teply, John SW$\frac{1}{4}$, Sec. 27, T. 97 N, R. 67 W.	1925	888'?	1645'	14 lbs.	1677'	12
40	DeHaan Bros. NE$\frac{1}{4}$, Sec. 36, T. 97 N, R. 68 W.	1931	?	1430'	20 lbs.	1476'	15
41	Dagber, Ervin SW$\frac{1}{4}$, Sec. 33, T. 98 N, R. 65 W.	1926	980'	1663'		1633'	
42	Ludens NE$\frac{1}{4}$, Sec. 20, T. 98 N, R. 67 W.	1947	1000'	1704'		1584'	
43	Winia, Clarence SE$\frac{1}{4}$, Sec. 10, T. 98 N, R. 68 W.	1949	750'	1404'	15 lbs. app.	1439'	37

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
44	Holter, Kenneth NE$\frac{1}{4}$, Sec. 19, T. 98 N, R. 68 W.	1948	1100'	1786'		1606'	
45	Oldham NW$\frac{1}{4}$, Sec. 17, T. 98 N, R. 69 W.	1894	500'?	1370'			200 App.
46	Jones, William F. SE$\frac{1}{4}$, Sec. 31, T. 98 N, R. 68 W.	1904	640'	1380'	8 lbs. App.	1398'	3
47	Arsham, Harold NW$\frac{1}{4}$, Sec. 35, T. 98 N, R. 69 W.		960'	1438'	8 lbs.	1456'	5
48	Dirteen NW$\frac{1}{4}$, Sec. 10, T. 99 N, R. 67 W.	1924	825'	1634'	Pumped	1609'	
49	Morken, Oscar SE$\frac{1}{4}$, Sec. 23, T. 99 N, R. 67 W.	1906	850'	1658'		1568'	
50	Platte City Well NE$\frac{1}{4}$, Sec. 13, T. 99 N, R. 68 W.	1936	838'	1608'		1590'	
51	Dyke, Harm SE$\frac{1}{4}$, Sec. 19, T. 99 N, R. 68 W.	1950	636'?	1519'	10 lbs.	1542'	20
52	Visscher, William SW$\frac{1}{4}$, Sec. 31, T. 99 N, R. 68 W.	1929	950'	1642'		1500'	
53	Beltman, Hubert NW$\frac{1}{4}$, Sec. 35, T. 99 N, R. 68 W.			1582'	1 lb.	1584'	1/3
54	Samuelson, O. W. SE$\frac{1}{4}$, Sec. 2, T. 99 N, R. 69 W.	1948	962'	1686'		1562'	

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
55	Guikeisen, Nick SW$\frac{1}{4}$, Sec. 8, T. 99 N, R. 69 W.	1928	850'	1654'		1614'	
56	Guikeisen, Nick NW$\frac{1}{4}$, Sec. 11, T. 99 N, R. 69 W.	1949	850'	1500'	20 lbs.	1546'	18
57	Fish, George SW$\frac{1}{4}$, Sec. 23, T. 99 N, R. 69 W.	1912	900'	1550'	40 lbs.	1642'	5
58	Paulson, Jonas SE$\frac{1}{4}$, Sec. 30, T. 99 N, R. 69 W.	1918	1000'	1654'		1618'	
59	Paulson, Leonard NW$\frac{1}{4}$, Sec. 32, T. 99 N, R. 69 W.	1944	900'	1544'	14 lbs.	1576'	3
60	Fife, L. A. NE$\frac{1}{4}$, Sec. 5, T. 99 N, R. 70 W.	1947	900'	1520'	15 lbs.	1555'	14
61	Garrett, Bolties NW$\frac{1}{4}$, Sec. 13, T. 100 N, R. 67 W.	1948	941'	1620'		1585'	
62	Sly, Rex NE$\frac{1}{4}$, Sec. 21, T. 100 N, R. 67 W.	1926	715'?	1631'	App. 4 lbs.	1640'	5
63	Knoll, Nick SE$\frac{1}{4}$, Sec. 30, T. 100 N, R. 67 W.	1921	650'	1550'	App. 1 lb.	1552'	1 gal. per $2\frac{1}{2}$ min.
64	Kuipers, A. NW$\frac{1}{4}$, Sec. 13, T. 100 N, R. 68 W.	1903	735'	1504'	App. 2 lbs.	1509'	5
65	Gray, Wilbur NW$\frac{1}{4}$, Sec. 19, T. 100 N, R. 68 W.	1921	920'	1622'	Pumped	1618'	

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
66	Hoffman, Will NE$\frac{1}{4}$, Sec. 28, T. 100 N, R. 68 W.	1949	857'	1588'	4 lbs.	1597'	4
67	Cedar Grove Hereford Ranch SW$\frac{1}{4}$, Sec. 20, T. 100 N, R. 69 W.	1946	1049'	1725'		1580'	
68	Lucas, Fred SE$\frac{1}{4}$, Sec. 12, T. 100 N, R. 70 W.	1943	912'	1712'		1661'	
69	Turgeon, Dolar NE$\frac{1}{4}$, Sec. 18, T. 100 N, R. 71 W.	1927	1000'	1758'		1506'	
70	Turgeon, Dolar SW$\frac{1}{4}$, Sec. 26, T. 100 N, R. 71 W.	1896	688'	1368'			Estimated 1700
71	Olson, Pete SW$\frac{1}{4}$, Sec. 16, T. 100 N, R. 71 W.	1946	625'?	1416'	30 lbs.	1485'	110
72	Olson, Pete NW$\frac{1}{4}$, Sec. 28, T. 100 N, R. 71 W.	1947	900' ?	1554'	25 lbs.	1611'	15
73	Olson, Pete NW$\frac{1}{4}$, Sec. 33, T. 100 N, R. 71 W.	1946	500' ?	1324'	30 lbs.	1393'	30
	Bon Homme County						
74	Kooley, Ralph NW$\frac{1}{4}$, Sec. 3, T. 92 N, R. 60 W.	1936	705'	1268'	60 lbs.	1406'	120
75	Jacobs, W. F. NE$\frac{1}{4}$, Sec. 17, T. 92 N, R. 60 W.	1935	475'	1229'	30 lbs.	1298'	20

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
76	Peska, Peter SW¼, Sec. 4, T. 93 N, R. 58 W.	1948	750'	1321'	8 lbs.	1339'	20
77	Bon Homme Colony SW¼, Sec. 8, T. 93 N, R. 58 W.	1941	580'	1265'	20 lbs.	1311'	30
78	Bon Homme Colony NW¼, Sec. 16, T. 93 N, R. 58 W.	1931	500'	1271'	10 lbs.	1294'	12
79	Bon Homme Colony NE¼, Sec. 21, T. 93 N, R. 58 W.	1948	400'	1261'	6 lbs.	1277'	10
80	Broz Bros. NE¼, Sec. 6, T. 93 N, R. 59 W.			1335'	20 lbs.	1381'	20
81	McCann, Gordon SE¼, Sec. 10, T. 93 N, R. 59 W.	1911	720'	1253'	4 lbs. app.	1262'	3
82	Colman, Roy NE¼, Sec. 17, T. 93 N, R. 59 W.	1946	630'	1350'	3 lbs.	1357'	5
83	Springfield City SE¼, Sec. 23, T. 93 N, R. 60 W.	1946	650'	1294'	40 lbs.	1386'	400
84	Springfield City NE¼, Sec. 23, T. 93 N, R. 60 W.	1943	650'	1292'	40 lbs.	1384'	400
85	Springfield City [illegible], Sec. 26, T. 93 N, R. 60 W.	1911	650'	1287'	40 lbs.	1379'	400
86	Hutchinson, W. R. [illegible], Sec. 34, T. 93 N, R. 61 W.	1896	1030'	1512'		1482'	

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
87	Van Aspern, Sam NW¼, Sec. 23, T. 93 N, R. 62 W.	1947	500'	1236'	20 lbs.	1282'	20
88	Tyndall City Well SE¼, Sec. 6, T. 94 N, R. 59 W.	1949	733'	1400'			140
89	Humpal, Gene NE¼, Sec. 14, T. 94 N, R. 59 W.	1938	850'	1350'	6 lbs.	1364'	3
90	Felton, Fred SE¼, Sec. 18, T. 94 N, R. 59 W.	1896		1374'	4 lbs. app.		1½
91	Eggers, M.E. NE¼, Sec. 20, T. 94 N, R. 59 W.	1942	696'	1363'	30 lbs. app.	1432'	45
92	Byrne Farm NE¼, Sec. 12, T. 94 N, R. 60 W.	1912	850'	1433'	3 lbs. app.	1440'	1
93	Brown Ranch SW¼, Sec. 31, T. 94 N, R. 60 W.	1941	750'	1318'	15 lbs. app.	1353'	12
94	Collins, Harold NE¼, Sec. 12, T. 95 N, R. 58 W.	1946	530'	1365'		1315'	
95	Meyer, Dale SW¼, Sec. 1, T. 95 N, R. 61 W.	1903	1100'	1674'		1574'	
96	Whitely, Art SW¼, Sec. 7, T. 95 N, R. 61 W.	1911	800'	1597'		1569'	

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
	CLAY COUNTY						
97	Hubener, Tony SW¼, Sec. 19, T. 92 N, R. 51 W.	1947	385'	1141'	8 lbs.	1159'	5
98	Severson, Clarence SW¼, Sec. 10, T. 92 N, R. 52 W.	1950	400'	1164'	5 lbs.	1175'	4
99	Barton Buel NW¼, Sec. 27, T. 93 N, R. 53 W.	1946	387'	1161'	12 lbs.	1181'	8½
100	Johnson Everett SE¼, Sec. 4, T. 93 N, R. 52 W.	1941	416'	1251'		1212'	
101	Mrs. Ben Johnson NW¼, Sec. 10, T. 93 N, R. 52 W.	1926	425'	1269'		1189'	
102	Rayman, Walt SE¼, Sec. 21, T. 93 N, R. 52 W.	1947	317'	1131'	9½ lbs.	1153'	6
103	Christopherson, Victor NE¼, Sec. 28, T. 93 N, R. 52 W.			1169'	9 lbs.	1189'	5
104	Rayman, Ford NW¼, Sec. 32, T. 93 N, R. 52 W.			1150'	4½ lbs.	1160'	10
105	Petrik, Albert NE¼, Sec. 6, T. 93 N, R. 53 W.	1910	360'	1168'	8 lbs.	1186'	4
106	Rayman, Walt NW¼, Sec. 12, T. 93 N, R. 53 W.	1940	386'	1150'	12 lbs.	1178'	8½

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
107	Miller, Hans SW$\frac{1}{4}$, Sec. 31, T. 93 N, R. 53 W.	1936	500'	1172'	9$\frac{1}{2}$ lbs.	1194'	2
108	Beaty, Don NE$\frac{1}{4}$, Sec. 35, T. 93 N, R. 53 W.			1151'	8 lbs.	1169'	2
109	Mrs. Ed Mart SE$\frac{1}{4}$, Sec. 7, T. 94 N, R. 52 W.	1916	335'	1231'			
110	Peacock, Perry SW$\frac{1}{4}$, Sec. 30, T. 94 N, R. 52 W.	1948	377'	1314'			
111	Johnson, Elmore SE$\frac{1}{4}$, Sec. 33, T. 94 N, R. 52 W.			1233'		1171'	
112	Hansen, Emil SW$\frac{1}{4}$, Sec. 5, T. 95 N, R. 51 W.	1901	320'	1297'			
113	Payson, C. W. SW$\frac{1}{4}$, Sec. 18, T. 95 N, R. 51 W.	1895	340'	1254'		1237'	
114	Bixler, Art NW$\frac{1}{4}$, Sec. 30, T. 95 N, R. 51 W.	1951	348'	1289'		?	
115	Norin Bros. SE$\frac{1}{4}$, Sec. 31, T. 95 N, R. 51 W.	1932	460'	1306'		1248'	
	Douglas County						
116	Lang, Art NW$\frac{1}{4}$, Sec. 5, T. 98 N, R. 62 W.	1941	883'	1570'	9 lbs.	1591'	15

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
117	Beir, Walter NW¼, Sec. 29, T. 99 N, R. 62 W.	1945	616'	1580'	1 lb.	1582'	1½
118	Drefs, John NE¼, Sec. 30, T. 98 N, R. 62 W.			1580'	2 lbs.	1585'	2
119	Armour Lake Well SE¼, Sec. 7, T. 98 N, R. 63 W.	1939	1040'	1515'	6 lbs.	1528'	20
120	Drefs, Rosina NE¼, Sec. 14, T. 98 N, R. 63 W.	1928	744'	1570'	5 lbs. app.	1582'	4
121	Willmow, L. L. NW¼, Sec. 24, T. 99 N, R. 63 W.			1560'	6 lbs. app.	1574'	4
122	Veurink, Cerrit H. SW¼, Sec. 10, T. 100 N, R. 66 W.	1911	1000'	1610'	2 lbs. app.	1615'	1½
123	Vanderhuhn, John SW¼, Sec. 19, T. 100 N, R. 66 W.	1921	1100'	1600'	15 lbs. app.	1635'	15
	<u>Hutchinson County</u>						
124	William Rames SE¼, Sec. 11, T. 97 N, R. 58 W.	1936	375'	1216'	16 lbs.	1253'	7
125	John Jackens NE¼, Sec. 10, T. 97 N, R. 58 W.	1946	410'	1208'	70 lbs.	1369'	150 app.
126	Bierman SE¼, Sec. 18, T. 97 N, R. 58 W.			1330'	12 lbs.	1358'	12

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
127	Maxwell Colony NW$\frac{1}{4}$, Sec. 36, T. 97 N, R. 58 W.			1204'	20 lbs.	1250'	30
128	Ray Gall NE$\frac{1}{4}$, Sec. 2, T. 97 N, R. 59 W.	1946	520'	1366'	70 lbs.	1527'	80
129	David Mehlhaff SE$\frac{1}{4}$, Sec. 16, T. 97 N, R. 59 W.	1949	585'	1400'	3 lbs.	1407'	1 1/3
130	Fred Heinsohn NE$\frac{1}{4}$, Sec. 21, T. 97 N, R. 59 W.	1947	530'	1400'	9 lbs.	1421'	12
131	Ed Voll NE$\frac{1}{4}$, Sec. 29, T. 98 N, R. 56 W.	1945	650'	1490'		1148'	
132	Reuben Bertsch SE$\frac{1}{4}$, Sec. 31, T. 98 N, R. 57 W.	1947		1370'	2 lbs. app.	1375'	1
133	John Walker NW$\frac{1}{4}$, Sec. 31, T. 98 N, R. 57 W.		330'	1266'	9 lbs.	1287'	4
134	Reib Brothers SE$\frac{1}{4}$, Sec. 21, T. 98 N, R. 59 W.	1941	395'	1350'	2 lbs. app.	1361'	1
135	Arnett Tiede NW$\frac{1}{4}$, Sec. 7, T. 98 N, R. 60 W.	1919	540'	1487'	12 lbs.	1515'	3
136	August Triewasser NW$\frac{1}{4}$, Sec. 27, T. 98 N, R. 60 W.	1949		1436'	15 lbs.	1450'	4
137	William Wallman SW$\frac{1}{4}$, Sec. 31, T. 99 N, R. 57 W.	1951	190'	1215'	1 lb.	1217'	1

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
138	Walter Juhnke SE¼, Sec. 6, T. 99 N, R. 58 W.	1944	205'	1134'	9 lbs.	1155'	3/4
139	Henry Voege NE¼, Sec. 17, T. 99 N, R. 58 W.	1939	211' ?	1244'	9 lbs.	1265'	2
140	Merlin Keiper SE¼, Sec. 3, T. 99 N, R. 59 W.	1950	169'	1138'	9 lbs.	1159'	6
141	Doc Sterling NW¼, Sec. 18, T. 99 N, R. 59 W.	1950	377'	1242'	7 lbs.	1258'	4
142	Stoener NW¼, Sec. 29, T. 99 N, R. 59 W.	1916	600'	1450'			8
143	Jake Mehlhoff SE¼, Sec. 33, T. 99 N, R. 59 W.	1943	535'	1410'	12 lbs.	1438'	4
144	Harold Tiede SW¼, Sec. 18, T. 99 N, R. 60 W.	1949	516'	1408'	15 lbs.	1443'	6
145	Erwin Matthies NE¼, Sec. 28, T. 99 N, R. 60 W.	1945	505'	1306'	2 lbs.	1311'	3
146	Frank L. Hoffer SW¼, Sec. 35, T. 99 N, R. 60 W.	1926		1440'			2
147	Carl Roth SE¼, Sec. 15, T. 99 N, R. 61 W.	1916	610'	1452'	2 lbs. app.	1457'	4
148	Walter G. Isaak SE¼, Sec. 34, T. 99 N, R. 61 W.	1914	567'	1440'	2 lbs. app.	1445'	2

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
149	Earnest Masturik SE$\frac{1}{4}$, Sec. 7, T. 100 N, R. 61 W.	1935	524'	1470'	3 lbs. app.	1477'	5
150	Frank Bochmer SE$\frac{1}{4}$, Sec. 22, T. 100 N, R. 61 W.		580'	1490'	12 lbs.	1517'	6
151	S. J. Walz SE$\frac{1}{4}$, Sec. 28, T. 100 N, R. 61 W.			1479'	6 lbs.	1493'	3
	Lincoln County						
152	Case Havelaar NE$\frac{1}{4}$, Sec. 18, T. 96 N, R. 48 W.	1951	488'	1428'		1070'	
153	Merlin Nelson SE$\frac{1}{4}$, Sec. 29, T. 96 N, R. 51 W.		350'	1246'		1166'	
154	Ted Ulrikson SE$\frac{1}{4}$, Sec. 10, T. 97 N, R. 49 W.	1951	510'	1479'		1179'	
155	E. E. Selom NE$\frac{1}{4}$, Sec. 34, T. 97 N, R. 49 W.	1950	413'	1316'		1146'	
156	Worthing Municipal Well SW$\frac{1}{4}$, Sec. 4, T. 98 N, R. 50 W.	1950	479'	1360'		1198'	
	Union County						
157	E. Werrick NE$\frac{1}{4}$, Sec. 30, T. 94 N, R. 50 W.	1951	374'	1315'		1144'	

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
158	Martin Albin SW$\frac{1}{4}$, Sec. 10, T. 92 N, R. 50 W.	1951	236'	1260'		1155'	
	<u>Yankton County</u>						
159	Lyle Van Osdel SE$\frac{1}{4}$, Sec. 18, T. 93 N, R. 54 W.	1939	280'	1176'	3 lbs.	1183'	3
160	Victor White SE$\frac{1}{4}$, Sec. 9, T. 93 N, R. 54 W.	1942	580'	1163'	30 lbs.	1232'	50
161	J. W. Batchellor SE$\frac{1}{4}$, Sec. 7, T. 93 N, R. 54 W.	1901	450'	1155'	12 lbs. app.	1183'	20
162	Charles Holock NE$\frac{1}{4}$, Sec. 14, T. 93 N, R. 54 W.	1947	601'	1170'	20 lbs.	1216'	15
163	Henry Halverson NE$\frac{1}{4}$, Sec. 27, T. 93 N, R. 54 W.	1916	300'	1165'	4 lbs. app.	1174'	4
164	Yankton State Hospital NE$\frac{1}{4}$, Sec. 1, T. 93 N, R. 56 W.	1891	750'	1286'		1245'	
165	Kabeiseman NW$\frac{1}{4}$, Sec. 17, T. 93 N, R. 56 W.	1944	600'	1248'	16 lbs.	1285'	20
166	Yankton City Well NE$\frac{1}{4}$, Sec. 13, T. 93 N, R. 56 W.	1914	942'	1212'	10 lbs.	1235'	
167	Jorgenson [illegible], Sec. 13, T. 93 N, R. 57 W.	1950	666'	1266'	5 lbs.	1278'	8

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
168	Henry Hazen SE$\frac{1}{4}$, Sec. 12, T. 94 N, R. 54 W.	1948	530'	1231'	8 lbs.	1249'	6
169	Hans Smith SW$\frac{1}{4}$, Sec. 18, T. 94 N, R. 54 W.	1932	318'	1198'	8 lbs.	1216'	2
170	Nelson NW$\frac{1}{4}$, Sec. 29, T. 94 N, R. 54 W.			1177'	15 lbs.	1211'	20
171	Stevens SW$\frac{1}{4}$, Sec. 32, T. 95 N, R. 54 W.	1951	458'	1249'		1229'	
172	Jess Berkley SE$\frac{1}{4}$, Sec. 35, T. 94 N, R. 54 W.	1946	570'	1185'	25 lbs.	1242'	30
173	John Mellegard SE$\frac{1}{4}$, Sec. 9, T. 94 N, R. 55 W.			1181'	15 lbs.	1215'	45
174	H. E. Swedlund SE$\frac{1}{4}$, Sec. 28, T. 94 N, R. 55 W.			1188'	5 lbs.	1200'	12
175	Ben Anderson SW$\frac{1}{4}$, Sec. 33, T. 94 N, R. 55 W.	1945	450'	1195'	7$\frac{1}{2}$ lbs.	1212'	12
176	Henry Voll SW$\frac{1}{4}$, Sec. 8, T. 95 N, R. 55 W.	1931	400'	1198'	4 lbs. app.	1207'	3
177	Andrew Madsen SW$\frac{1}{4}$, Sec. 16, T. 95 N, R. 55 W.	1947	500'	1238'	4 lbs.	1247'	6
178	Mary Schmidtgall NE$\frac{1}{4}$, Sec. 32, T. 95 N, R. 55 W.			1167'	4 lbs. app.	1176'	3

No.	Owner and Location	Date Drilled	Depth	Measuring Point Altitude Above Sea Level	Pressure	Top of Water Column Above Sea Level	Rate of Discharge Gal. per Min.
179	Bransted SW$\frac{1}{4}$, Sec. 30, T. 95 N, R. 56 W.	1948	240'?	1286'	$2\frac{1}{2}$ lbs.	1292'	1/5
180	Ben Bierseth SW$\frac{1}{4}$, Sec. 4, T. 96 N, R. 57 W.	1936	420'	1213'	16 lbs.	1250'	20
181	Gunderson Bros. SW$\frac{1}{4}$, Sec. 10, T. 96 N, R. 57 W.	1943	325'	1188'	5 lbs.	1200'	4
182	Bill Simple NW$\frac{1}{4}$, Sec. 29, T. 96 N, R. 55 W.	1947	250'?	1376'	5 lbs.	1388'	5
183	Jamesville Colony SW$\frac{1}{4}$, Sec. 28, T. 96 N, R. 56 W.	1946	500'	1220'	35 lbs.	1300'	20
184	Warren Bakken NW$\frac{1}{4}$, Sec. 11, T. 96 N, R. 57 W.			1187'	5 lbs.	1198'	15
185	George Mueller SW$\frac{1}{4}$, Sec. 8, T. 95 N, R. 57 W.	1946	569'	1372'		1292'	
186	Gussnald Gareldson SW$\frac{1}{4}$, Sec. 12, T. 95 N, R. 56 W.	1946	500'	1186'	15 lbs. app.	1220'	18
187	<u>Turner County</u> Viborg City Well	1951		1300'		1185'	

TABLE NO. 6

LOGS OF WELLS IN SOUTHEASTERN SOUTH DAKOTA

CHARLES MIX COUNTY

NW¼, Sec. 11, T. 99 N, R. 70 W. --- Nick Guikeisen Well
Elevation --- 1500 feet

	Feet
Glacial drift	75
Pierre shale	135
Niobrara chalk	120
Carlile shale	260
Greenhorn limestone	55
Graneros shale	85
Dakota sandstone	40
Fuson shale	50
Lakota sandstone	50
Total depth	870

NW¼, Sec. 17, T. 100 N., R. 68 W. --- Schoenrock Farm
Elevation --- 1635 feet

Glacial drift	230
Pierre shale	40
Niobrara chalk	120
Carlile shale	270
Greenhorn limestone	30
Graneros shale	120
Dakota sandstone	160
Total depth	970

SE¼, Sec. 4, T. 95 N., R. 65 W. --- Pickstown Well
Elevation --- 1489 feet

Glacial drift	170
Niobrara chalk	168
Codell sandstone	25
Carlile shale	230
Greenhorn limestone	30
Graneros shale	170
Dakota sandstone	84
Total depth	850

NE$\frac{1}{4}$, Sec. 7, T. 96 N., R. 64 W. --- Rest Haven
Elevation --- 1454 feet

	Feet
Glacial drift	350
Codell sand	60
Carlile shale	30
Greenhorn limestone	30
Graneros shale	110
Dakota sandstone	80
Fuson shale	50
Lakota sandstone	190
Sioux quartzite	50

DOUGLAS COUNTY

Armour City Well --- Elevation - 1514 feet

Glacial drift	90
Pierre shale	165
Niobrara chalk	72
Codell sandstone	60
Carlile shale	215
Greenhorn limestone	37
Graneros shale	70
Dakota sandstone	60
Total depth	757

HUTCHINSON COUNTY

SW$\frac{1}{4}$, Sec. 23, T. 100 N., R. 60 W. --- Elevation - 1335 feet

Glacial drift	100
Niobrara chalk	50
Carlile shale	210
Quartzite	3

Tripp City Well --- Elevation - 1580

Glacial drift	30
Niobrara chalk	290?
Codell sand	100
Carlile shale	300?
Dakota sandstone	95

SE$\frac{1}{4}$, Sec. 27, T. 98 N., R. 59 W. --- Elevation - 1310 feet

	Feet
Glacial drift	140
Niobrara chalk	50
Benton shales	150
Dakota sandstone	60

TURNER COUNTY

SW$\frac{1}{4}$, Sec. 25, T. 98 N., R. 54 W. --- Elevation - 1289 feet

Glacial drift	40
Niobrara chalk	110
Benton group	220
Dakota sandstone	90
Sioux quartzite	3

Viborg City Well --- Elevation - 1300

Glacial drift	50
Niobrara chalk	100
Codell sandstone	45
Carlile shale	65
Greenhorn limestone	15
Graneros shale	60
Dakota sandstone	70
Fuson shale	130
Lakota sandstone	75
Sioux quartzite	2

NW$\frac{1}{4}$, Sec. 35, T. 98 N., R. 54 W. --- Elevation - 1290 feet

Glacial gravel	80
Niobrara chalk	70
Benton group	267
Dakota sandstone	96

SW$\frac{1}{4}$, Sec. 1, T. 96 N., R. 56 W. --- Elevation - 1400 feet

Glacial drift	200
Niobrara chalk	80
Benton group	420
Dakota sandstone	15

SE$\frac{1}{4}$, Sec. 27, T. 96 N., R. 55 W. --- Elevation - 1420 feet

	Feet
Glacial drift	60
Niobrara chalk	140
Carlile shale	175
Greenhorn limestone	10
Graneros shale	100
Dakota sandstone	100

CLAY COUNTY

NW$\frac{1}{4}$, Sec. 15, T. 95 N., R. 52 W. --- Elevation - 1225'

Glacial drift	187
Benton group	283
Dakota sandstone	37

LINCOLN COUNTY

Worthing City Well ------------------ Elevation - 1360'

Glacial drift	143
Carlile shale	222
Greenhorn limestone	50
Dakota sandstone	64

Canton City Well -------------------- Elevation -

Glacial drift	100
Carlile shale	110
Greenhorn limestone	55
Graneros shale	143
Dakota sandstone	40

YANKTON COUNTY

C. M., St. Paul and Pacific R.R. at Yankton - Elev. - 1210'

Glacial drift	74
Carlile shale	36

Greenhorn limestone	30'
Graneros shale	200'
Dakota sandstone	80'
Fuson shale	60'
Lakota sandstone	75'

BON HOMME COUNTY

Tyndall City Well--------------------Elevation - 1400'

Glacial drift	95'
Niobrara chalk	100'
Carlile shale	20'
Codell sand member	65'
Carlile shale	135'
Greenhorn limestone	55'
Graneros shale	30'
Dakota sandstone	40'
Fuson shale	70'
Lakota sandstone	23'

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