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Shallow Artesian Wells of South Dakota

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Bulletin 49.

U. S.
EXPERIMENT STATION,
SOUTH DAKOTA.



IN CONNECTION WITH THE
SOUTH DAKOTA AGRICULTURAL COLLEGE.

SHALLOW ARTESIAN WELLS
OF SOUTH DAKOTA.

DEPARTMENT OF CHEMISTRY.

BROOKINGS, SOUTH DAKOTA.

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The Shallow Artesian Wells of South Dakota.

JAMES H. SHEPARD, Chemist.

The results recorded in this Bulletin are in continuation of investigations described in Bulletin No. 41 of the South Dakota Station. When this work was commenced it was my intention to include the waters from a wider area, from the Black Hills and from the outcrops of the Dakota sandstone along the foot hills of the Rocky Mountains. Arrangements had been made at that time with the U. S. Geological Survey to furnish this department with authenticated samples of waters from those outlying regions, for the purpose, if possible, of throwing some light upon the geological origin of the waters of the great artesian basin of the Dakotas. Owing, however, to the readjustment at that time of the work of the survey, Director Walcott had no men stationed at the points in question; so it became necessary to abandon that portion of the work for the time being. But arrangements are now in progress, by means of which it is to be hoped that the samples may be gathered and at no distant day the work may be carried to completion.

The results here recorded will find their chief value as follows: First, they will furnish a knowledge of the soluble constituents and the properties of the waters to those who are using or may wish to use them. Second they will tend to throw light upon the question of an eastern leakage from the great artesian basin, in which source these waters are often supposed to originate.

The analyses given in this Bulletin are from authenticated samples. Superintendent I. D. Aldrich, of Grant county, formerly an Assistant in this Department, collected the samples from the Grant county basin and secured the valuable data recorded. Mr. W. H. Knox, my Assistant, visited the other basins, collected the samples and obtained the data.

There are four known shallow artesian basins in South Dakota;

- 1st.—The Grant county basin.
 2nd.—The Hurley basin.
 3rd.—The Turkey Ridge Creek basin. } Both in Turner Co.
 4th.—The Sanborn county basin, which also extends southward into Hanson and Miner counties and gradually merges on the west into the great artesian basin.

Each one of these basins presents some marked peculiarities, worthy of note. The purposes of this Bulletin may be best subserved by a separate consideration of each basin.

THE GRANT COUNTY BASIN.

This basin lies in the north-east portion of the state and constitutes one of the most fertile areas to be found within its borders. The artesian waters are "hard waters" and contain no true or caustic alkali. They may all be used directly for irrigating purposes, but they are all susceptible of improvement by sedimentation in open vats or reservoirs.

Mr. Aldrich furnishes the following description and data from which a comprehensive idea of the basin may be obtained:

"The east base of the Coteau du Prairie or East Coteau lies in a north-west and southeast direction through the center of Grant county. West of this the land is rugged and broken for ten or fifteen miles and the elevation increases from seven to nine hundred feet in that distance. The three railroads passing through the county bend northward in ascending the hills for the sake of easier grades. The accompanying map of Grant county shows the elevation above sea level of most of the railway stations in and near the county, and indicates the base of the coteau.

There are about fifty flowing wells in the county, lying in a somewhat irregular line near the foot of the hills. They are believed to derive their "head" from the coteau.

That part of the country lying east of the coteau is the lowest part of South Dakota. On account of its lowness and the modifying influence of the hills, its crops are from ten days to two weeks earlier than those further west, even in a distance of fifteen or twenty miles.

A number of small streams, a part only of which are indicated on the map, issue from the hills and either lose themselves on the prairie or unite to form larger streams, eventually to find their way into the Whetstone or the Yellow Bank. As

the average distance between these streams at the foot of the hills is only about half a mile, the country is one of the best watered in the state, and a total crop failure from drouth has never been known. The accompanying table gives a general view of the conditions of some of these wells, and it is probable that those not included have similar characteristics.

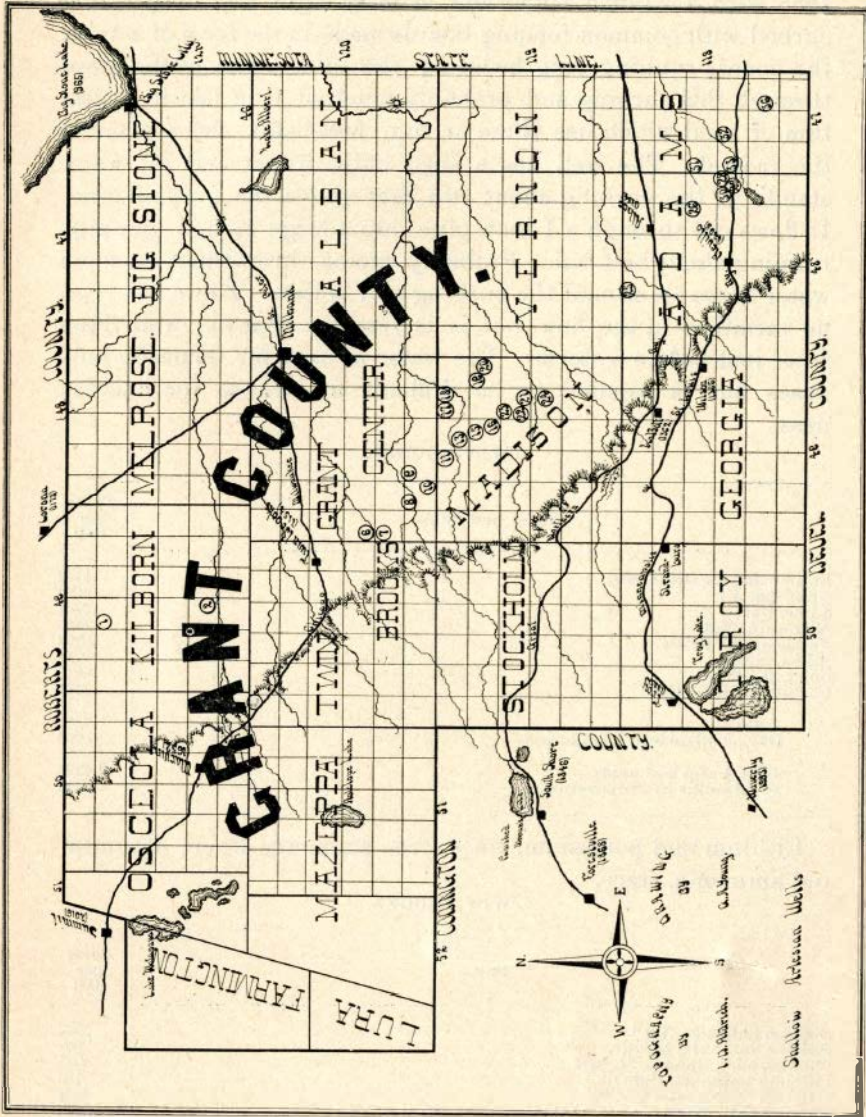
While unsuccessful efforts have sometimes been made to obtain a flowing well in this region, nevertheless, most of the attempts have succeeded. Nearly all of these wells have been bored by hand with a two-inch auger. Acknowledgements are due to Hon. W. O. Storlie, of Revillo, Mr. C. S. Amsden, of Milbank, and Mr. J. N. Safford, of Twin Brooks for assistance in collecting data."

TABULAR VIEW OF THE ARTESIAN WELLS OF THE GRANT COUNTY BASIN.

Map Number.	Owner.	Quarter section.	Depth.	Date of boring.	Approx. flows—Gals. per Minute.
1	KILBORN TOWNSHIP—				
2	Peter Gauthier	NW 9	50		5
3	Sarff	SE 23			
4	TWIN BROOKS TOWNSHIP—				
5	Geo. Breckenridge	NW 13	46	1886	5
6	Henry Rediker				5
7	W. M. Cowell				4
8	GRANT CENTER TOWNSHIP—				
9	H. Blood	SW 19	50		20
10	Thompson	NW 30			20
11	Asa Keefer	NW 32	45		20
12	B. Siers	NW 33	50		20
13	J. T. Winch	SE 32	47		20
14	MADISON TOWNSHIP—				
15	Geo. T. Manning	NE 4	65	1882	30
16	Frank Kibbe	SW 3	65	1882	1
17	C. S. Amsden	NW 10	63	1882	8
18			58		4
19	C. C. Morton	SE 10	35	1894	12
20	W. T. Burman	NW 2	60	1890	5
21	Chas. Hochmuth	NE 2	64		1
22	James Lockhart	NW 12	45	1883	8
23	A. P. Lindquist	NE 12	40		4
24	W. L. Scharoeder	SE 14	32	1895	15
25	F. W. A. Poppe	SW 14	45	1884	15
26	Wm. Baxter	NW 14	45	1886	1
27	H. L. Delamater	NE 23	32	18 93	36
28	VERNON TOWNSHIP—*				
29	ADAMS TOWNSHIP—West Portion.				
30	H. Post	NW 4	115	1889	5
31	E. O. Walseth	NE 14	40	1893	10
32	Wm. O. Storlie	NE 22	42	1888	7
33	Nels Vigen	NE 24	40	1894	7
34	Ole Peterson	SE 24	45	1895	4
35	John Hilstrom	NW 24	40	1879	
36	ADAMS—East Portion.				
37	Thos. Street	NW 18	36	1882	10
38	John Rome	NW 20	40	1885	15
39	W. O. Storlie	SW 10	40	1898	10
40	F. Mobust	SE 20	40	1887	10
41	G. Paulsen	SW 20	50	1898	5
42	P. Paulsen	SW 28	40	1882	5

REMARKS.—No. 2.—About like No. 1. Nos. 3, 4 and 5 are within twenty rods of each other in the village of Twin Brooks; Water is conducted from one through a cheese factory. Nos. 6, 7, 8, 9 and 10 have been flowing for several years but the date of boring was not learned. No. 11: Loam, 2 feet; yellow clay, 11; blue clay, 32; located near creek; flow in quicksand. No. 12: Flow in white sand; gravel bottom; also near creek. No. 13: Loam, 18 in.; yellow clay, 11 feet; balance blue clay; flow in blue sand. Nos. 14 and 15: Loam, 2 feet; yellow clay, 11; balance blue clay; flow in gravel; thickness of vein, 2 feet; these two wells on same vein as raising or lowering exit of either effects the other. No. 16: This well is located in a swale running in an easterly direction; shallowness due perhaps to its being lower ground. No. 17: Characteristics of soil about as in preceding. No. 22: Near a spring water course or dry run. No. 27: There are two other similar wells near this in Revillo. No. 30: Stopped up.

*There are a few flowing wells in the south-western part of this township. No data from them was obtained.



THE TWIN BROOKS WELL.

This well, costing about one dollar per foot, was bored in 1888 with a 22-inch auger and is forty-eight feet deep. It is curbed with common fencing boards made in the form of a tube, the boards running lengthwise of the tube. The water seeps through this curbing and probably much of it is lost in a stratum of sand which lies three or four feet below the surface of the ground. The well has a shed built over it and the water stands in the curbing about two feet above the ground level. It flows out through a 1-inch pipe into a large trough, the pipe running about half full. Probably two or three times as much water seeps up around the curbing and is lost. There has been no variation in the flow, but it is thought that the well flows freer just before a storm. The water is used for domestic purposes but is reputed to be difficult to cleanse for laundry uses.

TWIN BROOKS.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO_3	5152
Chlorine, Cl	0026
Lime, CaO	2494
Magnesia, MgO	1658
Ferric oxide, Fe_2O_3	0100
Silica, SiO_2	0264
Soda, Na_2O	0013
Carbon dioxide, CO_2	1577
Total.....	12182
Oxygen displaced by chlorine.....	0006
Total bases and acids.....	12176
Total solids by evaporation.....	12216

Lithium and potassium, trace; free ammonia, trace; albuminoid ammonia, trace.

TWIN BROOKS.

Salts.	Parts per 1000
Sodium chloride, NaCl	0043
Sodium sulphate, Na_2SO_4	2837
Magnesium sulphate, MgSO_4	4965
Calcium sulphate, CaSO_4	1183
Calcium carbonate, CaCO_3	3384
Ferric oxide, Fe_2O_3	0100
Silica, SiO_2	0264
Total.....	12176
Total solids by evaporation.....	12216

THE AMSDEN WELL.

This well is on the farm of Mr. C. S. Amsden, section 10-119-49. It was bored in 1882 and is 65½ feet deep. The boring was done with a hand auger. The layers of earth encountered were: 2 feet black loam; 11 feet yellow clay; 32 feet blue clay; 6 inches sand; 20 feet blue clay; 2 feet bluish sand.

The cost of this well was the personal labor not to exceed \$5.00. It is tubed down to the blue clay with wooden tubing of 2-inch bore. It flows about 8 gallons per minute and it is thought that if the tubing were carried so high the water would rise to a height of 15 feet above the surface of the ground. No variation has been noticed in the flow and the water is used for all domestic purposes. Threshing engines come a long distance for this water. It does not foam in the boiler.

Mr. Amsden has another well which seems to be decreasing in its flow. It is situated about six rods from the well sampled.

The analysis of the Amsden well follows:

AMSDEN.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO ₃.....	.2956
Chlorine, Cl.....	.0022
Lime, CaO.....	.2064
Magnesia, MgO.....	.0906
Ferric oxide, Fe ₂ O ₃.....	.0110
Silica, SiO ₂.....	.0468
Soda, Na ₂ O.....	.0214
Carbon dioxide, CO ₂.....	.1128
Total.....	.7868
oxygen displaced by chlorine.....	.0003
Total bases and acids.....	.7865
Total solids by evaporation.....	.7896

Lithium and potassium, trace; free ammonia, none; albuminoid ammonia, trace.

AMSDEN.

Salts.	Parts per 1000
Sodium chloride, NaCl.....	.0038
Sodium sulphate, Na ₂ SO ₄.....	.0446
Magnesium sulphate, MgSO ₄.....	.2716
Calcium sulphate, CaSO ₄.....	.1521
Calcium carbonate, CaCO ₃.....	.2568
Ferric oxide, Fe ₂ O ₃.....	.0110
Silica, SiO ₂.....	.0468
Total.....	.7865
Total solids by evaporation.....	.7896

THE REVILLO WELL.

This well is owned by Hon. W. O. Storlie. It was dilled in 1889, and is 42 feet deep. In drilling this well the drill passed through the following: 3 feet black soil; 3 feet gravel; 30 feet blue clay and 6 feet greyish sand.

The finished well cost a dollar per foot. It is cased with 2-inch galvanized pipe and yields a flow of about $4\frac{1}{2}$ gallons per minute. There is no apparent variation in the flow, and the water is used for all purposes.

Mr. W. L. Case, a wheat buyer, has a flowing well in his elevator about 40 rods from the Storlie well. The water is used freely in the boiler and it is also considered excellent for domestic purposes.

The analysis of the Storlie well follows:

REVILLO WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO_2	6.344
Chlorine, Cl	0.156
Lime, CaO	3.316
Magnesia, MgO	2.086
Ferric oxide, Fe_2O_3	0.206
Silica, SiO_2	0.410
Soda, Na_2O	0.417
Carbon dioxide, CO_2	1.608
Total.....	1.4533
Oxygen displaced by chlorine.....	0.005
Total bases and acids.....	1.4498
Total solids by evaporation.....	1.4564

Lithium and potassium, faint traces; free ammonia, trace; albuminoid ammonia, parts per million, 14.

REVILLO WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl	0.257
Sodium sulphate, Na_2SO_4	0.643
Magnesium sulphate, MgSO_4	0.255
Calcium sulphate, CaSO_4	3.082
Calcium carbonate, CaCO_3	3.655
Silica, SiO_2	0.410
Ferric oxide, Fe_2O_3	0.206
Total.....	1.4498
Total solids by evaporation.....	1.4564

Mr. Knox obtained the data for the remaining wells and basins. The Hurley and Turkey Ridge Creek basins resemble each other in many respects.

THE HURLEY BASIN.

This basin lies to the north of the town and is confined to a valley running northeast and south-west that is about 80 rods wide by 160 rods long. This valley may have been in some former time the bed of a lake. The water lies at a depth of about 25 feet. Formerly these wells could be obtained in nearly all parts of the town, but now, owing probably to the dry weather, they are confined to the northern portion, none being found higher than midway up the slope. They have very little pressure, barely sufficient to raise the water about one foot above the surface of the ground.

The water is unpleasant for domestic purposes, owing to the soluble iron salts it carries, but stock relish it fairly well. Iron pipes through which it runs rust out very quickly. No vegetation grows where the water from these wells stands, owing to the iron deposited; indeed, the whole valley, to which this basin is confined can hardly be called fertile. This water can be fitted for domestic uses and irrigation purposes by allowing it to stand in open vats or reservoirs until the iron compounds are deposited. This water is a chalybeate water and as such may prove useful. During very wet seasons the water has been known to break forth spontaneously forming fair sized springs. The water is found in a fine white sand. Many of the wells were bored by hand and most of them are two inches in diameter. The flow is seldom more than thirty barrels per day and never more than thirty-five, usually varying from twenty-five to thirty barrels per day. They are all visibly affected by dry weather.

There are about six wells in the Hurley basin, one of which was taken, giving the following analysis:

HURLEY WELL.

This well belongs to S. W. Kellar, the proprietor of the livery barn. It is higher up the slope than any other of the wells. The water is fairly good for stock, but is not used for culinary purposes. Tin pails in which the water stands rust out very quickly. The well is twenty-five feet deep; has a 2-inch bore: the flow is from twenty-five to thirty barrels per day; the pres-

sure being sufficient to raise the water about one foot above the surface of the ground; the temperature was 49.5° F.

The log: Black loam, 3 feet; yellow clay, 19 feet; sand, 3 feet; the water being found in a fine white sand.

The analysis follows:

HURLEY WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO ₃	5401
Chlorine, Cl .....	.0071
Lime, CaO	5790
Magnesia, MgO	1723
Ferric oxide, Fe ₂ O ₃ .....	.0110
Silica, SiO ₂ .....	.0248
Soda, Na ₂ O .....	.0149
Carbon dioxide, CO ₂ .....	.1890
Total	1.8372
Oxygen displaced by chlorine .....	.0016
Total bases and acids	1.8372
Total solids by evaporation	1.8376

Lithium and potassium, faint trace; free ammonia, trace; albuminoid ammonia, trace.

HURLEY WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl .....	.0117
Sodium sulphate, Na ₂ SO ₄ .....	.0199
Magnesium sulphate, MgSO ₄ .....	.5184
Calcium sulphate, CaSO ₄ .....	.8218
Calcium carbonates, CaCO ₃ .....	.4286
Ferric oxide, Fe ₂ O ₃ .....	.0110
Silica, SiO ₂ .....	.0248
Total	1.8372
Total solids by evaporation	1.8376

THE TURKEY RIDGE CREEK BASIN.

This basin lies in the south-western part of Turner county and covers a strip of land about six miles wide and twelve miles long, lying north-west and south-east. The country slopes to the east and south-east and is drained by the Turkey Ridge creek. Swan Lake, a small body of water about one mile wide and three miles long, and extending north-west and south-east, lies to the north-west of this basin, the northern extremity of the basin lying west of the lake. The country is rolling and very fertile. There is no particular valley to which these wells

are confined, yet the extent of the basin is quite clearly defined. A farmer living one and one-half miles west of Swan Lake had a well put down 300 feet without finding water, while a mile and a half further west a flow of three hundred barrels per day was obtained at a depth of 110 feet.

The water is found at a depth of from 100 to 110 feet, in a stratum of chalk stone. A layer of iron pyrites is usually found resting upon the chalk stone. The water is good and is much used for both culinary purposes and for stock. It has been used for irrigating on a small scale with good success. These wells have a good pressure but no effort has ever been made to utilize it. The wells in the northern part of the basin have never been visibly affected by the dry weather, but some of those in the southern portion have, during the protracted drouth ceased to flow.

At present about twenty wells are distributed throughout the basin. The temperature of the water varies from 48 to 51° F.

Two wells were selected from this basin for analysis.

BUCHANAN WELL, (SWAN LAKE).

This well was drilled in 1882 and was the first flowing well found in that section of the country. It is 110 feet deep and was at first a 3-inch bore, but a 2-inch pipe has been forced down inside the original pipe, thus partially shutting off the flow and reducing the well to two inches. The flow at present is about 300 barrels per day. It does not seem to be in the least affected by drouth, the flow remaining about constant since it was reduced to two inches.

The tubing rises about three feet above the ground, an elbow has been put on and a pipe about four feet long conducts the water into a creamer vat, which is connected by an overflow with a large tank; from here the water runs across one corner of a pasture, part being absorbed by the ground, the remainder finding its way to Turkey Ridge creek.

The water is good for both culinary and stock raising purposes. It was used one season for irrigating on a small scale with very good success. The temperature is 49 1° F.

The formation passed through was about as follows: Black loam, 5 feet; yellow clay, 20 feet; white sand, 10 feet; blue clay,

65 feet; chalk stone, 10 feet; about two inches of iron pyrites rest upon the chalk stone in which the water was found.

When the well was drilled black iron pipes were put in but they rusted out so that in four years they had to be removed. Galvanized pipes were then put in, and upon these the water seems to have had no deleterious effect. It does not corrode tinware to any great extent.

This well is situated in the north-eastern part of the Turkey Ridge creek basin. The analysis follows:

BUCHANAN WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO_3.....	.6370
Chlorine, Cl}.....	.0051
Lime, CaO}.....	.3871
Magnesia, MgO}.....	.1000
Ferric oxide, Fe_2O_3.....	.0232
Silica, SiO_2.....	.0324
Soda, Na_2O}.....	.0621
Carbon dioxide, CO_2.....	.1928
Total.....	1.4912
Oxygen displaced by chlorine.....	.0012
Total bases and acids.....	1.4900
Total solids by coprecipitation.....	1.4884

Lithium and potassium, trace; free ammonia, per million, 1.62; albuminoid ammonia, per million, .08.

BUCHANAN WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl}.....	.0684
Sodium sulphate, Na_2SO_4.....	.1315
Magnesium sulphate, MgSO_4.....	.4798
Calcium sulphate, CaSO_4.....	.3854
Calcium carbonate, CaCO_3.....	.1770
Ferric oxide, Fe_2O_3.....	.0232
Silica, SiO_2.....	.0324
Total.....	1.4900
Total solids by evaporation.....	1.4884

IRENE WELL.

This well belongs to Peter Aggergaard, a farmer, living near Irene, in the southern portion of Turner county. It is the third well which Mr. Aggergaard has had drilled upon this farm. The first well was situated about half way up a small hill sloping toward the south-east. This well was drilled in

1881; was 110 feet deep, and when finished the flow exceeded 500 barrels per day. The flow gradually diminished, however, and in 1890 ceased flowing. A second one was sunk a little farther down down the slope in the fall of 1890, and a good flow obtained at about the same depth. Although this well had a good pressure at first, it proved to be but a partial success and four years later it had also ceased to flow.

Mr. Aggergaard now went down to the foot of the slope, about eighty rods distant from the first well and drilled the well from which the sample was obtained.

The well is 110 feet deep; is a 3-inch bore, and flows about 450 barrels per day. It is situated at the head of a small ravine. The casing extends about four feet above the surface of the ground. The water rises about two feet above the top of the pipe, boiling ever like some large spring and forming a great mud hole all around the well. It then finds its way down the ravine to the ditches along a neighboring railroad. The water is good; the temperature is 50° F. Galvanized pipes were used and show no signs of rusting. This well is situated at the south-eastern extremity of the Turkey Ridge creek basin.

The log was as follows: Black loam, 6 feet; yellow clay, 35 feet; blue clay, 65 feet; chalk stone, 4 feet. As in the other wells, the water was found in chalk stone.

The analysis follows:

IRENE WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO_3.....	.7356
Chlorine, Cl}.....	.0049
Lime, CaO}.....	.4332
Magnesia, MgO}.....	.1661
Ferric oxide, Fe_2O_3.....	.0220
Silica, SiO_2.....	.0316
Soda, Na_2O}.....	.0757
Carbon dioxide, CO_2.....	.1693
Total.....	1.6387
Oxygen displaced by chlorine.....	.0011
Total bases and acids.....	1.6376
Total solids by evaporation.....	1.6393

Lithium and potassium, trace; free ammonia, per million, 2.94; albuminoid ammonia, trace.

IRENE WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl.....	.0080
Sodium sulphate, Na ₂ SO ₄.....	.1633
Magnesium sulphate, MgSO ₄.....	.4989
Calcium sulphate, CaSO ₄.....	.5287
Calcium carbonate, CaCO ₃.....	.3842
Ferric oxide, Fe ₂ O ₃.....	.0220
Silica, SiO ₂.....	.0316
Total.....	1.6376
Total solids by evaporation.....	1.6388

THE SANBORN COUNTY BASIN.

There can be no exact boundary set for this basin since wells are found more or less irregularly distributed over a large portion of western Miner, northern Hanson and Sanborn counties. The basin gradually merges on the west into the deep basin of the James river valley. The country is rolling, affording good drainage. It is quite fertile, but like other portions of the state, has suffered from dry weather.

The wells in the northern portion of this basin are much shallower than those in the southern and western portions. Around Artesian they seldom exceed 150 feet, mostly varying from 100 to 120 feet in depth. As we go south they grow much deeper and we also find three distinct flows. The first of these flows is found from 200 to 275 feet below the surface; the second, from 350 to 400 feet; and the third flow from 450 to 600 feet. Many of the wells in the northern part of the basin have ceased flowing, as have also many of the first flow wells in the southern part. This is probably caused by faulty construction or by interference of sand, etc., since new wells sunk close by yield an abundant flow.

The water is good. It can be used for household purposes, and stock relish it. It has been used for irrigating small fields with great success.

The general formation passed through seems to be: Black loam, about 5 feet; coarse sand and yellow clay, about 50 or 60 feet; blue clay, sometimes mixed with a fine sand, down to the water formation. A cap rock of from one to six inches thick rests upon the water formation which is a porous or honey-combed sand rock. This sand rock is quite hard and it is a dif-

ficult task to drill through it. The washings are a fine white sand. The flow of these wells vary from fifty to 5,000 barrels per day. In some cases, with the heavier flow wells, the power is utilized to run fanning mills, churns, etc. These wells cannot be found on every farm but are more or less general throughout that section of the country.

Three samples were obtained from this basin.

THE ARTESIAN CITY WELL.

This well belongs to Hon. R. E. Dowdell, and is situated in the south-western part of the town of Artesian near the school house. It was drilled in 1886, is two inches in diameter and has barely sufficient pressure to raise the water one foot above the surface of the ground. The casing has an inclined position and if raised more than fourteen or fifteen inches from the ground, the water ceases to flow. There is no pipe to conduct the water from the well and consequently the well is surrounded by a mudhole. The well is 120 feet deep, and the flow is about fifty barrels per day. The temperature of the water is 51° F. The water is fairly good and suited to all purposes. Mr. Dowdell, during the summer of 1894, irrigated a garden of about 2½ acres with splendid success.

The log is as follows: Black loam, 6 feet; yellow clay and coarse sand, 45 feet; blue clay, 60 feet. The water formation was struck at 110 feet.

The analysis follows:

ARTESIAN CITY WELL. (SANBORN COUNTY.)

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO ₂.....	.7974
Chlorine, Cl.....	.0681
Lime, CaO.....	.3628
Magnesia, MgO.....	.0896
Ferric oxide, Fe ₂ O ₃.....	.0246
Silica, SiO ₂.....	.0100
Soda, Na ₂ O.....	2.318
Carbon dioxide, CO ₂.....	.0027
Total.....	1.7270
Oxygen displaced by chlorine.....	.0154
Total bases and acids.....	1.7116
Total solids by evaporation.....	1.7140

Lithium and potassium, trace; free ammonia, none; albuminoid ammonia, per million, .08.

ARTESIAN CITY WELL.

Salts,	Parts per 1000
Sodium chloride, NaCl.....	.1123
Sodium sulphate, Na ₂ SO ₄.....	.3941
Magnesium sulphate, MgSO ₄.....	.2387
Calcium sulphate, CaSO ₄.....	.6739
Calcium carbonate, CaCO ₃.....	.1880
Ferric oxide, Fe ₂ O ₃.....	.0246
Silica, SiO ₂.....	.0500
Total.....	1.7316
Total solids by evaporation.....	1.7140

BEAVER WELL, (MINER COUNTY).

This well is on the farm of R. R. Smith, and is a second flow well. It was drilled in 1888; is 430 feet deep, and is 2½ inches in diameter. The flow is about 3,500 barrels per day. The water is good. Galvanized pipes were used and show no signs of rusting out. The temperature of the water is 52° F. The man who owned the farm at the time the well was drilled has sold out and the present owner could give no data, concerning the log of the well. The water from this well has never been utilized except for ordinary farm purposes.

The analysis follows:

BEAVER WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO ₃	1.0222
Chlorine, Cl.....	.1485
Lime, CaO.....	.0072
Magnesia, MgO.....	.1631
Ferric oxide, Fe ₂ O ₃.....	.0060
Silica, SiO ₂.....	.0120
Soda, Na ₂ O.....	.3166
Carbon dioxide, CO ₂.....	.0658
Total.....	2.1663
Oxygen displaced by chlorine.....	.0636
Total bases and acids.....	2.1327
Total solids by evaporation.....	2.1216

Lithium and potassium, trace; free ammonia, per million, .07; albuminoid ammonia, none.

BEAVER WELL.

Salt.	Parts per 1000
Sodium chloride, NaCl	2449
Sodium sulphate, Na ₂ SO ₄	.4271
Magnesium sulphate, MgSO ₄	.4947
Calcium sulphate, CaSO ₄	.7684
Calcium carbonate, CaCO ₃	.1496
Ferric oxide, Fe ₂ O ₃	.0060
Silica, SiO ₂	.0420
Total	2.1327
Total solids by evaporation	2.1316

REDSTONE WELL, (HANSON COUNTY).

This well is on the farm of E. E. Foster. It was drilled in 1886, and is 480 feet deep. It is a third flow well. The water is good and has been used for irrigating with marked success. The flow is about 4,800 barrels per day. The following is the depth to and through the different flows. Depth to the first flow, 250 feet; depth through first flow, 25 feet; depth to second flow, 325 feet; depth to third flow, 465 feet. The formation between the flows was a mixture of blue and yellow clay, sometimes mixed with a fine sand. Galvanized pipes were used and show no signs of rusting. The temperature of water is 51° F. Following is the log of first 250 feet: Black loam, 6 feet; yellow clay and sand, 60 feet; blue clay, 184 feet.

The analysis of this well follows:

REDSTONE WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO ₃	1.0018
Chlorine, Cl	.1158
Lime, Ca	.3878
Magnesia, MgO	.1554
Ferric oxide, Fe ₂ O ₃	.0060
Silica, SiO ₂	.0124
Soda, Na ₂ O	.2977
Carbon dioxide, CO ₂	.0636
Total	2.0475
Oxygen displaced by chlorine	.0242
Total bases and acids	2.0113
Total solids by evaporation	2.0144

Lithium and potassium, faint trace; free ammonia, per million, 3.36; albuminoid ammonia, none.

REDSTONE WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl.....	1910
Sodium sulphate, Na ₂ SO ₄	4493
Magnesium sulphate, MgSO ₄	4059
Calcium sulphate, CaSO ₄	7451
Calcium carbonate, CaCO ₃	1446
Ferric oxide, Fe ₂ O ₃	10030
Silica, SiO ₂	3124
Total.....	20113
Total solids by evaporation.....	2.0144

A BROOKINGS SURFACE WELL.

For the sake of comparison a sample of water taken from my own well was analyzed. This is a surface well 40 feet deep, 6 feet in diameter and walled up with brick joined by Yankton cement. It furnishes a large supply of water which is used for domestic and irrigating purposes. This water may be taken as typical of a large number of surface wells found throughout the eastern portion of the state. The water is found in a sheet of sand and gravel after passing through about three feet of soil and 37 feet of yellow or boulder clay. Beyond this depth blue clay is usually found.

The sand and gravel sheet is not continuous over the whole region. In places the boulder clay rests upon the blue clay. Here a dry hole is obtained unless the blue clay is penetrated by digging or drilling from 100 to 400 feet.

Where the sand and gravel sheet exists the water often rises a few feet above it; in the well under consideration the distance is about 12 feet. These wells are little effected by drouth and respond only to a protracted fall of rain at the points where the water finds its way into the sand sheet.

The analysis follows:

SHEPARD WELL.

Bases and Acids.	Parts per 1000
Sulphuric anhydride, SO_3.....	.3694
Chlorine, Cl}.....	.0068
Lime, CaO}.....	.1919
Magnesia, MgO}.....	.1506
Ferric oxide, Fe_2O_3	trace
Silica, SiO_2.....	.0408
Soda, Na_2O}.....	.0688
Carbon dioxide, CO_2.....	.1586
Total.....	.9560
Oxygen displaced by chlorine.....	.0018
Total bases and acids.....	.9847
Total solids by evaporation.....	.9636

Lithium and potassium, trace; free ammonia, per million, .06; albuminoid ammonia, none.

SHEPARD WELL.

Salts.	Parts per 1000
Sodium chloride, NaCl}.....	.0026
Sodium sulphate, Na_2SO_4.....	.1458
Magnesium sulphate, MgSO_4.....	.4311
Magnesium carbonate, MgCO_3.....	.0147
Calcium carbonate, CaCO_3.....	.3427
Silica, SiO_2.....	.0408
Total.....	.9847
Total solids by evaporation.....	.9636

ORIGIN OF THE SHALLOW ARTESIAN WATERS.

The following table is given showing the principal bases and acids in the waters of the wells previously described. In order to make more clear the relation of the Sanborn county basin to the great artesian basin the Woonsocket well is included.

BASES.—Parts per 1000.

Well.	SO_3	Cl	CaO	MgO	Na_2O	CO_2
Twin Brooks.....	.5152	.0026	.2494	.1050	.0913	.1577
Amsden.....	.2956	.0022	.2064	.0008	.0214	.1128
Revillo.....	.6344	.0156	.3316	.2086	.0417	.1608
Hurley.....	.8401	.0071	.5790	.1729	.0149	.1880
Buchanan.....	.6370	.0031	.3871	.1600	.0621	.1923
Irene.....	.7356	.0019	.4352	.1664	.0757	.1688
Shepard.....	.3694	.0068	.1919	.1508	.0688	.1585
Artesian City.....	.7974	.0081	.3828	.0896	.2318	.0827
Beaver.....	1.0222	.1485	.4002	.1650	.3100	.0668
Redstone.....	1.0018	.1158	.3878	.1554	.2977	.0636
Woonsocket.....	1.0090	.0684	.3120	.1234	.4070	.0717

A simple glance over the bases and acids of the waters of the Grant County, Hurley and Turkey Ridge Creek basins will show a striking similarity. The variations of the bases liable to be precipitated, in these waters, are no greater than would naturally be expected. The chlorine content also indicates a striking similarity. Further, when compared with the Shepard well, the conclusion seems almost inevitable, that the waters of these basins are *surface* waters and do not owe their origin to any leakage from the deep artesian basin. This conclusion is rendered still more certain when a comparison is made with the Woonsocket well or with any of the deep artesian wells. It would be difficult to explain how seepage waters from the deep basin could suffer the diminution of chlorine shown by the waters of these three shallow basins.

In this connection it may be well to note that both surface and deep flow waters carry lithium in traces, throughout a large area in the west. Consequently its presence indicates nothing concerning the origin of any waters of the region.

It is altogether probable that these wells simply penetrate a tilted sand sheet lying just beneath the boulder clay. It is also probable that some of them, at least, penetrate the ancient beds of streams which were buried beneath that clay. As a remarkable confirmation of this hypothesis, it may be stated, that mixed with the sand and gravel of these water-bearing sheets, clay nodules are sometimes found which show the shaping influence of flowing water. In excavating the surface well supplying this institution with water these nodules were found plentifully in the gravel sheet, varying from one to eight or ten inches in diameter.

This sand and gravel sheet does not obtain its supply of water by the simple percolation of water falling on the surface of the ground. The impervious nature of the superimposed clay forbids. These inclined sheets must be regarded as carriers of the underflow waters of streams now extant. Moreover it is undoubtedly true that the non-artesian surface wells reaching the gravel sheets along the stream valleys of eastern South Dakota derive their waters from the underflow of neighboring streams or water courses.

In the case of the Sanborn County basin the origin of the flow appears to be far different. A comparison of these wells with

the deep flow well at Woonsocket reveals a striking similarity. In this case then, it is probable that the gradually ascending gradient of the Dakota sandstone taken together with the continued surface erosion of the upper and later formations have brought the water-bearing rock near the surface, and that the Sanborn County basin belongs to the great artesian basin of the state.

AN ISOLATED SHALLOW ARTESIAN WELL.

An interesting instance of an isolated shallow artesian well came to my notice last July. This well occurs on the farm of Hon. Oliver H. Gibbs, of Ramsay, McCook county. Mr. Gibbs sent me a sample of water writing at the same time as follows: "This water is from a small flowing well at the bottom of one of the gulches on my farm. It is only 16 feet deep, but is overlaid with an impervious clay, which makes the water nearly, if not quite, independent of surface conditions. It has been flowing for six years at the rate of about forty barrels per day. It rises in 2-inch black iron pipe and runs off 12 feet in 1¼-inch galvanized iron pipe."

A partial analysis of the water was made showing total solids 1.7568 parts per thousand. Iron, lime and magnesia were present in quantity as carbonates and sulphates. Chlorine was present in minute quantities only, while sulphuretted hydrogen occurred more plentifully.

Thinking that perhaps another small shallow basin unknown to me might possibly exist at that point I wrote Mr. Gibbs for further details. In his reply he states: "I do not think there is any basin here, for I have bored with a hand auger in several places in the same gulch where the well is, all the way from 30 to 90 feet deeper without finding water. In drilling a 6-inch well lower down the gulch we first struck water at 135 feet and drilling to 151 feet we found the Sioux Falls jasper rock.

"My theory of the little flowing well is that it comes from a crevice in the underlying jasper, and finding its way to within 16 feet of the surface is there met by an impervious stratum of clay. It then flows off under this stratum crosswise to a gulch in a south-westerly direction, coming to within six feet of the surface in the next gulch ½ mile distant, south, where I tapped

it with a post auger. I was guided to the spot by a small leak at the surface which never dried up.

"This is my opinion, but for all that, I wish you were here to make an examination for yourself."

While I have had no opportunity to make an examination of the well and its surroundings, nevertheless, it is certain that the water sent to me did not originate in any seepage from the deep artesian basin. It is more than likely that Mr. Gibbs has penetrated either an inclined gravel sheet or the underflow of some water course obliterated or extant.