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The Artesian Waters of South Dakota

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The Artesian Waters of South Dakota.

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The Artesian Waters of South Dakota.

JAMES H. SHEPARD, Chemist.

The artesian waters of South Dakota are used for three distinct purposes. In the first place they are used by cities as the source of water supply. When thus used they are employed for domestic use, for sprinkling lawns and gardens and for fire protection. Closely akin to these are the township or neighborhood wells where the water is used conjointly by communities for watering stock and for domestic use.

In the second place these waters are used for irrigating purposes mainly and for domestic use incidentally. In such cases the well may be owned by an individual or it may be owned by a stock company.

In the third place the waters of some wells are used wholly for power purposes; but the wells thus used are few in number. In any one of the cases mentioned the surplus waters may be used for the purpose of creating running streams or for creating artificial ponds or for irrigation. In some cases, however, the surplus water is discharged directly into some river or stream where it flows to waste. Most of the wells have controlling devices whereby the surplus water is reduced to a minimum. But in case the well is faulty in construction it runs without control.

The analysis of these waters was undertaken in the interests of the first two uses for which the water is employed. It is scarcely necessary to state that a chemical analysis could have little or no value in the case of a water employed for power purposes only. But when it comes to a question of sanitation, or healthfulness, or a fitness of these waters for irrigation the case is far different. No regular or systematic chemical investigation of the water supply of the great artesian basin has ever been made. It is true that a few partial analyses for special purposes have been made from time to time; but nothing like a complete examination has been undertaken. It was also hoped that the investigation might throw some light upon other obscure questions relating to the origin and movement of these underground waters.

In order to cover the field as completely as possible, wells were chosen which were geographically distributed as uniformly over the whole artesian basin in South Dakota as the circumstances in the case would permit. When several wells occurred at the same point, various considerations led to the choice made. Sometimes it was the vein or flow from which the water comes and sometimes it was the purpose for which the water is employed that decided in the final selection. When the list was completed it was recommended by the Station Council and sanctioned by the governing boards. State Engineer of Irrigation, C. S. Fassett, gave valuable advice in locating the wells.

The samples were taken from each well by Mr. C. G. Hopkins, then Assistant Chemist of this Station. He also observed the temperature of each well and collected such data as he was able to obtain. In many cases no log of the well had been kept by competent observers; and it was not possible for him to ascertain the difference in level between the railroad station and the mouth of the well. But this difference is never very large and considering the inaccuracy of some of the other information in regard to the depth of the well it is unessential. Some towns report that it is the general belief that fraudulent depths had been claimed by contractors in order to secure more money on their contracts than the true depth called for.

The samples collected were forwarded to the Station in sealed packages and none of the seals were broken. Thus the authenticity of all the samples is unquestionable.

SYSTEMIC EFFECTS OF ARTESIAN WATER SALTS.

Among the questions most frequently asked are: "What are the medicinal values of the salts carried by these artesian waters, and what would be their effects upon the human system?" Perhaps no better opportunity will ever offer than the present to answer this question fully. Therefore each salt will be considered separately.

SODIUM CHLORIDE, $NaCl$—This compound is the well known common "salt" so widely used for domestic purposes. It is not necessary here to recall its varied uses in domestic economy nor to discuss its importance to animal life. All these facts are well understood. But its uses in medicine are not so commonly known.

In small doses of from 10 grains to one drachm, or of .65 grams to 4 grams it is a stomachic tonic and an anthelmintic. In larger doses of from 8 to 15 grams it is a cathartic; still larger doses of from 15 to 30 grams dissolved in a little water, in many cases, act as an emetic which invigorates rather than depresses the system. It is also a styptic useful in checking internal hemorrhages or in stopping the flow of blood from external wounds.

Externally it is useful in sprains and bruises and its tonic value in the form of a "salt bath" is well understood.

Salt which has been taken into the system is rapidly removed by the kidneys. Sodium chloride is present in most of the drinking waters of this country whether they are derived from surface wells, from springs, or from running streams.

SODIUM BICARBONATE, $NaHCO_3$—This is also a well known salt which is largely employed iu preparing effervescent drinks and medicines. It is used in enormous quantities in preparing baking powers. In the analyses the compound formed between sodium and carbonic acid is given as the normal carbonate, Na_2CO_3. The bicarbonate passes into this form upon the application of heat to the dry salt. In medicine the bicarbonate is used as an antacid. It has been found valuable in cases where an excess of uric acid has caused calculous deposits. It has been found useful in diabetes since it lessens the sugar in in the urine. The dose for an adult is from .65 to 4 grams. It is further employed in cases of croup, pneumonia, and membranous angina.

This salt is not a common constituent of drinking waters either in this state or elsewhere.

SODIUM SULPHATE, Na_2So_4. This salt is commonly know as Glauber Salts. In doses of from 15 to 32 grams it acts as a hydragogue cathartic. When it is taken in smaller doses it acts as an aperient and a diuretic. It is not much used in medicine at present as most practitioners prefer magnesium sulphate instead. Veterinarians however, employ it extensively in their pratice.

This salt is not of uncommon occurrence in drinking waters.

CALCIUM CARBONATE, $CaCO_3$—This compound occurs abundantly in nature in impure forms known as limestone, chalk, marble, calcite, etc. The pure salt is used in medicine as an antacid and it is especially useful in cases of diarrhœa when accompanied by an acid condition of the digestive tract. It is employed as a remedial agent for gout, dyspepsia and acidity of the stomach. Its use in scrofulous diseases is followed by good results. The dose for an adult is from .65 to 3 grams. Externally it is beneficially applied to burns and scalds.

This compound occurs in drinking waters nearly everywhere.

Ferrous Carbonate, $FeCO_3$—In the analyses the iron is reported in the form of ferric oxide, Fe_2O_3. But as one would naturally infer, iron does not exist in the natural waters in this insoluble condition. As it occurs in solution it is in the form of ferrous carbonate, a tonic and chalybeate. When the water is evaporated or when it has stood for some time the ferrous carbonate is decomposed and the iron is thrown down as a reddish sediment consisting largely of the ferric oxide and hydroxide. Upon the application of heat the conversion to ferric oxide is completed.

Ferrous carbonate occurs in most drinking waters.

Calcium Sulphate. $CaSO_4$—In an impure form this compound occurs as gypsum. When calcined it is known as Plaster of Paris. It probably exerts little effect upon the system; at least it is not given internally. It is a common constituent of drinking water.

Magnesium Carbonate, $MgCO_3$—Magnesium carbonate is an antacid and in most cases a laxative. The dose is from 1 to 2 grams. It is largely used in the preparation of medicated waters.

Magnesium Sulphate, $MgSO_4$—This salt is commonly known as Epsom Salts. It is an active but safe refrigerant cathartic operating with little pain or nausea. It is more acceptable to the stomach than most medicines. It is useful in colic and in severe cases of constipation and operates without relaxing the stomach and bowels. A moderate dose is 1 ounce or about 31.1 grams. In smaller doses magnesium sulphate may act as a diuretic. It is a common constituent of drinking waters.

Lithium Salts.—Lithium is a rare metal and its salts are seldom found in drinking waters. By a spectroscopic examination these salts have been found to exist in all the artesian waters analyzed. The lithium salts are valuable in treating rheumatism.

EFFECT PRODUCED BY A COMBINATION OF SALTS.—It is impossible, except in a general way to predicate just what the effects of any combination of salts as they occur in natural waters would be. To a certain extent they each modify or accentuate the effect which any one would produce singly. If all the salts carried by any water had the same tendency the result might easily be foretold. But such waters are rare. It seems as if nature modifies and ameliorates the effects produced by the salts in mineral waters just as the skilled pharmacist ameliorates the effect of one drug by a skillful and judicious combination with others. In general it would be safe to say that the artesian waters as a rule are tonic-laxative in their effects upon the system.

All the artesian waters of this state carry a larger amount of salts than would be desired in a first-class potable water. But it nevertheless remains a fact that in some cities these waters are used with impunity for all domestic purposes and in fact no other water is used at all. From these places no complaint comes as to any injurious effect. Moreover, wherever the water is used for watering stock no unfavorable results follow. In fact stock seems to thrive by its use. At any rate it is far preferable to the stagnant water which stock is so frequently compelled to drink in other sections of the country.

The explanation as to why water carrying a more than ordinary amount of salts may be used for drinking purposes without injurious results, especially in the case of these artesian waters, may not be difficult to find. The following ones suggest themselves most readily. In the first place these waters are free from organic contamination and consequently carry no germs of contagious disease. Consequently the energies of the system are neither weakened nor prostrated at any time by these more to be dreaded agencies which are at work where organically impure waters are used for drinking purposes. It may be that the system finds it less difficult to eliminate the excess of saline compounds than it does to ward off the injurious effects of albuminoid poisons and disease germs. Then again it is a well known fact that one finally becomes accustomed to a certain water and that the system finally thrives best upon it, even though at first it was not particularly palatable. In these cases it seems that the system actually adjusts itself to the elimination of any surplus that might by its accumulation prove detrimental. It is a well known fact that persons accustomed to the use of hard waters upon going into a country where soft waters prevail, actually find the soft waters flat and unpalatable. The water seems to lack something to the taste, and physiological symptoms seem to indicate that the system also misses some of the constituents of the hard waters.

The only complaints concerning the use of artesian waters as potable waters that have come to my knowledge are that at first they had proven laxative in some cases. But this effect soon passes off as a rule. Then again many complain that the water is too warm and consequently somewhat unpalatable, just as any water is under like conditions. This is usually remedied by cooling the water before it is used.

In some places where artesian water is used for other purposes, it is not used for drinking. In these places a supply of water with less salts is available and more palatable.

In this connection it might be well to say that in these towns where first-flow, soft artesian waters are used for drinking purposes, should any evil effects ensue, that the corrective which most readily suggests itself would be fruit acids. The acids of fresh fruits would certainly tend to neutralize the effects of the ant-acid salts the waters contain.

Another thought suggests itself here, and that is, one would need to drink an inordinate quantity of most of these artesian waters to get any other than a tonic effect from any of the salts held in solution. This will become apparent to any one who cares to take the trouble to make the necessary computation. It is probable that the laxative effects arise from the combined influence of the principal salts and more especially from a cumulative effect caused by their continued use. It is not unreasonable to suppose that after tbe system has become adjusted to the water, that the cumulative effect ceases owing to a prompt elimination of any excess of the salts in question.

THE EFFECTS OF ARTESIAN WATER SALTS UPON SOILS AND PLANTS.

To the irrigator there is no question of greater importance than those relating to the effects produced upon soils and plants by the saline constituents of the water which he is applying to his land. Waters may carry salts that act as fertilizers or they may carry substances detrimental to soil and vegetation alike. Again they may carry such large amounts of salts, which of themselves in ordininary quantities are either beneficial or harmless to vegetation, that the soil may become overcharged and barren. And further the salts though small in quantity may be such as destroy the tilth of the land or they may cause crops to wither away and die.

In discussing the effect of any water upon soils and vegetation it will be necessary to take up each of its saline constituents in detail. There is one other fact, which should at the outset be set forth clearly, and which is true of every saline substance however valuable it may be as a fertilizer or as a plant food, and that is, the addition of any salt to a soil will not increase the fertility of that soil provided there is already present a sufficient supply of the salt to meet all the requirements of plant growth.

SODIUM CHLORIDE, NaCl.—This salt has been applied to land since time immemorial. It is more beneficial to inland soils where there is a deficiency of the salt. In soils where plenty of this compound exists further applications are not beneficial.

In its action common salt is not a direct fertilizer since plants as a rule require little sodium; small quantities of chlorine also will meet all requirements. It is one of the so-called "indirect" fertilizers. Its value when applied to soils may be attributed to the following causes:

1. It acts upon the undecomposed rocky constituents of soil liberating lime, magnesia, and phosphoric acid for plant use. Its greatest action is upon lime and then upon the other substances in the order named. These substances which in their undecomposed state were mostly combined as insoluble silicates, through the kindly offices of salt assume a soluble condition in which form plants can readily assimilate them.

2. Salt also tends to check a too rank growth of stalks and straw; and it is often applied to over fertile soils for this purpose. It is also mixed with other powerful fertilizers, such as gauno, to modify their action. It gives the best results upon grains, grasses, cotton, hemp, asparagus, cabbages, tomatoes, celery, onions, horse radish, cauliflowers, etc. It is not applicable to potatoes since it diminishes the yield and makes the tubers waxy. The amount that is applied per acre varies from 200 to 600 pounds.

An over dose of salt is fatal to all vegetation. It is more destructive to young plants than it is to older ones, hence its frequent use for destroying young weeds where the crop has attained some size. As a germicide salt is supposed to possess some virtues. It is thought to be destructive to the spores of the fungous diseases of various plants.

3. Salt is also beneficial to the tilth of land since it flocculates clay and prevents it from puddling. It is a commonly known fact that the addition of salt to the roily waters of a well will coagulate the suspended clay causing it to settle and leaving the water clear.

An excess of salt is detrimental to the process of nitrification which is going on constantly during plant growth in fertile soils. An excess therefore prevents the plant from obtaining sufficient nitrogen to reach maturity. This action of salt might be readily surmised from its well known antiseptic properties as illustrated in the use of brine in the preservation of meats and other substances.

The only remedy for a soil surcharged with common salt is efficient and thorough drainage.

SODIUM SULPHATE, Na_2SO_4.—This salt is a valuable fertilizer for cereals, potatoes, grasses, clovers, peas, and other legumes. It is applied in doses of from 175 to 250 pounds per acre.

This sulphate as well as those to be mentioned hereafter act in soils as oxidizing agents. By this action nitrogen in nitrogen compounds is changed into ammonia, carbon into carbon dioxide, etc. The ammonia thus produced is now seized upon by the nitrifying organisms in the soil and converted into nitrites and nitrates. It is from these forms that plants largely secure nitrogen for building up their albuminoids. Moreover these albuminoids contain sulphur obtained from the breaking down of these same sulphates.

Sodium sulphate is one of the chief ingredients of the so called "mild" or "bland" alkali which occurs as an incrustation on low places in various parts of this state. These places are mostly small, a few rods in diameter, and this salt can be removed from them by drainage. By means of deep plowing and by the admixture of much coarse manure to decrease the capillarity of the soil in these places, large crops of grasses may be obtained. But the permanent cure of all soils overcharged with this salt is drainage.

SODIUM CARBONATE Na_2CO_3.—This compound has a favorable effect upon vegetation when it is present in small quantities in soils rich in organic matter. It furnishes a readily salifiable base to unite with the nitrous and nitric acids produced by the nitrifying organisms present in all fertile soils. The organisms convert this carbonate into sodium nitrite and nitrate, valuable fertilizers.

But when present in large quantities the sodium carbonates constitute the dreaded "black alkali" which occurs in undrained places in California, India and elsewhere. Black alkali is pernicious in its action upon both soils and plants. It puddles clayey soils, or as it is usually termed turns them into "gumbo." It also dissolves the humus of fertile soils which it leaves in black rings or patches as the water evaporates from places where it has been standing in puddles. It is owing to this circumstance that it has received the name of black alkali. Its action on plants is corrosive, actually eating off the plant at the crown. Moreover this salt, as well as all of the sodium salts, has a tendency to creep upward. The rising soil waters bring them up to the surface and leave them as a white incrustation on the surface of the soil. Waters carrying much sodium carbonate should not be used for irrigation, unless, indeed, the land is first thoroughly underdrained.

Analyses of the Rio Grande river waters covering a period from June 1st, to Nov. 1st, 1893, show an average of .0036 parts of sodium carbonate per 1000. (Bul. 12, N. M.) This water is considered excellent for irrigation.

Hilgard gives the analyses of two artesian waters from the San Bernardino Valley carrying respectively .0102 and .0021 parts of sodium carbonate per 1000. (Waters and Water Supply, 1889.) He also reports in Warm Creek waters supplying the Riverside Canal, .020 parts per 1000. These waters are considered good for irrigating purposes. In the California report for 1888 and 1889 he gives the analysis of the artesian water used for irrigation at the San Joaquin Station. This water has .0334 parts of sodium carbonate per 1000. He thinks this water would require a corrective such as gypsum.

But it would be difficult to state just how much of this salt might be considered safe for any particular section. An amount that would be safe to use in one place might prove disastrous in another. This uncertainty is due to many factors, such as the saline constituents already present in the soil, and various climatic conditions such as rainfall, winds, humidity of the atmosphere, etc. Moreover, the mechanical condition of the soil and subsoil together with the natural drainage constitute important factors in the problem. These will be discussed further on.

Soils containing an excess of sodium carbonate may be reclaimed by applications of gypsum or by drainage or by both. There is a reaction between the gypsum and the sodium carbonate whereby the carbonate is converted into the sulphate, in which condition it becomes mild, while the gypsum is changed into lime. Drainage simply carries the salt away. Sometimes it is best to apply the gypsum first and then drain afterward. This would undoubtedly be the best plan for reclaiming the small gumbo patches which are found in a few places in this state. In this way the humus would be retained and the surplus of salts removed without detriment to the land. Such spots would then become exceedingly fertile and easy of cultivation.

It will be noticed that none of the second flow wells contain sodium carbonate. In the Miller well, a first-flow well, sodium carbonate is also wanting. This is probably due to the fact that the water has come in contact with or has passed through deposits of gypsum occurring in the water bearing rock itself. This supposition is strengthened by the large amount of sodium sulphate present. Another striking case is found in the Aberdeen well where the first and second flow waters are intermingled. Here the gypsum of the second flow well has transformed nearly all of the sodium carbonate of the first flow, only .010 parts of the carbonate per thousand remaining.

MAGNESIUM SULPHATE, $MgSO_4$.—Magnesium compounds are indispensable to plant life. They form an important part of the herbaceous and woody parts of plants and occur in the ashes of all seeds. It is in the seeds, however, that magnesium compounds occur most plentifully. It appears that calcium and magnesium salts act more favorably when they are used in conjunction.

Besides acting as a direct plant food magnesium compounds also aid largely, and to a greater extent than sodium compound do, in the decomposition of soils to liberate potash and phosphoric acid in soluble forms. Magnesium salts are applicable to all crops. Magnesium sulphate is used in compounding certain special manures. It is also occurs to a considerable extent in the white incrustations of soils. In such cases, if it is too abundant, it can be rendered insoluble by applications of calcium carbonate or lime stone. The lime stone is thus changed to gypsum while the magnesium sulphate is changed into the more insoluble magnesium carbonate.

MAGNESIUM CARBONATE, $MgCO_3$.—This compound of magnesium is usually preferable to the sulphate, especially where the soil already has sufficient sulphates, owing to its greater insolubility. This carbonate is frequently applied to lands where dolomite or magnesium limestone is used. Its actions is beneficial to soils and crops alike.

CALCIUM CARBONATE, $CaCO_3$—Lime stone soils are famed for their fertility. It is not strange that this should be so. Lime improves the tilth of soils, prevents clay from puddling, promotes nitrification, assists in the decomposition of soils, and besides all this it is itself an important plant food. For our soils it is probable that the carbonate as it exists in our artesian waters is preferable to burned or quick lime. The amount that may be applied per acre is large, probably much larger than would be supplied by artesian waters for years to come. From 2 to 10 tons per acre of quick lime are used and in some countries this application is repeated every six or eight years. Lime may be applied to all crops and acts advantageously where the supply of organic matter is fully maintained. If the organic matter is not maintained, lime aids materially in the rapid exhaustion of soils.

Calcium carbonate is also an efficient agent in sweetening sour and boggy soils a property possessed by no other salt of calcium.

CALCIUM SULPHATE, $CaSO_4$.—Gypsum has been applied to land for many years. Its probable effects upon soils and vegetation have been a cause of much writing and speculation by agricultural chemists. So much indeed has been written concerning gypsum, and so many different qualities have been assigned to it and so many theories as to its action have been advanced that even a brief resume of all these here would be neither possible nor profitable. It is generally conceded that it may act in many respects like the common carbonate of lime, like the other suphates previously mentioned, and that it may fix the volatile ammonium carbonate of soils by converting it into the nonvolatile sulphate while the gypsum itself passes into calcium carbonate.

It acts as a stimulant to plant growth in soils where lime and sulphates are wanting and it may applied to any crop. But its best effects have been observed upon corn, grasses and clovers.

Some agriculturists maintain that gypsum aids crops to withstand drouth. There may be some reason in this since gypsum contains two molecules of water of crystallization. From this water it is exceedingly loth to part. So great is the tenacity with which this water is held that some agriculturists maintain that the plant is unable to appropriate it. But it may be possible that the powers of the plant in this direction have been underrated. One fact concerning it, however, is certain and that is that when gypsum bas been deprived of any or all of its water of crystallization it becomes exceedingly hygroscopic, so much so in fact, that it will soon make good its loss from the atmosphere if necessary or from dew, rain or soil moisture. No one is more painfully aware of the hygroscopic nature of gypsum than the chemist who is endeavoring to find the exact weight of the water free residue of a water carrying much gypsum. It does not seem wholly impossible then that gypsum might act as a water carrier between the plant and the atmosphere.

In this connection it might be well to mention that crystallized sodium sulphate contains ten molecules of water of crystallization and crystallized magnesium sulphate contains seven. They part with this water more readily than gypsum, and consequently they too might exert some influence in this direction.

SILICA, SiO_2, AND FERRIC OXIDE, Fe_2O_3.—In natural waters these substances do not occur in these insoluble forms. But when the water is evaporated they assume the forms given here. Our soils are abundantly supplied with both substances. Both are necessary to plant growth and since they assume the insoluble condition so readily there is little danger of an injurious accumulation of them in our soils.

In the regular course of analysis alumina is thrown down with the iron; but the quantity of both in any of the artesian waters is so small that no separation was attempted. Both are reported as ferric oxide.

SOME NUMERICAL CONSIDERATIONS.

In the reports of the analyses which follow, the amount of each salt that each water carries is given in grams per litre or approximately in parts per 1000 at 73 ° F. There is no uniform practice followed by analysts in reporting results. Sometimes the results are given in parts per 10,000, or in parts of 100,000 or even in parts per 1,000,000. Should it be desired to reduce the results given in this bulletin to any one of the other ratios it would simply be necessary to multiply them by 10, 100, or 1000 as the case might be.

Again some analysts report results in grains per Imperial gallon. The results as given here may be reduced to that scale by multiplying by 70. Again if it be desired to reduce the results as here given to grains per U. S. gallon, that may be accomplished approximately by multiplying by the factor 58.3296, since the U. S. gallon of water at 60 °F. weighs 58.329.6 grains.

But for some purposes it is simpler to report results in parts per 1000 since it simplifies computations. For example if we wish to determine how many pounds of residue per acre the waters of a well will furnish the soil when a certain number of inches of water are used for irrigation purposes, the results may be obtained by multiplying the total solids of that water first by 2, then by

113.17, and then by the number of inches of water applied. The result obtained is so many pounds per acre.

The chemical terms employed in the analyses have been already explained. It might be well to say here that the salts are reported in the anhydrous condition. The following data are given to facilitate other computations that may be desired:

1 gram=15.432 grains,=.03527 oz. avoirdupois=.03215 oz. troy.

1 litre=33.8149 fluid oz.=2.113 pints.

DESCRIPTIONS AND ANALYSES.

YANKTON (WHITING) WELL.

This well was put down in the year 1893 for the purpose of irrigating Mr. Whiting's nursery. The well has uever clogged nor thrown sand and the water is bard and very clear. First a 4½ inch casing was sunk for a distance of 185 feet. Then the bore of the well was contracted. A three inch pipe extends from the top to the bottom of the well lacking twenty feet. The last 22 feet were perforated. The drilling extended into the water bearing rock for a distance of 85 feet. About three smaller flows were obtained before the large flow was reached. Some think that by going deeper still another flow may be had, but this is merely conjecture. The analysis indicates second flow water. Mr. Geo. H. Whiting, the owner of the well furnished the information.

The altitude of Yankton is 1196 feet above the sea level according to rail road surveys. The mouth of the well is about 3 feet higher. The well is 521 feet deep and the bottom of the well is about 678 feet above sea level. The pressure is 49 pounds per square inch when the well is closed. Mr. C. S. Fassett, State Engineer of Irrigation, estimates the flow to be from 300 to 400 gallons per minute, but the flow has never been measured.

For irrigating purposes, the waters of this well are among the best in the state. The residue of solids carried by this water is less than that of any other well analyzed. The piping in this well is galvanized and this will make it one of the longest lived wells in the state. After standing a long time the water from this well deposits its iron as a reddish precepitate.

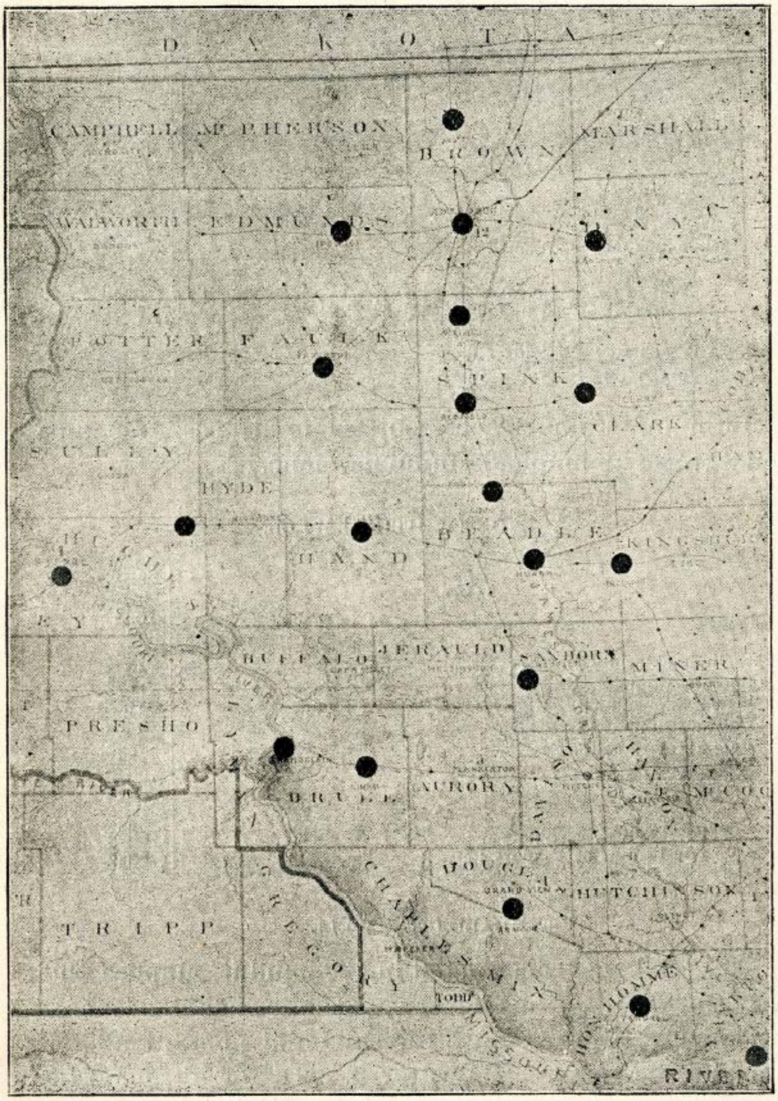
No log was kept for this well but the strata do not differ much in all probability from those encountered in the Carr and Ritchie Mill Well. The log of that well is appended.

*LOG. CARR & RITCHIE MILL WELL, YANKTON.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil, sand and gravel	38	38
2	Chalk rock	62	100
3	Shale	26	126
4	Hard rock	4	130
5	Sand (rock)	34	164
6	Shale	65	229
7	Sand (rock)	25	254
8	Shale	135	389
9	Sand and clay, sand water bearing	100	489
10	Water bearing sand (rock)	106	595

*Vol. 4, Senate Ex. Doc. 1891-2.

Since no uniform practice prevails in combining acids and bases to form salts, the bases and acids will be reported as well as the salts.



ARTESIAN BASIN IN SOUTH DAKOTA.

YANKTON (WHITING) WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.7860
Chlorine, Cl	.0996
Ferric oxide, Fe_2O_3	.0032
Lime, CaO	.4304
Magnesia, MgO	1054
Silica, SiO_2	.0070
Soda, Na_2O	.1384
Carbon dioxide CO_2	.0548
Total	1.6248
Oxygen displaced by chlorine	.0225
Total bases and acids	1.6023
Total solids by evaporation	1.6052

Lithium, strong traces; potassium, traces; free ammonia, trace; albuminoid ammonia, none.

YANKTON (WHITING) WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl,	.1643
Sodium sulphate, Na_2SO_4	.1172
Magnesium sulphate, $MgSO_4$	.3160
Calcium sulphate, $CaSO_4$	.8700
Calcium carbonate, $CaCO_3$	.1246
Silica, SiO_2	.0070
Ferric oxide, Fe_2O_3	.0032
Total salts	1.6023
Total solids by evaporation	1.6052

TYNDALL CITY WELL.

This well was constructed in 1888 and it supplies the city with water. It has never clogged nor has it been repaired. It has thrown but little sand and none at all for the past three years. The water is used for all domestic purposes (except washing) and for watering lawns and gardens. One weak flow was passed before striking the one in use. The analysis shows that the water comes from the second flow. There are upwards of 40 wells in this county. The water comes through a 4½ inch common iron casing extending throughout the whole depth of the well. The information was furnished by Mayor V. Kabena.

The altitude of Tyndall is 1418 feet and the depth of the well is 735 feet. Consequently the bottom of the well is about 683 feet above the sea level. The pressure is 39 pounds per square inch and the flow is 530 gallons per minute. The temperature is 62.6° F.

By long sedimentation this water deposits a reddish iron precipitate.

The Log of this well is as follows:

*LOG OF TYNDALL CITY WELL.

NO.	KIND OF ROCK.	Thickness.	Total.
1	Loam	4	4
2	Yellow clay	40	44
3	Blue clay	171	215
4	Shale	100	315
5	Hard rock	7	322
6	Shale	75	397
7	Sand (rock)	60	457
8	Shale	243	700
9	Water bearing sand rock (Stopped on quartz).	35	735

*Vol. 4, Sen. Ex. Doc. 1891-2.

TYNDALL CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9842
Chlorine, Cl	.1478
Lime, CaO	.5118
Magnesia, MgO	.1346
Ferric oxide, Fe_2O_3	.0246
Silica, SiO_2	.0076
Soda, Na_2O	.1732
Carbon dioxide, CO_2	.0398
Total	2.0236
Oxygen displaced by chlorine	.0333
Total bases and acids	1.9903
Total solids by evaporation	1.9938

Lithium, strong traces; potassium, traces; ammonia, free and albuminoid, none.

TYNDALL CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.2438
Sodium sulphate, Na_2SO_4	.1002
Magnesium sulphate, $MgSO_4$	.4036
Calcium sulphate, $CaSO_4$	1.1199
Calcium carbonate, $CaCO_3$	.0905
Ferric oxide, Fe_2O_3	.0246
Silica SiO_2	.0076
Total salts	1.9902
Total solids by evaporation	1.9938

ARMOUR CITY WELL.

This well supplies the city water works. It was drilled in 1890. The water is used for all domestic purposes; in fact other waters are not much used in Armour. The well has never clogged nor thrown sand since it cleared itself the first week after it was completed. At this time it threw out about one hundred loads of sand. The water is hard and very clear and the analysis shows that it comes from the second flow. Upon long standing it deposits a reddish precipitate of iron compounds.

An 8-inch casing goes down about 400 feet. Inside, a 6-inch pipe extends from the top to within about 70 feet from the bottom. This last 70 feet is not cased. Mr. B. F. Boylan furnished the information.

The pressure of this well is 57 pounds per square inch and the flow is 1600 gallons per minute. The temperature is 68.3° F. The elevation of Armour is 1514 feet. The depth of the well is 757 feet and the bottom of the well is about 757 feet above the level of the sea. The log of the well is as follows:

*LOG OF THE ARMOUR CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil	1	1
2	Yellow clay (sandy)	39	40
3	Blue clay (greasy)	47	87
4	Blue shale	119	206
5	Black shale	49	255
6	Chalk rock	52	307
7	Lime rock (blue)	26	333
8	Yellow sand rock	25	358
9	Yellowish sand rock soft	10	368
10	Gray sand rock very soft	22	390
11	Blue shale	50	440
12	Soap stone	25	465
13	Gray shale	58	523
14	Blue shale	83	606
15	Lime rock (yellowish)	25	631
16	Blue shale	60	691
17	Layers of sand and shale	10	701
18	Sand rock (pure)	56	757

*Vol. 4, Sen. Ex. Doc. 1891-2.

ARMOUR CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	1.0214
Chlorine, Cl	.1745
Lime, CaO	.5214
Magnesia, MgO	.1671
Ferric, oxide, Fe_2O_3	.0122
Silica, SiO_2	.0090
Soda, Na_2O	.2046
Carbon dioxide, CO_2	.0684
Total	2.1786
Oxygen displaced by chlorine	.0394
Total bases and acids	2.1392
Total solids by evaporation	2.1386

Lithium, strong traces; potassium, traces; free ammonia, trace; albuminoid ammonia, none.

ARMOUR CITY WELL.

SALTS.	Parts per 1000
Sodium Chloride, NaCl	.2879
Sodium Sulphate, Na_2SO_4	.1186
Magnesium Sulphate, $MgSO_4$	.5011
Calcium sulphate, $CaSO_4$	1.0550
Calcium carbonate, $CaCO_3$	.1554
Ferric oxide, Fe_2O_3	.0122
Silica, SiO_2	.0090
Total salts	2.1392
Total residue by evaporation	2.1386

CHAMBERLAIN MILL WELL.

This well was constructed in 1890 for the purpose of supplying power to a flouring mill. It answered this purpose admirably, but it is thought that the bore through the cap rock was too large for the pipe. This has caused a leak around the pipe which necessitated repairs this season. The leak is nearly closed but the repairs are not completed at this writing (November).

This is an eight inch well throughout and it yields a flow of 5000 gallons of water per minute, with a pressure of 95 pounds to the square inch. But the pressure varies somewhat depending upon the leakage. The water flows clear and comes from the second flow having a temperature of 71.6° F. This water deposits a reddish sediment of iron compounds upon standing.

The altitude of Chamberlain is 1370 feet and the well is 600 feet deep. The bottom of the well is about 770 feet above the sea level. Mr. Hopkins could obtain no information concerning the rock passed through but the strata could not vary much from that of the city well which is given below in a condensed form. The city well is on a high bluff while the mill well is lower down and close to the Missouri river. The bottom of mill well is in open sand rock. In this respect it differs from the city well. There is also less over lying clay.

*LOG OF CHAMBERLAIN CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil	3	3
2	Clay	107	110
3	Blue clay	15	125
4	Shale	30	155
5	Chalk rock	260	415
6	Shale	85	500
7	Slate	21	521
8	Sand rock	17	538
9	Shale	12	550
10	Shale with layers of soft sand	50	600
11	Shale	113	713
12	Iron pyrites and sand, first flow	3	716
13	Sand rock	4	720
14	Shale	38	758
15	Sand rock, second flow	2	760
16	Sand rock	15	775
17	Shale	5	780
18	Iron pyrites, sand shale	5	785

*Vol. 4, Sen. Ex. Doc. 1891-2.

CHAMBERLAIN MILL WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	1.0440
Chlorine, Cl	.1091
Lime, CaO	.4554
Magnesia, MgO	.1579
Ferric oxide, Fe_2O_3	.0116
Silica, SiO_2	.0088
Soda, Na_2O	.2536
Carbon dioxide, CO_2	.0692
Total	2.1096
Oxygen displaced by chlorine	.0246
Total bases and acids	2.0850
Total solids by evaporation	2.0826

Lithium, strong traces; potassium, trace; ammonia free, trace; albuminoid ammonia, parts per million, .02.

CHAMBERLAIN MILL WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.1800
Sodium, sulphate, $NaSO_4$	.3618
Calcium sulphate, $CaSO_4$	.8920
Magnesium sulphate, $MgSO_4$	.4735
Calcium carbonate, $CaCO_3$	.1573
Ferric oxide, Fe_2O_3	.0116
Silica, SiO_2	.0088
Total salts	2.0850
Total solids by evaporation	2.0826

KIMBALL CITY WELL.

This well was drilled in 1886 for city uses. It has never been repaired and has never thrown sand worth mentioning. The diameter of the well is 6 inches at the top and 4½ inches at the bottom. It is not known whether the pipe extends to the bottom or not. In drilling this well the first flow was reached at 967 feet and the present flow at 1002 feet. It is claimed that in other wells another flow has been found about 90 feet deeper. Mr. E. P. Ochsner gave the information.

The temperature of this well is 66.9° F. And the analysis indicates a second flow well. The water yields the usual deposits of iron compounds found in other second flow wells. The depth of this well is 1067 feet and the elevation is 1823 feet, making the bottom of the well 756 feet above sea level. The closed pressure is 22 pounds per square inch and the flow is 300 gallons per minute.

*LOG OF THE KIMBALL CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Clay	230	230
2	Quicksand	100	330
3	Shale	610	940
4	Sand rock	20	960
5	Salt and rock	20	980
6	Hard rock	8	988
7	Soft sand rock	80	1068

*Vol. 4, Sen. Ex. Doc. 1891-2.

KIMBALL CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	1.0698
Chlorine, Cl	.1023
Lime, CaO	.5277
Magnesia, MgO	.1612
Ferric oxide, Fe_2O_3	.0090
Silica, SiO_2	.0072
Soda, Na_2O	.1861
Carbon dioxide, CO_2	.0720
Total	2.1353
Oxygen displaced by chlorine	.0231
Total bases and acids	2.1122
Total residue by evaporation	2.1166

Lithium, strong traces; potassium, traces; free ammonia, trace; albuminoid ammonia, none.

KIMBALL CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, $NaCl$	.1688
Sodium sulphate, Na_2SO_4	.2211
Magnesium sulphate, $MgSO_4$	.4834
Calcium sulphate, $CaSO_4$	1.0592
Calcium carbonate, $CaCO_3$	.1636
Ferric oxide, Fe_2O_3	.0090
Silica, SiO_2	.0072
Total salts	2.1123
Total solids by evaporation	2.1166

WOONSOCKET CITY WELL.

This well was drilled in 1890 for city uses. When first made it was cased with 6-inch casing down to the cap rock, a distance of 680 feet. The well was shut off entirely in the fall of 1891. Upon opening an immense amount of detritus was thrown out and the flow has never reached its original volume since. When first opened it flowed 3300 gallons per minute. After much difficulty the well was repaired by inserting a 4 inch pipe. Since that time the water has been nearly clear. It comes as has been supposed from the second flow. But the analysis would seem to indicate a first flow water that has been transformed by coming in contract with beds of gypsum. The large amount of sodium sulphate present hardly seems probable in a pure second flow well.

This is about the only water used in Woonsocket. Its temperature is 61. 5 ° F.

This well was faulty in construction. The last 41 feet should have been cased with perforated pipe. Had this been done no doubt the well would be running through the original 6 inch casing with its full force. The original pressure was 153 pounds per square inch, but this has fallen off to 130 pounds, while the flow has diminished under the altered conditions.

The altitude of Woonsocket is 1308 feet and the well is 725 feet deep which leaves the bottom of the well 683 feet above the sea level. It will be noticed that the bottom of this well is about 73 feet lower than that of the Kimball well. If the flow be a first flow the dip of the water bearing rock from Kimball to Woonsocket must be over from 100 to 150 feet in less than 50 miles. The sediment formed in this water by long standing was slight but different from that of the other second flow wells. It had some iron, a little sand and a little clay. The two latter could be accounted for by the faulty construction of the well, but the iron compounds were not so prominent as in the wells previously noted. But the chlorine, lime and magnesia present seem to indicate a second flow well. It is possible that the waters consist of both flows.

*LOG OF WOONSOCKET CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil and clay	110	110
2	Shale	240	350
3	Iron pyrites (soft sand rock)	2	352
4	Shale	180	532
5	Hard sand rock, iron pyrites	30	562
6	Shale	118	680
7	Hard sandcap rock	4	684
8	Soft sand rock (water)	41	725

*Vol. 4, U. S. Sen. Ex. Doc. 1891-2.

WOONSOCKET CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	1.0090
Chlorine, Cl	.0681
Lime, CaO	.3120
Magnesia, MgO	.1234
Ferric oxide, Fe_2O_3	.0072
Silica, SiO_2	.0256
Soda, Na_2O	.4070
Carbon dioxide, CO_2	.0717
Total	2.0243
Oxygen displaced by chlorine	.0154
Total bases and acids	2.0087
Total residue by evaporation	2.0100

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

WOONSOCKET CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.1128
Sodium sulphate, Na_2SO_4	.7941
Magnesium sulphate, $MgSO_4$	.3701
Calcium sulphate, $CaSO_4$	.5360
Calcium carbonate, $CaCO_3$	.1630
Ferric oxide, Fe_2O_3	.0072
Silica, SiO_2	.0256
Total salts	2.0088
Total solids by evaporation	2.0100

EAST PIERRE INDIAN SCHOOL WELL.

This well was sunk for the use of the Indian school located at East Pierre. The purposes for which the water is used are to supply the ordinary needs of the school and to irrigate the large gardens in connection therewith.

An eight inch casing extends down 475 feet into gray shale rock. Within this is a 6 inch casing which extends from the top of the well to within 30 feet of the bottom. The pressure is about 166 pounds to the square inch and the flow is about 900 gallons per minute. The temperature of the water is 91.8 ° F.

This a first flow well and its waters are uuique. It carries a larger residue than any other well of the twenty analyzed. Its waters are charged with methane gas and they also carry au enormous quantity of ammonia for a deep well water. But this ammonia does not militate against the purity of the water, since it probably owes its origin to the same causes that produce the methaue. The strong flow of gas was fouud iu No. 13, at a depth of 800 feet. Other deep wells are reported as carrying small quantities of natural gas which probably come from some coal measures of very limited extent. This water is further remarkable for the almost entire absence of sulphates, the sulphates being replaced by chlorides. It is extremely doubtful if this water proves of value for irrigation. The large amount of common salt and sodium carbonate point in this direction strongly. Its greatest value will probably be found in its medicinal qualities. Another well has been opened at the Locke Hotel, Pierre. The waters are very similar to those of the School well. The East Pierre water gave no sediment upon standing.

The altitude of Pierre is 1440 feet and the bottom of the well is 248 feet above the level of the sea.

*LOG OF EAST PIERRE INDIAN SCHOOL WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Gumbo	10	10
2	Yellow clay (sandy)	25	35
3	Blue sandy clay	20	55
4	Blue clay	17	72
5	Gray shale	20	92
6	Blue shale with hard streaks of rock	88	180
7	Black shale	70	250
8	Blue shale	70	320
9	Gray Shale	145	465
10	Blue lime stone very hard	3	468
11	Gray shale, dark color	132	600
12	Blue shale	110	710
13	Dark gray shale	160	870
14	Yellow lime rock	5	875
15	Blue shale sticky	45	920
16	Blue shale cavey	90	1010
17	Blue shale with streaks of sand and lime	140	1150
18	Sand rock, white, main flow	20	1170
19	Shale light color	22	1192

*1893 Rep. State Eng. Irrigation.

EAST PIERRE INDIAN SCHOOL WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	traces
Chlorine, Cl	1.7004
Lime, CaO	.0432
Magnesia, MgO	.0024
Ferric oxide, Fe_2O_3	.0051
Silica, SiO_2	.0122
Soda, Na_2O	1.8226
Carbon dioxide, CO_2	.2734
Total	3.8596
Oxygen displaced by chlorine	.3836
Total bases and acids	3.4760
Total solids by evaporation	3.4790

Lithium, traces; potassium, strong traces; free ammonia, parts per million, 6.05; albuminoid ammonia, none.

EAST PIERRE INDIAN SCHOOL WELL.

SALTS.	Parts per 1000
Sodium chloride, $NaCl$	2.8052
Sodium carbonate, Na_2CO_3	.5711
Magnesium carbonate, $MgCO_3$	.0050
Calcium carbonate, $CaCO_3$	.0771
Ferric oxide, Fe_2O_3	.0054
Silica, SiO_2	.0122
Total salts	3.4760
Total residue by evaporation	3.4790

HARROLD CITY WELL.

This well was sunk in 1888 for town purposes. An 8-inch casing extends down 405 feet from the top of the well. Within this a 6¼ inch pipe extends downward from the top 1002 feet. In the bottom of the well there are 550 feet of 5⅝ inch pipe, the last eighteen feet of which are perforated. The well has never been repaired. It clogged with sand in 1889, but it was readily opened by means of an iron weight on the end of a rope. It has thrown some sand but for the past year or two the water has been clear. Mr. W. A. Lichtenwallner gave the information.

The altitude of Harrold is 1801 feet and the well is 1453 feet deep, making the bottom of the well about 348 feet above the level of the sea. The temperature of this water is 94.9° F. The closed pressure of this well is 27 pounds to the square inch and the flow is 84 gallons per minute. This water gave no sediment after standing.

*LOG OF HARROLD CITY WELL.

No.	KIND OF ROCK.	Thickness	Total.
1	Soil	2	2
2	Yellow clay	38	40
3	Blue clay	70	110
4	Bowlders in clay	15	125
5	Blue shale	155	280
6	Limestone	2	282
7	Blue shale	168	450
8	Gray shale, streaks limestone	100	550
9	Black shale	50	600
10	Black sandy shale	140	740
11	Gray shale	160	900
12	Blue shale	40	1300
13	Blue shale, streaks limestone	133	1433
14	Lignite	2	1435
15	Sandstone main flow	16	1451
16	Brown shale	2	1453

*Vol. 4, Sen. Ex. Doc. 1891-2.

HAROLD CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.2562
Chlorine, Cl	.4867
Lime, CaO	.0160
Magnesia, MgO	.0274
Ferric oxide, Fe_2O_3,	trace
Silica, SiO_2	.0122
Soda, Na_2O	.8482
Carbon dioxide, CO_2	.2010
Total	1.8477
Oxygen displaced by chlorine	.1098
Total bases and acids	1.7379
Total solids by evaporation	1.7456

Potassium, faint trace; lithium, trace; free ammonia, parts per million, .02; albuminoid ammonia, parts per million, .02.

HAROLD CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.8029
Sodium carbonate, Na_2CO_3	.3817
Sodium sulphate, Na_2SO_4	.4550
Magnesium carbonate, $MgCO_3$	.0575
Calcium carbonate, $CaCO_3$	.0286
Silica SiO_2	.0122
Total salts	1.7379
Total solids by evaporation	1.7456

MILLER TOWNSHIP WELL.

This well is a new one and was completed in 1894. The water is used for watering stock, for all domestic purposes and for watering lawns, trees and gardens. Thus far it has proven very satisfactory. It has not clogged nor thrown sand to any extent. A few grains of coarse sand were found in the sample analyzed, but no sediment was deposited by standing.

The pipes used in the construction of this well are as follows, each extending from the top downward: 213 feet, 6-inch; 680 feet, 4½ inch; and 1106 feet, 3-inch. The bottom lengths of the inner pipe were not perforated. The well is situated in the city but it is owned by the township.

The altitude of Miller is 1586 feet, the depth of the well is 1139 feet, and the bottom of the well is about 447 feet above the level of the sea. The closed pressure is 118 pounds per square inch and the flow is 363 gallons per minute. The temperature of the water is 79.8 ° F.

The following log is taken from the report of Commissioner A. S. Ober to the Miller township board. He concludes his report by saying: "Making the depth of the well 1139 5-12 feet." But it appears upon adding the thickness of the different strata that there is a discrepancy of 52 feet. Just where the discrepancy exists, whether in the thickness of the strata or in the depth of the well I have been unable to learn. This well cost $2,830.50.

LOG OF THE MILLER TOWNSHIP WELL.

No.	KIND OF ROCK.	Thick-ness.	Total.
1	Clay	15	15
2	Sand	3	18
3	Clay	4	22
4	Sand	5	27
5	Sand and clay	26	53
6	Blue clay	10	63
7	Sand	20	83
8	Sand blue clay	62	145
9	Water bearing sand	12	157
10	Light sandy shale	240	397
11	Sand	3	400
12	Sandy shale	10	410
13	Dark shale	130	540
14	Light shale	115	655
15	Dark Shale	121	776
16	Sand rock	3	779
17	Soap stone	169	948
18	Sand rock and iron pyrites	$1\frac{8}{12}$	949
19	Shale	20	969
20	Blue shale and lime rock	54	1023
21	Sand rock	2	1025
22	Shell rock and iron pyrites	28	1053
23	Caprock	10	1063
24	Water bearing rock	$24\frac{2}{12}$	$1087\frac{5}{12}$

MILLER TOWNSHIP WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9667
Chlorine, Cl	.0910
Lime, CaO	.1883
Magnesia, MgO	.0886
Ferric oxide, Fe_2O_3	trace
Silica, SiO_2	.0092
Soda, Na_2O	.6156
Carbon dioxide, CO_2	.0935
Total	2.0529
Oxygen displaced by chlorine	.0205
Total bases and acids	2.0324
Total residue by evaporation	2.0390

Potassium and lithium, traces; free ammonia, parts per million, .03; albuminoid ammonia, parts per million, .04.

MILLER TOWNSHIP WELL.

SALTS.	Parts per 1000
Sodium chloride, $NaCl$	.1501
Sodium sulphate, Na_2SO_4	1.2265
Magnesium sulphate, $MgSO_4$	.2657
Calcium sulphate, $CaSO_4$	.1683
Calcium carbonate, $CaCO_3$	.2125
Silica, SiO_2	.0092
Total salts	2.0323
Total solids by evaporation	2.0390

HURON (RISDON) WELL.

This well is situated a short distance north of Huron. It was constructed in 1891. It was sunk in hopes of obtaining natural gas. At a depth of 960 feet the strong flow of water encountered prevented further work. An 8-inch casing extends downwards 703 feet and within this a 6-inch casing goes from the top to within 58 feet of the bottom. The well is 960 feet deep and the elevation is 1290 feet making the bottom of the well 330 feet above sea level. The closed pressure is 165 pounds to the square inch and the flow is 2250 gallons per minute. This well is supposed to be capable of developing 100 horse power and of covering 20 acres 6 inches deep every 24 hours. The well is under litigation and is not used at present. This water deposits the usual sediment of iron found in second flow wells.

*LOG OF THE HURON (RISDON) WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Ordinary clay and shale to small flow	240	240
2	Rock and iron pyrites	5	245
3	Shale	215	460
4	Limestone, second flow	50	510
5	Shelly lime, third flow	2	512
6	Shale	88	600
7	Sand and shells, fourth flow	5	605
8	Shale	35	640
9	Shelly lime, fifth flow	1	641
10	Shale	49	690
11	Shelly lime, sixth flow	1	691
12	Shale	9	700
13	White shale and sand rock, seventh flow	3½	703½
14	Water bearing rock	29½	733
15	White slate with water	117	850
16	Flint	820	871
17	Sand and slate	20	890
18	Very hard cap rock	12	902
19	Soft sand rock, flow	33	935
20	Soft sand rock, heavy flow	25	960

*Vol. 4, Senate Ex. Doc. 1891-2.

HURON (RISDON) WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9806
Chlorine, Cl	.1240
Lime, CaO	.3340
Magnesia, MgO	.1421
Ferric oxide, Fe_2O_3	.0290
Silica, SiO_2	.0080
Soda, Na_2O	.3743
Carbon dioxide, CO_2	.0684
Total	2.0613
Oxygen displaced by chlorine	.0280
Total bases and acids	2.0333
Total solids by evaporation	2.0328

Lithium, traces; potassium, faint trace, free ammonia, parts per million, .04; albuminoid ammonia, parts per million, .02.


TRISDON ARTESIAN WELL. 6 INCH NOZZLE.
HURON, SOUTH DAKOTA.

HURON (RISDON) WELL.

SALTS.	Parts per 1000
Sodium cloride, NaCl	.2046
Sodium sulphate, Na_2SO_4	.6083
Magnesium sulphate, $MgSO_4$	.1261
Calcium sulphate, $CaSO_4$	.6020
Calcium carbonate. $CaCO_3$	.1554
Ferric oxide, Fe_2O_3	.0290
Silica, SiO_2	.0080
Total salts	2.0334
Total solids by evaporation	2.0328

IROQUOIS CITY WELL.

This well was constructed in 1890 for city use and it has never been repaired. It flows a little sand and mud at times but not so much at present as formerly. The sample analyzed was slightly turbid. The small residue by sedimentation consisted of clay, lime and a few grains of coarse sand.

There are some discrepancies in the reports regarding the flows encountered. Some say that the first weak flow encountered was reached at 885, others say at 500 feet. Some say that the present flow was reached at 900 feet, and others say it was 840 feet. The depth of the well is also questioned. The analysis shows it to be a first flow well. The pipe was perforated to take both flows. Mr. J. L. Hammond gave the information.

The casing used is of three different sizes, 6-inch, 5-inch and 4½ inch. The depth of the well said to be 1135 (1100. See log) feet; the altitude is 1403 feet and the bottom of the well is about 268 feet above the level of the sea. But it is likely that the bottom of the well is nearer 300 feet above the sea level. The closed pressure is 85 pounds to the square inch and the flow is 213 gallons per minute. The temperature of the water is 71.4 ° F.

*LOG OF THE IROQUOIS CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Black loam	2	2
2	Blue clay	40	42
3	Shale	358	400
4	Sand rock, very light flow	2	402
5	Shale	198	600
6	Sand rock, very light	2	602
7	Shale	248	850
8	Sand rock, flow	5	855
9	Sand rock, no flow	55	910
10	Soft rock, probably shales	190	1100

*Vol. 4, U. S. Sen. Ex. Doc. 1891–2.

IROQUOIS CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9345
Chlorine, Cl	.1575
Lime, CaO	.0109
Magnesia, MgO	.0168
Ferric oxide, Fe_2O_3	.0040
Silica, SiO_2	.0060
Soda, Na_2O	.9860
Carbon dioxide, CO_2	.1280
Total	2.2187
Oxygen displabed by clortne	.0355
Total bases and acids	2.1832
Total residue by evaporation	2.1880

Potassium and lithium, strong traces; free ammonia, parts per million, .02; albuminoid ammonia, parts per million, .04.

IROQUOIS CITY WELL.

SALTS.	Parts per 1000.
Sodium chloride, $NaCl$	.2598
Sodium sulphate, Na_2SO_4	1.6153
Sodium carbonate, Na_2CO_3	.2432
Magnesium carbonate, $MgCO_3$	.0353
Caicinm carbonate, $CaCO_3$	.0195
Ferrric oxide, Fe_2O_3	.0040
Silica, SiO_2	.0060
Total salts	2.1832
Total solids by evaporation	2.1880

HITCHCOCK CITY WELL.

This well was drilled in 1885, and it has never been repaired. It gives clear water when the flow is undisturbed. A $\frac{1}{8}$ inch stream is left flowing night and day. If a larger stream is turned on, the well throws some sand. The pipes are thought to be worn out at a considerable depth. The pipes are of common iron and extend to within 33 feet of the bottom of the well. The first string of casing is $4\frac{1}{2}$ inches, and the inner casing is $3\frac{3}{4}$ inches in diameter. The outer casing extends downwards 800 feet and the inner one simply laps by 40 feet. This is a faulty method of construction. The inner casing should always go the whole length of the well and the bottom lengths should be perforated. This prevents the great rush of water at the lower end of the pipe and avoids the loose joint which sooner or later gives out. This loose joint is a special source of weakness in wells where it is necessary to open and close them. Probably the water works downward between the casings and soon cuts out a cavity which may become large enough to allow the pipes to lop over sideways and become completely disconnected. This has occured in other wells and this may be the trouble in the Hitchcock well. When this well is thrown wide open it will nearly clog with sand. Formerly the water was used to operate a flouring mill, but at present it is used to run a feed mill. It has also been used for irrigation purposes. This water gives the same sediment found in other second flow wells.

The altitude of the well is 1339 feet and its depth is 953 feet, making the bottom of the well about 386 feet above the level of the sea. The closed pressure is 155 to 158 pounds per square inch and the flow is 1240 gallons per minute. The temperature of the water is 70.1° F.

*LOG OF HITCHCOCK CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil and yellow clay	100	100
2	Blue shale	350	450
3	Shales	470	920
4	Cap rock	4	924
5	Sand rock small flow	4	928
6	Sand rock and sandy shale	22	950
7	Sand rock (flow)	3	953

*Vol. 4, U S. Sen. Ex. Doc. 1891-2.

HITCHCOCK CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	1.0479
Chlorine, Cl	.0967
Lime, CaO	.3737
Magnesia, MgO	.1462
Ferric, oxide, Fe_2O_3	.0158
Silica, SiO_2	.0088
Soda, Na_2O	.3520
Carbon dioxide, CO_2	.0675
Total	2.1086
Oxygen displaced by chlorine	0218
Total bases and acids	2.0868
Total residue by evaporation	2.0892

Lithium, strong traces; potassium, traces; ammonia, none.

HITCHCOCK CITY WELL.

SALTS.	Parts per 1000
Sodium Chloride, $NaCl$	.1595
Sodium Sulphate, Na_2SO_4	.6120
Magnesium Sulphate, $MgSO_4$	.4384
Calcium sulphate, $CaSO_4$	.6989
Calcium carbonate, $CaCO_3$	.1534
Ferric oxide, Fe_2O_3	.0158
Silica, SiO_2	.0088
Total salts	2.0868
Total solids by evaporation	2.0892

FAULKTON CITY WELL.

This well was drilled in 1890, and it has never been repaired. The flow was clear until the fall of 1893, when the well clogged entirely. It gradually resumed its flow but the water has remained muddy. The sediment from the sample analyzed consisted of fine sand, clay, disintegrated shale and some iron compounds.

This well was faulty in construction. The tubing is in several pieces. Beginning with a 6-inch tube at the top, a smaller tube was dropped down inside and the ends were not fastened. Within the second a still smaller tube was placed and so on until the bore was reduced to 2½ inches at the bottom of the well. These different pipes are all disconnected. It is possible that they may overlap in some places, but it is quite probable that somewhere near the bottom of the well they are entirely disconnected and that the water is now cutting the walls of the well. It is not thought safe to attempt any repairs.

The altitude of the Station at Faulkton is 1550 feet. The surface at the well is a little higher. The depth of the well is doubtful. 1296 feet were paid for, but the well now measures but 1032. It is not known whether the well is filled up 264 feet or whether the contractors gave fraudulent measurements. Some of the parties who drilled this well have since been arrested for making false measurements elsewhere. The flow of this well as determined by Col. Nettleton was 100 gallons per minute and the pressure has varied from 25 to 34 pounds to the square inch. The temperature of the water is 74.5° F. No log was obtainable. Captain H. A. Humphrey gave most of the information.

FAULKTON CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.4443
Chlorine, Cl	.4007
Lime, CaO	.0264
Magnesia, MgO	.0341
Ferric oxide, Fe_2O_3	.0198
Silica, SiO_2	.0096
Soda, Na_2O	.9188
Carbon dioxide CO_2	.2164
Total	2.0701
Oxygen displaced by chlorine	.0904
Total bases and acids	1.9797
Total solids by evaporation	1.9794

Lithium, trace; potassium, faint trace; ammonia, none.

FAULKTON CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.6610
Sodium sulphate, Na_2SO_4	.7891
Sodium carbonate, Na_2CO_3	.3814
Magnesium carbonate, $MgCO_3$	.0716
Calcium carbonate, $CaCO_3$	.0471
Silica, SiO_2	.0096
Ferric oxide, Fe_2O_3	.0198
Total salts	1.9796
Total solids by evaporation	1.9794

REDFIELD CITY WELL.

This well was drilled in 1886. It has never been repaired and it has never clogged. It throws a little sand when it is wide open but it soon clears itself. It supplies the city with water for all purposes and it is also used for irrigating lawns, trees and gardens. It gives excellent satisfaction. The water deposited no sediment.

The outside casing of 480 feet is 6¼ inches in diameter; the inner casing 501 feet long is 5 3-16 inches and laps upon the outer casing 40 feet. This pipe is seated in the cap rock. At the bottom of the well is 53 feet of 4½ inch pipe, the bottom of which is perforated. The altitude of Redfield is 1295 feet and the well is 964 feet deep which leaves the bottom of the well about 331 feet above sea level. The closed pressure is 171 pounds per square inch and the flow is 1260 gallons per minute. The temperature of the water is 70.1° F. Most of the data were furnished by Mr. E. B. King, water commissioner, Redfield.

*LOG OF REDFIELD CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Sand and clay	140	140
2	Shale	610	750
3	Sand rock, small flow	1	751
4	Shale and iron pyrites	40	791
5	Shale	150	941
6	Hard sand rock, iron pyrites cap	3	944
7	Sand rock, flow	20	964

*Vol. 4, U. S. Sen. Ex. Doc. 1891-2.

REDFIELD CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.8841
Chlorine, Cl	.1592
Lime, CaO	.0478
Magnesia, MgO	.0316
Ferric oxide, Fe_2O_3	.0088
Silica, SiO_2	.0114
Soda, Na_2O	.8546
Carbon dioxide, CO_2	.0931
Total	2.0906
Oxygen displaced by chlorine	.0359
Total bases and acids	2.0547
Total residue by evaporation	2.0544

Potassium and lithium, traces; free ammonia, parts per million, .06; albuminoid ammonia, none.

REDFIELD CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl,	.2626
Sodium sulphate, Na_2SO_4	1.5701
Sodium carbonate, Na_2CO_3	.0499
Magnesium carbonate, $MgCO_3$	.0664
Calcium carbonate, $CaCO_3$	.0854
Silica, SiO_2	.0114
Ferric oxide, Fe_2O_3	.0088
Total salts	2.0546
Total residue by evaporation	2.0544

DOLAND CITY WELL.

This well was bored in 1890. It was constructed for the purpose of furnishing the city supply. It has never clogged and it has never been repaired. Once when nearly shut off, sand, etc., accumulated but when the well was opened it soon cleared itself. It is a first flow well and the water is soft and is used for all domestic purposes. In this well a 6-inch casing extends downward about 200 feet. Within this a 4½ inch casing extends from the top of the well down to the hard cap rock which is about 7 feet thick. Then a 3-inch perforated pipe 38 feet long extends down 13½ feet into the water bearing rock, and to the bottom of the well. Mr. Joseph Labrie gave the information. The water from this well was perfectly clear and gave no sediment upon standing.

The altitude of Doland is 1335 feet and the well is 957 feet, consequently the bottom of the well is 378 feet above sea level. The flow is 600 gallons per minute and the closed pressure is 112 pounds per square inch. The temperature of the water is 69.05 ° F. It will be noticed that the following log gives a depth differing from that given by Mr. Labrie, viz., 897 feet.

*LOG OF DOLAND CITY WELL.

NO.	KIND OF ROCK.	Thickness.	Total.
1	Yellow clay	12	12
2	Black clay 30	30	42
3	Blue shale, hard	33	75
4	Blue shale, soft	200	275
5	Soapstone	50	325
6	Blue shale	135	460
7	Shale, sand and lime, small flow	90	550
8	Blue shale, lime streaks	330	880
9	Sandstone, main flow	15	895
10	Blue shale	2	897

*Vol 4, Sen. Ex. Doc. 1891-2.

DOLAND CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.8497
Chlorine, Cl	.2105
Lime, CaO	.0129
Magnesia, MgO	.0244
Silica, SiO_2	.0104
Ferric oxide, Fe_2O_3	.0070
Soda, Na_2O	.9641
Carbon dioxide, CO_2	.1222
Total	2.2012
Oxygen displaced by chlorine	.0475
Total bases and acids	2.1537
Total solids by evaporation	2.1528

Potassium, traces; lithium, strong traces; ammonia, trace of free ammonia only.

DOLAND CITY WELL.

SALTS.	Parts per 1000.
Sodium chloride, Na Cl	.3473
Sodium sulphate, Na_2SO_4	1.5091
Sodium carbonate, Na_2CO_3	.2057
Magnesium carbonate, $MgCO_3$	.0512
Calcinm carbonate, $CaCO_3$	.0230
Ferrric oxide, Fe_2O_3	.0070
Silica, SiO_2	.0104
Total salts	2.1537
Total solids by evaporation	2.1528

NORTHVILLE WELL.

This well was constructed in 1893 for the purpose of furnishing power for a flouring mill. An outside casing 8 inches in diameter, extends down into the black shale of No. 4. The inner 6-inch casing extends from the top of the well to within 15 feet of the bottom. The last 57 feet of this pipe are perforated. The well has always thrown clay and sand, large deposits of which have accumulated around the well. Pieces of sand stone and lignite are also ejected. The sample of water analyzed was somewhat turbid and upon standing the sediment arranged itself in four layers according to its degree of fineness. The sediment consisted of clay, fine sand, shale and bits of lignite. The usual deposit of red iron compounds found in second flow wells also separated out.

Soon after the sample was taken, repairs were begun upon tbe well with the intention of inserting a 4½ inch pipe throughout the whole length, but the 6-inch pipe was found to be disconnected and the well is now clogged. This disconnected pipe accounts for the large amount of sediment ejected. Moreover it is probable that the sample of water analyzed is not a pure second flow water. The first flow was encountered at 675 feet, the second at 956 feet and the total depth of the well is 980 feet. The altitude of the station is 1299 feet and the bottom of the well is 319 feet above sea level. The closed pressure of the well is 156 pounds per square inch and the flow was 1900 gallons per minute. The information was obtained from Mr. N. Underwood and State Engineer Fassett. The temperature of the water is 66.1° F. The following log appears in the state engineer's report for 1893:

LOG OF NORTHVILLE WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Fine yellow sand	45	45
2	Blue clay	25	70
3	Light gray shale	30	100
4	Black shale	75	175
5	Gray shale	175	350
6	Blue shale, streaks of lime	360	710
7	Blue shale, tough and sticky	60	770
8	Shale and sand shale alternately	105	875
9	Sand rock, quite hard	14	889
10	Layers of lime rock, sand rock and shale	69	958
11	Sand rock, soft	22	980

Strong vein of gas encountered in No. 4 at 135 feet. Nice little flow in No. 9. Small veins in No. 10. Main flow from No. 11.

NORTHVILLE WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.4911
Chlorine, Cl	.3877
Lime, CaO	.4064
Magnesia, MgO	.1330
Ferric oxide, Fe_2O_3	.0148
Silica, SiO_2	.0368
Soda, Na_2O	.4102
Carbon dioxide, CO_2	.2455
Total	2.1255
Oxygen displaced by chlorine	.0875
Total bases and acids	2.0380
Total solids by evaporation	2.0356

Lithium, trace; potassium, faint trace; free ammonia, none; albuminoid ammonia, parts per million, .02.

NORTHVILLE WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.6396
Sodium sulphate, Na_2SO_4	.1620
Magnesium sulphate, $MgSO_4$	.3988
Calcium sulphate, $CaSO_4$	.2280
Calcium carbonate, $CaCO_3$	.5580
Ferric oxide, Fe_2O_3	.0148
Silica SiO_2	.0368
Total salts	2.0380
Total solids by evaporation	2.0356

IPSWICH WELL.

This well was drilled in 1885 for supplying the city water works. The diameter of the well at the top is 4 inches and at the bottom it is 3 inches. Although this well is faulty in construction it gave no trouble until in 1891, at which time it choked so that the present flow is only one-tenth of what it formerly was. The well at that time began to throw mud so that the city pipes clogged. An attempt was made to repair the well but the tools stuck at 1000 feet. 1265 feet were paid for when the well was completed, but that depth is now questioned by some Ipswich men. This well has been flowing clear for about two years, furnishing water from the first flow. It is now believed that the well was not cased for the last 200 to 250 feet, excepting that a 16-feet piece of perforated pipe was simply dropped in. Where it finally rested is only conjecture. The foregoing information was furnished by Messrs. John L. Wells and G. J. Barker of Ipswich.

The altitude of Ipswich station is 1531 feet, consequently the present flow comes from a level 531 feet above the sea. No log was kept.

The temperature of the water is 71.6° F. The closed pressure has varied from 85 to 126 pounds per sqare inch. The present flow has not been determined.

IPSWICH CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.2858
Chlorine, Cl	.4903
Lime, CaO	.0134
Magnesia, MgO	.0265
Ferric, oxide, Fe_2O_3	.0090
Silica, SiO_2	.0050
Soda, Na_2O	1.0653
Carbon dioxide, CO_2	.3333
Total	2.2286
Oxygen displaced by chlorine	.1106
Total bases and acids	2.1180
Total solids by evaporation	2.1162

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

IPSWICH WELL.

SALTS.	Parts per 1000
Sodium cloride, $NaCl$	.8089
Sodium sulphate, Na_2SO_4	.5076
Sodium Carbonate, Na_2CO_3	.7079
Magnesium carbonate, $MgCO_3$	.0557
Calcium carbonate, $CaCO_3$	.0239
Ferric oxide, Fe_2O_3	.0090
Silica. SiO_2	.0050
Total salts	2.1180
Total solids by evaporation	2.1162

ABERDEEN NEW DEEP CITY WELL.

The well was constructed in 1893 for the purpose of augmenting the city water supply. The type of construction here employed is one of the very best and it commends itself to all who are to sink artesian wells hereafter. 8-inch casing was first settled to a depth of 200 feet, thus effectually shutting off all quicksand, etc., which has heretofore given much trouble in sinking the casings. This casing extends nearly 100 feet into the upper layers of shale rock. From the bottom of this pipe the bore was contracted and a 6-inch pipe extends down from the top of the well to a distance of 1055 feet. This pipe passes through the first flow which it shuts out effectually. The last 60 feet of this pipe were perforated to allow a smaller second flow to enter. This flow, however, is not used at present. At this point the well was again contracted and 1125 feet of 4½ inch pipe were used, the last 60 feet of which were also perforated to take the main second flow. Then the 4½ and the 6-inch pipes are hermetically closed at the top of the well. Consequently there are no loose joints and no place for the pipes to fall apart and allow the walls of the well to be washed away to the detriment of both the well itself and the water furnished. Of course the capacity of the well could have been increased by continuing the 6-inch pipe down 70 feet further with suitable perforations to take both lower flows. And again the last 190 feet of drilling were unnecessary as no water was encountered within that distance. The method of inserting the casings in this well allows the inner pipe to be withdrawn for repairs, a very commendable feature. The well has yielded clear water. It is 1300 feet deep with an elevation of 1300, consequently the bottom of the well is exactly at sea level. The flow is 400 gallons per minute and the temperature of the water is 66.9 ° F.

Mr. O. S. Cook, who kindly furnished the information, states that the pressure varies from 80 to 90 pounds to the square inch, but that it has not been accurately determined. He also thinks that the old first flow city well gives a somewhat greater pressure. It is the general opinion that, owing to the sinking of so many wells in the vicinity of Aberdeen, the pressure has diminished of late years. W. E. Swan states that the old R. R. well at Aberdeen, the oldest in the state, drilled in 1881-2, had a pressure of 180 pounds. C. H. Stillwell of Tyndall, gives the pressure of the same well at 178 pounds. This new well has aroused much interest since the drill has here penetrated through the entire Dakota formation into the Archaeau.

It was expected that the sample of water from this new deep well would be an undoubted second flow water. But unfortunately for this purpose the city authorities have connected this well and the old first flow well to the same mains; consequently a free commingling of both flows is permitted. If it is true as stated that the old well has a somewhat greater pressure there is undoubtedly a steady current passing from the old well into the new when all outlets are closed. One would therefore, expect to draw at any time a mixed sample of water; and the analysis confirms this expectation. The sample analyzed deposited a sediment of clay, lime, sand and iron compounds. The following log of the new deep well is from the report of the Engineer of Irrigation for 1893:

ABERDEEN NEW DEEP CITY WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Black loam	2	2
2	Yellow clay	18	20
3	Blue clay	12	32
4	Quick sand	58	90
5	Dark gray shale	95	185
6	Black shale	125	310
7	Brown shale	87	397
8	Gray shale	23	420
9	Light gray shale	180	600
10	Dark gray shale	100	700
11	Light gray shale	100	800
12	Light gray sand shale	120	920
13	Sand rock, 380 gals. per min.	15	935
14	Conglomerate	60	995
15	White sand rock, 300 gals.	5	1000
16	Blue shale	77	1177
17	White sand rock, 400 gals.	23	1100
18	Conglomerate	35	1135
19	Blue shale	37	1172
20	Pink and white shale	5	1177
21	White sand rock, no water	34	1211
22	Archaen formation or quartz	46	1257
23	Granite	33	1290

Mr. Stacy gives depth at 1300.

ABERDEEN NEW DEEP CITY WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9312
Chlorine, Cl	.1443
Lime, CaO	.0492
Magnesia, MgO	.0386
Ferric oxide, Fe_2O_3	.0094
Silica, SiO_2	.0098
Soda, Na_2O	.8552
Carbon dioxide, CO_2	.0857
Total	2.1234
Oxygen displaced by chlorine	.0326
Total bases and acids	2.0908
Total solids by evaporation	2.0896

Potassium and lithium, strong traces; free ammonia, trace; albuminoid ammonia, parts per million, .01.

ABERDEEN NEW DEEP CITY WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	.2381
Sodium sulphate, Na_2SO_4	1.6538
Sodium carbonate, Na_2CO_3	.0108
Calcium carbonate, $CaCO_3$	.0879
Magnesium carbonate, $MgCO_3$	.0811
Ferric oxide, Fe_2O_3	.0094
Silica, SiO_2	.0098
Total salts	2.0909
Total solids by evaporation	2.0896

ANDOVER WELL.

This well was drilled for the use of the railroad in 1882. It furnishes the city supply and no other water is used in Andover. The water foams in steam boilers when other surface waters are mixed with it so the railroads can not use it. This property is due to the sodium carbonate carried by the water. This well has never clogged and the water always flows clear, depositing no sediment upon standing. It has 735 feet of 6-inch casing and 1050 feet of 4½ inch pipe within, extending from the top to within 20 feet of the bottom of the well. Both pipes are joined at the top. The boring only penetrated the water bearing rock about 3 feet. Mr. W. E. Swan furnished the information.

The altitude of Andover is 1475 feet and the depth of the well is 1070 feet, leaving the bottom of the well about 405 feet above sea level. The pressure is 90 pounds per square inch and the flow is 300 gallons per minute. The temperature of the water is 71.6° F.

*LOG OF ANDOVER WELL.

No.	KIND OF ROCK.	Thickness.	Total.
1	Soil, sand and clay	45	45
2	Blue clay	30	75
3	Blue shale	500	575
4	Limestone	15	590
5	Shale streaks limestone	480	1070
6	Sandstone, main flow	5	1075

*Vol. 4, U. S. Sen. Ex. Doc. 1891-2.

ANDOVER WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.9332
Chlorine, Cl	.2005
Lime, CaO	.0139
Magnesia, MgO	.0214
Ferric oxide, Fe_2O_3	.0088
Silica, SiO_2	.0094
Soda, Na_2O	1.0445
Carbon dioxide CO_2	.1371
Total	2.3688
Oxygen displaced by chlorine	.0453
Total bases and acids	2.3235
Total solids by evaporation	2.3232

Lithium, traces; potassium, trace; free ammonia, trace; albuminoid ammonia, parts per million, 01.

ANDOVER WELL.

SALTS.	Parts per 1000
Sodium cloride, NaCl	.3308
Sodium sulphate, Na_2SO_4	1.6573
Sodium carbonate, Na_2CO_3	.2476
Calcium carbonate, $CaCO_3$	.0248
Magnesium carbonate, $MgCO_3$	.0449
Silica, SiO_2	.0094
Ferric oxide, Fe_2O_3	.0088
Total salts	2.3236
Total solids by evaporation	2.3232

WESTPORT WELL.

This well was constructed in 1893 for irrigation purposes. The well is cased with 6-inch pipe which extends to within 30 feet of the bottom. It has thrown sand and mud ever since it was completed. It nearly clogged before it was cleaned. It was cleaned in July, 1893. For six weeks previous to the taking of the sample analyzed the water had been coming tolerably clear with a flow of about one-fourth of the original flow. The sediment in the sample analyzed consisted of clay, fine sand, disintegrated shale, and some iron compounds. The water comes from the first flow. When the well was at its best the pressure was 40 pounds to the square inch but it has now declined to 35 pounds.

The well is situated about five miles west of Westport. The flow has not been measured, but it filled the six acre reservoir constructed for irrigation purposes 5 feet deep in thirty days. Mr. H. Barnard, foreman of the farm, furnished the information. The temperature of the water is 66.2 ° F. The altitude of Westport Station is 1313 feet and the depth of the well is 1030 feet. Therefore the bottom of the well is about 300 feet above sea level.

At this writing (October, 1894) Mr. Fassett informs me that the well is entirely clogged. This well should be deepened to second flow and cased to the bottom with a perforated pipe where the second flow enters. There is too much sodium chloride, sulphate and carbonate in this water for long and continued use with safety.

No log of the well was obtainable.

WESTPORT WELL.

BASES AND ACIDS.	Parts per 1000
Sulphuric anhydride, SO_3	.2352
Chlorine, Cl	.9111
Lime, CaO	.0112
Magnesia, MgO	.0184
Ferric oxide, Fe_2O_3	.0118
Silica, SiO_2	.0114
Soda, Na_2O	1.3004
Carbon dioxide, CO_2	.2561
Total	2.7556
Oxygen displaced by chlorine	.2055
Total bases and acids	2.5501
Total solids by evaporation	2.5540

Potassium and lithium, faint trace; free ammonia, trace; albuminoid ammonia, none.

WESTPORT WELL.

SALTS.	Parts per 1000
Sodium chloride, NaCl	1.5031
Sodium sulphate, Na_2SO_4	.4177
Sodium carbonate, Na_2CO_3	.5475
Magnesium carbonate, $MgCO_3$	.0386
Calcium carbonate, $CaCO_3$	.0200
Ferric oxide, Fe_2O_3	.0118
Silica, SiO_2	.0114
Total salts	2.5501
Total solids by evaporation	2.5540

SALTS SOLUBLE AND INSOLUBLE AFTER EVAPORATION.—To the irrigator it is of the utmost importance whether the salts a water contains are soluble or insoluble after the water which carries them has evaporated. Salts that become insoluble become a fixed and valuable part of the soil. To this class belong all the calcium salts, silica, iron compounds and magnesium carbonate. Those which again dissolve when brought in contact with water are all of the sodium salts and magnesium sulphate. Potassium salts belong to the same class These salts often become a nuisance owing to their excessive accumulation in and at the surface of the soil and so as a class are undesirable, especially when in large quantities in a water intended for irrigation purposes.

In the analyses of the second flow wells it will be noticed that all of the magnesia is returned as magnesium sulphate while some of the lime is returned as the carbonate. It is difficult always to determine in just what way bases and acids are combined in a natural water, especially when the water under question is charged with carbonic acid gas and in addition to this also carries a large number of salts. But it is safe to say that at some point in the concentration of the water as it evaporates and parts with its carbonic acid gas, a reaction will take place between the calcium carbonate and a portion of the magnesium sulphate whereby magnesium carbonate and calcium sulphate will be formed. Both of these compounds are insoluble after evaporation. Strictly speaking it would be better to say of all the so called insoluble substances, that they are very *sparingly* soluble in water, since water does dissolve minute quantities of substances which are seemingly perfectly insoluble.

In the following table the soluble and insoluble salts are returned according to the analyses. Consequently in the soluble salts magnesium sulphate is included. But if allowance be made for the reaction just mentioned the soluble salts would be reduced by the magnesium sulphate changed over to carbonate while the insoluble salts would be increased by a like amount. But there is another feature of our subsoils that should be taken into account at this point and that is this: over a large area of the state there is at depths of from one to three feet a thick layer of calcareous or marly clay which would for a long time continue the conversion of the magnesium sulphate into carbonate. In this way the whole of that sulphate might be transferred to the insoluble column, while the soluble salts would be to a like extent reduced.

	Total Salts.	Soluble after Evaporation	Insoluble after Evaporation.
Yankton	1.6023	.5975	1.0048
Tyndall	1.9902	.7476	1.2426
Armour	2.1392	.9076	1.2316
Chamberlain	2.0850	1.0153	1.0697
Kimball	2.1123	.8733	1.2390
Woonsocket	2.0088	1.2770	.7318
Pierre	3.4760	3.3763	.0997
Harrold	1.7379	1.6396	.0983
Miller	2.0323	1.6423	.3900
Huron	2.0334	1.2390	.7944
Iroquois	2.1831	2.1183	.0648
Hitchcock	2.0868	1.2099	.8769
Faulkton	1.9796	1.8315	.1481
Redfield	2.0546	1.8826	.1720
Doland	2.1537	2.0621	.0916
Northville	2.0380	1.2004	.8376
Ipswich	2.1180	2.0244	.0936
Aberdeen	2.0909	1.9027	.1882
Andover	2.3236	2.2357	.0879
Westport	2.5501	2.4683	.0818

Artesian Waters Not Uniform.—By an inspection of the following table it will be seen at a glance that the waters of the different wells are not uniform either with respect to the kinds of salts they carry or as to the amounts of the salts which are common. In order to bring this fact out more conspicuously the same method of combining the bases and acids has been adhered to in every case.

As to the first kind of variation it will appear that all of the second flow wells have no sodium carbonate while all the first flow wells either have this salt or they have in its place sodium sulphate which may have been produced by bringing the sodium carbonate in contact with gypsum. Moreover, in the case of the Pierre well the absence of all sulphates is a strange anomaly. This is difficult to account for unless, indeed, the waters in that vicinity have come into thorough contact with some barium or strontium compounds. Of such contact the water itself gives no evidence.

As to the second kind of variation the total disagreement of all the figures affords striking illustrations. But one variation deserves more than a passing notice, and that is the compartively large amounts of calcium and magnesium salts in the second flow waters as compared with the quantities found in the first flow waters; while on the other hand the preponderance of sodium salts in the first flow waters as compared with the second is most conspicuous. This variation is of such vital importance that it will be a potent factor in determining to what uses the different flows shall be put. For example the second flow waters are better adapted for irrigation while the first flow are more suitable for town and domestic uses. The first flow yields nearly soft water, better adapted for washing, etc., while the second flow wells furnish a hard water that can scarcely be used without cleansing.

The reason for the differences between the two flows is easy to find. The cause lies in the different strata from which these waters are derived. The first stratum of rock is more strongly charged with sodium compounds while the deeper lying second flow stratum carries more gypsum and magnesium compounds and less sodium. Now the waters of these two flows may have a common origin, and may be similarly charged at first, but during their passage through their different conducting strata each flow dissolves out the soluble constituents of the rocks with which it comes in contact.

PRINCIPAL SALTS (PARTS PER 1000.)

	Sodium Chloride Na Cl.	Sodium Sulphate Na_2SO_4	Sodium Carbonate Na_2CO_3	Magnesium Sulphate $Mg\,SO_4$	Magnesium Carbonate $Mg\,CO_3$	Calcium Sulphate $CaSO_4$	Calcium Carbonate $CaCO_3$
Yankton	.1643	1172	......	.3160	......	.8700	.1246
Tyndall	.2438	.1002	......	.4036	......	1.1199	.0905
Armour	.2879	.1186	......	.3011	......	1.0530	.1954
Chamberlain	.1800	.3618	......	.4735	......	.8820	.1573
Kimball	.1688	.2211	......	.4834	......	1.4592	.1636
Woonsocket	.1128	.7941	......	.3701	......	.5366	.1630
Pierre	2.8052	......	.5711	......	.0050	......	.0771
Harrold	.8029	.4550	.3817	......	.0575	......	.0256
Miller	.1501	1.2965	......	.2857	......	.1683	.2125
Huron	.2046	.6084	......	.4261	......	.6080	.1554
Iroquois	.2598	1.6153	2432	......	.0353	......	.0195
Hitchcock	.1595	.6120	......	.4381	......	.6969	.1534
Faulkton	.6610	.7801	.3814	......	.0716	......	.0471
Redfield	.2626	1.5701	.0499	......	.0664	......	.0854
Doland	.3473	1.5091	.2057	......	.0512	......	.0230
Northville	.6306	.1620	......	.3988	......	.2280	.5580
Ipswich	.2060	.5076	.7079	......	.0557	......	.0239
Aberdeen	.2481	1.6538	.0108	......	.0811	......	.0879
Andover	.3308	1.6573	.2176	......	.0449	......	.0248
Westport	1.5031	.4177	.5475	......	.0358	......	.0200

SOURCE OF THE ARTESIAN WATERS.—It frequently occurs that waters carry internal evidence that betrays their origin. It was hoped that the analysis made in this investigation might tend to throw some light upon the origin of the waters underlying the great Dakota basin. Whether any progress in that direction could be made or not, would naturally enough, depend much upon the rocks conveying the waters from their source to the points where they are delivered. If the rocks contain but little or no soluble substances, the problem would not be difficult to determine. If on the other hand the rocks through which the waters pass are charged with the same substances which the water carries before entering them, the problem would present greater difficulties. But even in the latter case the waters themselves might furnish evidences which would determine pretty accurately the direction which the underground current or movement assumes.

The following table of the principal bases and acids is given to make clear the statements which follow. In this table the second flow wells are printed in italics.

PRINCIPAL BASES AND ACIDS (PARTS PER 1000.)

	Soda Na_2O	Lime CaO	Magnesia MgO	Carbon dioxide CO_2	Sulphur trioxide SO_3	Chlorine Cl.
Yankton	.1384	.4304	.1054	.0348	.7860	.0096
Tyndall	.1732	.5118	.1318	.0398	.9642	.1178
Armour	.2046	.5214	.1071	.0681	1.0214	.1745
Chamberlain	.2536	.4554	.1579	.0692	1.0440	.1091
Kimball	.1861	.5277	.1012	.0720	1.0608	.1023
Woonsocket	.1070	.3120	.1234	.0717	1.0040	.0081
Pierre	1.8226	.0432	.0024	.2734	trace	1.7101
Harrold	.2482	.0160	.0274	.2010	.2562	.4867
Miller	.6156	.1883	.0860	.0035	.9667	.0010
Huron	.3743	.3349	.1421	.0681	.9806	.1210
Iroquois	.9860	.0109	.0168	.1289	.9095	.1555
Hitchcock	.2520	.3737	.1482	.0675	1.0479	.0967
Faulkton	.9188	.0264	.0341	.2104	.4443	.1007
Redfield	.8546	.0478	.0310	.0931	.8841	.1592
Doland	.9641	.0129	.0214	.1222	.8497	.2105
Northville	.4102	.4064	.1330	.2155	.4911	.3877
Ipswich	1.0653	.0134	.0265	.3833	.2858	.4903
Aberdeen	.8552	.0492	.0508	.0857	.9312	.1443
Andover	1.0145	.0139	.0214	.1371	.9382	.2065
Westport	1.3004	.0112	.0184	.2561	.2352	.4111

Let us consider the second flow wells only. Now it is evident that if the rocks carrying this flow, contain certain soluble salts which under no circumstances form insoluble combinations, we should find an increase in such salts as we follow down the underground current. Again, if we had a water carrying a certain substance not found in that stratum and one that enters into no insoluble combination, we might expect to find that substance tolerably uniform throughout the whole length of the stream.

Of the bases given in the table it is evident that lime and magnesia would not serve as indicators of origin or direction. They are liable to enter into insoluble forms that may be precipitated in such a slow moving current as that of the underflow. But in sodium we have a base that makes no insoluble compounds under any conditions likely to arise in these underground waters.

The preponderance of physical and geological evidence points to the out crops of the Dakota sandstone, lying along the foothills of the Rocky mountains to the north and west of the Dakota basin, and to outcroppings of the same sandstone around the Black Hills, as the points of entrance of the waters in question. It is believed that the waters of the melting snows and of the rainfall of large areas lying above these outcrops furnish the great artesian supply. If now a line be drawn from Aberdeen to Yankton we shall have a line running a little east of south, or if we broadly take into consideration Chamberlain, Kimball, Armour and Tyndall, we practically have a line running nearly south. Now, if the second flow stratum contains small quantities of soda we should find a gradual increase in that base in coming from Aberdeen south, provided the ground movement is in that direction. If the stratum carries no sodium we should find practically the same amount of soda in all of these wells.

Now, if we take the wells in order, Aberdeen, Northville, Hitchcock, Huron, Woonsocket, Kimball, Chamberlain, Armour, Tyndall and Yankton, we find that they carry in milligrams per litre of soda, respectively, 855, 410, 352, 374, 407, 186, 253, 204, 173 and 138. At first glance these figures would seem to indicate that the stratum carries a little soda and that the movement is from south to north. But this we know is an absurdity. A short distance southeast of Yankton the Dakota sandstone crops out bearing springs coming probably from the second artesian flow. And again we know that with a low pressure at Yankton it would be impossible for water entering at the south to raise water to the level of Huron, much less to cause the enormous pressure at the latter place. Consequently some other explanation must be sought. Now as previously stated, the Aberdeen water is undoubtedly contaminated by first flow waters that carry as a rule much soda. The Northville well is suffering the same contamination on account of leaky pipes but to a slighter extent, while the Hitchcock well is leaking still less, and Woonsocket is at best doubtfully a pure second flow. If suitable allowance be made for these factors it will not be unreasonable to deduce the conclusion that the second flow stratum carries little or no soda and that the flow cannot be from north to south along the line of the James river. Only one other hypothesis is available so far as direction is concerned and that is, that the waters must come from a westerly direction. If we consider the Kimball, Armour and Tyndall wells we find the soda to be practically the same, viz: 186, 204 and 173 milligrams per liter. These wells lie in a direction north of west from Tyndall. But it is probable that the direction of the flow is still less north of west since Yankton has still less soda than any of the three.

Again the hypothesis may not prove untenable that the second flow stratum may have a gradually increasing amount of soda from Yankton north. If the waters come from a westerly direction this would agree perfectly with that supposition. Of course it might be possible that the waters enter this stratum comparatively free from soda and that they receive all their soda at some point west or north of the region covered by these analyses, and that the stratum so far as explored contains practically none. But still that fact, if proven, could not by any means indicate that the underground movement follows the James river valley.

It is probable that the first flow stratum is more irregular in its composition than the lower second. Indeed the rule seems to be that the upper strata contain more soluble salts than the lower. But still if we leave out the anomalous waters of Pierre, we find in a west to east section from Harrold to Iroquois, milligrams of soda per litre as follows: Harrold, 848; Miller, 615; Iroquois, 986. Going still farther north we find at Ipswich, 1065, and at Andover, on the eastern border, 1044. These at least point to no movement from north to south.

But there is an acid radicle that may throw some further light upou this subject. I refer to chlorine. While carbonic and sulphuric acids might easily be thrown out of solution, there is probably no base in the Dakota formation that would in the least have this effect upon the chlorine. Now taking the second flow wells in the order previously mentioned, we have for chlorine the numbers (beginning at Aberdeen,) 144, 378, 96, 124, 68, 102, 109, 174, 147 and 99. In these numbers we find a still further confirmation of the probability that the waters come from a westerly direction, and surely not from a northerly one. It is true that these numbers do not show an exact agreement nor should it be expected over so great a distance. But the contamination of the northern wells from the first flow does not exert a very prominent influence in the case of chlorine. It will be noticed that several of the first flow wells contain chlorine not varying much from these figures. This latter fact would go to show, in the light of what has already been said, that the waters of both flows have a common origin and that the first flow stratum is quite irregular in its composition. Moreover the presence of Lithium, a rare element, which occurs in waters of both flows, also points to a commou origin. The "great springs" above Great Falls in Montana, whose waters have a temperature of 51.5° F. also carry lithium. In this connection it might be well to recall a fact concerning the temperatures of these artesian waters. Mr. Hopkins determined the temperatures of all the wells analyzed and so the data are comparable with more certainty than most of the physical data of the wells examined. It will be noticed that the deeper or second flow waters as a rule have a lower temperature than the first flow waters. Here is another fact involving an apparent contradiction. The usual rule is, the deeper the water the higher its temperature, after the line of no variation from surface influences is passed. These wells are all certainly below climatic influences. To what is this anomaly due? To me it seems there is but one explanation, and that is, the first flow waters are more affected by heat involved in chemical changes in the water itself. Some of these changes have been previously mentioned, such as reactions between magnesium sulphate and calcium carbonate or between sodium carbonate and calcium sulphate. The waters at Pierre show evidences of changes even greater than these with a correspondingly high temperature. It is not impossible that with the carbonic acid and ammonia present in these waters, a portion of the sodium chloride present may have been changed to sodium carbonate.

Now, it must be distinctly understood that the statements made apply to the region covered by the wells analyzed. More work is necessary to confirm or disprove the conclusions reached even in this section. Waters should be collected in the regions where the Dakota outcrops occur and they should be subject to analysis. The data thus obtained would certainly do much more towards throwing some light upon the origin of the artesian waters of the Dakota basin. If the source can be determined, computations can then be made with more certainty concerning the supply at the disposal of consumers residing in the artesian belt.

Again it is believed by many that the first flow pinches out or at least comes very near the surface in the southern part of the State where many shallow artesian wells are to be had. These waters should be analyzed. Again there are shallow artesian wells in the northeastern and southeastern part of the State and supposably outside the artesian belt altogether. These await investigation.

Artesian Waters for Irrigation.—The question is frequently asked, "Will the artesian waters of the Dakota basin be injurious to the soil and to vegetation?" Different replies have been made. Some have thought that the waters carry too much mineral matter for safe application to crops and to soils. Upham (Am. Geologist, Oct. 1894) states that the saline residue after continued use of the waters would certainly prove injurious to crops so that the soil would become worthless. He bases his opinion on a single analysis, that of the well at Jamestown, N. D., and upon the fact that much purer waters have proven disastrous in India. This positive opinion is certainly based upon meagre data and partially upon a misconception of facts in relation to the conditions in India. In the first place the well at Jamestown carries, out of a total residue in parts per 1000 of 2.2226, 1.7442 parts of salts soluble after evaporation. Now, this is a higher proportion of soluble salts than any of the second flow wells carry. In fact it more nearly corresponds with such first flow wells as Faulkton, Miller and Redfield. Again, he attributes the accumulation of salts on the surface of the soil of India to the evaporation of the irrigation water which has left its salts behind. The truth of the matter is the soil and sub-soil of India already contain large quantities of alkali which are brought up by the application of water. It matters not what the water might be under similar circumstances, even if it were distilled water, the rise of the alkali would follow, owing to upward leaching and surface evaporation.

But there are still other differences which exist between the arid plains of India and the sub-humid plains of South Dakota. In the first place Dakota soils are not already loaded with soluble salts. It is true that some few low lying gumbo patches do exist in some parts which are poorly drained. But these spots are of such limited extent, often but a few rods across, that they may be neglected. In the second place the rainfall of South

Dakota is greater and more evenly distributed as is always the case in sub-humid regions, and consequently there is less water needed for irrigation purposes. In the third place the natural drainage is far superior to that of India or of any of the countries where alkali has become troublesome. Indeed the country is altogether too well drained, so much so that the storm waters find a too rapid and too easy exit from the borders of the State. Those who have given the subject the most thought are now seriously advocating the damming up of all runs, draws, sloughs, lake beds and creeks for the conservation of the natural storm waters. In the fourth place the subsoils of this State are porous and admit of the easy passage of storm waters to underground levels or reservoirs whence they gradually find their exit by seepage into runs, creeks and rivers. Moreover the open and loamy soils of this region would be less affected by saline residues than the stiffer clays of India.

In view of all these facts it is not permissible to draw inferences from conditions entirely dissimilar. In short, the conditions prevailing in South Dakota, are such that all problems relating to artesian irrigation must be decided upon by taking into account factors immediately concerned and factors that are unique to this region.

It is undoubtedly true that the artesian waters of the Dakota basin do carry large quantities of soluble constituents. The residues from these waters are larger than those of most waters used for irrigation; but when the various climatic conditions of the basin are taken into consideration, and when the drainage and soil conditions of the most favorable kind are considered, it is not unwarrantable to suppose that favorable results may be obtained by an economic and judicious application of the artesian waters. Especially is this true when one remembers that during many years no irrigation is at all desirable. And then again all parts of the basin are subject to such heavy falls of rain that any accumulating salts must of necessity be washed away. Then again, even in the dryest years, the period when crops would be benefitted by irrigation is short, so that only a limited application of water would be needed. All these facts would lead one to believe that such irrigation as needed here may be accomplished by artesian waters.

In all probability success may be confidently expected by a strict attention to the following details: deep and thorough cultivation; a judicious use of only sufficient water to insure a crop; a careful conservation of all storm waters; the systematic planting of trees and shelter belts and the storage of all surplus artesiau waters. Moreover it must be remembered that the second flow wells are safer than first flow wells especially on land at all inclined to he clayey. And finally, should evil effects from the water become manifest, the remedial agencies of land plaster, lime and under drainage should be promptly applied. The large deposits of gypsum occurring in the Black Hills will be sufficient for all time.

In this connection an objection to artesian irrigation raised by Major Powell may be profitably noticed. He affirms that the supply would not prove adequate to the needs of the country requiring irrigation. He admits, however, that the supply is not as yet developed to its full capacity. And it is difficult to say with our present knowledge how great the available supply may be. But this is known; it is very great, the greatest artesian basin in the world, and there is little evidence that the water is showing any signs of diminution in spite of the wasteful manner in which it is utilized. It is true that both the pressure and flow of some wells are diminishing; and it is true that some wells have clogged and ceased flowing altogether. But both of these phenomena can he more readily explained by the careless and faulty construction of the wells under consideration. Indeed this is more likely the true explanation since when properly constructed wells are sunk in the immediate vicinity of these failing wells a copious supply is always obtained.

Right here may be noticed other objections sometimes raised, viz: that the wells are too expensive and that they are not durable. It must be evident to the careful reader of the foregoing pages that the reason why some of the wells are not durable is not difficult to find.

Who would expect a string of disconnected pipe passing through soft shaly walls to make a durable well? Who would expect that water, driven on by the tremendnous pressure to which it is subjected, would not cut away the soft sand stone rock through which it comes without any protection to the walls by perforated pipes reaching down through the water bearing stratum? How long would it take to tear out a cavern so vast at the bottom of the well that the overlying soft and flexible strata of shale would bend down and cut off the flow? And again why have not more galvanized casings been used so long as it is a well known fact that waters carrying salts are quickly corrosive to common iron? Moreover, wells carrying out sand and rocks with the great velocity observed act in a most destructive manner upon the pipes, actually wearing them out. This is one of the most active causes in shortening the life of a poorly constructed well. Taking all these things into consideration it is scarcely to be wondered at that wells have failed. The cost of construction is gradually diminishing. Notwithstanding all these objections, it is quite probable that wells can be made durable enough and cheap enough and with sufficient supply of water to irrigate a portion of nearly every section in the James River Valley. It is undoubtedly true that any bonanza operation might not prove entirely successful financially and it is undoubtedly true that any project looking forward to wheat raising on a large scale by irrigation would suffer the same fate. But it is equally true that wheat raising or any one crop system under the best possible conditions imaginable would prove disastrous.

What the farmer of the Dakota Artesian Belt should aim to achieve should be a small farm with sufficient water supply to insure successful intensive cultivation. The home should be furnished with a garden and fruit trees, and small fruits should be provided, while shade trees and shelter belts should surround all. Stock of all kinds should be kept and special pains should be taken to maintain the fertility of the soil. Pigs, poultry, mutton sheep, dairy cows and work horses should be found on every farm and if these are to be kept in large numbers more land should be provided and used as permanent pasture and meadow without any attempt to cultivate or to irrigate. In this way our wealth of native grasses would all be utilized and we should have thousands of happy and prosperous homes where the land is now entirely unused. The rule and watchword then would be, "Intense cultivation or no cultivation at all." Diversified farming with all its manifold blessings would then make a reality of what is now but a dream. A healthier tone would pervade everywhere and there would be no further desire to rob this beautiful belt of its fertility and reduce the land to a barren waste by the prevailing and wasteful one crop system which has been so widely practiced. Some wheat together with corn, potatoes, rye, millet, oats, green fodders and root crops would be produced and prosperity would follow.

If, in addition to all this the storm waters were carefully conserved *throughout the whole belt* and an equally extensive and systematic planting of trees [illegible] to be practiced, the whole aspect of the country would be changed and even the climatic conditions of the whole region would be profoundly affected for the better.

SOME HINTS ON ARTESIAN WELL CONSTRUCTION.—From some of the results obtained in the past some useful hints for future well construction may be gathered. The following are suggested:

1. The pipes used should be galvanized and should be connected by specially strong couplings.

2. An outside casing should be sunk and firmly seated in the rock below all sand and quick sands.

3. As soon as a flow is reached the drill should be closely followed by the casing in order that no washing or caving of the walls may occur.

4. The lower end of the iuner pipe that is to penetrate the flow should be perforated to prevent any great rush of water at any point in the sand-rock that carries the water.

5. The bore through the cap rock should be of such size that the casing will fit snugly in order to prevent the water from working up around the outside of the pipe and thus cutting the cap rock away.

6. All pipes used within the first or outside casing should come to the top of the well and should there be securely joiued to the outer pipe.

It is true that some of the wells, iu fact some of the oldest ones, have not been thus carefully constructed. But in some cases the cap rock and even the water bearing rock are very firm and hard. Hence no trouble has come as yet. But these wells will be found difficult to repair when their common iron pipes are worn and rusted out. Again some wells have encountered no quick-sand but there is always danger that the casings may stick and thus entail needless expense and unnecessarily increase the cost of construction.

It must be borne in mind that the Dakota sand stone varies greatly in its nature. In some places it seems little more than loose sand while in other localities it becomes quite hard and compact. And it is to the non-observance of some one or more of the foregoing precautions that what would otherwise have proven strong and durable wells, have proven unsatisfactory and some times a complete failure.