UNITED STATES DEPARTMENT OF THE INTERIOR

WATER SUPPLY OF THE DAKOTA SANDSTONE IN THE ELLENDALE-JAMESTOWN AREA NORTH DAKOTA

WITH REFERENCE TO CHANGES BETWEEN 1923 AND 1938

Prepared in cooperation with the
NORTH DAKOTA GEOLOGICAL SURVEY

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 889-A

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

GEOLOGICAL SURVEY
W. C. Mendenhall, Director

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Contributions to the hydrology of the United States, 1941
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ABSTRACT

The Dakota sandstone underlies most of North Dakota and South Dakota and considerable parts of nearby States. In most of the area that it occupies it is covered with thick deposits of younger formations, chiefly shale, that confine the water in the sandstone under considerable pressure. Where the topography is favorable, as it is in the Ellendale-Jamestown area in southeastern North Dakota, wells that tap the sandstone flow at the surface.

The first well in North Dakota to tap the Dakota sandstone was drilled in 1886 in the city of Ellendale. It was started as an 8- or 10-inch hole and was finished at a depth of 1,087 feet with a 3¾-inch casing. It flowed 600 to 700 gallons a minute and had a pressure reported by different persons as being from 115 to 175 pounds to the square inch.

The expense of drilling such large and deep wells discouraged their construction for a time. About 1900, however, the jetting method of drilling was introduced, and during the following two decades hundreds of farm wells 1 inch to 2 inches in diameter were sunk to the sandstone. The decline in artesian head that resulted from the increased draft on the basin was not apparent at first, but by about 1915 the flow of most wells had decreased noticeably and the flow of a few wells in the western part of the area of flow stopped entirely. It is estimated that by 1923 the artesian head at the western boundary of the area of artesian flow had fallen about 330 feet from its original level.

In 1916 steps were taken to initiate measures for conserving the artesian water in North Dakota, but it was not until 1921 that the State legislature passed a law providing for the reduction of flow of artesian wells to that which could be used beneficially. The enforcement of the law was placed in the office of the State geologist, and this difficult task was assigned to H. E. Simpson, who directed the work until his death in 1938. Between 1923 and 1928 each artesian well in the Ellendale-Jamestown area was visited and advice was given the owner regarding the flow to which his well should be reduced. Many of the wells were visited again between 1928 and 1935 in order to check on whether the flow had been

sufficiently reduced. Through this program much artesian water was conserved and much valuable information was obtained on the discharge from the basin.

It is estimated that between 1920 and 1923 the artesian head in the western part of the Ellendale-Jamestown area declined at an annual rate of about 4 feet, whereas in 1938 the rate of decline was only about 0.5 foot a year. Between 1915 and 1923 the part of the area of artesian flow in the Edgeley quadrangle was reduced an average of 16.5 square miles a year as a result of the eastward movement of the western boundary of the area. Between 1923 and 1938, however, the average rate of shrinkage of this part of the area of artesian flow was only about 4.5 square miles a year. The perennial recharge to each row of townships in the area of artesian flow has been estimated to be about 500 gallons a minute. In 1923 the flow from wells in T. 129 N., Rs. 50 to 65 W., was about 1,000 gallons a minute, or twice the estimated recharge. In 1938 the flow from wells in this row of townships was about 520 gallons a minute, or only slightly more than the estimated recharge. Thus it appears that a balance is being approached between the withdrawal of water from the basin and the perennial recharge to it.

It is believed that the water withdrawn from the basin in excess of the perennial recharge has been obtained from storage by the compression of the sandstone and associated beds of shale due to the increased load placed upon them by the decline in artesian pressure. Calculations made on this theory indicate that the coefficient of storage is about 0.001—that is, about 0.001 cubic foot of water is released from each column of sandstone and shale 1 foot square for each foot of decline in artesian head. Additional computations show that the effect of the large decline in artesian pressure in southeastern North Dakota probably has caused only a few feet of lowering of artesian head at distances of more than 100 miles west of the area of artesian flow.

The quality of the artesian water is very poor and much of it is unfit for human consumption. Of the 33 analyses included in this report, all show total dissolved solids of more than 2,200 parts per million. Much of the water is salty, and all contains sufficient fluoride to cause mottling of the enamel of the teeth. The temperature of the water from flowing wells ranges from 47° to 69° F.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The investigation on which this report is based is a unit of a State-wide program of ground-water studies begun in July 1937 by the Geological Survey, United States Department of the Interior, in cooperation with the North Dakota Geological Survey. The purpose of the program is to make a thorough study of the distribution and character of the principal sources of ground water throughout the State, the quantity and quality of the water from each source, the state of depletion, and the quantity of water that is perennially available. This information made generally available will contribute to a satisfactory and economical solution of the problem of water-supply insofar as it relates to underground sources. In 1937 a State-wide system of observation wells [1] was established, by means of which

[1] Water levels and artesian pressure in observation wells in the United States in 1937: U. S. Geol. Survey Water-Supply Paper 840, pp. 319–328, 1938. Water levels and artesian pressure in observation wells in the United States in 1938: U. S. Geol. Survey Water-Supply Paper 845, pp. 346–369, 1939.

ground-water levels are observed periodically and are interpreted with respect to depletion of the supply and natural replenishment by the water from rain and snow. A critical study was also undertaken of the decline of artesian pressure and flow in the Dakota artesian basin in the Ellendale-Jamestown area and of the problem as to the future of the artesian water supply under efficient regulation.

In the investigation of the Dakota basin an attempt has been made to ascertain the change in artesian pressure that has occurred since an artesian water conservation program was started in 1923 (see pp. 6–10), with a view to determining whether the conservation work has resulted in restoring the artesian head of the water in the basin or at least in checking the decline. Field work for the study was done in 1937 chiefly by H. H. Sand and H. E. Simpson, Jr., both of the North Dakota Geological Survey, and in 1938 chiefly by Mr. Sand. The study was conducted under the general direction of O. E. Meinzer, geologist in charge of the Division of Ground Water in the Federal Geological Survey. L. K. Wenzel, of the Federal Geological Survey, was the engineer personally in charge of the ground-water investigation. Cooperation was carried on through H. E. Simpson, State geologist, until his untimely death in 1938; thereafter through his successor, F. C. Foley.

The Ellendale-Jamestown area is shown on plates 1 and 2 and includes all or parts of six quadrangles, namely, Columbia, Eckelson, Edgeley, Ellendale, Jamestown, and La Moure. Intensive field work was carried on chiefly along the western edge of the area of artesian flow in the Edgeley and Ellendale quadrangles. Data on the remainder of the area were obtained mostly from records collected between 1923 and 1935 by the State Geological Survey.

THE DAKOTA ARTESIAN BASIN

The group of strata commonly known as the Dakota sandstone are of Cretaceous age and underlie most of North Dakota, South Dakota, and Nebraska, and considerable parts of Kansas and other nearby States. These strata in one region probably are not exactly equivalent to those in another. In most places the Dakota sandstone is covered with younger formations, chiefly shales, and it appears at the surface only at widely separated localities, such as along the East Front Range of the Rocky Mountains, in the vicinity of the Black Hills, and in a belt extending from northeastern Nebraska to south-central Kansas and beyond. Consequently, in North Dakota, where the Dakota sandstone does not crop out, and over other wide areas its character is known only from samples obtained in drilling operations. In sinking deep wells in North Dakota and in many other parts of the region underlain by the Dakota sandstone, the drill, after passing through the overlying strata, encounters alternating beds of sandstone and shale that range in aggregate thickness from less than a hundred feet to a few hundred feet. Meinzer [2] points out that it is generally assumed that the first distinct sandstone stratum encountered by the drill marks the top of the Dakota sandstone and that the entire succession of alternating shales and sandstones belong to this formation, although it is recognized that the lower strata may belong to one or more other formatious. To what extent the alternating sandstone and shale beds are continuous over wide areas is not definitely known, but the group of beds is believed to be continuous in the aggregate.

The permeable Dakota sandstone and the overlying impermeable shales form the Dakota artesian basin, a basin that is one of the most remarkable in the United States with respect to its great extent, the long distances through which its water percolates, and the high pressure under which the water in it was originally confined. Water from rain and snow seeps into the sandstone where it crops out at high altitudes along the East Front Range and in the vicinity of the Black Hills and then percolates slowly eastward. The dip of the strata in and near the western outcrops is steep. Eastward the dip becomes more gentle, and in the eastern parts of North Dakota, South Dakota, and Nebraska the sandstone rises toward the east.[3] Thus the sandstone forms a great syncline which functions as a U-tube or an inverted siphon through which water slowly percolates from west to east (fig. 1).

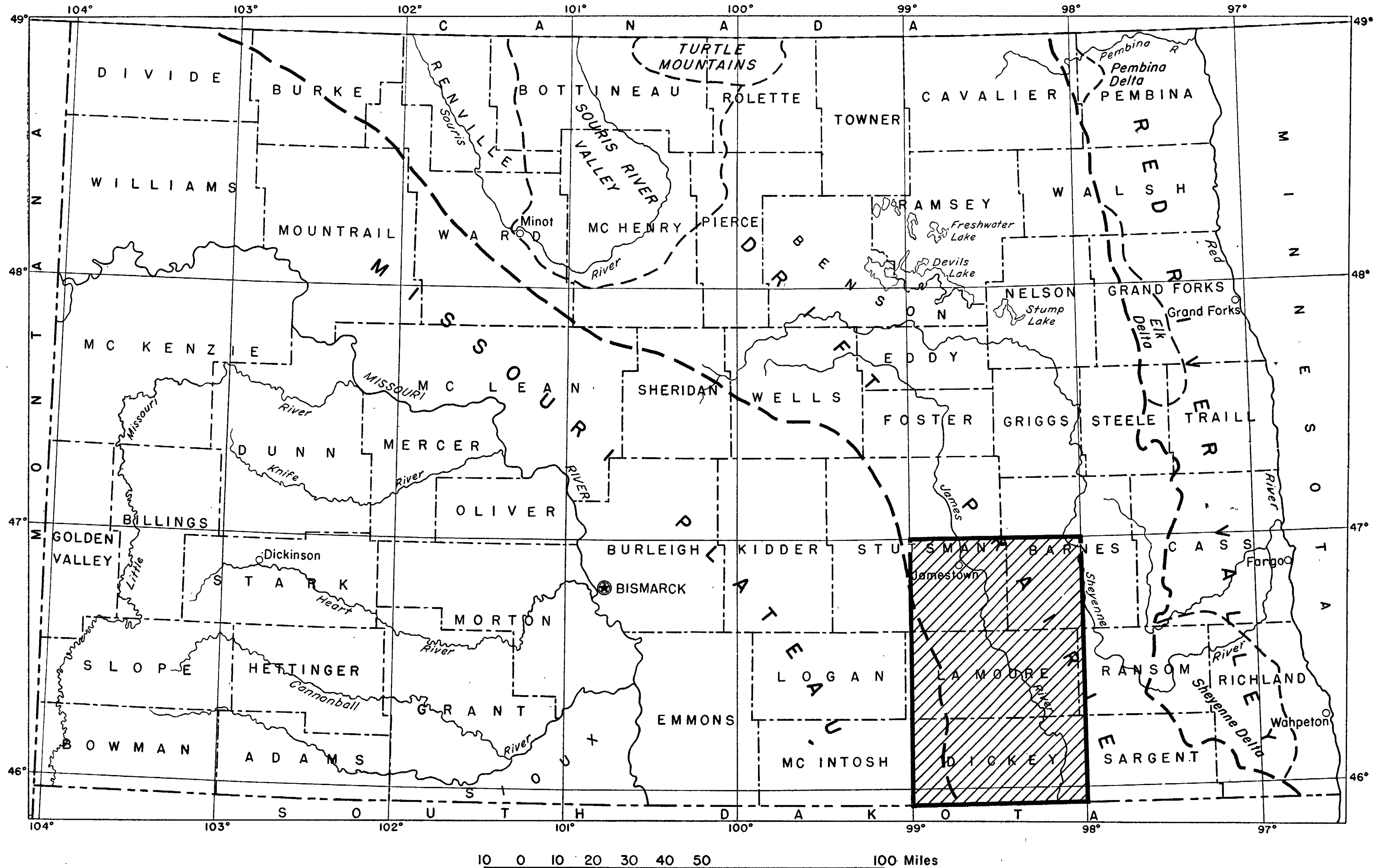
Much of the hydrostatic head due to the high altitude of the areas of intake is lost through friction as the water percolates through the sandstone. Thus the head of the water diminishes gradually from west to east across the basin. Nevertheless, the sandstone dips so steeply from the mountains that the water is under sufficient head to rise considerably above the top of the sandstone in wells over most of the basin. Where the land surface is relatively low, as in some of the stream valleys and much of the eastern part of the basin, the head is sufficient to lift the water in wells above the land surface (fig. 1).

The tremendous pressure under which water is confined in parts of the basin where the aquifer is deeply buried is illustrated by the record of a deep artesian well in the Cheyenne Indian Reservation at Red Scaffold, S. Dak. According to Robinson,[4] the pressure at the approximate land surface in 1936 was 120 pounds to the square inch, which is sufficient to lift the water about 275 feet above the surface. The depth of the well was 2,385 feet, and hence the pressure at the bottom

[2] Meinzer, O. E., Problems of the soft-water supply of the Dakota sandstone, with special reference to conditions at Canton, S. Dak.: U. S. Geol. Survey Water-Supply Paper 597, p. 147, 1929.

[3] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pl. 58, 1905.

[4] Rothrock, E. P. and Robinson, T. R., Artesian conditions in west-central South Dakota: South Dakota Geol. Survey report of investigations No. 26, p. 43, 1936.



MAP SHOWING THE PHYSIOGRAPHIC REGIONS OF NORTH DAKOTA AND THE LOCATION OF THE ELLENDALE-JAMESTOWN AREA.

(and presumably in the sandstone) was about 1,160 pounds to the square inch.

Originally the pressure at the surface in the eastern parts of North Dakota and South Dakota was great enough to expel the water from wells with great force, creating such spectacular scenes as that shown by a photograph, taken by N. H. Darton [5] in 1895, of the famous well at Woonsocket, S. Dak., from which water spurted up more than 100 feet. The pressure in the Woonsocket well was reported by Powell [6] to be about 250 pounds to the square inch at the land surface, thus indicating that the water would have risen in a tight casing to about

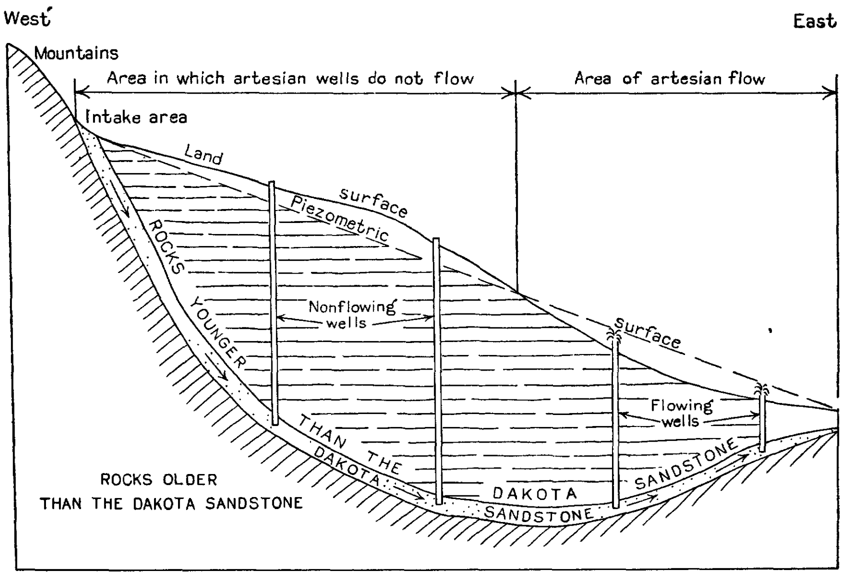


FIGURE 1.—Diagrammatic section across the Dakota artesian basin showing the general position of the Dakota sandstone and the hydrostatic head of the water in it.

575 feet above the surface. This is the highest pressure reported and may possibly have been somewhat in error. Nettleton,[7] in 1892, reported 29 artesian wells in North Dakota and South Dakota with pressures at the surface of 100 pounds or more to the square inch, the highest reported being 177 pounds in a well at Redfield, S. Dak. Nettleton gave the pressure in the Woonsocket well as 130 pounds to the square inch.

Although reports are at variance regarding the original pressures, it is apparent that pressures of more than 100 pounds were common.

[5] Darton, N. H., Preliminary report on the artesian waters of a portion of the Dakotas: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pl. 78, 1896.

[6] Powell, J. W., Artesian irrigation on the Great Plains: U. S. Geol. Survey 11th Ann. Rept., pt. 2, p. 269, 1891.

[7] Nettleton, E. S., Artesian and underflow investigation: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, table 74, 1892.

A map prepared by Darton [8] in 1890, based chiefly on Nettleton's measurements, shows the extent of the area of artesian flow and the approximate artesian head in different parts of the area. The area of artesian flow from the Dakota sandstone, as mapped by Darton, averaged about 60 miles in width and extended from the South Dakota-Nebraska line to the vicinity of Jamestown and Valley City, N. Dak. According to a more detailed map prepared by Simpson [9] prior to 1929, the area of artesian flow in North Dakota stretched in a general northwest direction from the South Dakota line to the Canadian border, the width ranging from about 100 miles in the southeastern part of North Dakota to less than 10 miles in the north-central part of the State. The area of artesian flow in North Dakota, as outlined later by Simpson, is shown on plate 2.

HISTORY OF THE ARTESIAN-WATER CONSERVATION PROGRAM IN NORTH DAKOTA

In the early years of well drilling in the Dakota artesian basin little thought was given to the safe yield of the aquifer and to the possibility of over-developing the supply. The fact that wells could be constructed almost everywhere over a wide area and that the water pressure in them was so great led many persons to believe that the supply of the basin was inexhaustible. A notable exception, however, was J. W. Powell, second Director of the United States Geological Survey, who in 1890 made a statement [10] on the yield of the artesian basin indicating that the high pressures might only be temporary and that the permanent supply might be considerably less than the initial supply. He also called attention to the danger of disaster through exploitation of the supply and to the need for a scientific investigation of the basin.

Serious consideration was not given, however, to his conservative estimates regarding the supply of the basin; and for many years wells were allowed to flow freely, and the water ran to waste. Between 1886 and 1896 several hundred wells were drilled to the Dakota sandstone in southeastern North Dakota, and during the next 20 years several thousand additional wells were constructed.

It is now known that the artesian head and the flow of the wells began to decline as soon as the first wells were drilled to the sandstone; but it was not until later, as more wells were constructed, that this decline caused concern. The decline became especially noticeable along the western edge of the area of artesian flow when some of the

[8] Darton, N. H., Preliminary report on the artesian waters of a portion of the Dakotas: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pl. 98, 1896.

[9] Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, pl. 1, 1929.

[10] Powell, J. W., op. cit., pp. 260–276.

wells ceased flowing and the water level in them declined below the land surface. Farther east the decline in head was reflected chiefly by the decrease in flow of the wells. The situation became so alarming that in 1916 the North Dakota Legislature directed the State engineer "to investigate all matters and conditions connected with the construction, use, and maintenance of our artesian wells in the State of North Dakota." The State engineer reported to the Governor on November 1, 1918, that "a large proportion of the wells where the original pressure is known have ceased to flow and in all cases the flow has been greatly reduced." Recognizing that there was a danger of losing the flow entirely, the legislature in 1921 passed a law providing for the regulation of the flow of wells with the intent of reducing the flow to that which could be used beneficially. The law further specified that an inventory of wells be taken by the township assessors and that the enforcement of the law be placed in the hands of the State geologist. The late H. E. Simpson assumed this work, with the title of State water geologist.

A nearly complete census of all artesian wells was made by the township assessors in the spring of 1921, and the census was checked in 1922 and 1923. During the field season of 1921 Prof. Simpson and his assistant John Buchanan made a survey of a belt 6 miles wide that extended from the Red River Valley in T. 140 N. to the western edge of the area of artesian flow. The detailed study of the belt provided the basis for a general inspection of individual wells that was begun in 1923 and is still in practice.

Each known artesian well in the Dakota basin has been inspected at least once by the State geologist or his deputy, and those wells that were found flowing in excess of the quantity that could be used beneficially have been inspected two or more times. Owners and tenants were advised by the field inspector as to suitable methods for repairing their wells and saving water, the maximum flow compatible with proper management, and hence the flow to which their wells should be reduced. Essentially the same advice was later mailed from the office of the State Geological Survey in Grand Forks. The complete stopping of the flow of wells by means of valves was not found practical because then the water frequently froze in the wells or distributing pipes in cold weather. Moreover, the flow of many of the wells decreased after being shut off or the water became roily. Advice was therefore given to reduce the flow to the minimum that would prevent freezing and at the same time be sufficient for the consumer's needs. Although handicapped at times by lack of funds, this educational program has been carried on almost continuously since 1923, and in general the program has received the willing cooperation of the well owners.

The artesian water law,[11] as passed by the North Dakota Legislature in 1921 and amended in 1925 is given herewith:

THE ARTESIAN WATER LAW

17TH LEGISLATIVE SESSION, 1921, H. B. 41 (Shimmin)

As amended by the

19TH LEGISLATIVE SESSION, 1925, S. B. 63 (Carey)

[The amendments are printed in italic]

ARTESIAN WATERS

AN ACT Providing for the preservation and control of the artesian waters of the State.

Be it enacted by the Legislative Assembly of the State of North Dakota:

SECTION 1. Every person, stock company, association or corporation owning or controlling the real estate upon which is located an artesian, or flowing well, shall, within 60 days after the passage of this act, provide for each such well a valve, or valves, capable of controlling the discharge from such well and shall keep said valve, or valves so adjusted that only such supply of water shall escape as is necessary for ordinary use by the owner of, or the person in control of, said land in conducting his business: *Provided, however,* That in the winter such flow may be permitted as will prevent freezing of the well, and in those cases where it is necessary a sufficient flow may be allowed to prevent clogging of the well: *Provided, however, That such owner of an artesian well shall be required by means of the construction of a reservoir or otherwise to prevent the flow of his well from running upon land belonging to another or from running into any ditch along any public highway except a regularly established drainage ditch.*

SEC. 2. Every person, stock company, association, or corporation which shall drill an artesian, or flowing well, shall drill a small smooth hole through the cap-rock to closely fit the pipe, and shall use every possible means to seal around the main pipe in such a manner that no water can escape from the flow. No dynamite or other explosives shall be used in penetrating the water covering layer (cap rock). This does not apply to boulders of granite or other obstacles in non-water bearing horizons. Where the top part of the water-bearing layers of any given flow are soft and crumbling, yielding muddy or sandy flow, the driller may not end the well at this level but must test the layers by boring on down a reasonable distance, from 5 to 25 feet at least, and more if the owner of the land require, to locate a terminus in a firm sand rock which will stand firm, preventing dirty flow and permit regulation of the flow. Once the firm stratum is located the driller shall attach in it at the end of the well pipe, a strainer of noncorrosive material, with numerous small perforations to insure clear pure water and nonclogging. If the owner request, the driller must place a valve below frost level with a handle reaching to the surface so that well may be entirely shut off at will. He shall extend the outside or surface casing to, and fit same solidly into, the shale or hard clay formation a sufficient distance to entirely prevent a flow around the casing. He shall seal between casing and pipe.

SEC. 3. In cases of new wells in any soft formation where clay, sand or any sediment is liable to cause clogging, the valve may be left open until the well has sufficiently cleared. It shall then be finally adjusted, to normal condition. This act shall apply to all "wild" wells, or wells out of control due to rusted pipes,

[11] Simpson, H. E., The conservation of artesian water: North Dakota Geol. Survey Bull. 5, pp. 12-14, 1926.

improper construction, etc., however, if it be determined that such well can not be repaired, no valve shall be attached, but every effort shall be made by the owner to seal, plug or cut off the same, when in the estimation of the State geologist it will cause no loss other than reasonable amount of repair cost. Old wells which might be damaged by so doing may not be shut off, but such wells must be put in repair at the earliest possible date and be regulated thereafter.

SEC. 4. The owner or person in control of an artesian, or flowing well, who shall allow the same to flow without a valve or sufficient contrivance for checking the flow, as required by law, or without proper repair pipes, valves, etc., or who shall interfere with the same when properly adjusted by the proper authority, or shall permit the water to waste unnecessarily, *or permit the water to run upon the lands of another or into the ditches along any public road except a regularly established drainage ditch*, or shall interfere with any officer duly authorized to inspect the same or measure its flow or pressure, shall be guilty of a misdemeanor and on conviction thereof shall be punished by a fine not less than five dollars and not to exceed fifty ($50) dollars, at the discretion of the court. The provisions of this section shall also apply to the officer or board in charge of wells belonging to the State, or any county, township or municipality.

SEC. 5. The county and township assessors shall list all artesian or flowing wells, in their respective districts each year at time of making the assessment, giving the quarter section on which each is situated, the owner, with his address, also as far as possible, the diameter, depth to the main flow, and size of flow. This data is to be forwarded by the county auditor to the State geologist or his deputy. Hereafter in case of new flowing wells, the driller shall also file with the State geologist or deputy all of the foregoing data, and any other valuable data, as to the formation. This shall be done within two weeks after the completion of the well.

SEC. 6. The State geologist or his deputy shall have the general oversight and supervision of the waters of the State, and shall advise the citizens of the State as to the practicability of measures affecting the underground waters of the State. It shall be his duty to counsel and consult with the owner and assist him to work out the most desirable control and use of his well. He shall select at least three representative flowing wells in each county having that number, and as many more as he may deem advisable, and he shall cause the record of their flow and pressure to be taken from time to time, to learn as much as possible of the decline, fluctuations and permanence of the artesian supply, and also plan and conduct, such other investigations as he may find advisable to ascertain the best method of prolonging the utility of the same. He shall keep a record of the location, size, depth, flow, size of flow, character of water, construction and history of all artesian wells of the State, and keep it on file for public reference. He shall secure the enforcement of all laws pertaining to artesian and phreatic waters of the State. He shall publish from time to time, as he may deem advantageous, bulletins containing information concerning the artesian wells and phreatic waters of the State. The State geologist and State engineer and the county superintendent of schools where such well is located, as the majority shall determine, shall make such additional reasonable rules and regulations, and they shall each receive $10 per day and actual traveling expenses.

SEC. 8. Enforcement of this act shall be in the charge of the State geologist or his deputy, who shall be a specialist, skilled in the control of flow and pressure, and of methods of construction of artesian wells. There shall be appropriated from State funds not otherwise appropriated the sum of $2,500 biennially for the purpose of carrying out this act. An appeal from the geologist's ruling may be had, if made within five days to a board of arbitration consisting of the State engineer, assistant State geologist who shall review the matter and render final orders.

SEC. 9. The deputy who shall be appointed by the State geologist may be removed for cause, and whose salary shall be $10 for each day and actual traveling expenses.

SEC. 10. EMERGENCY.—Whereas an emergency exists this act shall be in full force and effect after its passage and approval.

Approved, March 10, 1921. Amendment approved, February 13, 1925.

PREVIOUS INVESTIGATIONS

The unique features of the Dakota artesian basin, including its great extent and the tremendous pressure of the water in it, attracted much attention, especially in the early years of development. In 1890 and 1891 a reconnaissance survey of the basin was made by the United States Department of Agriculture, the results of which were published in a report by E. S. Nettleton.[12] A few years later the United States Geological Survey undertook extensive and somewhat detailed investigations of the geology and hydrology of the basin. This work was carried on under the direction of N. H. Darton, and numerous reports on the subject were published. Most of these reports relate to areas in South Dakota,[13] but some reports cover parts of the artesian basin that lie in other States, including North Dakota. The results of the more recent investigations of the artesian basin in North Dakota by Abbott, Hard, Meinzer, Simpson, Voedisch, and others are published in reports listed on p. 11. Several papers have been published on geologic and hydrologic theory that utilize the artesian basin to some extent as a basis of discussion, among which may be mentioned the discussion of compressibility and elasticity of artesian aquifers by Meinzer[14] and the rather controversial discussions of Russell,[15] Piper,[16] Terzaghi,[17] and Thompson[18] on the origin of artesian pressure.

Although many reports have been published on different parts of the basin, there is still a great lack of specific data for determining the hydrology of the artesian system and the future artesian water supply. The difficulties of obtaining adequate data have thus far proved insurmountable. The great depth at which the sandstone strata occur over much of the basin has discouraged the drilling of wells except in the areas of artesian flow, and thus there are large parts of the basin about which very little is known. Even where there are numerous wells, it is difficult to obtain precise data on the character of the sandstone, depths to the several sandstone strata, the artesian

[12] Nettleton, E. S., Artesian and underflow investigation: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, 1892.

[13] The following publications of the United States Geological Survey relate to artesian water in South Dakota: 11th Ann. Rept., pt. 2; 17th Ann. Rept., pt. 2; 21st Ann. Rept., pt. 4; Prof. Papers 32, 65; Geol. Folios 85, 96, 97, 99, 100, 107, 108, 113, 114, 128, 156, 164, and 165; Water-Supply Papers 34, 90, 227, and 428.

[14] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology, vol. 23, No. 3, pp. 263-291, 1928.

[15] Russell, W. L., The origin of artesian pressure: Econ. Geology, vol. 23, No. 2, pp. 132-157, 1928.

[16] Piper, A. M., The origin of artesian pressure: Econ. Geology, vol. 23, No. 6, pp. 683-696, 1928.

[17] Terzaghi, C., The origin of artesian pressure: Econ. Geology, vol. 24, No. 1, pp. 94-100, 1929.

[18] Thompson, D. G., The origin of artesian pressure: Econ. Geology, vol. 24, No. 7, pp. 758-771, 1929.

head of water in the strata, and other important geologic and hydrologic conditions because of the jetting method of drilling, leakage of wells, and the effect on wells of the flow from other wells.

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The following is a list of publications relating wholly or in part to the Dakota artesian basin in North Dakota that have been utilized to some extent in the preparation of this report. Attention should be called especially to the report by Meinzer and Hard on the artesian water supply of the Dakota sandstone in North Dakota, which contains quantitative estimates that have served as bases for several conclusions in this report.

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WATER-BEARING FORMATIONS [19]

The surficial formations of the Ellendale-Jamestown area consist chiefly of glacial drift and associated deposits of alluvium and lake silt, all belonging to the Quaternary system. The Pierre shale, of Cretaceous age, occurs everywhere in the area. In general it lies immediately beneath the surficial deposits, but in a few places where the Quarternary formations are absent it is exposed at the surface. The Niobrara formation and Benton shale are believed to underlie the Pierre shale. Though they apparently have been penetrated by the drill in many wells they generally are grouped by the driller with

[19] For a description of the physiography, geology, and general ground-water conditions of the area, see Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, 312 pp., 1929.

the overlying Pierre and thus do not usually appear in well logs. The Dakota sandstone, which lies below the Benton shale, is the deepest formation to which wells are generally drilled in the Ellendale-Jamestown area. Sedimentary rocks of early Paleozoic age are believed to underlie the Dakota sandstone.

As is shown in a general way in figure 1 the land surface slopes gently from west to east across the eastern part of the artesian basin and the Dakota sandstone rises toward the east. Thus the depth at which wells penetrate the Dakota decreases from west to east across the Ellendale-Jamestown area. The thickness of the shales overlying the sandstone also decreases toward the eastern part of the area.

Ground water in the Ellendale-Jamestown area occurs chiefly in the surficial deposits of glacial drift, lake silt, and alluvium, in the Pierre shale, and in the Dakota sandstone. The Niobrara formation and Benton shale are not known to be sources of water supply in the area, and no wells in the area are known to draw water from formations below the Dakota sandstone.

GLACIAL DRIFT AND ASSOCIATED DEPOSITS

The Ellendale-Jamestown area is covered by glacial drift and associated deposits of alluvium and lake silt except at a few isolated places where the Pierre shale is exposed, such as south of Edgeley, west of Ellendale, and south of Valley City.

The thickness of the drift in the Edgeley and La Moure quadrangles is shown in plates 3 and 4 respectively of Geological Survey Bull. 801,[20] and the areal distribution of the drift and alluvium in the Jamestown and Eckleson quadrangles is shown on the areal geologic maps of the Jamestown-Tower folio.[21] The drift is by far the most widespread surficial deposit of the Ellendale-Jamestown area and in places is more than 500 feet thick. Alluvium occurs mainly in the valleys of the larger streams, such as the James, Sheyenne, and Maple Valleys, although some alluvium is found also in the valleys of most smaller streams. The alluvium ranges from a few feet to 50 feet and more in thickness.

Lake silt occurs as a mantle over a plain 6 to 10 miles wide in the lower James Valley from about Oakes southward to the State line. Its origin is glacial in that the lake in which it was deposited was formed by a morainal dam left across the James River in South Dakota.[22]

[20] Hard, H. A., Geology and water resources of the Edgeley and La Moure quadrangles, North Dakota: U. S. Geol. Survey Bull. 801, pls. 3, 4, 1929

[21] Willard, D. E., U. S. Geol. Survey Geol. Atlas, Jamestown-Tower folio (No. 168), 1909.

[22] Simpson, H. E., Geology and ground-water resources of North Dakota: U. S. Geol. Survey Water-Supply Paper 598, p. 113, 1929.

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The glacial drift consists chiefly of till, or boulder clay, and deposits of sand and gravel interbedded with the till or underlying the valleys. The alluvial deposits are composed of roughly sorted gravel, sand, and silt of glacial origin; and the lake silt, as its name implies, consists mainly of rather fine materials. The drift, alluvium, and lake silt contain some sand that generally yields moderate and rather dependable supplies of water to wells. On the whole, however, the surficial deposits are fine-grained sediments with low permeability; and hence they consitute rather poor water-bearing materials. Their specific yield is also generally low; that is, they will yield a relatively small quantity of water for each unit volume of water-bearing material that is drained. Therefore relatively small withdrawals of water from the sediments may cause the water level in them to decline appreciably. In general, the underground reservoirs formed by the surficial deposits do not possess large storage capacities, and they may become seriously depleted in times of drought.

Wells that end in the surficial deposits generally deliver sufficient water, except in some dry years, for most farm and home uses. A few public supplies, including those for Jamestown, La Moure, and Oakes, are obtained from the more permeable parts of them. Most of the wells that are supplied by water in the surficial deposits are shallow dug or bored wells. The more permeable parts of the deposits in some places are overlain with clay or silt, which confines the water under hydrostatic pressure. Where such conditions exist the water rises in wells above the level at which it is encountered, and in some low places shallow flowing wells are obtained.

SAND STRATA IN THE CRETACEOUS FORMATIONS ABOVE THE DAKOTA SANDSTONE

The Pierre shale, which occurs directly below the surficial deposits in the Ellendale-Jamestown area, furnishes very small quantities of water to wells from sandy beds in its upper part. The water, moreover, is generally brackish and otherwise of poor quality. The public supply of Edgeley, however, is an exception. The city wells, which tap water in the upper 20 to 60 feet of Pierre shale, furnish a small but adequate supply of fairly good water. The Niobrara formation and Benton shale, which lie beneath the Pierre shale, are not generally a source of water supply in North Dakota,[23] and no wells in the Ellendale-Jamestown area are known to derive water from them.

DAKOTA SANDSTONE

The Dakota sandstone is found almost everywhere in the area below Benton shale or, where that is absent, below the younger formations.

[23] Simpson, H. E., The ground waters of North Dakota: North Dakota Geol. Survey Bull. 7, Artesian Water Paper 5, p. 13, 1932.

Its texture and composition are known only from drilling because the sandstone does not crop out. The formation consists of a gray ferruginous sandstone, poorly cemented and interbedded with layers of clay and shale.[24] In places it includes beds of fine loose sand. The depth below the land surface at which it is encountered ranges from about 800 feet in the eastern part of the area to 1,600 feet or more in western Dickey and La Moure Counties.

Two or more sandstone beds, separated by shale layers, are recognized by most drillers; and all these strata are generally assigned to the Dakota, although it is commonly recognized that the lower sediments may belong to other formations. The aggregate thickness of the sandstone and shale beds ranges from less than a hundred feet to a few hundred feet. As the artesian head and the chemical character of the water from the various beds usually differ considerably, the beds are commonly classified as distinct artesian horizons. Correlating the horizons from place to place, however, is difficult, and the precise horizon that a well taps is not generally known with certainty. According to Hard,[25] as many as seven successive flows have been obtained in drilling one well, the water-bearing beds being separated by shale or dense sandstone.

The chemical character of the water probably provides as good a basis as any for differentiating between the several flow horizons. The water from the upper part of the sandstone is generally soft but somewhat salty and is often assigned to the "first flow." The waters from the sandstone at greater depths are usually much harder but lower in chloride and are commonly regarded as "second flow" waters. However, a water of very high mineral content but apparently of no consistent chemical character is encountered in some places in the deepest sandstone beds; it is designated by some drillers as "third flow" water. A general differentiation of this kind apparently was recognized by Hard,[26] who wrote,

> The water from the artesian wells that end at the first horizon of the Dakota sandstone is generally usable for all purposes except in the region west of a line from Monango to Grand Rapids, where much of it is too bitter for drinking by man. Water from the second and third flow horizons contains too much mineral matter for drinking or for boiler use.

The following somewhat different concept was expressed by Simpson,[27] in discussing the water supplies at Ellendale. "This supply of water came from what is known locally as the 'second flow' or 'soft-water flow' * * * a fourth well, popularly known as the 'hard-water well' was drilled to the 'third flow' during the same year."

[24] Simpson, H. E., op. cit. (Water-Supply Paper 598), pp. 40–41.

[25] Hard, H. A., Geology and water resources of the Edgeley and La Moure quadrangles, North Dakota: U. S. Geol. Survey Bull. 801, p. 49, 1929.

[26] Hard, H. A., op. cit., p. 74.

[27] Simpson, H. E., op. cit., p. 115.

Meinzer[28] divided the sandstone and associated shale strata into upper and lower parts, the upper part producing soft water and the lower part producing hard water. He states that

the upper part does not form a single stratum but rather an indefinite group of sandstone strata and lenses interbedded with shale; the sandstone of the lower part has been reached by so few wells that there is no very definite information as to its thickness and character.

Each of the designations cited above probably express closely the conditions in certain localities. On the other hand, probably none of them can be applied with confidence over the entire artesian basin. The results of this investigation appear to indicate that for the Ellendale-Jamestown area the first differentiation of flow horizons—that which denotes the "first flow" as soft water, the "second flow" as hard water, and the "third flow" as a highly mineralized water of uncertain type—is most generally applicable. Such a designation is therefore used in this report. In computations that follow, however, wells assigned to the "third flow" have been omitted.

Most of the wells in the Dakota sandstone tap only the first flow, although there are many wells that tap the second flow and a few that tap the third flow. The decline in artesian pressure presumably was greatest at first in the upper sandstone, but owing to increased development of the second flow and leakage from the second horizon to the first, the pressures in the two beds are now about equal. The few wells that have been drilled recently to the third flow, however, have encountered water under distinctly higher pressure than exists in the overlying beds. The Dakota still supplies adequate quantities of water in most places for home, farm, and public use despite the great decrease in artesian pressure that has occurred since development of the supply was begun. The public supplies of Ellendale, Forbes, Fullerton, Ludden, Monango, and Verona are obtained from the sandstone by pumping or natural flow.

WATER IN THE DAKOTA SANDSTONE

USE

Most of the water from the Dakota artesian basin in southeastern North Dakota is highly mineralized and at many places is unsuited for general use, especially for household purposes. Nevertheless, the water is used extensively over the area, chiefly because adequate supplies of more potable water are not available. Water from the surface deposits and Pierre shale is generally utilized wherever possible.

The water from the Dakota artesian basin is used for cooking and washing, although it commonly turns some vegetables dark and stains

[28] Meinzer, O. E., and Hard, H. A., The artesian water supply of the Dakota sandstone in North Dakota, with special reference to the Edgeley quadrangle: U. S. Geol. Survey Water-Supply Paper 520, p. 79, 1925.

clothes. The water of the first flow is soft, in contrast with the waters of the second and third flows, which are hard, and is therefore the water most desirable for washing purposes. The water is regarded as excellent for stock and is used extensively for this purpose. Because the temperature of the Dakota water is higher than the temperature of the drift and shale water, cows will drink more Dakota water during the cold winter months, and as a result the production of milk and cream is said to be increased.

Very little of the water is used for irrigation because of its high mineral content. A small vegetable garden was irrigated during the recent years of drought from a well on the farm of A. L. Stevens in the SE¼ sec. 7, T 131 N., R. 63 W. Mr. Stevens reported that the minerals left by evaporation of the water caused the soil to become hard and lumpy and that the plants grew very poorly. However, a hedge on the farm was watered sparingly with the artesian water with fair success. In many places in the area almost all the vegetation has been killed along pools and ditches into which waste artesian water has been drained.

Some of the uses to which the water from the Dakota basin was originally put are not now generally possible. When the artesian pressure was high the water furnished fire protection for individual farm homes without pumping and furnished power to operate dynamos and other mechanical devices. The water was originally piped about the farms to convenient taps and into farm houses where it served as a general supply. For public supplies the wells were connected directly to the mains and the artesian pressure was sufficient to operate the system without pumping. At one time the operating of small electric light plants, feed mills, blowers in blacksmith shops, and washing machines by artesian water power was common.

The original high pressures of the first and second flows have now been largely dissipated, and as a result the uses of the water insofar as they depend on high water pressure or high flow have greatly decreased. The third-flow wells still have considerable pressure, as indicated by a well drilled in July 1937 by F. W. Schulz, of Aberdeen, S. Dak., in the SE¼ sec. 23, T. 131 N., R. 63 W., which is now used to operate a dynamo. The well is said to have flowed about 60 gallons a minute when it was finished. Because of the piping arrangement it was not possible to measure the flow during the present investigation.

TEMPERATURE

During the present investigation the temperature of water from 77 artesian wells was observed. Of these wells, 66 were flowing wells and 11 were nonflowing wells. The measurements were made at the mouths of the wells where possible, otherwise at the nearest tap. The temperature of the water from flowing wells ranged from 47° F. to 69° F. and averaged 60.2° for the 66 wells. The water from nonflowing wells ranged from 47° to 59° and for the 11 wells averaged 52.3°. These temperatures for the artesian water compare with temperatures ranging from 42° to 45° for the shallow ground water of the area.

Hard [30] gives a table showing the temperature of the water from 13 artesian wells in the Edgeley-La Moure area. The highest temperature shown is 70° and the lowest temperature 48°. The average temperature of the 13 wells listed is 62.3°—about 2° higher than the average temperature of the 66 flowing wells measured during the course of the present investigation.

The sandstone strata in the area lie from about 800 feet to 1,600 feet below the land surface, and it is to be expected that the temperature of the artesian water would be appreciably higher than the temperature of the shallow ground water. The variation in depth of the sandstone, however, does not appear to account entirely for the rather wide range in temperature noted above. The lower average temperature of water from nonflowing wells doubtless is caused chiefly by the cooling of the water as it stands in the casing. The water from some of the wells is probably cooled during its rise to the surface. Such cooling action would not seem to account for the low temperature of the water from some of the flowing wells, although the time taken for the water to rise from the sandstone to the surface is appreciable. The rate of flow of water through a 1½-inch pipe discharging 1 gallon a minute is about 10.8 feet a minute. Thus 100 minutes is required for water to reach the surface from a depth of 1,080 feet through a 1½-inch well flowing 1 gallon a minute. That some cooling does take place in this interval is indicated in a general way by the discharge-temperature relation of the flowing wells. The average flow from wells having water temperature from 47° to 55° was about 1.4 gallons a minute; from wells having water from 56° to 60°, 1.8 gallons a minute; from wells having water from 61° to 65°, 2.0 gallons a minute; and the average flow from wells having water temperatures from 66° to 69° was 3.0 gallons a minute. Other factors that may lower the temperature of the water at the surface are the piping arrangement at the surface and the evolution of gas.

CHEMICAL CHARACTER

By G. A. Abbott

In connection with projects of the Federal Emergency Relief Administration and the Works Progress Administration sponsored by the North Dakota Geological Survey, the chemical character of samples of water from more than 1,000 wells in North Dakota has

[30] Hard, H. A., Geology and water resources of the Edgeley and La Moure quadrangles, North Dakota: U. S. Geol. Survey Bull. 801, p. 76, 1929.

been determined in the chemical laboratory of the University of North Dakota.[31] Analyses were made of water from all formations in North Dakota that yield appreciable quantities of water to wells. The following discussion of the chemical character of the water from the Dakota sandstone is based on analyses made as a part of the projects mentioned above.

The nature and significance of the constituents of ground waters are well known. They have been fully discussed in publications of the Federal Geological Survey[32] and elsewhere,[33] so repetition here seems unnecessary. The following table gives analyses of water from 33 wells in the Dakota sandstone in southeastern North Dakota, arranged according to the flow horizon each well is believed to tap. Such an arrangement must be regarded as somewhat presumptive because for most wells the flow horizon could not be definitely ascertained. Moreover, the water from some of the wells likely consists of a mixture of water from two or more horizons.

Following modern convention the analyses are reported in parts per million of the respective constituents without regard to hypothetical combinations, except that total hardness and total alkalinity are expressed also in terms of equivalent quantities of calcium carbonate. Fresh samples of the waters contain an excess of carbon dioxide, thus indicating that the alkalinity is entirely due to bicarbonate.

The analyses show that waters from the Dakota sandstone are unsatisfactory for domestic supplies. All of them greatly exceed the upper limit of 1,000 parts per million of total solids specified by the United States Public Health Service for interstate carriers, and the individual constituents of many of them also exceed the limits of toleration. The fluoride content in some of them is excessive, and all of them carry sufficient fluoride to cause mottled enamel in teeth.

Unfortunately, in many localities no water supply other than that from the Dakota sandstone is available in the immediate vicinity. Thus the water, although objectionable, is rather widely consumed. Persons long accustomed to drinking the artesian water claim they suffer no ill effects, and many report that less mineralized water tastes flat and insipid to them. Those unaccustomed to drinking the water often suffer mild gastric and intestinal disturbances, which, however, gradually diminish and finally disappear with continued use of the water.

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[31] Abbott, G. A., The fluoride content of North Dakota ground waters: North Dakota Geol. Survey Bull. 9, 15 pp., 1937. Abbott, G. A., and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geol. Survey Bull. 11, 99 pp., 1938.

[32] Collins, W. D., Relations between quality of water and industrial development in the United States: U. S. Geol. Survey Water-Supply Paper 559, 43 pp., 1926; Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596, pp. 235–266, 1927. Collins, W. D., Lamar, W. L., and Lohr, E. W., The industrial utility of public water supplies in the United States: U. S. Geol. Survey Water-Supply Paper 658, 135 pp., 1934.

[33] Abbott, G. A., and Voedisch, F. W., op. cit., pp. 22–26.

Analyses of waters from the Dakota sandstone in southeastern North Dakota

[Parts per million. Analyses made in the chemical laboratory of the University of North Dakota]

First-flow wells

Sec.	T. N.	R. W.	County	Owner	Depth of well (feet)	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Alumina (Al_2O_3)	Manganese (Mn)	Zinc (Zn)	Fluoride (F)	Total alkalinity as $CaCO_3$	Total hardness as $CaCO_3$
24	138	58	Barnes	J. Saugstad	1,100	2,964	12	1.0	45	22	1,007	394	471	1,115	44	15	0.0	22	2.8	322	240
24	138	58	do	M. Thoreson	1,100	2,703	34	.7	62	45	853	342	646	861	26	15	.0	.6	3.4	280	342
7	129	59	Dickey	Village of Ludden	980	2,568	14	.4	18	28	875	486	537	781	1.3	14	.0	4.0	3.6	398	124
12	129	63	do	City of Ellendale	1,087	2,777	28	.5	29	10	993	590.9	435	939	6.2	14	.0	.0	3.2	484	114
35	129	65	do	Village of Forbes	1,400	2,377	21	1.4	18	24	837	810.0	177	781	26	15	.0	2.8	1.8	664	154
15	131	62	do	Village of Fullerton	1,160	2,748	23	3.0	37	4.4	1,029	566.0	231	1,160	22	15	.0	7.0	2.4	464	126
11	134	56	Ransom	City of Lisbon	890	2,786	5	.3	36	7.6	910	271	1,316	357	2.7	9.6	.0	3.0	2.8	222	168
11	134	56	do	do	751	2,753	6	.2	30	7.6	889	278	1,264	355	.4	11	.0	7.0	3.8	228	120
23	134	57	do	Village of Elliott	1,200	2,598	6	.0	7	1.3	904	261	1,137	379	.7	14	.0	2.0	3.2	214	23
13	130	52	Richland	City of Lidgerwood	360	3,152	25	.4	20	10	1,070	466	1,248	502	11	11	.3	0.2	7.5	382	92
6	132	51	do	Village of Wyndmere	545	2,646	5	.1	16	8.3	915	302	1,178	412	2.2	9.8	.0	3.0	6.5	248	78
16	130	54	Sargent	H. Dyste	720	3,045	17	2.2	26	17	991	573	1,116	475	2.2	13	.0	14	5.0	470	160
16	130	54	do	O. Lyngved	700	2,738	11	.2	26	26	871	364.2	1,164	380	5.3	32	1.5	.0	9.2	299	174
19	130	54	do	O. Peterson	800	2,721	24	.0	35	15	864	335	1,158	372	31	15	.0	12	5.5	275	166
18	130	55	do	C. Lilja	800	2,713	26	.1	33	14	865	362	1,089	403	36	19	.0	14	5.2	297	161
1	130	56	do	J. Bond	785	2,652	16	.4	21	11	910	367	1,015	485	27	20	.0	.0	5.0	301	100
1	130	56	do	E. Isakson	700	2,790	7	2.8	23	9.2	930	385	1,170	398	6.6	15	.0	8.0	6.0	316	113
1	130	56	do	Village of Forman	840	2,571	19	.9	24	20	858	420	981	449	5.7	17	.0	4.0	5.0	344	150
2	130	57	do	Village of Cogswell	1,000	2,502	19	.1	26	7.9	815	315	1,162	293	4.4	13	.0	12	4.0	258	115
2	130	57	do	H. Webster	900	2,523	23	.5	24	7.4	834	327	1,128	328	9.7	14	.0	12	3.8	268	108
9	132	54	do	G. Mundy	665	2,613	1	.7	32	15	898	310	1,214	405	4.4	8.0	.0	6.0	4.0	254	151

Second-flow wells

Sec.	T. N.	R. W.	County	Owner	Depth of well (feet)	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Alumina (Al_2O_3)	Manganese (Mn)	Zinc (Zn)	Fluoride (F)	Total alkalinity as $CaCO_3$	Total hardness as $CaCO_3$
13	137	57	Barnes	Village of Nome	1,350	2,995	22	2.4	181	76	683	219	1,356	468	8.8	21	.0	6.0	1.6	180	778
25	137	60	do	Village of Litchville	1,300	2,640	20	3.0	184	74	541	207	1,315	280	22	28	.0	4.0	1.4	170	779
17	136	54	Ransom	Village of Sheldon	624	2,669	17	1.3	134	56	661	225	1,263	355	11	16	.0	2.8	2.0	184	572
9	130	54	Sargent	Peterson	800	2,590	11	.2	134	40	684	328.5	1,065	419	3.4	12	.0	1.0	5.5	286	499
9	130	54	do	George	800	2,601	32	.3	129	40	682	348.5	1,042	412	2.6	17	.1	.6	6.0	286	486
19	130	54	do	W. Fladby	665	2,647	8	.1	202	69	574	371	1,144	371	6.2	13	.0	5.0	7.3	304	795
1	130	56	do	Sargent County	900	2,823	7	1.4	58	38	827	239	1,080	555	6.6	7.0	.0	10	4.4	196	321
30	131	54	do	O. Wyum	630	2,696	27	.8	116	61	691	361	1,173	368	3.5	9.9	.0	7.0	6.5	296	553

Third-flow wells

8	131	59	Dickey	Federal Land Bank	1,140	4,040	9	Trace	63	13	1,283	370.9	1,871	525	3.1	10	.1	.0	2.8	304	211
17	131	60	do	do	1,286	2,208	11	Trace	94	25	636	198.8	1,220	73	13	7	Trace	.0	1.6	163	333
23	131	63	do	Farmers & Mechanics Bank	1,480	2,548	10	.1	256	58	741	200.0	1,244	80	17	2	.2	.0	2.0	164	879
1	138	63	Stutsman	E. Steege	1,500	6,090	27	.2	4	45	2,304	561.2	19	3,346	3.5	5	.2	.0	1.6	460	197

The principal constituents in the waters from the first and second horizons are sodium and sulphate. The waters from the first flow horizon are, however, somewhat lower in calcium and magnesium and correspondingly higher in sodium than those from the second flow horizon. The average total hardness of 21 samples of water from the first flow horizon is about 140; that of 8 samples from the second flow horizon is about 600. The water from the upper horizon is therefore preferable for some uses. The waters from both horizons contain moderate amounts of bicarbonate. The iron content of the waters from both horizons is quite variable, ranging from 0.0 to 3.0 parts per million. Proportionately more of the analyses of second flow waters show a high iron content (more than 1.0 part per million) but the number of analyses is too small and the variation in iron content is too great to draw definite conclusions. Six of the samples of waters from the first flow horizon differ from the general sodium sulphate type. These waters are relatively much lower in sulphate and higher in chloride. Some also contain considerably more bicarbonate, and some are somewhat harder. The total mineral content of these waters is comparable, however, with that of other waters from the horizon.

Three of the four analyses of waters from the third-flow horizon also show sodium sulphate waters; the fourth shows a sodium chloride water, containing 3,346 parts per million of chloride and more than 6,000 parts of dissolved mineral matter. The analysis of this water also shows an unusual calcium-magnesium relationship. The three sodium sulphate waters differ considerably in the content of other constituents present, both among themselves and in comparison with the sodium sulphate waters from the first and second flow horizons.

OCCURRENCE AND DISTRIBUTION OF FLUORIDE

By G. A. Abbott

The recent discovery that fluorides in drinking water cause the dental disintegration long known as enamel dystrophy, or "mottled enamel," has aroused the interest of health departments and led to the more thorough examination of ground waters. The Nation-wide dental survey conducted by the United States Public Health Service located areas throughout the country where mottled enamel is endemic and severe. Such a district was found in northeastern South Dakota and in Richland, Sargent, Dickey, and some other counties in southeastern North Dakota. The dental defect had long been noted as common and severe near Lidgerwood and Forman. Other endemic areas include parts of Ransom, La Moure, Cass, and Traill Counties; but these are by no means the only localities in North Dakota where mottled enamel is found.

As early as November 1, 1929, Dr. William G. Movius, dentist, of Lidgerwood, N. Dak., suspected that the mottling of children's teeth might be caused by the artesian water from the Dakota sandstone. On that date he wrote to the late Prof. Simpson for assistance in testing this hypothesis. He was furnished with a map of the Dakota sandstone artesian area and with the analytical data available at that time. By November 29 of the same year, Dr. Movius had convinced himself that the dental malady was definitely associated with the drinking of the artesian water, as indicated by his letter to Frederick S. McKay, D. D. S.[34]

In 1931 M. C. Smith, E. Lanz, and H. S. Smith,[35] working at the Arizona Agricultural Experiment Station, investigated the occurrence of mottled enamel at St. David, Ariz., and demonstrated that the defective enamel whether observed in men or animals, is definitely caused by certain small concentrations of fluorides in drinking water.

After this announcement dentists in the regions where mottled enamel prevailed requested information on the fluoride content of waters, and submitted samples of water for analysis. Early in 1934 the writer became actively interested in the fluoride problem in North Dakota. Representative artesian waters were analyzed and those from Forman were found to carry as much as 6 parts per million of fluoride. Late in June of the same year, a State Geological Survey project was organized under provisions of the Federal Emergency Relief Administration which included a fluoride survey. At first the survey was limited to the Dakota sandstone and Red River Valley artesian areas; but later under provisions of a Works Progress Administration project it was extended to include representative ground waters of the entire State. The results of the survey were published in Bulletins 9 and 11 of the North Dakota Geological Survey.

On account of the distribution of fluoride in the Dakota sandstone artesian waters and its significance in the present investigation, the fluoride map included in Bulletin 9 is here reproduced for convenient reference (pl. 3). It will be observed that the fluoride content of the artesian waters can be represented on a map of the region by regular contour lines enclosing concentric areas or zones of ground water whose fluoride content ranges from about 3 parts per million in the outer zone through regularly increasing amounts, as the included areas become successively smaller, finally narrowing down to a small district near Lidgerwood, where the fluoride content was the highest observed, one sample showing about 9 parts per million.

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[34] McKay, F. S., Does water affect children's teeth? Water Works Engineering, Vol. 82, No. 25; p. 1773 Dec. 4, 1929.

[35] Smith, M. C., Lanz, E., and Smith, H. S., Cause of mottled enamel: Arizona Agr. Exper. Sta. Tech. Bull. 32, pp. 254-282, 1931.

Comparison of the analytical results with information supplied by the county dental surveys showed a correlation that was complete and convincing. In every instance where mottled enamel was reported as general and severe, the waters of the locality showed correspondingly high fluoride contents, and in certain localities within the artesian area where shallow fluoride-free waters are used, mottled enamel was observed only among those who had moved into these districts from the regions using the artesian waters. Throughout the whole area the severity of the disintegration of enamel was found to follow the contour lines of the fluoride map.

The explanation of this persistent distribution of the fluoride in the Dakota sandstone artesian waters presents a perplexing problem for the geologist and the geochemist. All attempts to correlate the fluoride contents with any other constituent of the waters have been unsuccessful.

FLUCTUATION OF ARTESIAN HEAD CAUSED BY CHANGES IN ATMOSPHERIC PRESSURE AND EMISSION OF GAS

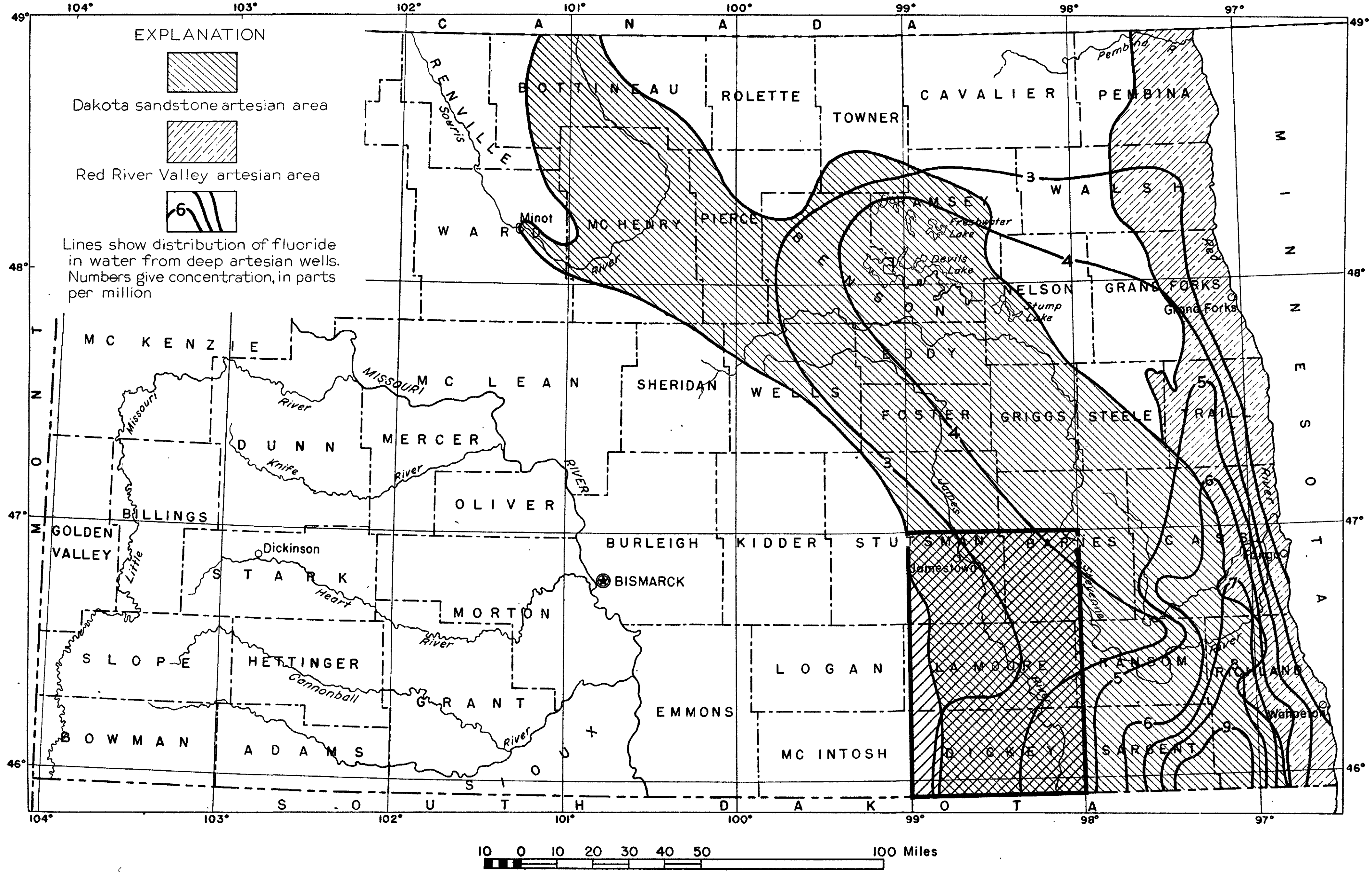
Many wells drilled to the Dakota sandstone originally yielded much combustible gas in addition to artesian water. Where the quantity of gas obtained from wells was sufficient, farm homes were heated and lighted by it. According to Hard [36] perhaps 50 wells have yielded volumes of gas sufficient for the domestic needs of single families in the Edgeley and La Moure quadrangles. The Murphy well in the NW¼ sec. 11, T. 133 N., R. 64 W., and the Davis well in the SE¼ sec. 24, T. 134 N., R. 64 W., each furnished enough gas to light and heat the house for several years. The gas from the Davis well was reported sufficient to fill a cylindrical tank 5½ by 5½ feet in 2 hours, and its pressure lifted a 150-pound weight on the top of the tank.[37] The gas supplied 13 burners day and night, a gas range, and a gas heater. The Weller well in Edgeley was drilled in 1906 for gas and not for water, but it did not yield gas in sufficient quantities to be utilized.

The quantity of gas liberated from most artesian wells at the present time is too small to be noticed by casual observation. It is probable, however, that some gas is given off by most wells. This is illustrated by the Davis well northwest of Edgeley, which stopped flowing about 1921 and now is abandoned. The water level in it stands about 2 to 3 feet below the land surface. An inspection of the well indicated no signs of gas, but the charts obtained by an automatic water-level recorder installed on the well show clearly that small quantities of gas are more or less regularly emitted from the well.

A chart from the recorder is reproduced in figure 2, together with a graph showing the atmospheric pressure at Bismarck. The barometric

[36] Hard, H. A., op. cit., p. 77.

[37] Hard, H. A., op. cit., p. 78.



MAP OF NORTH DAKOTA SHOWING FLUORIDE CONTENT OF WATER FROM DAKOTA SANDSTONE AND RED RIVER VALLEY ARTESIAN BASINS.

After Abbott, G. A. North Dakota Geol. Survey Bull. 9, pp. 8–9.

curve has been converted from inches of mercury into equivalent feet of water, for convenient comparison with the hydrograph. The hydrograph shows that the water level in the well attains a peak about every 2 or 3 hours and that after the peak is reached the water level

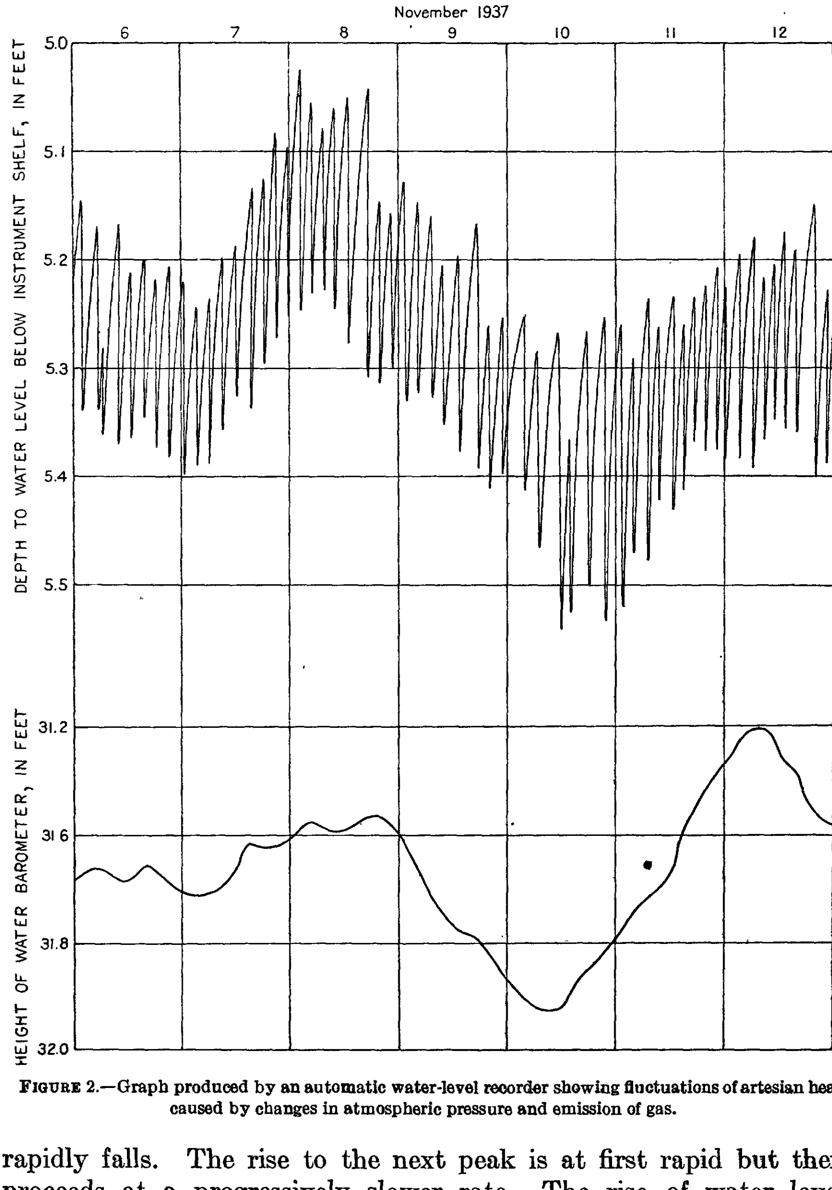


Figure 2.—Graph produced by an automatic water-level recorder showing fluctuations of artesian head caused by changes in atmospheric pressure and emission of gas.

rapidly falls. The rise to the next peak is at first rapid but then proceeds at a progressively slower rate. The rise of water level apparently is caused by the collection of gas in the well, which causes the column of water in the well to become gradually lighter. When sufficient gas has accumulated, probably in pockets, it is emitted at the water surface and the water level declines abruptly. After the gas is liberated it starts to collect once more and the process is repeated.

The hydrograph indicates that the peaks and troughs formed by the water surface undergo a fluctuation that is not caused by gas in the water. A comparison with the curve showing fluctuations of atmospheric pressure indicates that the high and low stages of the water level reached each few hours fluctuate in general inversely with changes in atmospheric pressure. Where there is a confining bed above the water-bearing formation that effectively prevents the transmission of changes in atmospheric pressure to the water in the formation, a rise or fall in atmospheric pressure causes a corresponding increase or decrease in pressure on the water surface in the well. An increase in atmospheric pressure reduces the effective hydrostatic head of the water in the well and the water level declines. Conversely, a decrease in atmospheric pressure increases the effective hydrostatic head and the water level rises in the well.

The fluctuation of the water level in the Davis well over the period shown on the chart did not follow uniformly the fluctuation of the barometric pressure in Bismarck. For the three major fluctuations in atmospheric pressure shown on the chart—a rise from November 7 to 8, a decline from November 8 to 10, and a rise from November 10 to 12—the water level in the well changed 55, 34, and 13 percent, respectively, as much as the water barometer. This variation in response to changes in atmospheric pressure is probably more apparent than real and probably is caused by differences between fluctuations of atmospheric pressure recorded at Bismarck, which is about 100 miles west of the well, and those that occurred at the well.

WELLS IN DAKOTA SANDSTONE

HISTORY OF ARTESIAN-WELL DRILLING

The first well sunk to the Dakota sandstone in North Dakota was drilled in the city of Ellendale. It was drilled by the percussion-tool method, to a depth of 1,087 feet. The work on the derrick was begun in December 1885, and the well was completed April 6, 1886, at a cost of $4,440 for drilling and casing. Board, room, and other incidental expenses of the operators were said to have raised the total cost to more than $5,000. The well was started at the surface as an 8- or 10-inch hole but it was reduced in size during the process of drilling and was finished at the bottom with 3¾-inch casing.

According to Nettleton,[38] a well for public water supply was started at Jamestown in 1886 and completed the next year at a depth of

[38] Nettleton, E. S., Artesian and underflow investigation: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, p. 70, 1892.

1,476 feet. The well was cased with pipe of five different sizes, ranging from 3¼ to 6¼ inches, and the lowest 30 feet of casing was perforated with ⅛-inch holes. The cost of the well was reported to be $6,700.

In 1890 a well was drilled at the State Insane Asylum,[39] near Jamestown, to a depth of 1,524 feet, at a cost of $7,000. During the same year a well for public water supply was completed at Oakes [40] at a depth of 977 feet. A 6-inch well drilled for the public water supply of Edgeley in 1892 was finished at a depth of 1,365 feet.

Drilling to the Dakota sandstone by the percussion-tool method was so expensive that it was not generally economically feasible to construct such wells for individual farm and home use. Soon after 1900, however, the jetting method of drilling, by means of which small holes are sunk through soft shale and materials of similar character with considerable efficiency, came into general use and the cost of constructing artesian wells in the Dakota sandstone dropped greatly. It then became possible to construct farm wells for a reasonable cost; and as a result thousands of small wells, ranging in diameter from 1¼ to 3 inches, were drilled throughout the artesian basin.

Much of the credit for developing apparatus and methods for constructing small artesian farm wells is due the late Peter Norbeck, once a prominent well driller in South Dakota and later the Governor of the State and then a United States Senator from that State. His brother, George Norbeck, with whom he was associated in the drilling business, wrote in a memoir:[41]

> Up to this time [about 1900] there was no thought of being able to drill a small diameter well as deep as 1,000 feet. In a few instances townships voted bonds for a township well, or counties voted bonds and sunk one or more wells to 1,000 feet or deeper, but they had to be drilled with the so-called cable tool and slush-bucket process, at a cost of $3,500 and upward. The designing and manufacturing of equipment and the working out of hundreds of other problems to make it possible to drill small diameter wells to the necessary depth to obtain artesian water, fell to the ingenuity and organizing ability of Peter Norbeck and he did a very effective job of it.

Most of the artesian wells were drilled between 1902 and 1920. Of the 941 wells in the Ellendale-Jamestown area whose records are given at the end of this report, information regarding the year of drilling is available for 734. This information is given in the table following. A summary shows that 341 of the wells were drilled between 1902 and 1910, 341 were drilled between 1911 and 1920, and 47 were drilled between 1921 and 1937. Five of the wells were drilled prior to 1902.

[39] Idem, pp. 70–71.

[40] Idem, p. 68.

[41] The Johnson National Driller's Journal, p. 13, Jan.–Feb. 1937.

Number of recorded artesian wells drilled, by years, in the area

Year	Number of wells	Year	Number of wells	Year	Number of wells
1886	1	1910	51	1923	2
1890	1	1911	20	1925	1
1892	1	1912	27	1926	8
1898	1	1913	42	1928	2
1899	1	1914	41	1929	2
1902	16	1915	38	1930	5
1903	31	1916	57	1931	3
1904	32	1917	40	1933	3
1905	37	1918	30	1934	2
1906	39	1919	25	1935	2
1907	40	1920	21	1936	2
1908	52	1921	9	1937	2
1909	43	1922	4		

WELL CONSTRUCTION AND UNDERGROUND LEAKAGE

Throughout the artesian basin the jetting method of drilling is now used almost exclusively. Because the jetting of small wells is both a rapid and an economical method of drilling through relatively fine grained soft or unconsolidated materials, the method is excellently suited for use in the artesian basin.

In the jetting method the material is both loosened and carried to the surface by water under pressure.[42] Water under pressure is led into the well through a small pipe and is forced downward and out the drill bit at the bottom of the hole. The material thus loosened is carried to the surface between the pipe and the wall of the well by the return stream of water. The jarring of the bit assists the water to break up the formation and the turning of the drill pipe insures a straight hole.

Most of the artesian wells are started as 2¾- or 3¼-inch holes in order that a 2½- or 3-inch casing may be carried to the Pierre shale through the drift or other surficial deposits. This casing, which generally is called a surface casing, prevents the unconsolidated material above the shale from caving into the hole during subsequent drilling operations and also seals out the shallow ground water. Drilling to the sandstone is carried on inside the surface casing with a 2- or 2½-inch bit attached to 1¼- or 1½-inch drilling pipe. A hole is thus jetted through the shale to the sandstone. The drilling pipe is then pulled out of the hole and a 1- to 1½-inch casing is inserted. The annular space between the inner casing and the surface casing is usually sealed at the land surface.

Inasmuch as the hole drilled through the shale is somewhat larger than the casing that is set in it, a passageway along the outside of the casing is provided for the escape of artesian water from the sandstone to the land surface. Water coming up outside the casing may escape, of course, into sandy lenses in the shale, and where the surface casing

[42] Bowman, Isaiah, well-drilling methods: U. S. Geol. Survey Water-Supply Paper 257, p. 75, 1911.

does not extend to the shale or where it is improperly seated, the artesian water may also escape into the drift or other surficial deposits. It has been assumed by some that the shale would cave around the casing and thus the upward leakage of artesian water would be prevented. At many of the wells, however, this caving apparently has not been complete, for the space between the inner and surface casing has had to be sealed at the surface, usually with lead, to prevent water from issuing between the two casings.

The extent to which underground leakage has been a contributory cause of the decline of artesian head in the Dakota basin is a subject of such speculation. The methods used for the construction of wells apparently have not been effective in preventing leakage. Moreover, the water has corroded many of the well casings and has thus opened up channels of escape. It appears probable that underground leakage has been considerable, especially in the past, and that a part of the decline in artesian head has resulted from it. Under the prevailing low artesian head, however, underground leakage doubtless is much less now than in the past when the head was high.

Many wells that formerly flowed but that are now west of the flowing-well area have been converted into pumped wells. Where the water level is only a few feet below the land surface pitcher pumps or other suction pumps have been attached directly to the inner well casings. Where the water level stands farther below the land surface, however, the inner casings have been cut off and pump cylinders have been lowered into the surface casing, thus providing a deep-well pumping system. Reservoirs, similar to dug wells, have been constructed around some wells, and both casings have been cut off below the land surface. Water then flows into the reservoirs, from which it is pumped as needed.

Most of the reservoirs are poorly constructed, and much water is lost from them by seepage into surficial deposits. Many of the reservoirs are uncovered and are very unsanitary. The chemical character of the water is such that thick ferruginous deposits quickly form on the sides of casings and reservoirs. These deposits break off and are pumped to the surface along with the water, thus rendering the water objectionable for some uses.

WILD WELLS

There are in North Dakota a few so-called "wild" wells—that is, wells whose flows have gotten out of control and have opened up large channels of escape for the artesian water. This has been caused in most instances by the seepage of artesian water under high pressure upward along the outside of the well casing. The flow of the wild wells, which in the aggregate equals the combined flow of a great many controlled wells, has probably appreciably accelerated the decline of artesian head in the basin. The flow of some of these wild wells has been brought under control; attempts to control the flow of others have proved unsuccessful. Several typical wild wells are described below.

In the spring of 1906 a 3-inch well was drilled for the village of Sheldon. At a depth of 228 feet a rock was encountered that caused the part of the hole below that depth to be drilled very crooked. Considerable difficulty was experienced also in driving the casing, but nevertheless drilling was continued until the sandstone was penetrated. Water was encountered under a pressure of about 150 pounds to the square inch, and a flow of 600 gallons a minute was obtained. Water started coming up outside the casing soon after the well was completed, so an attempt was made to substitute a larger casing. The 3-inch casing was broken while it was being pulled. An 8-inch casing was then driven over the remainder of the smaller pipe. The flow of the well was thus brought under control and remained under control until 1912, when all the casing dropped into the hole. In 1915, the Northern Pacific Railway and city officials dumped 3 carloads of sandbags down the hole but with no appreciable decrease in flow. At the present time a comparatively small flow of water issues from a 30-foot crater formed by the sand emitted from the well.

In 1915 a well near Oakes, in the SW¼ sec. 17, T. 131 N., R. 60 W., was drilled to a depth of 1,286 feet. It is believed to tap the third flow. Water soon started coming to the surface outside the casing, and in 1924 the well was recased. At that time an attempt was made to reduce the flow by installing a drill rod in the bottom of the well. The casing apparently rusted through, and by 1935 water again came to the surface outside the casing and the flow within the casing became roily. An attempt was made to recase the well with ¾-inch pipe but an obstruction was encountered in the well at a depth of about 800 feet. The ¾-inch pipe was then removed from the well and a larger surface casing was driven outside the original 2-inch surface casing. This stopped the flow coming up outside the casing, but the water from the inner casing continued to be roily. In the spring of 1938, water began coming to the surface in a field about 350 feet south of the well; and by the summer of 1938 water was observed issuing from eight openings within a few hundred feet of the well. Leakage from the well into the Pierre shale and the drift apparently occurs below the surface under sufficient pressure to bring the water to the surface. The chemical composition of water from the well and from the different openings has been found to be identical.

A well drilled in 1900 on the farm of Fred Budke in sec. 23, T. 139 N., R. 54 W., yielded large quantities of water and sand, much of which came to the surface outside the well casing. The combined flow from inside and outside the casing, which was not measured accurately, filled a 10-inch pipe. The overflow soon partly filled a nearby coulee with sand, and before the flow decreased of its own accord 80 acres of land had been covered with sand. Mr. Budke moved all the farm buildings to section 26 and drilled a second well about 2 rods southwest of his house on the north bank of a ravine. The action of the second well proved to be similar to that of the first, and before it was brought under control by the sinking of an 8-inch outer casing and by a natural decrease in flow, Mr. Budke was obliged to move his house again. The land surface was deformed to such an extent that the floors of the house assumed a very objectionable slope and the doors could not be closed. A third well was drilled on the south bank of the ravine in 1915. The driller believed the flow to be under control and after completion of the drilling a tee-joint was installed on the top of the casing. Water flowed from both ends of the tee in the evening, but by the next morning the casing and tee-joint were found to have dropped from sight into the hole. The flow of the well was greatly reduced by 1919, and it is now less than 1 gallon a minute.

ARTESIAN HEAD AND FLOW OF WELLS TAPPING THE DAKOTA SANDSTONE

ORIGINAL HEAD AND WESTERN LIMIT OF AREA OF ARTESIAN FLOW

The original artesian head in the Ellendale well, the first to be drilled to the Dakota sandstone in North Dakota, was reported by Powell [43] to be 175 pounds to the square inch, by Nettleton [44] to be 115 pounds, and by J. R. Lacey,[45] a resident of Ellendale who was present when the well was drilled, to be 145 pounds to the square inch. Nettleton [46] reports the pressure as 97 pounds per square inch in the Jamestown well, 70 pounds in the Asylum well near Jamestown, and 125 pounds in the Oakes well. These pressures, however, are probably only approximate and are valuable mainly for showing the general high pressure that originally existed in the basin.

The artesian-water map of South Dakota by Darton,[47] which was published in 1909 but which probably shows approximate conditions

[43] Powell, J. W., Artesian irrigation on the Great Plains: U. S. Geol. Survey 11th Ann. Rept., pt. 2, p. 273, 1891.

[44] Nettleton, E. S., Artesian and underflow investigation: 52d Cong., 1st sess., S. Ex. Doc. 41, pt. 2, pp. 67, 68, table opposite p. 74, 1892.

[45] Meinzer, O. E., and Hard, H. A., The artesian-water supply of the Dakota sandstone in North Dakota: U. S. Geol. Survey Water-Supply Paper 520-E, p. 81, 1925.

[46] Nettleton, E. S., op. cit., table opposite p. 74.

[47] Darton, N. H., Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, pl. 11, 1909.

of a considerably earlier time, indicates that in the southern part of the Edgeley quadrangle the area of artesian flow extended westward nearly to the 1,800-foot contour. A similar map, by Darton and Williard,[48] of the Jamestown quadrangle, which lies just north of the Edgeley quadrangle, shows the west margin of the area of artesian flow at the boundary between the two quadrangles as about 1,725 feet above sea level. This map shows the western limit directly west of Jamestown as about 1,700 feet above sea level. Meinzer [49] concludes that the west boundary of the area of artesian flow in the Edgeley quadrangle was originally somewhat less than 1,800 feet above sea level in the northern part and gradually rose to an altitude of somewhat more than 1,800 feet in the southern part. Therefore, it appears reasonable that the western limit of the area originally ranged more or less uniformly from about 1,700 feet above sea level west of Jamestown to somewhat more than 1,800 feet above sea level at the South Dakota line. (See pl. 2.)

DECLINE IN HEAD AND EASTWARD MOVEMENT OF WESTERN BOUNDARY OF AREA OF ARTESIAN FLOW FROM 1886 TO 1923

Meinzer,[50] in his report on the Edgeley quadrangle, states that there probably was an appreciable drop in artesian head in the Dakota artesian basin prior to 1902. Wells drilled about 1900 appear to have had less head than those drilled earlier, but the pressure was still very high and doubtless the decline in head was not particularly apparent to the residents of the area. However, during the period of active well drilling, from about 1902 to 1915, the artesian head declined rapidly. According to computations made by Meinzer [51] on 20 wells in the Edgeley quadrangle, the average annual decline of artesian head from 1902 to 1915 was 12.7 feet—a total of 165 feet for the period. From 1915 to 1920 the decline, based on similar computations for 12 wells, averaged about 4 feet a year, or 20 feet for the period. From 1920 to 1923, according to computations on 20 wells, the decline averaged about 4 feet a year, or 12 feet for the 3-year period. Meinzer concluded that from 1886 to 1923 the decline in artesian head ranged from about 250 to 300 feet or more in different parts of the quadrangle.

The 1,800-foot contour lies well up the east front of the Coteau du Missouri—a conspicuous upland that has a deep cover of glacial drift and an irregular morainal topography. The front of the Coteau slopes rather steeply eastward to the flat land of the James River Valley,

[48] Williard, D. E., U. S. Geol. Survey Geol. Atlas, Jamestown-Tower folio (No. 168), 1909.
[49] Meinzer, O. E., and Hard, H. A., op. cit., p. 82.
[50] Meinzer, O. E., and Hard, H. A., op. cit., pp. 82-84.
[51] Meinzer, O. E., and Hard, H. A., op. cit., p. 82.

and thus the decline in artesian head at first moved the western limit of the area of artesian flow down the Coteau front and then eastward across more gently sloping land. Although the decline in head from 1886 to 1915 was great—probably 225 feet or more in most places—the western edge of the area of artesian flow moved eastward only 3 to 5 miles (pl. 2) because the movement was chiefly down the steep front of the Coteau. The decline of 30 feet or more in head that occurred between 1915 and 1923, however, moved the western edge of the area from 2 to 8 miles farther east (pl. 2) because the movement was mostly along the more gently eastward sloping land. Meinzer [52] states that

the belt in which flowing wells were originally obtained but in which wells have ceased to flow [in 1923] is about 10 miles wide in the northern part of the quadrangle [Edgeley] and 5 miles in the southern part. Fully half this belt has "gone dry" in the 8-year period since 1915, during which only a few wells were drilled.

It is obvious that by 1923 the decline of artesian head had carried the western boundary of the area of artesian flow eastward down to such a level (from about 1,550 to 1,500 feet or less above sea level) that a continuation of the decline at about the same rate would cause the area to contract sharply.

DECLINE IN HEAD AND CHANGE IN POSITION OF WESTERN BOUNDARY OF AREA OF ARTESIAN FLOW FROM 1923 TO 1938

Since 1923 the representatives of the State Geological Survey have visited most of the wells in the Dakota artesian basin and have made measurements of their flow. The records of flow, together with other data on the wells, are filed systematically at the office of the State geologist, in Grand Forks. During the investigation on which this paper is based, in 1937 and 1938, the wells along the western boundary of the area of artesian flow were visited, measurements of depth to the water level in nonflowing wells were made when possible, and measurements of discharge of flowing wells were made. The records for the wells visited by the State geologist or his deputy since 1923 and the records for the wells visited during the present study are given in the table at the end of this report. The location of the wells is shown on plate 2.

Only a very few measurements of artesian head were made by the State geologist or his deputy in the course of their inspection of the wells, and no measurements of pressure were made by the writers during their investigation. The reasons for this are numerous. In order to measure the shut-in pressure of the water in the wells the flow must necessarily be stopped. Where the sandstone is composed of

[52] Meinzer, O. E., and Hard, H. A., op. cit., p. 84.

very fine grains the stopping and opening of wells sometimes cause sand grains to enter the wells, and the wells must then be cleaned out. Some wells, after having been closed, fail to flow again when reopened or flow roily water. On account of the chemical character of the water, the casings of almost all the artesian wells are badly corroded, many to the extent that water may escape through the casing into pervious material. The building up of pressure during the course of a pressure measurement may burst the casing where it is thin, or where the casing is already corroded through, the increase in pressure may open up new channels of escape for the water or may enlarge old channels. The well owners are therefore very reluctant to allow pressure measurements to be made on their wells.

The depths to water level below the land surface in wells west of the area of artesian flow reflect the artesian head in the wells. Therefore, during this investigation measurements of water level were made whenever possible in nonflowing wells in order to compare the artesian head in 1937 and 1938 with that reported for the same wells in earlier years. The water-level measurements, like pressure measurements, may be considerably in error because the well casings may be corroded through and water may be escaping into formations above the sandstone. Moreover, some of the wells are pumped and cones of depression may exist around them at the time the water-level measurements are made. Both possible sources of error cause the water level to stand lower in the wells than it would if the wells were tightly cased and unused.

The following table gives the change in artesian head from 1923 to 1938 in wells along the western limit of the area of artesian flow from the South Dakota State line to a line about 3 miles northeast of Edgeley. The table includes 27 wells on which data are available. The artesian head in some of the wells was measured in 1937 and not in 1938. For such wells the measured head has been corrected by subtracting from it the average decline observed in other wells from 1937 to 1938 (see p. 35). The location of the wells is shown on plate 2, and the records of the wells appear in a table at the end of this report. In 1923 the head of water in these wells ranged from 15 feet above the land surface to 40 feet below the surface, and in 1938 the head ranged from 3.5 feet above the land surface to 70 feet below. The head in 21 of the wells was lower and in 6 of the wells was higher in 1938 than in 1923. The change in head in different wells ranged from a decline of 35 feet to a rise of 29 feet, the declines occurring chiefly in the southern part of the area and the rises mainly in the northern part. The water levels in the 27 wells averaged 8.7 feet below the surface in 1923 and 18.6 feet below the surface in 1938. Thus an average net decline in artesian head of 9.9 feet is indicated for the 15-year period.

Change in artesian head in wells along the western boundary of the area of artesian flow, 1923–38

Location				Head in 1923 [1] (feet)	Head in 1938 [2] (feet)	Change in head (feet)
Quarter	Section	T. N.	R. W.			
SE.	33	129	65	−10	−26.5	−16.5
SW.	9	130	64	+15	−8.5	−23.5
NE.	19	130	64	−4.5	−30.5	−26
SW.	28	130	64	+10	−10	−20
SE.	29	130	64	+4	−8	−12
SW.	1	130	65	−27	−45.5	−18.5
NW.	2	130	65	−35	−70	−35
NE.	14	130	65	−27	−36	−9
NE.	4	131	63	+3	−12.5	−15.5
SW.	4	131	63	+3	−5	−8
NE.	18	131	63	−9	−3	+6
NE.	21	131	63	+5	−6.5	−11.5
SE.	29	131	63	+6	−28.5	−34.5
SE.	7	131	64	−20	−55.5	−35.5
NE.	11	131	64	+2	−14	−16
NE.	36	131	64	+2	−9.5	−11.5
NE.	13	131	65	−40	−11	+29
NE.	25	131	65	−15	−40.5	−25.5
NE.	35	131	65	−35	−14.5	+20.5
SW.	11	132	63	+12	−1	−13
SW.	34	132	63	+1	−2	−3
SW.	30	132	64	−30	−22.5	+7.5
NW.	11	133	64	−14	−15	−1
SW.	2	134	63	+2.5	−4.5	−7
NE.	30	134	63	−11.3	+3.5	+14.8
SE.	24	134	64	−11	−1.5	+9.5
SE.	24	134	64	−11	−24.5	−13.5

[1] From Hard, H. A., Geology and water resources of Edgeley and La Moure quadrangles, N. Dak.: U. S. Geol. Survey Bull. 801, pp. 79–87, 1929.
[2] With reference to land surface at well.

A decline of 9.9 feet in artesian head from 1923 to 1938 represents an average annual decline of approximately 0.66 foot. This compares with an average annual decline of 12.7 feet between 1902 and 1915, and an average annual decline of about 4 feet between 1915 and 1923.[53]

Measurements were made in both 1937 and 1938 of the depth to water level in 21 wells. The artesian head in 1937 and in 1938, as indicated by the measurements, and the change in head between the two measurements are given in an accompanying table. The artesian head in the 21 wells averaged 18.91 feet below the measuring points in 1937 and about 19.34 feet below the same measuring points in 1938, thus indicating a net average decline in head in the wells of about 0.43 foot. The period between measurements averaged 47 weeks and hence an average annual decline of about 0.48 foot is indicated. For the 21 wells, the head declined in 14 and rose in 7. The greatest decline was 2.96 feet; the largest rise was 1.49 feet.

[53] Meinzer, O. E., op. cit., pp. 82–83.

Change in artesian head in wells along the western boundary of the area of artesian flow, 1937–38

Location				Head, in feet below measuring point		Change in head (feet)
Quarter	Section	T. N.	R. W.	1937	1938	
SW.	7	129	64	0.00	0.82	−0.82
SE.	7	129	64	2.35	2.51	−.16
SE.	9	129	64	75.74	76.43	−.69
NE.	4	129	65	94.76	95.90	−1.14
SE.	24	129	65	76.78	78.42	−1.64
SW.	35	129	65	9.50	10.60	−1.10
SW.	36	129	65	7.15	7.22	−.07
SE.	29	130	64	7.56	8.55	−.99
NE.	4	131	63	13.15	13.18	−.03
NE.	18	131	63	3.68	4.32	−.64
NE.	21	131	63	6.04	9.00	−2.96
NE.	32	131	64	10.00	11.08	−1.08
NE.	36	131	64	10.47	10.42	+.05
NE.	13	131	65	11.69	11.35	+.34
NW.	17	132	63	13.65	13.60	+.05
SW.	34	132	63	5.79	4.62	+1.17
SW.	30	132	64	23.80	24.20	−.40
NW.	11	133	64	16.94	16.41	+.53
SW.	2	134	63	3.63	5.12	−1.49
NE.	30	134	63	1.55	.17	+1.38
SE.	24	134	64	2.89	2.29	+.60

The water level in most of the wells doubtless fluctuates with changes in atmospheric pressure and in some of them with the emission of gas (see p. 24). Thus the water in the wells is likely to stand at different levels at different times of the day and also from day to day. The change in water level represented by the difference between two spot measurements may represent, therefore, mostly the fluctuation caused by a change in atmospheric or gas pressure. A part of the average 0.48-foot decline in head indicated by the measurements in 1937 and 1938 may be caused by such changes in pressure in individual wells, but because the measurements for each year were made over a period of several months and at different times of the day, it is likely that much of the effect is compensated by computing the average change in water level.

The measurements made in 1937 and 1938 indicate in a general way that the rate of decline of the artesian head is now greatest in the southern part of the area and least in the northern part. This may be due in part to the effect of the flow of wells in Brown County, S. Dak., which lies immediately south of Dickey County. According to the report [54] of the State Planning Board, Brown County contains 1,937 artesian wells, the largest number in any county in South Dakota. Of these wells, 343 have stopped flowing, 1,117 have a decreased flow, and 477 are reported as still flowing strongly.

Although the foregoing computations of the decline in artesian head may not show precisely the actual decline, they are believed to show the general trend and magnitude. The records appear to indicate a

[54] Artesian well flow in South Dakota: South Dakota State Plan. Board, p. 54, 1938.

general retardation in the rate of yearly decline from an average of more than 12 feet for the period 1902–15 to about 0.5 foot for the period 1937–38.

SHRINKAGE OF AREA OF ARTESIAN FLOW

The assumed position of the western limit of the area of artesian flow when wells were first drilled in the basin in 1886 is shown in plate 2. Lines showing the western limit in the Edgeley quadrangle in 1915 and 1923, as determined by Hard,[55] and the western limit in 1938 as determined by the present investigation are also shown. The shrinkage of the area of artesian flow in the Edgeley quadrangle was approximately 115 square miles prior to 1915; about 132 square miles between 1915 and 1923; and about 67 square miles between 1923 and 1938, or a total shrinkage of about 314 square miles during the 53 years between about 1886 and 1938.

The annual rate of shrinkage from 1886 to 1915 was about 4 square miles, from 1915 to 1923 about 16.5 square miles, and 1923 to 1938 about 4.2 square miles. The average annual rate of shrinkage since development began has been about 5.9 square miles. Inasmuch as the quadrangle extends about 34.5 miles from north to south the western boundary of the area of artesian flow has migrated eastward an average of 9.1 miles since 1886, or an average of about 0.17 mile a year.

From 1886 to 1923 the greatest shrinkage of the area of artesian flow in the Edgeley quadrangle occurred in the northern part, where the western boundary migrated eastward about 13 miles. In the southern part of the quadrangle the eastward movement was only from 5 to 6 miles. From 1923 to 1938, however, the greatest shrinkage has taken place in the southern part of the quadrangle and the least in the northern part. In the vicinity of Monango the western limit of the area has moved eastward 6 to 7 miles since 1923, but farther north the eastward movement has in most places been only 1 to 2 miles. Northwest of Edgeley the direction of movement has been reversed and several square miles has been added to the area of flow.

The relatively slow shrinkage of the area of artesian flow from 1886 to 1915 was the result, of course, of the movement of the western boundary down the comparatively steep eastern front of the Coteau du Missouri. The much more rapid eastward movement from 1915 to 1923, although accompanied by a much smaller decline in artesian head, resulted from the western boundary reaching the gentle sloping land east of the Coteau. That the rate of eastern movement of the western boundary from 1923 to 1938 was only about one-fourth that

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[55] Hard, H. A., Geology and water resources of the Edgeley and La Moure quadrangles: U. S. Geol. Survey Bull. 801, pl. 3, 1929.

from 1915 to 1923 indicates an appreciable retardation of the shrinkage of the area of artesian flow because the slope of the land over which the movement took place in the two periods is about the same.

YIELD OF FLOWING WELLS

The flow of the Ellendale well, drilled in 1886, was reported by Powell [56] to be 600 gallons a minute, and the flow of the well at Edgeley, drilled in 1892, was reported by Darton [57] to be 500 gallons a minute. The diameter of the Ellendale well at the bottom was 3¾ inches and that of the Edgeley well 6 inches. Hard [58] estimated that the original discharge of 1¼-inch wells in the Edgeley and La Moure quadrangles was from about 50 to 100 gallons a minute. According to Meinzer,[59] however, the original discharge, as estimated by drillers and well owners, of 116 wells drilled between 1902 and 1914 in the Edgeley quadrangle was about 22⅓ gallons a minute. The wells were nearly all 1¼ or 1½ inches in diameter.

Reported original flow, in gallons a minute, of wells tapping the Dakota sandstone

Year drilled	Number of wells	Maximum yield reported	Minimum yield reported	Average yield	Year drilled	Number of wells	Maximum yield reported	Minimum yield reported	Average yield
1902	12	75	20	35.4	1914	21	25	4	14.7
1903	19	70	2	24.7	1915	18	50	2	13.1
1904	19	80	7	33.6	1916	27	60	3	15.9
1905	24	45	4	21.6	1917	15	40	5	17.8
1906	22	40	6	20.5	1918	20	55	6	17.7
1907	20	40	5	19.5	1919	15	30	4	12.5
1908	28	45	5	18.6	1920	10	25	4	12.9
1909	31	60	1	20.6	1921	3	20	10	16.7
1910	32	35	4	20.2	1922	4	25	10	13.8
1911	6	40	4	20.1	1923	2	15	12	13.5
1912	6	25	5	13.3					
1913	21	50	3	14.3	1902–23	375	80	1	19.3

The table at the end of this report gives estimates, made chiefly by the well owners, of the original flow of 375 wells drilled to the Dakota sandstone between 1902 and 1923 in the Ellendale-Jamestown area. The wells are mostly 1¼ or 1½ inches in diameter. As computed from the reports, the aggregate original flow of these wells was 7,235 gallons a minute and the average was 19.3 gallons a minute. It is to be expected that this estimate would be somewhat lower than Meinzer's estimate because his computation included wells drilled only prior to 1914, whereas the present estimate includes wells

[56] Powell, J. W., Artesian irrigation on the Great Plains: U. S. Geol. Survey 11th Ann. Rept., pt. 2, p. 269, 1891.

[57] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: U. S. Geol. Survey 17th Ann. Rept., pt. 2, p. 661, 1896.

[58] Meinzer, O. E., and Hard, H. A., The artesian-water supply of the Dakota sandstone in North Dakota: U. S. Geol. Survey Water-Supply Paper 520–E, p. 86, 1925.

[59] Idem, p. 86.

drilled through 1923. The table on page 38 summarizes the reported original flow of wells by years. In spite of many irregularities, the table shows that the original flow persistently declined from 1902 to 1923.

Meinzer [60] reported that the flow of 41 wells measured by Hard in the Edgeley quadrangle in 1919 and 1920 ranged from less than 1 gallon to 20 gallons a minute and averaged 7⅜ gallons. He also reported [61] that in 1923 C. E. Turnbaugh, well driller at Edgeley, measured the flow of 111 artesian wells—nearly all in the Edgeley quadrangle—and found the wells to have an aggregate flow of 343 gallons a minute, or an average flow of 3.09 gallons a minute.

From 1923 to 1928 the regulated flow of the artesian wells in the Ellendale-Jamestown area was measured by representatives of the State Geological Survey. The results are summarized by townships in the following table. In all, the flow of 815 artesian wells was measured, and the aggregate flow was found to be 2,202 gallons a minute, or an average of 2.7 gallons a minute.

Flow, in gallons a minute, of artesian wells measured in the period 1923–28

Location		Number of wells	Aggregate flow	Location		Number of wells	Aggregate flow
T. N.	R. W.			T. N.	R. W.		
129	59	14	54.6	133	62	22	49.8
129	60	37	145.6	133	63	14	28.4
129	61	28	84.9	134	58	8	15.9
129	62	14	36.5	134	59	28	61.3
129	63	27	52.3	134	60	9	40.2
129	64	11	31.0	134	61	9	36.8
129	65	4	5.8	134	62	26	66.7
130	59	10	29.4	134	63	11	24.7
130	60	26	74.4	135	58	5	8.6
130	61	23	56.3	135	59	24	69.8
130	62	24	66.2	135	60	3	7.9
130	63	29	36.1	135	61	0	.0
130	64	14	29.2	135	62	6	35.0
131	59	24	70.3	136	59	12	10.9
131	60	35	94.6	136	60	6	9.9
131	61	33	78.9	136	61	2	1.0
131	62	29	58.1	136	62	0	.0
131	63	23	33.4	136	63	2	5.3
131	64	4	5.6	136	64	2	18.0
132	59	34	120.4	137	59	8	5.3
132	60	23	74.4	137	60	1	35.0
132	61	25	80.5	137	61	1	1.0
132	62	28	37.7	138	61	1	1.7
132	63	13	25.6	138	63	2	27.2
133	58	12	26.4	139	58	6	32.3
133	59	28	70.2	139	60	3	6.5
133	60	15	49.3	141	60	1	0.5
133	61	16	75.0				
						815	2,202.3

The flow of the wells given in the above table is the regulated flow or flow under normal operating conditions and therefore in general is less than the unreduced flow. The unreduced flow from 122 of the wells was also measured. The unreduced flow was found to average

[60] Meinzer, O. E., and Hard, H. A., op. cit., p. 86.
[61] Meinzer, O. E., and Hard, H. A., op. cit., p. 86.

4.85 gallons a minute, whereas the regulated flow averaged 2.09 gallons. Thus these 122 wells were flowing under normal operating conditions at only 43 percent of their capacity. If it is assumed that all the 815 wells were flowing at 43 percent of capacity in the period 1923–28 the potential unreduced flow of the wells was about 5,100 gallons a minute, in contrast to their measured regulated flow of about 2,200 gallons.

Representatives of the State Geological Survey remeasured the normal operating flow of many of the 815 wells between 1931 and 1935. The average flow of 402 wells visited was found to be 2.1 gallons a minute, in contrast to 2.7 gallons a minute for the 815 wells measured between 1923 and 1928. The wells revisited, however, were chiefly those of the 815 that were found in 1923–28 to have excessive flows; so the reduction of their flows was greater than that indicated above. The aggregate flow of the 402 wells under normal operating conditions in the 1923–28 period was 1,391 gallons a minute, or an average flow of 3.47 gallons a minute for each well. Thus the reduced flow of the 402 wells in the 1931–35 period was only 60.5 percent of their reduced flow in the 1923–38 period. On the basis of a 39.5-percent reduction, it is computed that the flow under normal operating conditions in the 1931–35 period for all the 815 wells was about 1,340 gallons a minute.

During the course of the present investigation the flow under normal operating conditions of 98 wells throughout the Ellendale-Jamestown area was measured. It was found to aggregate 125 gallons a minute, and to average 1.29 gallons a minute for each well. The unreduced flow of the same 98 wells in the 1923–28 period aggregated 245 gallons a minute, or an average of 2.5 gallons a minute for each well. Thus since 1923–28 the flow of the 98 wells has decreased 48.5 percent. If this percentage is applied to the flow of all the 815 wells measured in the 1923–28 period a reduction in flow from 2,202 gallons a minute to 1,140 gallons a minute is indicated. This compares with a computed aggregate flow of about 1,340 gallons a minute for the 1931–35 period and indicates a rather steady decrease in the discharge of the wells.

TOTAL DISCHARGE OF FLOWING WELLS AND SAFE YIELD OF THE ARTESIAN BASIN

The persistent decline in artesian head from year to year and the accompanying decrease in flow of wells indicates that the quantity of water discharged from the basin each year has exceeded the quantity that has been added to it through underground recharge. Inasmuch as the artesian pressure decreases gradually between the outcrop of the sandstone to the west and the area of flowing wells farther east, the percolation of water is from west to east and recharge must occur through the eastward percolation of water into the area of artesian flow.

Meinzer [62] made an estimate of the eastward percolation based on a hydraulic gradient of 10 feet to the mile and an average thickness of sandstone strata of 60 feet.[63] By using Slichter's formula [64] he calculated that the eastward percolation was about 80 gallons a minute for each mile of width of the sandstone—about 500 gallons a minute for the width of a township. This estimate—the safe yield for the row of townships—appears to be reasonable and probably cannot be improved upon without additional information on the hydrologic properties and thickness of the sandstone.

A further computation with Meinzer's figures shows that the sandstone used in his estimate had a coefficient of permeability [65] of about 200. This value agrees closely with the average of the coefficients of permeability of four samples of Dakota sandstone obtained from a test well drilled for oil near Glenfield, about 30 miles north of the area covered by this report. The samples were sent to the hydrologic laboratory of the Federal Geological Survey in Washington, by Professor Simpson. The permeability, as determined by V. C. Fishel, of the Geological Survey, is shown in the accompanying table. The average of the coefficients, weighted according to the thickness of the sandstone each sample represents, is 222. The physical properties of samples of Dakota sandstone from outcrops in Iowa and Oklahoma are given in a separate table.

Physical properties of Dakota sandstone from a well near Glenfield, N. Dak.

[Determined in the hydrologic laboratory of the Geological Survey at Washington, D. C., by V. C. Fishel]

Lab. No.	Depth of sample (feet)	Mechanical analysis (percent by weight)							Apparent specific gravity	Porosity (percent)	Moisture equivalent (percent by volume)	Coefficient of permeability
		Larger than 2.0 mm.	2.0–1.0 mm.	1.0–0.50 mm.	0.50–0.25 mm.	0.25–0.125 mm.	0.125–0.062 mm.	Smaller than 0.062 mm.				
2442	1,645 to 1,665	0.1	3.0	12.7	33.1	41.3	6.6	2.5	1.56	42.1	3.2	290
2443	1,665 to 1,690	.4	1.5	6.4	34.7	46.0	8.1	2.6	1.43	39.9	5.7	65
2444	1,690 to 1,715	1.4	3.0	10.0	44.9	33.0	5.4	2.2	1.51	43.5	5.6	240
2445	1,715 to 1,735	.8	2.6	7.0	52.5	30.9	4.3	1.9	1.46	45.6	4.0	340

[62] Meinzer, O. E., and Hard, H. A., The artesian-water supply of the Dakota sandstone in North Dakota: U. S. Geol. Survey Water-Supply Paper 520-E, p. 90, 1925.

[63] Meinzer, O. E., Occurrence of ground water in the United States, with a discussion of principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 119, 130, 1924.

[64] Slichter, C. S., Field measurements of the rate of movement of underground water: U. S. Geol. Survey Water-Supply Paper 140, pl. 2, 1905.

[65] The coefficient of permeability of a water-bearing material is defined in Meinzer's units as the number of gallons a day, at 60° F., that is conducted laterally through each mile of water-bearing bed under investigation, measured at right angles to the direction of flow, for each foot of thickness of bed and for each foot to the mile of hydraulic gradient.

Physical properties of Dakota sandstone from Iowa and Oklahoma

[Samples from Iowa collected by T. W. Robinson and H. G. Hershey; samples from Oklahoma collected by S. L. Schoff. Analyses made in the hydrologic laboratory of the Geological Survey, Washington, D. C., by V. C. Fishel]

Lab. No.	Mechanical analysis (percent by weight)						Apparent specific gravity	Porosity (percent)	Moisture equivalent (percent by volume)	Coefficient of permeability
	Larger than 1 mm.	1.0–0.5 mm.	0.50–0.25 mm.	0.25–0.125 mm.	0.125–0.062 mm.	Smaller than 0.062 mm.				
2446	1.9	21.3	70.6	3.0	1.6	1.7	1.76	33.8	4.0	[1] 1,300
2447	.2	.2	3.6	81.8	10.4	3.9	1.65	38.2	5.6	100
2448	.1	.1	2.0	83.6	12.2	1.9	1.73	35.7	4.0	65
2429	1.4	17.6	77.4	1.7	.9	.7	1.94	27.8	6.5	255
2430		.1	3.8	83.0	10.2	2.1	1.69	37.1	2.8	50
2431		.1	7.4	85.5	5.8	.4	1.87	30.8	2.7	155
2432		.5	31.5	61.5	4.5	1.2	1.95	27.9	5.5	30
2433		.7	84.3	13.0	1.1	.6	1.83	39.4	1.9	90
2434		.4	4.8	82.2	10.0	2.4	1.96	35.6	7.6	50

[1] Test made on loose material. Sample disintegrated when saturated.

2446. SW¼SE¼ sec. 15, T. 75 N., R. 32 W. From base of exposure on south side of small creek and about 4 to 6 feet above contact with upper Pennsylvanian limestone in Cold Spring State Park, 1 mile south of Lewis, Cass County, Iowa.
2447. About 15 feet above sample 2446.
2448. SW¼SW¼ sec. 15, T. 89 N., R. 47 W. From a quarry in an outcrop that forms the bluffs on the west side of Floyd River, and 50 to 75 feet below top of sandstone, Sioux City, Woodbury County, Iowa. About 600 feet northwest of well 4, Lowell pumping station, Sioux City.
2429. Sec. 10, T. 1 N., R. 1 E., Seneca Creek, Cimarron County, Okla.; from lowest 10 feet of the Dakota sandstone.
2430. Same location, 10–19.5 feet above base.
2431. Same location, 19.5–31.5 feet above base.
2432. Same location, 31.5–39 feet and 47.55 feet above base.
2433. Same location, 39–47 feet above base.
2434. Sec. 32, T. 5 N., R. 5 E., Flag Spring, Cimarron County, Okla.

In 1923 all flowing wells in the row of Tps. 129 N., Rs. 50 to 65 W., were measured by C. E. Turnbaugh.[66] There were 331 wells, including 6 town wells and 5 farm wells that were closed except when the faucets were turned on, and it was estimated that the combined flow from the wells was about 1,005 gallons a minute. If the percentages of reduction of flow that were computed for the 1931–35 and for 1937–38 periods—39.5 percent and 48.5 percent respectively—are applied to the wells in this row of townships, an aggregate flow of about 610 gallons a minute is indicated for the 1931–35 period and about 520 gallons a minute in 1937–38. Thus the present flow of the wells is approaching closely the calculated safe yield of the row of townships.

In addition to the water that is discharged by the wells at the surface, there is, of course, underground loss through corroded casings and other avenues of escape. This loss, which is believed to be appreciable, should be added to the discharge of the wells in order to determine the total discharge of the basin. In addition, there probably is some escape of water at the extreme eastern limit of the basin, where the position of the sandstone strata in relation to the overlying beds is unknown.

Meinzer[67] estimates that the average discharge for the row of townships during the 38-year period from 1886 to 1923 was about

[66] Meinzer, O. E., and Hard, H. A., The artesian-water supply of the Dakota sandstone in North Dakota, with special reference to the Edgeley quadrangle: U. S. Geol. Survey Water-Supply Paper 520–E, p. 88, 1925.
[67] Meinzer, O. E., op. cit., pp. 88–89.

3,000 gallons a minute. From 1923 to 1938 the discharge has apparently declined from about 1,000 gallons a minute to about 520 gallons a minute, and thus, based on the assumption that the rate of decrease was uniform, the averaged discharge was about 760 gallons a minute for the period. This gives for the 53-year period from 1886 to 1938 an average discharge for the row of townships of about 2,470 gallons a minute—about 2,000 gallons a minute in excess of the estimated safe yield.

Inasmuch as the sandstone strata have not been unwatered by the withdrawal of water from the basin, a question is raised as to the source of the water that has been recovered in excess of the perennial safe yield. Meinzer[68] concludes that the water has been withdrawn chiefly from storage in the sandstone as the result of a compaction or compression of the aquifer. Under artesian conditions the formation in which water is confined supports a part of the weight of the overlying beds and the water in the formation supports the other part. Therefore a decline in artesian pressure reduces the part of the load borne by the water and correspondingly increases the load supported by the formation. This in turn may compress the formation and remove from storage some of the water that is stored in it.

The behavior of water in artesian aquifers has convinced many investigators that most formations possess a volume elasticity. The time required for the development of the cone of depression around an artesian well after withdrawal of water from it has started, the corresponding time required for building up pressure in the well after its discharge has stopped, and the fluctuations of head in wells caused by passing trains, changes in atmospheric pressure, earthquakes, and tides all appear to indicate that formations are expanded and compressed as the result of changes in external and internal forces.

Meinzer[69] calculated that near Ellendale the beds overlying the sandstone strata, owing to their weight, exert a pressure equal to a column of water about 2,070 feet high. If the original head of the artesian water in this locality was 333 feet at the surface, then the artesian head at the top of the sandstone (assuming the sandstone surface to be 1,035 feet below the land surface) was that of a column of water 1,368 feet high. Thus of the pressure exerted by the overlying beds, the water in the sandstone supported an equivalent of 1,368 feet of head and the sandstone supported an equivalent of only 702 feet of head. The water level in wells at Ellendale in 1923 stood about at the land surface, thus indicating a decline in artesian head of about 333 feet. The burden on the sandstone therefore was increased an equivalent of 333 feet of head, from 702 feet to 1,035 feet, an increase of 47½ percent.

A withdrawal from storage of 2,500 gallons a minute for 38 years

[68] Meinzer, O. E., op. cit., pp. 90–93.

[69] Meinzer, O. E., and Hard, H. A., The artesian-water supply of the Dakota sandstone in North Dakota: U. S. Geol. Survey Water-Supply Paper 520-E, p. 92, 1925.

(1886–1923) from the 18 townships described as T. 129 N., Rs. 48–65 W, would amount to a layer of water 4.4 inches deep over the area and would necessitate a compression of the sandstone strata of 0.6 percent, assuming a thickness of strata of 60 feet.[70] If it is assumed that the compression occurred as the result of a decline in artesian head of 333 feet, the sandstone apparently was compressed an average of less than 0.002 percent for each foot of head lost. It appears likely, however, that some of the compression took place in the associated beds of shale and hence that the sandstone was compressed less than the value computed above.

The withdrawal from storage of 4.4 inches, or 0.367 foot, of water for a 333-foot decline in artesian head indicates a coefficient of storage [71] of the sandstone of about 0.0011. That is 0.0011 cubic foot of water is withdrawn from storage because of the compression of the aquifer and associated beds of shale for each foot of decline of artesian head. According to a previous computation (p. 43) it is estimated that for the 15-year period 1923–38 the average discharge in the row of townships under consideration was about 760 gallons a minute. Following Meinzer's general estimate of 500 gallons a minute for the perennial safe yield, an average withdrawal from storage of 260 gallons a minute for the 15-year period is indicated. This is equivalent to 0.18 inch, or 0.015 foot, of water over the area of the row of townships. Using a coefficient of storage of 0.0011, it is computed that the withdrawal from storage of 0.18 inch of water would necessitate a lowering of artesian head of about 13.8 feet, or an average lowering of about 0.9 foot a year from 1923 to 1938. This compares with an average lowering from 1923 to 1938 of 9.9 feet—about 0.7 foot a year—calculated from the observed decline of water levels in 25 wells situated along the western boundary of the area of artesian flow (p. 35). The difference in the two estimates is probably the result of errors of assumption, but there are indications that the decline of artesian head has been greater in the interior of the area of artesian flow than it has been along the western boundary and thus that the average lowering of head for the row of townships from 1923 to 1938 may have been more than the 9.9 feet.

Considerable speculation exists as to the effect of the large decline in artesian pressure in southeastern North Dakota on the artesian head farther west, and especially on the water level in the intake area along the East Front Range. Unfortunately, no data are available on the artesian head in these areas. The general magnitude of the decline in head may be deduced, however, by a mathematical analysis of the problem.

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[70] Meinzer, O. E., Compressibility and elasticity of artesian aquifers: Econ. Geology, vol. 23, No. 3, p. 281, 1928.

[71] The coefficient of storage is defined by C. V. Theis as the quantity of water, in cubic feet, discharged from each vertical column of the aquifer with base of 1 square foot, as the water level falls 1 foot. For artesian conditions it is equal to the water obtained from storage by the compression of a column of the aquifer 1 foot square as a result of lowering the head 1 foot.

From p.45, WSP 889-A

(1) $s = \frac{720 Q r}{T} \left[\frac{e^{-Z^2}}{\sqrt{\pi}\, Z} - \frac{2}{\sqrt{\pi}} \int_Z^\infty e^{-Z^2} dZ \right]$

where $Z = 1.367\, r \sqrt{\frac{S}{Tt}}$

Following solution by R.H.B. & W.F.G.: (September 1947)

(5) $e^{-Z^2} = 1 - Z^2 + \frac{Z^4}{2!} - \frac{Z^6}{3!} + \frac{Z^8}{4!} - \cdots$

(2) $\int_0^\infty e^{-Z^2} dZ = \frac{1}{2}\sqrt{\pi}$ ← p. 63, integral #492, A Short Table of Integrals by B.O. Peirce, Ginn & Co. 1929

(3) $\int_0^Z e^{-Z^2} dZ = Z - \frac{1}{3}Z^3 + \frac{Z^5}{5 \cdot 2!} - \frac{Z^7}{7 \cdot 3!} + \cdots$ ← p. 97 integral #800

(4) $\int_Z^\infty e^{-Z^2} dZ = (2) - (3)$

$= \frac{1}{2}\sqrt{\pi} - Z + \frac{Z^3}{3} - \frac{Z^5}{5 \cdot 2!} + \frac{Z^7}{7 \cdot 3!} - \cdots$

substituting (4) + (5) in (1) gives:

(6) $s = \frac{720 Q r}{T} \left[\frac{\left(1 - Z^2 + \frac{Z^4}{2!} - \frac{Z^6}{3!} + \frac{Z^8}{4!} - \cdots\right)}{\sqrt{\pi}\quad Z} - \frac{2}{\sqrt{\pi}}\left(\frac{\sqrt{\pi}}{2} - Z + \frac{Z^3}{3} - \frac{Z^5}{5 \cdot 2!} + \frac{Z^7}{7 \cdot 3!} \cdots\right) \right]$

$= \frac{720 Q r}{\sqrt{\pi}\, T Z} \left[1 - \sqrt{\pi}\, Z + Z^2 - \frac{Z^4}{3 \cdot 2!} + \frac{2 Z^6}{5 \cdot 3! \cdot 2!} - \frac{6 Z^8}{7 \cdot 4! \cdot 3!} + \frac{24 Z^{10}}{9 \cdot 5! \cdot 4!} - \cdots \right]$

.01.77

for $r = 5{,}000$

$T = 250{,}000$ gpd/ft.

$t = 1$ yr. $= 365$ days

$q = 0.417$ gpm/ft.

$S = 0.00035$

$$s = \frac{720(0.417)}{\sqrt{\pi}\ 5(0.01337)}\left[1 - \sqrt{\pi}\,(0.01337)\right]$$

$$= \frac{3.39}{(0.01337)}(0.9763)$$

$$= 247$$

$$Z = (1.367)\,5000\sqrt{\frac{0.00035}{250{,}000(365)}}$$

$$= \frac{(1.367)\,5000\,(1.87)}{(1{,}580)\,(6.05)}$$

$$= 0.01337$$

---

if $S = 0.035$

$$Z = (1.367)\,5000\sqrt{\frac{.035}{250{,}000(365)}}$$

$$= \frac{(1.367)\,5000\,(1.87)}{(1{,}580)\,(6.05)}$$

$$= 0.1337$$

$$s = \frac{3.39}{0.1337}\left[1 - \sqrt{\pi}\,(0.1337)\right]$$

$$= 19.4$$

---

if $S = 0.10$

$$Z = \frac{(1.367)\,5000}{(1{,}580)\,(19.1)} = 0.226$$

$$Z^2 = 0.0512$$

$$s = \frac{3.39}{(.226)}\left[1 - \sqrt{\pi}\,(.226) + 0.051\right]$$

$$= 9.75$$

---

if $S = 0.35$

$$Z = \frac{(1.367)\,5000\,(1.87)}{(1{,}580)\,(19.1)}$$

$$= 0.423$$

$$Z^2 = 0.179$$

$$s = \frac{3.39}{(0.423)}\left[1 - \sqrt{\pi}\,(0.423) + 0.179\right]$$

$$= 3.43$$

It has been assumed previously that all the water in excess of 500 gallons a minute discharged from the row of townships designated by 129 N., Rs. 48–65 W., has been taken from storage in the sandstone east of the western boundary of the area of artesian flow. Thus, an average of 500 gallons a minute has percolated into the area of artesian flow from the western part of the artesian basin. If a ditch to the sandstone, or a tunnel in the sandstone, were constructed 6 miles long in a north-south direction at the western boundary of the area of artesian flow and 500 gallons a minute were withdrawn from the ditch or tunnel, the effect on the artesian head farther west would be about the same as if this quantity of water continued its eastward percolation, as presumably it does now. The decline in artesian head at any distance from a ditch discharging water at a uniform rate is given by a formula developed by Theis.[72]

$$s=\frac{720Qr}{Pm}\left[\frac{e^{-Z^2}}{\sqrt{\pi}Z}-\frac{2}{\sqrt{\pi}}\int_Z^{\infty}e^{-Z^2}dZ\right]$$

in which s is the decline in head, in feet; Q is the flow to the ditch, in gallons a minute per foot of trench; r is the distance to the point at which the draw-down s occurs, in feet; P is the coefficient of permeability, defined in Meinzer's units; m is the thickness of the water-bearing stratum, in feet; and

$$Z=1.367r\sqrt{\frac{S}{Pmt}}$$

S is the coefficient of storage of the water-bearing stratum, and t is the time since the ditch began discharging, in days.

The formula is based on the assumptions that the water-bearing stratum is horizontal, that it is confined between two impervious horizontal beds, that its permeability and thickness is uniform throughout, and that there is no initial hydraulic gradient to the ditch and hence no initial percolation of ground water in the system.

In applying the formula to the Dakota sandstone in North Dakota the following assumptions, based on estimates given previously in this report, are made: (1) The flow into the ditch is 500 gallons a minute for a 6-mile length of trench; (2) the coefficient of permeability is 200 and the thickness of the sandstone stratum is 60 feet; (3) the coefficient of storage is 0.0011. The flow to the ditch occurs only from the west and thus the decline in artesian head is twice that computed by the formula—which assumes flow from both directions. Since the temperature of the water in the sandstone is about 60° F. no temperature correction is made to the coefficient of permeability.

The decline in artesian head 1, 10, 30, 50, 70, 90, 110, and 130 miles west of the trench for periods of discharge of 1, 10, 25, 38, and 53 years

[72] Theis, C. V., U. S. Geological Survey, personal communication, 1938.

is given in the accompanying table. Profiles of the piezometric surface constructed from these data are shown in figure 3. The table indicates that at the end of a year the artesian head 1 mile west of the trench, at the western boundary of the area of flowing wells, would have dropped 40 feet. The decline would have been 146 feet by 1895, 237 feet by 1910, 294 feet by 1923, and 349 feet by 1938.

Computed decline in artesian head, in feet, for several periods and at several distances from the western limit of the area of artesian flow

Period of discharge	Distance from postulated discharge ditch (miles)							
	1	10	30	50	70	90	110	130
1 year (1886)	40.0	2.8						
10 years (1895)	146.2	76.0	10.6	0.5				
25 years (1910)	236.8	159.4	54.6	14.2	2.4	0.3		
38 years (1923)	294.2	214.5	93.7	33.8	9.9	2.3	0.4	
53 years (1938)	349.2	267.9	139.0	60.6	23.2	7.6	2.1	0.5

Both the table and the profiles show that the effect of the discharge is transmitted westward very slowly. The decline in head 130 miles west of the trench would be less than 1 foot after 53 years.

To what extent the above computations may be taken to represent actual conditions in the Dakota sandstone is, of course, uncertain. The computed 53-year decline in head 1 mile west of the ditch agrees closely with the observed decline. On the other hand, the computed decline from 1923 to 1938 is more than five times the decline observed in that period. The discharge in the Edgeley and La Moure quadrangles from the two rows of Tps. 130 and 131 N., in the period 1923–28 was only about 40 percent and 12 percent respectively of the discharge from the row of townships designated 129 N. Thus some water in addition to 500 gallons a minute that reaches the Tps. 129 N. from the west probably percolates into the townships from the north. This would make the observed decline in head in T. 129 N. less than the computed decline, which was based on a recharge of only 500 gallons a minute. In addition, the observed decline would be further retarded by the existence of an initial eastward percolation in the sandstone strata.

Making due allowance for discrepancies between actual and assumed conditions, the foregoing analysis indicates rather clearly that the decline in head in the interior of the artesian basin has been very small and that practically no decline has occurred at the outcrop area of the sandstone.

EFFECT OF ARTESIAN-WATER CONSERVATION PROGRAM

A balance is being approached between the withdrawal of water from the artesian basin and the recharge to it. This is shown by the

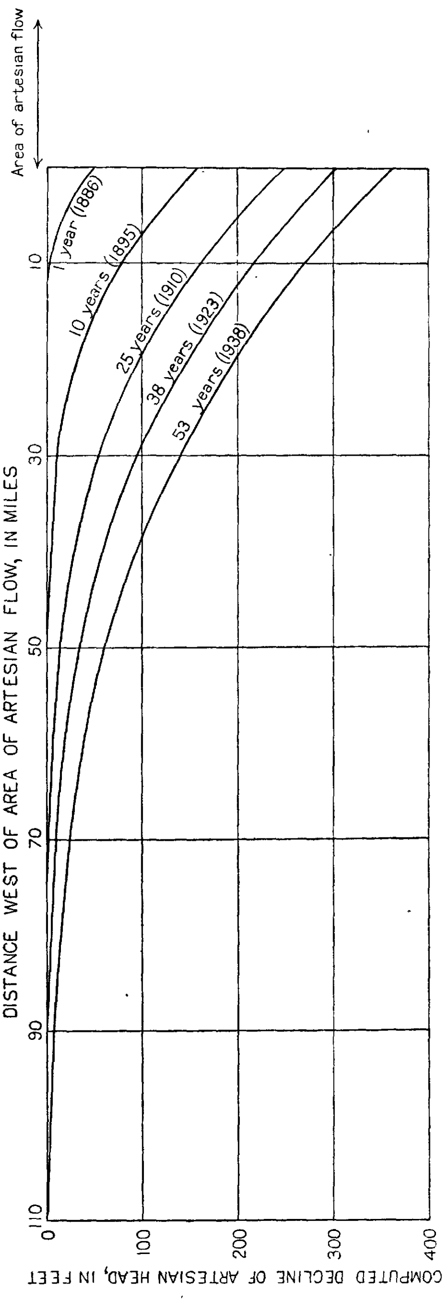

FIGURE 3.—Profiles of the piezometric surface showing computed decline in artesian head at several distances west of the area of artesian flow.

decrease in rate of decline of artesian head in wells along the western boundary of the flowing-well area and the decrease in rate of shrinkage of the area. Computations on the decline in flow of the wells in T. 129 N. indicate a reduction also in flow from about 1,000 gallons a minute in 1923 to about 520 gallons a minute in 1937–38—the latter discharge being only a few gallons above Meinzer's general estimate of the safe yield for that row of townships. The increase of artesian head in wells and the expansion of the area of artesian flow northwest of Edgeley from 1923 to 1938 shows that in that locality a balance between discharge and recharge has been reached at least temporarily.

Through the efforts of the State Geologist the flow of most of the artesian wells has been reduced and the waste of water has been largely eliminated. The late Professor Simpson estimated, on the basis of information obtained in connection with the inspection of 320 artesian wells in T. 129 N., Rs. 50 to 65 W., that the flow that could be used beneficially from an average well is about 1.18 gallons a minute.[73] In 1923 the average flow of the wells in this row of townships was 3.02 gallons a minute,[74] or about 2½ times the estimated beneficial flow. In 1938, however, the average flow of 98 representative artesian wells throughout the Ellendale-Jamestown area was found to be 1.29 gallons a minute (p. 40), or only slightly more than the beneficial flow estimated by Simpson.

Previous computations (p. 43) indicate that the aggregate flow of wells in the row of Tps. 129 N., Rs. 50 to 65 W., averaged about 760 gallons a minute from 1923 to 1938. Had the flow of the wells been unrestricted for this period, the aggregate flow might have averaged as much as 1,760 gallons a minute (on the basis that the flow under normal operating conditions averaged 43 percent of the unrestricted flow; see p. 40). A discharge of 1,000 gallons a minute (1,760–760) from the row of townships for the 15-year period is equivalent to about 0.058 foot of water over the area; this would have been yielded from storage through the compression of the sandstone and shale, assuming a coefficient of storage of 0.0011, with an accompanying decline of artesian head of about 53 feet. This is about five times the average decline observed in the period. It is apparent from these computations, even though the data on which they are based may not be precise, that the conservation program has materially reduced the rate of decline of artesian head. Through educational work "wild" wells have to some extent been brought under control and leaking wells have been repaired. In this manner the program has increased the quantity of water that is available for beneficial use.

[73] Meinzer, O. E., and Hard, H. A., The artesian water supply of the Dakota sandstone in North Dakota, with special reference to the Edgeley quadrangle: U. S. Geol. Survey Water-Supply Paper 520–E, p. 89, 1925.
[74] Idem, p. 88.

WELL RECORDS

Records of artesian wells in the area

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
Witzenburg	NW.	2	129	59	900	1¼	1916				2.4	Aug. 17, 1923	1.5	Aug. 22, 1931		
K. Esterby	SE.	3	129	59	840	2–1	1915			7	1.7	Aug. 7, 1923				
Ludden	SW.	6	129	59	980	1¼					5.7	Aug. 8, 1923				
Capitol Stock Co.	NE.	16	129	59		2–1	1917				3.8	Aug. 7, 1923				
C. Lovell	SW.	18	129	59	1,100		1912				10.0	Aug. 8, 1923	3.5	Aug. 22, 1931		Muddy and roily.
G. Bailey	NE.	19	129	59	820						5.5	do	2.5	do		
J. Stehly	NW.	21	129	59	880	1¼				10	1.0	Aug. 22, 1923				
E. Beck	SW.	22	129	59	837	2–1					4.0	1923	2.0	Aug. 22, 1931		
J. Ahman	SW.	23	129	59	830	1¼				10	2.0	Aug. 22, 1923				
E. Marten	NW.	27	129	59		2–1					3.3	Aug. 7, 1923				
F. Paulsen	SW.	28	129	59	850	2½–1¼	1915				3.0	do				
H. Hyatt	NW.	30	129	59	881	2–1	1907				5.4	Aug. 8, 1923	3.1	Aug. 22, 1931		
J. Brady	SE.	32	129	59	900		1910				3.2	Aug. 7, 1923	1.7	do		
F. Kessinger	SW.	33	129	59	1,065		1930			32						
J. Shimmons	SW.	34	129	59	810	2½–1¼	1920				3.6	Aug. 7, 1923	1.9	Aug. 22, 1931		
C. Brown estate	SW.	1	129	60							5.3	Aug. 4, 1923	.3	Aug. 21, 1931		Piped to house.
E. Hubbard	SE.	2	129	60	908	1¼	1907			5	2.3	Aug. 3, 1923				
Baker estate	NE.	3	129	60							3.7	Aug. 13, 1923				
Peterson and Bundy	SW.	3	129	60	1,000	1¼	1909			3	3.0	Aug. 2, 1923				
J. Bundy	SW.	3	129	60	1,035	1¼				15	2.4	Aug. 21, 1923				
F. Graham	SE.	3	129	60	1,350	2½–1¼					2.3	Aug. 3, 1923	1.6	Aug. 5, 1938	62	Flow not reduced in 1923. Flows roily at times.
C. Denison	SW.	5	129	60	1,000	1½	1918			8	3.8	Aug. 1, 1923				
F. Tobin	NW.	7	129	60	970	2½–1¼	1914				4.0	1923	.9	Aug. 5, 1938		Piped to house and stock tank. In good condition.
Cartney	SE.	8	129	60							1.0	Aug. 11, 1923				
R. Thomas	NE.	9	129	60	965	2½–1¼	1908				2.2	1923				Piped to house; flow reduced.
J. Lenville	SE.	10	129	60	972	1¼	1908			15	3.3	Aug. 2, 1923				
L. Townsen	NE.	11	129	60		2½–1¼	1919				5.0	1923	.5	Aug. 21, 1931		
G. Limatta	SW.	11	129	60		2–1					.9+	1923				
L. Korpna	SE.	11	129	60		2½–1¼					10.0	1923				
M. Alkofer	SE.	15	129	60	1,100	1¼					1.1+	Aug. 3, 1923				
C. Holmes	NE.	17	129	60	1,061	2				14	3.3	Aug. 1, 1923				
M. McCartney	NE.	18	129	60		2½–1¼	1909				2.3	do				

M. Olason	SE.	19	129	60		2½-1¼					1.5	Aug. 3, 1923				Water carries a black sediment.
W. McCoy	NW.	20	129	60	900	1¼				5	1.6	do				
O. Bradna	SE.	20	129	60	1,004	2½-1¼	1930			10						
K. Mysil	NE.	21	129	60		2½-1¼					8.0	Aug. 20, 1931				Well in poor condition; flow wasted.
A. Buro	NW.	23	129	60	1,100	5-2					2.0	1923				
L. Baldwin	SE.	23	129	60	930	2-1					1.0	Aug. 4, 1923				
U. Doyen	SW.	24	129	60	842	1¼					2.3	do				
N. Stankka	SE.	24	129	60	996	1¼	1911				.9	do				
J. Erickson	NE.	26	129	60	900	2½-1¼					.5	do				
I. Juniske	SW.	26	129	60		2½-1¼					20.0	do	4.0	Aug. 21, 1931		
W. Wattula	SE.	26	129	60	990	2½-1¼	1909				7.0	do	2.2	do		
L. Sampon	NW.	27	129	60	950	3-1	1906				1.3	1923				
J. Hansen	NW.	28	129	60	950	2½-¼	1914				3.5	1923	1.5	1931		
A. Puffer	NE.	29	129	60							2.6	Aug. 13, 1923	1.6	Aug. 25, 1931		
M. Bostrup	NW.	29	129	60	1,100	2-1				8	5.7	Aug. 1, 1923				
D. Stoell	SW.	29	129	60	1,100	1	1898				12.0	Aug. 3, 1923	2.5	Aug. 20, 1931		
D. Cowley	SW.	30	129	60	1,100	1½				20	7.6	Aug. 1, 1923				
B. Pederson	NE.	31	129	60	980	1¼	1919			12	1.0	Aug. 3, 1923				
C. Austin	SE.	31	129	60	1,100	1¼	1907			10	3.5	do	1.2	Aug. 20, 1931		Piped to house, stock tank, and pasture.
D. Ferris	NE.	32	129	60	1,150	2½-1¼				40	2.0	do				
W. Courtney	NW.	33	129	60	920+	2½-1¼	1912				3.1	do				
J. Koupua	NE.	35	129	60	1,035	1¼	1906				10.6	Aug. 4, 1923	2.0	Aug. 2, 1931		
Hovey estate	NE.	1	129	61		2½-1¼	1911				3.6	1923				
M. Peterson	SE.	3	129	61	1,345	3-2				75	2.4	1923				
S. Minard	NE.	4	129	61							3.5	July 31, 1923				
A. Stende	SW.	4	129	61			1928				3.5	Aug. 20, 1931				Temperature 60° F. in 1923.
E. Strand	NE.	6	129	61	1,100	1¼	1913			4	3.2	July 31, 1923				Third-flow well.
Silverleaf	SW.	6	129	61	1,100	2½-1¼	1913				.5	do				Town well.
H. Perry	NW.	7	129	61	1,100	2½-1¼					.5	1923				Flow reduced; water carries sand when well is open.
S. Stende	NE.	8	129	61	1,100	2½-1¼					3.0	July 31, 1923				
K. Stende	NW.	9	129	61	1,050	1	1902			20	.9	do				
H. Thomas	NE.	10	129	61		2½-1¼					3.0	do				
E. McGinnis	NW.	10	129	61	1,100	2½-1¼					3.8	do				
S. Berntson	SE.	13	129	61	1,160	¾	1911				1.8	Aug. 1, 1923				
I. Youle	NW.	14	129	61	1,006	1¼				14						
J. McGinnis	NE.	18	129	61	1,050	1¼	1909			10						Flows roily at times.
G. Cuslow	NW.	18	129	61	1,160	2½-1¼	1917				6.0	1923	1.2	Aug. 20, 1931		
E. Paso	SW.	19	129	61		2½-1¼					.3	July 31, 1923				
A. Winters	SW.	20	129	61							1.3	do	1.0	Aug. 20, 1931		Pipes leaking.
J. Skoglund	NE.	21	129	61	1,130	1¼	1904			75						
M. Hokana	SW.	22	129	61	1,140	1¼	1907			10	.3	Aug. 1, 1923				
O. Rosenquist	SE.	23	129	61	1,250						12.0	do	[1] 1.0	Aug. 20, 1931		
C. Hoybeck	NE.	24	129	61			1911				1.5	do				
N. Burkhardt	NE.	25	129	61	1,000	1¼	1908			15	4.0	do	[1] 1.0	Aug. 20, 1931		
T. Kyllonen	SW.	28	129	61	1,165	2½-1¼	1913			50	6.0	do	[1] 1.0	do		
H. Lumatta	SW.	29	129	61	1,200	1¼	1919			15	5.0	do	.8	do		
W. Paykko	NE.	30	129	61	1,073	2-1¼				30	1.4	July 31, 1923				
J. Martinson	NW.	31	129	61	1,120	1	1905			45	1.1	do				

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
Martinson Bros	NW.	31	129	61	1,306	2½-1	1930			50						Third-flow well; water highly mineralized.
J. Lako	SW.	31	129	61	1,240	2½-1¼	1913				1.8	July 31, 1923				
H. Limetta	SW.	32	129	61	1,200	2½-1¼	1918			8	1.8	Aug. 30, 1927	0.3	Aug. 20, 1931		Flows into cistern.
Do	SW.	32	129	61	1,070	2½-1¼	1903			2	1.5	Aug. 1, 1923				
W. Hokana	NE.	33	129	61	1,100	1¼	1911			40	3.8	do				
M. Hokana	NW.	34	129	61	1,075	1¼				12						
J. Saari	NW.	34	129	61	1,175	2-1				40	7.5	Aug. 1, 1923	[1]1.0	Aug. 20, 1931		
P. Weitala	SW.	34	129	61	1,120	1¼	1905			40	3.1	do	[1]1.0	do		
N. Burkhardt	NW.	35	129	61	1,300	1½	1903			15	2.1	do				
W. Kassella	SE.	35	129	61	1,200	2½-1¼	1931			35						
Baldwin Corporation.	NW.	1	129	62	1,158	2½-1½	1930			5						
H. Peterson	NE.	2	129	62	1,020	2½-1¼					3.0	July 30, 1923	1.5	Aug. 20, 1931		
R. Uttke	SE.	3	129	62	1,045	2½-1¼	1915									
M. Mangerson	SW.	4	129	62	900+	2½-1¼	1917				1.3	July 30, 1923	1.6	Aug. 8, 1938	69	Temperature indicates a third-flow well.
E. Rathburn	SE.	10	129	62		2½-1¼					5.0	July 28, 1923	3.0	Aug. 20, 1931		
J. Wilson	SE.	11	129	62	1,140	2½-1¼					2.2	do				
W. Gibson	NW.	12	129	62	1,040	2½-1¼				6	3.5	July 30, 1923				
W. St. Oris	SW.	14	129	62	1,020	1½-1¼	1905				4.0	do	1.5	Aug. 20, 1931		
O. Billey	SE.	15	129	62	1,010		1916			30	6.0	do	3.0	do		Emits sand at times.
J. Webster	NE.	17	129	62	1,040	2½-1¼	1920			4	.7	July 28, 1923				
M. Schmierer	NW.	17	129	62	1,120	1¼	1908				2.0	do				
M. Stahl	NE.	18	129	62	1,110	2½-1¼	1919				1.7	do				
J. Hillion	SE.	18	129	62	1,100	2½-1½					.8	do				
C. Dinsmore	SW.	22	129	62		3 -2	1904				4.0	July 30, 1923	2.0	Aug. 20, 1931		
L. Flatt	SW.	25	129	62	1,341	2½-1	1933			50						Third-flow well.
J. Covey	NW.	26	129	62	1,296	2½-1½	1933			65						Do.
N. Bjornsted	NW.	30	129	62	1,083	2- 1	1903				1.2	July 30, 1923				
J. Pollard	NE.	33	129	62	1,020	2½-1¼	1906				1.1	do				
N. Holmen	SE.	36	129	62	1,341	2½-1	1929			60						
F. Bohling	SE.	1	129	63	1,150	1¼					.8	July 27, 1923				
E. Bodle	NW.	3	129	63	980	1¼					1.6	do				
D. Coleman	NW.	6	129	63	1,100	1¼	1904				2.0	do				

M. Griffin	NE.	7	129	63	1,175	1¼	1911				2.4	do				
F. Hill	NW.	7	129	63	1,190	1¼	1905				.6	do	4.0	Sept. 10, 1937		Emitted some sand when first drilled. Cleaned in 1937 and flow increased to 4 gallons a minute.
W. Fleming	NW.	8	129	63	1,265	3 -1¼	1916				1.2	do				
M. Fleming	NW.	9	129	63	1,150	1	1904				.8	1923	1.4	Aug. 8, 1938		Flow roily before storms. Flow measured in basement in 1938.
J. Johnson	SE.	9	129	63	1,200	1¼	1902			50	.9	July 27, 1923				
Ellendale Electric Co.	SE.	11	129	63	1,050	3 -2	1920			12	8.5	Aug. 1, 1923				
Ellendale	SW.	12	129	63	1,087	3¾	1886			700						First well drilled to Dakota sandstone in North Dakota. Now abandoned.
F. Gannon	NW.	13	129	63	1,290	2					1.9	July 21, 1923				Pumped Aug. 19, 1931.
F. Thompson	SW.	13	129	63	1,100	1¼					1.2	July 27, 1923				
W. Wenkstern	NE.	14	129	63	1,150	1¼					[1] 1.0	do				
H. Hermanson	NE.	19	129	63	1,100	2½-1¼					1.5	1923				
M. Goldborg	NW.	19	129	63	1,100	1¼				29	8.2	July 28, 1923	.8	Aug. 19, 1931		
E. McShane	SE.	20	129	63	1,200	1	1909				.8	do				
A. Strand	SE.	21	129	63	1,100	1¼	1903				1.5	July 17, 1923				
A. Edgerly	SE.	22	129	63	1,120	2½-1¼	1899				1.3	July 27, 1923				
P. Bjornsted	NE.	23	129	63	1,142	1¼					.8	do				
P. Klinker	SW.	23	129	63							1.0	do				
G. Falls		25	129	63	1,240	1¼	1917			20	4.5	do				
R. Klinker	NW.	26	129	63							1.4	do				
Eredelo	NW.	27	129	63	1,100	2½-1¼					.4	do				
S. Barsness	SW.	27	129	63	1,180	1¼					1.6	do	.7	Aug. 19, 1931		
E. Kehl	SE.	30	129	63	1,100	3 -1¼					.5	July 28, 1923				
O. Strand	NW.	33	129	63	1,260	1¼	1917			15	2.0	1923				
B. Hall	SE.	34	129	63	1,150	2½-1¼					2.7	July 27, 1923	1.6	Aug. 19, 1931		
R. Hall	NW.	34	129	63	1,050	1¼	1909				1.2	1923	1.0	do		
Anderson Bros.	SW.	3	129	64	1,211	1¼				35	2.3	July 26, 1923	1.5	Aug. 18, 1931		Probably leaking into upper part of formation.
G. Phelps	SE.	4	129	64		1¼					3.2	do				
C. Fuller	NE.	5	129	64	1,265	3 -1¼	1909			25	3.5 1.9	1923 Aug. 11, 1937	2.8 1.7	Aug. 18, 1931 July 21, 1938	63	Casing rusted and leaking. Water piped into house and then to tank.
Federal Land Bank.	SW.	7	129	64	1,262	3 -1¼	1916	0.00 −.82	Aug. 10, 1937 July 20, 1938	25	2.9	July 26, 1923	1.0	Aug. 18, 1931	57	Measuring point, land surface. Flows into reservoir below land surface.
M. Whelan	SE.	7	129	64	1,210	1¼	1902	−2.35 −2.51	Aug. 11, 1937 July 20, 1936	35	1.5	do				Measuring point, top of concrete platform 0.7 foot above land surface. Flows into reservoir below land surface.
A. Wilson	SE.	9	129	64	1,215	2½- ¾		−75.74 −76.43	Aug. 19, 1937 July 19, 1938							Measuring point, hole in coupling at T joint 0.5 foot above land surface. Abandoned.
B. Hodges	NE.	12	129	64		1¼					.7	July 26, 1923				
R. Griffin	SW.	12	129	64	1,150	1½	1902			55	2.0	do				Cleaned in 1934; reported yield then 9 gallons a minute.

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
A. Harrison	SW.	15	129	64	1,215	2½–1¼	1936				1.5	Aug. 19, 1937	3.3	July 20, 1938	56	Flow measured at tank, about 2 feet above land surface. Flow reduced.
Do	SW.	15	129	64	1,100	2½–1¼					4.0	July 28, 1923	.3 .3	Aug. 19, 1937 July 20, 1938		Used for watering hogs.
G. Mock	SW.	19	129	64	1,100	3 –1¼	1916	−4.21	Aug. 10, 1937		2.2	July 26, 1923	1.2	Aug. 18, 1931	52	Measuring point, top of 1¼-inch pipe 2.4 feet above land surface.
C. Scott	NW.	21	129	64		2½–1¼					1.4	1923				
W. Phillips	NW.	23	129	64	1,207	1¼	1917				7.3	July 28, 1923	4.0	1931		
J. J. Markel	SW.	31	129	64												Destroyed. Stopped flowing in 1926.
Bank of New Ulm.	NE.	32	129	64												Destroyed. Attempt at recasing in 1931 was unsuccessful. Water level reported 15 feet below land surface.
O. Olek	NW.	33	129	64		¾					.9	Aug. 10, 1937	.7	July 20, 1938	59	Unreduced flow measured at stock tank 20 feet west of well. Recased in 1930.
J. McGannon	NW.	1	129	65	1,350	2½–1¼	1913	−30.25	Aug. 11, 1937							Measuring point, top of coupling in bottom of reservoir 7.1 feet below land surface. Stopped flowing about 1920.
L. Leet	SW.	2	129	65	1,375	1¼	1908									Destroyed.
G. Quashnick	NE.	1	129	65	1,200	3–1¼		−94.76 −95.90	Aug. 11, 1937 July 20, 1938							Measuring point, top of 1-inch board at side of casing 1.0 foot above land surface. In 1914 water level was 80 feet below surface.
W. Schuett	SW.	11	129	65	1,350	1¼										Did not flow in 1923.
L. Nelson	NW.	15	129	65	1,375	1¼										Destroyed. Did not flow in 1923.
U. Brown	SW.	24	129	65	1,300	2–1¼	1910	[2]–6	Aug. 7, 1937		2.0	July 26, 1923			52	Water roily before storms.
A. Smith	SE.	24	129	65	1,350	1¼		−76.78 −78.42	do July 19, 1938							Measuring point, top of 1¼-inch casing 0.5 foot above land surface.

R. Wright	SE.	27	129	65	1,350	1½		[2]−4	July 25, 1923							Water level more than 30 feet below land surface in 1937.
Union Life Insurance Co.	SW.	28	129	65	1,350			[2]−10	1923							Destroyed.
Cartlidge Bros.	SW.	32	129	65	1,300		1907									Destroyed. Did not flow in 1923.
G. Lynd	SW.	33	129	65	1,250											Plugged. Ceased flowing in 1918.
M. Goldberg	SE.	33	129	65	1,250	3½-2	1916	[2]−10 −26	July 25, 1923 Aug. 6, 1937							
C. Reimers	SW.	35	129	65	1,250	2-1½	1913	−9.50 −10.60	Aug. 7, 1937 July 19, 1938		1.5	July 25, 1923				Measuring point, land surface. Reservoir constructed around casing. Ceased flowing in 1931.
Forbes	SW.	35	129	65	1,400	6-1½										Water level at about land surface in 1937.
G. O'Dill	SW.	36	129	65	1,100	2-1¼	1907	−7.15 −7.22	Aug. 7, 1937 July 19, 1938		1.5	July 26, 1923				Measuring point, top of wood casing 1.1 feet above land surface.
J. Schmidt	SE.	1	130	59	906	2½-1	1910			20	2.5	Sept. 2, 1927	2.5	Aug. 26, 1935		
D. Brennan	NW.	2	130	59	932	2-1	1908			15	2.5	do	2.0	do		
A. Kliment	SW.	2	130	59	877	2-1	1908			5	1.1	do	.9	Aug. 5, 1938	58	
M. Reinhart	NW.	3	130	59	860	3-2	1919			30	3.2	do	3.5	Aug. 26, 1935		
J. Donnelly	NE.	5	130	59	935	2½-1¼	1921			10	1.8	do	2.1	do		
M. Redden	SE.	17	130	59	918	2-1	1914			10	1.5	do				
E. Kliment	NE.	18	130	59	900	1¼	1911			15	10.0	do	7.0	Aug. 26, 1935		
O'Brien	SW.	18	130	59	885	2½-1¼	1912				4.3	Aug. 26, 1935				
W. Shafer	SW.	19	130	59	885	2½-1¼	1919			10	1.8	Sept. 2, 1927				
H. Robins	SW.	31	130	59	847	2½-1¼	1918			15	3.0	do	1.5	Aug. 26, 1935		
Scott Bros.	NW.	36	130	59		2½-1¼	1910				2.0	do	3.3	do		
H. Koehn	SE.	1	130	60	1,035	2½-1¼	1923			12	4.8	Sept. 1, 1927				
A. Ditch	NW.	2	130	60	1,000	2½-1¼	1916			6	2.5	do				
Lund estate	SW.	2	130	60	950	2-1	1906			6	1.8	do				
W. Denning	NE.	3	130	60	1,000	2½-1¼	1912				1.0	do	.5	Aug. 5, 1938	70	Temperature of water affected by piping arrangement.
J. Snow	NE.	4	130	60	1,108	2½-1¼	1912				2.5	do	2.0	Aug. 23, 1935		
H. Johnson	NE.	6	130	60	980	2½-1¼	1917			7	.3	Aug. 21, 1927	.5	do		
P. Kunrath	SE.	6	130	60	960	1¼	1913			7	1.0	Aug. 3, 1927	1.3	do		
G. Kunrath	NE.	8	130	60	1,000	2½-1¼					1.0	Sept. 1, 1927				Water clear at all times.
M. Houl	NE.	9	130	60		2½-1¼	1912				2.5	do	2.0	Aug. 23, 1935		
W. Rollo	NE.	12	130	60	1,040	2½-1¼	1919			20	6.0	do	1.0	do		
K. Morgan	SE.	12	130	60	1,103	2½-1¼	1920			12	3.0	Aug. 31, 1927				
H. Low	SE.	13	130	60	900	2½-1¼	1910			15	1.5	do				
J. Rehovsky	SW.	14	130	60		2½-1	1910				1.0	Aug. 3, 1927				
Kendall Bros.	SE.	14	130	60	972	3-2	1908			45	7.5	Aug. 31, 1927				
I. Houl	NE.	15	130	60		2½-¾	1908				3.6	Sept. 1, 1927				
J. Smith	SE.	17	130	60		2½-1¼	1908				2.0	do	1.7	Aug. 23, 1935		
H. Kunrath	NE.	19	130	60	945	2-1	1906				1.4	Aug. 31, 1927	1.2	do		
R. Murray	SE.	21	130	60		2½-1¼	1914				1.5	Sept. 1, 1927	1.3	do		
L. Frederick	SW.	22	130	60	1,100	2½-1¼				7	1.0	do	1.5	do		
Brown	SW.	24	130	60		2½-1¼	1905				1.0	Aug. 31, 1927				
M. Waiste	SE.	26	130	60	950	2½-1¼	1904			7	2.5	do	1.6	Aug. 5, 1938	64	
S. Baker	SE.	27	130	60		2½-1¼	1914				3.0	do	1.5	Aug. 23, 1935		

[2] Reported.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
L. Maddock	NE.	28	130	60	1,100	2½-1¼	1913			5	1.0	Sept. 1, 1927				
C. Maddock	SE.	28	130	60	900	2½-1¼	1916			6	3.0	Aug. 31, 1927	2.0	Aug. 23, 1935		
H. Van Meter	NW.	29	130	60	1,050	2½-1½	1905			6	3.0	do	2.5 2.1	do Aug. 5, 1938	62	Water used occasionally for irrigation.
F. Courtney	SW.	29	130	60	1,140	4-1¼	1904				15.0	do	2.5	Aug. 23, 1935		"Wild" well.
M. Page	SW.	2	130	61	1,117	3-1¼	1906				1.0	Aug. 30, 1927	.4 2.0	do Aug. 6, 1938	62	Well repaired and flow increased November 1937.
H. Beck	SE.	2	130	61	1,155	3-2	1920			7	3.0	do	.9	Aug. 23, 1935		
F. Appelquist	SE.	4	130	61	1,050	2½-1¼	1906			8	1.5	do	1.2	do		
J. Sommers	SW.	5	130	61	1,030	2½-1¼	1916			50	2.7	Aug. 29, 1927	1.4	do		
O. Carlson	SE.	6	130	61	1,128	2½-1¼	1909			15	2.5	do	1.1	Aug. 20, 1935		
G. Hatfield	SE.	7	130	61	1,020	2-1	1910			23	1.5	do	.5	Aug. 13, 1935		
M. McCartney	SW.	8	130	61	1,100	2½-1¼	1914			25	3.0	do	3.8	Aug. 23, 1935		
Baldwin Corporation.	SW.	11	130	61	1,160	2				10	4.8	Aug. 30, 1927	2.0	do		
Federal Land Bank.	SW.	12	130	61	1,000	3-2	1914			5	1.7	do	1.1	do		
L. Kvigne	NE.	14	130	61	1,050	1	1907			20	4.3	do	3.8	do		
J. Houl	SE.	14	130	61	1,050	2½-¾	1910			35	5.8	do	[1] 1.5 1.3	do Aug. 6, 1938	56	
J. Morgan	NW.	15	130	61	1,150	4½-2				100	2.0	do	1.9	Aug. 23, 1935		
Baldwin Corporation.	NW.	20	130	61	1,293	2½-1	1934			65	[1] 28	Aug. 23, 1935				Third-flow well.
Do	NW.	20	130	61	1,100	2½-1	1916			10	.5	Aug. 29, 1927				
Do	NW.	21	130	61	1,075	2½-1¼	1916			25	1.1	do	.9	Aug. 23, 1935		
Do	SE.	22	130	61		2½-1¼	1916				8.0	Aug. 30, 1927	5.0 5.0	Aug. 24, 1935 Aug. 6, 1938	60	
Do	NE.	23	130	61	1,012	3-2	1926			12	1.2	do				
Do	NW.	24	130	61	1,050	2½-¾	1916			10	1.3	do				
F. Hayenda	NE.	25	130	61	988	1¼	1926			2.5	2.5	1926				
M. McCartney	SW.	28	130	61	1,000	2	1910			20	1.6	Aug. 29, 1927	1.3	Aug. 24, 1935		
Baldwin Corporation.	SE.	30	130	61	1,110	3-2	1916			25	.2	do				
F. Higgs	SW.	32	130	61	1,100	1	1915			50	1.8	1927				
A. Higgs	SE.	33	130	61	940	2-1¼	1902				.5	Aug. 28, 1927	.3	Aug. 24, 1935		

First National Bank.	NW.	35	130	61		2 -1	1914			15	3.8	Aug. 30, 1927	2.1	do		
A. Burley	SW.	35	130	61	1,100						1.0	July 21, 1923	2.5	Aug. 30, 1927		
E. Canfield	NE.	3	130	62	1,200	3 -2	1902	+25	Dec. 12, 1923	75	2.6	Dec. 12, 1923				Estimated unrestricted flow in 1923 was 20 gallons a minute.
S. Helfenstein	NE.	6	130	62	1,040	2½-1¼	1913			15	.9	do	.0	Aug. 22, 1935		
E. Shannon	SW.	7	130	62	1,068	2½-1¼	1910	+12	Dec. 12, 1923	17	2.3	do	.0	do		
													.0	Aug. 8, 1938		
H. Collett	NE.	8	130	62	1,170	2½-1¼	1919			9	1.9	do	.5	Aug. 22, 1935		
Bank of North Dakota.	SW.	9	130	62	1,090	2½-1¼	1908	+16	Dec. 13, 1923	24	6.0	Dec. 13, 1923	[1] 2.0	Aug. 23, 1935		Estimated unrestricted flow in 1923 was 9 gallons a minute.
Dahlgren	NE.	12	130	62	1,180	2½-1¼	1919	+12	Dec. 12, 1923	14	6.0	Dec. 12, 1923	1.3	do		Estimated unrestricted flow in 1923 was 10 gallons a minute.
J. Miller	SE.	13	130	62	960	2½-1¼	1911	+9	Dec. 14, 1923	4	1.5	Dec. 14, 1923	1.1	do		Estimated unrestricted flow in 1923 was 2.5 gallons a minute.
G. Jury	NE.	14	130	62	1,080	2½-1¼	1904	+7	do	20	1.8	do				Unrestricted flow in 1923.
M. Schmier	SW.	14	130	62	1,022	2½-1¼	1912	+15	do	18	3.0	do	2.1	Aug. 23, 1935		Estimated unrestricted flow in 1923 was 9 gallons a minute.
R. Krausie	SW.	15	130	62	1,048	1¼					1.5	Aug. 23, 1935				
C. Mattheis	SW.	17	130	62	1,070	2½-1¼	1918	+9	Dec. 13, 1923	8	1.5	Dec. 13, 1923				Estimated unrestricted flow in 1923 was 5 gallons a minute.
J. Johnson	NE.	18	130	62	1,060	2½-1¼	1905	+20	do	25	7.0	do	4.0	Aug. 23, 1935		Estimated unrestricted flow in 1923 was 8 gallons a minute.
C. Mattheis	NE.	19	130	62	1,050	2 -1	1905	+10	Dec. 12, 1923	10	3.0	Dec. 12, 1923				Unrestricted flow in 1923.
J. Schmidt	SW.	20	130	62	1,100	2½-1¼	1903	+3	Dec. 13, 1923	25	4.3	Dec. 13, 1923	3.7	Aug. 22, 1935		Do.
D. Rankey	SE.	22	130	62	1,090	2½-1¼	1907	+4	Dec. 14, 1923	20	2.0	Dec. 14, 1923	1.0	Aug. 23, 1935	55	Do.
													.9	Aug. 8, 1938		
C. Weis	NW.	24	130	62	1,140	2½-1¼	1915	+3	do	5	.8	do				Do.
C. Pierce	NE.	25	130	62	1,080	1¼					1.0	Sept. 10, 1937				
T. Lee	SW.	26	130	62	1,050	2½-1¼	1916	+12	Dec. 14, 1923	11	1.7	Dec. 14, 1923				Estimated unrestricted flow in 1923 was 4 gallons a minute.
C. Wentzel	SE.	26	130	62	1,130	2½-1¼	1914	+12	do	15	1.7	do	1.4	Aug. 23, 1935		Estimated unrestricted flow in 1923 was 4 gallons a minute.
M. Halte	NE.	30	130	62	1,080	2½-1¼	1903	+15	Dec. 13, 1923	70	4.0	Dec. 13, 1923	2.1	Aug. 22, 1935	63	Estimated unrestricted flow in 1923 was 15 gallons a minute.
													1.2	Aug. 8, 1938		
J. Kosel	SW.	31	130	62	1,080	2½-1¼	1911	+3	do		.8	Dec. 12, 1923				Unrestricted flow in 1923.
E. Williams	SE.	31	130	62	1,100	2½-1¼	1902	+5	do	25	3.0	Dec. 13, 1923	1.5	Aug. 22, 1935		Estimated unrestricted flow in 1923 was 3½ gallons a minute.
A. Johnsen	NW.	32	130	62	1,193	2½-1½	1930			6						
C. Schaggs	SE.	32	130	62	1,080	2-1	1909	+16	Dec. 14, 1923	17	3.5	Dec. 14, 1923	[1] 4.0	Aug. 22, 1935		Unrestricted flow in 1923.
I. Covey	SW.	34	130	62	1,080	2½-1¼	1919	+20	do	20	4.0	do	2.0	do		Estimated unrestricted flow in 1923 was 6 gallons a minute.
C. Wonderly	SE.	34	130	62	1.040	2½-1¼	1909	+11	do	21	1.7	do	1.3	Aug. 23, 1935		Estimated unrestricted flow in 1923 was 3 gallons a minute.
O. Giebelstin	NW.	35	130	62	1,150	2½-1¼	1913	+12	do	10	.6	do				Do.
B. Salinger	SE.	35	130	62	1,090	2½-1¼	1909	+8	do	15	.6	do				Unrestricted flow in 1923 was 2.4 gallons a minute.
W. Sukert	SW.	1	130	63	1,160	2½-1¼	1908			20	2.0	Nov. 17, 1923	.4	Aug. 8, 1938	68	
M. Gannon	SE.	2	130	63	1,120	2½-1¼	1915	+9	Nov. 17, 1923	14	1.5	do	1.1	Aug. 21, 1935		
W. Tsudi	NE.	6	130	63	1,165	2½-1¼	1915			9	.0	Nov. 18, 1923				Stopped flowing in 1922.

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location: Quarter	Location: Section	Location: T. N.	Location: R. W.	Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−): Head or water level (feet)	Estimated artesian head: Date	Flow (gallons a minute): Reported original flow	Flow: Measured flow	Flow: Date	Flow: Measured flow	Flow: Date	Temperature (° F.)	Remarks
G. Rose	NW.	6	130	63	1,170	2½–1¼	1909	+3	Nov. 15, 1923	15	0.5	Nov. 15, 1923				Unrestricted flow.
E. Retzlaff	SE.	7	130	63	1,180	2½–1¼	1904	+5	do.	20	.9	do.				Estimated unrestricted flow in 1923 was 3 gallons a minute.
E. Byer	SE.	9	130	63	1,165	2½–1¼	1902	+4	Nov. 16, 1923	20	1.0	Nov. 16, 1923				Estimated unrestricted flow in 1923 was 4 gallons a minute.
J. Gray	NE.	10	130	63	1,125	2½–1¼	1918	+6	Nov. 17, 1923	7	2.8	Aug. 18, 1923				Unrestricted flow in 1923.
C. Cheselbro	SE.	10	130	63	1,120	2½–1¼	1909	+5	Nov. 16, 1923	25	.3	Nov. 16, 1923				
E. Durey	NW.	11	130	63	1,150	2½–1¼	1908	+9	Nov. 17, 1923	18	1.0	Nov. 17, 1923				Unrestricted flow in 1923 was 2.2 gallons a minute.
I. Letsen	SW.	12	130	63	1,160	2½–1¼	1903	+2	Nov. 18, 1923	20	.6	Aug. 18, 1923				Unrestricted flow in 1923 was 5.4 gallons a minute.
C. Hanson	SE.	14	130	63	1,100	2½–1¼	1905	+3	Nov. 17, 1923	18	.5	do.				Unrestricted flow in 1923 was 0.8 gallon a minute.
E. Spencer	NE.	15	130	63	1,180	2½–1¼	1914	+6	Nov. 16, 1923	20	1.3	Nov. 16, 1923	[1] 0.2	Aug. 21, 1935		
E. Byer	NW.	15	130	63	1,165	2½–1¼	1918	+9	do.	6	.5	do.				Estimated unrestricted flow in 1923 was 6 gallons a minute.
G. Radtke	SW.	17	130	63	1,165	2½–1¼	1903	+9	Nov. 15, 1923	20	2.4	Nov. 15, 1923	5.0 .4	Aug. 21, 1935 Aug. 8, 1938	68	
H. Wedell	SE.	19	130	63	1,120	2½–1¼	1912	+6	do.	5	1.5	do.	.0	Aug. 21, 1935		Filled in.
J. Byer	NE.	21	130	63	1,158	2 1	1905	+3	Nov. 16, 1923	15	.5	Nov. 16, 1923				Estimated unrestricted flow in 1923 was 2 gallons a minute.
Do.	NE.	21	130	63	1,158	1¼	1931			6	.0	Aug. 21, 1935				Pumped in 1935.
J. Janett	NE.	22	130	63	1,180	2½–1¼	1902	+3	Nov. 16, 1923	30	1.3	Nov. 16, 1923	.0	Aug. 21, 1935		Do.
J. Byer	NW.	22	130	63	1,236	3–2	1920	+7	do.	18	.6	do.				Estimated unrestricted flow in 1923 was 6 gallons a minute.
G. Elliott	SE.	25	130	63	1,210	2½–1¼	1910	+3	1923	20	.6	1923				Unrestricted flow in 1923.
M. Bainbridge	NE.	26	130	63	1,180	2½–1¼	1910	+3	Nov. 17, 1923	25	3.0	Nov. 17, 1923	.0	Aug. 21, 1935		Stopped flowing about 1932.
Middleton Trust Co.	SE.	26	130	63	1,050	2½–1¼	1907	+2	1923	20	1.5	1923				
W. Wheelihan	NE.	27	130	63	1,165	2–1	1907	+2	Nov. 16, 1923	14	.8	Nov. 16, 1923				
H. Gentz	NW.	28	130	63	1,180	2–1	1904	[1] −8	Nov. 15, 1923	20						Stopped flowing in 1920.
P. Weedle	NE.	28	130	63	1,260	2½–1¼	1909	+4	Nov. 16, 1923	20	1.2	Nov. 16, 1923	.4	Aug. 8, 1938	68	Estimated unrestricted flow in 1923 was 2 gallons a minute.
E. Dathe	NE.	29	130	63	1,160	2½–1¼	1913			6	1.9	Nov. 15, 1923	.0	Aug. 21, 1935		

H. Gentz	SE.	29	130	63	1,180	2-1¼	1916	+6	Nov. 15, 1923	15	2.0	do	1.0	do		Estimated unrestricted flow in 1923 was 6 gallons a minute.
R. Pomplum	SE.	30	130	63	1,160	2-1	1902	+10	do	25	1.7	do				Flow unrestricted in 1923.
M. Gannon	NE.	34	130	63	1,180	2½-1¼	1916	+3	Nov. 16, 1923	6	.7	Nov. 16, 1923				
E. Rietsch	SE.	35	130	63	1,180	2½-1¼	1912	+5	do	25	1.1	do				Estimated unrestricted flow in 1923 was 2 gallons a minute.
G. Dean	SE.	36	130	63	1,380		1914	+10	Nov. 17, 1923	25	2.4	Nov. 17, 1923				Flow unrestricted in 1923.
F. Zinter	SW.	9	130	64	1,320	2½-1¼	1905	+15 −4.60 −9.48	Nov. 10, 1923 Aug. 12, 1937 July 28, 1938	25	2.0	Nov. 10, 1923	1.5	Aug. 21, 1935		Measuring point, top of hole in 2- by 12-inch plank 1.0 foot above land surface. Estimated unrestricted flow in 1923 was 6 gallons a minute.
C. Maack	SE.	10	130	64	1,180	2½-1¼	1908	+4	Nov. 14, 1923	5	1.5	Nov. 14, 1923	0.0	Aug. 20, 1937		Unrestricted flow in 1923. Stopped flowing in 1934. Abandoned.
H. Schaller	NE.	11	130	64	1,280	2½-1¼	1912	+3	do	5	2.4	do	1.3 1.6 1.6	Aug. 21, 1935 Aug. 26, 1937 July 28, 1938	 65 65	
E. Retzlaff	NW.	13	130	64	1,180	2½-1¼	1905			45	1.0	Nov. 15, 1923				Estimated unrestricted flow in 1923 was 9 gallons a minute.
A. Noess	SW.	13	130	64	1,242	2½-1¼	1906			40	1.5	do				Unrestricted flow in 1923 was 4.3 gallons a minute.
H. Tiegs	SE.	13	130	64	1,180	1¼	1906			30	2.4	do	1.6	Aug. 21, 1935		
F. Kalbus	NE	15	130	64	1,400	2½-1¼	1908			32	3.0	Nov. 14, 1923	1.8 .8 .6	Aug. 21, 1935 Aug. 20, 1937 July 28, 1938	 62 62	Estimated unrestricted flow in 1923 was 4 gallons a minute.
C. McEntee	NE.	19	130	64	1,300	2½-1¼	1913	[1] −4.5 [2] −30	Nov. 10, 1923 Aug. 13, 1937	15						Stopped flowing in 1921.
W. Retzlaff	SE.	22	130	64	1,100	2½-1¼	1910	[1] −15	Nov. 12, 1923	25						Stopped flowing in 1922.
E. Heine	SE.	24	130	64	1,260	2½-1¼	1909			35	2.4	Nov. 12, 1923				
M. Fleming	SW.	27	130	64	1,227	3-2	1920			25	3.0	do	1.8 1.4 .3	Aug. 21, 1935 Aug. 26, 1937 July 20, 1938	 65 	
Federal Land Bank.	SW.	28	130	64	1,280	2½-1¼	1910	+10 [2] −10	Nov. 10, 1923 July 21, 1938	35	2.0	Nov. 10, 1923			52	
F. Bobbe	SE.	29	130	64	1,165	2½-1¼	1910	+4 −7.56 −8.55	Nov. 10, 1923 Aug. 13, 1937 July 21, 1938	15	1.0	do				Measuring point, top of concrete curb of reservoir under 6-inch loose plank 0.5 foot above land surface.
G. Shepard	SW.	30	130	64	1,320	2½-1¼	1910	[1] −6	Nov. 11, 1923	10						Stopped flowing in 1920. Destroyed.
N. Quinn	SE.	32	130	64	1,230	2½-1¼	1916			20	4.0	Nov. 12, 1923	1.0 .5 1.2	Aug. 21, 1935 Aug. 12, 1937 July 20, 1938	 59 66	Cleaned in 1937 and again in 1938. Change in temperature probably due to difference in effect of sun on piping arrangement.
J. Flynn	SW.	34	130	64	1,156	2	1918			24	3.0	1923	1.8	July 21, 1935		
M. Vennum	SW.	1	130	65	1,400	2½-1¼	1903	[1] −27 [2] −45	Nov. 8, 1923 Aug. 20, 1937	25						
Farmers and Merchants Bank.	SE.	1	130	65	1,400	2½-1¼	1909	−24.3	Nov. 9, 1923	9						Stopped flowing in 1915.

[1] Estimated. [2] Reported.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
N. Davis	NW.	2	130	65	1,440	4-1¼	1903	[1] −35 −70.49	Nov. 8, 1923 Aug. 20, 1937	25						Measuring point, top of wood pit on west side, 1.0 foot above land surface.
F. Davis	NE.	12	130	65	1,470	2½-1	1904	[1] −19	1923	18					54	Stopped flowing in 1917.
S. Bristol	NE.	14	130	65	1,420	3-2	1913	[1] −27 [1] −36	1922 Aug. 20, 1937	3						Stopped flowing in 1914.
T. Clark	NE.	15	130	65	1,375	2½-1¼	1905	[1] −30	1922	15					53	Stopped flowing in 1913.
Eaton and Eaton	SE.	22	130	65	1,600	3-2	1914			4						Stopped flowing in 1915. Destroyed.
C. Gulkey	SW.	25	130	65	1,400	2½-1¼	1910	[2] −11	1937	25						Stopped flowing in 1916.
F. Moore	NE.	29	130	65	1,600	2½-1¼	1909			1						Stopped flowing about 1909.
Lockie and Nelson	NE.	2	131	59	1,160	3-2	1916				6.3	Sept. 6, 1927	4.5 [1] 3.0	July 27, 1932 Aug. 5, 1938		
N. Nelson	NW.	2	131	59	1,000	2½-2	1912				3.3	do	3.1	July 27, 1932		
W. Lockie	SW.	2	131	59	940	2½-¾	1904				1.0	do				
E. Christenson	SW.	3	131	59	1,000	3-2	1920				4.0	do	2.9	July 27, 1932		
B. Swanson	NE.	4	131	59	1,200	3-2	1907				3.0	do	3.0	do		
E. Rasmusen	NW.	6	131	59	1,005	2½-1¼	1911			30	3.8	do	4.0	do		
J. Nelson	NE.	8	131	59	1,000	3-2	1916				2.5	do	5.0	do		
Federal Land Bank.	SW.	8	131	59	1,140	3-2	1919				3.7	do	3.0 7.5	do Sept. 7, 1938	69	Third-flow well.
J. Deiffenbacker	NW.	9	131	59		2½-1¼	1920				2.1	do	2.0	July 27, 1932		
W. Bergstrom	SE.	9	131	59		2½-1¼	1918				7.1	do	3.0	do		
N. Nelson	NE.	10	131	59	920	3-2	1911				2.0	do				
Thompson	SW.	12	131	59	1,040	3-2	1916				.5	do				
O. Anderson	NW.	14	131	59	1,000	2½-¾	1913				1.3	do	.8	July 27, 1932		
A. Gramlow	SW.	18	131	59	1,002	2½-1½	1919			15	3.0	do	2.0 1.6	do Aug. 5, 1938	62	
R. Wick	SE.	18	131	59	998	3-2	1914			14	2.8	do	2.5	Sept. 27, 1932		
A. Wedel	SW.	19	131	59	1,000	2-1	1907			8	1.0	do				
Oakes	SW.	20	131	59												
Do	SW.	20	131	59							[1] 4	Sept. 7, 1927				
Do	SW.	20	131	59		4										
Do	SW.	21	131	59												Capped.

Catholic Parsonage.	SW.	21	131	59												Do.
C. Melander	SE.	23	131	59	890	2½- ¾	1912				2.8	Sept. 3, 1927	.0	Sept. 27, 1932		Pumped in 1932.
Farmers and Merchants Bank.	SE.	23	131	59	1,427	3 1¼	1937			45						Third-flow well.
C. Knox	SW.	26	131	59	900	2½-1¼	1916				7.5	Sept. 3, 1927	3.0	Sept. 27, 1932		
G. Schaub	SW.	28	131	59		2 -1	1908				.6	Sept. 7, 1927				
Oakes	NE.	29	131	59	977		1890			817						Abandoned.
H. Johnson	NW.	29	131	59		2 -1	1912				3.0	Sept. 7, 1927				
L. Beckwith	NE.	30	131	59	900	2½- ¾	1910				2.0	Sept. 3, 1927	2.0	Aug. 27, 1932		
H. Berggren	NE.	31	131	59		2½-1¼	1916				2.0	do				
H. Blazer	NW.	31	131	59	950	1¼	1915			10	1.0	do				
H. Becker	NE.	2	131	60	940	2½-1¼	1910			30	.3	Sept. 9, 1927				
J. Redene	NE.	3	131	60	890	2½-1¼	1913			4	3.1	do				
J. Kraft	SE.	3	131	60	1,100	2½- ¾	1910			7	2.5	do				
M. Morgan	NW.	5	131	60	1,000	2½-1¼	1921			20	.3	Sept. 13, 1927				
A. Stevens	SE.	7	131	60	1,140	2½-1¼	1915			15	1.5	Sept. 12, 1927	2.1	Aug. 5, 1938		
A. Gramlow	SW.	8	131	60	980	3 -2	1916			60	3.8	Sept. 13, 1927	2.5	July 26, 1932		
A. Pedersen	NE.	11	131	60	1,000	2½-1¼	1908			22	3.5	Sept. 9, 1927	2.5	do		
C. Pedersen	SW.	11	131	60	955	1½	1918			55	1.4	do	1.8	do		
A. Ditch	SE.	13	131	60	1,000	2½-1¼	1921				1.5	Sept. 10, 1927				
W. Hazzard	NE.	15	131	60	1,012	2½-1½	1922			10	1.5	Sept. 9, 1927	1.0	July 26, 1932		
A. Johnson	NE.	17	131	60	1,060	2½- 3.	1914			25	3.0	Sept. 12, 1927	2.0	do		
Federal Land Bank.	SW.	17	131	60	1,286	2-1¼	1915			30	16.0	do	5.5	Sept. 6, 1938	65	Third-flow well.
M. Morgan	SE.	18	131	60	1,080	2½-1½	1910			16	6.0	do	3.8	July 26, 1932		
N. Gergen	NW.	20	131	60	1,100	2½-1½	1912				5.5	do	1.9	do		
F. Pfeifer	SE.	21	131	60	1,047	2½-1¼	1921			20	2.1	Sept. 10, 1927	1.3	do		
M. Pfeifer	NW.	22	131	60	1,060	3 -2	1904			80	5.0	Sept. 12, 1927	3.5	do		
G. Hackbarth	NE.	23	131	60	920	1½	1910			25	1.5	Sept. 9, 1927	1.0	July 27, 1932		
J. Kehovsky	NE.	24	131	60		2½-1¼	1917				1.0	Sept. 10, 1927				
D. Adams	SE.	24	131	60	980	1½	1907			30	2.1	do	1.8	July 27, 1932		
L. Johnson	NW.	25	131	60	960	2½-1½	1918			40	.6	do				
C. Frogen	SE.	25	131	60	1,060	3 -2	1909			60	2.0	do	1.5 2.5	July 27, 1932 Aug. 5, 1938		
P. Gemar	NW.	26	131	60	1,068	2½-1½	1913				6.0	Sept. 9, 1927	2.9	July 27, 1932		
K. Hoybak	NE.	27	131	60	1,030	3 -2	1904			50	6.1	Sept. 10, 1927	1.2	do		
J. Pfeifer	SW.	27	131	60	1,047	2½-1¼	1917			40	2.5	do				
P. Gemar	SE.	27	131	60	1,060	2½-1½	1912			10	4.5	do	2.4	July 27, 1932		
A. Kieffer	SW.	28	131	60	959	1½	1920			6	2.1	1927	1.0	July 26, 1932		
Nord estate	NE.	29	131	60	1,100	3 -2	1912				2.8	1927	1.8	do		
J. Carr	SW.	29	131	60		2½-1¼	1910				.9	Sept. 12, 1927				
C. Johnson	SW.	30	131	60	980	2½-1¼	1912				[1] 1.0	do				
J. McKee	SW.	31	131	60	988	2½-1½	1913				1.5	do	2.0	July 26, 1932		
C. Knox	NE.	32	131	60	857	1½	1914			25	2.1	Sept. 10, 1927	1.5	do		
A. Erickson	NW.	33	131	60	1,060	2½-1¼	1915			15	3.0	do	1.5	do		
B. Gallagher	SW.	33	131	60	1,030	1½-1¼	1906			30	7.5	Sept. 12, 1927	1.8	do		
L. Zimbelman	NE.	35	131	60	995	2½-1¼	1917			30	3.0	Sept. 10, 1927	.6	July 27, 1932		
Denning estate	SW.	35	131	60		3 -2	1904				1.3	do				
A. Koch	SE.	36	131	60	960	2½-1½	1913			15	2.1	do	2.0	July 27, 1932		

[1] Estimated.

[2] Reported

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
L. Brandell	NE	1	131	61	1,059	2 -¾	1917			40	1.0	Aug. 27, 1927	0.8	July 22, 1932		
E. Robertson	SE.	1	131	61		2½-1¼	1903				5.0	do	3.5	July 26, 1932		
C. Schneider	NW.	2	131	61	977	1¼	1913				4.0	Aug. 25, 1927	3.0	do		
E. Vernland	SE.	2	131	61	950	1¼	1913			16	1.0	do	1.0	Aug. 6, 1938		
E. Arndt	NE.	4	131	61	900	2½-¾	1913				2.5	do	2.0	July 22, 1932		
E. Weston	SE.	4	131	61	1,050	2½-1¼	1918				2.5	do	1.8	do		
A. Gemar	NW.	6	131	61	1,030	2½-1¼	1920			5	.8	Aug. 26, 1927				
J. Schiemann	SE.	6	131	61	1,030	2½-1¼	1913				1.0	do				
J. Zembleman	NW.	8	131	61	1,040	2½-1¼	1910				2.3	do	1.8	July 22, 1932		
G. Ulmer	SE.	8	131	61	1,040	1	1902				3.0	do	2.5	do		
H. Pugh	SE.	9	131	61	1,000	1	1907				.8	Sept. 22, 1923				
G. Ulmer	NW.	10	131	61	1,050	1¼	1913			6	1.0	Aug. 25, 1927				
G. Wahl	SW.	10	131	61	935	2½-¾	1916				.8	Aug. 26, 1927				
R. Webster	NW.	11	131	61							1.3	July 25, 1932				
M. Morgan	NE.	13	131	61	1,280	2 -1¼	1914			12	6.0	Aug. 27, 1927	6.0	July 22, 1932		
J. Morey	SW.	17	131	61	1,030	2-1	1904				1.5	1927	1.5	do		
A. Ulmer	NW.	18	131	61	1,140	2½-1¼	1918			40	2.3	Aug. 26, 1927	2.0	do		
A. Nuss	NW.	19	131	61	1,022		1915				3.0	do	2.0	do		
L. Nuss	SW.	19	131	61	1,100	2½-¾	1910				2.0	do	1.8	July 23, 1932		
——	SE.	19	131	61	1,013	2-1	1905			18	2.0	1927	.8	Aug. 6, 1938	52	
J. Schneider	NW.	20	131	61	1,100	1¼	1910				2.0	Aug. 26, 1927	1.5	July 23, 1932		
Baldwin Corporation.	NW.	22	131	61	1,100	2	1920				.6	Aug. 27, 1927				
C. Minard	SE.	23	131	61		2	1913				1.5	do	1.3	July 23, 1932		
T. Tollefson	SW.	24	131	61	1,130	2½-1¼	1917			25	3.8	Aug. 21, 1927	2.0	July 25, 1932		
Baldwin Corporation.	NE.	25	131	61	1,200	2½-1¼	1915				1.3	Aug. 27, 1927				
H. Perlinflen	SW.	25	131	61	1,280	1¼	1918			35	5.0	do	2.0	July 22, 1932		
O. Bakkegard	NE.	29	131	61	1,330	1¼	1906			10	2.3	Aug. 26, 1927	1.8	July 25, 1932		
J. Ucker	SE.	29	131	61	1,013	2-1	1905			18	2.0	do				
H. Webster	SW.	31	131	61	1,113	2½-1¼	1926				3.0	do	1.3	July 25, 1932		
A. Wedel	NW.	33	131	61	1,030	2½-1¼	1908				1.5	Aug. 27, 1927	1.0	July 23, 1932		
Baldwin Corporation.	NW.	34	131	61	1,100	3-2	1916				3.4	do	2.5	do		
M. Homerberg	SE.	34	131	61	1,010	1¼	1916			8	1.5	do	1.3	do		

D. Coleman	SW.	35	131	61	995	1¼	1918			7	2.5	do	1.3	July 25, 1932		
School land	NE.	36	131	61	1,100	2½-1¼	1918			15	6.0	do	[1] 2.5	do		
P. Gemar	SE.	1	131	62	1,050	2½-1¼	1915	+7	Dec. 7, 1923	12	.8	Dec. 7, 1923				Estimated unrestricted flow in 1923 was 6½ gallons a minute.
N. Erickson	NE.	3	131	62	1,205	2½-1½	1916	+7	do	12	1.3	do	1.0	July 22, 1932		Estimated unrestricted flow in 1923 was 4½ gallons a minute.
R. Sheppard	NW	3	131	62	1,150	2½-1¼	1903	+3	do	20	1.5	do				Unrestricted flow.
J. Skoda	SE.	5	131	62	1,175	2½-1¼	1917	+9	Dec. 11, 1923	15	1.3	Dec. 11, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
F. Hackel	SE.	6	131	62	1,160	2½-1¼	1914	+7	do	15	1.3	do				Do.
H. Oberman	NW.	7	131	62	1,145	2½-1¼	1906	+7	Dec. 8, 1923	20	.8	Dec. 8, 1923	.1	July 21, 1932		Unrestricted flow in 1923 was 1.7 gallons a minute.
J. Sidlick	SE.	9	131	62	1,160	2½-1¼	1917	+7	do	6	2.0	do	1.3	do		Estimated unrestricted flow in 1923 was 4 gallons a minute.
A. Mooney	NE.	10	131	62	1,160	2½-1¼	1917	+7	do	10	2.8	do	2.0	July 22, 1932		Do.
R. Webster	NW.	11	131	62	1,083	2½-1¼	1908				2.0	Aug. 26, 1927				
F. Seyer	SW.	11	121	62	1,080	2½-1¼	1918	+18	Dec. 11, 1923	10	1.7	Dec. 11, 1923	1.2	July 22, 1932		Estimated unrestricted flow in 1923 was 6 gallons a minute.
S. Elliot	SW.	12	131	62	1,140	2½-1¼	1905	+12	Dec. 8, 1923	25	1.5	Dec. 8, 1923	1.5	do		Do.
J. Daine	SE.	12	131	62	1,100	2½-1¼	1905	+10	Dec. 7, 1923	30	3.0	Dec. 7, 1923	1.7	do		Estimated unrestricted flow in 1923 was 6½ gallons a minute.
W. Lubins	SW.	13	131	62	1,140	2½-1¼	1909	+10	Dec. 8, 1923	20	1.0	Dec. 8, 1923	3.8	Aug. 8, 1938	54	Estimated unrestricted flow in 1923 was 6 gallons a minute.
F. Ritmiller	NE.	14	131	62	1,140	3-2	1904	+10	do	25	2.0	do	1.5	July 22, 1932		Estimated unrestricted flow in 1923 was 5 gallons a minute.
Fullerton	NE.	15	131	62	1,160	3-2	1904	+22.5	Dec. 11, 1923	75						Estimated unrestricted flow in 1923 was 30 gallons a minute.
E. F. Sweet	SW.	15	131	62	1,160	2½-1½	1917	+18	do	15	3.0	Dec. 11, 1923	2.0	July 21, 1932		
J. Stepina	NE.	17	131	62	1,140	3-1¼	1919	+5	Dec. 8, 1923	4	1.7	Dec. 8, 1923	1.0	1937		
Do.	NW.	17	131	62	1,130	2½-1¼	1919	+5	do	5	.9	do				
M. Johnson	SW.	17	131	62	1,040	2 -1	1907	+18	Dec. 11, 1923	30	4.6	Dec. 11, 1923	5.0	July 21, 1932		Estimated unrestricted flow in 1923 was 6 gallons a minute.
J. Skoda	NW.	18	131	62	1,160	2½-1¼	1910	+12	Dec. 8, 1923	18	4.0	Dec. 8, 1923	1.3	do		Estimated unrestricted flow in 1923 was 10 gallons a minute.
Do.	NW.	20	131	62	1,230	2½-1¼	1919	+9	Dec. 11, 1923	5	1.7	Dec. 11, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
J. Johnson	SW.	23	131	62	1,140	3 -2	1903	+15	do	60	6.0	Dec. 8, 1923	2.5	July 22, 1932		Estimated unrestricted flow in 1923 was 12 gallons a minute.
C. Persinger	NW.	25	131	62	1,100	2½-1¼	1912	+12	Dec. 12, 1923	17	3.0	Dec. 12, 1923	2.0	do		Estimated unrestricted flow in 1923 was 6 gallons a minute.
A. Welander	SE.	27	131	62	1,200	2½-1¼	1914				2.0	Aug. 25, 1927	2.0	Sept. 26, 1935		
R. Walter	SE.	29	131	62	1,050	2½-1¼	1910	+9	Dec. 11, 1923	25	1.5	Dec. 11, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
E. Smith	SE.	30	131	62	1,140	2 -1	1905	+8	do	18	.4	do				
F. Hanna	NE.	31	131	62	1,160	2½-1¼	1910	+11	do	18	.8	do				Estimated unrestricted flow in 1923 was 2½ gallons a minute.
C. Couche	SW.	31	131	62	1,160	2 -¾	1905	+9	do	18	1.5	do	1.2	Sept. 21, 1932		

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location: Quarter	Location: Section	Location: T. N.	Location: R. W.	Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−): Head or water level (feet)	Estimated artesian head (+) or depth to water level below measuring point (−): Date	Flow (gallons a minute): Reported original flow	Flow: Measured flow	Flow: Date	Flow: Measured flow	Flow: Date	Temperature (° F.)	Remarks
J. Warner	SE.	32	131	62	1,160	2½–1¼	1906	+11	Dec. 12, 1923	20	2.0	Dec. 12, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
First National Bank.	NW.	34	131	62	1,160	2½–1¼	1910	+9	Dec. 11, 1923	19	2.0	Dec. 11, 1923	1.8 .7	Sept. 22, 1932 Aug. 8, 1938	69	Do.
J. Thorn	NE.	4	131	63	1,180	2½–1¼	1909	+3 −13.15 −13.18	Nov. 22, 1923 Oct. 7, 1937 July 27, 1938	19	.6	Nov. 22, 1923	.0	July 21, 1932		Pumped in 1932. Measuring point, hole in curb cover, 0.5 foot above land surface.
Do.	SW.	4	131	63	1,180	2½–1½	1914	+3 −5.86	Nov. 22, 1923 Oct. 7, 1937	20	5.5	do	.5	do		Unrestricted flow in 1923. Measuring point, top of curb, 1.3 feet above land surface.
B. Scott	NW.	5	131	63	1,280	2½–1¼	1909	+2.5	Nov. 22, 1923	18	.2	do				Destroyed.
Monango	SE.	8	131	63	1,380	3 –2	1902	+3	do	45	2.0	do				
Chicago, Milwaukee, St. Paul & Pacific R. R.	SW.	8	131	63				−2.29	Sept. 24, 1937							Measuring point, curb of reservoir, 1.3 feet above land surface.
A. Nash	NW.	11	131	63	1,150	2½–1¼	1905	+10	Nov. 23, 1923	30	3.3 2.0	Nov. 23, 1923 Oct. 8, 1937	3.0 1.8	July 21, 1932 July 27, 1938	63	
W. Dickinson	NE.	12	131	63	1,130	2½–1¼	1909	+10	Nov. 23, 1923	25	3.5	Nov. 22, 1923	1.3	July 21, 1932		
G. Knox	NE.	13	131	63	1,130	3 –2	1907			40	1.1	do				
D. Hagen	SE.	15	131	63	1,170	2½–1¼	1915	+5	Nov. 23 1923	8	.3	Nov. 23 1923				Destroyed.
F. Duncanson	NE.	18	131	63	1,200	2½–1¼	1907	[3] −8.8 −3.68 −4.32	Nov. 22 1923 Sept. 21, 1937 July 27, 1938	19						Stopped flowing in 1917. Measuring point, top of 2- by 4-inch curb 1.4 feet above land surface.
Caldwell estate	NW.	19	131	63	1,210	3 –2	1916	[3] 0	Nov. 14, 1923	6						Stopped flowing in 1921.
Do.	NW.	19	131	63	1,220	2½–1¼	1902	+2	do	25	.1	Nov. 14, 1923				Pumped in 1937.
E. Reitch	NE.	21	131	63	1,175	2½–1¼	1910	+5 −6.04 −9.00	Nov. 23, 1923 Oct. 7, 1937 July 29, 1938	19	1.5	Nov. 23, 1923				Measuring point, top of casing 2.2 feet above land surface. Pumped with windmill.
Northrup Bros.	NW.	22	131	63	1,200	2½–1¼	1902	+5	Nov. 23, 1923	20	1.5	Nov. 23, 1923	.8	July 21, 1932		Abandoned.
V. S. Collard	NW.	23	131	63	1,140	2½–1¼	1913	+10	do	20	1.2 .3	do Oct. 7, 1937	.8 .3	do July 29, 1938	57	Estimated unrestricted flow in 1923 was 2 gallons per minute.

Farmers & Mechanics Bank.	SE.	23	131	63	1,480	3-1¼	1937								69	Third-flow well. Reported unrestricted flow 60 gallons a minute.
H. Keller	NW.	24	131	63	1,280	3-2	1916	+6	Nov. 22, 1923	8	1.0	Nov. 22, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
Do	NW.	24	131	63	1,180	2½-1¼	1906	+1	do	20	1.2	do				
S. Vix	SE.	24	131	63	1,170	2½-1¼	1909	+20	Nov. 17, 1923	30	.8	Nov. 17, 1923				Estimated unrestricted flow in 1923 was 6 gallons a minute.
E. Bennett	NW.	25	131	63	1,160	2½-1¼	1910	+7	do	20	2.4	do	1.0	July 21, 1932		
Do	NE.	26	131	63	1,150	2½-1¼	1907	+6	do	9	1.1	do				
R. Newton	NE.	27	131	63	1,140	3-2	1919	+9	Nov. 23, 1923	10	1.5	Nov. 23, 1923	.4 1.1	Oct. 7, 1937 July 29, 1938	55 55	Estimated unrestricted flow in 1923 was 6 gallons a minute. Cleaned about once a month by pumping.
Newton estate	NW.	27	131	63	1,140	3-2	1915	+10	1923		1.5	1923				
W. Brown	SE.	29	131	63	1,200	2½-1¼	1908	+6 -29.33	Nov. 23, 1923 Oct. 7, 1937	18	1.0	Nov. 23, 1923				Measuring point, top of casing, 1.1 feet above land surface. Well filled in, 1938.
W. Tsudi	SE.	31	131	63	1,180	2½-1¼	1915	+2	Nov. 17, 1923	3	.0	Nov. 17, 1923				Found plugged in 1937.
P. Brown	SW.	35	131	63	1,130	2-1	1918	+6	Aug. 18, 1923	6	.3	Aug. 18, 1923				
H. Chiltree	SE.	36	131	63	1,160	2½-1¼	1908	+9	Nov. 17, 1923	20	2.8	Nov. 17, 1923	.5	July 21, 1932		
C. Bollinger	SE.	7	131	64	1,330	3-2	1904	[1]-20 [2]-55	Nov. 10, 1923 Aug. 31, 1937	35						Stopped flowing in 1915.
Middleton Trust Co.	NE.	9	131	64	1,300	2½-1¼	1909	+10	Nov. 10, 1923	20	1.3	Nov. 10, 1923	.0	July 21, 1932		Pumped in 1932.
J. Gephardt	NE.	11	131	64	1,280	2½-1¼	1904	+2 -14.81	do Aug. 26, 1937	25	1.2	do				Stopped flowing in 1932. Measuring point, top of casing, 1.3 feet above land surface.
C. Peek	NE.	18	131	64	1,320	3-2	1915			20						Stopped flowing in 1917.
D. Brandenburger	SW.	18	131	64	1,320	3-1½	1914	[1]-20	Nov. 10, 1923	5					52	Stopped flowing in 1916.
H. Haussler	NE.	32	131	64	1,340	2½-1¼	1914	-10.00 -11.08	Aug. 31, 1937 July 28, 1938	15	3.0	Aug. 18, 1923			59	Stopped flowing in 1930. Measuring point, top of casing, 1.3 feet above land surface.
State of North Dakota.	NE.	36	131	64	1,180	2½	1916	+2 -10.47 -10.42	Nov. 14, 1923 Sept. 24, 1937 Sept. 17, 1938	3	.1	Nov. 14, 1923				Measuring point, top of casing, 1.0 foot above land surface.
C. Gephardt	NW.	12	131	65	1,390	3-1¼	1907	[1]-40 -11.69 -11.35	Nov. 8, 1923 Aug. 31, 1937 July 27, 1938	20					47	Stopped flowing in 1914. Measuring point, west edge of 4- by 6-inch beam 0.3 foot above land surface.
R. Bartell	NE.	25	131	65	1,480	5-2½	1913	[1]-15 [2]-40	Nov. 8, 1923 Aug. 31, 1937	12						Stopped flowing in 1917.
J. Olson	NE.	35	131	65	1,480	3-2	1917	[1]-35 -14.70	Nov. 8, 1923 Aug. 30, 1937	0						Well never flowed. Measuring point, top of plank above casing 0.5 foot above land surface.
D. Squashnick	SE.	35	131	65	1,434	3-2	1920	[1]-27	Nov. 8, 1923	0						Well never flowed.
O. Rosinquist	NW.	2	132	59	960	2½-1¼	1911			12	.8	Sept. 8, 1927				
Federal Loan Co.	SW.	5	132	59		2-1¼	1904				2.5	do	1.3	Oct. 4, 1935		
J. Guyott	NE.	6	132	59	933	2½-1¼	1918			20	3.8	do	1.0	do		

[1] Estimated. [2] Reported. [3] Below land surface.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
M. Rasmussen	SW.	9	132	59	1,050	2-1¼	1907				0.6	Sept. 8, 1927				
Do	SW.	9	132	59	1,168	3-2	1926				15.0	do	5.5 7.5	Oct. 3, 1935 Aug. 5, 1938	60	
F. Elliott	SE.	10	132	59	1,160	3-2	1908				7.3	do	3.8 7.5	Oct. 3, 1935 Aug. 5, 1938	62	
P. Anderson	NE.	11	132	59	1,100	3-2	1915				3.1	do	1.3	Oct. 4, 1935		
H. Marks	SW.	11	132	59	1,135	3-2	1916			16	.9	do	1.1	Oct. 3, 1935		
E. Clark	SW.	12	132	59	964	2½-1½	1915				2.2	do	1.9	Oct. 4, 1935		
F. Zimmerman	SE.	12	132	59		2½-1¼	1916				3.0	do	1.6	do		
Jones estate	NE.	14	132	59		2½-1¼	1907				7.5	do	5.0	Oct. 3, 1935		
E. Miller	SW.	14	132	59		3-2	1910				2.5	do	[1] 1.0	do		
F. Elliott	SE.	15	132	59		4-¾	1903				2.3	do	1.0 .7	do Aug. 5, 1938	52	
E. Larson	SE.	17	132	59	1,000	2½-1¼	1910				.8	do				
Boyle	SW.	18	132	59	1,100	2½-1¼					1.0	do				
Ulland Mortgage Co.	SW.	20	132	59		2½-¾	1906				2.5	do	2.4	Sept. 27, 1935		
P. Hansen	SE.	20	132	59	900	2½-1¼	1918				4.8	Sept. 9, 1927	2.5	do		
A. Christianson	SW.	22	132	59		4½-2	1911				5.0	Sept. 8, 1927	3.3	Oct. 3, 1935		
J. Dethlefsen	NW.	23	132	59		2½-1¼	1908				2.5	Sept. 7, 1927	1.0	do		
Do	NW.	24	132	59	904	2½-1¼	1903				1.3	do				
P. Schmitz	SE.	24	132	59	900	2½-1¼	1916				.7	do				
E. Christianson	NW.	26	132	59	1,095	3 -2	1917			20	.5	do				
N. Anderson	SE.	26	132	59		2 -1	1907				4.5	do	2.5	Oct. 3, 1935		
Christianson estate.	NE.	27	132	59	1,026	3 -2	1918			16	2.5	do				
J. Haulbar	NE.	28	132	59		2½-1¼					7.5	Sept. 9, 1927	1.1	Oct. 3, 1935		
Do	NE.	28	132	59		2½-1¼					.5	do	1.1	do		
Do	NE.	28	132	59		3 -2					15.0	do	6.0	do		
N. Anderson	SE.	29	132	59	1,100	3 -1¼	1918				.8	do				
D. Dethlefsen	NW.	30	132	59	975	2½-1¼	1916				3.8	do	1.0	Sept. 27, 1935		
Anderson	SE.	30	132	59	995	2½-1¼					.4	do				
F. Hallett	SE.	32	132	59	890	2½-1½	1918				4.8	do				
O. Jacobson	SE.	34	132	59	920	3 -2	1917			5	3.0	Sept. 7, 1927	1.3	Oct. 3, 1935		
C. Nelson	NE.	35	132	59	1,025	3 -2	1917			15	4.5	do	3.0	do		

O. Nelson	NW.	35	132	59	1,060	3 -2	1920				2.5	do	2.5	do		
J. Anderly	SW.	2	132	60		2-1¼	1921				1.5	Sept. 14, 1927	.7	Sept. 27, 1935		
Glover Co	SE.	3	132	60		2½-1¼	1904				1.8	do	1.8	do		
L. Larson	NW.	4	132	60		2½-1¼	1912				2.5	1927	.3	1935		
M. Olson	NE.	7	132	60	900	2½- ¾	1919				8.3	Sept. 14, 1927	4.5	Sept. 26, 1935		
Glover Co	SE.	9	132	60	980	2½-1¼	1917			15	1.0	do	.4	Sept. 27, 1935		
Do	SE.	10	132	60	938	1¼	1918			8	2.5	do	1.7	do		
Federal Land Bank.	NW.	12	132	60	900	2½-1¼	1916				2.5	do	1.2[1]	do		
C. Andrus	SW.	12	132	60		2½-1¼	1913				1.3	do	.5	do		
Glover Town Hall	SE.	13	132	60		3 -2	1916				3.0	do	4.0			
Glover Co	SE.	13	132	60		2½-1¼	1914				.8	do				
Do	SE.	13	132	60	1,084	2	1907			40	2.5	do				
Do	SW.	14	132	60		3 -2	1910				2.8	Sept. 13, 1927				
Do	SW.	15	132	60	955	2½-1¼	1919			10	3.0	do	1.8	Sept. 27, 1935		
A. Lampert	SE.	17	132	60	1,000	2½-1¼	1920			20	3.0	do	.8	do		
P. Bergstrom	SW.	20	132	60	930	2½-1¼	1907				3.8	do	3.0	do		
Ulland Mortgage Co.	NW.	21	132	60	880	2½-1¼	1918			10	4.3	do	2.0	do		
P. Kraft	SW.	24	132	60		2½-1¼	1907				2.5	do	3.0	do		
Bank of North Dakota.	SW.	25	132	60	896	2½-1½	1907			12	3.8	do	4.0	do		
A. Fladager	NW.	26	132	60	1,000	2½-1¼	1915				3.7	do	4.0	do		
G. Strutz	NW.	30	132	60	1,050	2½-1¼	1906				3.0	do	4.0	Sept. 26, 1935		
J. Lillebridge	SW.	33	132	60	980	3 -2	1917				1.3	do				
Johnston estate	NW.	34	132	60	913	2½-1¼	1910			20	7.5	1927	6.0	Sept. 27, 1935		
W. Zieman	SE.	35	132	60	1,100	1½	1916			16	8.0	Sept. 13, 1927	4.0	do		
J. Jacobson	NE.	1	132	61		2½- ¾	1916				5.0	Aug. 23, 1927	4.0[1]	Sept. 26, 1935		
E. Mattson	NE.	2	132	61	990	2½-1¼	1905				1.0	do	2.5	Sept. 25, 1935		
													1.9	Aug. 6, 1938	60	
J. Greene	NW.	3	132	61	1,050	3 -1¼	1908				2.1	do	1.4	Sept. 25, 1935		
E. Matson	SE.	3	132	61	950	2½-1¼	1915				2.1	do	1.3	do		
G. Kloubec	NW.	4	132	61	1,060	2½-1¼	1920				1.5	do	1.2	do		
Federal Land Bank.	NE.	6	132	61	1,100	2½-1¼	1905				4.8	do	2.8[1]	do		
H. Montgomery	SW.	7	132	61	1,040	2½-1¼	1917				3.3	Aug. 24, 1927	1.1[1]	do		
Lloyd Mortgage Co.	NW.	8	132	61	1,020	2½-1¼	1913			30	.8	Aug. 23, 1927				
C. Arndt	NW.	9	132	61	1,050	4 -1¼	1914			25	2.0	do	2.0	Sept. 25, 1935		
G. Julian	SE.	9	132	61	1,020	2½-1¼	1914				1.5	Aug. 24, 1927	1.1	Sept. 26, 1935		
Thompson estate	SE.	10	132	61	950	2½-1¼	1907				15.0	1927				At foot of valley bluff. Leaked 12 gallons a minute in 1927.
R. Nelson	NE.	11	132	61	950	2½- ¾	1908			40	4.3	Aug. 23, 1927	3.0	Sept. 26, 1935		
B. Bergstrom	NW.	14	132	61	940	2½-1¼					1.8	Aug. 24, 1927	4.0	do		
Anderson estate	NE.	18	132	61	1,040	2½-1¼	1914				1.5	do	1.5	Sept. 25, 1935		
A. Olson	NW.	19	131	61	1,100	1½-1¼	1919				2.8	do	.4	do		
J. Paul	SE.	19	132	61	1,000		1913				.4	do				
E. Hill	SE.	22	132	61	1,040	2½-1¼	1916				3.3	Aug. 25, 1927	4.0	Sept. 26, 1935		
J. Johnson	NW.	27	132	61	1,040	2½-1¼	1915				1.5	do	.6	do		
W. Wittenberg	NW.	28	132	61		2½-1¼	1918				1.0	Aug. 24, 1927	2.0	do		

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location: Quarter	Location: Section	Location: T. N.	Location: R. W.	Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−): Head or water level (feet)	Estimated artesian head: Date	Flow (gallons a minute): Reported original flow	Flow: Measured flow	Flow: Date	Flow: Measured flow	Flow: Date	Temperature (° F.)	Remarks
A. Ulmer	NE.	31	132	61	1,050	2½–1¼	1918				1.5	Aug. 26, 1927	3.0 2.7	Sept. 26, 1935 Aug. 6, 1938	 61	
W. Ulmer	SW.	31	132	61	1,040	2½–1¼	1907				1.0	do				
C. Luke	NE.	32	132	61	960	1¼	1906				7.5	Aug. 24, 1927	6.0+	Sept. 26, 1935		
Federal Land Bank.	NW.	33	132	61	960	2½–1¼	1916				2.0	1927	1.8	do		
J. Arndt	NE.	35	132	61	1,040	2½–1¼	1905				7.5	Aug. 25, 1927	5.5 4.8	do Aug. 6, 1938		
O. Luke	NW.	35	132	61	1,050	2½–1¼	1913				4.3	do	3.0	Sept. 26, 1935		
G. Krook	SW.	1	132	62	1,020	2½–1¼	1916	+2.5	Dec. 6, 1923	9	1.7	Dec. 6, 1923	.6	Sept. 25, 1935		Estimated unrestricted flow in 1923 was 3 gallons a minute.
E. Ubben	NE.	4	132	62	1,120	2½–1¼	1916	+3	do	8	.7	do				Estimated unrestricted flow in 1923 was 1 gallon a minute.
S. Darby	SE.	6	132	62	1,206	2½–1¼	1913	+2.5	Dec. 5, 1923	20	1.0	Dec. 5, 1923				Unrestricted flow.
J. Anderson	SW.	7	132	62	1,145	2½–1¼	1909	+2	do	25	1.0	do				Unrestricted flow in 1923 was 4.3 gallons a minute.
First National Bank.	SE.	7	132	62	1,123	2½–1¼	1915	+3.5	do	8	.4	do				Estimated unrestricted flow in 1923 was 1 gallon a minute.
E. Dahl	SW.	8	132	62	1,135	2½–1¼	1913	+3	do	18	.4	do				Unrestricted flow.
J. Nelson	SW.	10	132	62	1,120	2½–1¼	1906	+3.5	Dec. 6, 1923	18	1.4	Dec. 6, 1923	.6	Sept. 25, 1935		Estimated unrestricted flow in 1923 was 3 gallons a minute.
C. Larson	SE.	10	132	62	1,060	2½–1¼	1916	+3.5	do	12	2.0	do	1.5	do		Estimated unrestricted flow in 1923 was 4 gallons a minute.
H. Larson	SE.	14	132	62	1,040	2½– ¾	1906	+3	do	20	1.5	do	.3	Aug. 8, 1938	58	Estimated unrestricted flow in 1923 was 3 gallons a minute.
M. Kelly	NE.	15	132	62	1,140	2½–1¼	1920	+3.5	do	20	2.0	do	2.4	Sept. 25, 1935		Estimated unrestricted flow in 1923 was 15 gallons a minute.
F. Anderson	SW.	17	132	62	1,060	2½– ¾	1904			40	.5	Aug. 24, 1927				
J. Champlin	SW.	17	132	62	1,175	2½–1¼	1906	+2.5	Dec. 5, 1923	18	1.3	Dec. 5, 1923				Unrestricted flow.
Julian & Stripp	NE.	18	132	62	1,140	2½–1¼	1904	+.7	do	20	.5	do				Do.
B. Banning	SW.	21	132	62	1,100	3 –2	1911	+3	do	20	.6	do				Estimated unrestricted flow in 1923 was 7 gallons a minute.
T. Kelsh	SE.	23	132	62	1,035	2½–1¼	1909	+15	Dec. 6, 1923	20	1.5	Dec. 6, 1923	2.0	Sept. 25, 1935		Estimated unrestricted flow in 1923 was 8 gallons a minute.

F. Olin	SW.	24	132	62	1,100	3 -2	1906	+3	do	30	1.0	do	.8	do	----	Estimated unrestricted flow in 1923 was 10 gallons a minute.
J. Ulmer	SE.	24	132	62	1,075	2½-1¼	1917	+8	Dec. 7, 1923	10	1.2	Dec. 7, 1923	------	------	----	Estimated unrestricted flow in 1923 was 6½ gallons a minute.
M. Beethe	NE.	25	132	62	1,040	2½-1¼	1906	+12	do	20	2.5	do	1.1	Sept. 25, 1935	----	Estimated unrestricted flow in 1923 was 7 gallons a minute.
C. Johnson	SE.	26	132	62	1,025	2½-1¼	1909	+12	do	15	1.9	do	.5	Sept. 25, 1935	----	Estimated unrestricted flow in 1923 was 4 gallons a minute.
J. Pazandak	SE.	27	132	62	1,070	2½-1¼	1913	+3.5	Dec. 5, 1923	10	1.5	Dec. 5, 1923	------	------	----	Unrestricted flow in 1923 was 2.7 gallons a minute.
F. McCartney	NW.	30	132	62	1,090	2½-1¼	1908	+3	Nov. 26, 1923	18	.8	Nov. 26, 1923	------	------	----	Estimated unrestricted flow in 1923 was 2 gallons a minute.
F. Beaver	SW.	31	132	62	1,160	2½-1¼	1908	+3	do	10	1.7	do	------	------	----	
	NE.	32	132	62	1,150	2 - ¾	1903	[1]-32	do	12	------	------	------	------	----	Stopped flowing in 1920.
	NW.	32	132	62	1,010	2½-1¼	1908	+3	do	10	.5	Nov. 26, 1923	------	------	----	Estimated unrestricted flow in 1923 was 2 gallons a minute.
R. Youngquist	SW.	32	132	62	1,040	2½-1¼	1908	+3	do	10	1.0	do	.5	Aug. 8, 1938	----	Unrestricted flow in 1923 was 1.7 gallons a minute.
M. Bliss	NE.	33	132	62	1,080	2½-1¼	1908	+2.5	Dec. 5, 1923	20	2.0	Dec. 5, 1923	0.0	Sept. 25, 1935	----	Unrestricted flow in 1923 was 2.4 gallons a minute. Pumped in 1935.
T. Boldstad	SE.	34	132	62	1,207	2½-1½	1916	+10	Dec. 7, 1923	15	1.6	Dec. 7, 1923	1.1	Sept. 25, 1935	----	Estimated unrestricted flow in 1923 was 4 gallons a minute.
J. Hotter	SE.	35	132	62	1,166	2½-1¼	1906	+3	do	20	3.0	do	0.0	Sept. 25, 1935	----	Estimated unrestricted flow in 1923 was 10 gallons a minute. Plugged in 1933.
H. Zimbleman	NE.	36	132	62	1,200	2½-1¼	1913	+9	do	15	2.5	do	1.1	Sept. 25, 1935	----	Estimated unrestricted flow in 1923 was 4 gallons a minute.
S. Jonason	NE.	3	132	63	1,199	2½-1¼	1915	+3.5	Nov. 24, 1923	15	1.9	Nov. 24, 1923	.9 .6 .5	Sept. 24, 1935 Sept. 28, 1937 Aug. 1, 1938	---- 52 52	Unrestricted flow in 1923.
J. Vorke	SW.	11	132	63	1,180	2½-1¼	1910	+12 -1.30	1923 Sept. 25, 1937	20	[1]6.0	1923	.0	Sept. 24, 1935	----	Unrestricted flow in 1923. Plugged in 1935. Measuring point, top of casing, 1.0 foot above land surface.
H. Johnson	SW.	13	132	63	1,160	2½-1¼	1907	+3.5	Nov. 24, 1923	20	2.0	Nov. 24, 1923	.4	Sept. 24, 1935	----	Estimated unrestricted flow in 1923 was 3½ gallons a minute.
Clancy estate	SE.	14	132	63	1,180	2½-1¼	1906	+2	do	20	1.7	do	1.1	Sept. 24, 1935	----	Estimated unrestricted flow in 1923 was 4 gallons a minute.
W. Schwartz	SW.	15	132	63	1,180	2½-1¼	1913	+3.5	Nov. 20, 1923	19	2.0 .3	do Sept. 28, 1937	.5 .3	Sept. 24, 1935 Aug. 1, 1938	---- 51	Do.
T. Sand	NW.	17	132	63	1,040	------	------	-13.65 -13.60	Sept. 28, 1937 Aug. 1, 1938	----	------	------	------	------	47	Measuring point, top of plank on reservoir platform, 3.2 feet above land surface.
J. Cook	SE.	22	132	63	1,180	3 -2	1915	+3.5	Nov. 26, 1923	10	3.0 1.0	Aug. 20, 1923 Sept. 28, 1937	1.5 .9	Sept. 24, 1935 Aug. 1, 1938	---- 56	Unrestricted flow in 1923.
S. Eggert	SW.	23	132	63	1,200	2½-1¼	1905	+2.5	Nov. 24, 1923	15	.5	Aug. 20, 1923	------	------	----	Do.
G. Strobeck	SE.	26	132	63	1,180	2½-1¼	1908	+3	do	20	1.0	Nov. 24, 1923	2.0	Sept. 24, 1935	----	Estimated unrestricted flow in 1923 was 3 gallons a minute.

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
J. Cook	NE.	27	132	63	1,170	2½-1¼	1913	+6	1923	16	1.3	Aug. 20, 1923	0.6 .3 .4	Sept. 24, 1935 Sept. 25, 1937 Aug. 1, 1938	 52 	
E. Jacobson	SW.	27	132	63	1,140	2½-1¼	1906	+2	Nov. 26, 1923	20	4.0	Nov. 26, 1923	.0	Sept. 24, 1935		Unrestricted flow in 1923. Found plugged in 1935.
E. Witt	SW.	34	132	63	1,140	2½-1¼	1905	+1 −5.79 −4.62	do Sept. 25, 1937 July 29, 1938	25	1.1	do				Measuring point. top of 2- by 4-inch beam at southwest corner of reservoir 2.4 feet above land surface.
A. Moore	NW.	35	132	63	1,200	2 -1¼	1910	+2.5	1923	5	.8	1923				Abandoned.
L. Golden	SW.	36	132	63	1,150	2½-1¼	1910	+1.5	Nov. 26, 1923	15	1.3	Nov. 26, 1923	1.6 1.0	Oct. 12, 1937 Aug. 1, 1938	59 59	
G. Chambers	NW.	6	132	64	1,380	3 -1½	1910			4	.0	Nov. 17, 1923				Stopped flowing in 1911. Destroyed.
C. Rempfer	NW.	26	132	64	1,250	2½-1¼	1907	.0	Nov. 12, 1923	25	Trace	Nov. 12, 1923				
L. Talbot	SW.	30	132	64	1,370	2½-1¼	1907	[1] −30 −23.80 −24.20	Nov. 7, 1923 Aug. 31, 1937 Aug. 1, 1938	20					50	Stopped flowing in 1911. Measuring point, top of plank supporting pump 1.7 feet above land surface.
O. Roezler	SW.	31	132	64	1,390	3 -1½	1909	.0	Nov. 7, 1923	20	Trace Trace	Nov. 7, 1923 Sept. 25, 1937				
F. Holland	NW.	23	132	65	1,420	2½-1¼	1905			4						Destroyed.
T. Kocian	NE.	24	132	65	1,380	3 -1¼	1904			20						Stopped flowing in 1909. Destroyed.
G. Webb	SE.	36	132	65	1,385	2½-1¼	1905	[1] −8	Nov. 8, 1923	15						Destroyed.
M. Webber	NW.	7	133	58	910	1¼	1919				2.7	Sept. 26, 1923	1.4	Aug. 5, 1931		
H. Webber	SE.	7	133	58	1,000	1¼					1.3	Sept. 28, 1923				
V. Marx	NW.	8	133	58	864	1¼	1911				2.0	do				
O. Lee	SW.	8	133	58	1,080	1¼	1926				2.0	1926				
Northwest Investment Co.	SW.	17	133	58		1¼	1917				1.9	Sept. 23, 1923	.8	Aug. 5, 1931		
Bailey	NE.	18	133	58	1,025	1¼	1917				2.0	Sept. 28, 1923				
O. Reynolds	SE.	18	133	58	900	1¼					.6	do	1.3	Aug. 5, 1931		
F. Hurt	NE.	19	133	58		1¼	1917				1.3	do				
J. Mikvold	NW.	19	133	58	890	1¼	1912				2.2	Sept. 26, 1923	1.5	Aug. 5, 1931		

T. Winter	NW.	29	133	58	900	1¼	1913				[1] 1.0	Sept. 28, 1923			
R. Magill	NW.	30	133	58	930	2½-1¼	1902				1.4	Sept. 26, 1923			
G. Anderson	SE.	30	133	58	930	2	1914				6.5	Sept. 28, 1923	1.0	Aug. 5, 1931	
R. McCann	NW.	32	133	58	1,300	1¼	1912				3.5	Sept. 29, 1923	4.3	do	
C. White	NW.	1	133	59	935	1¼	1907				2.7	Sept. 26, 1923			
Verona	NW.	2	133	59		2 -1¼					[1] 2.0	do			
Do	NW.	2	133	59	1,200	3 -1¼					4.3	do			
J. Gaughan	NE.	3	133	59	900	1¼					2.4	Sept. 25, 1923			
E. Utecht	SE.	3	133	59	915	1¼	1912				1.0	do	.9	Aug. 3, 1938	
H. Utecht	NE.	9	133	59	1,100	1¼	1912				3.0	do			
E. Utecht	NE.	11	133	59	1,000	1¼	1916				2.4	Sept. 26, 1923			
H. Peterson	NE.	12	133	59	900	1¼	1913				4.9	do	1.4	Aug. 5, 1931	
W. Brademeyer	SW.	14	133	59	1,080	1¼	1921				2.7	do	1.7	do	
Bjone Bros	NE.	15	133	59		2½-1¼	1911				1.6	do	2.6	do	
G. Kalkbremer	SW.	15	133	59	900	1¼	1911				2.9	Sept. 25, 1923	[1] 1.0	do	
Minneapolis Trust Co.	NW.	18	133	59	975	2½-1¼	1905				1.9	do	4.5 3.7	Sept. 14, 1927 Aug. 5, 1931	
Barkey estate	NW.	19	133	59		2½-1¼					3.8	Sept. 14, 1927			
J. Seifert	NW.	23	133	59	1,250	1¼					2.0	Sept. 26, 1923	[1] 2.0+	Aug. 5, 1931	
Artesian Well Co.	SE.	25	133	59		2½-1¼	1914				1.9	do			
G. Hansen	NW.	26	133	59			1907				2.9	do			
G. Billiard	SE.	26	133	59	915		1906				1.9	do	1.5	Aug. 5, 1931	
A. Raatz	NE.	27	133	59	988	2				40					
H. Raatz	SW.	27	133	59			1917				.4	Sept. 25, 1923			
E. Raatz	NE.	28	133	59		2-1	1917				1.3	do			
Johnson Land Co.	SE.	28	133	59	900	1¼					4.0	do	2.4	Aug. 5, 1931	
F. Dedrick	SE.	28	133	59	986	1¼					.8	July 22, 1926			
C. Raatz	SW.	29	133	59	1,000	1¼	1913				4.0	Sept. 25, 1923			
Folsum	NW.	31	133	59			1915				2.7	do	1.9	Aug. 5, 1931	
F. Domine	SE.	31	133	59	1,000	1¼	1917				4.3	do			
F. Schuman	NW.	33	133	59	900	1¼					3.0	do			
M. Schuman	SE.	33	133	59			1910				2.0	do			
A. Hanson	NE.	34	133	59							.5	Sept. 26, 1923			
N. Hanson	SW.	34	133	59			1907				1.3	Sept. 25, 1923			
H. Rasmusson	SE.	35	133	59			1904				4.0	Sept. 26, 1923			
W. Brademeyer	SE.	36	133	59	950	1¼	1912				2.2	do			
McCartney Land Co.	NE.	1	133	60	950	1¼	1916				1.5	Sept. 24, 1923			
A. Benn	SE.	1	133	60	985	2½-1¼	1913				1.2	do			
H. Lutgen	NE.	4	133	60		1¼	1911				2.2	do			
C. Twete	NW.	4	133	60	1,000	1¼	1919				1.0	do	1.7	Aug. 4, 1938	61
A. Isenberger	NE.	10	133	60	1,000	1¼	1915				2.4	do			
C. Malm	NW.	12	133	60	1,007	2½-1¼	1915				2.4	do			
A. Hegardt	SW.	14	133	60	935	2½-1¼	1912				3.0	Sept. 22, 1923	2.1	Aug. 5, 1931	
P. Peterson	NW.	19	133	60	846	2½-1¼	1915				6.0	do	4.0	Aug. 4, 1931	
B. Triplett	SW.	24	133	60	1,040	1¼- ¾	1906				3.0	do	1.5 1.1	Aug. 5, 1931 Aug. 4, 1938	54
Fargo Loan Agency.	SW.	25	133	60	980	1¼- ¾					3.0	do			
Do	SW.	26	133	60	980	1¼				19	3.8	do	3.5	Aug. 4, 1931	

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
Juberg estate	NE.	29	133	60	1,000	1¼					8.0	Sept. 22, 1923	18.0 6.5	Aug. 4, 1931 Aug. 4, 1938	 62	
F. Morse	NE.	32	133	60	900	1¼	1908				4.5	do	4.0	Aug. 4, 1931		
E. Haisley	NW.	34	133	60		2½-1¼					2.0	do	1.9	do		
Glover Holding Co.	SW.	35	133	60	980	1¼	1920				5.3	do	3.8	do		
La Moure	SE.	1	133	61	1,332	4½	1910	[4] +223	Aug. 21, 1923		30.0	Aug. 21, 1923	0.0	Aug. 5, 1931		Found plugged at 400 feet in 1931.
Do	SE.	1	133	61	906	2	1903	[4] +171	do				0.0	do		Do.
H. Neverman	NW.	3	133	61	922	2-1¼	1905				5.6	Aug. 22, 1923	7.4	do		
M. Whitson	NE.	6	133	61	1,000	1¼	1909				4.0	do	1.1	do		
J. McManus	NE.	8	133	61	1,020	1¼	1910				4.0	Aug. 21, 1923	2.0 1.3	do Aug. 4, 1938	 62	
H. Albrecht	NW.	10	133	61		2½-1¼	1918				2.1	Sept. 22, 1923	7.9	Aug. 5, 1931		Recased July 1931.
Merkel Bros	NE.	17	133	61	1,060	2½-1¼	1919				3.0	Sept. 21, 1923	[1] 1.0	do		
H. Salseider	NW.	18	133	61			1921				3.0	do	[1] 2.5	do		
S. Phillips	NE.	19	133	61		2½-1¼	1917				4.0	do	.4	Aug. 4, 1931		
M. Emerson	SE.	20	133	61		2½-1¼					1.1	do				
A. Hunt	SE.	26	133	61		1¼	1905				3.0	do	3.0	Aug. 4, 1931		
M. Johnson	NE.	28	133	61							[1] 3.0	June 6, 1931				
M. Kline	NW.	30	133	61	1,000	2½-1¼	1917				.7	Sept. 21, 1923				
P. Adams	SW.	31	133	61	1,050	1¼	1915				2.6	do	[1] .2	Aug. 4, 1931		
E. Dean	NE.	32	133	61	1,036	1¼	1920				1.6	do	.8 .4	do Aug. 4, 1938	 62	
Do	SE.	32	133	61	1,030	1¼	1906				3.3	do	2.5	Aug. 4, 1931		
R. Albaugh	NW.	35	133	61	1,000	1¼					4.0	do	2.5	do		
G. Young	NW.	3	133	61	1,150	1¼	1903				4.0	Sept. 20, 1923				
J. Ness	SE.	5	133	62		1					.1	Sept. 19, 1923				
R. Beeber	SW.	6	133	62	1,200	2-1					1.2	do				
W. Carse	NE.	7	133	62	1,185	1	1909				.1	do				
F. Ziekur	NW.	9	133	62	1,200	1	1908				4.0	do	.0	Aug. 4, 1931		Pumped by windmill in1931
P. Ketterling	SW.	12	133	62	1,100	2½-1¼	1913				2.0	Sept. 20, 1923	2.0 .8	do Aug. 3, 1938	 62	
H. Williamson	NE.	13	133	62		2-1	1913				2.0	do	2.0	Aug. 4, 1931		
J. Orness	NE.	14	133	62	1,040	1¼	1908				4.0	do	.3	do		

J. Worrell	SW.	16	133	62	1,250	1	1909				3.0	Sept. 19, 1923	1.0 [1] 0.3	do Aug. 3, 1938		
A. Pellatze	SE.	17	133	62	1,100	1	1907				6.0	do	1.4	Aug. 4, 1931		
C. Earl	SW.	20	133	62	1,200	1	1909				.8	Sept. 18, 1923				
A. Ellingson	SW.	21	133	62	1,170	1	1906				2.0	do	.4	Aug. 4, 1931		
Ulland Mortgage Co.	SE.	22	133	62	1,125	1¼	1907				2.4	Sept. 19, 1923	1.1	1931		
C. Johnson	SE.	25	133	62	1,030	2-1	1908				1.5	do				
A. Ellingson	NW.	27	133	62	1,100	1	1908				2.0	do	.6	Aug. 4, 1931		
J. Lacina	NE.	28	133	62	1,200	1	1908			7	4.3	do	2.7	1931		
W. Sayre	SW.	28	133	62	1,166	2	1915				1.1	Sept. 18, 1923				
J. Southall	NE.	29	133	62	1,160	2½-1¼	1920				3.0	do	[1] 1.0	Aug. 4, 1931		
F. Everson	NW.	30	133	62	1,200	1	1908			20	1.2	do				
T. Lacina	SW.	33	133	62	1,165	1	1915			2	2.0	do	.0	Aug. 4, 1931		Pumped in 1931.
H. Gordon	NW.	34	133	62	1,200	1	1908				.7	Sept. 19, 1923				
J. Holiechek	SE.	36	133	62	1,030	1¼	1908				2.4	do	.3	Aug. 4, 1931		
A. Ness	NE.	1	133	63		3	1908	+.5	July 30, 1937		[1] .1	July 30, 1937				Stopped flowing 1919.
F. Fradet	NW.	2	133	63			1903				.2	Sept. 19, 1923				
F. Carow	NE.	3	133	63	1,201	1¼	1909				5.0	Aug. 20, 1923	1.1	1926		Abandoned.
Do	NE.	3	133	63	1,210	3-2	1926			5	2.0	Oct. 13, 1937	2.0	July 30, 1938	59	Flow measured 1.9 feet above land surface.
O. Nelson	NE.	6	133	63	1,165	2-1	1908				.0	Sept. 19, 1923				Stopped flowing in 1920. Abandoned.
Federal Land Bank.	SE.	8	133	63	1,200	2	1915				4.0 .3	Aug. 20, 1923 Oct. 6, 1937	[1] 2.0 1.4	Aug. 4, 1931 July 29, 1938		
D. McCullock	SW.	10	133	63		3		.0	July 30, 1937		.1	Aug. 20, 1923	Trace	do		Water level in 1937 and 1938 at top of casing, 0.9 foot above land surface.
H. Frizland	SE.	12	133	63		1¼	1914				1.5	Sept. 18, 1923	[1] 1.0	Aug. 4, 1931		
P. Gunderson	NE.	13	133	63			1917				2.4	Sept. 19, 1923	.9	do		
F. Stapleton	NE.	22	133	63	1,240	2	1917				2.4	Aug. 20, 1923	.0	1931		Pumped in 1931.
L. Nelson	NW.	24	133	63	1,200	3-2	1919				3.7	Sept. 19, 1923	1.3	Aug. 4, 1931		
Do	SW.	28	133	63	1,243	1¼	1934			1	.6	Oct. 6, 1937	.6	July 29, 1938	59	Flows into large reservoir.
M. Meachen	SW.	30	133	63	1,200	2-1	1902				1.5	Sept. 18, 1923				Destroyed.
J. Caldwell	NW.	31	133	63			1908				.0	do				Stopped flowing in 1916. Destroyed.
S. Anderson	SE.	34	133	63		2½-1¼					.0	do				Stopped flowing in 1918. Destroyed.
J. Caldwell	NW.	36	133	63	1,160	2½-1¼	1917				5.0	do	3.8 3.2 1.8	Aug. 4, 1931 Oct. 6, 1937 Aug. 1, 1938	 59 59	Flow measured 2.1 feet above land surface in 1937 and 5 feet above land surface in 1938.
D. Weller	SE.	3	133	64	1,380	3-2	1906			20						Destroyed.
Edgeley	SE.	3	133	64	1,365	6	1892			500	.0	Nov. 28, 1923				Stopped flowing about 1913.
G. Murphy	NW.	11	133	64	1,370	2½-1¼	1905	[1] −14 −16.94 −16.41	Nov. 28, 1923 July 30, 1937 June 27, 1938	20						Stopped flowing in 1916. Measuring point, bottom of 1¼-inch opening in casing collar 1.2 feet above land surface.
O. Nelson	NW.	5	134	58	980	1½	1906				1.7	July 21 1926				
State of North Dakota.	NW.	7	134	58	930	1½					2.1	do	[1] 1.4	June 22, 1932		

[1] Estimated.

[4] Measured.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
W. Hanson	NW.	8	134	58	930	1¼					1.2	July 21, 1926				
G. Sherwood	SW.	17	134	58	1,080	1¼					2.6	do				
S. Jenson	SW.	18	134	58	940	1¼					1.5	do				
W. Mowry	NE.	19	134	58	960	1½					4.3	do	1.9	June 22, 1932		
C. Bellinger	NE.	30	134	58	950	1¼	1907				.4	do				
P. Hautkooper	SW.	32	134	58	950	1½					2.1	do	1.2	June 22, 1932		
F. Breiluis	SW.	1	134	59	930	1¼	1912				1.2	July 22, 1926				
First National Bank.	NE.	2	134	59	1,080	1¼				8	1.7	do	1.4	June 21, 1932		
E. Fick	SW.	2	134	59		1¼					3.0	do	2.0	do		
H. Spaulding	NW.	3	134	59		1½					3.4	do	2.1	do		
J. Kelder	NE.	4	134	59	960	1¼					2.3	do				
J. Milloux	SW.	10	134	59	1,000	1¼	1904				0.6	do				
T. Mathew	NW.	11	134	59	960	1¼					1.5	do				
J. Anderson	NW.	12	134	59		1¼					1.4	do	1.5 3.3	June 21, 1932 Aug. 2, 1938	55	
W. Mowry	SE.	12	134	59	1,100	2					2.1	do	1.0	June 21, 1932		
H. Nurnberger	NE.	14	134	59		¾					1.5	do				
Kuecks estate	SW.	14	134	59	1,000	1¼	1903				4.4	do	4.4	June 21, 1932		
J. Kuecks	SW.	14	134	59	1,000	1¼				15	3.5	do	.8 .2	do Aug. 3, 1938		
G. Regan	NE.	15	134	59		2¼	1931						1.9	June 21, 1932		
H. Duffelmyer	SE.	15	134	59	986	1¼					[1] 5.0	July 22, 1926	1.2	do		
Artesian Well Co.	NW.	17	134	59	1,004	1¼	1921				2.1	do	.8	do		
N. Lind	NE.	18	134	59	1,000	1¼				15	1.2	do				
A. Ferch	SE.	20	134	59	996	1¼	1915			5	2.0	do	1.4	June 21, 1932		
R. Creighton	SW.	23	134	59	980	1¼–¾	1906				1.0	do				
T. Thomson	NE.	24	134	59	960	1¼–¾	1914				1.5	do				
First Minneapolis Co.	NE.	25	134	59	850	1¼	1909				5.0	do	3.7	June 21, 1932		
First National Bank.	SW.	26	134	59	980	1¼					2.1	do	1.4 1.1	do Aug. 3, 1938	56	
H. Dufelmeier	SE.	26	134	59	1,000	1¼	1904				2.1	do	1.3	June 21, 1932		
C. Peterson	SW.	27	134	59	1,004	¾					2.5	do				
Straus Bros	NE.	30	134	59	953	1¼					1.0	do				

G. Feltis	SE.	31	134	59	1,004	1¼					1.5	do				
A. Malander	SW.	34	134	59	1,100	1½					1.0	do				
C. Lemma	SW.	35	134	59	920	1¼	1909				1.2	do				
F. Bartha	SE.	35	134	59	988	1¼					[1] 1.5	do	.9	June 21, 1932		
H. Werner	SW.	36	134	59	1,110	1¼					4.0	Oct. 22, 1923	2.0	do		
J. Johnson	SW.	7	134	60	1,100	1¼	1915				3.4	July 29, 1926	1.7	June 20, 1932		
H. Kopp	SE.	14	134	60	1,000	1¼-¾					3.3	do				
C. Samberger	NW.	17	134	60	1,000	1¼	1916				3.5	do	3.4	June 20, 1932		
D. Brozuk	SE.	20	134	60	1,000	1¼					3.3	do	2.4	Aug. 4, 1938		
P. Lux	SW.	22	134	60	900	1¼					9.0	do	2.5	June 20, 1932		
S. Sandness	NW.	24	134	60	1,020	1¼					2.8	do	2.0 .8	do Aug. 4, 1938		
F. Ritch	NE.	26	134	60	1,005	1¼-¾	1914				1.9	July 27, 1926	.8	June 20, 1932		
M. Lutgen	SE.	27	134	60	1,000	1¼					.0	June 20, 1932				Stopped flowing in 1923.
M. Julian	NW.	28	134	60	1,000	2					10.0	July 29, 1926	6.0	June 20, 1932		
S. Downing	NW.	33	134	60	1,100	2					3.0	do	1.3	do		
M. Shockman	SW.	6	134	61	1,000	4 -1¼					3.0	July 30, 1926	.0	do		Pumped in 1932.
C. Kinney	SE.	17	134	61							.4	do				
M. Johnson	SE.	18	134	61	1,100	1¼-½					4.6	do	[1] 4.0	June 20, 1932		
M. Marshall	SE.	24	134	61		1¼					4.0	do	3.0	do		
P. Adams	SW.	27	134	61							3.0	do	1.5	do		
F. Dathe	NW.	28	134	61	1,150	1¼	1917				3.0	do	1.8	do		
J. Axelson	NE.	29	134	61	1,100	1¼	1906				.8	do	2.1	Aug. 4, 1938	54	
D. Diesen	SE.	35	134	61	888	3	1906				15.0	do	11.0	June 20, 1932		
C. Freese	SE.	2	134	62	1,160	2 -1	1910	+4	Dec. 3, 1923	20	4.0	Dec. 3, 1923	3.0 2.0	June 16, 1932 Aug. 3, 1938	58	Estimated unrestricted flow in 1923 was 6 gallons a minute.
H. Titzloff	NE.	3	134	62	1,200	2 -1	1906			18	.0	Dec. 1, 1923				Stopped flowing in 1922. Abandoned.
W. Richards	SW.	3	134	62	1,175	2 -1	1909	+3	Dec. 1, 1923	20	3.0	do				Pumped in 1932.
H. Muske	SE.	3	134	62	1,140	2½-1¼	1906	+4	do	20	.5	do				
G. Leppart	NW.	4	134	62	1,180	2½-1¼	1904	+5	do	30	2.4	do	1.0	June 16, 1932		
N. Shockman	NE.	7	134	62	1,172	2½-1¼	1916	+3	Nov. 28, 1923	4	1.0	Nov. 28, 1923				Estimated unrestricted flow in 1923 was 3 gallons a minute.
G. Kohler	SW.	7	134	62	1,170	2½-1¼	1922	+2.5	do	10	2.7	do	2.0 1.4	June 16, 1932 Aug. 3, 1938	47	Estimated unrestricted flow in 1923 was 10 gallons a minute.
C. Earl	SW.	10	134	62	1,170	2½-1¼	1903	+3	Dec. 1, 1923	20	2.4	Dec. 1, 1923				Pumped in 1932.
F. Hoffman	SE.	11	134	62	1,160	2½-1¼	1909	+2.5	do	10	4.0	do	1.8	June 16, 1932		Estimated unrestricted flow in 1923 was 10 gallons a minute.
Do	NE.	15	134	62	1,163	2½-1¼	1904	+3	do	25	2.4	do	2.0	do		Estimated unrestricted flow in 1923 was 5 gallons a minute.
A. Shockman	NE.	17	134	62	1,180	2½-1¼	1910	+12	do	20	.9	do				Estimated unrestricted flow in 1923 was 10 gallons a minute.
A. Van Ornum	SE.	17	134	62	1,170	2½-1¼	1905			20	5.0	do				Unrestricted flow in 1923.
Eaton & Eaton	NE.	18	134	62	1,160	2½-1¼	1909	[1] −11	Nov. 28, 1923	30						Stopped flowing in 1916.
M. Frosland	SE.	19	134	62	1,165	2 -1	1908			18	1.1	Dec. 1, 1923				
J. Southall	SW.	23	134	62		2	1929						1.9	June 18, 1932		
M. Siedschlag	SE.	23	134	62	1,160	2 - ¾	1903	+2.5	Dec. 3, 1923	15	1.3	Dec. 3, 1923				
Siedschlag estate	SE.	24	134	62	1,160	2½-1¼	1904	+4	do	19	4.5	do	4.0	June 18, 1932		
M. Siedschlag	SE.	26	134	62	1,036	2½-1½	1923	+15	do	15	6.0	do	10.0	do		Estimated unrestricted flow in 1923 was 15 gallons a minute.

[1] Estimated.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported original flow	Measured flow	Date	Measured flow	Date		
E. Long	NW.	27	134	62	1,214	2 -1	1909	+2	Dec. 4, 1923	18	2.6	Dec. 4, 1923	1.5	June 18, 1932		Unrestricted flow in 1923 was 3.4 gallons a minute.
F. Young	NW.	29	134	62	1,190	2½-1¼	1909	+2.5	Nov. 28, 1923	25	1.0	Nov. 28, 1923	2.0	June 16, 1932		Unrestricted flow in 1923 was 4.6 gallons a minute.
E. Horsager	SW.	30	134	62	1,200	2½-1½	1908	+2	do	25	4.4	do	[1]1.0	do		Flow unrestricted in 1923.
W. Blatcaford	SE.	30	134	62	1,160	3 -2	1919	+2.5	do	8	6.0	do	2.0	do		Do.
C. Ray	NE.	31	134	62	1,180	2 -1	1909	[1]−7	do	18						Stopped flowing in 1920.
D. Blake	NE.	32	134	62	1,170	2½-1¼	1908	+4	Dec. 1, 1923	20	1.5	Dec. 1, 1923	3.0	June 16, 1932		Estimated unrestricted flow in 1923 was 6 gallons a minute.
Berlin	NW.	33	134	62	1,165	3 -2	1904	+2.5	Dec. 4, 1923	35	3.0	Dec. 4, 1923	[1]1.0	do		Estimated unrestricted flow in 1923 was 9 gallons a minute.
J. Young	SE.	33	134	62	1,175	2½-1½	1910	+3	Dec. 3, 1923	30	.9	Dec. 3, 1923				Estimated unrestricted flow in 1923 was 6 gallons a minute.
Z. Shockman	SW.	34	134	62	1,160	2½-1¼	1906	+3	do	18	1.1	do	1.1	June 18, 1932		Do.
P. Shockman	NW.	35	134	62	1,155	2½-1¼	1910	+3	do	30	6.0	do	4.1 1.8	do Aug. 3, 1938	 62	Estimated unrestricted flow in 1923 was 12 gallons a minute.
F. Johll	SW.	2	134	73	1,200	2½-1¼	1914	+2.5 −3.63 −5.12	Nov. 27, 1923 Oct. 26, 1937 July 30, 1938	8	1.3	Nov. 27, 1923				Began pumping in 1931. Measuring point, opening in casing collar, 0.5 foot above land surface.
Union Central Life Insurance Co.	NW.	6	134	63	1,360	2½-1¼	1905	+2.5	Nov. 27, 1923	18	.4	do				Flow unrestricted in 1923. Pumped in 1937.
Luce estate	SW.	8	134	63	1,350	2½-1¼	1906	+2.5 [1]5.5	do June 16, 1932	25	.4	do				Pumped in 1937.
A. Cloke	NW.	14	134	63	1,240	3 -1¼	1926			3	3.0	1926	.1	Oct. 14, 1937		Pumped in 1937 to increase flow.
A. Carrow	SE.	18	134	63	1,271	2½-1¼	1914	[1]−9	1923	6						Water level in 1937 about at land surface.
Do.	SE.	18	134	63	1,360	2½-1¼	1903			30						Plugged.
National Life Insurance Co.	NW.	21	134	63	1,360	1¼										Pumped in 1937.
F. Peek	SW.	21	134	36	1,360	2½-1¼	1914	[1]−6		5						Pumped in 1923.
H. McDonald	SW.	22	134	63	1,235	2½-1¼	1914	+2.5	Nov. 27, 1923	15	6.0	Nov. 27, 1923	2.2 1.7	Oct. 13, 1937 July 30, 1938	59 59	Unrestricted flow in 1923.
Farmers & Merchants Bank.	SW.	25	134	63	1,165	1¼	1926	+2.5	Aug. 16, 1926		4.8	Aug. 16, 1926				
N. Rausch	SE.	25	134	63		1¼					3.4	June 16, 1932				

H. Horsager	SE.	26	134	63	1,200	2 -1	1903	+2	Nov. 28, 1923	20	1.7	Nov. 28, 1923				
H. Strating	SW.	27	134	63	1,200	2 -1	1908	.0	Nov. 27, 1923	15	[1] 1.0	Oct. 13, 1937				Pumped in 1923.
J. Owen	NE.	28	134	63	1,210	2½-1¼	1908	+1	do	15	.0	Nov. 27, 1923				Found plugged in 1937.
W. Frahm	NE.	30	134	63	1,300	2 -1	1905	−11.3 [2] −18 −11.5 −1.55 −.17	do 1927 June 16, 1932 July 29, 1937 June 27, 1938		[2] 1.0 [2] .3	1919 1920				Measuring point, top of casing, extended 3.5 feet above land surface.
C. Leppert	NE.	36	134	63							3.7	June 16, 1932				
L. Bethke	SW.	3	134	64	1,400	2½-1¼	1903			18						Stopped flowing in 1910. Destroyed.
F. Davis	SE.	24	134	64	1,284	4 -1¼	1903	[1] −11 −2.89 −2.29	1923 July 27, 1937 June 27, 1938	29						Abandoned. Measuring point, top of casing collar, 0.6 foot above land surface.
Do	SE.	24	134	64	1,265	4 -2	1916	[1] −11 −24.37	1923 July 27, 1937	12						Pumped. Measuring point, top of casing, 0.3 foot above land surface.
O. Runungen	NE.	18	135	58	900	1¼	1919				3.0	Aug. 7, 1928				
H. Berntson	SE.	18	135	58	800	1¼	1918			16	2.0	do				
J. Nelson	SW.	29	135	58		1¼					[1] 1.5	Aug. 6, 1928	.5	Oct. 10, 1935		
Bank of Crichton	SW.	31	135	58	940	1¼					1.2	do				
O. Christianson	SE.	31	135	58	1,000	1¼	1914				.9	do				
H. Olson	SW.	2	135	59	900	2½-1¼	1917				2.0	Sept. 17, 1927	2.0	Sept. 23, 1935		
Union Central Life Insurance Co.	NE.	3	135	59		4 -1½	1907				5.0	do	[1] 1.5	do		
C. Hartman	SW.	5	135	59	1,120	2½-1¼	1922			2.5	.5	do				
C. Olson	NE.	6	135	59	999	2½-1¼	1909			30	2.3	do	2.5	Sept. 23, 1935		
C. Ellison	SE.	10	135	59	1,036	2½-1¼	1907				2.1	Sept. 23, 1927	1.3	do		
Do	SW.	11	135	59	1,156	2½-1¼	1916				2.5	do	1.0	do		
R. Rasmussen	NE.	13	135	59	1,027	2½-1¼	1916				1.0	Sept. 17, 1927				
M. Abler	NW.	13	135	59	1,200	2½-1¼	1918				7.5	do	.8	Sept. 23, 1935		
H. Bjone	SW.	14	135	59	937	3 -2	1911				1.0	Sept. 23, 1927				
F. Hudson	NE.	17	135	59		2½-1¼	1920				4.0	Sept. 17, 1927	2.1	Sept. 23, 1935		
Honsanger Bros.	SW.	18	135	59		2½-1¼										Stopped flowing in 1915.
J. Simpson	NE.	20	135	59		2½-1¼	1903				1.0	Sept. 17, 1927	.5	Sept. 24, 1935		
J. Schroedl	SW.	21	135	59	1,060	2½-1½	1916				5.0	Do	3.5	do		
E. Holub	NW.	23	135	59	1,300	3 -1¼	1918				7.5	Sept. 23, 1927	3.0	Sept. 23, 1935		Third-flow well.
F. Holub	SW.	23	135	59	900	2½-1½	1916				3.4	do				
A. Norbeck	NE.	25	135	59		2½-1¼	1914				3.8	do	2.1	Sept. 24, 1935		
B. Isaakson	SE.	25	135	59		2½-1¼	1910				3.8	do	3.0	do		
J. Hanson	NE.	27	135	59	950	3 -2	1915				4.6	Sept. 17, 1927	2.5	do		
W. Trueke	NW.	27	135	59		2½-1¼	1914				2.5	do	1.8	do		
D. Loyd	SE.	28	135	59		2½-1¼	1914				.6	do	1.0	do		
H. Warner	SE.	29	135	59		2½-1¼	1910				.8	do				
A. Walterson	NE.	30	135	59	970	2½-1¼	1911				1.1	do				
J. Wilson	NW.	32	135	59	1,000	2½-1¼	1916				1.0	do				
H. Diercks	SW.	36	135	59		2½-1¼	1916				3.8	Sept. 23, 1927	2.4	Sept. 24, 1935		
M. Jenson	SE.	36	135	59	1,000	2½-1¼	1915				3.0	do	1.8	do		

[1] Estimated.

[2] Reported.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported flow	Measured original flow	Date	Measured flow	Date		
F. Haslen	NW.	8	135	60		4½–1¼	1904				3.0	Sept. 16, 1927	2.5	Sept. 23, 1935		
O. Rysgaard	SE.	9	135	60	1,380	2	1933				3.7	Sept. 23, 1935				Third-flow well.
C. Nordean	SW.	10	135	60	1,175	3 –2	1914				1.9	Sept. 16, 1927	.4	Sept. 23, 1935		
D. Loyd	NW.	21	135	60		3 –2	1914				3.0	do	1.0	do		Do.
Dickey	NW.	3	135	62	1,575	3 –2	1910			60	[1] 35	Dec. 4, 1927	.0	do		Casing rusted through. Abandoned.
Dickey	NW.	3	135	62		3 –2										Stopped flowing in 1925.
Dickey	SW.	3	135	62	1,330	3 –2	1905				.0	Dec. 4, 1923				Plugged in 1910.
Loyd Mortgage Co.	NE.	9	135	62	1,185	2½–1¼	1905				.0	do				Sealed about 1921.
N. Erskine	SW.	18	135	62	1,205	2½–1¼	1908	+2.5	Dec. 4, 1923		.5	do				
A. Fenno	SE.	32	135	62	1,185	2 –1	1909	+2.5	do	15	2.4	do				
N. Lowry	NE.	35	135	62	1,160	2½–1¼	1908			19	.0	do				Stopped flowing in 1914. Destroyed.
First National Bank.	SW.	35	135	62	1,170	2½–1¼	1908				.0	Nov. 28, 1923				Stopped flowing in July 1923. Destroyed.
G. Grashan	NW.	18	135	63	1,250	2½–1¼	1903			23						Stopped flowing in 1915. Destroyed.
Kreutsberg Estate.	NW.	28	135	63	1,220	2½–1¼	1907			18	.0	Nov. 27, 123				Do.
C. Brown	SW.	30	135	63	1,380	2½–1¼	1903			20	.0	do				Stopped flowing in 1918. Destroyed.
O. Silsand	NW.	30	136	58	996	1¼	1906				1.5	Aug. 4, 1926	1.1	Aug. 6, 1932		
C. Rasmussen	SW.	30	136	58	996	1¼					1.7	do	1.2	do		
T. Borgerson	SE.	2	136	59	950	1¼	1914				1.1	do				
S. Platon	SE.	3	136	59	970	1¼					1.5	do				
J. Thorson	SE.	5	136	59	1,156		1925				.2	do				
P. Smith	NW.	17	136	59	1,050	1¼					1.0	Aug. 3, 1926				
R. Kinzer	NE.	18	136	59	1,040	1¼					1.5	do	1.1	Aug. 5, 1932		
J. Olson	SW.	18	136	59	1,035	1¼					.7	do				
T, Smedshammer	NE.	26	136	59	955	1¼	1905				.6	do				
T. Smedshammer	NW.	26	136	59	945	1¼	1910				.5	do				
H. Peterson	NW.	30	136	59	1,010	1¼					.0	Aug. 2, 1926				Pumped in 1926.
J. Dunham	SW.	30	136	59	1,000	1¼	1909				.6	Aug. 3, 1926				
G. Alber	SW.	2	136	60	1,225	1¼					3.0	Aug. 2, 1926				

W. Newmann	NE.	10	136	60	1,180	1½					2.5	do				
R. Van Zyle	SW.	13	136	60	1,160	1¼					.9	do				
L. Olson	NE.	14	136	60	1,180	1¼					2.2	do				
F. Hodgson	NE.	17	136	60	1,190	1¼					1.3	do				
W. Haselue	SW.	24	136	60	1,190	1¼					.0	1926				Stopped flowing in 1922.
C. Steffensen	SE.	30	136	61	1,100	1½					.0	Aug. 2, 1926				Pumped in 1926.
J. Waldie	SE.	32	136	61	1,160	1½					[1] 1.0	do				
F. Miller	SW.	6	136	62	1,430						.0	do				Stopped flowing in 1923.
F. Marsel	NE.	24	136	62	1,100						.0	do				Stopped flowing about 1910.
J. Kanouski	NE.	13	136	63							.0	do				Stopped flowing about 1919.
A. Ziegenhagen	SE.	22	136	63	1,184	1¼-1					5.3	do	[1] 1.5	Aug. 5, 1932		
J. Lewis	SW.	7	136	64	1,400	2					3.0	July 31, 1926	.7	do	64	Probably a third-flow well.
											2.1	Oct. 26, 1937	2.1	Oct. 26, 1938		
Eaton & Eaton	NW.	20	136	64	1,200	2					[1] 15	July 31, 1926	[1] 4.5	Aug. 5, 1932	66	"Wild" well. Probably a third-flow well.
											3.5	Oct. 27, 1937	4.6	Aug. 1, 1938		
R. Brandt	NW.	15	136	65	1,500	4					.0	1926				Stopped flowing in 1926.
R. Connover	NE.	5	137	58	1,300	2					1.2	July 25, 1928				
L. Platon	SW.	9	137	59	1,000	1½					1.0	do				
H. Stoneberg	SE.	11	137	59	1,050	1¼					.4	do				
O. Newall	SW.	18	137	59	1,150	1½					[1] .1	do				
K. Olson	NE.	26	137	59	1,100	2					1.1	do				
E. Peterson	SW.	29	137	59							[1] .1	do				Pumped to increase yield.
D. Vikstrom	SE.	32	137	59	1,050	1¼	1903				.0	do				Pumped.
C. Salberg	NE.	33	137	59	1,150	1¼					1.4	do				
Litchville	NE.	25	137	60	1,300	3					[1] 35	July 26, 1928				Drilled from 1,115 to 1,300 feet to lower flow in 1925.
L. DeCrame	SE.	9	137	61	1,700	1¼					1.0	do				Third-flow well.
Union Central Life Insurance Co.	SE.	12	137	6	[2] 1,485	3					.0	Aug. 19, 1927				Plugged.
M. Lee	SE.	21	137	63	1,600	3 —1½					.3	Oct. 27, 1937	.3	July 14, 1938	54	
S. Sortland	SW.	8	138	60	1,185	1½		—13.60	July 13, 1938							Stopped flowing in 1920. Measuring point, plank on reservoir, flush with land surface.
A. Larson	NE.	21	138	60	1,175	1½	1912	[2] —20	do							
S. Aandahl	SE.	27	138	60	1,170	1½					.0	July 13, 1938				Pumped in 1938.
J. Applequist	SE.	28	138	60	1,100	1½										Destroyed.
T. Nelson	NE.	32	138	60	1,175	1½					.0	July 22, 1928				
C. Bruhn	NW.	24	138	61	1,350	1¾					1.7	July 25, 1928	.7	July 13, 1938	62	
E. Steege	SW.	1	138	63	1,500	2					[1] 9.1	Aug. 19, 1927	[1] 6.0	Sept. 21, 1935		"Wild" well with much gas.
													6.0	Oct. 27, 1937	68	
													6.0	July 14, 1938	68	
S. Corwin Co.	NW.	9	138	63	1,460	2½					[1] 18	do	3.0	Sept. 21, 1935		Third-flow well.
Fiske estate	NW.	8	139	58	1,144	2	1917				4.3	July 11, 1928	4.0	Sept. 20, 1935		
C. Zaun	SE.	8	139	58	1,230	2					2.0	do				
F. Pederson	NE.	9	139	58	1,020	2	1908				3.0	do	3.5	Sept. 20, 1935		
P. Hanson	SW.	20	139	58	930	2	1917				15.0	do	3.0	do		
E. Schermer	SE.	20	139	58	809	2	1917				6.0	do	6.0	Sept. 21, 1935		
A. Nelson	NE.	21	139	58	804	2					2.0	do				

[1] Estimated. [2] Reported.

Records of artesian wells in the area—Continued

Owner	Location				Depth (feet)	Diameter (inches)	Date completed	Estimated artesian head (+) or depth to water level below measuring point (−)		Flow (gallons a minute)					Temperature (° F.)	Remarks
	Quarter	Section	T. N.	R. W.				Head or water level (feet)	Date	Reported flow	Measured original flow	Date	Measured flow	Date		
H. Krenslick	SE.	12	139	60	1,367	2					0.7	Aug. 19, 1927				
L. Stephen	NW.	14	139	60	1,365	2					1.3	do	1.6	Sept. 21, 1935	59	
											1.6	Oct. 14, 1937	1.7	July 8, 1938		
A. Kee	SW.	20	139	60	1,376	2	1916				4.5	Aug. 19, 1927	4.3	Sept. 21, 1935		Found plugged in 1938.
P. Sauer	NE.	22	139	60	1,477	2½–1¼	1936			12	3.0	July 12, 1938	.0	July 12, 1938	65	
O. Larson	NE.	31	139	60	1,600	3	1928				8.0	Sept. 21, 1935	.4	July 12, 1938	59	
G. Bignall	SW.	32	139	60	1,400						.8	July 12, 1938			58	
Federal Land Bank.	NE.	17	139	63	1,460	2½					.3	Oct. 28, 1937	.2	July 14, 1938		Casing believed to be rusted through below land surface.
R. Briggs	SW.	4	140	58	1,284	2	1921				1.5	Aug. 20, 1929	.1	Sept. 20, 1935		
N. Jorgenson	SE.	20	140	58	1,280	2	1913				1.9	do	1.6	do		
H. Faust	NE.	8	140	59	1,389	1¾	1935				[1] 13	Sept. 20, 1935				
R. McDonald	NW.	26	140	59	1,267	2	1935				2.6	do				
Western Electric Co.	SW.	25	140	64	1,487	3–2										
P. Stephan	NE.	36	141	60	1,300						[1] .5	July 28, 1928				

[1] Estimated.

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