GROUND WATER IN THE FESSENDEN AREA,

WELLS COUNTY, NORTH DAKOTA

(Progress Report)

By

Leonard Filaseta

North Dakota Ground Water Studies No. 1

March, 1946

North Dakota State Water Conservation Commission

North Dakota Geological Survey

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CONTENTS

ILLUSTRATIONS

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Introduction

Locations and General Features of the Area

The Fessenden area of this report (Fig. 1) lies in the central part of Wells County. It has a total area of about 285 square miles. It is crossed in a northwest-southeast direction by two railroads and the five towns within the area are located upon them: Fessenden, Manfred and Emrick upon the Minneapolis, St. Paul and Sault Ste. Marie, and Heimdal and Hamberg upon the Great Northern. Fessenden, with a population of about 950 inhabitants, is the County Seat and largest town in the area.

The area forms a part of the drift prairie_/ near its southwestern margin.

_/ Simpson, H. E. Geology and ground-water resources of North Dakota: U. S. Geological Survey Water-Supply Paper 598, 1929. Figure 1.

The physiographic features of the area have resulted largely from the work of the continental ice sheet which covered it during the most recent of the Wisconsin stages and probably during at least one earlier stage._/ The total relief in the

_/ Alpha, A. G., Geology and ground-water resources of Burke, Williams, Divide and Mountrail Counties: Masters Thesis, Department of Geology, University of North Dakota, 1935.

area is only about 120 feet, ranging from 1500 feet above sea level on the Sheyenne River west of Heimdal to 1620 feet in the moraine areas north and southwest of Fessenden. These morainal ridges represent recessional moraines. They consist of gently sloping hills and enclosed basins and kettles, the combination giving rise to a moderately undulating surface some portions of which are stoney in character. The area from the James River to Fessenden and a large area south of Fessenden from a nearly level drift plain. The valley of the James River has very little relief except where it cuts through the moraine northeast of Fessenden. Heimdahl and Hamberg are located in an ancient stream valley which is followed by the railroad.

Purpose and Scope of Investigation

The study of the Fessenden area is a part of the State-wide ground water investigations being made in North Dakota by the U. S. Geological Survey in cooperation with the State Water Conservation Commission and the State Geologist. These investigations are being made to determine the occurrence, availability, quality and amount of ground water which can be safely developed by wells in the various areas of the State. The Fessenden area was selected by the State Geologist and the State Water Conservation Commission as a starting point for one of the first of these studies because the town of Fessenden is in critical need of additional municipal water. A progress report is being released at this time because it is believed that sufficient information has already been gathered to indicate the general location of the more productive aquifers in the area shown on the map, Figure 1.

The field work was done chiefly by T. G. McLaughlin, Leonard Filaseta and P. D. Akin, of the U. S. Geological Survey.

Previous Investigations and Acknowledgements

A comprehensive report on the geology and ground-water resources of North Dakota was made by Howard E. Simpson in 1929. In addition to the over-all treatment of the ground waters throughout the State, the report includes specific details about the occurrence and development of ground water in each county with analysis of water from representative wells._/ A report on the municipal ground-water

_/ Simpson, Howard E., Geology and ground-water resources of North Dakota: U. S. Geological Survey, Water-Supply Paper 598, pp. 262-265.

supplies of North Dakota was made by Abbott and Voedisch in 1938._/

_/ Abbott, G. A. and Voedisch, F. W., The municipal ground-water supplies of North Dakota: North Dakota Geological Survey, Bull. 11, pp. 86-87.

This report contains analysis of waters and other data from 11 wells in Wells County. A typewritten report on "Ground-water conditions in the vicinity of Fessenden, North Dakota" by Thad G. McLaughlin was prepared and released in 1945 in cooperation with the North Dakota Geological Survey and the State Department of Health.

Data from these earlier investigations have been drawn upon freely in the preparation of the present report and some sections of Dr. McLaughlin's report are repeated here so that the data may be more widely available. Appreciation is expressed for the cooperation given by City officials, well drillers and others in the Fessenden area in furthering the studies upon which this report is based.

Water-bearing Formations

The surface materials in the Fessenden area are the glacial drift and associated alluvial deposits. In adjacent parts of Wells County the drift reaches a maximum reported depth of about 500 feet,_/ but in the Fessenden area well logs indicated an average depth of only about 150 feet. See the logs given in this repor

_/ Simpson, H. E., op. cit., p. 263.

and figures 2 and 3. The drift is underlain in descending order by the Pierre shale Niobrara formation, Benton shale, and Dakota sandstone, all of Cretaceous age, and unknown thicknesses of Paleozoic rocks. The Fox Hills formation is shown on the geologic map of the State_/ to underlie the drift in the extreme western part of Wells County, and remnants of this formation may occur above the Pierre in parts of

_/ Geologic map of North Dakota complied by Virginia A. Kline.

the Fessenden area. There are nearly 2000 feet of Cretaceous beds, chiefly shale, between the base of the drift and the top of the Dakota sandstone in the Fessenden area.

Cretaceous Formations

The Cretaceous beds form a broad basin in North Dakota largely covered by drift in the eastern part of the State and by Tertiary formations in the western part._/ Wells County lies above the eastern limb of this structure, where the beds

_/ Laird, Wilson M., Stratigraphy and structure of North Dakota: North Dakota Geological Survey, Bull. 18, 1944.

have gentle westward dips.

The Fox Hills formation occurs beneath the drift west of the Fessenden area, and remnants may occur between the drift and the Pierre shale within the area. Some good to poor wells have been developed in the marine sandstones of the Fox Hills in other areas but it is not likely to be an important aquifer in the Fessenden area. Of the numerous well logs examined during the present investigation, only one (148.71.35.N) recorded a sand or sandstone at the base of the drift which may possibly represent the Fox Hills formation.

The Pierre formation is chiefly shale but locally small amounts of highly mineralized water are obtained from fine sandy layers chiefly in its upper portion. So far as known, no wells in the Fessenden area derive water from the Pierre formation.

The Niobrara and Benton formations are represented by relatively impervious shale throughout the State and there is no evidence that successful wells can be developed from these formations in the Fessenden area. It is the custom of well drillers in this general region to stop at the base of the drift unless an artesian flow from the Dakota sandstone is wanted because the intervening formations very rarely yield ground-water supplies.

The Fessenden area lies near the southwestern margin of the region in which flowing wells can be obtained from the Dakota sandstone._/ but no wells have been

_/ Simpson, Howard E., op. cit., Plate I.

drilled to this horizon within the area itself. Wells to the Dakota have been drilled at Harvey, about 18 miles northwest of Fessenden, and at Carrington, about 27 miles southeast of Fessenden. The well at Harvey_/ is reported to be 2235 feet

_/ Simpson, Howard E., op. cit., p. 264 and 305.

deep. The flow of $2\frac{1}{2}$ gallons a minute from a $1\frac{1}{4}$ inch pipe had diminished to 1 gallon a minute in 1917. The water is soft but highly mineralized and contains 3400 parts per million of total dissolved solids, chiefly sodium bicarbonate and sulphate. According to McLaughlin the well at Carrington "encountered the Dakota sandstone at a depth of more than 1900 feet. The water contained 2870 parts per million of dissolved solids and the chloride content was 950 parts per million."_/

/ McLaughlin, T. G., Ground-water conditions in the vicinity of Fessenden, North Dakota: Manuscript report, p. 8.

Glacial Drift and Associated Deposits

The hydrologic characteristics of the glacial drift in the Fessenden area and in much of North Dakota have been determined largely by the character of the bedrock over which the ice passed. The materials of the drift were derived chiefly from the abraided bedrock and redistributed by the ice and melt waters. The usual conception of ice sheets moving large amounts of material for long distances is somewhat erroneous. It is true that small quantities of material riding high in the ice can be transported for long distances. However, the heavily burdened basal ice, from which most of the drift is derived, usually moves only short distances.

The bedrock beneath the Fessenden area is shale, as it is also for long distances in the direction from which the ice came. The material incorporated in the ice was therefore chiefly clay. The absence of even moderate quantities of hard rocks in the ice precluded the formation of extensive sand and gravel deposits on the outwash plains of the area. The moraines in the area are less rugged and there are no major inequalities in altitudes of the drift hills and kettles such as are common in areas where the drift materials were of a coarser nature. The less rugged topography results from the very low angle of repose of clayey, water-filled drift. Slumping of such material tends to remove or subdue what would otherwise be a rough glacial topography.

A large recessional moraine occupies most of the northern part of the area shown on the map (Figure 1). The James River runs between this moraine and the outwash (?) plain to the south in the western half of the area, but in the eastern half the river cuts through a part of the moraine. Farther north the moraine is cut by an ancient stream valley which extends entirely across the area in a southeasterly direction from the bend in the Sheyenne River northwest of Heimdahl to Hamberg and beyond. The trend of the moraine is westerly to northwesterly. A smaller moraine extends from the larger one in a southeasterly direction from Manfred to the region southwest of Fessenden.

South of each moraine are drift plains which were probably formed at least in part by outwash from the moraines. Unlike most outwash plains, however, their surfaces are mantled chiefly by clay and silt rather than by sand and gravel deposits.

Logs of Wells

Attached to this report are logs of over 60 wells in the Fessenden area. The locations of these wells are shown on Figure 1. Although not exhaustive, the list includes a fair representation of the types of materials encountered by the vast majority of wells on the drift plain and in the morainal belt. A number of the wells obtain their supplies from pockets of sand -- usually fine sand -- at or near the surface. A few obtain supplies from thin beds of sand and sometimes gravel within the drift. A third group obtains water usually from sand and gravel at or near the base of the drift. In no instance, however, does the character of the materials encountered in drilling or the performance of wells in the area give evidence of an aquifer which is likely to yield a water supply sufficient for more than a few families. On the contrary, reports of "dry holes" are almost as common as reports of successful wells, and numerous wells are reported to have "gone dry" when being pumped at the rate of only a few barrels a day. An average of all the well logs shows that more than 88 percent of material encountered was clay. If the remaining 12 percent of water-yielding material were in extensive beds having access to recharge the beds might prove to be important aquifers but the evidence indicates that they are small, isolated lenses, many of them completely enclosed by the nearly impermeable clay.

Sand and Gravel at the Base of the Drift

A large number of wells have been drilled to the base of the drift in the Fessenden area and a majority of them went directly from the glacial clay into shale. The material encountered by other wells at this horizon is fine sand, usually only a few feet in thickness. A notable exception is the August Leitner well (148.70.6.P4) which encountered 23 feet of fine gravel. It is reported to have produced 25 barrels of water a day for about a month. Since that time it has been possible to get only a few gallons a day for household use. It would thus appear that the aquifer although very permeable and fairly thick was of very limited extent.

The largest aquifer thus far encountered at the base of the drift is the one penetrated by the municipal wells in the town of Fessenden. Water in these wells is reported to have risen to within 35 feet of the land surface when they were drilled, but the water level has steadily declined since that time. Test drilling which has almost circled these wells has proved the lenticular character and limited extent of the aquifer. (See figures 2 and 3.)

Buried as they are beneath 100 feet or more of relatively impermeable material, the aquifers at the base of the drift appear to lack opportunity for rapid recharge. Those that have been "pumped dry" appear to recover very slowly, perhaps being replenished by water squeezed out of the overlying clay.

There is always a possibility in a glaciated area of encountering a preglacial stream channel of considerable linear extent, in which case storage might be sufficient or opportunity for distant recharge furnished, so that a large perennial water supply would be assured. No evidence of such a channel has been found in the Fessenden area and the possibilities of such an occurrence seem remote.

Sand Lenses within the Drift

Logs of wells in the Fessenden area indicate that the drift is composed chiefly of an upper 10 to 20 feet of yellow clay underlain by blue clay to a total depth of 110 to 175 feet. The clay contains occasional boulders and some sand and gravel. Lenses of sand, chiefly fine sand, within the drift, furnish water for some farm wells. In most cases the supplies of water derived from this source are inadequate even for farm wells. As they are surrounded by relatively impermeable clay, recharge to such aquifers is very slow.

Outwash Materials

Typical outwash sand and gravel deposits appear to be restricted to a very narrow belt on the south side of the recessional moraines shown in Figure 1. According to McLaughlin _/ "The outwash sands and gravels have been encountered by

_/ McLaughlin, T. G., op. cit., p. 10

several wells in the vicinity of Fessenden, including the city well northeast of town...(They) lie near the land surface and are rapidly recharged by precipitation. Because of the limited extent of these deposits, however, the quantity of water added by recharge over a period of years probably would not equal the quantity needed by Fessenden." The area of the Fessenden well number 3, in Sec. 36, T. 149 N., R. 70 W., was rather thoroughly prospected by auger holes and two cable-tool test holes put down in 1944. This was considered one of the most promising of the outwash gravel areas. The drilling showed the deposit to be basin-shaped with a maximum thickness of about 40 feet, a width of about 200 feet and an undetermined but apparently small linear extent. This basin is reported to have been pumped dry in supplying a part of the Fessenden municipal supply from 1941 to 1944.

As pointed out by McLaughlin, the outwash materials are susceptible to rapid recharge for they are permeable and lie at or near the surface. For this reason the water level in Fessenden well number 3 may rise rapidly and possibly show a complete recovery in a single season. However, deposits of this type in the area appear to be so limited in extent that they do not furnish sufficient storage to meet the needs of large continuous withdrawals.

Stream Alluvium

Sand and gravel deposits left by streams along their valley floodplains serve as important sources of ground water in many areas. Two such stream valleys occur in the Fessenden area. One is the valley if the James River; the other an ancient valley followed by the railroad from the abrupt bend in the Sheyenne River in Sec. 13, T. 150 N., R. 71 W. southeastward through Heimdal and Hamberg and beyond.

From its rather uncertain and sluggish course across the area, marked by numerous backwaters and sloughs, the course of the James River appears to be consequent upon the glacial topography in this area. At any rate it has done little work of either eroding or depositing materials along its channel. A test well put down in 1944 in the river valley about 400 feet below the municipal dam (Sec. 26, T. 149 N., R. 70 W.) encountered 18 feet of sandy clay underlain by 27 feet of clay, to a total depth of 45 feet. Other wells drilled in the valley have encountered only fine sand, silt and clay.

The character of the water table described in a subsequent section indicates that the James River functions very poorly, if at all, as a ground-water drain through the area. If its channel were underlain by any considerable thickness of permeable materials it would likely act as a very efficient drain.

It appears,therefore, that the valley alluvium along the James River in this area offers little prospect of furnishing a dependable ground-water supply.

The stream valley followed by the railroad through Heimdal and Hamberg appears to have been formed by the Sheyenne River during some earlier period of its history. It may have flowed eastward through this valley during the later Wisconsin glacial epoch when its course northward was obstructed by ice or other material. Or the valley may be unrelated to the Sheyenne River and may have been formed as a distributary from glacial Lake Souris. The inner valley is an eighth to a quarter of a mile wide with what appear to be higher terraces extending back one-half to one mile further in some localities.

The inner valley at least appears to be everywhere underlain by sand and gravel. Numerous wells dug in the valley have penetrated only sand and gravel but none of them are over 30 feet deep and most of them are only 10 to 15 feet deep. It is not known whether the depth of the wells indicates the thickness of the sands or merely the depth at which sufficient water for the well was obtained.

Two dug wells about 14 feet deep and about 8 by 12 feet across supply the Great Northern Railroad at Heimdal. Only one well has been used during the war an' it is reported to have been ample for the needs of about 150,000 gallons a day. Water from a well in the valley at the mouth of a coulee east of Heimdal is hauled to Fessenden to augment an inadequate supply there. The owner of the well which supplies the town of Heimdal reports that his well held up during the drought period of the nineteen thirties and that he could see no difference in its yield during that time.

The town of Bremen is located in this valley a few miles southeast of Hamberg. A well located there and owned by the railroad company had a capacity of 264,000 gallons a day as reported by Simpson_/. Numerous shallow wells in the

_/ Simpson, Howard E., op. cit., p. 264.

valley at the towns and elsewhere are reported adequa e for domestic and farm needs.

Little is known of the extent and hydrologic properties of the alluvium in this valley but the information outlined above appears to be sufficiently promising to warrant a quantitative study.

The Water Table

In 1940 the North Dakota Geological Survey in cooperation with the Works Progress Administration and the county assessors compiled information on most of the wells in the State including those in Wells County. The water levels given are reported rather than measured levels and are given only to the nearest foot. Nevertheless, a rough water table map of the Fessenden area was prepared using water levels in several hundred wells listed in these reports and using elevations taken from the topographic maps. The results are not considered to be sufficiently accurate to be reproduced in this report but a number of interesting observations made from a study of the map are worth mentioning.

It was noted that water levels in the deeper wells were usually considerably lower than those in the shallow wells and that in instances where water levels for more than one year were given, many of the deep wells had experienced a lowering of water level since they were drilled. This is in harmony with the experience at Fessenden, where water levels in the municipal wells have declined continuously with use, and probably the slowness of recharge to these deeper aquifers. The rather considerable differences in water levels in closely adjacent wells also indicates the lack of interconnection between the aquifers and the slow movement of water through the intervening clay. There is a distinct trough in the shallow water surface along the Heimdal-Hamberg valley but no such trough is indicated along the James River valley.

Ground-water Development

General

Almost all of the Fessenden area is dependent upon wells for domestice and farm water supplies. The James River in this area has a very small perennial flow and the Sheyenne River is far removed from most of the area. No other perennial surface water bodies occur in the area.

The water supplies of farms have been rather inadequate in most cases but by drilling numerous wells a large number of small but relatively satisfactory supplies have been found. The wells at Heimdal, Hamberg and Emrick are reported to be adequate but those of Manfred and Fessenden are inadequate. The situation at Fessenden is so critical that a short history of their water supply development is quoted below from McLaughlin_/.

_/McLaughlin, T.G., op. cit., pp. 4-6.

History of Fessenden water supply

"The quantity of water now used by Fessenden is estimated at 36,000 gallons a day, of which approximately 7,000 gallons a day is being pumped from well No. 2, situated at the elevated tank within the city, and approximately 14,000 gallons a day is being hauled from a well 5 miles northeast of town. The rest of the water is hauled from a well at Heimdal, a distance of 12 miles. It is estimated that the total water need of Fessenden, allowing for moderate future expansion, will be 50 gallons a minute, or approximately 70,000 gallons a day.

"For many years the town was supplied with water from well No. 1 at the pumping station in the southern part of town. The well was about 165 feet deep a the static water level is reported to have been about 218 feet below land surface when the well was drilled. The well obtained water from a fine sand between the depths of 128 and 160 feet. The water-bearing sand is limited in lateral extent and is overlain primarily by relatively impermeable clay, so that very little water is added to it by recharge from precipitation. The well, therefore, was taking water out of the water-bearing sand more rapidly than the sand was being replenished by recharge. By 1938 the well would no longer yield an adequate quantity of water for the needs of the town.

"Fourteen test holes were drilled in and near the town during the winter of 1938-1939 in order to find an adequate supply of water in the lenses of sand at the base of the glacial drift. These test holes ranged in depth from 155 to 227 feet. The thickness of sand encountered in the wells ranged from less than 1 foot to 21 feet and averaged 14 feet. A test hole 70 feet southwest of the city well penetrated 21 feet of sand between the depths of 133 and 154 feet, but only the lower 11 feet of the sand was saturated, indicating that the upper 10 feet of the sand had been unwatered by pumping from the city well. As a result of the test drilling, well No. 2 was constructed at a point about 60 feet west of the old well. The new well encountered 32 feet of fine sand, 17 feet of which had been unwatered by pumping from well No. 1. The new well was gravel walled and records in the office of the City Engineer show that it was test pumped at the rate of 31 gallons a minute for 24 hours." By 1945 it is reported that 29 feet of the sand was dry and that the well was being pumped at the rate of 6 gallons a minute from the remaining 3 feet of saturated sand.

"After two years of pumping, the new city well would no longer supply an adequate quantity of water, as the yield declined to about 11 g.p.m. Approximately 16 test holes were drilled during 1941 at distances as much as 5 miles from Fessenden in a search for a supplementary supply of water. Most of the test holes were between 20 and 40 feet deep, but four were drilled to depths of 162, 171, 172, and 174 feet respectively. As a result of the test drilling, a well was constructed in July, 1941, near the center of Sec. 36, T. 149 N., R. 70 W., (well 3 on Fig. 1), which is about five miles from the municipal storage tank. The well was drilled in outwash sand and gravel on the south side of a small recessional moraine. It encountered clay at a depth of 31 feet, and the static water level was about 12 feet below the land surface. The well was screened with 12 feet of 5-inch screen and cased with 19 feet of 5-inch steel casing. It was equipped with a 2-inch horizontal centrifugal pump powered by a gasoline engine and had a reported initial yield of about 100 gallons a minute, although later it was pumped at a much lower rate. At the beginning of 1944, the water level in this well had declined more than 12 feet and the yield was reduced to less than 10 gallons a minute."

Test drilling was resumed in April and several cable-tool holes and a large number of auger holes were put down. In December 1945 two test holes were put down with the State-owned drilling rig before sub-zero weather prevented further drilling.

The winter of 1945-46 was a particularly difficult one with respect to the Fessenden water supply. Drifting snow prevented haulage of water from Heimdal on several occasions and mechanical failure of the town well cut off for a time the small supply which was being obtained from it.

Conclusions

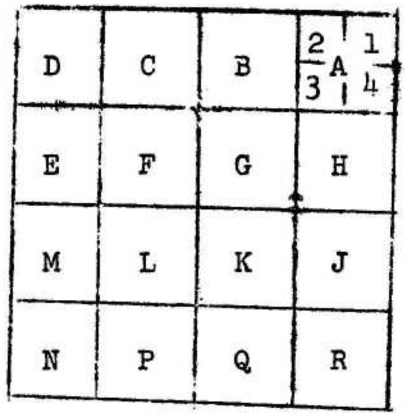
Water in sufficient quantity for municipal supplies is not likely to be obtained in the Fessenden area from bedrock formations above the Dakota sandstone. Flowing wells can probably be obtained from the Dakota in most of the area at a depth of about 2000 feet. Water from the Dakota sandstone is soft but very highly mineralized and it is not generally considered suitable for domestic uses.

Glacial outwash materials are very limited in occurrence and those thus far discovered are thin and of small lateral extent. Recharge is rapid to this type of deposit and satisfactory farm wells can be obtained where these outwash sands occur. No bodies of outwash sand and gravel sufficiently large to supply water for more than a few families are known. Sand lenses within the drift furnish only small amounts of water. Sand and gravel deposits at the base of the drift are not common and those thus far encountered in the drilling of numerous wells and test holes have proven to be of very limited size and to obtain recharge very slowly. Possibilities of obtaining enough water for more than a few families from this source seem to be remote.

Very little stream alluvium has been deposited in the James River valley but the ancient Heimdal-Hamberg valley followed by the Great Northern Railroad in the northern part of the Fessenden area is floored with sand and gravel of undetermined thickness and extent. Single shallow dug wells in this alluvium have furnished from 100,000 to 250,000 gallons of water a day, and the wells are reported to have yielded adequate water supplies throughout the severe drought years. The alluvial materials of this valley appear to be the most promising source of large ground-water supplies and a quantitative hydrologic investigation of the valley is proposed for the near future. The investigation will be made by the U. S. Geological Survey in cooperation with the North Dakota State Water Conservation Commission and the State Geological Survey and will be released in a report covering the geology and ground-water resources of Wells County.

Drillers' Logs of Wells in Fessenden Area

The number preceding each log gives the location of the well. The first number designates the township north, the second number the range west, and the third number the section. The section is divided into 40-acre tracts to which the capital letters A through R, omitting I and O, are assigned, as in the accompanying diagram. Each 40-acre tract is further divided into 10-acre tracts to which numerals 1 to 4, inclusive, are assigned, as indicated on the diagram. If more than one well within a 10-acre tract is listed they are distinguished by small letters beginning with a. Thus 148 . 70 . 17 . A3 signifies a well in Township 148 North, Range 70 West, Section 17, and located in the SW$\frac{1}{4}$ of the NE$\frac{1}{4}$ of the NE$\frac{1}{4}$ of that section. All thicknesses and depths are given in feet.



Wells near Fessenden shown on Figures 2 and 3

148.70.7.R4a
Well A

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	18	19
Boulders and clay	2	21
Clay, yellow	9	30
Clay, blue	4	34
Sand and gravel	1	35
Clay, blue	92	127
Boulders	1	128
Sand	32	160
Shale	4	164

148.70.7.R4b
Well B

Material	Thickness	Depth
Topsoil	3	3
Clay, yellow	21	24
Clay, sandy, blue	106	130
Sand	31	161
Shale	1	162

148.70.7.R4c
Well C

Topsoil, black	1	1
Clay, yellow	18	19
Sand, fine with clay, yellow	4	23
Clay, blue	106	129
Clay, with sand, blue	4	133
Sand ($2\frac{1}{2}$ g.p.m.)	21	154
Shale	6	160

148.70.18.H1
Well H

Topsoil, black	1	1
Clay, sandy, yellow	17	18
Clay, yellow	14	32
Clay, blue	4	36
Clay, blue, mixed with gravel	6	42
Clay, blue	103	145
Sand, mixed with clay (1 gpm)	11	156
Shale	30	186

(Water level reported 47 feet below surface.)

148.70.8.P3
Well D

Material	Thickness	Depth
Topsoil, Black	1	1
Clay, yellow	1	2
Gravel, with some clay	8	10
Clay, yellow	22	32
Boulders & gravel	4	36
Clay, blue	97	133
Sand (3 g.p.m.)	12	145
Clay, blue	17	162
Shale	18	180

148.70.7.Q1
Well F

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	30	31
Clay, blue	19	50
Clay, sandy, with sandy streaks	6	56
Clay, blue	59	115
Coal	1	116
Clay, blue	22	138
Gravel & boulders	1	139
Sand (3 g.p.m.)	5	144
Clay, blue	15	159
Shale	2	161

148.70.7.R3
Well G

Material	Thickness	Depth
Clay, yellow	17	17
Sand	6	23
Clay, yellow	5	28
Sand, with clay streaks	9	37
Clay, blue	18	55
Sand	6	61
Clay, blue	26	87
Sand (1 g.p.m.)	8	95
Clay, blue	33	128
Sand	1	129
Clay, Blue	33	162
Shale	38	200

148.70.17.E2b
Well I

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	2	3
Sand and gravel (dry)	14	17
Clay, yellow	8	25
Sand, (dry)	3	28
Clay, yellow	6	34
Clay, blue	18	52
Sand ($1\frac{1}{2}$ g.p.m.)	5	57
Clay, blue	86	143
Sand (dry)	1	144
Clay, blue	13	157
Shale	70	227

148.70.7.R2
Well J

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	22	23
Clay, blue	15	38
Gravel	1	39
Clay, blue	35	74
Clay, sandy	6	80
Clay, blue	55	135
Coal	1	136
Clay, sandy (dry)	9	145
Clay, blue	12	157
Shale	19	176

148.70.8.M4
Well K

Material	Thickness	Depth
Clay, yellow	24	24
Sand, (dry)	5	29
Clay, blue	113	142
Shale	6	148

148.70.7.R4d
Well L

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	31	32
Clay, blue	97	129
Sand ($1\frac{1}{2}$ g.p.m.)	20	149
Clay, blue	6	155
Shale	10	165

(Water level reported 143 feet below land surface.)

148.70.17.D1
Well M

Material	Thickness	Depth
Topsoil, black	3	3
Clay, yellow	17	20
Clay, blue	155	175
Shale	22	197

148.70.7.K4
Well N

Material	Thickness	Depth
Topsoil, black	1	1
Clay, yellow	19	20
Clay,blue,mixed with gravel	9	29
Gravel,coarse	4	33
Clay, blue	96	129
Sand, fine	2	131
Boulders	2	133
Clay, soft	16	149
Boulders	2	151
Clay, blue	20	171
Shale	9	180

Wells near Fessenden shown on Figure 1.

147.69.13.A1

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	8	10
Clay, blue	57	67
Sand, coarse	3	70

Shale encountered at a depth of 139 ft. in a "dry hole" 600 ft. east of this well.

147.70.3.D

Material	Thickness	Depth
Clay, yellow	20	20
Clay, blue	115	135
Sand, coarse	1	136

147.70.4M

Material	Thickness	Depth
Clay, yellow	20	20
Clay, blue	85	105
Gravel	2	107
Clay, blue	13	120

147.70.5G

Material	Thickness	Depth
Sand	20	20

147.70.6R1

Material	Thickness	Depth
Sand	8	8
Gravel, fine	3	11

147.70.7A1

Material	Thickness	Depth
Sand	8	8
Clay, blue	2	10
Quicksand	3	13

147.70.17.D2

Material	Thickness	Depth
Clay, yellow	11	11
Sand (1 bbl.p.day)	1	12
Clay, yellow	9	21
Clay, blue	24	45
Sand, (1bbl.p.day)	1	46
Clay, blue	28	74
Sand (water)	6	80
Clay, blue	13	93

(Water level reported as 73 feet below land surface.)

147.70.18.R1

Material	Thickness	Depth
Clay, Sandy	8	8
Clay, yellow	13	21
Clay, blue	17	38
Quicksand	10	48

147.70.19.J1

Material	Thickness	Depth
Soil, sandy	8	8
Clay, yellow	11	19
Quicksand	8	27

147.70.20.M2

Material	Thickness	Depth
Topsoil	3	3
Clay, sandy, yellow	11	14
Clay, sandy,yellow (water)	6	20
Clay,blue and silt	15	35
Clay, sandy, blue	16	51

147.71.11.D3a

Material	Thickness	Depth
Clay, yellow	19	19
Clay, sandy	6	25
Clay, stoney, blue	5	30
Shale	32	62

147.71.11.D3b

Clay, yellow	15	15
Clay,sandy,blue	7	22
Clay	10	32
Shale	19	51

147.71.11.R3

Clay, yellow	18	18
Clay, blue	57	75
Sand	3	78
Clay, blue	22	100
Silt, sandy	5	105

147.71.12.F4

Topsoil	2	2
Clay, yellow	16	18
Clay, blue	116	134
Sand, coarse	4	138

147.71.12.G3

Topsoil	2	2
Clay, yellow	18	20
Clay, blue	160	180
Shale	173	353

147.71.24.A3

No long	26	26
Quicksand	1	27
Clay, blue	9	36

148.68.29.C

Topsoil	2	2
Clay, yellow	16	18
Clay, blue	172	190
Shale	5	195

(five other "dry holes" are reported to have been drilled to shale in various parts of the NW$\frac{1}{4}$ Sec. 29.)

148.69.4.H3

Topsoil	2	2
Clay, yellow	16	18
Clay, blue	105	123
Sand, coarse	2	125

(Water level reported 40 feet below land surface when not pumping and 85 feet when pumping.)

148.69.9.J1

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	18	20
Clay, blue	108	128
Sand	8	136

(Water level reported 40 feet below land surface.)

148.69.21.B

Topsoil	1	1
Clay, yellow	19	20
Clay,with sand layers	112	132
Clay, silty	10	142

148.70.4.Q

Topsoil	2	2
Clay, yellow	22	24
Clay, blue	3	27
Clay with sand layers	13	40
Clay, blue	92	132

148.70.6.P4

Clay, yellow	22	22
Clay, blue	97	119
Gravel, fine	23	142

(reported to have "gone dry" in furnishing 25 bbls.per day for 1 month)

148.70.7.P3a

Topsoil	2	2
Clay, yellow	23	25
Clay, blue	143	168
Shale	4	172

148.70.7.P3b

Topsoil, black	1	1
Clay, yellow	5	6
Sand and gravel	10	16
Clay, yellow	9	25
Clay, blue	13	38
Sand	1	39
Clay, blue	110	149
Coal	1	150
Clay, blue	5	155
Shale	35	190

148.70.8.L

Material	Thickness	Depth
Clay, yellow	18	18
Clay, blue	14	32
Sand	1	33
Clay, blue	2	35

148.70.13.C

Clay, yellow	18	18
Clay, blue	44	62
Sand	3	65
Clay, blue	19	84

148.70.17.E2a

Topsoil	2	2
Clay, yellow	23	25
Clay, blue	8	33
Clay,blue,and rocks	7	40
Clay, blue	130	170
Shale	5	175

148.70.18.B3

Topsoil	1	1
Clay, yellow	26	28
Clay, sandy, blue	110	138
Clay, blue	33	171
Shale	3	174

148.70.19.M

Topsoil	1	1
Clay, yellow	16	17
Clay, blue	12	29
Sand	7	36

148.70.21.M2

Clay, yellow	20	20
Clay, blue, gravelly	46	66
Gravel, fine, hard	2	68

148.70.29.H4

Topsoil	1	1
Clay, stoney,yellow	7	8
Clay, blue	112	120
Clay, sandy	6	126

148.70.30.H1

Material	Thickness	Depth
Clay, yellow	18	18
Clay, hard, blue	12	30
Silt, sandy	3	33
Clay, blue	15	48

148.70.34.D

Topsoil	2	2
Clay, yellow	16	18
Clay, blue	85	113
Sand,fine,silty	7	120

(Water level reported 39 ft. below land surface.)

148.71.10.P3

U.S.G.S.rotary test hole No.1

Clay, sandy, yellow	13	13
Clay, sandy,yellow,blue	6	19
Clay,sandy to fine gravelly, blue	30	49
Clay, blue with boulders	5	54
Clay, sandy, blue	25	79
Clay, gravelly, blue	10	89
Clay, gravelly, grey	12	101
Clay and boulders	8	109
Clay, sandy, blue	50	159
Gravel,fine,sandy,clay	13	172

(Hole ended on boulder at 172 ft.)

148.71.12.D3

Topsoil	1	1
Clay, yellow	14	15
Clay,yellow with gravel	11	26
Gravel	1	27
Sand	2	29
Clay, blue	90	119
Sand	17	136
Clay, blue	42	178
Shale	31	209

148.71.12.D4

Topsoil	1	1
Clay, yellow	14	15
Clay and gravel	10	25
Clay, blue	2	27
Gravel and boulders	3	30
Clay,blue	67	97
Gravel	3	100
Clay, blue	17	117
Sand	18	135
Clay, blue	37	172
Shale	36	208

148.71.12.C4

Material	Thickness	Depth
Topsoil	1	1
Clay, yellow	5	6
Sand and gravel	4	10
Clay, yellow	21	31
Clay, blue	79	110
Sand	11	121
Clay, blue	55	176
Shale	44	220

148.71.12.J

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	12	14
Clay, blue	115	129
Sand	1	130
Clay, blue	56	186

148.71.12.P

Material	Thickness	Depth
Topsoil	1	1
Clay,sandy,yellow	13	14
Clay, blue	71	85
Sand	21	106

148.71.14.D4

Material	Thickness	Depth
No log	22	22
Clay, sandy, blue	4	26
Clay, blue	6	32

148.71.14.K2

Material	Thickness	Depth
Clay, yellow	20	20
Clay, blue	25	45
Sand	5	50
Clay, silty, blue	40	90
Sand	9	99
Clay, blue	19	118

148.71.21.P

Material	Thickness	Depth
No log	37	37
Sand	8	45
Clay, blue	5	50
Sand	6	56

148.71.24.A

Material	Thickness	Depth
Topsoil	1	1
Clay, sandy	4	5
Sand	3	8
Clay, blue	38	46
Sand	1	47
Clay, blue	27	74

148.71.26.D

Material	Thickness	Depth
No log	19	19
Clay, blue	21	40

148.71.26.Q

Material	Thickness	Depth
Clay, yellow	20	20
Clay, blue	13	33
Sand	3	36
Clay, blue	16	52

148.71.34.B

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	13	15
Clay, sandy, blue	35	50
Sand, silty	10	60
Sand	45	105

148.71.35.N

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	17	19
Clay, blue	111	130
Sandstone, green	2	132
Clay, silty	2	134

(Last 4 ft.may be in Fox Hills formation.)

148.71.36.C

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	14	16
Clay, blue	117	133
Sand, hard	1	134

148.71.36.Q

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	4	6
Clay, blue	23	29

149.69.31.J1

Material	Thickness	Depth
Clay, yellow	23	23
Clay, blue	83	106

149.69.35.H3a

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	6	8
Clay, blue	174	182
Shale	8	190

149.69.35.H3b

Material	Thickness	Depth
Topsoil	2	2
Clay, yellow	8	10
Clay, blue	149	159
Sand, coarse	1	160

149.70.3.E3

U.S.G.S. rotary test hole No. 2

Material	Thickness	Depth
Topsoil	1	1
Clay, yellow	7	8
Sand, coarse & gravels	7	15
Clay, blue and gravel	14	29
Clay, blue & gravel	86	115
Sand, fine	5	120
Clay, blue & gravel	40	160

149.70.16.M2

Clay, yellow	18	18
Clay, blue	10	28
Silt, sandy	6	34
Clay, blue	31	65
No log	125	190

149.70.27.B4

Topsoil	2	2
Clay, grey	8	10
Clay, yellow	10	20
Clay, blue & boulders	6	26
Clay, sandy, blue	21	47

149.70.27.C3

Topsoil	2	2
Clay, grey	8	10
Clay, sandy, yellow	20	30
Clay, blue	8	38

149.70.27.C4

Topsoil	2	2
Sand & gravel, hard	4	6
Clay, sandy, yellow	20	26
Clay, blue	16	42

149.70.27.D2

Topsoil	2	2
Gravel, rocks and clay	8	10
Clay, grey	10	20
Clay, blue	23	43

149.70.28.H4

Topsoil	2	2
Clay, yellow	8	10
Clay, blue	30	40

149.70.30.E3

Material	Thickness	Depth
Topsoil	1	1
Clay, yellow, sand	11	12
Sand, yellow	8	20
Sand with some gravel	13	33
Clay, blue	8	38

149.70.33.B2

Clay, yellow	18	18
Clay, blue	38	56
Sand	4	60
Clay	20	80

149.70.36.E2

Topsoil	2	2
Clay, yellow	14	16
Clay, blue	26	42

149.70.36.F1

Soil, black	1	1
Clay, grey	2	3
Sand & gravel, yellow	10	13
Sand, sharp, blue	18	31
Clay, blue	1	32

149.70.36.F2

Topsoil	1	1
Sand & gravel, yellow	11	12
Sand, fine	13	25
Sand & gravel, coarse	14	39

149.71.9.H4

Clay, yellow	22	22
Clay, blue	10	32
Sand, fine	8	40

149.71.16.N1

No log	120	120
Sand, coarse	3	123

(Two "dry holes" nearby. Shale reported encountered in them at 125 feet & 175 feet)

149.71.28.H3

Sand	29	29

149.72.29.J1

Material	Thickness	Depth
Clay and sand	20	20
Clay, blue	4	24
Sand	4	28
Clay, blue	13	41

150.70.30.C1

Material	Thickness	Depth
Clay, yellow	20	20
Clay, blue	20	40
Sand and Rock	5	45

150.70.30.P

Material	Thickness	Depth
Soil, black	3	3
Sand and Clay	2	5
Sand	6	11

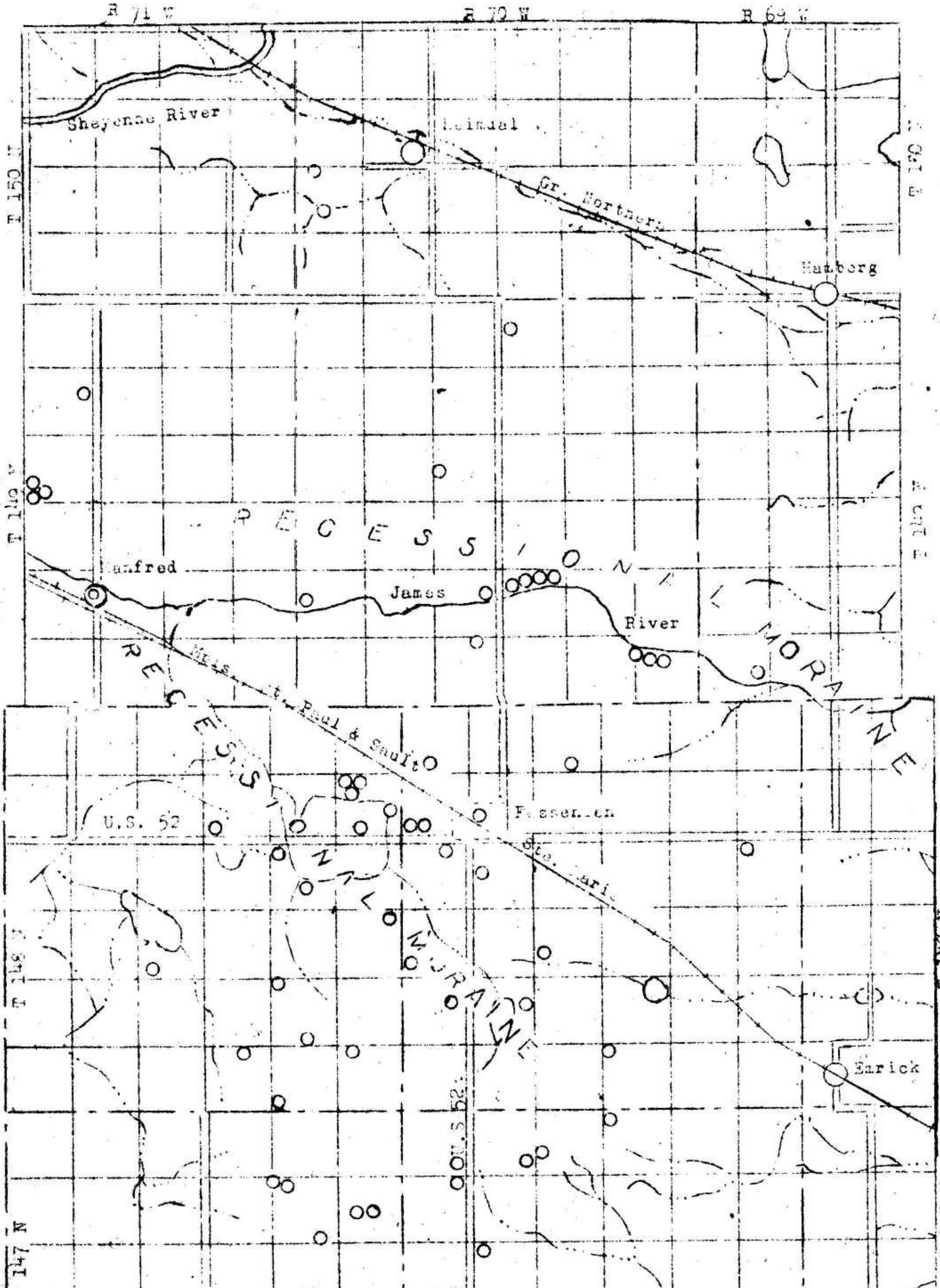
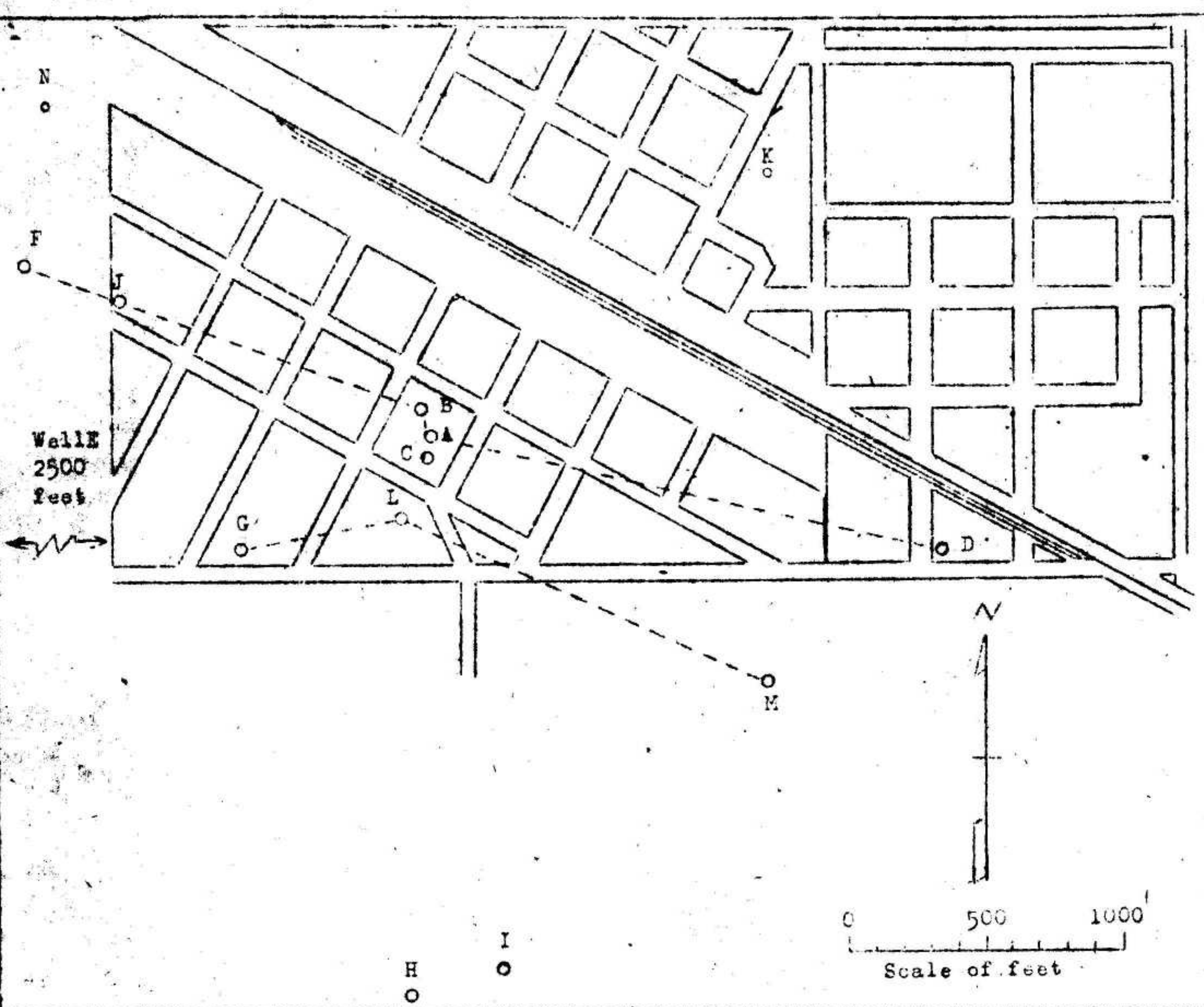
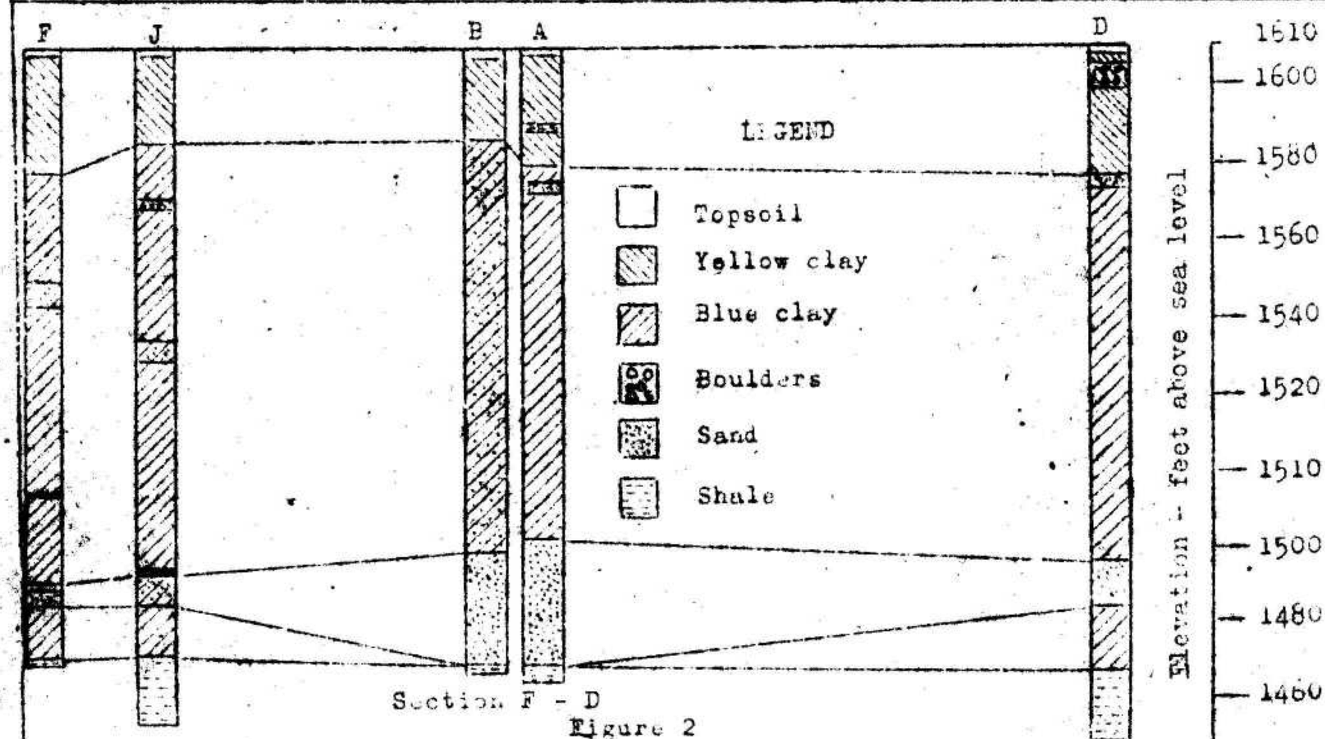


Figure 1. Map of Fessenden area showing locations of wells for which logs are given and geographic features.

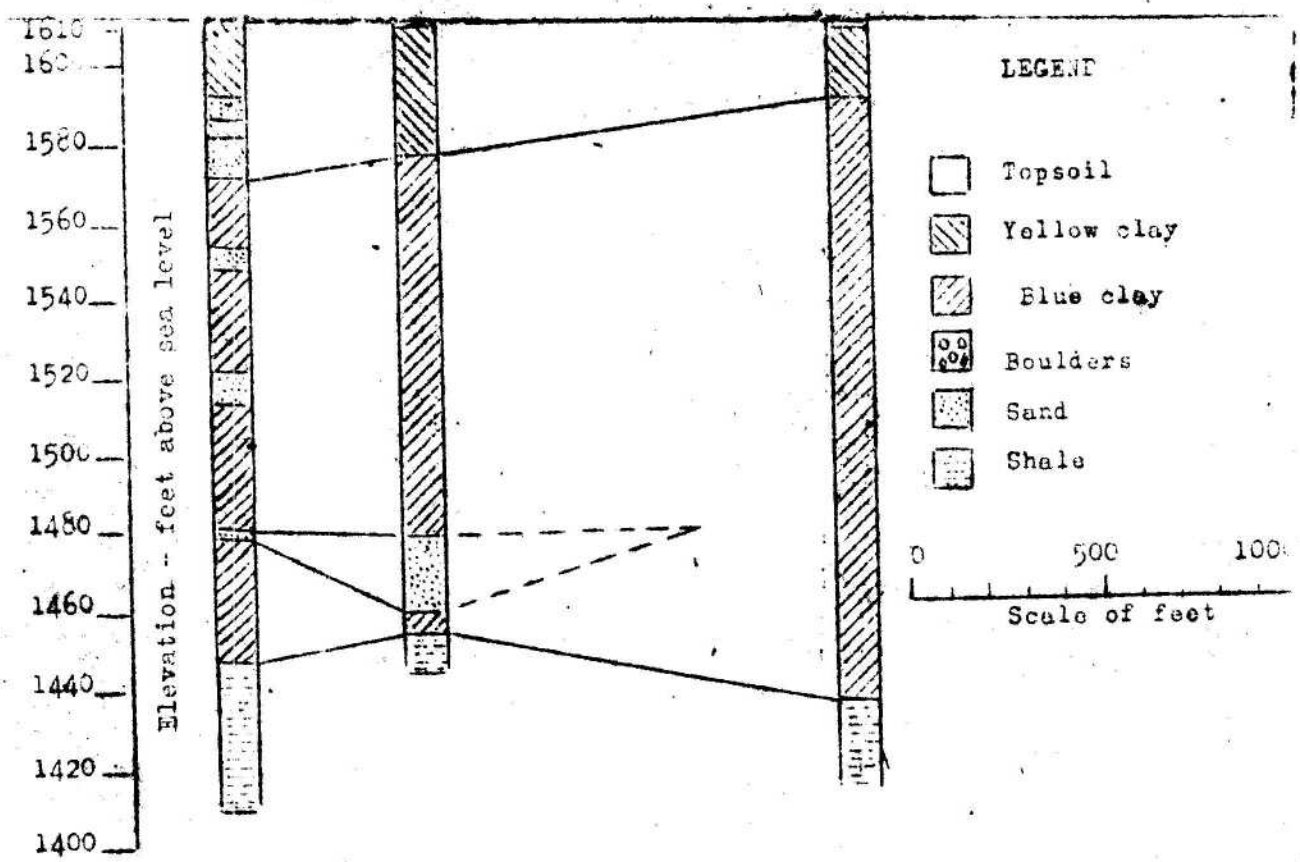


Map showing locations of test wells in vicinity of Fessenden.

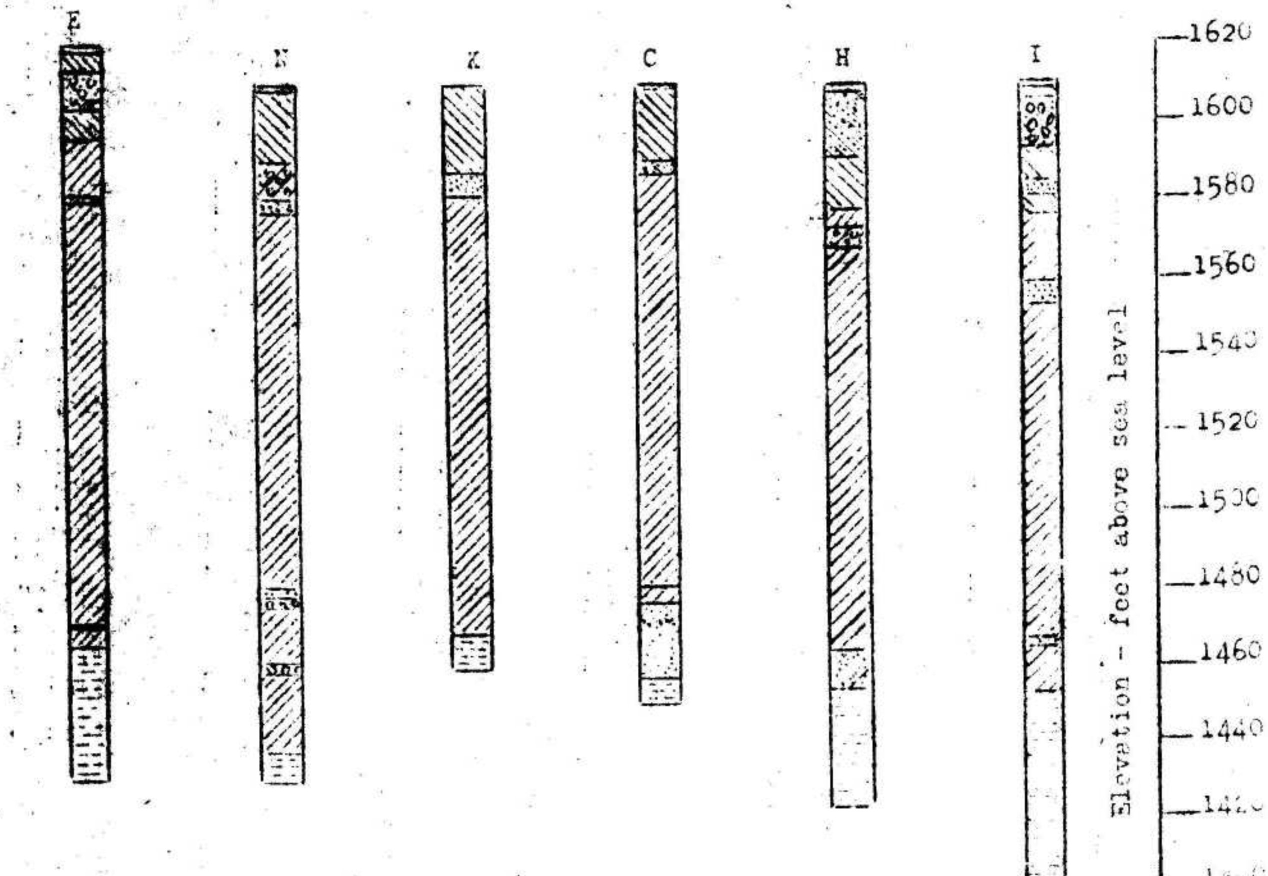


Section F - D

Figure 2



Section G - N



Graphic logs of test wells in the vicinity of Fessenden

Figure 5