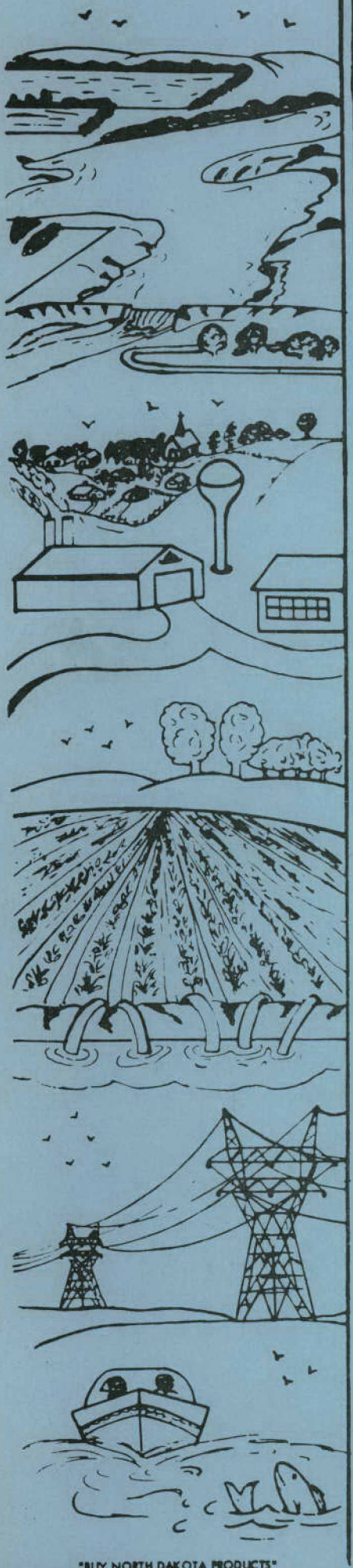

"BUY NORTH DAKOTA PRODUCTS"

Ground-Water Resources of the Edgeley Area

LaMoure County, North Dakota

North Dakota Ground-Water Studies
No. 82

By

Charles E. Naplin

Ground-Water Hydrologist

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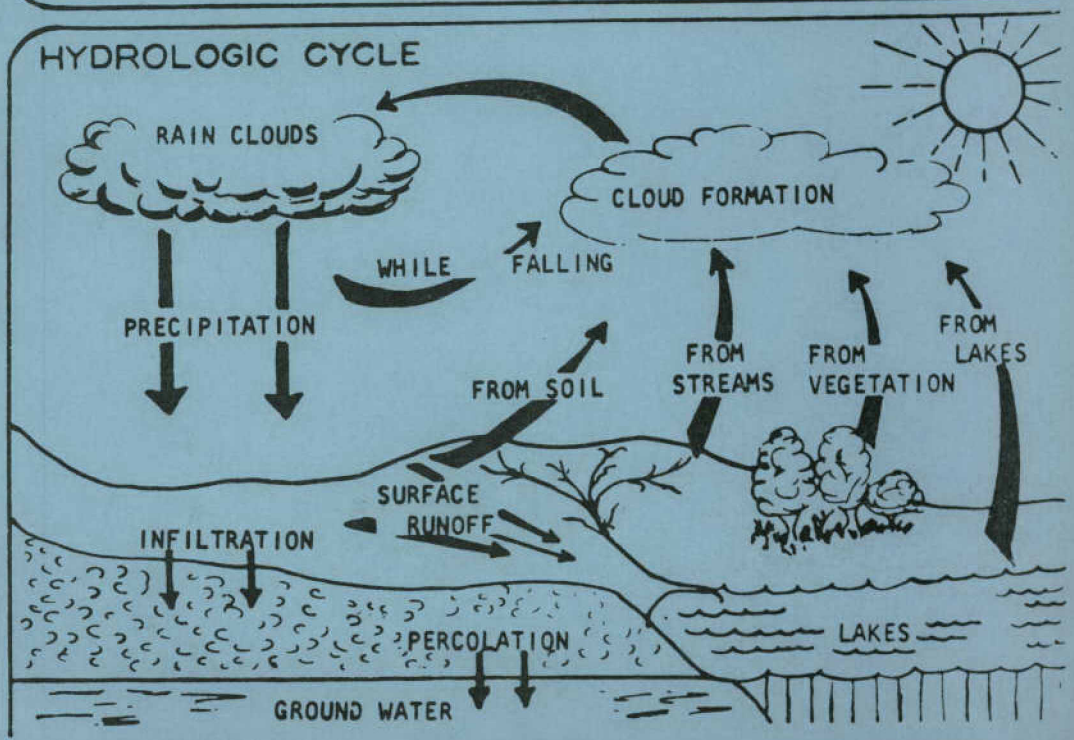

GROUND-WATER RESOURCES OF THE EDGELEY AREA LAMOURE COUNTY, NORTH DAKOTA

NORTH DAKOTA GROUND-WATER STUDIES NUMBER 82

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GROUND-WATER RESOURCES OF THE EDGELEY AREA

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INTRODUCTION

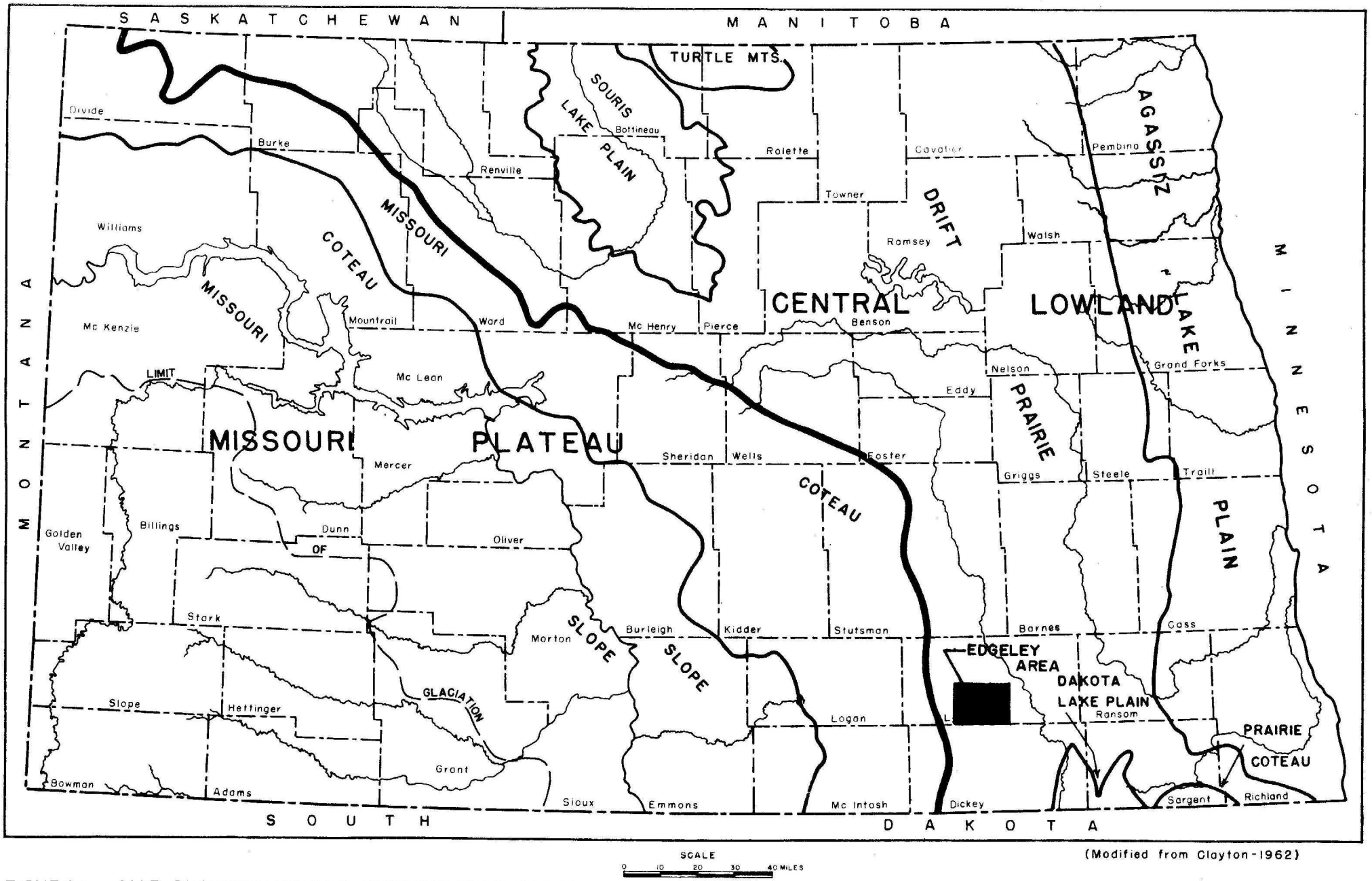
PURPOSE AND SCOPE

On July 11, 1973 the Edgeley City Council passed a resolution requesting the North Dakota State Water Commission to conduct a ground-water investigation for the city. An agreement was approved by the Commission on August 24, 1973 and field work was conducted during June, July, and October 1973.

Ground-water conditions in the Edgeley area were determined by test drilling, installation of observation wells, collection of water samples for chemical analysis, an aquifer test, and an inventory of selected wells. Field data and information from additional sources was evaluated during February and March 1974.

ACKNOWLEDGEMENTS

Test drilling was accomplished by Lewis Knutson and James Zidow using the state-owned hydraulic rotary drilling machine. Field work was under direct supervision of the author. The aquifer test was conducted by R. W. Schmid, ground-water hydrologist, with assistance from David Law. Chemical analyses were performed by Garvin Muri, State Water Commission chemist, at the North Dakota State Laboratories Department in Bismarck. Special acknowledgement is extended to Mayor Robert Mathson for information concerning city wells and water facilities.



SCALE
0 10 20 30 40 MILES

(Modified from Clayton-1962)

FIGURE I--MAP OF NORTH DAKOTA SHOWING PHYSIOGRAPHIC PROVINCES AND LOCATION OF THE EDGELEY AREA

LOCATION AND GENERAL FEATURES

The Edgeley area is located in south-central LaMoure County and is the Drift Prairie division of the Central Lowland physiographic province of North Dakota (fig. 1). Geohydrologic data collected during this investigation describe a 195-square mile area located in all or portions of Townships 133,134, and 135 N., Ranges 62, 63, 64, and 65 W.

Climatic conditions in the Edgeley area are characterized by cold snowy winters and warm summer days with cool nights. The average annual temperature at Edgeley is 41.4°F. based on a 71-year period of record (National Weather Service, 1971). The average annual precipitation for the same period of record was 17.59 inches.

Relief in the area is gently rolling to nearly flat and surface elevations range from 1,460 to 1,860 feet above mean sea level. Cottonwood Creek and Maple River drain the area and regional slope is to the east.

Edgeley (1970 population 888) is an agricultural community and is served by U. S. Highway 281 and State Highway 13. The city is also served by branch lines of the Burlington Northern and Chicago, Milwaukee, St. Paul, and Pacific Railroads.

WELL-NUMBERING SYSTEM

The wells and test holes listed in Table 3 are numbered according to a system based on the location in the public land classification of the United States Bureau of Land Management (fig. 2). The first numeral denotes the township north of a base line, the second numeral denotes the range west of the fifth principal, and the third numeral denotes the section in which the well is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). For example, well 133-64-15DAA is in the $NE\frac{1}{4}NE\frac{1}{4}SE\frac{1}{4}$

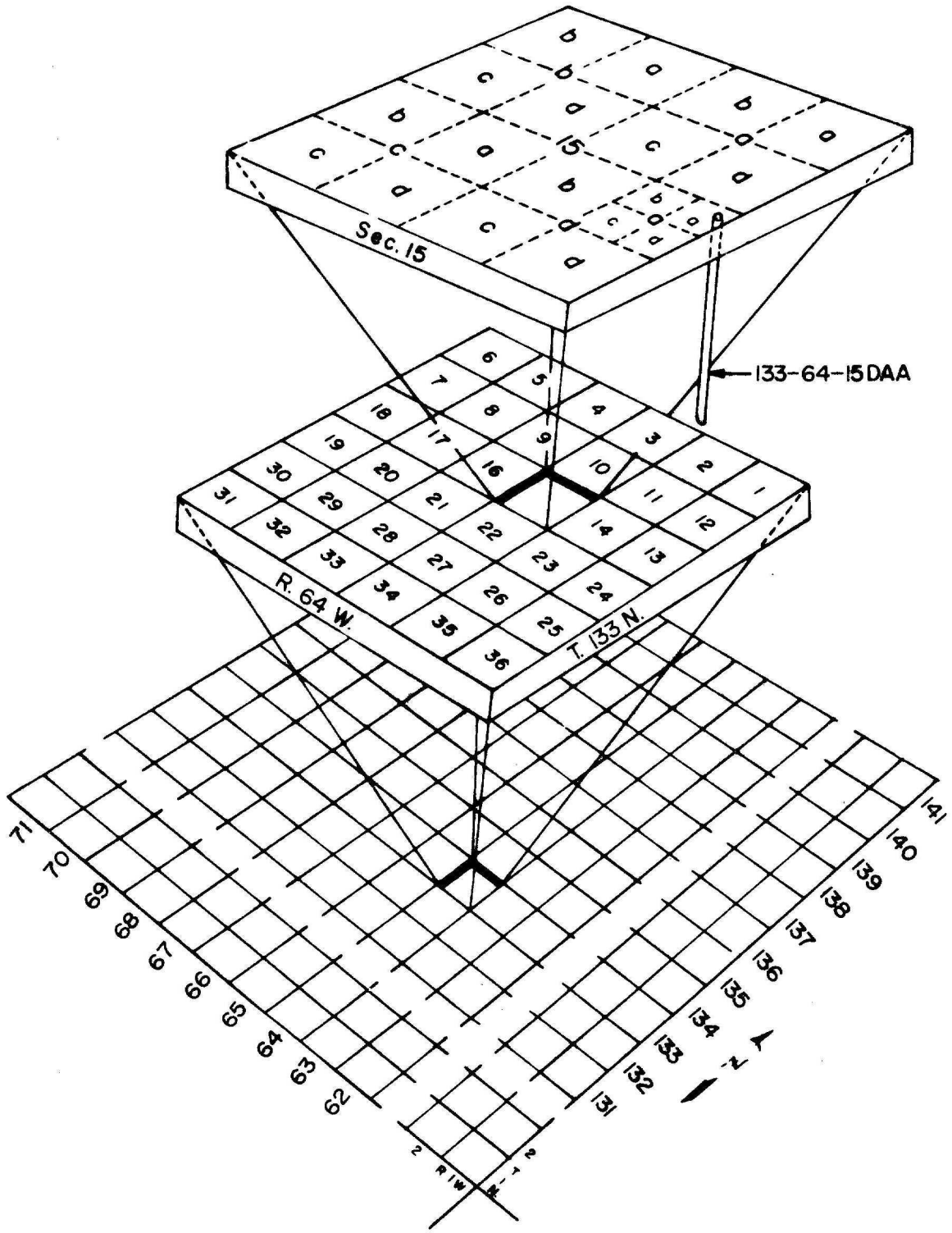


FIGURE 2--DIAGRAM SHOWING WELL-NUMBERING SYSTEM

Section 15, Township 133 N., Range 64 W. Consecutive terminal numerals are added if more than one well is located in a 10-acre tract.

PRESENT WATER SUPPLY

The city of Edgeley obtains its water supply from four wells. Three wells tap the Pierre shale at depths ranging from 92 to 122 feet and are cased with 6-inch slotted or perforated steel casing. One well taps a thin gravel deposit in the glacial drift at a depth of 82 feet and is completed with 6-inch steel casing and 7 feet of screen. Pumping rates range from about 30 to 40 gpm and water is stored in a 50,000 gallon elevated storage tank.

The city's present (1973) water supply is inadequate, especially during periods of peak demand, and water quality is quite poor. During 1973 the city's daily water consumption averages about 67,000 gallons per day. It is estimated that Edgeley needs about 100,000 gallons per day to satisfy demand during peak periods and provide for adequate fire protection.

PREVIOUS INVESTIGATIONS

Simpson (1929, p. 150-154) described in general terms the geology and ground-water resources of LaMoure County. His report includes a discussion of glacial and bedrock geology, a selected well inventory of municipal and private wells, and a few chemical analyses. He placed particular emphasis on artesian wells tapping sandstones of the Dakota Group.

A detailed study titled the Geology and Water Resources of the Edgeley and LaMoure Quadrangles, North Dakota was made by Hard in 1929. This report presents a comprehensive discussion of the geology, mineral resources, and ground-water conditions near Edgeley and includes quadrangle maps of the glacial geology, and artesian conditions in the area.

A ground-water survey of Dickey and LaMoure Counties was initiated in 1973 and is currently in progress. This investigation is a cooperative

program between the U. S. Geological Survey, North Dakota State Water Commission, North Dakota Geological Survey, and the County Water Management Districts. The study will consist of three parts, Part 1 - Geology, Part 2 - Basic Data, and Part 3 - Ground-Water Resources. It will serve as a reconaissance survey of the counties' ground-water resources and provides information on geology, hydrology, and water quality.

DEFINITION OF SELECTED TERMS

Aquifer - - A permeable, water-bearing deposit that will yield significant quantities of water to wells.

Artesian well - - A well in which the water level stands above an artesian or confined aquifer. A flowing artesian well is a well in which the water level is above land surface.

Bedrock - - Semi-consolidated rock underlying glacial and alluvial deposits of pleistocene and/or Holocene age.

Discharge - - The removal or loss of water from an aquifer or the flow of water into a stream.

Evapotranspiration - - The process by which water is returned to the atmosphere through direct evaporation from water or land surfaces and by transpiration of vegetation.

Ground water - - Water in the zone of saturation.

Ground-water movement - - The movement of ground water in the zone of saturation.

Infiltration - - The movement of water from the surface towards the zone of saturation.

Observation well - - A well from which hydrologic data are measured and recorded.

Outwash - - Sediments consisting generally of sand and gravel deposited by streams flowing from a glacier.

Permeable rock - - A rock that has a texture permitting water to move through it under ordinary pressure differentials.

Recharge - - The addition of water to the zone of saturation.

Specific capacity - - The rate of discharge of water from a well divided by the drawdown of the water level, normally expressed as gallons per minute per foot of drawdown.

Storage - - The quantity of water contained in openings in the zone of saturation.

Storage coefficient - - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an artesian aquifer the water derived from storage comes mainly from a change in pressure due to a decline in head. In a water-table aquifer water derived from storage is the result of gravity drainage of the voids.

Transmissivity - - The rate at which water, at the prevailing temperature, is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity is normally expressed in units of square feet per day but can be expressed as the number of gallons of water that will move in one day under a hydraulic gradient of one foot per foot through a vertical strip of aquifer one foot wide extending the full saturated height of the aquifer.

Water table - - The upper surface of the zone of saturation where the hydrostatic pressure is equal to atmospheric pressure. The configuration of the water table commonly is a subdued expression of the land surface.

Zone of saturation - - The zone below the water table.

WATER QUALITY

All natural water occurring on the earth's surface or underground contains dissolved minerals. Precipitation begins to dissolve mineral matter as it falls to the surface and continues to dissolve minerals as

it infiltrates into the ground. Dissolved minerals in ground water vary in type and concentration depending primarily upon the composition and solubility of rocks encountered, the length of time the water is in contact with the rocks, and the amount of carbon dioxide and soil acids in the water. Water that has been underground for a long time, or that has travelled a long distance from the recharge area, usually contains more dissolved mineral matter than water that has been underground for only a short time and is withdrawn close to a recharge area.

Dissolved mineral constituents are reported in milligrams per liter (mg/l). A milligram per liter is one thousandth (0.001) of a gram of dissolved material per liter of solution. Hardness is usually reported in milligrams per liter, but may be converted to grains per U. S. gallon (gr/gal) by dividing milligrams per liter by 17.12.

Table 1 gives the significance of the various chemical constituents of water for a domestic or municipal water supply in North Dakota. Results of chemical analyses for wells in the study area are listed in Table 2.

BASIC HYDROLOGIC CONCEPTS

All ground water of economic importance is derived from precipitation. After the precipitation falls on the earth's surface, part is returned to the atmosphere by evaporation, some runs into streams, and the remainder percolates into the ground. Much of the water that sinks into the ground is held temporarily in the soil and is returned to the atmosphere either by evaporation or by transpiration. The remainder infiltrates downward and becomes ground water.

Ground water moves under the influence of gravity from areas of recharge to areas of discharge. The movement of ground water is generally very slow and may be only a few feet per year. The rate of movement is

TABLE 1 -- Dissolved chemical constituents in water -- their effects upon usability and recommended concentration limits for domestic and municipal water supplies in North Dakota.

Constituent or Parameter	Effects of dissolved constituents on water use	Significance for water supplies in North Dakota[1]	U.S Public Health Service recommended limits for drinking water[2]
Silica (SiO_2)	No physiological significance		
Iron (Fe)	Concentrations over 0.3 mg/l will cause staining of fixtures. Over 0.5 mg/l may impart taste and colors to food and drink.		0.3 mg/l
Manganese (Mn)	Produces black staining when present in amounts exceeding 0.05 mg/l		0.05 mg/l
Calcium (Ca) and Magnesium (Mg)	Calcium and magnesium are the primary causes of hardness. Over 125 mg/l may have a laxative effect on persons not accustomed to this type of water.		
Sodium (Na)	No physiological significance except for people on salt-free diets. Does have an effect on the irrigation useage of water.		
Potassium (K)	Small amounts of potassium are essential to plant and animal nutrition.		
Bicarbonate (HCO_3) and Carbonate (CO_3)	No definite significance, but high bicarbonate content will impart a flat taste to water.		
Sulfate (SO_4)	Combines with calcium to form scale. More than 500 mg/l tastes bitter and may be a laxative.	0-300 mg/l - low 300-700 mg/l - high over 700 mg/l - very high	250 mg/l
Percent Sodium and Sodium Adsorption Ratio (SAR)	Indicate the sodium hazard of irrigation water.		
Chloride (Cl)	Over 250 mg/l may impart a salty taste, greatly excessive concentrations may be physiologically harmful. Humans and animals may adapt to higher concentrations.		
Flouride (F)	Flouride helps prevent tooth decay within specified limits. Higher concentrations cause mottled teeth.	Limits of 0.9 mg/l to 1.5 mg/l	Recommended limits depend on average of daily temperatures. Limits range from 0.6 mg/l at 32°C. to 1.7 mg/l at 10°C.
Nitrate (NO_3)	Over 45 mg/l can be toxic to infants. Larger concentrations can be tolerated by adults. More than 200 mg/l may have a deleterious effect on livestock health.		45 mg/l
Boron (B)	No physiological significance. Greater than 2.0 mg/l may be detrimental to many plants.		
Total dissolved solids	Persons may become accustomed to water containing 2,000 mg/l or more dissolved solids.	0-500 mg/l - low 500-1400 mg/l - average 1400-2500 mg/l - high over 2500 mg/l - very high	500 mg/l
Hardness (as $CaCo_3$)	Increases soap consumption, but can be removed by a water-softening system.	0-200 mg/l - low 200-300 mg/l - average 300-450 mg/l - high over 450 mg/l - very high	
pH	Should be between 6.0 and 9.0 for domestic consumption		
Specific Conductance	An electrical indication of total dissolved solids measured in micromhos per centimeter at 25°C. Used primarily for irrigation analyses.		

[1] Schmid, 1965.
[2] U.S. Public Health Service, 1962.

governed by the permeability of the deposits through which the water moves and by the hydraulic gradient. Gravel and well-sorted medium to coarse sand are usually very permeable. Fine-grained materials such as silt, clay and shale usually have low permeability, and may act as confining barriers that restrict the free movement of ground water into or out of more permeable rocks. A ground-water reservoir that contains enough saturated permeable material to yield water in sufficient quantity to serve as a source of supply is called an aquifer.

Artesian aquifers are confined by relatively impermeable beds. Ground water contained within these aquifers is under pressure due to the weight of water at higher levels of recharge in the aquifer and to the weight of overlying rocks. The water level in a well completed in an artesian aquifer will be higher than the top of the aquifer.

When the upper surface of an aquifer is the water surface and this surface is free to fluctuate with recharge and discharge, the aquifer is called a water-table aquifer. The shape of the upper surface of the zone of saturation is called the water table. (It is controlled by gravity and topographic relief.)

Pumping a well causes its water level to be lowered and the water-level surface surrounding the well will resemble a cone referred to as the cone of depression. Water-level drawdown is the difference between static and pumping levels. The amount of drawdown is controlled by the hydraulic properties of the aquifer, the physical characteristics of the well, and the rate and duration of pumping. During constant and uniform discharge from a well, the water level declines rapidly at first and continues to decline at a decreasing rate as the cone of depression expands.

GROUND WATER IN PREGLACIAL ROCKS

Nearly 2,800 feet of sedimentary Paleozoic and Mesozoic rocks underlie the Edgeley area, that is situated near the eastern edge of the Williston

basin. These rocks consist mainly of shale, limestone, dolostone, and sandstone that dip to the west and thicken in that direction. Potential bedrock aquifers include the Pierre shale and several sandstone units of the Cretaceous Dakota Group.

DAKOTA ARTESIAN SYSTEM

The log from an oil test (133-65-12ba) located four miles west of Edgeley indicate the sandstones comprising the Dakota artesian system may be encountered at depths ranging from about 1,300 to 1,700 feet. Individual beds are as much as 40 feet thick but may contain thin shale interbeds. Dakota Group sandstones are described as being generally subrounded, light tan in color, fine-to medium-grained, and contain reddish-brown concretions and pellets. The sandstones have good permeability as evidenced by flows of several hundred gallons per minute that have been obtained from artesian wells tapping these units.

The first recorded artesian well in the study area was drilled for the city of Edgeley in 1892 and was completed in a sandstone bed of the Dakota Group at a depth of 1354 feet. This well had an original gauge pressure of 60 psi (pounds per squre inch) at land surface and flowed at a rate of 500 gpm. Pressure of this magnitude is capable of lifting a column of water about 138 feet above land surface (Simpson, 1929). Over a period of years from 1892 to 1919 there was a steady drop in pressure in the Edgeley Dakota well and the observed head declined from 138 feet above land surface to 15 feet below land surface. Many Dakota wells were allowed to flow freely for many years in western LaMoure County, resulting in a loss of artesian pressure and a regional decline in head within the Dakota Group.

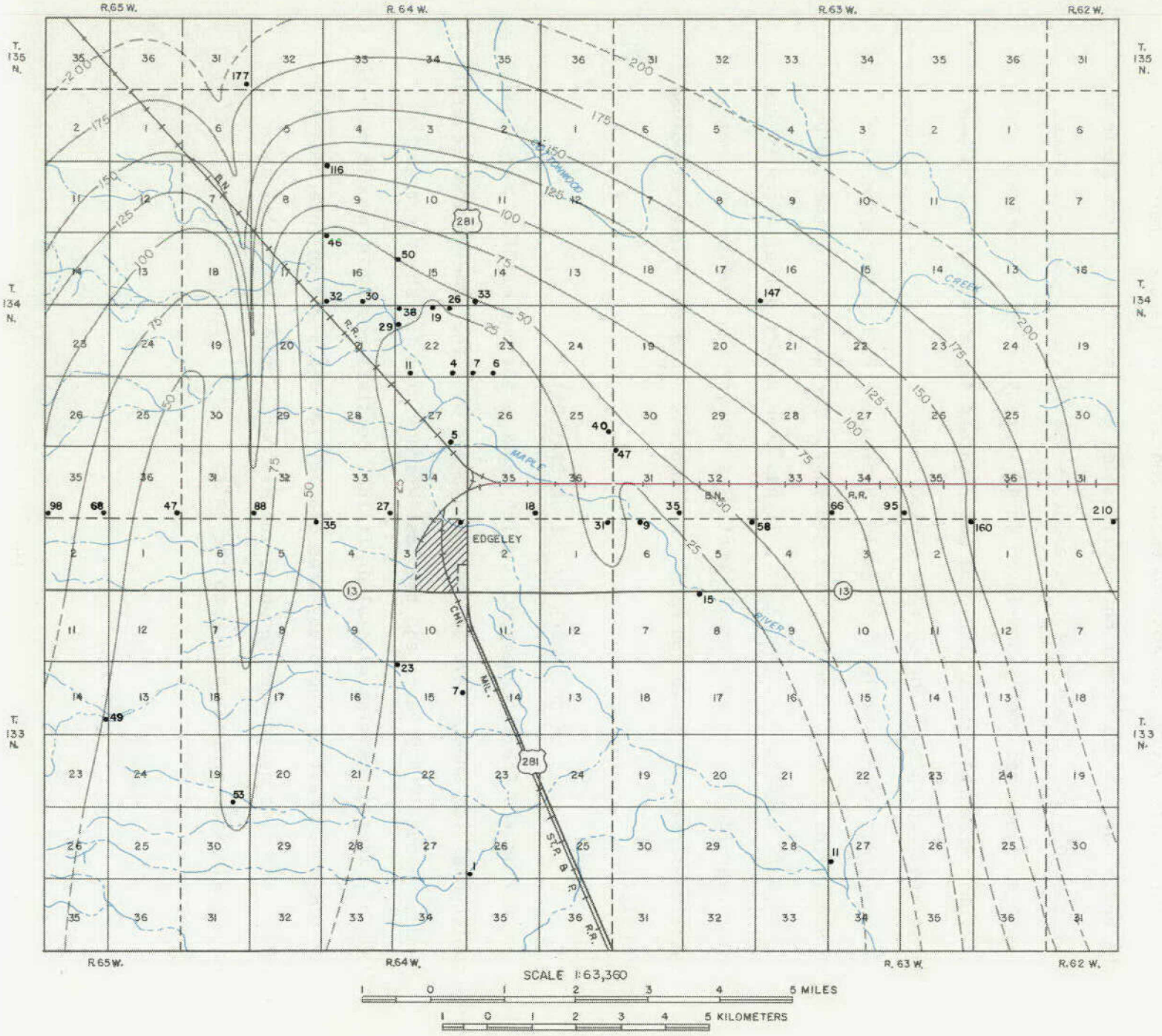
Two water samples from Dakota wells in the study area contained dissolved solids exceeding 5,500 mg/l and indicated a sodium chloride type water. Dakota water is not desirable for domestic purposes but is sometimes used when water from other sources is not available. It is occasionally used for watering livestock and in sewer systems.

Natural gas (methane) was produced along with water from several Dakota wells near Edgeley. Hard (1929, p. 76-78) cites numerous instances where natural gas was used to heat and light private dwellings, a store, and a hotel at Edgeley in the early 1900's. However, the volumes of gas produced from the Dakota wells decreased rapidly with the depletion of artesian head in the area, and the use of natural gas as a fuel was abandoned.

PIERRE FORMATION

The Pierre Formation directly underlies glacial drift in the Edgeley area as substantiated by test drilling. Subsurface data compiled during this investigation show that the top of the Pierre was encountered at a maximum elevation of 1,650 feet (above mean sea level) in test hole 8691 (134-65-35ccc) and a minimum elevation of 1,280 feet in test hole 8734 (133-62-6AAA). Geologic section A-A' (pl. 2) illustrates the irregular configuration of the Pierre subcrop. More than 400 feet of Pierre has been removed by erosion in this area, prior to and during glaciation. Test drilling indicates that preglacial and/or glacial streams have eroded valleys into the Pierre shale both west and east of Edgeley (fig. 3).

The buried escarpment and associated bedrock valley located east of Edgeley was also encountered east of Ellendale during that ground-water investigation. This valley may represent a preglacial drainage system that at one time flowed out of South Dakota and through Dickey and LaMoure Counties and into other portions of North Dakota.



EXPLANATION

66 CONTROL POINT-- NUMBER INDICATES THICKNESS OF GLACIAL DRIFT IN FEET.

CONTOUR INTERVAL 25 FEET-- DASHED WHERE INFERRED.

FIGURE 3-- MAP SHOWING THICKNESS OF GLACIAL DRIFT IN THE EDGELEY AREA

Drill cuttings indicate the Pierre Formation is a dark gray to grayish-black, moderately hard, brittle, siliceous, non-calcareous shale. Out crops of the Pierre south of Edgeley show that it weathers to a light gray color and becomes flakey and loose when exposed to the atmosphere. It is often bentonitic and may contain reddish-brown limonitic concretions.

Three city wells, and most domestic and stock wells are completed in the upper part of the formation. Well yields are small due to the shale's low permeability. Ground-water movement is restricted to openings along cleavage planes and poorly developed joint systems in the formation's upper horizon. Recharge occurs as ground water enters fractures in the shale by filtering down through the overlying glacial drift.

Thirteen water samples from wells tapping the Pierre contained dissolved solids ranging from 873 to 3,310 mg/l. The water is of the sodium bicarbonate sulfate type (table 2). It has been reported that a few Pierre wells near Edgeley produce small quantities of hydrogen sulfide gas that has a distinctive "rotten egg odor", and imparts a bad taste when dissolved in water.

GROUND WATER IN THE GLACIAL DRIFT

During the Pleistocene Epoch, which began about one million years ago, continental ice sheets have advanced southward over the Edgeley area several times. About 12,000 years ago the last Wisconsinian ice sheet retreated from the area depositing glacial drift that consists mostly of ground moraine and outwash. West of the study area glacial ice deposited an interconnected series of hills and ridges known as the Missouri Coteau, that rise above the relatively flat ground moraine to the east.

Ground moraine in the study area consists predominately of till, which is an unsorted mixture of clay, silt, sand, gravel, cobbles, and boulders. The till ranges in thickness from 0 to more than 200 feet (figs. 3, 4). Till was deposited as the ice stagnated, melted, and released its sediment load of glacial debris which accumulated on top of the bedrock surface (pl. 2). Drill cuttings of an average section of till in North Dakota reveal that it is olive-gray in color when encountered below the water table. Above the water table it has been weathered and oxidized and is yellowish-brown in color. Till is relatively impervious and will not readily yield water to wells.

The Edgeley outwash plain and a few terrace deposits, consisting of sand and gravel, are associated with ground moraine near Edgeley (Fig. 4). Sand and gravel constituting the outwash, was deposited as meltwater streams washed, sorted, and dropped their sediment load as they flowed southeastward along and parallel to the receeding ice front. Test drilling indicates the Edgeley outwash consists of well-sorted coarse sand and gravel. The deposit attains a maximum known thickness of 43 feet in test hole 8717 (134-64-16DAA).

Holocene deposits consisting of alluvial clay, silt, and sand, and eolian (windblown) sand and silt have been deposited since glaciation. These deposits directly overlie ground moraine are thin, very fine grained, and often unsaturated.

TILL-ASSOCIATED AQUIFERS

Several test holes penetrated small, lenticular deposits of sand and gravel associated with till in the study area. These deposits range in thickness from a few feet to as much as 24 feet in test hole 8730 (133-65-14DDA). Because of their small areal extent and limited recharge potential, the till-associated deposits are only capable of yielding small quantities of water

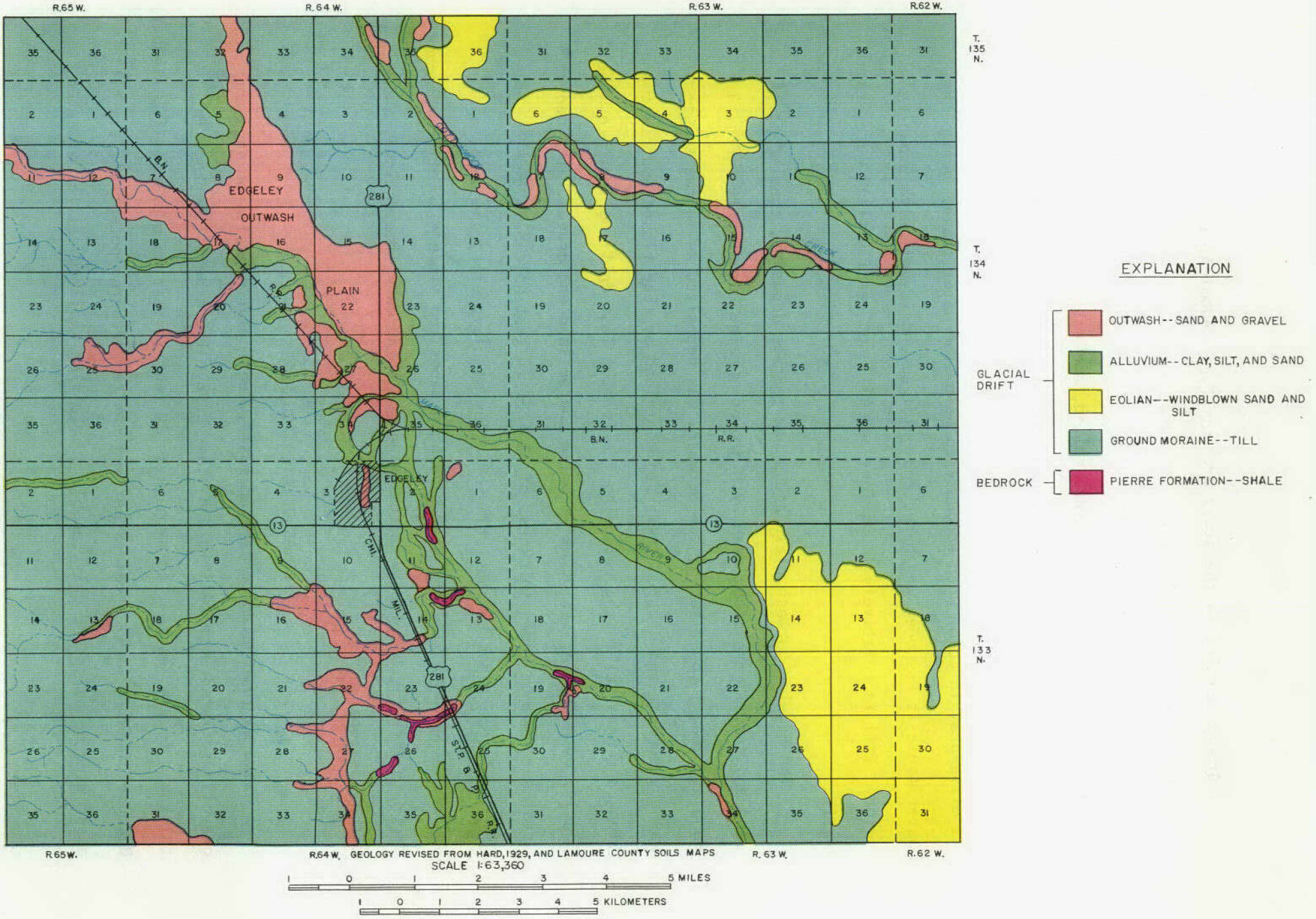
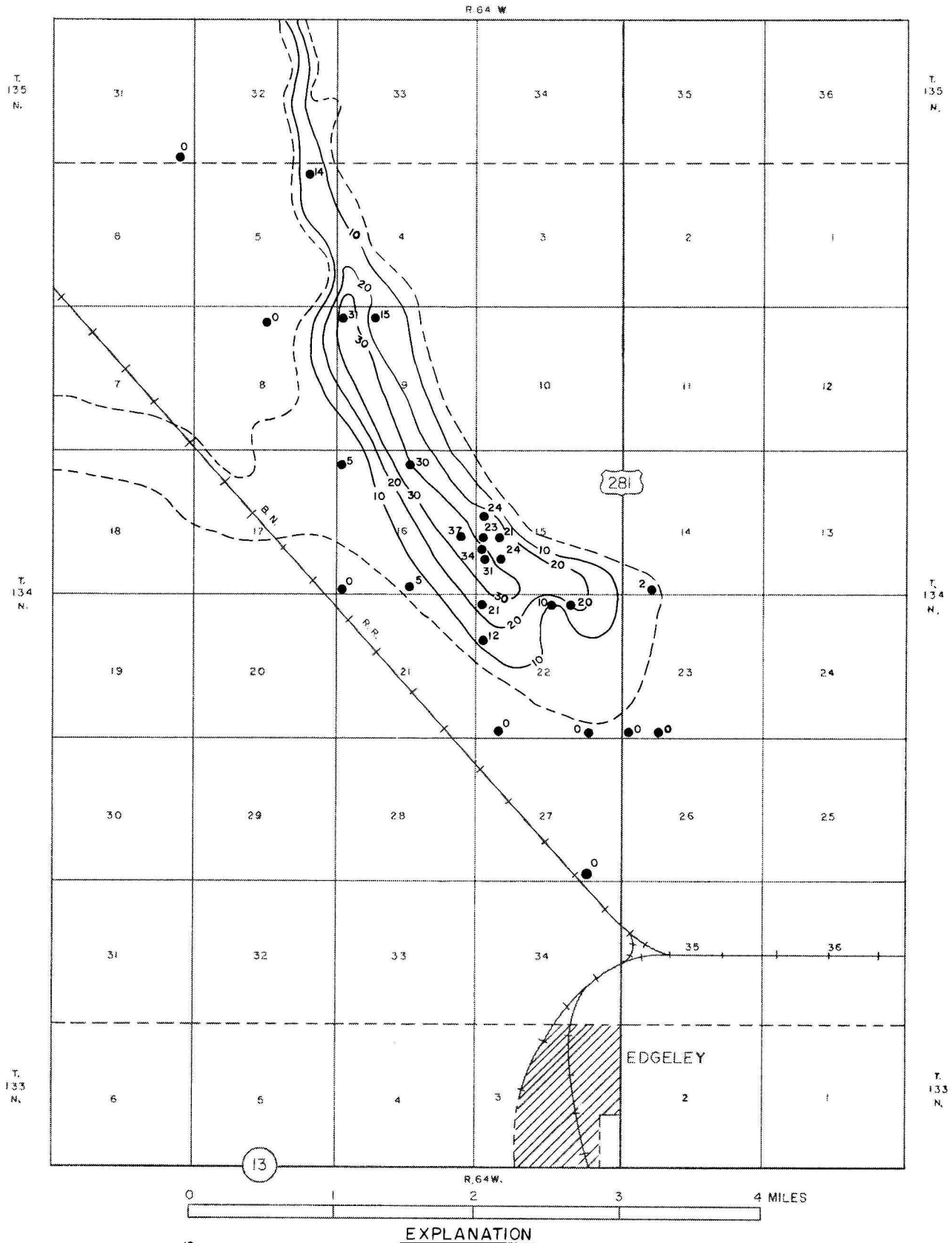


FIGURE 4--GLACIAL MAP OF THE EDGELEY AREA



EXPLANATION

● 12 SELECTED CONTROL POINT-- NUMBER INDICATES SATURATED AQUIFER THICKNESS IN FEET.

DASHED LINE INDICATES INFERRED AQUIFER BOUNDARY

CONTOUR INTERVAL 10 FEET.

FIGURE 5-- LOCATION AND SATURATED THICKNESS OF THE EDGELEY AQUIFER

to domestic and stock wells. Four water samples from till-associated aquifers indicated water of the calcium or sodium bicarbonate type and contained dissolved solids of less than 1,000 mg/l.

EDGELEY AQUIFER

This investigation served to locate and partially define an outwash deposit located 3½ miles northwest of the city, herein called the Edgeley aquifer (fig. 5). The Edgeley aquifer was the only significant glacial drift aquifer encountered during this study.

The Edgeley aquifer consists of material ranging in size from fine sand to coarse gravel with cobbles. The aquifer material is highly permeable as substantiated by the loss of drilling fluid that occurred in several test holes that penetrated the deposit. Occasional thin layers of clay and silt occur as interbedded material, but generally the aquifer material is clean and well-sorted. Wells tapping the deposit range from 13 to 40 feet in depth.

Seventeen test holes penetrated the aquifer and encountered saturated sand and/or gravel ranging in thickness from 2 feet in test hole 8714 (134-64-14CCD) to 37 feet in test hole 8717 (134-64-16DAA). The average saturated thickness was determined to be about 10 feet. The configuration of the Edgeley aquifer and a contour map showing its saturated thickness are shown on figure 5.

Existing data indicates the aquifer overlies an area of about 5 square miles. It is a surficial deposit and receives direct recharge through the infiltration of precipitation. Plate 2 shows that the aquifer generally overlies glacial till except in the vicinity of Section 22, Township 134 N., Range 64 W. where it directly overlies the Pierre shale. Altitudes of water levels in observation wells indicate ground water is moving to the southeast and to the north from an area in portions of Sections 8, 9, 16, and 17, Township 134 N., Range 64 W. (fig. 6) Ground water contained in the

aquifer is generally under water-table conditions, but where the deposit is interbedded with clay semi-confined artesian conditions exist.

An aquifer test was conducted during October 1973 using an 8-inch diameter well located 4 miles north and ½ mile west of Edgeley ($134\text{-}64\text{-}15CBB_5$). The test well was drilled by C. A. Simpson and Son, Bisbee, North Dakota, and was completed from 29½ to 39½ feet below land surface with an 8-inch diameter 0.025-inch v-slot screen.

The test was started at 0900 hours on October 20, 1973 and a pumping rate of 171 gpm was maintained for 5 days. Water levels were measured in 13 observation wells and the test well. Significant drawdown occurred only in the test well and the six observation wells located nearest to the test well. The drawdown ranged from 0.67 foot in well 8915-A ($134\text{-}64\text{-}15CBB_2$) to 12.36 feet in the test well ($134\text{-}64\text{-}15CBB_5$). Table 2 lists data on selected observation wells and the test well and figure 7 graphically illustrates the drawdown and recovery of water-levels.

Evaluation of the aquifer test data indicates a transmissivity of 5000 $ft.^2$ per day. A storage coefficient of 0.075 was determined for an average section of the aquifer under leaky artesian conditions. The specific capacity of the test well (discharge divided by drawdown) after 24 hours of pumping was determined to be 15.3 gpm /foot of drawdown.

Assuming a specific yield of .075, an average saturated thickness of 10 feet, and an area of 5 square miles, the aquifer contains about 2,400 acre-feet of ground-water in storage. Yields of 250 to 350 gpm

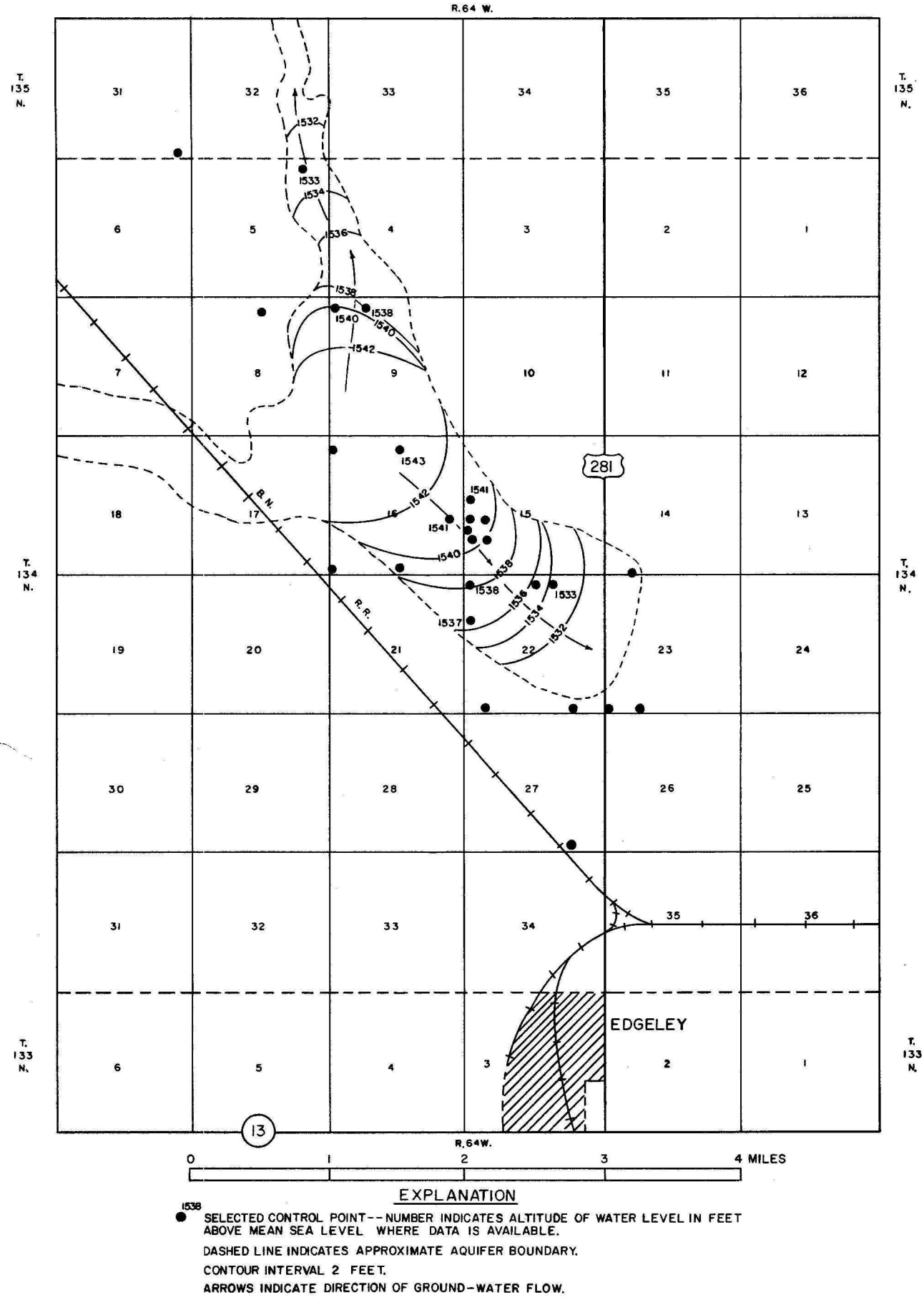


FIGURE 6--ALTITUDES OF WATER LEVELS IN THE EDGELEY AQUIFER AUGUST 9-11, 1973

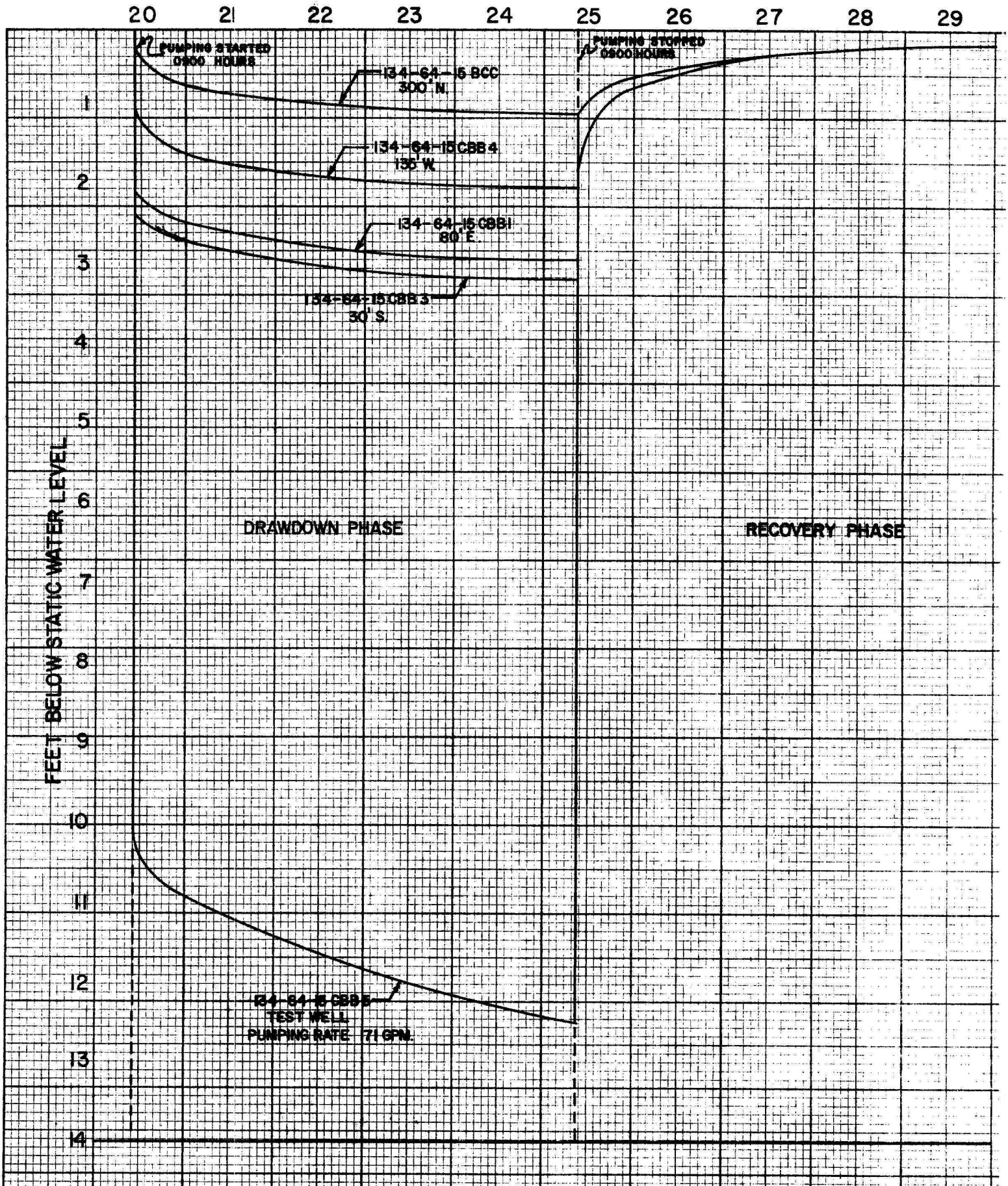


FIGURE 7--DRAWDOWN AND RECOVERY OF THE TEST WELL AND SELECTED OBSERVATION WELLS DURING THE EDGELEY AQUIFER TEST

TABLE 2 - - AQUIFER TEST DATA

WELL	LOCATION	DISTANCE FROM TEST WELL IN FEET	DEPTH OF WELL IN FEET	STATIC WATER LEVEL IN FEET BELOW LAND SURFACE 10-9-73	DRAWDOWN IN FEET BELOW STATIC WATER LEVEL
Test Well	134-64-15CBB$_5$		39½	8.20	12.36
8915-B	134-64-15CBB$_3$	30' S.	43	8.07	3.21
8915	134-64-15CBB1	80' E.	39	6.92	*2.98
8915-D	134-64-15CBB$_4$	135' W.	43	8.35	2.00
8717	134-64-16DAA	200' W.	40	7.35	1.50
8915-C	134-64-15BCC	300' N.	35	4.03	1.17
8915-A	134-64-15CBB$_2$	350' SE.	26	3.16	**0.67

* Excessive drawdown probably due to nearby aquifer boundary.

** Water used in well development may have induced recharge during pumping and influenced the degree of drawdown.

may be possible from properly constructed wells completed at locations having the greatest saturated thickness.

Fifteen chemical analyses indicated the water is a moderately hard calcium bicarbonate type that contains dissolved solids ranging from 308 to 937 mg/l. Iron and manganese generally exceed the recommended limits set by the U. S. Public Health Service and the water will require treatment and removal of these constituents for municipal use. Sodium-adsorption ratios range from 0.3 to 7.6 and specific conductances are generally less than 1000 micromhos

SUMMARY

This investigation obtained and evaluated geohydrologic data within a 196-square mile area around Edgeley in LaMoure County. The area is situated within the Drift Prairie division of the Central Lowland physiographic province of North Dakota. The average annual precipitation is 17.59 inches and the average annual temperature is 41.4°F. Maple River and Cottonwood Creek drain the area.

An oil test west of Edgeley indicates that about 2,800 feet of westward-dipping sandstone, limestone, dolostone, and shale underlie the glacial drift. Several of these rock units contain water that is highly mineralized and generally not desirable for domestic use. Sandstone beds of the Dakota Group were tapped by numerous artesian wells in the late 1800's and early 1900's and used as a source of water supply. Wells completed in the Dakota Artesian System at one time flowed at land surface, but due to a regional decline in artesian pressure, many wells ceased to flow within a few years after they were drilled. Water contained in the Dakota sandstones is moderately soft, and high in dissolved solids and sodium.

The Pierre Formation directly underlies the glacial drift and is a dark gray shale that has low permeability and contains poor quality water.

The majority of domestic and stock wells in the Edgeley area are completed in the Pierre shale.

Glacial drift overlies the Pierre shale in the Edgeley area and consists generally of ground moraine and outwash. Ground moraine is composed of till and is relatively impervious. Outwash consists of sand and gravel and has water-yielding potential where it is saturated.

The Edgeley aquifer, an outwash deposit, was the only significant glacial drift aquifer encountered during this study. Data collected during the course of this investigation indicates the aquifer extends over an area of five square miles and consists of sand and gravel ranging in saturated thickness from 2 to 37 feet. Aquifer test data indicates the deposit has a transmissivity of 5,000 $ft.^2$/day and a storage coefficient of 0.075. Assuming an average saturated thickness of ten feet, and areal extent of five square miles, and a specific yield of 0.075 the aquifer contains about 2,400 acre-feet of available water in storage. Water contained in the aquifer is of the calcium bicarbonate type and contains less than 1,000 mg/l dissolved solids. Treatment and removal of iron and manganese may be required.

The Edgeley aquifer appears to have good hydraulic conductivity and the outwash is highly permeable. Subsurface and aquifer test data indicate the aquifer can provide the city of Edgeley with a reliable water supply.

TABLE 3 -- CHEMICAL ANALYSES

(Analytical results are in milligrams per liter except where indicated)

AQUIFERS Owner or Designation	Location	Depth of Well (feet)	Temp. (Deg. C)	Date of Collection	(SiO_2)	(Fe)	(Mn)	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	(SO_4)	(Cl)	(F)	(NO_3)	(B)	Total Dissolved Solids	Total Hardness as $CaCO_3$	Total Hardness Noncarbonate	Percent Sodium	SAR	Specific Conductance	pH
DAKOTA ARTESIAN SYSTEM																									
L. Little	134-63-16ccc	1,300	10	11-1-72	9.3	4.50	0.06	46	28	2,760	46	639	0	28	4,100	0.9	1.0	6.60	6,980	228	0	95	79	12,700	7.7
Walter Davis	134-64-24dc	1,280	9	9-10-70	9	5.80	0.09	63	18	2,140	32	590	0	62	3,180	1.4	0	4.40	5,600	232	0	94	61	10,100	82
PIERRE FORMATION																									
Willow Bank Tp.	133-63-5dcc	30	7	11-1-72	28	1.30	0.22	31	11	309	8.6	565	0	279	55	0.3	4.6	2.30	987	123	0	83	12	1,560	7.5
Richard Musland	133-63-8bbb	130	8	11-2-72	29	0.08	0.50	146	44	743	16	804	0	772	537	0.2	12	3.60	2,670	546	0	74	14	4,030	7.6
Leurie Hartwig	133-63-18bcc	140	9	10-31-72	28	0.30	0.16	23	9.1	297	7.4	652	0	164	27	0.2	6.6	1.90	873	95	0	86	13	1,390	7.7
Ilia Podenski	133-63-20bca	80	10	10-31-72	29	0.31	0.06	15	5.0	516	9.3	868	0	24	324	0.3	8.8	3.10	1,390	58	0	94	29	2,330	7.7
Milton Musland	133-64-2dcc	110	8	10-31-72	29	4.90	1.50	53	30	413	9.8	312	0	665	124	0.2	11	1.30	1,470	257	1	77	11	2,180	7.3
City of Edgeley	133-64-3adc	101	8	6-15-72	28	0.31	1.18	115	39	432	12	478	0	459	406	0.1	2.5	0.29	1,690	446	54	67	8.9	2,720	7.5
City of Edgeley	133-64-3ca	122	10	6-15-72	28	0.09	1.85	42	17	428	8.3	492	0	595	79	0.2	8.3	0.89	1,480	173	0	84	14	2,130	7.5
City of Edgeley	133-64-3dcc	92	10	6-15-72	17	0.55	0.69	72	23	454	9.6	587	0	248	407	0.4	0.5	1.70	1,590	276	0	77	12	2,520	7.7
Glenn Olson	133-64-9aaa	111	9	10-31-72	29	1.00	0.30	22	7.8	490	8.3	772	0	413	74	0.4	9.8	3.00	1,420	87	0	92	23	2,180	7.7
Wesley Everet	133-64-17daa	160	8	11-1-72	29	0.16	0.08	38	12	1,010	15	1,190	0	575	593	0.3	0.4	4.50	2,830	144	0	93	37	4,470	7.7
Bob Hanson	133-64-27aaa	60	7	10-31-72	30	0.62	0.68	31	10	527	9.3	375	0	822	106	0.3	14	1.90	1,710	119	0	90	21	2,510	7.5
Earl Houfstatter	134-64-34aba	25	7	11-1-72	27	2.30	0.08	281	148	529	9.8	484	0	1,980	46	0.3	48	0	3,310	1,310	913	47	6.3	3,980	7.8
Roger Priebe	134-64-32bcc	140	9	11-1-72	27	0.66	0.08	12	4.1	505	6.8	818	0	333	115	0.5	8.5	3.60	1,450	47	0	95	32	2,240	7.8
TILL ASSOCIATED DEPOSITS																									
City of Edgeley	133-64-3bd	82	9	6-15-72	28	0.61	0.58	69	20	216	8.3	398	0	106	231	0.1	6.7	0.43	877	256	0	64	5.9	1,490	7.6
Elmer Heim	133-65-2acc	Spring	8	11-1-72	27	0.62	1.40	92	22	189	11	374	0	370	55	0.2	6.3	1.10	933	322	15	55	4.6	1,410	7.4
Kulm-Edgeley Dam	133-65-14cda		9	7-11-73	23	0.45	0.08	41	16	18	17	253	0	26	4.2	0	1.0	0.19	272	170	0	17	0.6	449	8.1
Emil Weist	134-63-30ccc		9	10-31-72	27	0.20	0.66	50	17	140	6.9	395	0	128	43	0.2	4.1	0.34	563	195	0	60	4.4	926	7.5
EDGELEY AQUIFER																									
Test Hole 8736	134-64-5aab	20	7	7-13-73	26	6.90	0.38	65	21	26	7.0	309	0	41	13	0.2	1.0	0.09	360	250	0	18	0.7	549	7.8
Test Hole 8722	134-64-9bab	40	8	7-11-73	22	2.10	0.25	44	12	220	8.9	473	0	180	69	0.4	2.0	0.60	794	160	0	74	7.6	1,250	8.2
Test Hole 8721	134-64-9bbb	25	7	7-10-73	26	2.80	0.74	67	25	22	6.0	266	0	75	14	0.1	2.5	0.13	372	270	52	15	0.6	564	7.9
Test Well	134-64-15cbb5	40	7	9-20-73	26	0.86	0.16	45	16	42	3.1	274	0	32	11	0.2	0.2	0	308	180	0	33	1.4	513	7.6
Test Well	134-64-15cbb5	40	7	10-20-73	26	0.86	0.17	45	19	40	3.1	271	0	35	9.6	0.4	1.0	0.17	309	190	0	31	1.3	509	7.7
Test Well	134-64-15cbb5	40	8	10-22-73	26	0.90	0.17	45	19	39	3.2	268	0	40	9.3	0.3	0.2	0	320	190	0	30	1.2	500	7.6
Test Well	134-64-15cbb5	40	7	10-25-73	26	0.94	0.17	47	20	36	2.9	267	0	45	15	0.2	2.5	0.30	310	200	0	28	1.1	510	7.6
Test Hole 8718	134-64-16abb	40	7	7-10-73	25	0.87	0.40	65	31	28	5.8	267	0	130	8.5	0.1	1.0	0.16	428	290	71	17	0.7	642	8.0
Test Hole 8717	134-64-16daa	40	7	7-9-73	26	1.10	0.36	53	24	25	4.5	265	0	69	7.6	0.1	1.0	0.16	343	230	13	19	0.7	519	7.9
Anton Forsman	134-64-17bcb	13	8	11-1-72	27	0.14	0	72	36	14	2.8	268	0	44	21	0.1	92	0	385	329	109	8	0.3	685	7.6
Test Hole 8710	134-64-22aba	26	7	6-22-73	26	0.72	0.30	53	26	70	6.6	405	0	61	11	0.2	1.0	0.44	456	240	0	38	2.0	734	8.0
Test Hole 8712	134-64-22bbb	30	7	6-22-73	26	0.98	0.36	58	26	28	3.9	257	0	87	9.4	0.1	1.0	0.22	368	250	40	19	0.8	579	7.9
Test Hole 8726	134-64-22bcb	15	7	7-11-73	23	1.30	0.56	128	51	110	16	398	0	310	100	0.1	1.0	0	937	530	200	30	2.1	1,400	7.8
W. Moch	134-64-22dcc	21	8	11-1-72	24	0.14	0.12	80	37	73	5.1	452	0	109	21	0.1	22	0.04	612	352	0	31	1.7	956	7.4
W. Moch	134-64-22dcc	14	7	11-1-72	26	0.14	0.32	99	41	59	5.0	460	0	26	26	0.1	30	0.08	639	417	40	23	1.3	1,010	7.6

TABLE 4 -- LOGS OF TEST HOLES

The following test hole logs are a summary of data from driller's logs, geologist's sample descriptions and resistivity and spontaneous potential electric logs.

Grain-size classification is C. K. Wentworth's scale from Pettijohn (1957). Color descriptions are of wet samples and are based upon color standards of the National Research Council (Goddard and others, 1948).

Test holes are called observation wells when they have been completed with 1¼-inch diameter plastic casing and screened at the bottom. Well depths, screened producing intervals (S.I.) and water levels, with date of measurement, are so designated. Water levels are in feet below land surface.

Elevations, based on mean sea level datum, were obtained by the Water Commission survey crew and interpreted from the Edgeley Quadrangle, published by the U. S. Geological Survey.

Explanation of Lithologic Symbols

Sand or Gravel

Clayey Silt or Silty Clay

Till

Shale

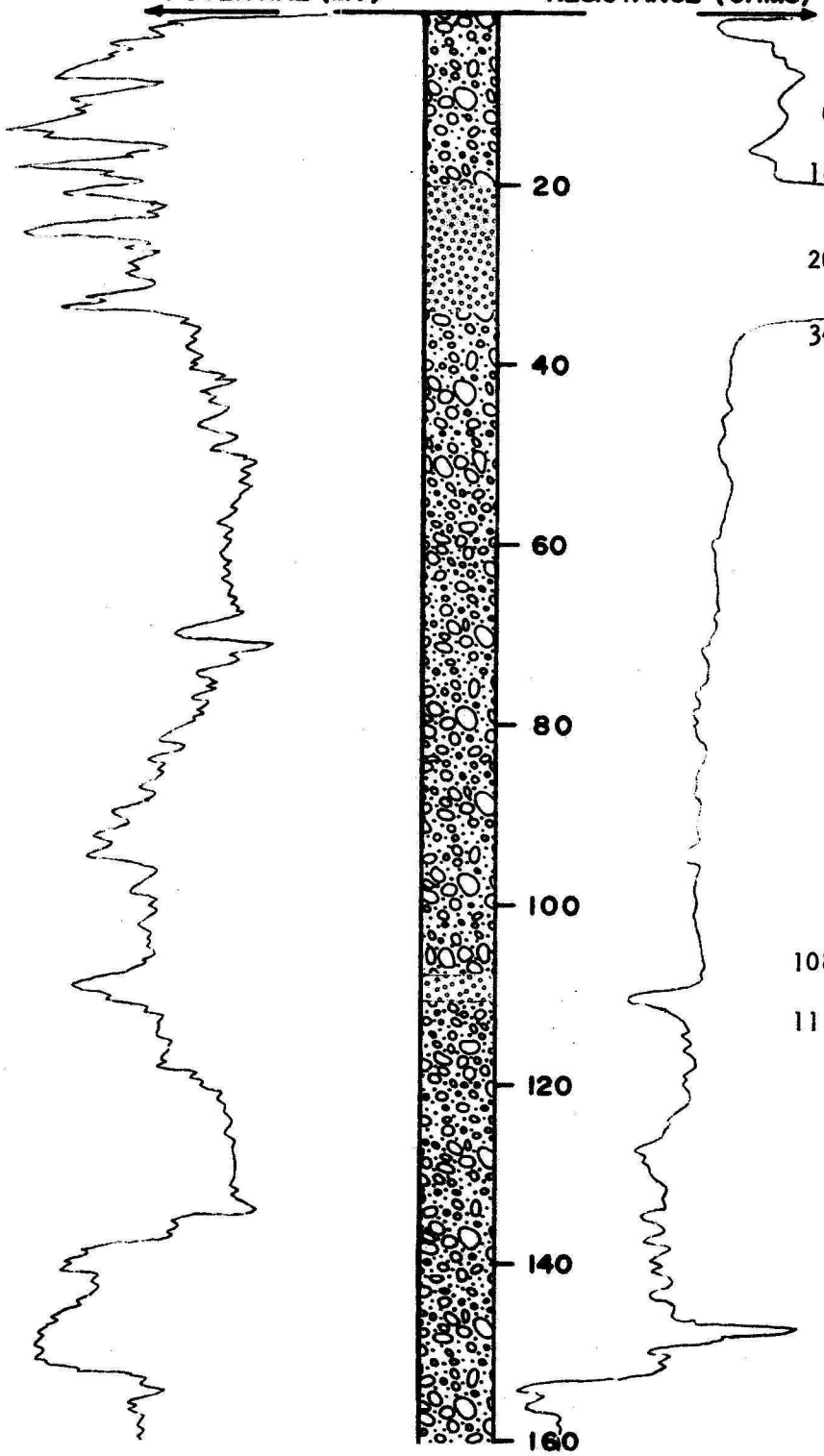
TEST HOLE 8734

LOCATION: 133-62-6AAA

DATE DRILLED: July, 1973

ELEVATION: 1490
(FT, MSL)

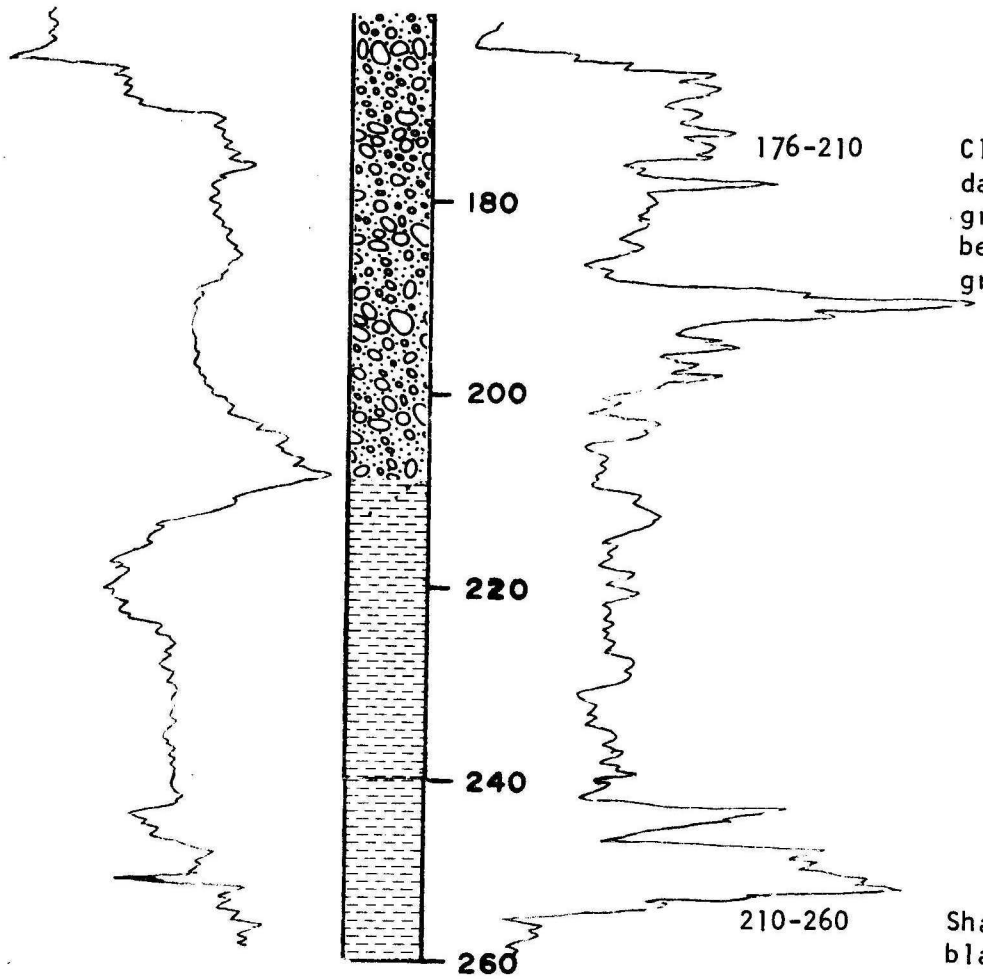
DEPTH: 260
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-18	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
18-20	Clay, silty, very sandy, pebbly, olive-gray, plastic, calcareous (till).
20-34	Sand, fine to coarse, shaly, well-sorted.
34-108	Clay, silty, sandy, pebbly, olive-gray, calcareous (till).
108-111	Gravel, fine to medium, sandy, loose.
111-176	Clay, silty, sandy, pebbly, olive-gray, gravel stringers, calcareous (till).



176-210 Clay, sandy, pebbly, medium-dark-gray with dark-greenish-gray mottling, much maserated bentonitic shale, lignitic, gravel stringers (till).

Pierre Formation

210-260 Shale, siliceous, grayish-black, bentonitic, slightly maserated, noncalcareous.

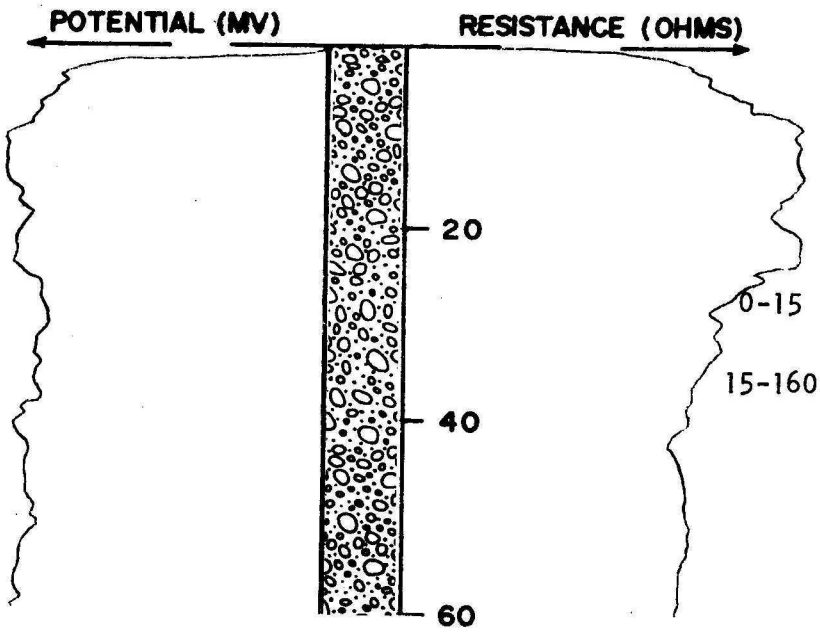
TEST HOLE 8705

LOCATION: 133-63-2AAA

DATE DRILLED: June, 1973

ELEVATION: 1495
(FT, MSL)

DEPTH: 180
(FT)

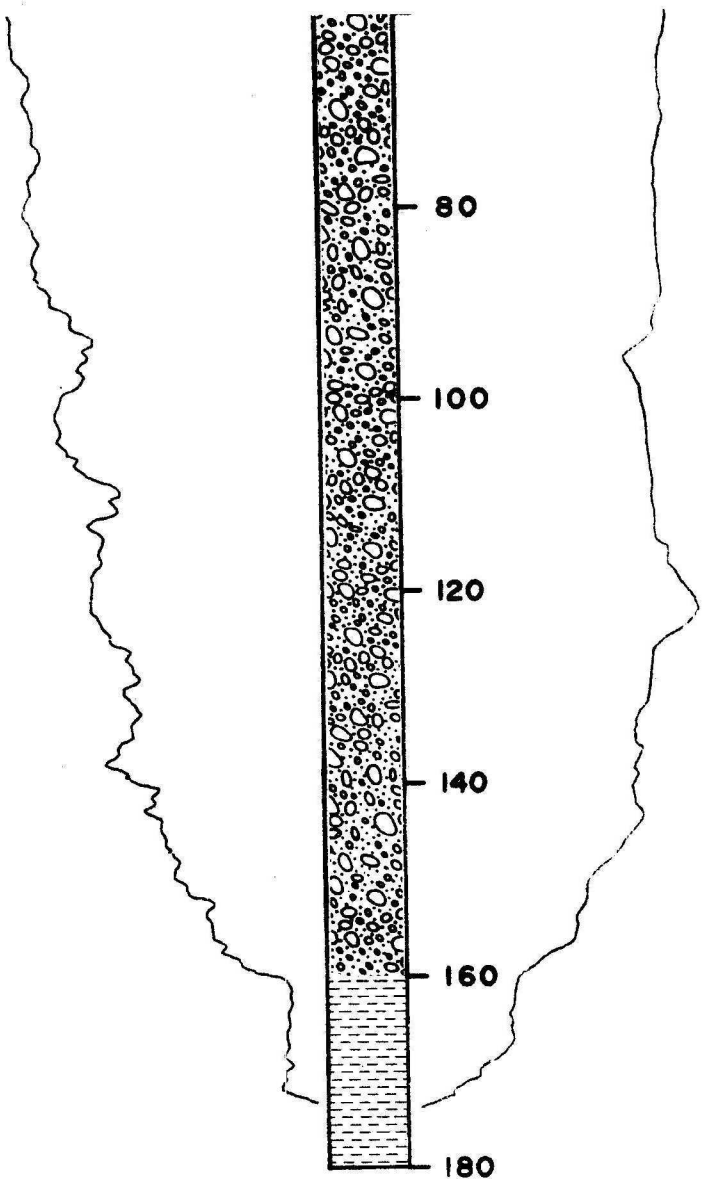


DESCRIPTION OF DEPOSITS

Glacial Drift

0-15 Clay, silty, pebbly, yellowish-brown, oxidized (till).

15-160 Clay, silty, pebbly, iron concretions, olive-gray, calcareous (till).



Pierre Formation

160-180 Shale, black, fractured, brittle, noncalcareous.

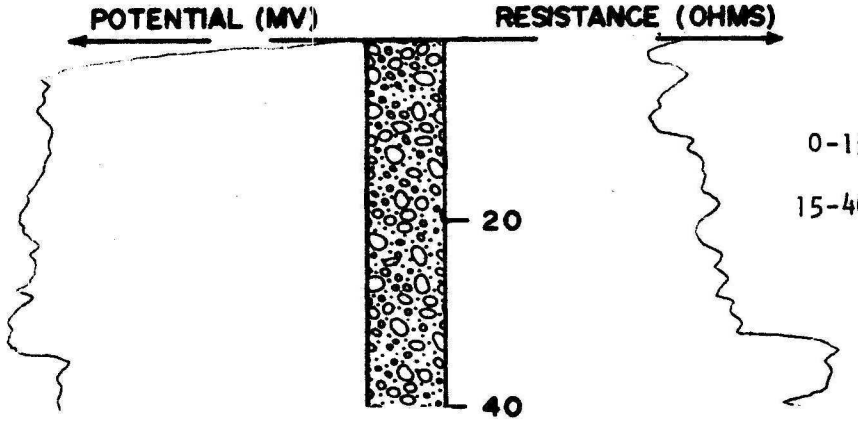
TEST HOLE 8702

LOCATION: 133-63-5AAA

DATE DRILLED: June, 1973

ELEVATION: 1525
(FT, MSL)

DEPTH: 80
(FT)

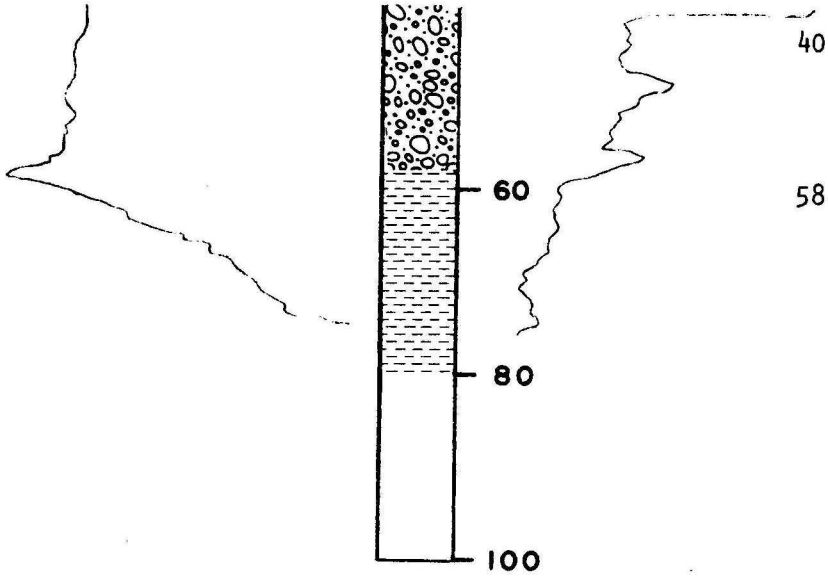


DESCRIPTION OF DEPOSITS

Glacial Drift

0-15 Clay, silty, gravelly, yellowish-brown, oxidized (till).

15-40 Clay, silty, olive-gray, numerous sand stringers, calcareous (till).



40-58	Clay, silty, pebbly, olive-gray, calcareous (till).
58-80	Pierre Formation Shale, siliceous, black, brittle, fissile, noncalcareous.

133-63-6BAA
Test Hole 8700
Elevation 1510 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, sandy clay loam, light brown	1	1
	Sand, medium to very coarse, gravelly, sub-angular to well-rounded, shaly	8	9
Pierre Formation:			
	Shale, siliceous, dark gray to black, fissile, fractured	11	20

133-63-8BBA
Test Hole 8732
Elevation 1520
Drilled July, 1973

Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	7	7
	Sand, medium to very coarse, gravelly, subrounded, fair sorting	8	15
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fractured	5	20

133-63-27CCB
Test Hole 8733
Elevation 1495
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, very silty, sandy, yellowish-brown, oxidized (alluvium)	5	5
	Sand, fine to very coarse, gravelly, sub-angular to subrounded, fair sorting, shaly	6	11
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fractured, noncalcareous	9	20

133-64-1AAA
Test Hole 8699
Elevation 1525 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, sandy, pebbly, yellowish-brown, oxidized (till)	21	21
	Clay, silty, pebbly, olive-gray, calcareous (till)	3	24
	Sand, fine to very coarse, well-rounded	7	31
Pierre Formation:			
	Shale, siliceous, dark-gray to black, fissile, fractured	29	60

133-64-3AAA
Test Hole 8697
Elevation 1545 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial Drift:			
	Topsoil, silty clay loam, black	1	1
Pierre Formation:			
	Shale, siliceous, yellowish-brown, weathered, oxidized, fractured	9	10
	Shale, siliceous, black, fractured	30	40

133-64-3ADC
City of Edgeley 1
(Log from C. A. Simpson and Son)
Elevation 1540 feet
Drilled July, 1967

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil	1	1
	Clay, sandy, rocks, yellow	14	15
Pierre Formation:			
	Shale, blue	86	101

Well completed with 42 feet of 6-inch and 64 feet of 5-inch diameter black steel casing, perforated lower 60 feet.
Finished well depth 101 feet.

133-64-3BD
City of Edgeley 2
(Log from C. A. Simpson and Son)
Elevation 1555 feet
Drilled July, 1963

Glacial drift:			
	Topsoil	1	1
	Clay, yellow	23	24
	Clay, blue	7	31
	Sand, very fine, clayey	20	51
	Sand, clayey	5	56
	Sand, fine, some clay	4	60
	Sand, gravelly, clayey	3	63
	Gravel, coarse, rocks	10	73
	Sand, clayey	1	74
	Sand, gravelly	1	75
	Clay, hard	½	75½
	Sand, gravelly, water	6½	82
	Clay, gravelly		82

Well completed with 78 feet of 6-inch diameter black steel casing and 7 feet of 6-inch telescope size, #40 slot, evurdur screen. Finished well depth 82 feet.

133-64-3CA
City of Edgeley 3
(Log from C. A. Simpson and Son)
Elevation 1560 feet
Drilled July, 1963

Glacial drift:		
Topsoil	1	1
Clay, sandy, gravelly	13	14
Clay, sandy, gravelly, rocks	24	38
Pierre Formation:		
Shale	84	122

Well completed with 64 feet of 6-inch and 61 feet of 5-inch black steel casing, perforated lower 80 feet. Finished well depth 122 feet.

133-64-5AAA
Test Hole 8695
Elevation 1605 feet
Drilled June, 1973

Glacial drift:		
Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	20	20
Clay, silty, pebbly, olive-gray, calcareous (till)	15	35
Pierre Formation:		
Shale, siliceous, grayish-black to black, brittle, fractured, noncalcareous	25	60

133-64-15ADD
Elevation 1560 feet
Drilled July, 1973

Glacial drift:		
Clay, silty, pebbly, yellowish-brown, oxidized (till)	7	7
Pierre Formation:		
Shale, siliceous, medium-dark-gray with reddish-brown staining, brittle, non-calcareous	13	20

133-64-15BBB
Test Hole 8731
Elevation 1560 feet
Drilled July, 1973

Glacial drift:		
Clay, silty, sandy, pebbly, cobbles, yellowish-brown, oxidized (till) ----------	11	11
Clay, sandy, pebbly, gravelly, olive-gray, calcareous (till) ----------	12	23
Pierre Formation:		
Shale, siliceous, grayish-black, brittle, fractured, noncalcareous ----------	17	40

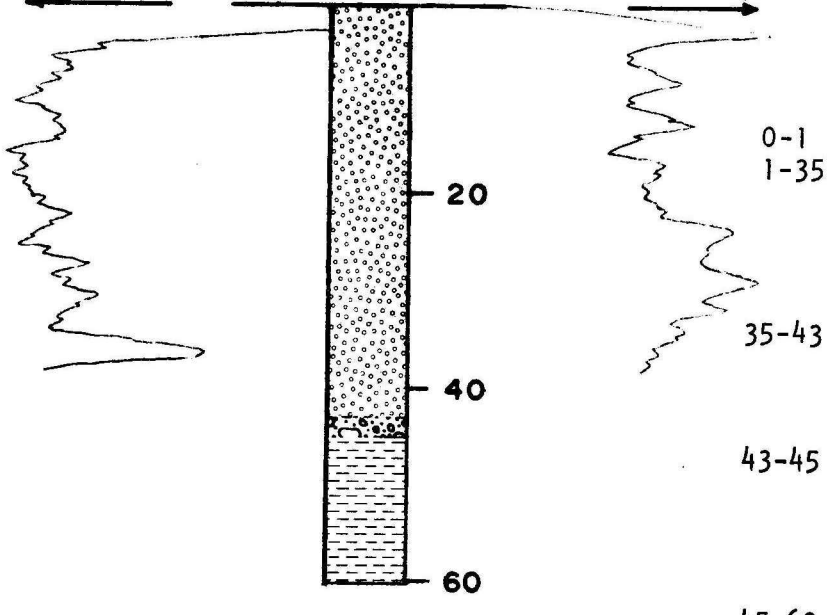
TEST HOLE 8915-D

LOCATION: 134-64-15CBB$_4$

DATE DRILLED: October, 1973

ELEVATION: (FT, MSL)

DEPTH: 60 feet (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, sandy loam, brown.

1-35 Sand, fine to very coarse, about 10 percent gravel, sub-rounded, moderately well-sorted, loose, taking water rapidly.

35-43 Gravel, fine to coarse, about 25 percent sand, subangular to well-rounded, fair sorting, loose, taking water.

43-45 Clay, silty, pebbly. olive-gray (till).

Pierre Formation

45-60 Shale, siliceous, grayish-black, brittle.

Observation Well
135 feet west of test well
Depth -- 43 feet
S. I. -- 37-43 feet
Water level -- 8.35 feet
Measured -- 10-9-73

134-64-15CBB$_5$
Test Well
Drilled October, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy loam, brown	1	1
	Sand, gravelly, oxidized	12	13
	Sand, gravelly, unoxidized	2	15
	Clay, silty, gravelly, pebbly, olive-gray (till)	8	23
	Gravel, sandy, cobbles, lignitic	16	39
	Sand, fine, clayey	1	40
	Clay, silty, gravelly, pebbly, olive-gray, (till)		40

Test well completed with 30½ feet of 8-inch diameter black steel casing and 10 feet of 25 slot 8-inch screen. Screened interval 29½-39½ feet. Casing and screen pulled and well was abandoned after test.

Water level -- 8.20 feet
Measured -- 10-20-73

133-64-19DCD
Test Hole 8729 .
Elevation 1620 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, fine to very coarse, gravelly, subrounded, oxidized	6	6
	Clay, sandy, silty, pebbly, yellowish-brown, oxidized (till)	6	12
	Clay, silty, pebbly, olive-gray, calcareous (till)	41	53
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fractured, noncalcareous	7	60

133-64-26CCC
Test Hole 8728
Elevation 1560 feet
Drilled July, 1973

Glacial drift:		
Topsoil, sandy, shaly, clay loam, black -	1	1
Pierre Formation:		
Shale, siliceous, grayish-black with reddish-orange oxidation staining, brittle, noncalcareous ----------	19	20

133-65-14DDA
Test Hole 8730
Elevation 1680 feet
Drilled July, 1973

Glacial drift:		
Clay, sandy, pebbly, cobbles, boulders, dusky yellow, oxidized (till) ----------	11	11
Sand, fine to very coarse, subrounded, uniform, shaly, partially oxidized ------	24	35
Clay, silty, sandy, pebbly, olive-gray, calcareous (till) ----------	14	49
Pierre Formation:		
Shale, siliceous, grayish-black, brittle, noncalcareous ----------	11	60

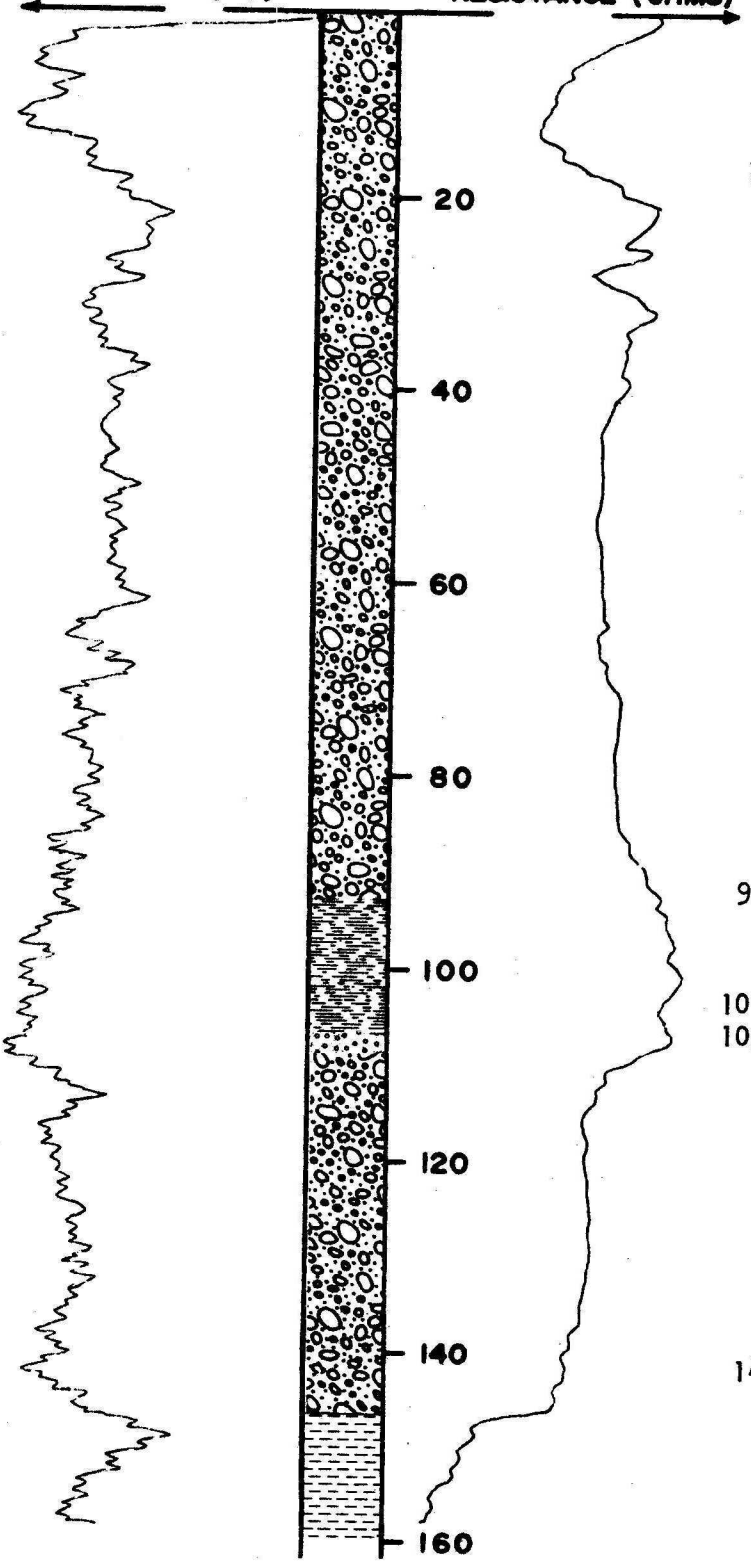
TEST HOLE 8706

LOCATION: 134-63-16CCC

DATE DRILLED: June, 1973

ELEVATION: 1510
(FT, MSL)

DEPTH: 160
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-14	Clay, sandy, silty, pebbly, yellowish-brown, oxidized (till).
14-93	Clay, silty, sandy, pebbly, olive-gray, calcareous (till).
93-107	Silt, sandy, clayey, dark-gray to black, calcareous (glaciofluvial deposit).
107-109	Sand, fine to medium, lignitic.
109-147	Clay, silty, sandy, pebbly, olive-gray, cohesive, carbonaceous (till).

Pierre Formation

147-160	Shale, siliceous, black, brittle, noncalcareous.

134-63-31BBB
Test Hole 8707
Elevation 1540 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	14	14
	Clay, silty, pebbly, olive-gray, calcareous (till)	33	47
Pierre Formation:			
	Shale, siliceous, dark-gray to grayish-black, brittle, fractured, noncalcareous	13	60

134-63-31DDD
Test Hole 8701
Elevation 1525 feet
Drilled June, 1973

Glacial drift:			
	Clay, silty, sandy, pebbly, gravelly, yellowish-brown, oxidized (till)	20	20
	Clay, silty, gravelly, olive-gray (till)	15	35
Pierre Formation:			
	Shale, black, brittle, fractured, noncalcareous	25	60

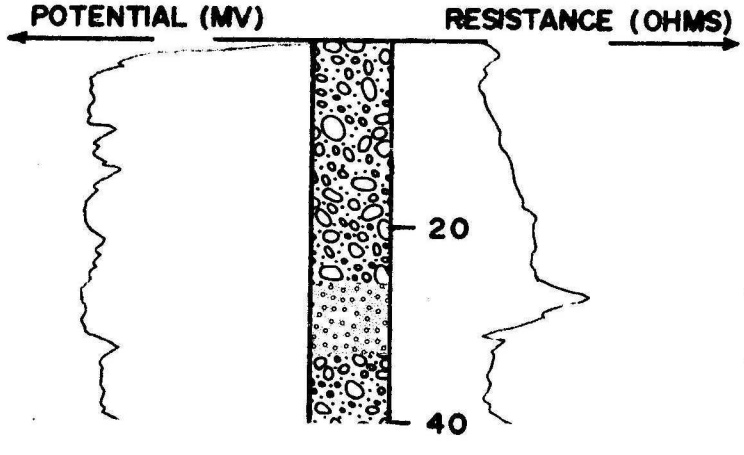
TEST HOLE 8703

LOCATION: 134-63-34CCC

DATE DRILLED: June, 1973

ELEVATION (FT, MSL): 1510

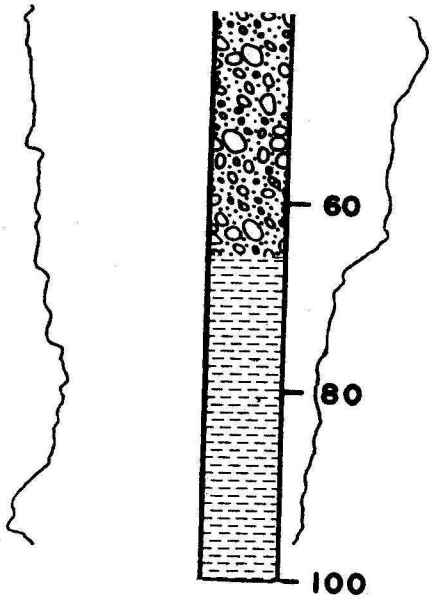
DEPTH (FT): 100



DESCRIPTION OF DEPOSITS

Glacial Drift

0-15	Clay, silty, gravelly, yellowish-brown, oxidized (till).
15-26	Clay, sandy, gravelly, olive-gray, calcareous (till).
26-33	Sand, fine to very coarse, lignitic.
33-66	Clay, sandy, gravelly, olive-gray, calcareous (till).



66-100 Pierre Formation

Shale, siliceous, black, brittle, fractured, noncalcareous.

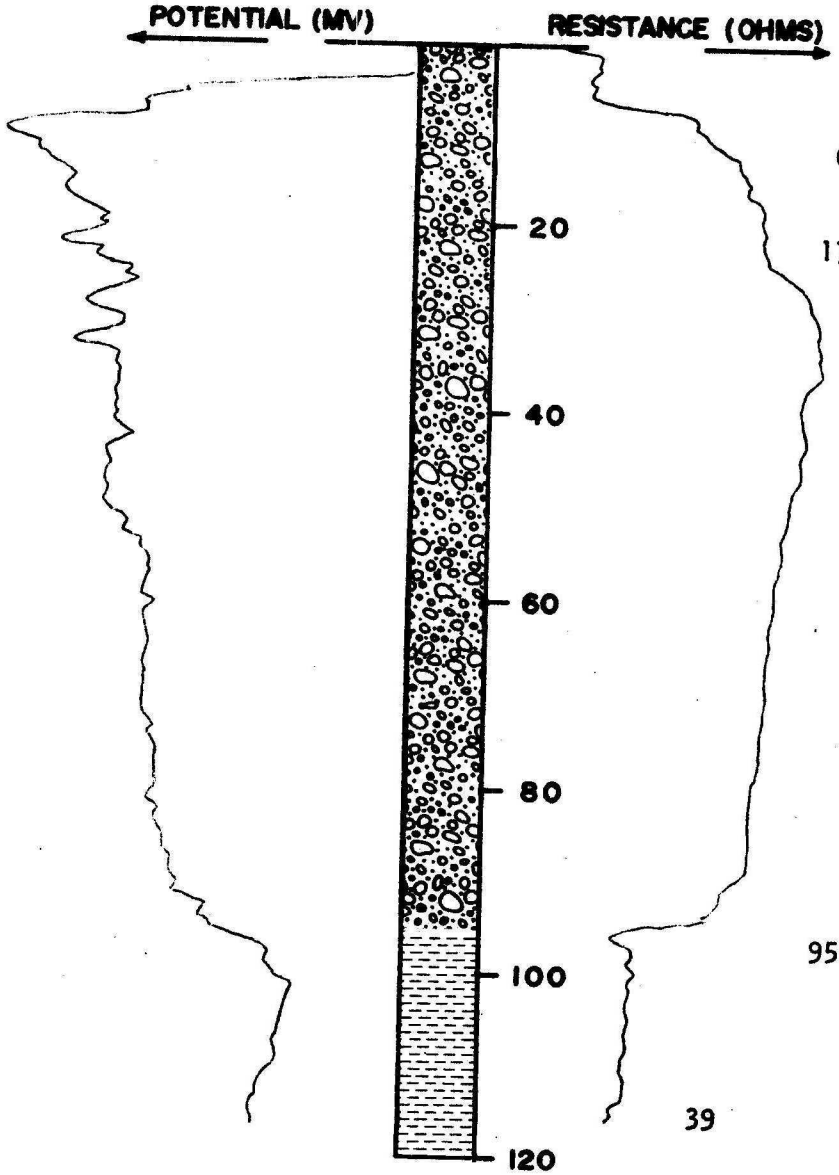
TEST HOLE 8704

LOCATION: 134-63-35CCC

ELEVATION: 1495 (FT, MSL)

DATE DRILLED: June, 1973

DEPTH: 120 (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-17 Clay, silty, sandy, gravelly, pebbly, yellowish-brown, oxidized (till).

17-95 Clay, silty, sandy, gravelly, olive-gray, gravel stringers, calcareous (till).

Pierre Formation

95-120 Shale, siliceous, black, brittle, fissile, noncalcareous.

134-64-5AAB
Test Hole 8736
Elevation 1536.5 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, very silty, medium gray, plastic, highly calcareous, (alluvium)	2	2
	Sand, fine to very coarse, light brown, loose, subrounded, well-sorted, oxidized	6	8
	Silt, clayey, medium-light-gray, lignitic, soft (glaciofluvial sediment)	5	13
	Sand, fine to very coarse, mostly coarse to very coarse, about 40 percent gravel, subangular to rounded, well-sorted, taking water, loose	10	23
	Clay, silty, pebbly, gravelly, olive-gray, (till)	17	40

Observation Well
Depth 20 feet
S.I. -- 17-20 feet
Water level -- 3.42 feet
Measured -- 8-10-73

134-64-8ABB
Test Hole 8723
Elevation 1550 feet
Drilled July, 1973

Glacial drift:			
	Topsoil, sandy loam, brown	1	1
	Sand, medium to very coarse, gravelly, reddish-brown, oxidized	3	4
	Clay, silty, sandy, pebbly, olive-gray, occasional gravel stringers, calcareous (till)	36	40

134-64-9BAB
Test Hole 8722
Elevation 1542.3 feet
Drilled July, 1973

Glacial drift:			
	Sand, fine to very coarse, about 15 percent gravel, dark gray, well-sorted, loose	13	13
	Clay, sandy, pebbly, olive-gray, calcareous (till)	23	36
	Gravel, fine to medium, about 30 percent sand, subangular to well-rounded, moderately well-sorted, loose, taking water rapidly	7	43
	Clay, silty, sandy, pebbly, olive gray (till)	17	60

Observation Well
Depth 40 feet
S. I. -- 37-40 feet
Water level -- 4.44 feet
Measured -- 8-10-73

134-64-9BBB
Test Hole 8721
Elevation 1547.8 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy loam, brown	½	½
	Sand, fine to very coarse, about 25 percent gravel, subangular to rounded, moderately well-sorted, shaly, lignitic, loose, taking water rapidly	19½	20
	Gravel, fine to coarse, about 30 percent sand, subrounded to well-rounded, well-sorted, loose, taking water	10	30
	Clay, sandy, pebbly, olive-gray (till)	2	32
	Gravel, fine to coarse, subrounded, loose	2	34
	Clay, silty, pebbly, olive-gray (till)	2	36
	Gravel, fine to coarse, about 30 percent sand, subangular to rounded, fair sorting, loose	9	45
	Clay, silty, pebbly, olive-gray (till)	71	116
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous	4	120

Observation Well
Depth 25 feet
S. I. -- 22-25 feet
Water level -- 7.97 feet
Measured -- 8-10-73

134-64-14CCD
Test Hole 8714
Elevation 1535 feet
Drilled June, 1973

Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown	12	12
	Clay, silty, sandy, pebbly, olive-gray	9	21
	Sand, coarse to very coarse	2	23
	Clay, silty, pebbly, olive-gray (till)	10	33
Pierre Formation:			
	Shale, black, brittle, fissile, non-calcareous	7	40

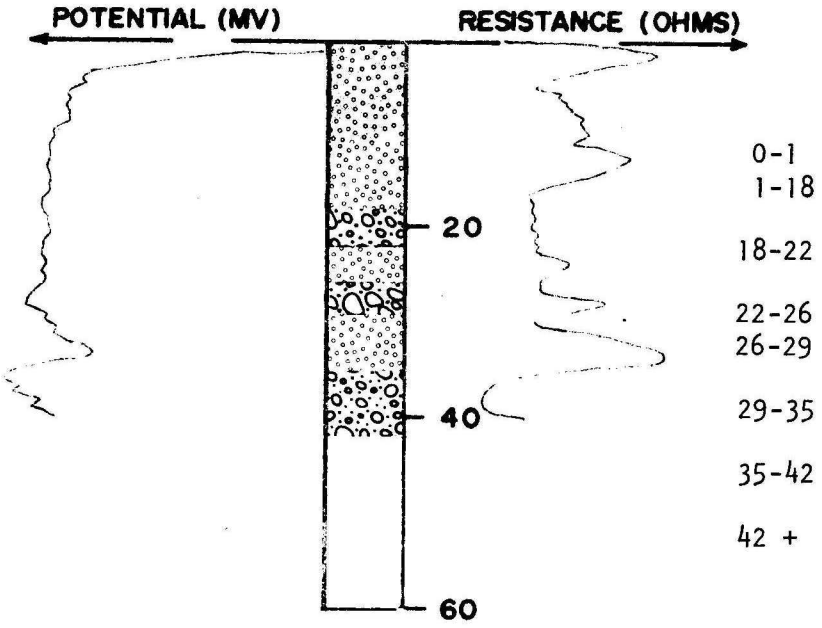
TEST HOLE 8915-C

LOCATION: 134-64-15BCC

DATE DRILLED: October, 1973

ELEVATION:
(FT, MSL)

DEPTH: 42 feet
(FT)



0-1
1-18
18-22
22-26
26-29
29-35
35-42
42 +

DESCRIPTION OF DEPOSITS

Glacial Drift

Topsoil, sandy, brown.
Sand, fine to very coarse, about 5 percent gravel, oxidized.
Clay, silty, pebbly, olive-gray (till).
Sand, medium to coarse.
Clay, silty, pebbly, olive-gray (till).
Sand, fine to very coarse, about 5 percent gravel.
Clay, silty, pebbly, olive-gray (till).
Boulder, granite, hard.

Observation Well
300 feet north of test well
Depth 35 feet
S. I. -- 29-35 feet
Water level -- 4.03 feet
Measured -- 10-9-73

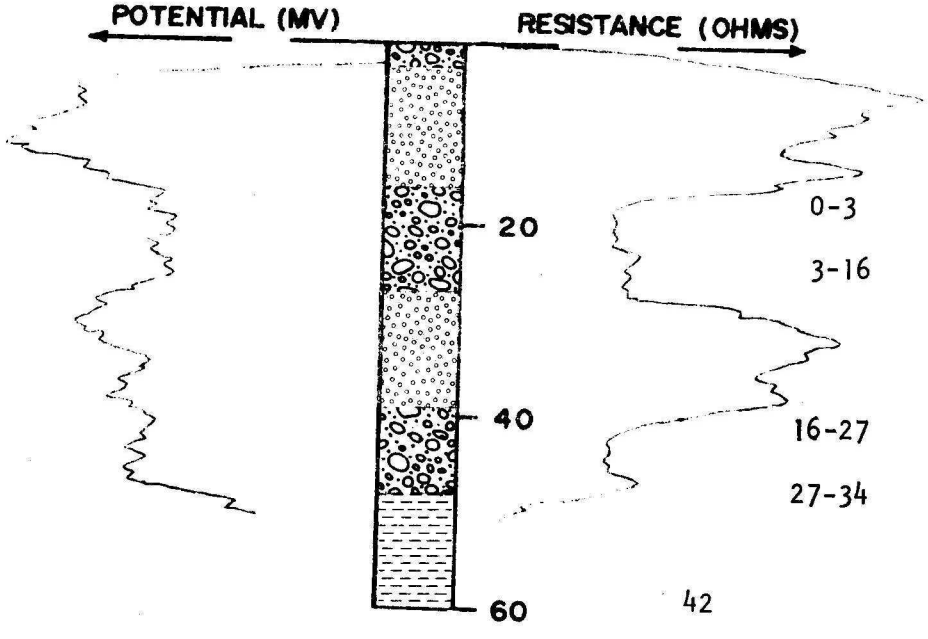
TEST HOLE 8915

LOCATION: 134-64-15CBB$_1$

DATE DRILLED: October, 1973

ELEVATION:
(FT, MSL)

DEPTH: 60 feet
(FT)



0-3
3-16
16-27
27-34

DESCRIPTION OF DEPOSITS

Glacial Drift

Clay, silty, pebbly, yellowish-brown (till).
Sand, fine to very coarse, about 10 percent fine gravel, subrounded, moderately well-sorted, shaly, oxidized to about 10 feet, taking water.
Clay, silty, pebbly, olive-gray (till).
Sand, fine to very coarse, subrounded, well-sorted, shaly, taking water.

34-39	Gravel, fine to coarse, about 20 percent sand, angular to well-rounded, taking water, loose.
39-48	Clay, silty, pebbly, olive-gray (till).
	Pierre Formation
48-60	Shale, siliceous, grayish-black, brittle, fissile, a few light gray concretions.

Observation Well
80 feet east of test well
Depth 39 feet
S. I. -- 36-39 feet
Water level -- 6.92 feet
Measured -- 10-9-73

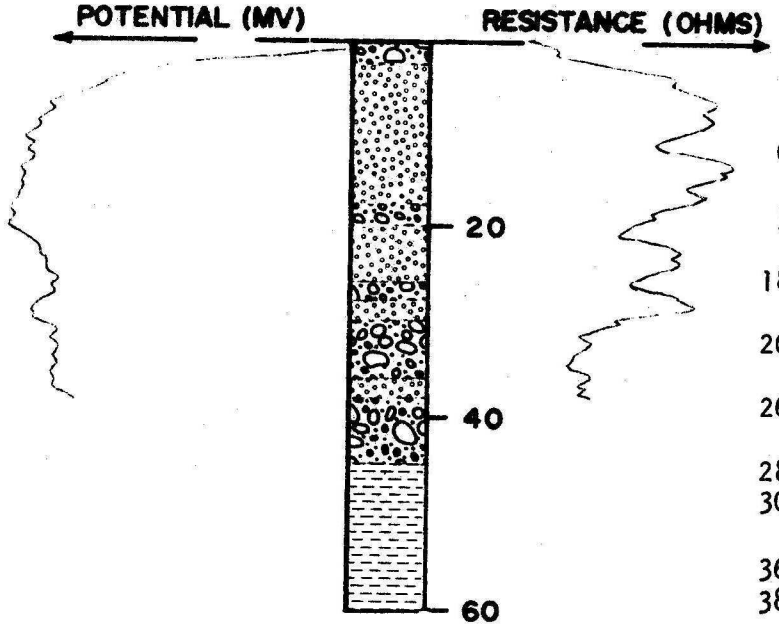
TEST HOLE 8915-A

LOCATION: 134-64-15CBB$_2$

DATE DRILLED: October, 1973

ELEVATION:
(FT, MSL)

DEPTH: 60 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-3	Clay, sandy, pebbly, yellowish-brown (till).
3-18	Sand, medium to coarse, well-sorted.
18-20	Clay, silty, pebbly, olive-gray (till).
20-26	Sand, fine to coarse, lignitic, loose, taking water.
26-28	Clay, sandy, pebbly, olive-gray (till).
28-30	Sand, fine to coarse, well-sorted.
30-36	Clay, silty, pebbly, olive-gray (till).
36-38	Gravel, sandy, fine to medium
38-45	Clay, silty, pebbly, olive-gray (till).
	Pierre Formation
45-60	Shale, siliceous, grayish-black, brittle.

Observation Well
350 feet southeast of test well
Depth 26 feet
S. I. -- 20-26 feet
Water level -- 3.16 feet
Measured -- 10-9-73

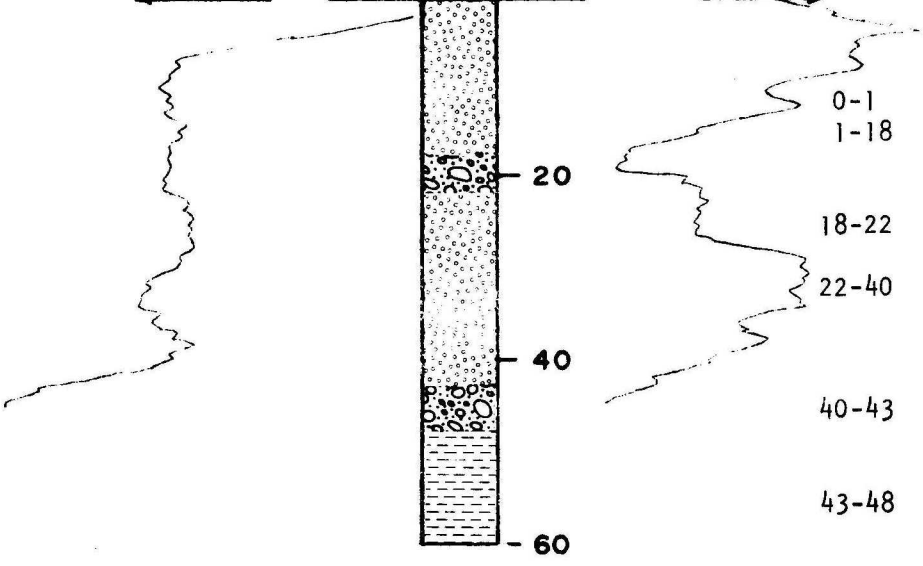
TEST HOLE 8915-B

LOCATION: 134-64-15CBB$_3$

DATE DRILLED: October, 1973

ELEVATION:
(FT, MSL)

DEPTH: 60 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, sandy loam, brown.
1-18	Sand, medium to very coarse, about 10 percent gravel, loose, fair sorting.
18-22	Clay, silty, pebbly, olive-gray (till).
22-40	Sand, fine to very coarse, about 20 percent gravel, lignitic, loose, taking water rapidly.
40-43	Gravel, fine to coarse, sub-angular to well-rounded, loose, taking water.
43-48	Clay, silty, pebbly, olive-gray (till).

Pierre Formation

48-60	Shale, siliceous, black, brittle.

Observation Well
30 feet south of test well
Depth -- 43 feet
S. I. -- 37-43 feet
Water level -- 8.07 feet
Measured -- 10-9-73

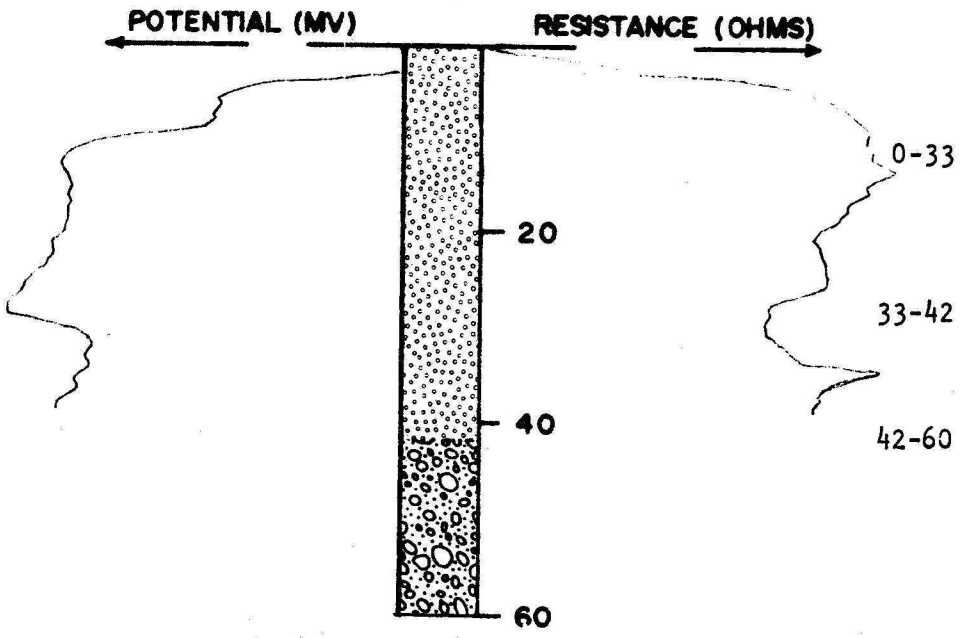
TEST HOLE 8718

LOCATION: 134-64-16ABB

DATE DRILLED: July, 1973

ELEVATION: 1554.5 feet
(FT, MSL)

DEPTH: 60 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-33 Sand, fine to very coarse, about 25 percent gravel, subangular to rounded, well-sorted, lignitic, loose, taking water.

33-42 Gravel, fine to medium, about 30 percent sand, subangular to well-rounded, shaly, loose, taking water rapidly.

42-60 Clay, silty, pebbly, olive-gray (till).

Observation Well
Depth 40 feet
S. I. -- 37-40 feet
Water level -- 11.43 feet
Measured -- 8-10-73

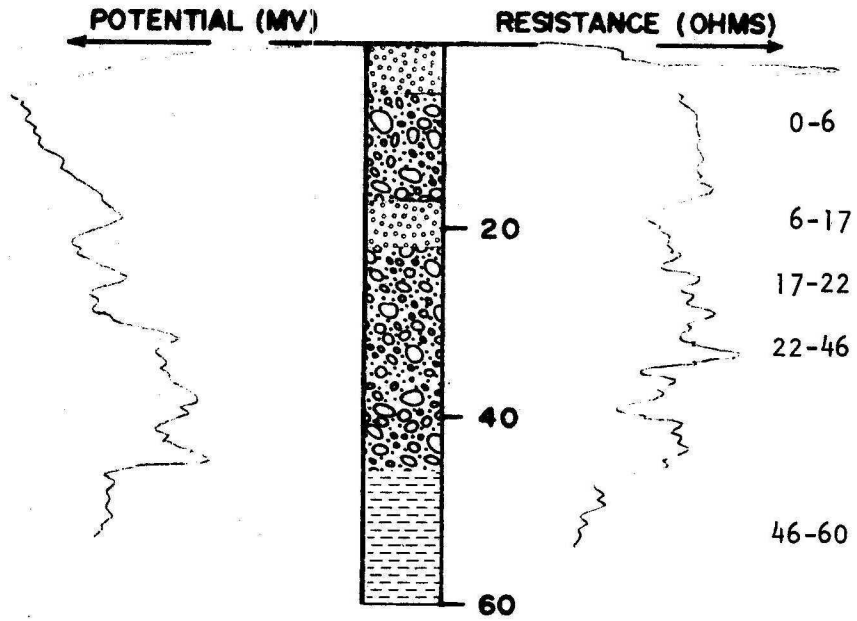
TEST HOLE 8719

LOCATION: 134-64-16BBB

DATE DRILLED: July, 1973

ELEVATION: 1560 feet
(FT, MSL)

DEPTH: 60 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-6 Sand, fine to very coarse, about 40 percent gravel, subangular to rounded, light brown, oxidized.

6-17 Clay, sandy, pebbly, olive-gray (till).

17-22 Sand, fine to very coarse, loose.

22-46 Clay, silty, sandy, pebbly, olive-gray, occasional gravel stringers (till).

Pierre Formation

46-60 Shale, siliceous, grayish-black, noncalcareous.

134-64-16CCC
Test Hole 8720
Elevation 1560 feet
Drilled July, 1973

Geologic Source	Material	Thickness (Feet)	Depth (feet)
Glacial drift:			
	Sand, fine to very coarse, about 30 percent gravel, light brown, oxidized	7	7
	Clay, silty, pebbly, olive-gray (till)	25	32
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, noncalcareous	8	40

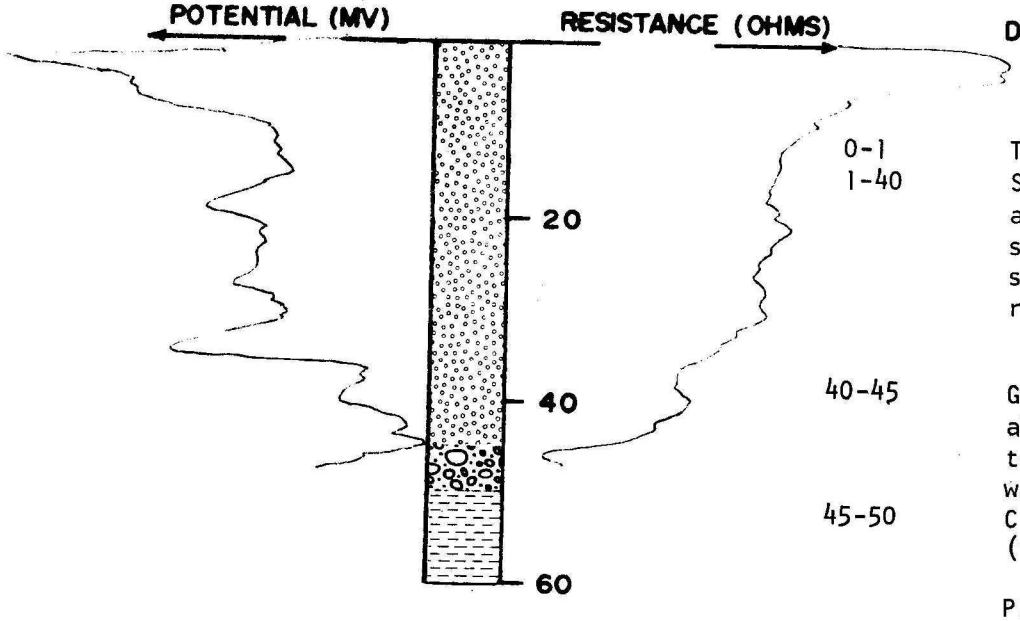
TEST HOLE 8717

LOCATION: 134-64-16DAA

DATE DRILLED: June, 1973

ELEVATION: 1548.5 feet (FT, MSL)

DEPTH: 60 feet (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1 Topsoil, silty, sandy, black.

1-40 Sand, fine to very coarse, about 20 percent gravel, subangular to rounded, well-sorted, loose, taking water rapidly.

40-45 Gravel, fine to coarse, cobbles, about 10 percent sand, angular to well-rounded, loose, taking water.

45-50 Clay, silty, pebbly, olive-gray (till).

Pierre Formation

50-60 Shale, siliceous, grayish-black, brittle, fissile, noncalcareous.

Observation Well
200 feet west of test well
Depth 40 feet
S. I. -- 37-40 feet
Water level -- 7.35 feet
Measured -- 8-10-73

134-64-16DCC
Test Hole 8713
Elevation 1545 feet
Drilled June, 1973

Glacial drift:		
Topsoil, sandy loam, brownish-black --------	1	1
Sand, fine to very coarse, gravelly --------	9	10
Clay, silty, pebbly, olive-gray (till) -----	20	30
Pierre Formation:		
Shale, siliceous, brittle, noncalcareous ---	10	40

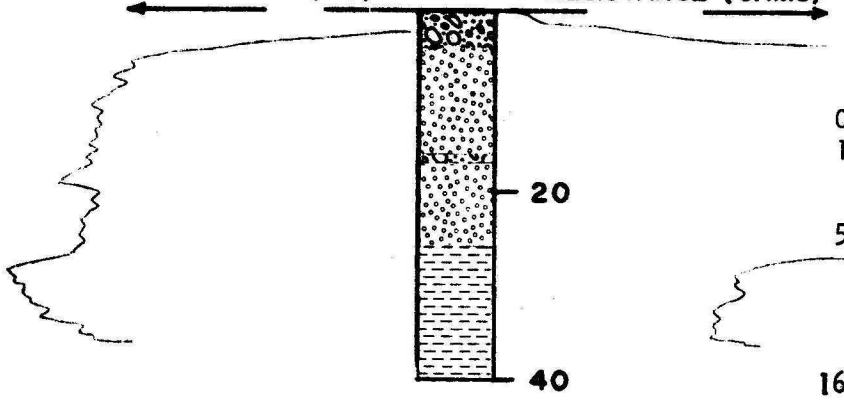
TEST HOLE 8710

LOCATION: 134-64-22ABA

DATE DRILLED: June, 1973

ELEVATION: 1537.4 feet (FT, MSL)

DEPTH: 40 feet (FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-1	Topsoil, sandy, black.
1-5	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till).
5-16	Sand, fine to very coarse, about 30 percent gravel, subangular to rounded, loose, oxidized.
16-17	Clay, silty, pebbly, olive-gray (till).
17-26	Sand, fine to very coarse, about 20 percent gravel, subangular to rounded, moderately well-sorted, loose.

Pierre Formation

26-40	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous.

Observation Well
Depth -- 26 feet
S. I. -- 23-26 feet
Water level -- 4.45 feet

134-64-22ABB
Test Hole 8711
Elevation 1545 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy silt loam, brown ----------	1	1
	Sand, fine to very coarse, about 10 percent gravel, subrounded, partially oxidized ----------	18	19
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous ----------	21	40

134-64-22BBB$_1$
Test Hole 8712
Elevation 1550.0
Drilled June, 1973

Glacial drift:			
	Topsoil, sandy loam, brownish-black -------	1	1
	Sand, fine to medium, about 5 percent gravel ----------	19	20
	Gravel, fine to coarse, about 10 percent sand, subangular to well-rounded, loose, taking water ----------	13	33
	Clay, silty, pebbly, olive-gray (till) ----	5	38
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous ----------	22	60

Observation Well
Depth -- 30 feet
S. I. -- 27-30 feet
Water level -- 11.45 feet
Measured -- 8-10-73

134-64-22BBB$_2$
Test Hole 9171
Elevation 1550
Drilled October, 1974

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, silty, black ----------	1	1
	Sand, fine to coarse ----------	25	26
	Gravel, fine to coarse ----------	8	34
	Clay, silty, pebbly, olive gray (till) -----	6	40

Observation Well
Well diameter 4-inch
Depth -- 32 feet
S.I. -- 27-32 feet

134-64-22BCB
Test Hole 8726
Elevation 1541.3 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Sand, fine to very coarse, about 30 percent gravel, subrounded, well-sorted, shaly	10	10
	Gravel, fine to coarse, about 40 percent sand, subangular to well-rounded, loose, taking water, fair sorting	6	16
	Clay, silty, pebbly, olive-gray, calcareous (till)	13	29
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, noncalcareous	11	40

Observation Well
Depth -- 15 feet
S. I. -- 12-15 Feet
Water level -- 3.87 feet
Measured -- 8-10-73

134-64-22CCD
Test Hole 8716
Elevation 1538 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy loam, brownish-black	1	1
	Sandy, very fine to fine, light brown, oxidized	2	3
	Clay, sandy, pebbly, yellowish-brown, oxidized (till)	8	11
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous	9	20

134-64-22DDC
Test Hole 8715
Elevation 1538 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, sandy clay loam, black	1	1
	Sand, very fine to fine, light brown, oxidized	3	4
Pierre Formation:			
	Shale, siliceous, black, brittle, fractured	16	20

134-64-23CCC
Test Hole 8724
Elevation 1535 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:	Sand, fine to very coarse, subrounded, light-brown, shaly, oxidized	7	7
Pierre Formation:	Shale, siliceous, grayish-black, brittle, noncalcareous	13	20

134-64-23CDC
Test Hole 8725
Elevation 1540 feet
Drilled July, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:	Sand, fine to very coarse, subrounded, shaly, well-sorted, partially oxidized	6	6
Pierre Formation:	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous	14	20

134-64-25DDA
Test Hole 8708
Elevation 1540 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:	Topsoil, silty, sandy loam, brownish-black	1	1
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	13	14
	Clay, silty, pebbly, olive-gray, calcareous (till)	15	29
	Sand, fine to medium, subrounded, iron-stained	3	32
	Silt, clayey, olive-gray	1	33
	Sand, very fine to medium, subrounded, iron-stained	3	36
	Clay, silty, pebbly, olive-gray, calcareous (till)	4	40
Pierre Formation:	Shale, siliceous, black, brittle, fractured, noncalcareous	20	60

134-64-27DDC
Test Hole 8709
Elevation 1537 feet
Drilled June, 1973

Glacial drift:		
Topsoil, silty, pebbly, clay loam, black --	1	1
Sand, medium to very coarse, light brown, oxidized ----------	4	5
Pierre Formation:		
Shale, siliceous, grayish-black, brittle, fractured, noncalcareous ----------	35	40

134-64-32CCC
Test Hole 8694
Elevation 1610 feet
Drilled June, 1973

Glacial drift:		
Clay, silty, pebbly, yellowish-brown, oxidized (till)----------	12	12
Clay, silty, pebbly, cobbles, olive-gray, a few gravel stringers, calcareous (till)-	26	38
Sand, very fine to medium, shaly, sub-rounded, lignitic ----------	2	40
Clay, silty, pebbly, olive-gray, calcareous (till) ----------	48	88
Pierre Formation:		
Shale, siliceous, grayish-black to black, brittle, fractured, noncalcareous --------	12	100

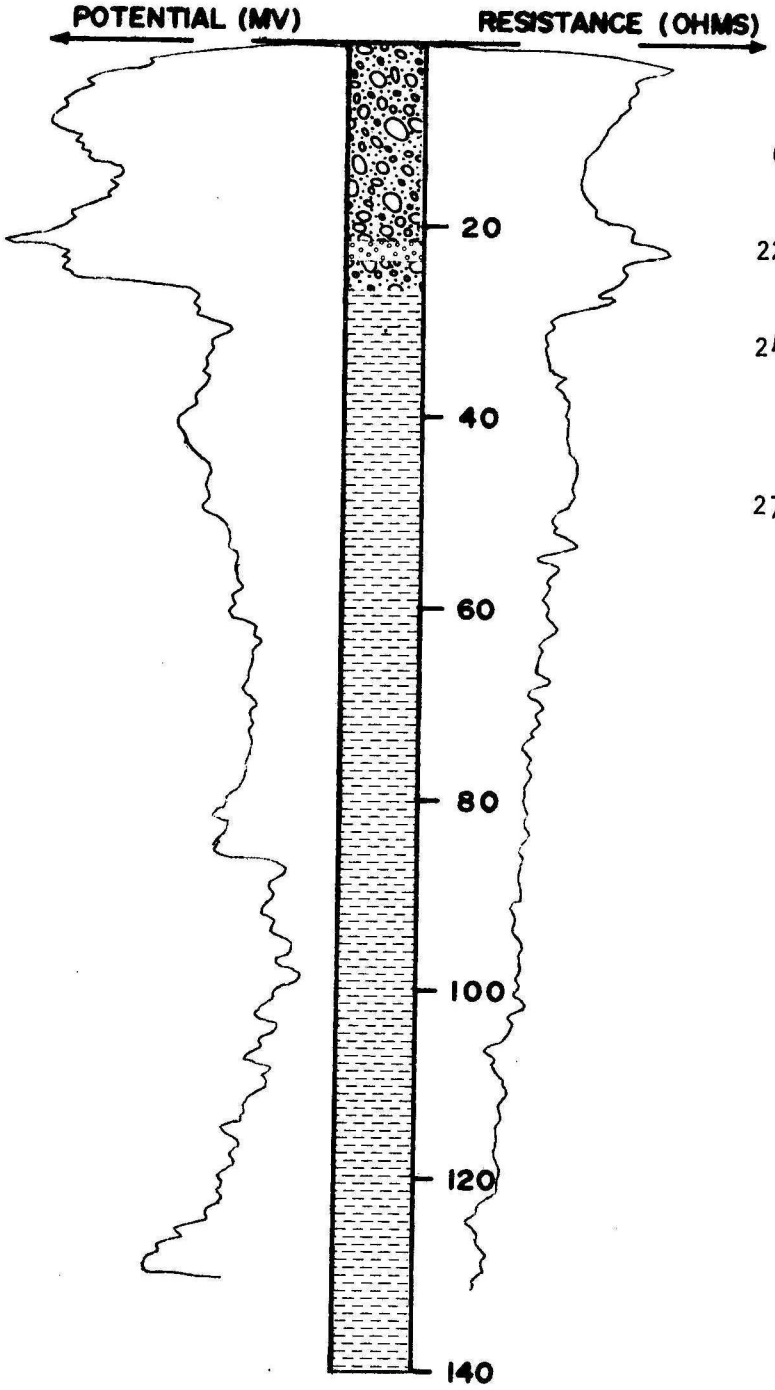
TEST HOLE 8696

LOCATION: 134-64-33DDD

DATE DRILLED: June, 1973

ELEVATION: (FT, MSL) 1565 feet

DEPTH: (FT) 140 feet



DESCRIPTION OF DEPOSITS

Glacial Drift

0-22 Clay, silty, pebbly, yellowish-brown, oxidized (till).

22-24 Sand, fine to very coarse, subrounded, well-sorted, shaly, lignitic.

24-27 Clay, sandy, gravelly, pebbly, olive-gray (till).

Pierre Formation

27-140 Shale, siliceous, grayish-black, brittle, fissile, fractured, a few yellowish-gray limestone concretions.

134-64-35DDD
Test Hole 8698
Elevation 1525 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, gravelly, yellowish-brown, oxidized (till)	14	14
	Clay, silty, sandy, pebbly, olive-gray (till)	4	18
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous	22	40

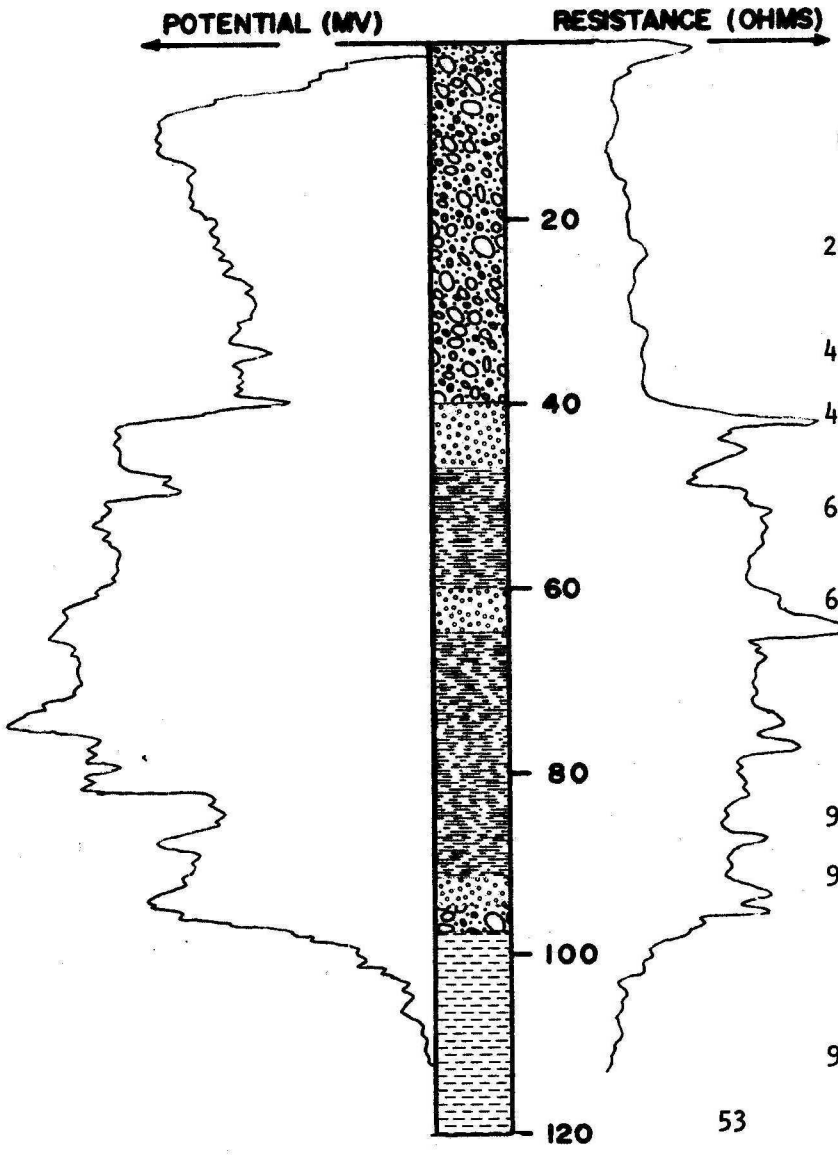
TEST HOLE 8691

LOCATION: 134-65-35CCC

DATE DRILLED: June, 1973

ELEVATION: 1750 feet
(FT, MSL)

DEPTH: 120 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-28	Clay, silty, pebbly, yellowish-brown, oxidized (till).
28-40	Clay, silty, pebbly, cobbles, olive-gray (till).
40-47	Sand, very fine to fine, clay layers, subrounded.
47-60	Silt, sandy, medium gray, soft, highly calcareous (glaciofluvial sediment).
60-65	Sand, very fine to medium, subrounded, well-sorted, shaly, lignitic.
65-92	Silt, sandy, medium gray, thin sand layers, soft, lignitic, highly calcareous (glaciofluvial sediment).
92-95	Gravel, fine to coarse, poorly sorted.
95-98	Clay, silty, pebbly, olive-gray, some maserated shale, calcareous (till).

Pierre Formation

98-120	Shale, siliceous, grayish-black, brittle, noncalcareous.

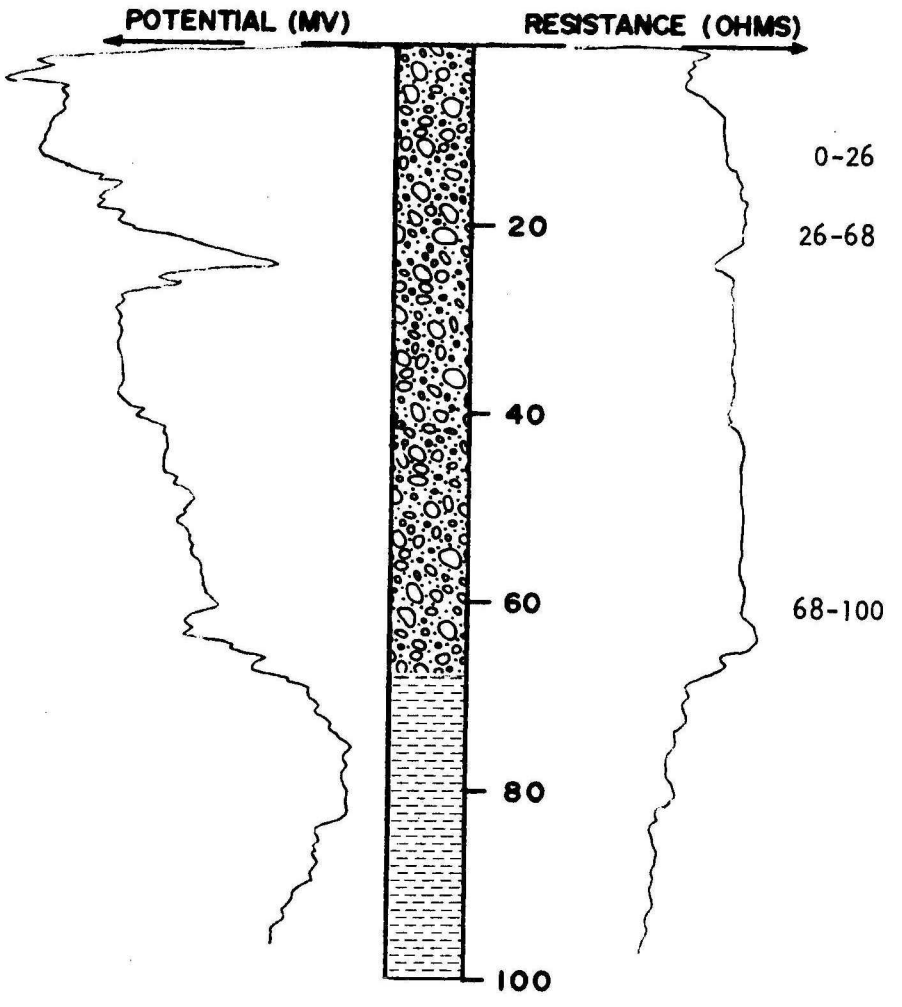
TEST HOLE 8692

LOCATION: 134-65-35DDD

DATE DRILLED: June, 1973

ELEVATION: 1690 feet
(FT, MSL)

DEPTH: 100 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-26 Clay, silty, pebbly, yellowish-brown, oxidized (till).

26-68 Clay, pebbly, cobbles, olive-gray, calcareous (till).

Pierre Formation

68-100 Shale, siliceous, grayish-black, brittle, noncalcareous.

134-65-36DDD
Test Hole 8693
Elevation 1665 feet
Drilled June, 1973

Geologic Source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Clay, silty, sandy, pebbly, yellowish-brown, oxidized (till)	25	25
	Clay, silty, pebbly, cobbles, olive-gray, calcareous (till)	22	47
Pierre Formation:			
	Shale, siliceous, grayish-black, brittle, fissile, noncalcareous	13	60

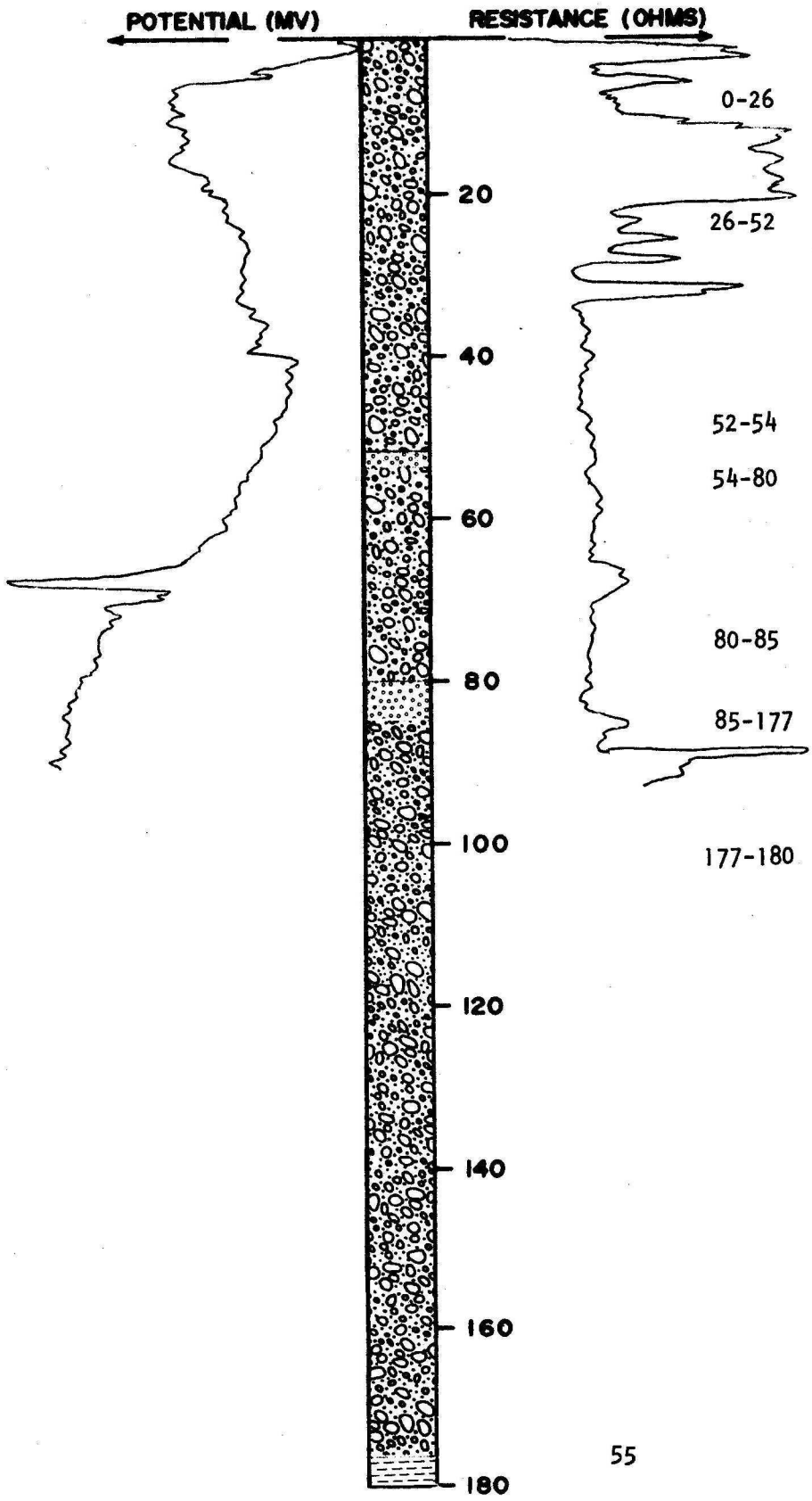
TEST HOLE 8735

LOCATION: 135-64-31DDD

DATE DRILLED: July, 1973

ELEVATION: 1560 feet
(FT, MSL)

DEPTH: 180 feet
(FT)



DESCRIPTION OF DEPOSITS

Glacial Drift

0-26 Clay, sandy, pebbly, yellowish-brown, oxidized (till).

26-52 Clay, silty, pebbly, olive-gray, calcareous (till).

52-54 Gravel, fine to coarse, subrounded.

54-80 Clay, pebbly, olive-gray, calcareous (till).

80-85 Gravel, fine to coarse, subangular to well-rounded, loose.

85-177 Clay, silty, pebbly, olive-gray, calcareous (till).

Pierre Formation

177-180 Shale, siliceous, grayish-black, brittle, noncalcareous.

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