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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
RESTON, VA. 22092

GROUND-WATER INVESTIGATION AT U.S. AIR FORCE LAUNCH CONTROL FACILITY E-0, RAMSEY COUNTY, NORTH DAKOTA

OPEN-FILE REPORT 77-619

Prepared in cooperation with the
United States Air Force,
Grand Forks Air Force Base,
North Dakota

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By P. G. Randich

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Bismarck, North Dakota
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SELECTED FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) OF METRIC UNITS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English units	By	To obtain SI units
Acres	0.4047	hectares (ha)
Feet (ft)	.3048	meters (m)
Gallons (gal)	3.785	liters (L)
Gallons per minute (gal/min)	.06309	liters per second (L/s)
Gallons per minute per foot [(gal/min)/ft]	.2070	liters per second per meter [(L/s)/m]
Inches (in)	25.40	millimeters (mm)
Miles (mi)	1.609	kilometers (km)

GROUND-WATER INVESTIGATION AT U.S. AIR FORCE LAUNCH CONTROL FACILITY E-0, RAMSEY COUNTY, NORTH DAKOTA

By P. G. Randich

ABSTRACT

U.S. Air Force Launch Control Facility E-0 is located in Ramsey County, North Dakota. Geohydrologic and water-quality data indicate that the fractured Pierre Shale is the only aquifer in the vicinity of the facility that will supply acceptable water at the required rate of 5 gallons per minute (0.32 liters per second). The chemical quality of the water is generally considered marginally satisfactory for the intended use due to the presence of high concentrations of dissolved solids, and chloride or sulfate.

INTRODUCTION

In response to a request from the U.S. Air Force, Grand Forks Air Force Base, N. Dak., in July 1976, the U.S. Geological Survey conducted a ground-water investigation in the vicinity of Launch Control Facility (LCF) E-0 in October 1976. The facility (fig. 1) is located in Ramsey County, northeastern North Dakota.

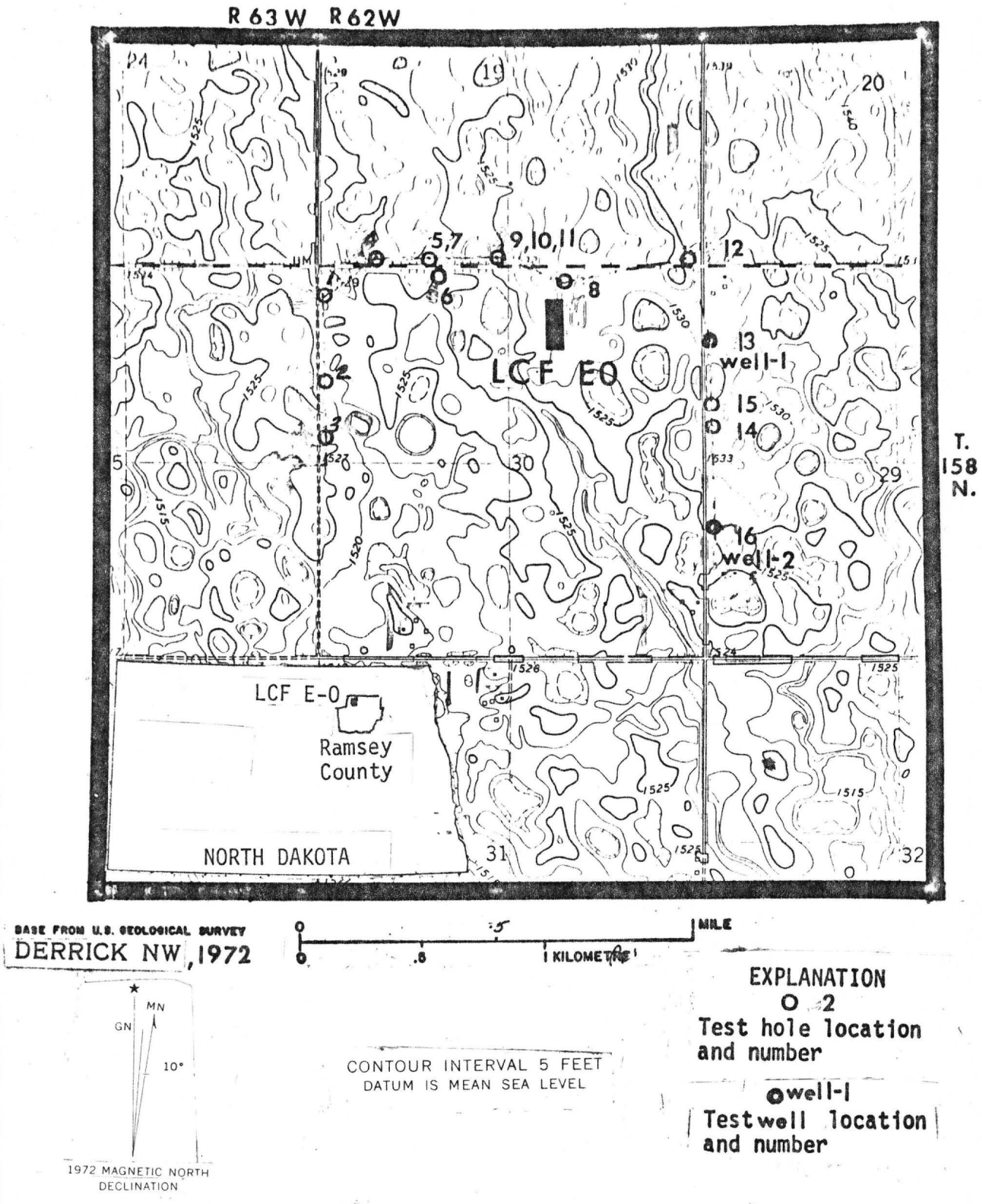

FIGURE 1.--Location of Launch Control Facility E-0 and data-collection points.

The purpose of the study was to determine whether an aquifer existed within a 0.5-mi (0.8-km) radius of LCF E-0 that would be capable of yielding 5 gal/min (0.32 L/s) of better quality water for public use than that from the present well.

The investigation included the following activities: (1) make a site study of local geohydrologic conditions; (2) plan a test-drilling program based on available data; (3) contract for, log, and supervise the drilling of 16 test holes for a total of 654 ft (199.3 m); (4) ream two of the test holes, case with 4-in (102-mm) plastic pipe, and install a screen in order to test the potential yields, measure water levels, and collect water samples; (5) obtain chemical analyses of two water samples; and (6) prepare a report outlining the findings of the study and recommending procedures for additional development.

Well- and Test-Hole-Numbering System

The well- and test-hole-numbering system used in this report is based upon a system of land survey in use by the U.S. Bureau of Land Management. The first numeral denotes the township north of a base line; the second numeral denotes the range west of the fifth principal meridian; 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 or 4-ha tract). Thus, well 158-062-30ABB is in the NW¼NW¼NE¼ sec. 30, T. 158 N., R. 62 W.

PRESENT WATER SUPPLY

The present water supply for LCF E-O is obtained from a well tapping a fractured zone in shale. The well, which was constructed in 1963, is cased with 7-in (178-mm) diameter steel pipe slotted from 79 to 126 ft (24.1 to 38.4 m) and cemented from 147 to 150 ft (44.8 to 45.7 m). The static water level in the well was reported to be 18 ft (5.5 m) below land surface, and the drawdown, while pumping at a rate of 5 gal/min (0.32 L/s), was 22 ft (6.7 m). This yield is adequate for LCF E-O.

The chemical quality of the water from the present well is unsatisfactory due to high dissolved solids and high concentrations of dissolved iron and chloride. Analyses of water samples taken from the well in 1969 and 1972 (table 1) show the following changes: dissolved-solids concentration decreased from 4,060 to 3,820 mg/L, chloride concentration decreased from 2,000 to 1,900 mg/L, iron concentration increased from 940 ug/L to 3,100 ug/L, and sulfate concentration increased from 33 mg/L to 77 mg/L. Other constituents remained relatively constant. The increase in iron and sulfate concentrations may be due to corrosion of the iron casing and reactions of sulfur-oxidizing bacteria in the well.

GEOHYDROLOGY

LCF E-0 is located in the glaciated region of North Dakota. The surface deposits consist of glacial drift generally less than 50 ft (15.2 m) thick. The drift overlies the Pierre Shale of Late Cretaceous age.

Pierre Shale

The upper part of the Pierre Shale was reached in 12 of the 16 test holes drilled during this investigation. The Pierre consists of dark-grayish-black fractured shale with thin seams of bentonite, which contains limonitic nodules in places. Test drilling indicates that some degree of fracturing occurs throughout the upper 150 ft (46 m) of the shale in this area. The fractured zone probably is the result of ice loading and movement during the Pleistocene age. The fractures contain water and the zone forms the only extensive aquifer in the area.

To determine hydrologic and water-quality characteristics of the aquifer, two test wells were installed in the fractured zone. The test wells were developed by backwashing with clear water, then alternate pumping and surging, using air lift for development. A submersible pump was used to determine well capacity and to collect water samples. Test well 1 (158-062-29BBC; fig. 1), screened from 34 to 49 ft (10.4 to 14.9 m), was pumped for 10 hours; it produced a maximum yield of 3 gal/min (0.19 L/s). Test well 2 (158-062-29CBC; fig. 1), slotted and screened from 40 to 60 ft (12.2 to 18.3 m), was pumped for 20 hours; it produced a maximum yield of 4 gal/min (0.25 L/s). These tests indicate that the aquifer should yield about 0.17 (gal/min)/ft [0.04 (L/s)/m] of screened interval; therefore, in order to obtain 5 gal/min (0.32 L/s) at these sites a well should have at least 30 ft (9.1 m) of screen or slotted openings in the aquifer.

Water samples collected from the two wells were analyzed by the U.S. Geological Survey Central Laboratory, Denver, Colo. The analyses show that water from well 1 is a sodium sulfate type. The dissolved-solids concentration is higher than that of the present well. The high concentration of sulfate would make the water undesirable for human consumption.

The water from well 2 is a sodium chloride type with a sulfate concentration high enough to cause a temporary cathartic effect. The high chloride concentration would impart a taste that may require acclimatization to be acceptable. Analyses from these two wells and from the present well (table 1) indicate that hardness and sulfate decrease while chloride increases with depth in this area.

Glacial drift

The glacial drift was penetrated in 12 of the 16 test holes. Thickness at the 12 sites ranged from 29 to 43.5 ft (8.8 to 13.3 m) and averaged 35 ft (10.7 m). The drift consists predominantly of till (oxidized near the surface), with some localized thin deposits of sand. The sand deposits generally are located near the base of the drift, but some are just below land surface. The sand deposits near the base of the drift are not extensive enough to be considered as a source for a ground-water supply at LCF E-O. In the vicinity of potholes the shallow sand deposits are hydraulically connected with the water in the potholes and therefore are highly susceptible to pollution.

A buried-valley aquifer located about 4 mi (6 km) west of LCF E-0 could supply an adequate quantity of fair quality water. North Dakota State Water Commission test hole 8780 (Hutchinson, 1977; table 2) penetrated a saturated sand and gravel interval in the buried-valley aquifer from 146 to 190 ft (44.5 to 57.9 m) below land surface. The chemical analyses of water from a well developed in this interval shows the water is a sodium chloride type containing 2,900 mg/l dissolved solids (158-063-32AAA, table 1). It has slightly lower concentrations of chloride and sulfate than well 1.

CONCLUSIONS AND RECOMMENDATIONS

Results of this study show that the present well at LCF E-0 is producing water high in dissolved solids, iron, and chloride. Reaction of the pumped water with the steel casing causes the excessive iron concentrations.

Test drilling in the vicinity of LCF E-0 indicates that the fractured zone in the Pierre Shale contains an aquifer capable of producing the desired quantity of water for the facility. The glacial drift in the vicinity does not contain aquifers capable of producing enough water. However, a buried-valley aquifer tapped by well 158-063-32AAA about 4 mi (6 km) west of the facility could supply the desired quantity of water.

Chemical analyses of water from the Pierre Shale aquifer indicate that the dissolved chloride concentration increases substantially as the well depth increases. Water from the buried-valley aquifer is somewhat better quality than that available near the site. However, none of the sites tested produced water that was of significantly better quality than that produced from the original well, or that meets U.S. Public Health Service (1962) recommended standards. Residents in the area indicate that they have used water from the Pierre Shale aquifer for domestic and stock purposes and that they have experienced no noticeable ill effects.

If it is decided to develop one or more wells in the upper interval of the Pierre Shale aquifer, it is suggested that 6-inch (152-mm) diameter plastic well casings and screens be used. Plastic well casing would eliminate effects of iron corrosion. Based on well capacity test data, about 30 ft (9.1 m) of screen or perforated casing in the upper part of the fractured shale, starting about 3 to 5 ft (0.9 to 1.5 m) below the shale-glacial drift contact, would be needed to obtain the 5 gal/min (0.32 L/s) required. The new well(s) should be located to the east or southeast of the present well, and if more than one is developed, they should be at least 250 ft (76.2 m) apart.

SELECTED REFERENCES

Hutchinson, R. D., 1977, Ground-water basic data for Ramsey County, North Dakota: North Dakota Geol. Survey Bull. 71, pt. II, and North Dakota State Water Comm. County Ground-Water Studies 26, pt. II, p. 335 and 342.

U.S. Public Health Service, 1962, Drinking water standards: U.S. Public Health Service Pub. 956, 61 p.

TABLE 1.--Well data and chemical analyses of water

(Values are in milligrams per liter, except as noted.)

	Test well 1	Test well 2	Present well 1969	Present well 1972	4 miles west
Location	158-062-29BBC	158-062-29CBC	158-062-30ABB		158-063-32AAA
Depth of well in ft	49	60	150	150	163
Depth, top of screen	34	40	79	79	--
Depth bottom of screen	49	60	147	147	163
Water level, depth below lsd (ft)	13	9	18	18	.1
Pump period (min)	600	1,200	Continuous	Continuous	Unknown
Max. yield, well (gal/min)	3	4	--	--	--
Alkalinity, total as $CaCO_3$	737	795	632	628	517
Aluminum[1] (µg/L)	0	0	--	--	--
Arsenic[1] (µg/L)	8	1	--	--	--
Barium[1] (µg/L)	0	0	--	--	--
Beryllium[1] (µg/L)	0	0	--	--	--
Bicarbonate	899	969	770	770	630
Boron[1] (µg/L)	3,100	3,400	--	--	--
Cadmium[1] (µg/L)	0	0	--	--	--
Calcium[1]	98	47	35	35	71
Carbonate	0	0	0	0	0
Chloride[1]	220	1,000	2,000	1,900	870
Chromium[1] (µg/L)	0	10	--	--	--
Cobalt[1] (µg/L)	1	1	--	--	--
Copper[1] (µg/L)	0	2	--	--	--
Dissolved solids, calc sum	3,950	3,450	3,990	3,940	2,810
Dissolved solids, ton/acre-ft	5.54	4.87	--	--	--
Dissolved solids, 180°C	4,070	3,580	4,060	3,820	2,900
Fluoride[1]	.4	.4	.4	.4	.4
Hardness, noncarbonate	0	0	0	0	0
Hardness total	400	200	150	150	250
Iron[1] (µg/L)	200	200	940	3,100	290
Lead[1] (µg/L)	0	1	--	--	--
Lithium[1] (µg/L)	350	360	--	--	--
Magnesium[1]	37	21	16	15	18
Manganese[1] (µg/L)	300	170	--	120	110
Mercury[1] (µg/L)	0	0	--	--	--
Molybdenum[1] (µg/L)	7	1	--	--	--
Nickel[1] (µg/L)	7	1	--	--	--
NO_2+NO_3 as N[1]	.20	4.2	1.4	--	1
pH Lab	6.7	6.8	8.1	7.6	8.2
Phosphorous[1] as P	.19	.18	--	--	--
Potassium[1]	18	16	--	--	14
SAR	26	37	53	53	25
Selenium[1] (µg/L)	1	1	--	--	--
Silica[1]	24	24	25	26	27
Sodium[1]	1,200	1,200	1,500	1,500	920
Sodium percent	86	92	--	95	88
Sp. conductance fld	7,000	7,000	--	--	--
Sp. conductance lab	5,540	5,820	6,950	7,000	4,550
Strontium[1] (µg/L)	1,200	730	--	--	--
Sulfate[1]	1,900	640	33	77	580
Vanadium[1] (µg/L)	3.2	6	--	--	--
Zinc[1] (µg/L)	40	60	--	--	--
Water temp (deg C)	6.5	6	--	--	6

[1]Dissolved.

TABLE 2.--Logs of test holes

Test hole 1
158-062-30BBB

Altitude: 1,520 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized----------	15	16
	Sand, medium to coarse, subrounded to rounded; 60 percent detrital shale, 20 percent igneous, and 10 percent carbonates-------	1	17
	Till, medium-dark-gray; granite boulder from 28 to 30 feet----------	13	30
	Till, olive-gray, silty-------	2	32
Pierre Shale:			
	Shale, grayish-black, siliceous----------	8	40

Test hole 2
158-062-30BCB

Altitude: 1,520 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	2	2
	Till, yellowish-brown, oxidized----------	14	16
	Till, medium-gray, silty------	16	32
	Boulder, limestone------------	1	33
	Sand, fine to medium; predominantly carbonates and detrital shale----------	.5	33.5
	Till, olive-gray--------------	1.5	35
Pierre Shale:			
	Shale, grayish-black, siliceous, very fractured---	5	40

Test hole 3
158-062-30BCC

Altitude: 1,522 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized----------	16	17
	Till, medium-gray-------------	16	33
	Cobbles; with some sand-------	1	34
Pierre Shale:			
	Shale, grayish-black, siliceous, fractured--------	6	40

Test hole 4
158-062-19CCD

Altitude: 1,523 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized----------	16	17
	Till, medium-gray, pebbly-----	16	33
	Boulders; with lenses of medium to coarse sand; predominantly granitics, carbonates, and silicates---	2	35
Pierre Shale:			
	Shale, grayish-black, siliceous, fractured--------	5	40

Test hole 5
158-062-19CDC1

Altitude: 1,519 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, sandy--	2	3
	Sand, medium to very coarse; some fine to medium subrounded to rounded gravel; about 30 percent carbonates, 30 percent detrital shale, 30 percent igneous, and 10 percent quartz----------	4	7
	Till, yellowish-brown---------	1	8
	Till, medium-gray------------	22	30
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, fractured--------	10	40

Test hole 6
158-062-30BAB

Altitude: 1,520 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, silty, oxidized------------	7	8
	Till, medium-gray, silty------	21	29
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, very fractured---	11	40

Test hole 7
158-062-19CDC2

Altitude: 1,519 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, silty, oxidized------------	10	11
	Till, medium-gray, silty------	9	20

Test hole 8
158-062-30ABB

Altitude: 1,530 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, silty, oxidized------------	24	25
	Till, medium-gray, silty------	17	42
	Boulders, granite------------	1.5	43.5
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, fractured; slightly silty in places----	16.5	60

Test hole 9
158-062-19CDD1

Altitude: 1,521 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, silty--	1	2
	Sand, fine to coarse; about 10 percent subrounded to rounded gravel; predominantly quartz, granitics, and carbonates----------	4	6
	Till, yellowish-brown, silty, oxidized----------	9	15
	Till, medium-gray, silty------	16	31
Pierre Shale:			
	Shale, grayish-black, siliceous, fractured--------	9	40

Test hole 10
158-062-19CDD2

Altitude: 1,521 feet

Glacial drift:			
	Topsoil, brownish-black, silty----------	1	1
	Till, yellowish-brown, silty, oxidized----------	14	15
	Till, medium-gray, silty------	5	20

Test hole 11
158-062-19CDC3

Altitude: 1,521 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Sand, fine to coarse, subrounded to rounded; about 15 percent fine gravel; predominantly carbonates and granitics----	3.5	4.5
	Till, yellowish-brown, silty--	2.5	7
	Till, medium-dark-gray, silty----------	13	20

Test hole 12
158-062-19DDD

Altitude: 1,525 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, silty----------	7	8
	Till, medium-dark-gray--------	24	32
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, fractured; limestone lens at 36 feet---	8	40

Test hole 13, Test well 1
158-062-29BBC

Altitude: 1,532 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized--------------------	22	23
	Till, medium-dark-gray--------	12	35
	Till, medium-gray; with streaks of gravelly sand----	2	37
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, very fractured---	13	50

NOTE: Installed 50 feet of 4-inch diameter plastic pipe with 4-inch diameter No. 12-slot plastic screen from 34 to 49 feet below land surface datum. Static water on October 11, 1976, was 9.87 feet below land surface datum.

Test hole 14
158-062-29BCC

Altitude: 1,532 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Sand, very fine to medium, oxidized--------------------	7	8
	Till, yellowish-brown, oxidized--------------------	11	19
	Till, medium-gray-------------	21	40
	Sand, fine to coarse, gravelly; abundant detrital shale--------------	2	42
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, fractured--------	2	44

Test hole 15
158-062-29BCB

Altitude: 1,528 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized----------	15	16
	Till, medium-gray, silty------	4	20

Test hole 16, and Test well 2
158-062-29CBC

Altitude: 1,526 feet

Glacial drift:			
	Topsoil, brownish-black-------	1	1
	Till, yellowish-brown, oxidized----------	21	22
	Till, medium-gray------------	1	23
	Till, medium-gray; with thin lenses of coarse sand----------	4	27
	Till, medium-gray------------	2	29
	Boulder, granite-------------	1	30
	Till, medium-dark-gray--------	5	35
Pierre Shale:			
	Shale, dark-grayish-black, siliceous, fractured--------	5	40
	Shale, dark-grayish-black, sandy, fractured----------	4	44
	Shale, dark-grayish-black, fractured; thin seams of bentonite containing some limonitic nodules from 60 to 100 feet----------	56	100

NOTE: Installed 57 feet of 4-inch diameter plastic pipe, slotted from 40 to 55 feet, and a 4-inch diameter plastic screen No. 12-slot from 55 to 60 feet below land surface datum. Static water level on October 11, 1976, was 8.85 feet below land surface datum.

NDSWC 8780
158-063-32AAA

Altitude: 1,501 feet

Geologic source	Material	Thickness (feet)	Depth (feet)
Glacial drift:			
	Loam, clayey, silty, grayish-black (topsoil)-----	1	1
	Clay, moderately sandy, moderately silty, pebbly, moderate-yellowish-brown, oxidized (till)----------	13	14
	Clay, slightly sandy, pebbly, olive-gray, calcareous (till)----------	6	20
	Clay, sandy, gravelly, pebbly, cobbly, olive-gray (till)----------	92	112
	Sand, fine to very coarse-----	5	117
	Clay, sandy, gravelly, pebbly, olive-gray, calcareous (till)----------	6	123
	Sand, fine to very coarse, very gravelly; contains a few lenses of very sandy clayey till----------	13	136
	Clay, sandy, pebbly, gravelly, olive-gray, calcareous (till)----------	10	146
	Sand, fine to very coarse, very gravelly; contains a few lenses of clay----------	10	156
	Gravel, fine to coarse, very sandy; consists of about 50 percent dark-gray shale; contains a few thin clay lenses--------	34	190
Pierre Shale:			
	Shale, grayish-black, siliceous, slightly fractured----------	10	200