Hydrogeology of the Plaza Area Mountrail County North Dakota

By
Allen E. Comeskey

North Dakota Ground-Water Studies
Number 94
North Dakota State Water Commission
Vernon Fahy, State Engineer

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GROUND–WATER RESOURCES OF THE PLAZA AREA MOUNTRAIL COUNTY NORTH DAKOTA

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INTRODUCTION

PURPOSE AND SCOPE

On July 14, 1986, the city of Plaza entered into an agreement with the State Water Commission to conduct a study of the ground–water resources in the vicinity of Plaza. Locating a source that improved the quality and quantity of water available to the city was the objective. Plaza's present supply contains concentrations of total dissolved solids and other constituents which exceed U. S. Public Health Service limits. Iron concentrations are high, which results in the staining of laundry and plumbing fixtures. Summer water use was also occasionally being curtailed. The present city well is being pumped at 28 gallons per minute. A capacity to pump 50 to 70 gallons per minute is desired.

To meet study objectives an aquifer composed of relatively high permeability sediments and containing better quality water than the city's present source was to be sought. The initial effort was to be directed towards locating such an aquifer in the glacial drift. If unsuccessful, efforts would be directed towards locating the best available source from the bedrock sediments underlying the glacial drift.

LOCATION

Plaza is located in the southeast quarter of Mountrail County about 16 miles south and 30 miles west of Minot (fig. 1). It is located in the Missouri Coteau physiographic province.

The project area totals 40 square miles and includes portions of Township 152 North, Range 88 West, Sections 1, 4, 5, 7, and 16; Township 152 North, Range 89 West, Section 1; Township 153 North, Range 87 West, Section 31; Township 153 North, Range 88 West, Sections 14, 15, 22, 23, 26, 29, 35, and 36.

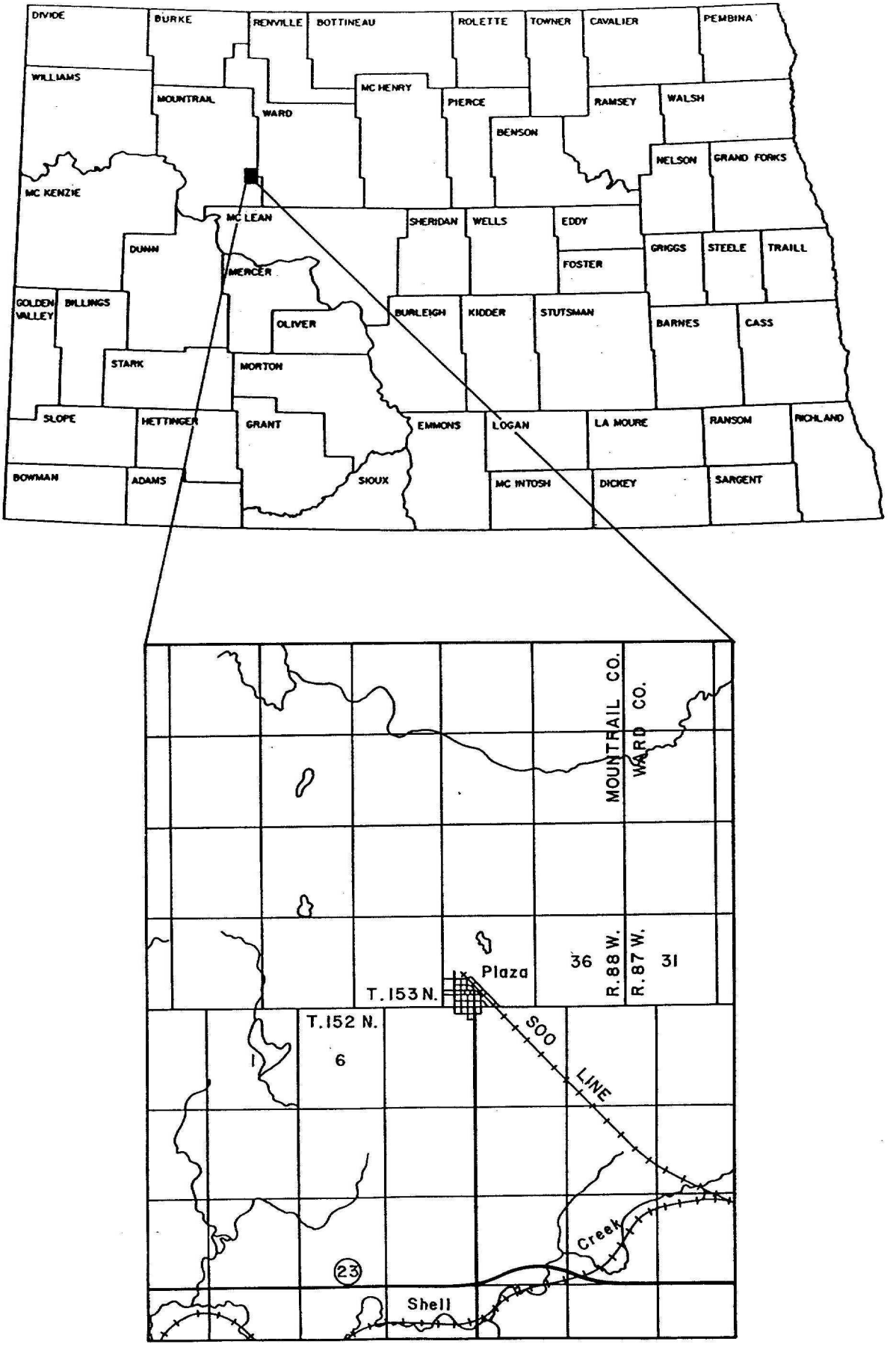

FIGURE I. Study Area Location.

PREVIOUS INVESTIGATIONS

Simpson (1929) presents a general overview of the geology and ground–water resources of North Dakota. Mountrail County is discussed on pages 174 through 177. Domestic wells and a railroad well located in Plaza are mentioned in a table of local wells and owners.

Schmid (1962) discusses general geology of the Parshall area, and lists test hole logs and water quality analysis for both glacial drift and bedrock aquifers.

Armstrong (1971) discusses the Sentinel Butte Formation as an aquifer on pages 22 and 23. Glacial drift and glacial drift aquifers are discussed starting on page 29. Plaza's water supply is discussed on page 74.

Clayton (1972) describes the geology of Mountrail County. Glacial and post–glacial sediments are discussed starting on page 20 with the Sentinel Butte and Tongue River Formation discussed on pages 23 through 28. A generalization of the hydrology of the county begins on page 30.

LOCATION NUMBERING SYSTEMS

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township north and Range west of the 5th Principal Meridian and base line (fig. 2). The third number indicates the section. The letters A, B, C, and D designate respectively the northeast, northwest, southwest, and southeast quarter section (160 acre tract), quarter–quarter section (40 acre tract) and quarter–quarter–quarter section (10 acre tract). Therefore a well denoted by 153–88–23AAA would be located in NE1/4 NE1/4 NE1/4 Section 23, Township 153 North, Range 88 West. Consecutive terminal numbers are added if more than one well is located in a 10 acre tract, e.g., 153–88–36CDD$_1$ and 153–88–36CDD$_2$.

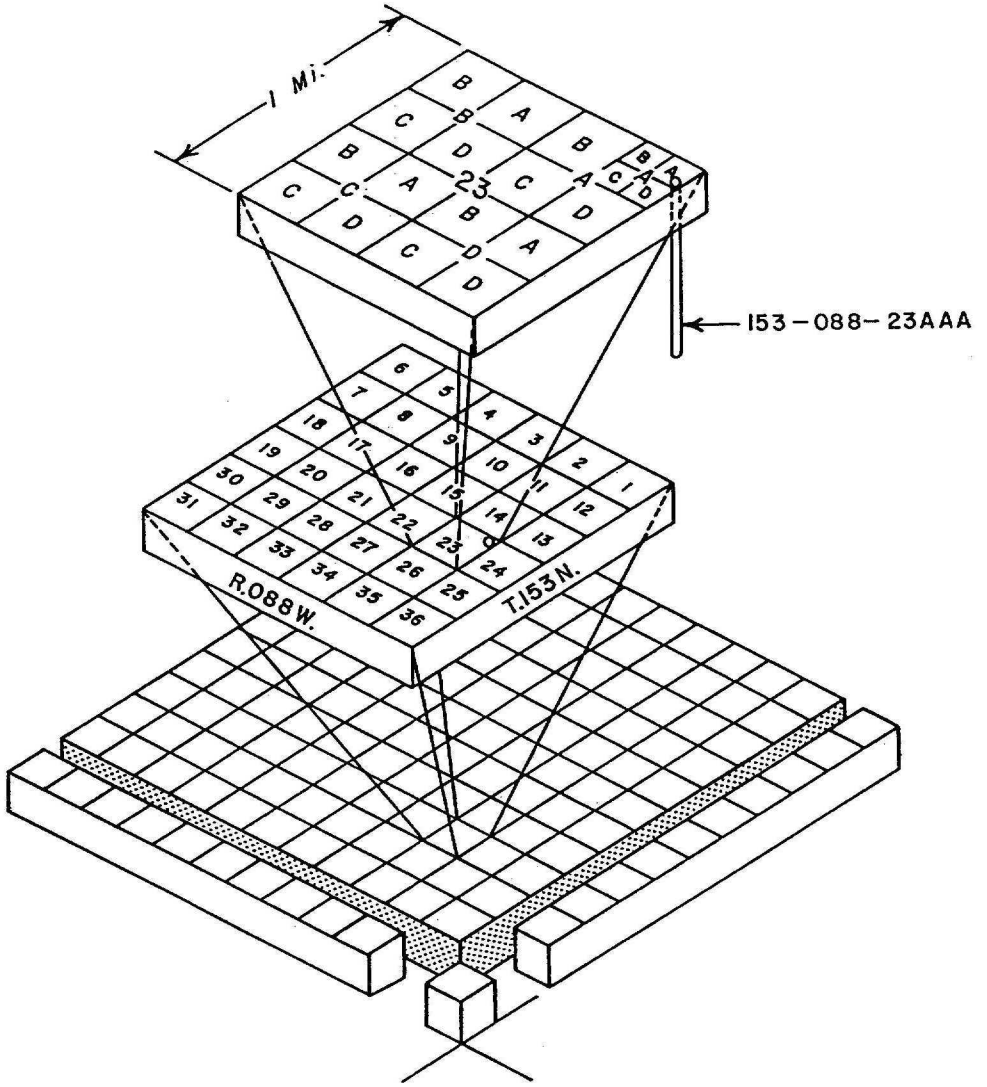

FIGURE 2. Location Numbering System.

PRESENT WATER SUPPLY

Plaza presently obtains its water supply from two wells (city wells no. 2 and 3) completed in the Sentinel Butte Formation. Their locations are shown on the test hole location map (Plate 1). Records of water use have not been kept until recently. Approximately 22 acre–feet was used in 1986.

Well 2 is pumped intermittently at about 12 gallons per minute as a supplement to well 3. It is located at 153–088–35CDB. C. A. Simpson and Son completed this well in May 1955. A description of the materials encountered by the driller and the well completion is included in the test hole logs in the appendix. The hole was drilled to 86 feet. Seventy–seven feet of eight inch–diameter casing with 10 feet of 8 inch–diameter, #30 to #40 slot screen was installed and gravel packed to 38 feet. The screened interval is from 76 to 86 feet below land surface.

Well 3 provides the majority of the water used and is pumped at about 28 gallons per minute. It is located at 152–88–01BBB. C. A. Simpson and Son completed this well in July 1959. A description of the materials encountered during drilling and the well completion is included in the test hole logs in the appendix. The hole was drilled to 100 feet and backfilled to 91 feet with pea gravel. Seventy–five feet of eight inch–diameter casing with 16 feet of 8 inch–diameter #60 slot screen was installed and gravel packed to 47 feet below land surface. The screened interval is from 75 to 91 feet below land surface.

METHODS

The study was accomplished by means of: 1) test drilling, which includes the recording of lithologic logs and borehole geophysical logs, and piezometer construction; 2) water sample collection and analysis; 3) water level monitoring; and 4) a step–drawdown pumping test on city well 3.

Test drilling was conducted from July 17 through 22, 1986; October 6 through 7, 1986; and on April 22, 1987. Thirty locations were drilled totaling 3,032 feet. Ten

piezometers were constructed. Thirteen water samples were collected and analyzed. Additional samples were collected and analyzed from local domestic wells and city wells 2 and 3. The step–drawdown test was conducted on March 31, 1987.

Test drilling was accomplished by the forward rotary–mud method generally using a 4 3/4 inch bit. Lithologic logs are written records of the materials encountered by the drill and are based on samples obtained from the drilling mud. These are compiled by the geologist. Geophysical logs are graphs of the electrical properties of the materials penetrated by the bore hole. The lithologic and geophysical logs have been included in the appendix. Piezometers provide access to the water contained in the aquifer by means of 1 1/4 inch pvc pipe and 1 1/4 inch pvc well screen of various slot sizes. The screen is sand packed and the annulus filled with grout. Water samples are obtained by air lifting the water from wells with air lines inserted into the wells and connected to portable air compressors. These samples were analyzed by the State Water Commission Laboratory. Results of the analysis are found in table 1 in the appendix. Water levels are obtained by inserting a steel surveyor's tape into the well and measuring depth to water. Continuous record water level recorders were also installed on selected wells. The water level data is included in the appendix.

HYDROGEOLOGY

TONGUE RIVER FORMATION

The Tongue River Formation directly underlies the basal sandstone unit of the Sentinel Butte Formation. It attains a thickness of about 600 feet in Mountrail County (Clayton, 1972) and is composed of alternating beds of claystone, siltstone, sandstone, and lignite.

Test hole 11823 (152–088–05AADC$_1$) was drilled to 400 feet to determine the nature of the bedrock at moderate depths.

One hundred fifty six feet of Tongue River were encountered from 244 to 400 feet

below land surface. Sandstone comprises 4.5% of the section with a cumulative thickness of seven feet. It is very fine to fine grain, well sorted, angular, clayey, and poorly indurated and friable. Lignite comprises 13.5% of the section with a cumulative thickness of 21 feet. The remainder of the section is comprised of low permeability claystone and siltstone. There were no piezometers completed in the Tongue River Formation therefore water levels and gradients are not known.

SENTINEL BUTTE FORMATION

The Sentinel Butte Formation overlies the Tongue River Formation and directly underlies the glacial drift in the vicinity of Plaza. Where it has not been eroded, it is about 300 feet thick (Clayton, 1972). It is composed of alternating beds of claystone, siltstone, sandstone, and lignite. Clayton (1972) stated that individual beds rarely exceeded a few hundred feet in lateral extent. Of wide occurrence, though, is a basal sandstone unit which occasionally attains a thickness of up to 100 feet and is generally encountered at a depth of about 200 feet.

In test hole 11823, forty–one feet of glacial drift overlies the Sentinel Butte Formation. Two hundred and three feet of Sentinel Butte was encountered from 41 to 244 feet below land surface. The basal sandstone is present. It is 50 feet thick, occurring from 194 to 244 feet below land surface. Sandstone comprises 47% of the section with a cumulative thickness of 96 feet. Individual beds range from 10 to 50 feet thick. It is very fine to fine grain, well sorted, angular, clayey, and poorly indurated and friable. Lignite comprises about 9% of the section with a cumulative thickness of 19 feet. Individual beds range from 1 to 7 feet thick. The remainder of the section is composed of low permeability claystone and siltstone.

Test holes 11802 and 11803, as well as 11823 encountered within the interval from 49 to 71 feet below land surface a sandstone bed ranging from 12 to 15 feet thick (unit A, Plate 2, C–C'). This bed is laterally persistent within the vicinity of Plaza. Also

encountered in these test holes was a lignite bed included within the screened intervals of the city production wells, indicating the degree of lateral extent of that individual bed (unit B, Plate 2, C–C'). Test holes 11813, 11920, 11921, and 11922 encounter a sandstone bed ranging from 26 to 50 feet thick, 23 to 28 feet below land surface (unit C, Plate 2, C–C'). It is composed of angular to subrounded, fine to medium grain sand, very arkosic, poorly indurated, and very friable. An attempt to core sections of this sandstone at 153–088–36CDD was unsuccessful due to its poorly consolidated nature. Directly beneath the sandstone is a lignite bed from .5 to 1.0 foot thick and with apparently the same areal extent as the sandstone.

Twelve piezometers are completed in various units of the Sentinel Butte Formation. One piezometer is completed in the basal sandstone unit at 152–088–05AADC$_2$ (11823$_A$). It is screened from 230 to 240 feet below land surface. Water levels have ranged from 57.78 to 58.10 feet below land surface. Water level elevations have ranged from 2038.56 to 2038.24 feet.

Three piezometers are completed in unit A. They are located at 152–088–04BBBD$_1$, 152–088–05AADC$_3$, and 153–088–35CDBB$_1$ (test holes 11803, 11823$_B$, and 11802). Water levels range from 19.988 to 31.06 feet below land surface. Water level elevations range from 2076.78 to 2063.67 feet.

Four piezometers are completed in unit B. Water levels range from 29.72 to 33.73 feet below land surface. Water level elevations range from about 2061 to 2066 feet.

Two piezometers are completed in unit C. Water levels range from about 33 to 20 feet below land surface. Water level elevations range from 2067.41 to 2069.32 feet.

One piezometer is completed in an isolated sandstone bed at 153–088–36CCD. It is screened from 106 to 111 feet below land surface. Water levels have ranged from 25.73 to 24.34 feet below land surface. Water level elevations ranged from 2061.16 to 2062.55 feet.

Overall, water levels have risen. Upon completion in May 1959, city well 3 had a static water level of about 48 feet below land surface. In January 1986 it had a static of

31.69 feet below land surface. This is an increase of about 16 feet. In a similar manner the static water level in well 2 has risen about 7.5 feet since 1955. The additional 16 feet of available drawdown in well 3 allows the well to be pumped at a greater rate or for a longer period of time without the water level declining below the pumping level of the well when constructed.

Continuous water level recorders were installed on piezometers completed in units A and B to observe the drawdown from the pumping of city well 3 during normal daily use. Responses to pumping reveal whether the units are as lateraly persistent as they appear from test hole data alone. The water level in Unit B had a greater response than those in Unit A. This supports what is suggested by the test holes and the drillers' well completion records that unit B (the lignite bed) is contributing the majority of the water to city well 3. Probably city well 2 is screened across this unit since it is persistent throughout the city. Unit A also responded to pumping, but only slightly, suggesting that leakage occurs between units of the Sentinel Butte Formation. This is significant because even though unit B may be the predominant source of water to the production wells, leakage from the surrounding units makes more water available than that stored within the lignite.

GLACIAL DRIFT

The drift ranges from 26 feet thick in the vicinity of Plaza to 142 feet thick in the buried valley north of town. Glacial drift is composed of till, lacustrine clay, and fluvial silt, sand, and gravel. Till is an unsorted sediment composed of all sizes of particles: clay, silt, sand, gravel, and boulders. Lacustrine clays are deposited in quiet water lakes that form near the edge of or in the glacial ice. Fluvial silt, sand, and gravel are the sediments of streams flowing away from the glacial ice or flowing on, within, or under the ice.

The present land surface topography reflects the buried bedrock topography. This is a result of the thin veneer of glacial drift that overlies the bedrock. These sediments were deposited over the pre–glacial landscape as the glacial ice advanced and retreated.

Generally, channels and depressions visible today correspond with buried channels and depressions. Test drilling was initially concentrated in the prominent channel two to three miles north of Plaza. Drilling revealed a shallow buried valley below the channel.

Test holes 11804 through 11820 were drilled across the shallow channel north of town. Test holes 11808 and 11809 encountered 11 and 13 feet of sand and gravel at the surface respectively. The sand and gravel is predominantly composed of subrounded to rounded coarse sand to pebbles. Grains are composed of quartz, shale, and limestone and are coated with an oxidized stain. Test hole 11810 encountered 11 feet of sand and gravel from 24 to 35 feet below land surface. The sediment is predominantly angular to rounded fine to very coarse sand.

Two observation wells are completed in the glacial drift. Water levels were measured during summer and fall of 1986 and spring of 1987.

The observation well at 153–88–23AAAD$_2$ is completed in an unconfined sand and gravel deposit of limited areal extent. It is screened from 8 to 13 feet below land surface. Water levels range from 5.55 to 6.85 feet below land surface. Saturated thickness ranges from 7.45 to 6.15 feet.

The observation well at 153–088–14DADA is completed in a confined sand and gravel deposit within the drift. It is screened from 30 to 35 feet below land surface. Water levels range from 12.85 to 13.58 feet below land surface.

FLOW DIRECTION

Horizontal and vertical flow directions were determined from screen elevations and water level elevations. Vertical flow direction is downward as determined from water level elevations in units A, B, and C. Natural, near surface, horizontal flow is masked by the cone of depression around city well 3. The gradient towards city well 3 averages about 16.5 feet per mile in unit B. The gradient in unit A is also towards city well 3 but is variable

due possibly to the variation in the degree of communication between units A and B and inhomogeneities in the hydraulic conductivity in unit A.

The apparent gradient in unit C is roughly towards the east at about 3.8 feet per mile.

PUMP TESTS

CITY WELL 2–1955

Upon its completion in May 1955, Fred Simpson conducted a pumping test on city well 2 for which drawdown and recovery were recorded for both the production well and an observation well (written communication, 1986). The static water level was 42 feet below land surface. Pumping was interrupted for additional development and the rate was not constant. About 27 feet of drawdown was observed after about 22 hours of pumping at about 18 gallons per minute. Specific capacity is about .67 gallon per minute per foot of drawdown.

CITY WELL 3–1959

Upon its completion in July 1959, Fred Simpson conducted a pumping test on city well 3 for which drawdown and recovery data were recorded (written communication, 1986). A time–drawdown plot of this data is presented in figure 3. The static water level was 48 feet below land surface. The well was pumped for 24 hours at a rate of 35 gallons per minute. After 23 hours and 40 minutes 9.07 feet of drawdown were observed. Specific capacity was 3.86 gallons per minute per foot of drawdown. Transmissivity values of 710.8 and 654.5 $feet^2/day$ were calculated from the drawdown and recovery data, respectively.

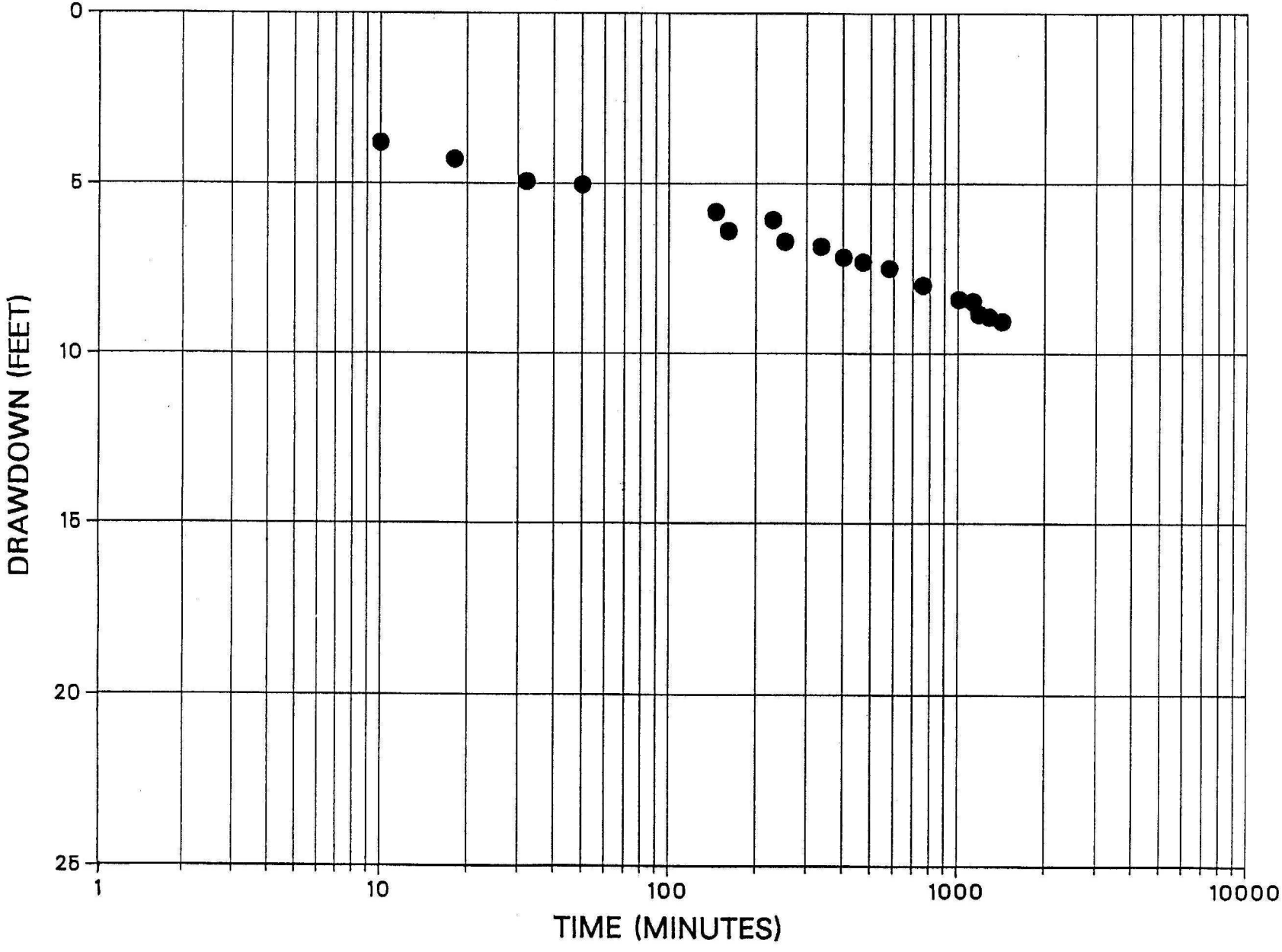

FIGURE 3. Time-drawdown plot, City well 3, 1959.

CITY WELL 3–1987

On March 31, 1987 a step–drawdown test was conducted on city well 3. The well was pumped for 120 minutes at 25 gallons per minute, 60 minutes at 35 gallons per minute, 60 minutes at 50 gallons per minute, and 30 minutes at 70 gallons per minute. A time–drawdown plot of this data is presented in figure 4. The specific capacity was calculated for each rate. They are 3.78, 3.78, 3.32, and 2.86 gallons per minute per foot of drawdown, respectively. The transmissivity was calculated from a time–drawdown plot of the first step at 765.8 ft^2/day.

NEW CITY WELL AND PUMP TEST

As a result of this study a new municipal well was constructed and pump tested between March 28 and April 5, 1988. It is located at 152–088–04BBAB. The hole was drilled to 87 feet and reamed to 10 inch diamter. Fifty seven feet of 6 inch–diamter casing with 27 feet of 6 inch–diameter, #10 slot wire wrap screen attached to the bottom were installed. The screened interval is from 57 to 84 feet below land surface. It was then gravel packed with buckshot gravel and grouted.

A pump test was conducted on April 4 and 5, 1988. Thre well was pumped at 37 gallons per minute for about 16 hours. Water levels were measured and recorded for the production well and the observation well at 152–088–04BBBD1. Efficiency of the well improved during the test. The pumping water level was 50.5 feet below land surface. Thirteen and one–half feet of drawdown were observed in the production well at the end of the test. Specific capacity of the well was calculated at 2.7 gallons per minute per foot of drawdown. Transmissivity and storage coefficient of the aquifer were calculated from a time–drawdown plot of the data from the observation well (fig. 5). They are 751 ft^2/day and 2×10^{-4}, respectively.

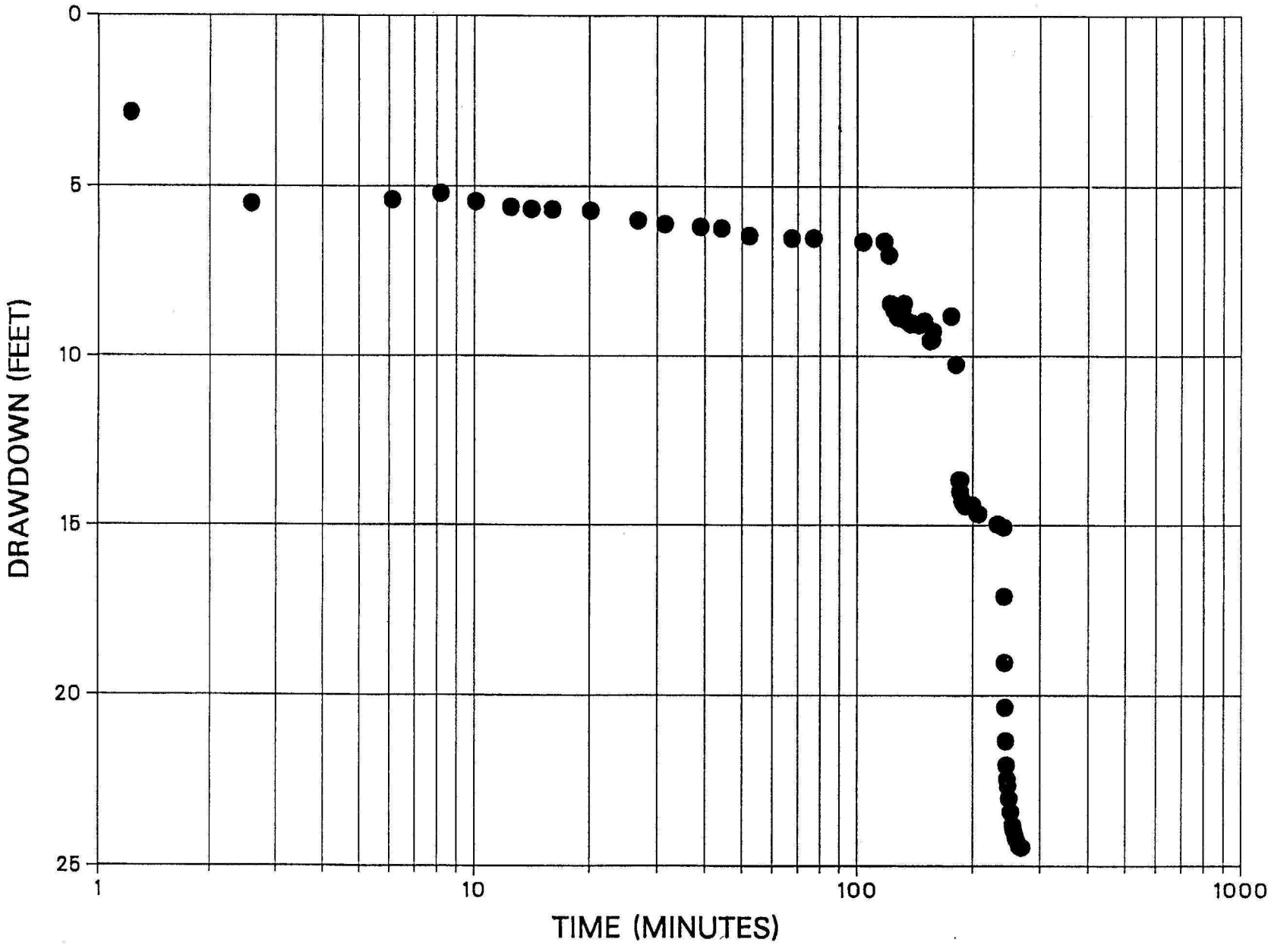

FIGURE 4. Time-drawdown plot, City well 3, 1987.

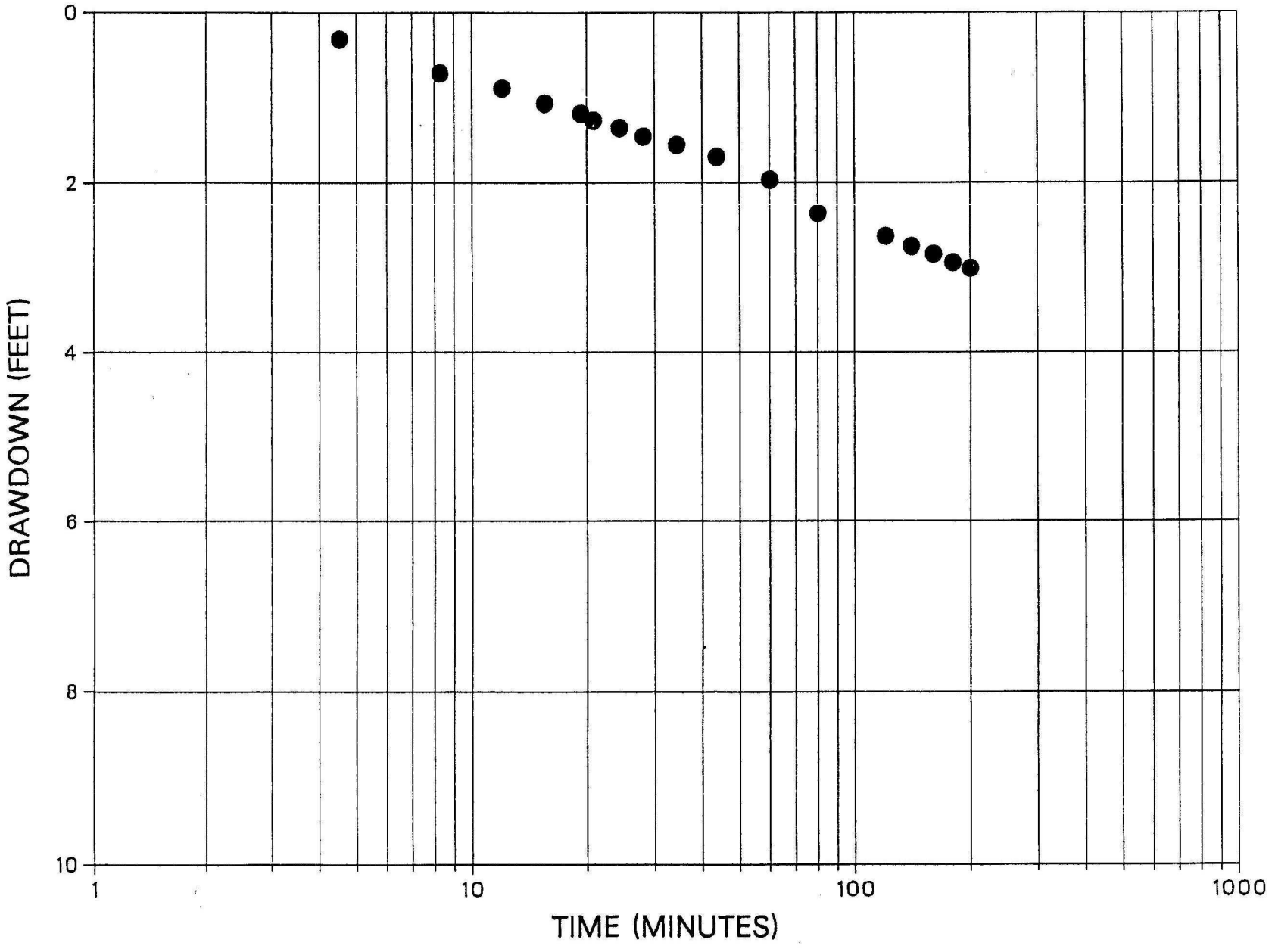

FIGURE 5. Time-drawdown plot, Observation well 152-088-04 BBBD

WATER QUALITY

There are no piezometers or domestic wells completed in the Tongue River Formation in the vicinity of Plaza therefore the quality of water available from it is not known.

One domestic well completed in the basal sandstone of the Sentinel Butte Formation was sampled (152–088–05DAD). Sodium is the predominant cation. There is no predominant anion. Dissolved solids concentration is 2890 milligrams per liter. Water from Unit A is generally a sodium bicarbonate type. Dissolved solids concentrations range from 1190 to 3430 milligrams per liter. Iron concentrations ranges from .17 to .58 milligrams per liter. Hardness ranges from 550 to 2400 milligrams per lier. Water from unit B is generally a sodium bicarbonate type. Dissolved solids concentrations range from 1150 to 2930 milligrams per liter. Iron concentrations range from .29 to 2.01 milligrams per liter. Hardness ranges from 70 to 1800 milligrams per liter.

Dissolved solids concentration ranges from 2590 to 3400 milligrams per liter in water from unit C. Hardness is 1700 milligrams per liter. Iron ranges from .05 to 6.1 milligrams per liter.

Analysis of most samples indicate most concentrations of constituents exceed standards set by the U. S. Public Health Service. Dissolved solids concentration exhibit no relation to depth. Percent sodium and sodium adsorption ratio (SAR) increased with depth. Hardness appears to decrease with depth. Other constituents exhibit no relation to depth or areal distribution.

Analysis of samples indicates that city wells 2 and 3 produce the best overall quality water available from the Sentinel Butte Formation. The character of the water from production well 3 has changed from 1967 to 1986. Percent sodium has decreased from 76% to 60%. Sodium adsorption ratio (SAR) has decreased from 12.0 to 6.8. Hardness has increased from 295 to 526 milligrams per liter. Iron has increased from 1.1 to 2.01 milligrams per liter. It is possible, but not definitely known, that there is some

relationship between the rise in water levels and change in water quality over the same period of time.

Water quality in the glacial drift is variable, ranging from a calcium bicarbonate type to a magnesium sulfate type. Dissolved solids concentrations range from 509 to 930 milligrams per liter. Hardness ranges from 410 to 670 milligrams per liter. Iron is .03 milligrams per liter.

SUMMARY AND CONCLUSIONS

Glacial drift sediments and the Sentinel Butte and Tongue River Formations were investigated for potential as aquifers. Sand and gravel of the glacial drift was of too limited an areal extent to support the development of a water supply. Permeable units of the Tongue River Formation are of inadequate thickness and too deep to be developed. Sandstone and lignite beds of the upper Sentinel Butte Formation possess the areal extent, water levels, and quality of water to support the development of a supplemental water supply. Withdrawals from city well 3 can be increased due to the increase in the available drawdown resulting from the rise in water levels. Location of additional wells should be with regard for the interference effects of pumping of the wells.

SELECTED REFERENCES

Armstrong, C.A., 1969, Geology and Ground–Water Resources of Burke and Mountrail Counties: Part II, Ground Water Basic Data, North Dakota Geological Survey Bull. 55 and North Dakota State Water Commission County Ground Water Studies 14.

Armstrong, C.A., 1971, Ground–Water Resources of Burke and Mountrail Counties; Part III, Ground–Water Resources: North Dakota Geol. Survey Bull. 55 – Part III and North Dakogta State Water Commission County Ground–Water Studies 14 – Part III (Plaza pp. 74–75).

Clayton, Lee, 1972, Geology of Mountrail County, North Dakota; Part IV, Geology: North Dakota State Geol. Survey Bull. 55 – part IV and North Dakota State Water Commission County Ground–Water Studies 14 – part IV.

Schmid, R. W., and Ziegler, Victor, E., 1962, Ground–Water Conditions in the Vicinity of Parshall, Mountrail County, North Dakota: North Dakota Ground–Water Studies 41.

Simpson, Howard E., 1929, Geology and Ground–Water Resources of North Dakota: U.S. Geol. Survey Water–Supply Paper 598, pp. 174–177.

APPENDIX

TEST HOLE LOGS

Grain size determination is based on the Wentworth (1922) size scale. Color description is based on the Geological Society of America (1963) rock color chart. Geophysical logs are single point resistance, neutron porosity, natural gamma, 16" and 64" normal electric logs, and spontaneous potential.

Explanation of Codes

Comments:

D – well destroyed

G – geophysical log available

C – chemical analysis of water sample available

W – water level measurements available

Source of data:

SWC – State Water Commission

or name of private drilling firm that supplied data

152–88–04BBA$_1$(east)
NDSWC 11917

Date completed: 10/6/86

Well type: piezometer

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): 71–76

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2095.05

Comments: c, w

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial drift		
Topsoil, very silty, black	2	0 – 2
Clay, very silty, sandy (very fine grain) soft, slightly plastic, oxidized, pale yellowish orange mottled with olive gray	13	2 –15
Clay, very silty, sandy, pebbly, oxidized, dark yellowish orange (till)	23	15 –38
Sentinel Butte Formation		
Claystone, non–silty, poorly indurated, plastic, oxidized, dark yellowish orange	1	38 –39
Lignite	1	39 –40
Claysgtone, very silty, carbonaceous, brown	2	40 –42
Claystone, non–silty, poorly indurated, slightly plastic	5	42 –47
Siltstone, slightly clayey, poorly indurated, interbedded very fine sandstone and silty claystone	6	47 –53

152–88–04BBA$_1$(east)
NDSWC 11917
(cont)

Claystone, silty, sandy, poorly indurated, slightly carbonaceous	14	53 –67
Lignite	1	67 –68
Claystone, non–silty, poorly indurated, waxy, greenish gray	2	68 –70
Sandstone, very fine grain, well indurated	1	70 –71
Sandstone, very fine grain, slightly clayey, slightly silty, poorly indurated, greenish gray	5	71 –76
Lignite	1	76 –77
Clay, non–silty, poorly indurated, waxy, greenish gray	3	77 –80

152–088–04BBA$_2$ (west)
NDSWC 11956

Date completed: 4/22/87

Well type: piezometer

Depth drilled (ft.): 95

Source of Data: SWC

Screened interval (ft.): 77–82

Principal aquifer: Sentinel Butte Fm.

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft):

Comments: C,P,W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 –2
Clay, very silty, soft, plastic, cohesive, oxidized, pale yellowish orange with reddish brown inclusions	11	2 –13
Clay, silty, sandy, pebbly, soft, plastic, cohesive, oxidized, yellowish brown (till)	26	13 –39
Sentinel Butte Formation		
Lignite	1	39 –40
Claystone, non–silty, soft, very plastic, cohesive, poorly indurated	8	40 –48
Sandstone, very fine grain, well soprted, well indurated	1	48 –49
Sandstone, very fine grain to silt, well sorted, angular, very clayey, poorly indurated	19	49 –68
Claystone, non–silty, soft, waxy, interbedded sandstone	11	68 –77
Lignite	2	77 –79
Claystone, silty, poorly indurated, interbedded lignite	16	79 –95

152–088–04BBB
Plaza City Well No. 3

Date completed: 7/30/59

Well type: Municipal

Depth drilled (ft.): 100

Source of data: C. A. Simpson & Son

Screened interval (ft.): 75–91

Principal aquifer:

Casing size (in) & type: 8.0 stl

Land surface altitude (ft): 2095.55

Comments: C,W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Topsoil	1	0 – 1
Yellow clay	38	1 –39
Gray clay	6	39 –45
Yellow clay, rust colored in places	9	45 –54
Gray clay	4	54 –58
Hard layer	2	58 –60
Gray clay	5	60 –65
Slightly sandy gray clay	8	65 –73
Coal chunks, gray clay or shale	2	73 –75
Gray shale with coal particles	0	75 –85
Coal	1.5	85 –86.5
Gray shale with coal particles	13.5	86.5 –100

152–088–04BBBD$_1$ (west)
NDSWC 11803

Date completed: 7/18/86

Well type: piezometer

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): 66–71

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2094.73

Comments: C, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0– 2
Clay, silty, soft, plastic, oxidized, yellowish brown mottled with reddish brown	11	2–13
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	10	13 –23
Sandstone (boulder)	1	23 –24
Clay, silty, sandy, pebbly, soft, plastic (till)	13	24 –37
Sentinel Butte Formation		
Siltstone, very clayey, slightly micaceous, oxidized, greenish gray to yellowish green	3	37 –40
Claystone, slightly silty, waxy, oxidized to 42 feet	3	40 –43
Siltstone, clayey, slightly oxidized	6	43 –49
Sandstone, slightly to very clayey, very fine to fine, angular	12	49 –61
Claystone, slightly silty, waxy, plastic	4	61 –65
Siltstone, as above	3	65 –68
Lignite	3	68 –71
Claystone, as above	9	71 –80

152–088–04BBBD$_2$ (east)
NDSWC 11955

Date completed: 4/22/87

Well type: piezometer

Depth drilled (ft.): 89

Source of data: SWC

Screened interval (ft.): 82–87

Principal aquifer: Sentinel Butte Fm.

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft):

Comments: C, P, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Silt, very clayey, soft, plastic, oxidized	12	2 –14
Clay, very silty, sandy, pebbly, soft, plastic, oxidized (till)	29	14 –43
Sentinel Butte Formation		
Siltstone, very clayey, poorly indurated	8	43 –51
Claystone, slightly silty, waxy, poorly indurated, interbedded siltstone	5	51 –56
Lignite	1	56 –57
Claystone, silty, bentonitic, waxy, poorly indurated	3	57 –60
Sandstone, very fine, angular, slightly clayey, poorly indurated	9	60 –69
Lignite	1	69 –70
Sandstone, very fine, angular, clayey, poorly indurated	1	70 –71
Claystone, non=silty, waxy, poorly indurated	5	71 –76
Siltstone, very clayey	6	76 –82
Lignite	4	82 –86
Claystone	3	86 –89

152–088–05AADC$_1$
NDSWC 11823

Date completed: 7/22/86

Well type: piezometer

Depth drilled (ft.): 400

Source of data: SWC

Screened interval (ft.): 50–60

Principal aquifer:

Casing size (in) & type: 2.0 pvc

Land surface altitude (ft): approx. 2096

Comments: well abandoned, G

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 –1
Silt, clayey, soft, plastic, oxidized, interbedded silty clay, dark yellowish orange	11	1 –12
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	29	12 –41
Sentinel Butte Formation		
Lignite	2	41 –43
Claystone, slightly silty, firm, waxy, greenish gray	6	43 –49
Sandstone, clayey, very fine, well sorted, angular, poorly indurated, micaceous, below 60 feet fine grain and friable	12	49 –61
Claystone, slightly silty, firm, waxy, plastic	2	61 –63
Lignite	1	63 –64
Claystone, as above, carbonaceous	9	64 –73
Lignite	1	73 –74
Claystone, as above, carbonaceous, brown	46	74–120

152–088–05AADC$_1$
NDSWC 11823
(cont)

Sandstone, clayey, very fine, well sorted, angular, poorly indurated	11	120–131
Claystone, non–silty, waxy, carbonaceous at 138 feet	9	131–140
Sandstone, very clayey, very fine grain, slightly carbonaceous	9	140–149
Lignite	6	149–155
Claystone	1	155–156
Lignite	8	156–164
Claystone, non–silty, firm, waxy, dark greenish gray to greenish gray	18	164–182
Lignite	5	182–187
Claystone, non–silty, firm, waxy, brownish to greenish gray, slightly carbonaceous	5	187–192
Lignite	9	192–201
Sandstone, slightly clayey, very fine to fine, angular, slightly friable, slightly carbonaceous, poorly indurated	52	201–253

152–088–05AADC$_1$
NDSWC 11823
(cont)

Tongue River Formation

Claystone, slightly silty, firm, waxy	8	253–261
Lignite	4	261–265
Claystone	5	265–270
Lignite	2	270–272
Claystone, sandy	6	272–278
Claystone, non–silty, firm, waxy, slightly carbonaceous	13	278–291
Lignite	6	291–297
Claystone, very silty and sandy, firm	10	297–307
Lignite	5	307–312
Claystone, non–silty, firm, waxy	4	312–316
Sandstone, very clayey, very fine grain, angular, well sorted	9	316–325
Claystone, non–silty, waxy, firm, carbonaceous, interbedded silty claystone	62	325–387
Lignite	7	394–400
Claystone, very sandy	6	394–400

152–088–05AADC$_2$
NDSWC 11823A

Date completed: 7/22/86

Well type: piezometer

Depth drilled (ft.): 240

Source of data: SWC

Screened interval (ft.): 230–240

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2096.34

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

152–088–05AADC$_3$
NDSWC 11823B

Date completed: 7/22/86

Well type: piezometer

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): 52–57

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2096.26

Comments: C,W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

152–088–05AADC$_4$
NDSWC 11957

Date completed:4/22/87

Well type: piezometer

Depth drilled (ft.): 88

Source of data: SWC

Screened interval (ft.): 82–87

Principal aquifer: Sentinel Butte Fm.

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft):

Comments: C, P, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Silt, very clayey, soft, plastic, cohesive, oxidized, dark yellowish orange with reddish brown inclusions	15	2 –17
Clay, silty, sandy, pebbly, soft, plastic, cohesive, oxidized (till)	25	17 –42
Sentinel Butte Formation		
Lignite	1	42 –43
Claystone, slightly silty, soft, slightly plastic, cohesive, poorly indurated	7	43 –50
Sandstone, very fine to fine, moderately well sorted, angular, slightly to moderately clayey, poorly indurated	25	50 –75
Claystone, silty, poorly indurated, interbedded clayey siltstone	8	75 –83
Lignite	4	83 –87
Claystone, silty, poorly indurated	1	87 –88

152–088–07AAA
NDSWC 11816

Date completed: 7/22/86

Well type: test hole

Depth drilled (ft.): 40

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, oxidized, mottled yellow brown and light gray	2	1 – 3
Clay, silty, sandy, pebbly, soft, plastic, oxidized, yellowish brown, boulder at 21 to 23 feet (till)	20	3 –23
Sand, gravelly, very coarse sand to granules, oxidized	3	23 –36
Sentinel Butte Formation		
Claystone, silty, poorly indurated, waxy	14	26 –40

152–088–07DDDA
NDSWC 11817

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): none

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, very silty, very carbonaceous	3	2 – 5
Sand, gravelly, coarse sand to pebbles, angular to rounded, oxidized	2	5 – 7
Clay, very sandy, slightly pebbly, oxidized, pale yellowish gray (till)	18	7 –25
Clay, silty, sandy, pebbly, soft, plastic, unoxidized, olive gray (till)	26	25 –51
Sentinel Butte Formation		
Claystone	3	51 –54
Lignite	1	54 –55
Claystone, carbonaceous, interbedded lignite	5	55 –60

152–088–16CDC
NDSWC 11822

Date completed: 7/23/86

Well type: Test hole

Depth drilled (ft.): 40

Source of data: SWC

Screened interval (ft.): none

Principal aquifer:

Casing size (in) & type: none

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 22 feet, dark yellowish orange then olive gray (till)	31	1 –32
Sentinel Butte Formation		
Lignite	3	32–35
Claystone, slightly silty, slightly carbonaceous	5	35–40

152–089–01ABB
NDSWC 11814

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, slightly silty, soft, plastic, oxidized, mottled dark yellowish orange and light gray	3	1 – 4
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 16 feet, dark yellowish orange then olive gray (till)	32	4 –36
Sentinel Butte Formation		
Siltstone, poorly indurated, interbedded with very fine sandstone	4	36 –40
Claystone, slightly silty, poorly indurated, waxy, slightly carbonaceous, interbedded lignite	10	40 –50
Sandstone, very fine, well sorted, angular, poorly indurated, friable	7	50 –57
Claystone, slightly silty, poorly indurated, waxy, slightly carbonaceous	3	57 –60

152–089–01DDD
NDSWC 11815

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, sandy, oxidized	1	1 – 2
Gravel, oxidized	1	2 – 3
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 15 feet, yellowish brown to olive gray (till)	29	3 –32
Sentinel Butte Formation		
Claystone, slightly silty, poorly indurated, greenish gray	4	32 –36
Sandstone, clayey, very fine grain, poorly indurated, interbedded siltstone	9	36 –45
Claystone, slightly silty, poorly indurated, interbedded siltstone	15	45 –60

153–087–31CCC
NDSWC 11921

Date completed: 10/7/86

Well type: piezometer

Depth drilled (ft.): 70

Source of data: SWC

Screened interval (ft.): 58–63

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2100.31

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	27	1 –28
Sentinel Butte Formation		
Sandstone, fine to medium grain, angular to subrounded, poorly indurated, very friable	36	28–64
Lignite	1	64–65
Claystone, non–silty, poorly indurated, waxy	15	65–70

153–088–14DAA
NDSWC 11811

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 160

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments: G

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, oxidized, pale yellowish gray	4	1 – 5
Clay, silty, sandy, pebbly, soft, plastic, oxidized, yellowish brown (till)	6	5 –11
Clay, non–silty to slightly silty, very plastic, oxidized to 15 feet, dark yellowish orange then olive gray (lacustrine)	22	11–33
Gravel, sandy, coarse sand to fine pebbles, predominantly granules to fine pebbles, angular to rounded, predominantly subrounded to rounded	4	33–37
Clay, silty, sandy, pebbly, soft, plastic, olive gray (till)	31	37–68
Clay, masserated(?) claystone with claystone pebbles	9	68–77
Claystone, silty, sandy, slightly pebbly, soft, plastic, oxidized to 101 feet, dark yellowish orange to 90 feet then mottles with olive gray then olive gray, interbedded detrital lignite and lacustrine clay (till)	65	77–142
Sentinel Butte Formation		
Siltstone, clayey, poorly indurated, slightly carbonaceous, greenish gray	18	142–160

153–088–14DADA$_{1 \text{ and } 2}$
NDSWC 11810 & 11810A

Date completed: 7/22/86

Well type: piezometer

Depth drilled (ft.): 140

Source of data: SWC

Screened interval (ft.): 30–35

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft):

Comments: G, C. W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Gravel, sandy, very coarse sand to pebbles, predominantly very coarse sand and granules, subangular to rounded, oxidized	3	1 – 4
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	7	4 –11
Clay, soft, very plastic, waxy, greenish to olive gray	13	11–24
Sand, gravelly, fine sand to pebbles, predominantly fine to very coarse sand, angular to rounded, oxidized	11	24–35
Clay, silty, sandy, pebbly, soft, plastic, olive gray (till)	31	35–66
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange, mottled with olive gray by 80 feet	21	66–87
Clay, silty, sandy, pebbly, firm plastic, slightly oxidized, olive gray, sandstone and shale inclusions (till)	37	87–124

153–088–14DADA$_{1 \text{ and } 2}$
NDSWC 11810 & 11810A
(cont)

Sentinel Butte Formation

Siltstone, slightly clayey, poorly indurated, interbedded medium grain, moderately to well indurated sandstone	16	124–140

153–088–15DDD
NDSWC 3487

Date completed: 7/21/67

Well type: Test hole

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft): approx. 2071

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil, silty loam, black	1	0 – 1
Clay, silty, very sandy, pebbly, soft, moderately cohesive, oxidized (till)	17	1 –18
Clay, silty, sandy, pebbly, soft, cohesive, bedrock inclusions, olive brown to olive gray (till)	7	18–25
Clay, silty, sandy, pebbly, soft, cohesive, olive gray (till)	20	25–45
Sentinel Butte Formation		
Lignite, black, fissile	2	45–47
Shale	13	47–60

153–088–22ADA
NDSWC 11820

Date completed: 7/23/86

Well type: Test hole

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Gravel, sandy, very coarse sand to pebbles, predominantly granules and pebbles, subrounded to rounded, oxidized	2	1 – 3
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 45 feet (till)	53	3 –56
Sentinel Butte Formation		
Sandstone, clayey, very fine grain, poorly indurated, slightly friable, interbedded siltstone	24	56–80

153–088–22ADD
NDSWC 11819

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 56 feet, dark yellowish orange to olive gray (till)	61	1 –62
Sentinel Butte Formation		
Siltstone, slightly clayey to clayey, poorly indurated, greenish gray, interbedded claystone	18	62–80

153–088–22DDD
NDSWC 11818

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 19 feet, dark yellowish orange to olive gray (till)	41	1 –42
Clay, silty, sandy, pebbly, firm, plastic, oxidized to 56 feet, dark yellowish orange to olive gray (till)	16	42–58
Sentinel Butte Formation		
Siltstone, clayey, poorly indurated, oxidized to 67 feet, interbedded claystone, fine grain sandstone and lignite	22	58–80

153–088–23AAAD
NDSWC 11809

Date completed: 7/21/86

Well type: Test hole

Depth drilled (ft.): 120

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments: G

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Sand, slightly gravelly, medium sand to granules, predominantly coarse sand, subangular to rounded, predominantly subrounded to rounded, oxidized	12	1 –13
Silt, clayey, soft, plastic, oxidized, dark yellowish orange	7	13 –20
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 38 feet, brownish gray then olive gray, interbedded gravel and cobbles (till)	34	20 –54
Clay, slightly silty, slightly sandy, slightly pebbly, firm, waxy, medium gray, interbedded reworked bedrock and fluvial sediments (till)	40	54 –94
Sentinel Butte Formation		
Siltstone, clayey, soft, slightly friable, interbedded silty claystone, well indurated zone at 108 feet	26	94 –120

153–088–23AAAD$_2$
NDSWC 11812

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 20

Source of data: SWC

Screened interval (ft.): 8–13

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft):

Comments: C, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Sand, gravelly, fine sand to pebbles, predominantly medium and coarse sand, subangular to rounded, oxidized	12	1 –13
Clay, silty, oxidized	7	13 –20

153–088–23AAD
NDSWC 11808

Date completed: 7/21/86

Well type: Test hole

Depth drilled (ft.): 120

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments: G

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Sand, gravelly, medium sand to pebbles, predominantly coarse sand to granules, subangular to rounded, predominantly subrounded to rounded	10	1 –11
Silt, slightly clayey, oxidized, dark yellowish orange	4	11 –15
Clay, very silty, slightly sandy, pebbly, soft, plastic, oxidized (till)	5	15 –20
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 31 feet, mottled yellowish brown to brown then olive gray, interbedded gravel and silt (till)	27	20 –47
Silt, slightly clayey, oxidized, dark yellowish orange, some interbedded till	9	47 –56
Clay, silty, sandy, pebbly, soft, plastic, olive to medium gray	39	56 –95

153–088–23AAD
NDSWC 11808
(cont)

Sentinel Butte Formation

Claystone, slightly silty, poorly indurated, waxy, slightly bentonitic, greenish gray	5	95–110
Siltstone, slightly clayey, friable, greenish gray	9	100–109
Claystone, as above	1	109–110
Siltstone, moderately to well indurated, medium gray to brown	3	110–113
Claystone, as above	7	113–127

153–088–23ADD
NDSWC 11807

Date completed: 7/21/86

Well type: Test hole

Depth drilled (ft.): 120

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments: G

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, silty, sandy, pebbly, soft, plastic, becomes more clayey with depth, oxidized, mottled dark yellowish orange and reddish brown (till)	69	2 –71
Lignite, detrital	2	71 –73
Clay, till as above interbedded with detrital lignite	13	73 –86
Sentinel Butte Formation		
Siltstone, slightly clayey, interbedded lignite, greenish gray	6	86 –92
Lignite, interbedded clay	2	92 –94
Siltstone, clayey to very clayey, interbedded lignite, greenish gray	16	94–110
Claystone, slightly silty, waxy, carbonaceous, greenish gray	10	110–120

153–088–23DADA
NDSWC 11806

Date completed: 7/18/86

Well type: Test hole

Depth drilled (ft.): 120

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, silty, oxidized, yellowish brown to dark yellowish orange	4	2 – 6
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	31	6 –37
Gravel, sandy, medium sand to granules, predominantly very coarse sand and gravel, subangular to rounded	3	37 –40
Silt, slightly clayey, oxidized, dark yellowish orange (fluvial)	11	40 –51
Clay, silty, sandy, pebbly, soft, plastic to slightly brittle, oxidized, yellowish brown (till)	24	51 –75
Silt, clayey, numerous lignite pebbles, olive gray	13	75 –88
Sandstone, very fine grain, well sorted, angular, slightly clayey, greenish gray (shore block)	2	88 –90
Clay, silty, sandy, pebbly, soft to firm plastic to brittle	8	90 –98
Sentinel Butte Formation		
Claystone, silty to very silty, moderately indurated, slightly waxy, interbedded siltstone and lignite	22	98–120

153–088–23DDD
NDSWC 11805

Date completed:7/18/86

Well type: Test hole

Depth drilled (ft.): 100

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Clay, silty, yellowish orange	6	2 – 8
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	36	8 –44
Siltstone, slightly clayey, soft, crumbly, oxidized, dark yellowish orange (shove block)	4	44 –48
Sandstone, fine grain, well indurated (shove block)	1	48 –49
Clay, silty, sandy, pebbly, soft, plastic, becomes more firm and brittle with depth, olive gray (till)	23	49 –72
Sentinel Butte Formation		
Siltstone, clayey, friable, slightly oxidized, mottled yellow brown to greenish gray	12	72 –84
Claystone, non–silty to silty, soft, waxy, greenish gray	16	84–100

153–088–26ADD
NDSWC 11804

Date completed: 7/18/86

Depth drilled (ft.): 60

Screened interval (ft.): None

Casing size (in) & type: None

Comments:

Well type: Test hole

Source of data: SWC

Principal aquifer:

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil, gravelly	2	0 – 2
Clay, silty, sandy, very pebbly, soft, plastic, oxidized to 25 feet, yellowish brown to olive gray (till)	24	2 –26
Gravel, angular to rounded, oxidized	1	26 –27
Clay, silty, sandy, very pebbly, soft, plastic (till)	9	27 –36
Sentinel Butte Formation		
Siltstone, very clayey, greenish gray	15	36 –51
Claystone, slightly to very silty, slightly oxidized, bentonitic, light brown	9	51 –60

153–088–29DDD
NDSWC 11821

Date completed: 7/23/86

Well type: Test hole

Depth drilled (ft.): 50

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 22 feet, dark yellowish orange then olive gray (till)	38	1 –39
Sentinel Butte Formation		
Claystone, poorly indurated, waxy, carbonaceous	1	39 –40
Lignite	6	40 –46
Claystone, as above	4	46 –50

153–088–35CDB
Plaza City Well No. 2

Date completed: 5/3/55

Depth drilled (ft.): 86

Screened interval (ft.): 77–87

Casing size (in) & type: 8.0 stl

Comments: C. W

Well type: Municipal

Source of data: C. A. Simpson & Son

Principal aquifer:

Land surface altitude (ft): 2098.32

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Topsoil	1	0 – 1
Yellow clay	31	1 –32
Darker yellow clay	30	32 –62
Yellow clay with gray sand	6	62 –68
Sandy gray clay	8	68 –76
Coal	3	76 –79
Gray clay or shale	7	79 –86

153–088–35CDBB$_1$(North)
NDSWC 11802

Date completed: 7/17/86

Well type: Piezometer

Depth drilled (ft.): 80

Source of data: SWC

Screened interval (ft.): 66–71

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2095.91

Comments: G, C, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	3	0 – 3
Clay, silty, sandy, pebbly, soft, plastic, oxidized, dark yellowish orange (till)	34	3 –37
Sentinel Butte Formation		
Siltstone, coarse, clayey, poorly indurated, slightly oxidized, micaceous, carbonaceous, yellowish green	19	37 –56
Sandstone, very fine, angular to rounded, predominantly subangular to rounded, slightly clayey, oxidized, coarse grain by 60 feet	15	56 –71
Lignite	1	71 –72
Claystone, very plastic, bluish green	2	72 –74
Siltstone, very clayey	2	74 –76
Lignite	1	76 –77
Claystone, as above	3	77 –80

133–088–35CDBB$_2$(South)
NDSWC 11954

Date completed: 4/22/87

Depth drilled (ft.): 83

Screened interval (ft.): 74–79

Casing size (in) & type: 1.25 pvc

Comments: C, P, W

Well type: Piezometer

Source of data: SWC

Principal aquifer: Sentinel Butte Fm.

Land surface altitude (ft):

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	2	0 – 2
Silt, very clayey, soft, plastic, cohesive, oxidized	9	2 –11
Clay, very silty, very sandy, slightly pebbly, soft, plastic, oxidized to 35 feet (till)	26	11 –37
Sentinel Butte Formation		
Siltstone, clayey, poorly indurated, partially oxidized	7	37 –44
Sandstone, very fine to silt, slightly arleasic and micaceous, carbonaceous, poorly indurated, interbedded siltstone	16	44 –60
Sandstone, very fine to fine, angular, slightly arkosic, poorly indurated	9	60 –69
Lignite	1	69 –70
Claystone, non–silty, waxy, poorly indurated	6	70 –76
Lignite	2	76 –78
Claystone, non–silty, waxy, poorly indurated	5	78 –83

153–088–36CCC
NDSWC 11918

Date completed: 10/6/86

Well type: Test hole

Depth drilled (ft.): 100

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, very silty, soft, plastic, oxidized, dark yellowish orange	6	1 – 7
Sand, gravelly, fine to coarse, poorly sorted, oxidized	6	7 –13
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 32 feet (till)	30	13 –43
Sentinel Butte Formation		
Siltstone, clayey, poorly indurated, friable	2	43 –45
Claystone, non–silty, poorly indurated, waxy	8	45 –53
Claystone, silty, poorly indurated, slightly micaceous, interbedded, clayey siltstone	13	53 –66
Sandstone, very fine grain, well indurated	1	66 –67
Siltstone	1	67 –68
Lignite	1	68 –69
Claystone, non–silty, poorly indurated, waxy	5	69 –74

153–088–36CCC
NDSWC 11918
(cont)

Claystone, very silty, poorly indurated, interbedded siltstone	6	74 –80
Lignite, interbedded brittle, fissile, carbonaceous shale	5	80 –85
Claystone, non–silty, poorly indurated, waxy	5	85 –90
Claystone, silty to sandy	10	90–100

153–088–36CCD
NDSWC 11919

Date completed: 10/6/86

Well type: Piezometer

Depth drilled (ft.): 115

Source of data: SWC

Screened interval (ft.): 106–111

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2086.89

Comments: C, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized to 24 feet (till)	25	1 –26
Sentinel Butte Formation		
Claystone, very silty, poorly indurated, oxidized to 57 feet, interbedded siltstone and sandstone	38	26 –64
Lignite	1	64 –65
Claystone, non–silty, waxy, bentonitic	2	65 –67
Claystone, very silty, carbonaceous	7	67 –74
Lignite	4	74 –78
Claystone, non–silty, poorly indurated, waxy, carbonaceous	4	78 –82
Claystone, very silty, poorly indurated	7	82 –89
Claystone, non–silty, waxy	8	89 –97
Sandstone, very fine, well indurated	2	97 –98
Sandstone, very fine to fine, angular, poorly indurated, friable	15	98–113
Sandstone, very clayey, very fine to fine grain, angular, poorly indurated	2	113–115

153–088–36CDD
NDSWC 11813

Date completed: 7/22/86

Well type: Test hole

Depth drilled (ft.): 60

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized, mottled, light gray and reddish brown (till)	23	1 –24
Sentinel Butte Formation		
Sandstone, very fine to fine grain, well sorted, angular, very poorly indurated, oxidized, yellowish brown	36	24 –60

153–088–36CDD$_2$
NDSWC 11920

Date completed: 10/7/86

Well type: Piezometer

Depth drilled (ft.): 100

Source of data: SWC

Screened interval (ft.): 85–90

Principal aquifer:

Casing size (in) & type: 1.25 pvc

Land surface altitude (ft): 2089.31

Comments: C, W

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, soft, plastic, oxidized (till)	22	1 –23
Sentinel Butte Formation		
Sandstone, fine grain, moderately indurated, slightly friable, oxidized	1	23 –24
Sandstone, very clayey, very fine to fine grain, poorly indurated, interbedded sandy and silty claystone, oxidized	18	24 –42
Sandstone, fine to medium grain, angular to subrounded, poorly indurated, very friable, oxidized to 47 feet, interbedded clayey sandstone	50	42 –92
Lignite	1	92 –93
Claystone, non–silty to slightly silty, poorly indurated, waxy	7	93–100

153–088–36CDD$_3$
NDSWC 11920A

Date completed: 10/7/86

Well type: Test hole

Depth drilled (ft.): 70

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft): Approx. 2089

Comments: Cored sandstone, bad recovery

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)

153–088–36DDA
NDSWC 11922

Date completed: 10/7/86

Well type: Test hole

Depth drilled (ft.): 67

Source of data: SWC

Screened interval (ft.): None

Principal aquifer:

Casing size (in) & type: None

Land surface altitude (ft):

Comments:

Lithologic Log

Unit description	Thickness (ft)	Depth (ft)
Glacial Drift		
Topsoil	1	0 – 1
Clay, silty, sandy, pebbly, plastic to slightly brittle, oxidized, dark yellowish orange (till)	27	1 –28
Sentinel Butte Formation		
Sandstone, fine to medium, angular to subrounded, very poorly indurated, very friable, very arkosic	26	28 –54
Sandstone, fine to medium, very clayey, cohesive, poorly indurated, arkosic	5	54 –59
Lignite	0.5	59 –59.5
Claystone, poorly indurated, waxy, greenish gray to gray	7.5	59.5 –67

TABLE 1. - Water levels.

152-088-04BBA1
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2095.05 — SI (ft)= 71-76

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/10/86	31.82	2063.23
12/10/86	30.34	2064.71
03/30/87	31.55	2063.50
03/31/87	31.02	2064.03
04/13/87	30.95	2064.10
04/27/87	31.15	2063.90

152-088-04BBA2
Sentinel Butte-Tongue River aquifer — SI (ft)= 77-82

Date	Depth to Water (ft)
04/27/87	31.26

152-088-04BBB
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2095.55 — SI (ft)= 75-91

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/30/59	47.98	2047.57
12/10/86	31.69	2063.86

152-088-04BBBD1
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2094.73 — SI (ft)= 66-71

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/23/86	30.69	2064.04
07/29/86	30.61	2064.12
10/10/86	30.23	2064.50
03/30/87	31.64	2063.09
03/31/87	30.86	2063.87
04/13/87	30.82	2063.91
04/27/87	31.06	2063.67

152-088-04BBBD2
Sentinel Butte-Tongue River aquifer — SI (ft)= 82-87

Date	Depth to Water (ft)
04/27/87	33.73

152-088-05AADC2
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2096.34 — SI (ft)= 230-240

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/29/86	49.43	2046.91
09/18/86	58.10	2038.24
12/10/86	57.86	2038.48
04/13/87	57.78	2038.56

TABLE 1. - Continued

152-088-05AADC3
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2096.26 — SI (ft)= 52-57

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
07/29/86	23.20	2073.06	03/31/87	20.18	2076.08
12/10/86	21.57	2074.69	04/13/87	20.41	2075.85
			04/27/87	19.98	2076.28
03/30/87	20.29	2075.97			

152-088-05AADC4
Sentinel Butte-Tongue River aquifer — SI (ft)= 82-87

Date	Depth to Water (ft)
04/27/87	32.91

153-087-31CCC
Undefined aquifer — LS Elev (msl,ft)= 2100.31 — SI (ft)= 58-63

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/86	33.19	2067.12
12/10/86	32.74	2067.57
04/13/87	32.90	2067.41

153-088-14DADA
Undefined aquifer — SI (ft)= 30-35

Date	Depth to Water (ft)
07/29/86	12.99
12/10/86	13.58
04/13/87	12.85

153-088-23AAAD2
Undefined aquifer — SI (ft)= 8-13

Date	Depth to Water (ft)
07/23/86	5.65
07/29/86	5.79
12/10/86	6.85
04/13/87	5.55

153-088-35CDB
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2098.32 — SI (ft)= 77-87

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/03/55	41.38	2056.94
12/10/86	33.91	2064.41

TABLE 1. - Continued

153-088-35CDBB1
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2095.91 — SI (ft)= 66-71

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/29/86	28.43	2067.48
12/10/86	27.88	2068.03
03/30/87	28.54	2067.37
03/31/87	28.24	2067.67
04/13/87	28.17	2067.74

153-088-35CDBB2
Sentinel Butte-Tongue River aquifer — SI (ft)= 74-79

Date	Depth to Water (ft)
04/27/87	29.72

153-088-36CCD
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2086.89 — SI (ft)= 106-111

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/10/86	25.73	2061.16
12/10/86	24.66	2062.23
04/13/87	24.34	2062.55

153-088-36CDD
Sentinel Butte-Tongue River aquifer — LS Elev (msl,ft)= 2089.31 — SI (ft)= 85-90

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/10/86	20.94	2068.37
12/10/86	20.89	2068.42
04/13/87	19.99	2069.32

Location	Well Depth (ft)	Date Sampled	(milligrams per liter) SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (umho)	Temp (^oC)
152-088-04BBA1	76	10-10-86	14	0.39	0.17	51	40	310	12	775		360	8	0.2	1	0.38	1180	290		69	7.9		
152-088-04BBA2	82	06-04-87	17	0.4	0.19	52	40	330	10	768		370	13	0.2		0.35	1210	290		70	8.4		
152-088-04BBB	91	04-25-67	11	1.1		58	37	460	9	917		522	13	0.2	3	0.47	1570	295		76	12.0		7.2
152-088-04BBB	91	02-10-86		2.01	0.39	93	72	362	10	821		558	39	0.2			1540	526		60	6.8		
152-088-04BBBD1	71	07-29-86	16	0.58	0.31	92	77	240	14	717		370	66	0.1	6	0.35	1240	550		48	48.0	2050	7.0
152-088-04BBBD2	87	06-04-87	16	0.5	0.07	13	9	550	7	1070	10	390	11	0.3	1	0.67	1540	70		94	29.0		
152-088-04BDA		-86		1.24	0.07	19	10	733	6	1200		630	11	0.3	3		2000	88		95	34.0		
152-088-05AADC3	57	07-29-86	22	0.17	1.8	180	110	360	17	950		810	11	0.2	8	0.54	1990	900	120	46	5.2	2850	12.0
152-088-05AADC4	87	06-04-87	16	0.29	0.15	52	42	440	11	844		570	18	0.2		0.48	1570	300		75	11.0		
152-088-05DAD		02-10-86		0.07	0.03	5	4	1080	3	1540		1000	34	1.8			2890	27		99	89.7		
152-088-16BAB		03-22-86		1.12	0.09	52	45	676	9	1150		847	8	0.2	8		2210	316		82	16.5		
152-088-16CDC		03-22-86		0.56	0.05	54	45	700	9	1160		861	8	0.2	7		2260	318		83	17.1		
153-087-31CCC	63	10-13-86	19	0.05	0.15	410	160	100	10	465		1300	49	0.3	39	0.21	2320	1700	1300	11	1.1	2940	11.0
153-088-13CCC	135	06-04-86		0.33	0.13	106	69	400	7	710		804	4	0.4			1740	549		61	7.4		
153-088-14DADA	35	07-29-86	27	0.03	1.8	110	32	28	7	359		140	5	0.2	3	0.17	531	410	110	13	0.6	890	7.0
153-088-23AAAD2	13	07-29-86	26	0.03	0.05	88	110	58	4	401		430	4	0.5	21	0.18	940	670	340	16	1.0	1440	8.0
153-088-23BBD	160	02-24-86		1.91	0.64	171	110	316	8	717		916	5	0.3			1880	879		44	4.6		
153-088-25CCA	61	02-11-86		10.7	3.51	369	150	285	12	795		1460	11	0.2			2680	1540		29	3.1		
153-088-27CDD		02-10-86		0.44	0.12	63	58	881	11	802		1700	9	0.2			3110	397		83	19.2		
153-088-34CDD1	65	02-18-86		0.63	1.61	395	224	120	11	450		1650	44	0.2	5		2670	1910		12	1.1		
153-088-34CDD2	65	02-18-86		4.09	13.2	659	138	87	11	739		1620	33	0.2			2910	2210		8	0.8		
153-088-35CBC	61	02-23-86		2.29	0.6	345	273	502	19	867		2140	77	0.2	82		3870	1990		35	4.9		
153-088-35CDB	87	04-25-67	13	1.1		126	85	175	11	690		459	11	0.2		0.27	1220	665	100	36	3.0		7.2
153-088-35CDB	87	02-12-86		1.54	0.16	67	109	186	11	668		428	18	0.1			1150	614		40	3.2		
153-088-35CDBB1	71	07-29-86	14	0.55	1.6	420	340	140	16	536		1800	110	0.2	6?	0.12	3170	2400	2000	11	1.2	4100	9.0
153-088-35CDBB2	79	06-04-87	16	0.47	1.3	330	240	160	14	674		1500	65	0.2	6	0.7	2670	1800	1300	16	1.6		
153-088-36CCD	111	10-10-86	10	0.11	0.1	65	45	1800	18	1910	10	2700	18	0.3	1	0.31	5610	350		91	42.0	7750	7.0
153-088-36CDD	90	10-10-86	21	6.1	1.0	490	120	380	12	813		1800	8	0.3	1	0.21	3240	1700	1100	32	4.0	3900	7.0

TABLE 2. - Chemical analysis of water samples

TABLE 3. – 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	Suggested limits for drinking water 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 0.1 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. High concentrations 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 usage 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.		250 mg/l
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, R. W., 1965, Water Quality Explanation: North Dakota State Water Commission, unpublished report, File No. 989.
2. U.S. Public Health Service, 1962, Public Health Service Drinking Water Standards: U.S. Public Health Service, Pub. No. 956, 61 p.