The Hydrogeology of the New Rockford Aquifer System in Wells County, North Dakota

By
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and
Gregory W. Knell

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NORTH DAKOTA

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THE HYDROGEOLOGY OF THE NEW ROCKFORD AQUIFER SYSTEM IN WELLS COUNTY, NORTH DAKOTA

By

J. C. PATCH and G. W. KNELL

INTRODUCTION

General statement

In April, 1986, the Environmental Protection Agency (EPA) requested the assistance of the North Dakota State Department of Health and the North Dakota State Water Commission in making a hydrogeologic investigation of a segment of the New Rockford aquifer in north–central North Dakota. A petition had been filed by a Wells County resident with the Environmental Protection Agency requesting that they designate the New Rockford aquifer as a Sole–Source aquifer. In order for an aquifer to be designated as a Sole–Source, it must supply 50 percent or more of the drinking water for an area. In addition, if the aquifer were to become contaminated, a significant hazard to public health would result.

The segment of the aquifer being investigated is the region surrounding the municipal water supply wells for the city of Fessenden in Wells County. Prior to this investigation, only a minimal amount of data was available on the ground–water flow system in this area.

Purpose and objectives

To provide a basis for making a sole source designation of the New Rockford aquifer, an understanding of the hydrogeologic framework of this area is necessary. The objectives of this study were to assess the following:

1) The size and shape of the aquifer, including the amount of overlying till and the depth to the underlying bedrock;
2) the ground–water flow system in and adjacent to the aquifer; and
3) the chemistry of the ground water and its relationship to the flow system.

To accomplish these objectives, a detailed investigation of the New Rockford aquifer in Wells County began in July 1986.

A two phase study approach was implemented. In Phase I, the spatial distribution of the ground water levels and water quality were assessed for the entire study area. Phase II entailed a site specific analysis and assessment of ground–water movement through till overlying the aquifer.

For Phase I, 13,979 feet of test hole were drilled at 45 sites, forty piezometers were installed and 57 water samples were collected and analyzed for major chemical constituents.

Six of the sites from Phase I were chosen for Phase II analysis. An additional 938 feet of test drilling was completed and 18 additional piezometers were installed at these six sites. Fifty–nine water samples were collected and analyzed for certain environmental isotopes and 18 water samples were collected and analyzed for major chemical constituents during Phase II.

Description of the study area

The study area is limited to a six township rectangle east of Harvey and north of Fessenden. The Fessenden municipal supply wells are near the center of the study area. The townships included are Township 149 North, Range 69 West; Township 149 North, Range 70 West; Township 149 North, Range 71 West; Township 150 North, Range 69 West, Township 150 North, Range 70 West, and Township 150 North, Range 71 West, all in Wells County.

The study area is located in central North Dakota in the Drift Prairie district of the Central Lowland physiographic province (fig. 1). The area is characterized by ground and end moraine deposits, lake deposits, and glacial outwash deposits.

The topography of the land surface in the study area ranges from nearly flat to hilly. Elevation ranges from a high of 1645 to a low of 1470 in the Sheyenne River valley. Most of the area consists of a gently undulating land surface.

The area is drained by the Sheyenne and James Rivers. Integrated drainage is present throughout the study area and some small undrained depressions also are present (Burtula,

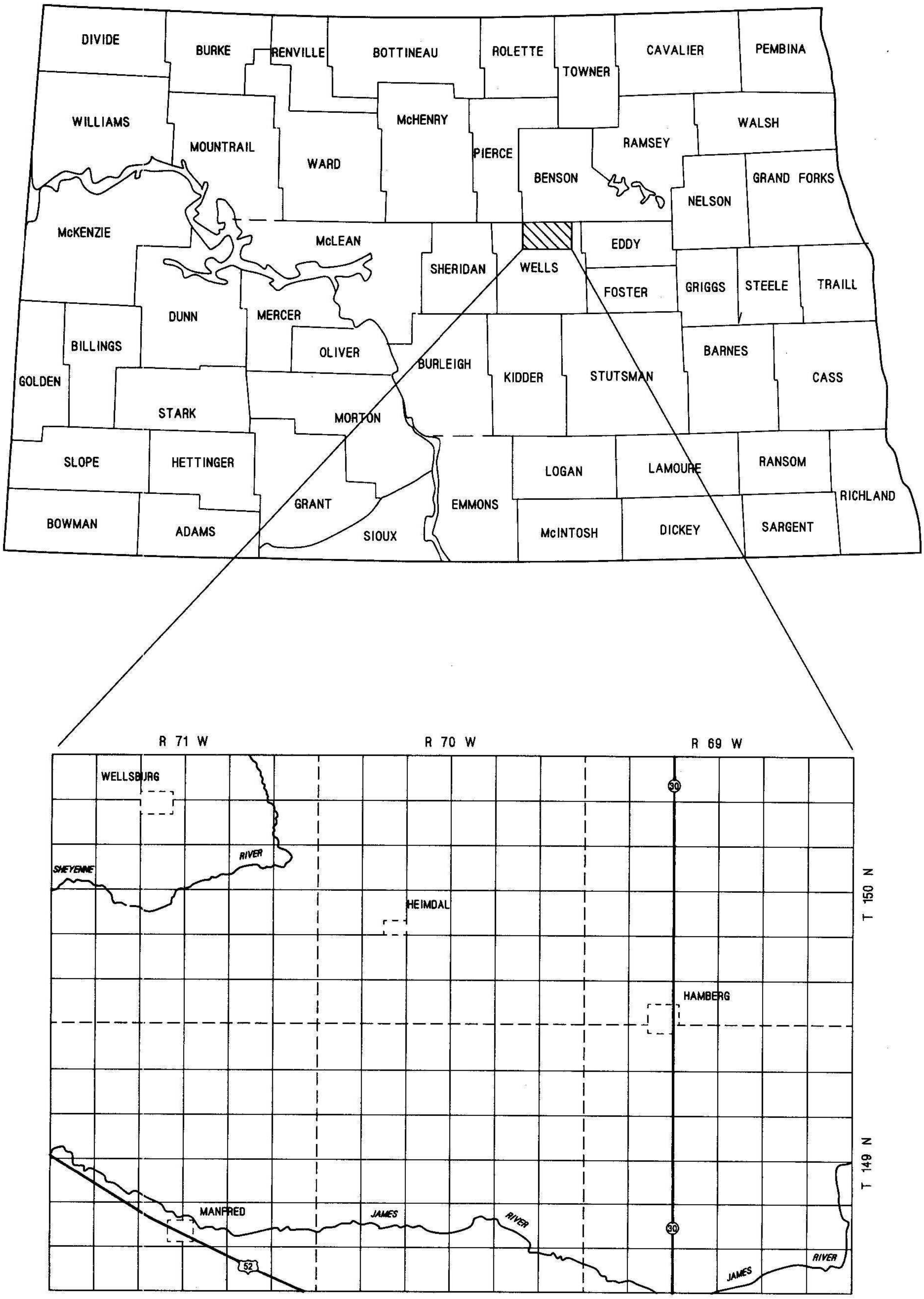

FIGURE 1. Study area location.

1970).

The area has a sub–humid continental climate with warm summers and cold winters. The average annual precipitation is about from 16.5 to 18.0 inches. Most of the precipitation occurs as rainfall from April through September. Average monthly temperature ranges from about 5^0F. in January to 70^0F. in July (USWB, 1982).

Acknowledgements

The authors express appreciation to John T. Betcher for his extensive work on this project which included some of the preliminary planning, chemical sampling, and interpretation of preliminary data. Milton Lindvig, State Water Commission; Paul Osborne, EPA; and Rick Nelson, ND State Department of Health are thanked for their administrative responsibilities and also their input into the scientific aspects of this report. Also to the State Water Commission personnel: Gary Calheim, for drilling the test holes; Allen Comeskey, for geophysical logging; Robert Shaver, David Ripley, and all of the other State Water Commission hydrologists for their assistance and guidance in all phases of the project. Greg Oberley from the Denver EPA office is thanked for his input in the interpretations of some of the data making up parts of this report.

We are also indebted to the cities of Fessenden and Harvey for the use of water from their municipal wells in our drilling operations.

Previous investigations

The geology and ground–water resources of Wells County were first discussed in a report by Simpson (1929) which described ground water conditions in North Dakota during 1911–1913.

Abbott and Voedish (1938) published a report on the municipal ground–water supplies of North Dakota that included data on several wells in Wells County.

Unpublished data on the ground–water conditions in the vicinity of Fessenden were prepared in 1945 by T. G. McLaughlin, in cooperation with the North Dakota Geological Survey and North Dakota State Department of Health. Part of McLaughlin's work was included in a report by Filaseta (1946).

A ground–water survey of Wells County was conducted on a cooperative basis by the North Dakota State Water Commission (NDSWC), the North Dakota Geological Survey (NDGS), and the United States Geological Survey (USGS). The results of the survey are reported in three parts. Part I, Geology, is a comprehensive investigation of the surficial geology and a general study of the sub–surface geology (Bluemle, et. al., 1967). Part II, Basic Data, is a compilation of well records, test hole logs, well logs, water level measurements, and chemical analyses (Burturla, 1968). Part III, Ground–Water Resources, presents a general evaluation of the water yielding potential and chemical quality of major aquifers in the bedrock and glacial drift of Wells County (Burturla, 1970). Preliminary identification and mapping of the New Rockford aquifer in Wells County was accomplished by the county ground–water study.

Jon Reiten (1985), prepared an unpublished report on the hydrogeology of the New Rockford aquifer system. He discusses the hydrogeology of the aquifer for its entire length across several counties, including Wells County.

Location–numbering system

The location–numbering system used in this report is based upon the location of a well or test hole in the Federal system of rectangular surveys of public lands (fig. 2). The first number denotes the township north of a baseline and the second number denotes the range west of the Fifth Principal Meridian. The third number indicates the section in which the well or test hole 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). Thus well 149–69–12AAA would be located in the $NE^1/_4$ $NE^1/_4$ $NE^1/_4$ Section 12, Township 149 North, Range 69 West. Consecutive terminal numerals are added if more than one well is located within a 10 acre tract. In this study, the first well drilled would be 12AAA, the second AAA1, the third AAA2.

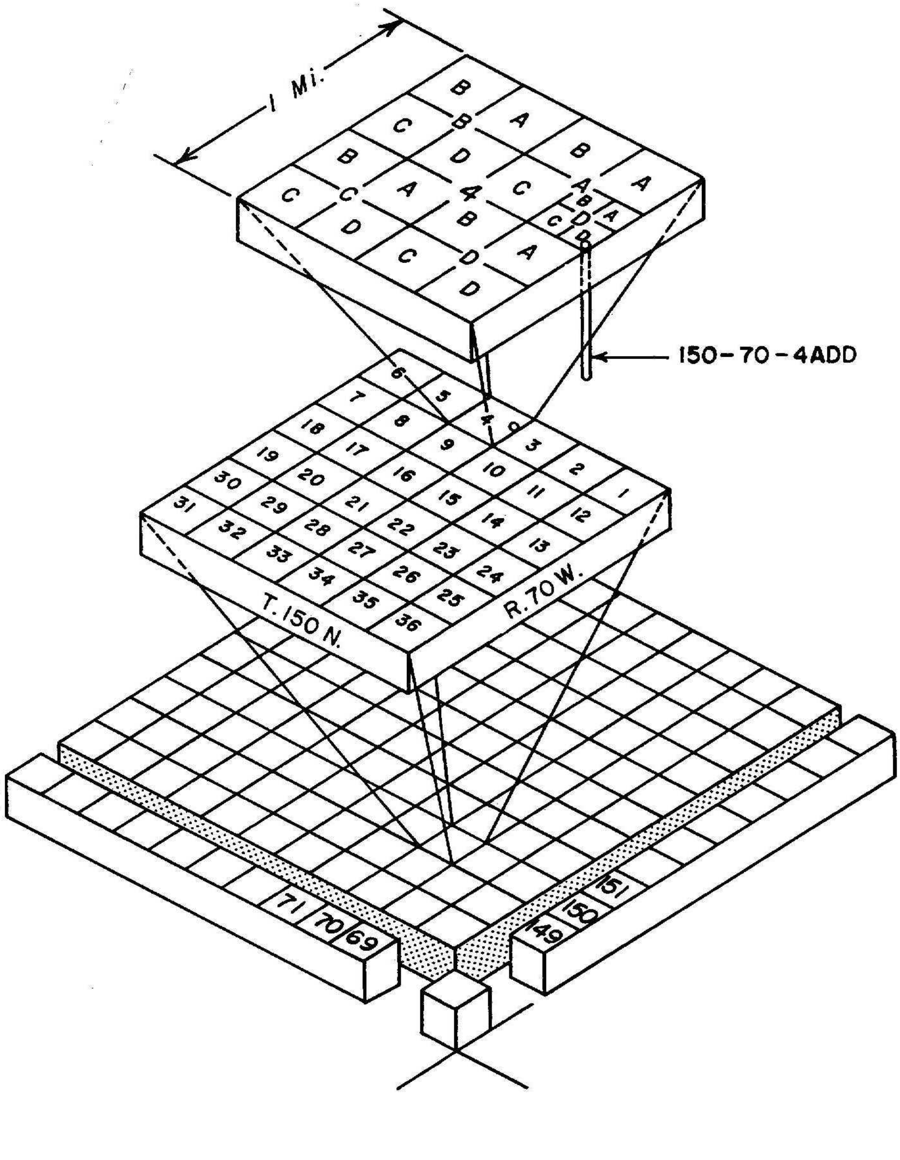

FIGURE 2. Location - numbering system.

FIELD METHODS

Drilling and installation of piezometers for Phase I

From July, 1986 to May, 1987, test holes were drilled at 45 sites in the study area. A forward mud rotary drilling rig was used to drill all test holes during Phase I. A geologic description of lithologies penetrated was prepared by the site geologist and a driller's log was prepared by the driller at each site. Geophysical logs including gamma, neutron, single point resistance, spontaneous potential, 16" normal resistance, and 64" normal resistance were run at most of the drilling sites.

Forty–five piezometers were installed at 34 of the 45 drilling sites. A 4 $^3/_4$ inch pilot hole was drilled at each site. At selected sites, the 4 $^3/_4$ inch hole was reamed to 6 $^1/_4$ inches to allow insertion of both the well casing and a tremie pipe. The piezometers were constructed with 20 foot lengths of 2 inch or 1 $^1/_4$ inch diameter SDR 21 pvc pipe and a .012 inch or .018 inch slot pvc screen. Screen lengths were generally 5 feet. A check valve was attached to the bottom of the screen. All casing joints were assembled with pvc solvent weld cement. Once inserted, the hole was backwashed with clean water to purge the hole of the drilling fluid. A 1 $^1/_4$ inch pvc tremie pipe was used to place sand pack around the screened interval and also to inject a cement slurry into the annulus from the top of the sand pack to land surface. At selected sites, the formation was collapsed around the screen, rather than sand packed. The collapse method was used where the overlying till was continuous with no significant sand and gravel lenses. After backflushing, compressed air is pumped through the casing and screen which blows the water from the annulus, causing the formation to collapse around the screen. When blown with air, the more competent till would stand open while the sand and gravel would generally slump into the hole. The annular space was then grouted from the top of the collapsed sand to land surface through a tremie pipe.

The sand pack was medium size (#10), commercially processed, quartzose sand. The grout consisted of either a neat cement slurry, or a mixture of a high solids bentonite grout and water. The neat cement slurry consisted of a 5% by weight bentonitic mix with portland cement. Approximately 9 gallons of water were used per bag of cement.

All water used in the drilling operation was obtained from the city of Harvey's municipal New Rockford aquifer well, or Fessenden's municipal New Rockford aquifer wells.

Upon completion, the wells were developed by pumping with the air lift method. A small diameter rubber air compressor hose was inserted down the well to just above the screen. The wells were pumped usually 4 to 8 hours at approximately 1 gallon per minute.

Drilling and installation of piezometers for Phase II

In November, 1986, 18 piezometers were installed at six sites. A truck mounted hollow–stem auger was used to drill all holes. A continuous core sample device was used to collect core samples from the deepest hole at each of the six sites. A lithologic description was prepared by the site geologist. Selected core samples were saved for laboratory analysis.

The piezometers were constructed with 20 foot lengths of 2 inch diameter SDR 21 pvc pipe with screen lengths ranging from 2.5 to 20 feet. Screen slot sizes were either .012 inch or .018 inch. A plug was placed on the bottom of the screen. All pipe connections were assembled with pvc solvent weld cement.

Once the holes were drilled to the desired depth, the pipe was installed through the hollow stem of the auger. The auger flights were then pulled from the hole leaving the well casing in place. The well screen was packed with either #10 commercial silica sand or "buckshot" gravel (coarse sand to 3mm gravel). Bentonite pellets were placed on top of the sand pack to a thickness of 2 to 3 feet. The annulus was then filled to land surface with a 5% by weight bentonite neat cement slurry. No water other than what was used for mixing the cement, was used in the drilling process for Phase II.

The auger hole drilled at nest site 149–69–4bbb was drilled through an 8 inch steel casing installed from land surface to a depth of 30 feet. The casing was installed to prevent a surficial sand and gravel unit (Heimdal aquifer) from collapsing into the hole when the auger flights were pulled up. An $11^3/_4$ inch diameter bit was used to drill down 30 feet. The casing was set in place and the annular space was grouted with a neat cement slurry.

Measurement of water levels

Upon completion of the piezometers for phase I and II, water levels were monitored on a monthly basis. In addition, 7 wells which were installed for the county studies program in the mid 1960s were incorporated into the monitoring network.

Water level measurements were obtained by running a chalked steel tape into the piezometer and recording the depth to water from the measuring point to the nearest 1/100 foot. On all of the wells with the exception of two (149–71–19CDD and 149–71–31CCB), measuring point and land surface elevations were determined by differential leveling techniques. The level circuits were completed to mean sea level elevation. The circuits were run with third order accuracy and the elevations were recorded to the nearest 1/100 foot.

Chemical sampling procedure

Water samples were collected for all wells completed in Phase I and Phase II of the study for major anion/cation analysis. Selected wells were also sampled for tritium and the stable isotopes of oxygen and hydrogen. The chemical parameters as well as methods of analysis used in this study are listed in Table 1 (p. 81).

Johnson–Keck submersible pumps were used to pump the wells at a rate of generally 0.5 to 1.5 gallons per minute. Wells which could be pumped continuously without going dry were pumped until at least three casing volumes of water were removed before the sample was collected. Wells which could be completely evacuated were either pumped or bailed dry and allowed to recover twice before the sample was collected.

Conductivity, temperature, and pH measurements were taken for each ground–water sample in the field at the time of sampling. The amount of dissolved oxygen present in ground–water samples was also measured in the field for selected samples.

A one–liter, 0.45 micron filtered sample was collected for major anion/cation analysis.

Two 120–ml samples were collected, 0.45 micron filtered, and preserved with nitric acid for iron and manganese analysis. Also, a 120–ml non–filtered sample was collected in a glass vial with zero head space (to eliminate any evaporation) for ^{18}O (oxygen–18) and ^{2}H (deuterium) analysis. Finally, a one–liter non–filtered sample was collected into a glass container for Tritium analysis.

Slug test procedure

Slug tests were conducted on selected wells to determine hydraulic conductivities. Slug tests were conducted by dropping a solid cylinder of known volume below the water level in a well, thereby creating an instantaneous rise in the water level and then recording the water level equilibration. A cylinder was designed and fabricated of steel pipe and capped at both ends. When fully submerged, the cylinder raised the water level one meter (3.28 feet) in the 2 inch piezometers installed for this study. The re–equilibration of the water level with time was then measured with an electric water level sensor at specific time intervals. On two wells screened in non–fractured till (149–69–09CBB4 and 149–69–24BCC3), a continuous water level recorder (Keck water level sensor) was used to monitor the water level re–equilibration.

GEOLOGY

Formation of the New Rockford buried valley

The New Rockford aquifer occupies a portion of a broad buried valley associated with Pleistocene glaciation. The valley trends generally northwest to southeast. The valley probably developed as Pleistocene glaciers advanced southward and blocked the north flowing drainage, diverting it to more southeasterly routes. The most important of the preglacial north flowing drainage in this area were the Knife and Cannonball Rivers which flowed from southwestern North Dakota (Bluemle et al., 1967).

Bluemle et al. (1967), named the resulting valley the Heimdal trench. Trapp (1968), renamed the Heimdal trench the New Rockford channel to avoid confusion with the Heimdal diversion channel, a surficial meltwater feature named by Lemke (1960). Burturla (1970), preferred the use of the term valley rather than channel and his terminology is used in this report.

The New Rockford valley was filled with glacial drift as a result of the Pleistocene glaciation. There is no surface expression of the New Rockford buried valley. A typical section of the New Rockford valley, the glacial drift fill, and the underlying bedrock is shown on figure 3.

Formation of the New Rockford aquifer

During the Pleistocene epoch, proglacial lakes formed when advancing ice dammed existing rivers or when ice lobes retreated from their position of maximum advance. Drainageways that connected the proglacial lake are of two types: melt–water streams, and glacial lake spillways.

Melt–water streams deposited coarse outwash sediment of broad fluvial plains in front of glaciers. These rivers formed braided, aggrading fluvial systems. Spillways are narrow, deep trenches usually incised through the glacial drift into bedrock. These valleys are basically huge channels that were cut by sudden catastrophic drainage of glacial lakes. Spillways are therefore

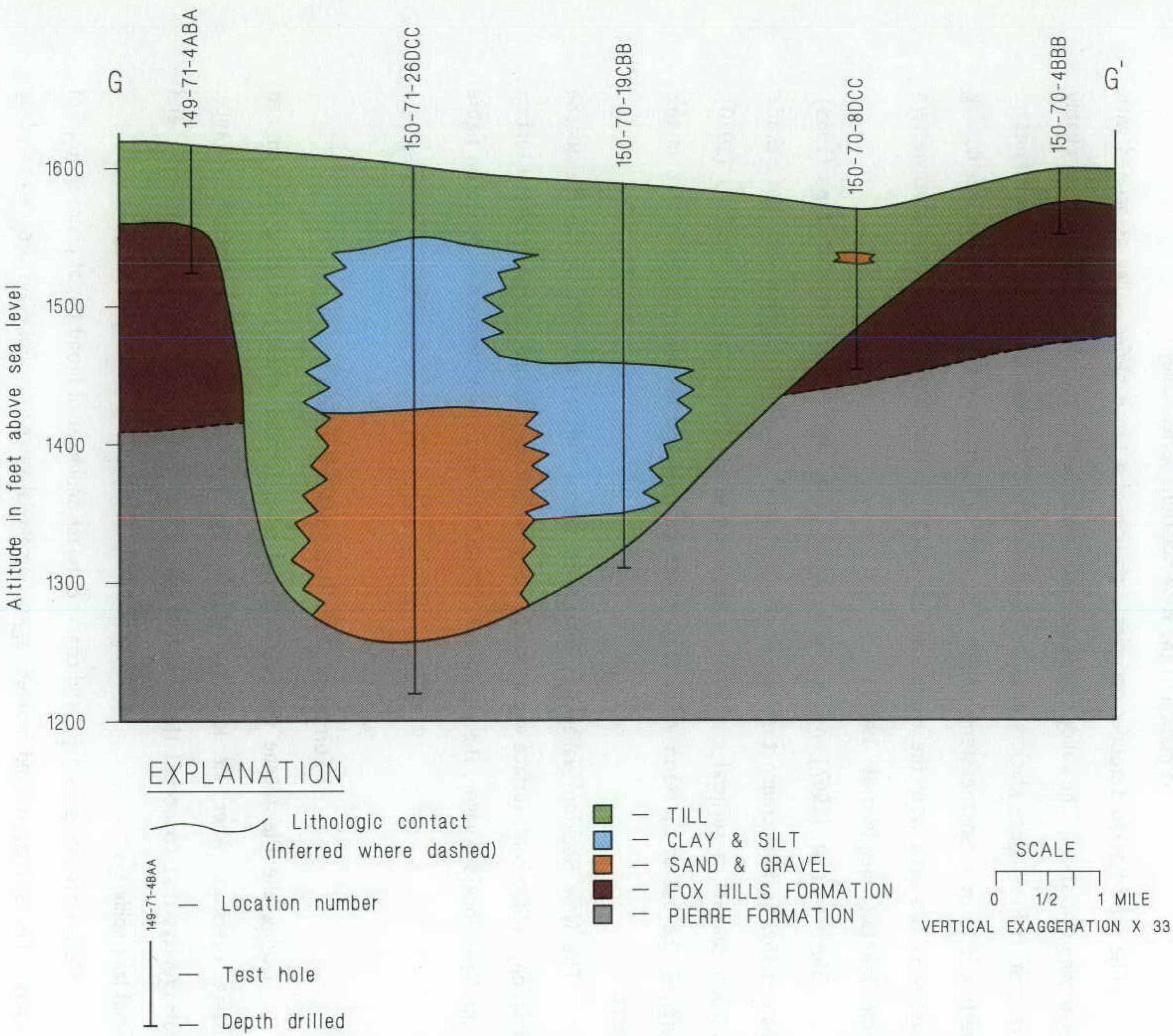

FIGURE 3. Geologic section of the New Rockford Buried Valley. (geology by J.C. Patch)

erosional rather than depositional features (Kehew, 1982; Kehew and Boettger, 1986; Lord and Kehew, 1987).

The New Rockford aquifer probably originated as a glacial lake spillway erosional event. Most of the channel fill sediments were probably deposited during interglacial periods (Kehew and Boettger, 1986). The complex spatial distribution of hydraulic heads in some areas of the aquifer system may reflect an anastomosing channel pattern of the original erosional event where the main trunk bifurcates around bedrock and till obstacles.

Stratigraphy

The Pierre Formation of Cretaceous age unconformably underlies the Pleistocene deposits of the Coleharbor Group throughout most of the study area. The Pierre Formation is composed of dark gray to black noncalcareous clay or shale and is believed to have been deposited in an offshore, marine environment.

The Fox Hills Formation of Cretaceous age conformably overlies the Pierre Formation and unconformably underlies the Coleharbor Group generally to the south and west of the study area. The Fox Hills lithologies in the study area consists generally of silt and silty clay with some interbedded lignite and lignitic shale. It is gradational downward with the clay and shale of the Pierre Formation. The Fox Hills Formation is believed to have been deposited in a marine coastal environment.

The Pleistocene Coleharbor Group unconformably overlies the Pierre Formation in the study area and also unconformably overlies the Fox Hills Formation to the south and west of the study area. The Coleharbor Group is divided by Bluemle (1979) into three main textural facies: (1) till, (2) silt and clay, and (3) sand and gravel.

The till facies of the Coleharbor Group is present throughout the entire study area ranging in thicknesses from 20 to 150 feet. The till is an unsorted mixture of material ranging in grain size from clay to boulders. Generally, till in the study area consists of nearly equal parts of sand, silt, and clay. Based on a textural analysis of twelve cores (table 2, p. 82) the till is composed of:

I.) Clay (<2 microns) – 20 to 25 percent

2.) Silt (2–50 microns) – 35 to 45 percent

3.) Sand and gravel (>50 microns) – 35 to 45 percent

The percent sand, silt, and clay with depth for various sites is shown in figure 4. The grain size composition of the till samples analyzed is fairly consistent below approximately 15 feet below land surface (fig. 4).

The unweathered till is characterized by medium to dark gray color and a very firm, cohesive texture. The weathered till is characterized by a yellow, rust color due to oxidation. Several fracture planes were intersected during continuous coring within the till. The fractures were present in all of the core samples taken of the weathered till. The fracture planes are randomly oriented and variably spaced. Iron and manganese staining is common along fractures with gypsum crystals evident in some fractures. Fractures observed in the till were not noted more than eight feet below the weathered till zone, and fractures were not detected in the till deeper than 27 feet below land surface.

The silt and clay facies of the Coleharbor Group is believed to have been deposited in a glaciolacustrine environment. The lithology ranges from clay and silt to fine sand. A 180 foot sequence of silt and clay deposits occur in the north–central part of the study area at 150–70–32ABB. Based on a textural analyses (table 2, p. 82) of five samples the silt and clay facies is composed of:

1.) Clay (<2 microns) – 0.2 to 14.1 percent

2.) Silt (2–50 microns) – 8.8 to 78.7 percent

3.) Sand (>50 microns) – 7.2 to 91.0 percent

The sand and gravel facies of the Coleharbor Group is believed to have been deposited in a glaciofluvial environment. Surficial expressions of the sand and gravel facies in the study area are generally kames and eskers. Also, the Heimdal aquifer exists as a surficial melt water channel deposit in the study area. The sand and gravel facies in the subsurface occurs as

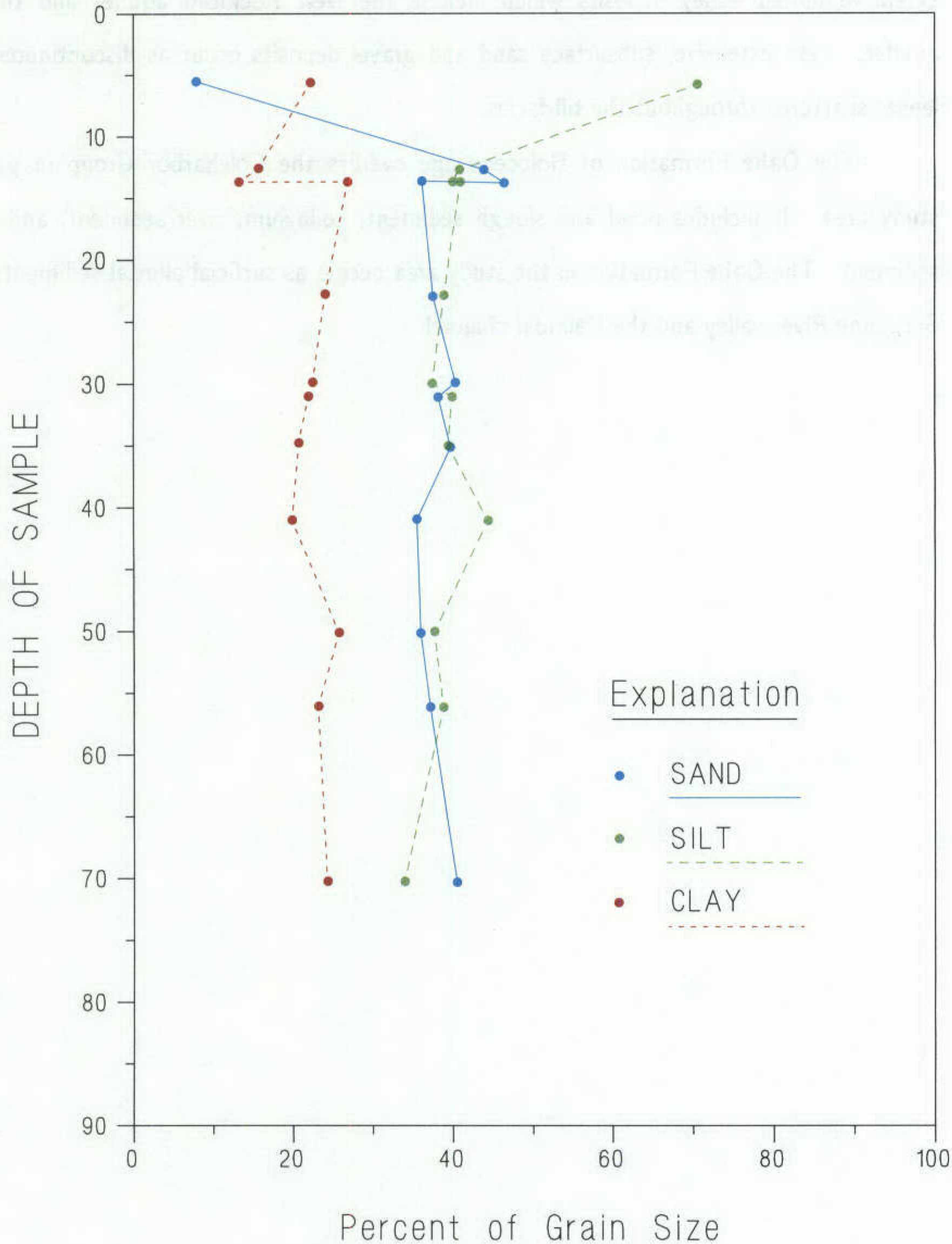

FIGURE 4. Clay, silt and sand fraction of the glacial till with depth at various locations.

extensive buried–valley deposits which include the New Rockford aquifer and the Manfred aquifer. Less extensive, subsurface sand and gravel deposits occur as discontinuous layers or lenses scattered throughout the till facies.

The Oahe Formation of Holocene age overlies the Coleharbor Group in parts of the study area. It includes pond and slough sediment, colluvium, river sediment, and windblown sediment. The Oahe Formation in the study area occurs as surficial alluvial sediments along the Sheyenne River valley and the Heimdal channel.

GROUND WATER HYDROLOGY

General statement

The science of ground–water hydrology relates to all aspects of the occurrence and movement of water in the subsurface. The discussion in this section, however, will be limited to the physical size and shape (the geometry) of the aquifers present in the study area, and the hydraulic flow system in and adjacent to them.

The geometry of the aquifers is interpreted from the test drilling. The hydraulic flow system is interpreted from the measurements of the hydraulic head (water level) in the piezometers.

The hydraulic head is a physical quantity, capable of being measured at any point in the flow system. The total hydraulic head is the sum of two components; the elevation head and the pressure head. The direction of ground–water flow will always occur from regions of higher hydraulic heads to regions of lower hydraulic heads regardless of direction in space. The potential for ground–water flow is determined from the hydraulic gradient. The rate of ground–water flow, however, is limited by the hydraulic conductivity.

The rate of ground–water flow is related to the hydraulic gradient and the hydraulic conductivity as defined by Darcy's law:

$$\nu = -K/n \; dh/dl$$

where:

ν = velocity of flow

K = hydraulic conductivity

dh/dl = hydraulic gradient

n = porosity

Discharge areas from confined aquifers to the land surface can occur where the potentiometric surface is at or above land surface. Topographic low areas are where discharge to the surface from confined aquifers usually occurs.

In a glaciated prairie environment, a water table condition is generally present in the surficial till overlying a buried aquifer. If the surface of the water table in the surficial till is above the potentiometric surface of the underlying aquifer, recharge to the aquifer can occur from downward flow through the till.

Water movement into the aquifer through the till is mainly by flow in the primary porosity (interstitial flow) of the till. However, fractures (secondary porosity) present in the upper 20 to 30 feet of the till increase in the hydraulic conductivity substantially.

Ground water occurrence in the study area

Ground water in the study area occurs as interstitial water in clay, silt, sand, and gravel. There are three major sand and gravel units within the study area which readily transmit water; the New Rockford aquifer, the Heimdal aquifer, and the Manfred aquifer (fig. 5). The finer–grained sediments surrounding these aquifers also store water but do not as readily transmit it. Nevertheless, the sediments surrounding the aquifers play an important role in the entire ground–water flow system. The finer–grained sediments adjacent to the aquifers in the study area are glaciolacustrine clay and silt; glacial till composed of sand silt and clay; and bedrock sediments composed of clay, silt, and shale.

Several cross–sections have been prepared to show the relationships of the stratigraphy in the study area. The cross–sections are presented in figures 6, 7, and 8 and are shown in map view on plate 1.

New Rockford Aquifer

The New Rockford aquifer is a channel deposit which developed sometime before the Late Wisconsin glaciers occupied this part of North Dakota. The aquifer consists generally of sand and gravel with some small amounts of clay and silt. The sand and gravel is rounded to angular and consists predominantly of igneous and metamorphic rock fragments, quartz, carbonates, shale and lignite.

In the study area, the New Rockford aquifer ranges in thickness from a few feet on the

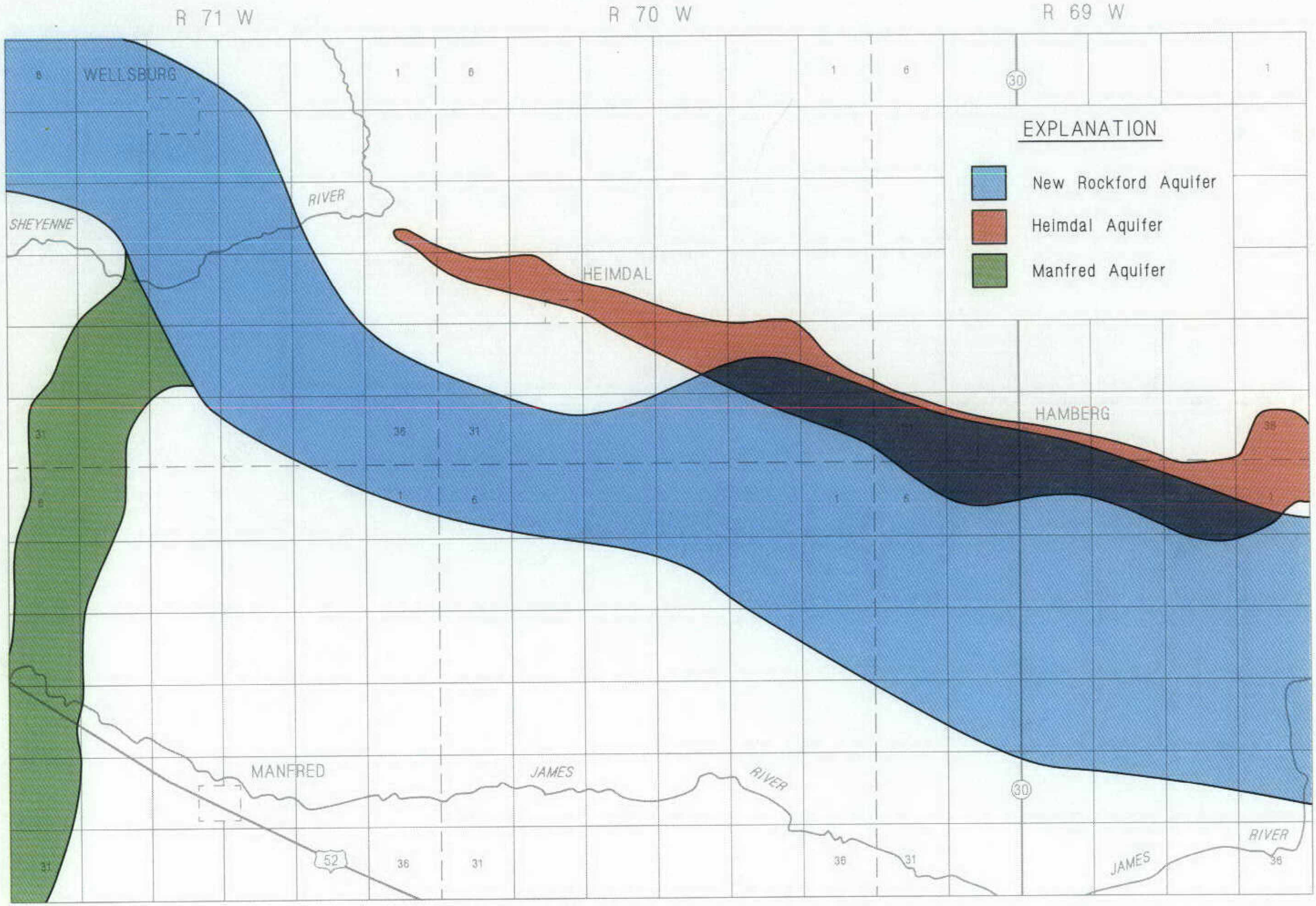

FIGURE 5. Location of the aquifers within the study area.

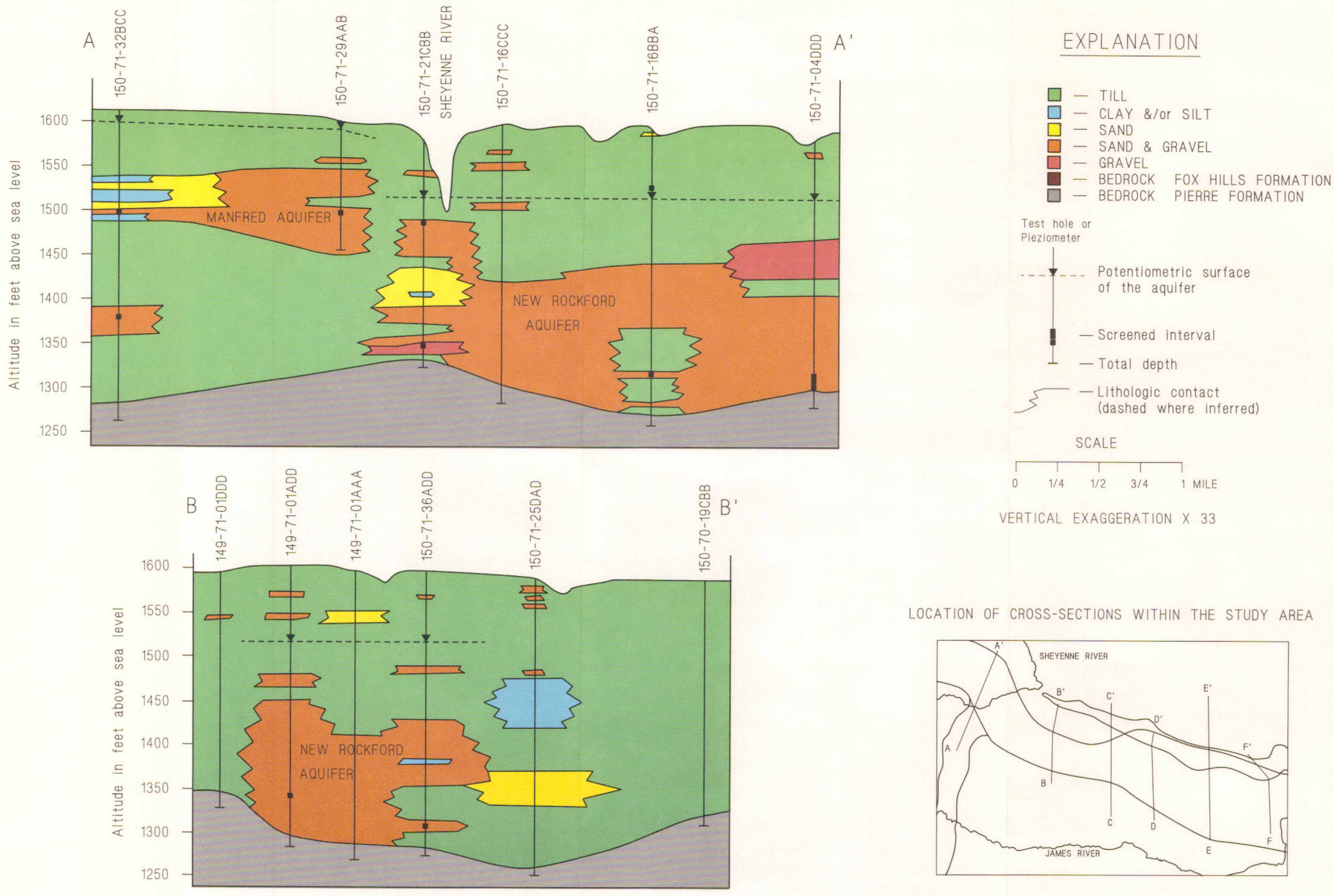

FIGURE 6. Geohydrologic sections A-A' and B-B'. (hydrogeology by J.C. Patch and G.W. Knell)

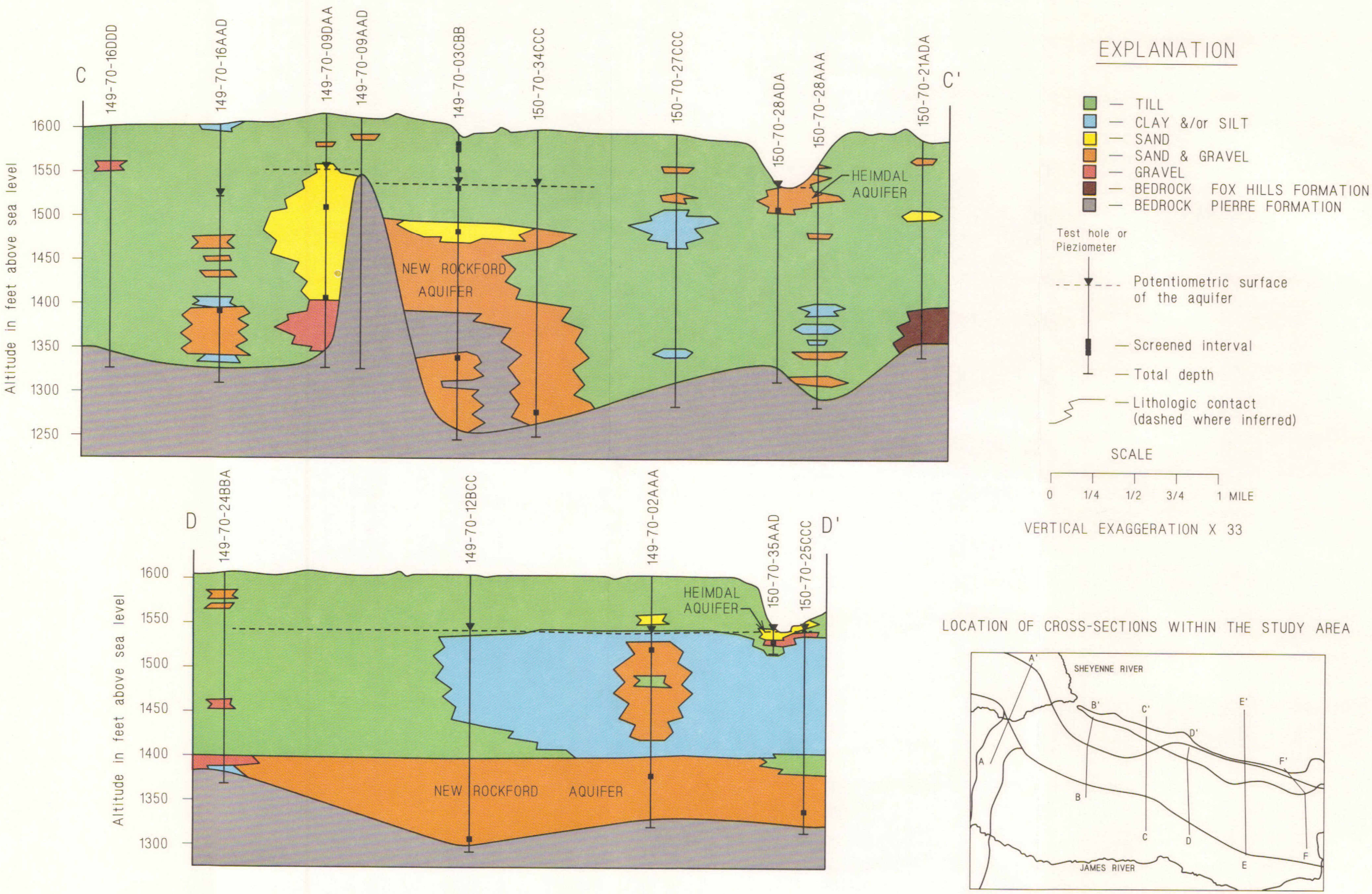

FIGURE 7. Geohydrologic sections C-C' and D-D'. (hydrogeology by J.C. Patch and G.W. Knell)

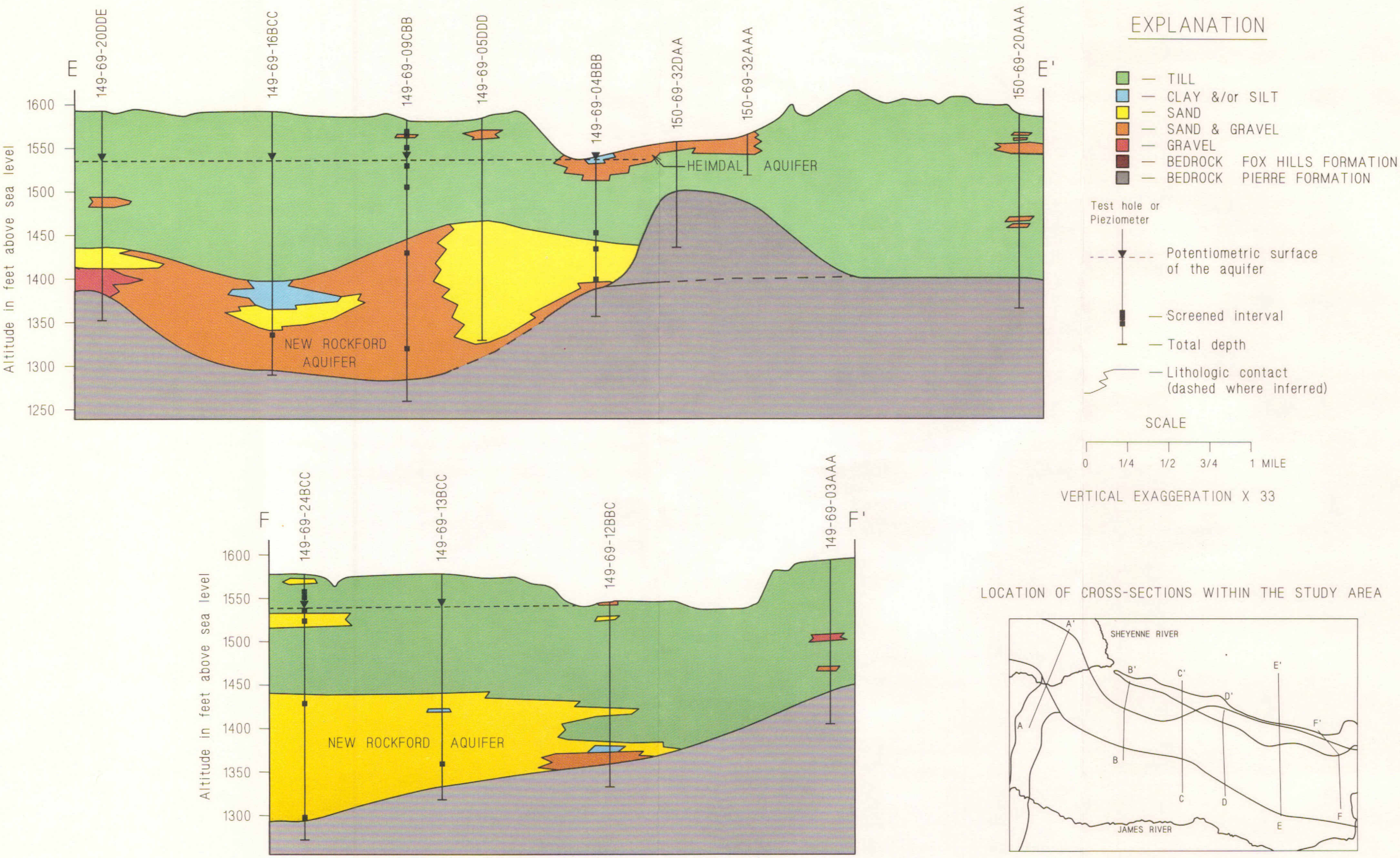

FIGURE 8. Geohydrologic sections E-E' and F-F'. (hydrogeology by J.C. Patch and G.W. Knell)

flanks to over 250 feet at test hole 149–69–06DCC. The average thickness in the study area is approximately 125 feet. The aquifer is usually present in the zone of 1250 to 1450 feet above mean sea level within the study area. The aquifer is generally incised into glacial till down to the underlying bedrock. The width varies from approximately 1 $^1/_2$ miles wide south of Heimdal (figure 6, cross section B–B'), to 5 miles wide south of Hamburg (figure 8, cross section E–E').

A bedrock high exists between the Fessenden city well field in 149–70–4DAA and the observation wells in 149–70–09DAA (figure 7, cross–section C–C'). At test hole 149–70–09ADD, the Pierre Formation was encountered at a depth of 60 feet below land surface. The test hole was drilled to a depth of 260 feet below land surface to ensure that the anomalously high occurrence of bedrock here is not a bedrock shove block. The bedrock high may be an erosional remnant left by a glacial lake outburst. The outburst may have formed an anastamosing channel and bifurcated around this obstacle.

The thickest continuous interval of sand and gravel encountered occurs at test hole 149–69–06DCC. The sand and gravel extends from 33 feet to 285 feet below land surface. At this location, the top of the aquifer occurs at a much higher elevation than at any of the surrounding test holes. The upper part of this sand and gravel interval may represent a younger fluvial sequence that was deposited on top of the older channel fill of the New Rockford aquifer.

The continuity of the aquifer is truncated by a low–transmissivity (T) barrier south of Heimdal. The barrier was intersected at test hole 149–70–4BBB. The transverse barrier may represent a glacial lake spillway that developed by catastrophic flooding as nearby proglacial ice–dammed lakes were breached (Kehew and Boettger, 1986). Catastrophic flooding is a mechanism that could account for the development of narrow trench–like channels which contain fine grained fluvial and lacustrine sediments consisting predominantly of silt and clay. The catastrophic flood hypothesis is supported by the occurrence of over 180 feet of lacustrine clays and silts at 150–70–32ABB. A re–advance of the ice deposited till above the fine grained fluvial and lacustrine channel fill.

Glacial scouring is another mechanism that could produce a transverse low–transmissivity barrier. Local glacial readvances into the ice marginal river valley could remove the glaciofluvial channel fill deposits and replace them with blocks of till.

Water levels measured in the piezometers east of the low–T barrier are 18 to 20 feet higher than water levels measured west of the barrier. A potentiometric map of the New Rockford aquifer (fig. 9) shows that the lateral hydraulic gradient on the western side of this divide is very small. There is, however, a slight gradient toward the Sheyenne River indicating that the Sheyenne River valley is a local discharge area for the New Rockford aquifer.

The potentiometric map (fig. 9) also shows that ground water in the eastern part of the study area flows generally eastward. The lateral hydraulic gradient ranges from nearly flat to 4 feet per mile. Using an estimated hydraulic conductivity of 400 feet per day for the type of material found in the aquifer, the velocity of the water is probably not more than 300 feet per year laterally.

A residual cone of pressure relief occurs around the Fessenden well field. The well field has not been used extensively since December 1986 and water levels in this area are recovering to pre–pumping static conditions. The city of Fessenden has been purchasing water for its municipal supply from Wells County Water Association since January 1987.

The sand and gravel interval south of a bedrock high in 149–70–9AAD is not in direct hydraulic connection with the rest of the aquifer. The water level in piezometer 149–70–9DAA1 is 10 to 15 feet higher than in other piezometers north of the bedrock high. In addition, anomalously high water levels in three other piezometers, 149–70–3CBB, 149–70–03DDD, and 150–70–32CCC, indicate the zone in which they are screened is not in direct hydraulic connection with the rest of the aquifer. At these three sites, an upper and a lower sand and gravel unit are present, separated by a low–transmissivity clay and/or clay and silt unit. The piezometers are screened in the lower sand and gravel unit. The anomalously higher water levels in the lower sand and gravel unit show the complex spatial distribution of the stratigraphy typical of the depositional environment in which the aquifer was deposited.

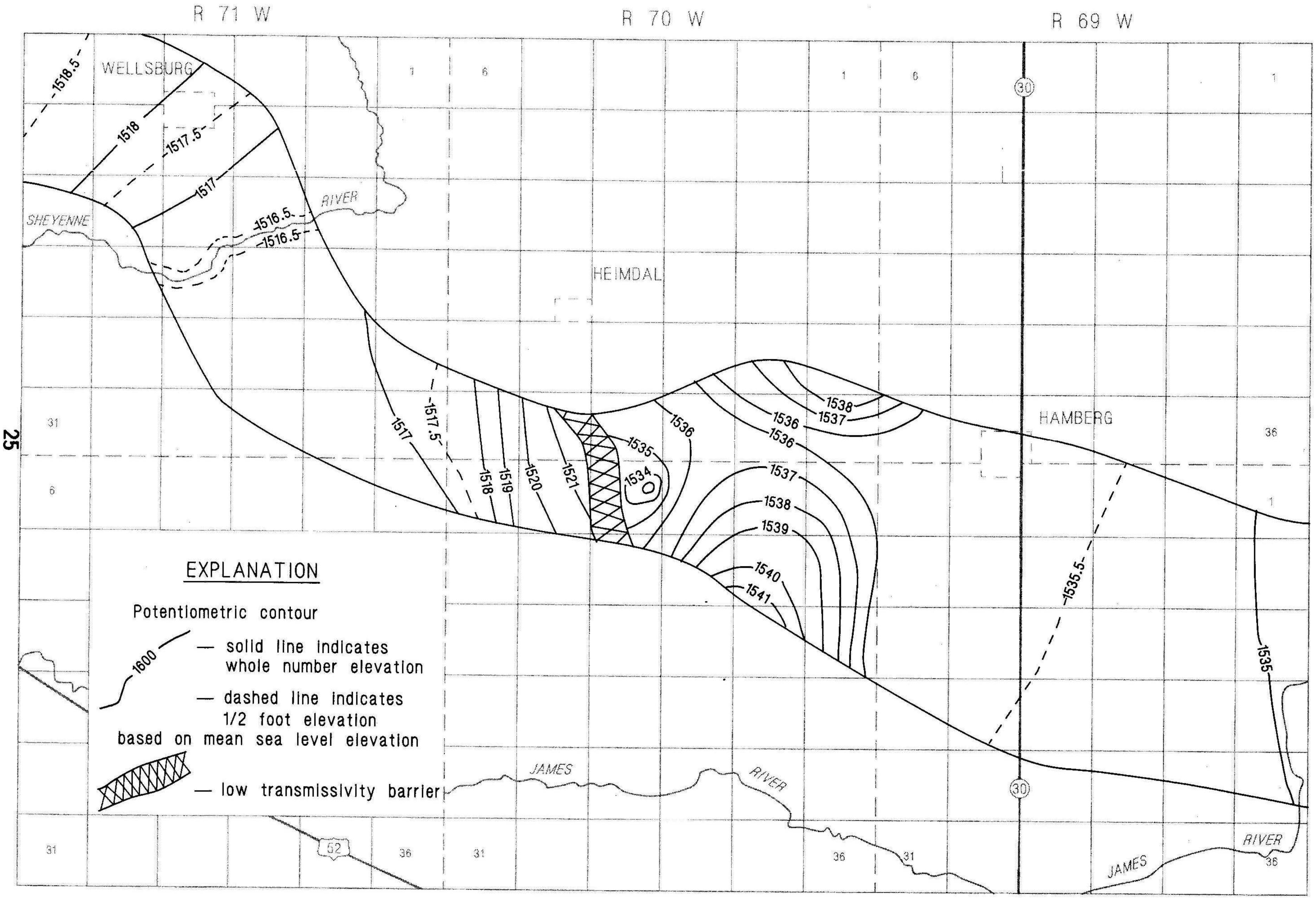

FIGURE 9. Potentiometric map of the New Rockford aquifer.

Heimdal aquifer

The Heimdal aquifer occupies a surficial glacial melt–water channel that overlies the New Rockford aquifer for much of its reach (figures 7 and 8, cross–sections C–C', D–D', and E–E'). The Heimdal aquifer is associated with Late Wisconsin diversion channels and is generally $^1/_2$ to 1 mile wide with an average thickness of approximately 30 feet. The aquifer is composed of fine sand to cobbles. The aquifer material consists of quartz, igneous and metamorphic rock fragments, carbonates, lignite and shale. The Heimdal and New Rockford aquifers are separated by 25 to 100 feet of till. at the five test hole sites where both aquifers were encountered.

Water in the Heimdal aquifer occurs under unconfined conditions. The aquifer is underlain by glacial till. Several sloughs are present in the Heimdal channel. The sloughs are windows in the water table of the Heimdal aquifer. A water table map of the Heimdal aquifer is presented in figure 10. The map shows flow in the Heimdal aquifer is generally eastward. Evapotranspiration from the connected surface water bodies directly affects the water level in Heimdal aquifer as declining water levels in the sloughs coincide with water level declines in the aquifer. Conversely, the influx of surface water runoff into the Heimdal valley increased the water level by at least 3 1/2 feet in the Heimdal aquifer during the snowmelt in March 1987.

Higher water levels in the New Rockford aquifer compared to water levels measured in the Heimdal aquifer at three sites where both aquifers are screened (149–69–04BBB & 04BBB1, 150–70–27DDA & DDA1, and 150–70–35AAD & 25CCC measured on September 10, 1987) shows that the Heimdal valley is a discharge area for the New Rockford aquifer. The Heimdal aquifer was described as a recharge area to the New Rockford aquifer in the Wells County ground–water study by Burtula (1970). The basis for this assumption was the high water level measured in a well thought to have been completed in the New Rockford aquifer. The well was located at 149–69–05DDD which is near the Heimdal aquifer. The water level in this well was much higher than water levels in other New Rockford aquifer wells which were installed further away from the Heimdal aquifer. Therefore, Burtula (1970) concluded water

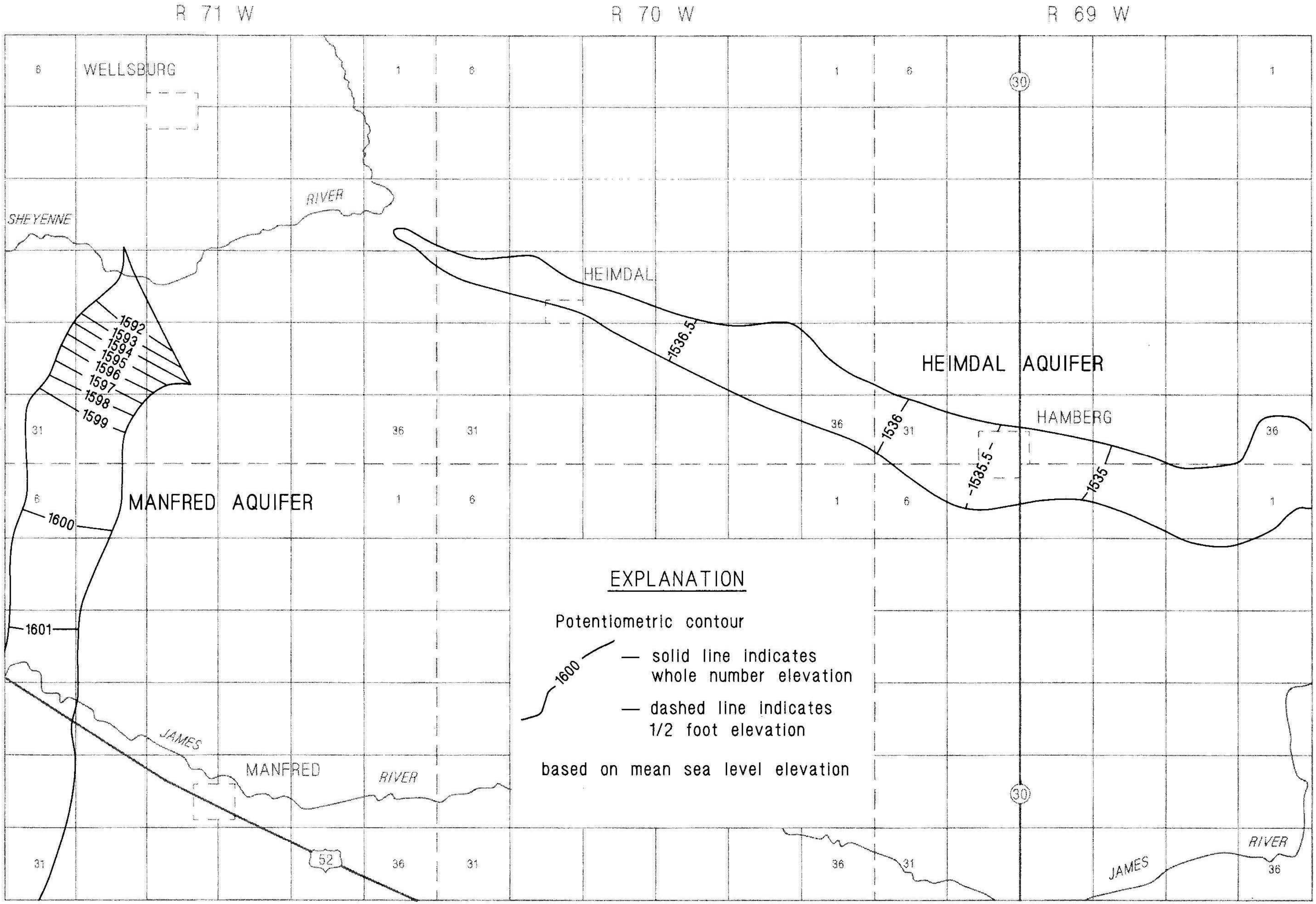

FIGURE 10. Potentiometric map of the Manfred and Heimdal aquifers.

was flowing from the Heimdal aquifer into the New Rockford aquifer. Additional water level measurements and water quality samples from more recent wells in this vicinity show that data from the well in 149–69–05DDD are not representative of the New Rockford or the Heimdal aquifers in this area. The well might have been plugged and/or collapsed which gave erroneous data.

Manfred Aquifer

The Manfred aquifer is a shallow buried valley deposit that exists in the western part of the study area. The aquifer is generally less than one mile wide and trends north–south. It may have been a tributary channel to the New Rockford valley (figure 6, cross–section A–A'). The average thickness is approximately 70 feet (Burtula, 1970). The aquifer consists of fine sand to cobbles primarily composed of quartz, igneous and metamorphic rock fragments, carbonates, shale, and large amounts of detrital lignite in some areas. Although the bottom of the Manfred aquifer is generally 10 to 20 feet higher than the top of the New Rockford aquifer, it does not appear to overlie any portion of the New Rockford aquifer.

Water in the Manfred aquifer occurs under confined conditions in the study area with confining lithologies consisting of either glacial till or Cretaceous shales below the aquifer and glacial till above the aquifer. A potentiometric surface map of the aquifer is presented in figure 10. The movement of water in the northern end of the Manfred aquifer is northward toward the Sheyenne River valley and New Rockford aquifer. The Manfred aquifer does not appear to be intersected by the Sheyenne River valley (fig. 6, cross–section A–A'). The difference in water levels, approximately 80 feet, between the Manfred and the New Rockford aquifers suggest no direct hydraulic connection (figure 6, cross section A–A').

Hydraulic properties of the glacial till

Nine slug tests were conducted at selected sites within the study area to determine point values of hydraulic conductivity. Five of these tests were conducted on wells screened in till and one test was conducted on a well screened in a lacustrine clay and silt deposit. Three slug tests were also conducted on sand, and sand and gravel deposits; one test each on sediments of the New Rockford aquifer, the Heimdal aquifer and on an inter–till sand deposit. The methods of Hvorslev (1951) and Cooper et al. (1967) were used to analyze the data. The results are shown in (table 3, p. 83).

Hydraulic conductivity values generally range from 10 to 10^4 feet per day in sand, and sand and gravel deposits (Freeze and Cherry, 1979). The one determined value of 144 feet per day in a New Rockford aquifer well is within this range. This well, 150–70–27DAA1, was observed to be screened in less permeable sediments than other New Rockford aquifer wells in the study area. This observation was made by noting its relatively slow pumping rate during well development. Therefore, hydraulic conductivity values, as a rule, are probably greater than 144 feet per day in the New Rockford aquifer. Water levels in wells screened in the Heimdal aquifer and an inter–till sand (150–70–27DAA and 149–69–24BCC3, respectively) recovered too fast during slug testing for time–versus–recovery measurements to be taken. Therefore, relatively high hydraulic conductivity values are indicated for these sediments also.

Hydraulic conductivity values generally range from 10^{-1} to 10^{-7} feet per day in glacial till (Freeze and Cherry, 1979). Hydraulic conductivity values for unweathered, non–fractured till in the study area range from 7.00×10^{-4} feet per day to 1.6×10^{-3} feet per day (Hvorslev method) and conform to those reported by Freeze and Cherry. Slug tests completed on two wells in fractured till show substantially higher values of hydraulic conductivity with values of 2.13×10^{-1} feet per day and 5.39×10^{-2} feet per day (Hvorslev method). This demonstrates that hydraulic conductivities are greatly increased in the till by fracturing. However, as stated before, fractures were not observed more than 8 feet below the weathered till zone during the continuous core augering in Phase II of the study. Therefore, increased hydraulic conductivity due to fracturing could not be established as an important control affecting the rate of downward movement of ground water at depth in the study area.

NESTED PIEZOMETER SITES IN TILL

Six sites were chosen for nested piezometer placement within the study area. At each of the six sites, groups of piezometers (nests) were installed and screened at various depths to assess the vertical ground–water movement through the till (figure 11). Table 4 (p. 84) lists nest site locations with piezometer screen intervals.

The first nest site is located at 149–69–09CBB (figure 11). This site typifies the geologic setting over much of the study area with approximately 100 feet of till overlying the New Rockford aquifer. Four piezometers were screened in the till and one piezometer each was screened in the upper and lower portions of the New Rockford aquifer.

A second nest site is at 149–70–3CBB (figure 11). This site is also geologically typical of the study area in that approximately 100 feet of till overlies the New Rockford aquifer. The site is located a short distance from the Fessenden municipal well field and therefore, the site was chosen to study the effects on the water levels from pumping. Three piezometers were screened in till and two piezometers were installed in the upper and lower portion of the New Rockford aquifer.

A third nest site is located at 149–69–24BCC (figure 11). At this site, an inter–till sand layer (45 to 60 feet below land surface) occurs in a relatively thick till sequence (138 feet) which overlies the New Rockford aquifer. The site was selected to evaluate the possible effects of inter–till sand intervals on recharge to the aquifer. Two piezometers screened in till above the inter–till sand interval, one in the inter–till sand, and one screened in the upper part of the New Rockford aquifer. An existing well screened in the lower portion of the New Rockford aquifer at this site was also used. Another piezometer screened in the till interval immediately below the inter–till sand was proposed and attempted here, however, this piezometer was not completed due to caving problems from the inter–till sand.

The fourth nest site is located at 149–69–06DCC (figure 11). At this site, a relatively thin layer of till (34 feet) overlies continuous sand and gravel deposits which, in turn, overlie the

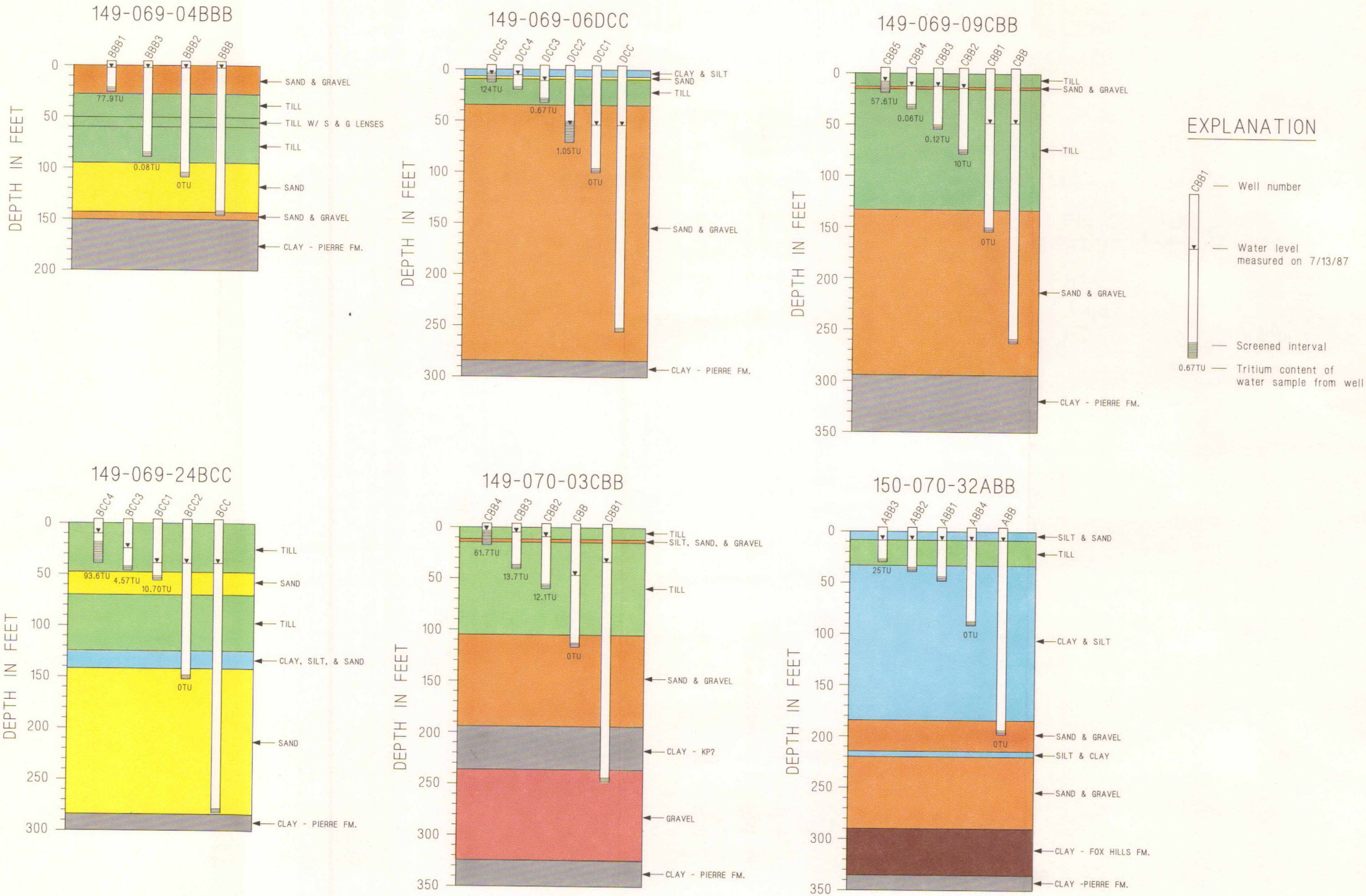

FIGURE 11. Nest site sections showing lithologies and tritium values. (hydrogeology by J.C. Patch)

New Rockford aquifer. The site was selected because of its potential as a recharge area to the New Rockford aquifer due to the relatively thin till cover. Three piezometers were screened in till and three piezometers were screened in the sand and gravel deposits (New Rockford aquifer).

The fifth nest site is located at 150–70–32ABB (figure 11). At this site, a relatively thin layer of till (33 feet) overlies approximately 100 feet of silt and clay which overlies the New Rockford aquifer. The silt and clay deposit is believed to be glaciolacustrine in origin. The site was selected to evaluate the effect of the lacustrine sediments on recharge to the New Rockford aquifer. One piezometer was screened in till, three piezometers were screened in the lacustrine sediments, and one piezometer was screened in the upper portion of the New Rockford aquifer.

The sixth nest site is located at 149–69–04BBB (figure 11). At this site, a 24 foot thick interval of the Heimdal aquifer overlies 68 feet of till which in turn overlies the New Rockford aquifer. The Wells County ground–water study (Burtula, 1970) indicated water was moving from the Heimdal aquifer to the New Rockford aquifer in this area. This site was selected to further evaluate this relationship. One piezometer was screened in the Heimdal aquifer, one in till, one in the upper portion of the New Rockford aquifer, and one in the lower portion of the New Rockford aquifer. Three piezometers screened in the till interval were proposed; however, only one of these was completed due to caving problems from the Heimdal aquifer.

The six nest sites define the direction of vertical ground–water flow in the study area. The vertical hydraulic gradients at the six sites range from 0 to 0.16 ft/ft. At nest sites 149–69–06DCC, 149–69–09CBB, 149–69–24BCC, and 149–70–03CBB, water levels decrease with increasing depth indicating downward ground–water movement. At nest sites 149–69–04BBB and 150–70–32ABB water levels increase with increasing depth indicating upward water movement. The upward gradient at 149–69–04BBB indicates water movement from the New Rockford aquifer upward through the till into the Heimdal aquifer. The anomalously high water level in the sand and gravel deposit at 150–70–32ABB compared with the rest of the aquifer indicates it is separated hydraulically from the aquifer. The upward gradient here indicates the sand and gravel unit is under enough hydrostatic pressure to cause upward water movement. The anomalously high hydrostatic pressure may be due to the weight of overlying sediments on this isolated sand and gravel interval.

CHEMICAL ANALYSIS

General Statement

Several processes in nature affect the ground water from its inception to the subsurface flow system to the time it is discharged from the system. The statement by Shaver (1985), best summarizes the problem the ground–water hydrologist faces when interpreting the ground–water chemistry in a glaciated prairie environment: "The water chemistry at any point in the flow system is the result of various combinations of processes which operate interactively. Therefore, it is difficult to verify the impact of each process on the observed water chemistry."

A major objective of this study is to assess the ground–water chemistry and its relation to the flow system. The development of a conceptual hydrogeochemical model is essential to adequately account for the observed water chemistry.

The conceptual model of the ground–water chemistry must account for the generally high dissolved solids concentration at the water table in the till as well as throughout the flow system. It must also account for the predominance of sodium (Na) and bicarbonate (HCO_3) in some waters and calcium (Ca), Magnesium (Mg), and sulfate (SO_4) in others.

The overall objective of the chemical analysis of the ground water in the study was to substantiate and/or further define the conceptual model of the ground–water flow system. The temporal and spatial distribution of chemical constituents may be used to indicate time and place of recharge, place of discharge and residence time within the aquifer.

Conceptual Hydrogeochemical Model

The first major process in the geochemical evolution occurs when the water passes through the organic rich soil horizons and acquires hydrogen ions (H^+) and hence lowers the pH. The H^+ are supplied primarily by three sources:

1) carbonic acid (H_2CO_3) from the decay of organic carbon compounds.
2) sulfuric acid (H_2SO_4) formed by the oxidation of organic sulfur (S).
3) sulfuric acid (H_2SO_4) formed by the oxidation of pyrite (FeS_2).

The formation of carbonic acid depends on the partial pressure of CO_2 in the organic–rich horizons of the soil. The partial pressure of CO_2 is typically much higher in the soil than it is in the earth's atmosphere due to the decay of organic carbonaceous material. The partial pressure of CO_2 in the soil is important because the CO_2 will react with water to form carbonic acid as follows:

$$CO_2(gas) + H_2O \longrightarrow H_2CO_3$$

Another acid producing element in the soil is organic sulfur. Organic sulfur enters the soil in the form of plant residues, animal wastes, chemical fertilizers, and rain water (Alexander, 1977). Also, organic sulfur was incorporated into the till in the form of coal chips and disseminated organics from the bedrock during glaciation (Hendry, 1984). The oxidation of organic sulfur which produces sulfuric acid is as follows:

$$2S + 3O_2 + 2H_2O \longrightarrow 4H^+ + 2SO_4^{2-}$$

The third acid producing reaction, the oxidation of pyrite, is expressed as follows:

$$4FeS_2 + 15O_2 + 14H_2O \longrightarrow 4Fe(OH)_3 + 16H^+ + 8SO_4^{2-}$$

In the three H^+ producing reactions above, the resulting pH of the ground water in the absence of buffering would become very low. However, if minerals are present that result in reactions that consume H^+, the pH will not decline as much as indicated.

The next major geochemical process, then, is carbonate mineral dissolution and pH control. The carbonate minerals, calcite and dolomite, are abundant throughout the till. These minerals are moderately soluble in water and dissolution to saturation occurs generally within a matter of days (Rauch and White, 1977). The dissolution reaction for calcite and dolomite can be expressed as follows:

$$CaCO_3 + H_2CO_3 \longrightarrow Ca^{2+} + 2HCO_3^-$$

$$CaMg(CO_3)_2 + 2H_2CO_3 \longrightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$$

$$2CaCO_3 + H_2SO_4 \longrightarrow 2Ca^{2+} + 2HCO_3^- + SO_4^{2-}$$

$$CaMg(CO_3)_2 + H_2SO_4 \longrightarrow Ca^{2+} + Mg^{2+} + 2HCO_3^- + SO_4^{2-}$$

The above equations show that as calcite and dolomite are dissolved, the H^+ is consumed and pH increases. Also, the Ca^{2+}, Mg^{2+}, HCO_3^-, and SO_4^{2-} increase. The concentration of these ions in solution will continue to rise until the water is saturated with respect to the carbonate minerals present. Mineral saturation of the solution will occur according to the following equilibrium reaction:

$$K_{eq}(\text{calcite}) = \frac{[Ca^{2+}]\ [HCO_3^-]}{[H^+]} = 102.15$$

$$K_{eq}(\text{dolomite}) = \frac{[Ca^{2+}]\ [Mg^{2+}]\ [HCO_3^-]}{[H^+]} = 10^{-6.14}$$

When saturation is attained, further dissolution of calcite and dolomite will not occur unless one of the bracketed constituents in the numerator decrease in value or the H^+ concentration in the denominator increases. Therefore, if Ca^{2+} is removed from solution, more calcite and dolomite will dissolve if these minerals exist in the system.

Another process that must be addressed at this time is gypsum precipitation/dissolution. If Ca^{2+} enters solution as a result of calcite or dolomite dissolution and if SO_4^{2-} enters solution as a result of the oxidation of organic sulfur or pyrite oxidation, the water may become saturated or supersaturated with respect to gypsum ($CaSO_4$). If supersaturation occurs, precipitation of gypsum will occur. This assumption is supported by the fact that gypsum crystals were noticed in several of the lithologic cores taken from the weathered till during phase II drilling for this study. The dissolution/precipitation reaction for gypsum is as follows:

$$Ca^{2+} + SO_4^{2-} + 2H_2O \longrightarrow CaSO_4 + 2H_2O$$

The equilibrium equation for gypsum is (Cherry, 1968):

$$K_{eq}(\text{gypsum}) = [Ca^{2+}]\ [SO_4^{2-}] = 10^{-4.664} \text{ @ } 10^{\circ}C$$

If the products, $[Ca^{2+}]$ and $[SO_4^{2-}]$, exceed the value of K_{eq}(gypsum) at the temperature of the system, gypsum will precipitate. The precipitation reaction proceeds quickly relative to the rate at which water moves in most subsurface systems (Groenewold et al., 1983).

A mode of concentrating the dissolved mineral components of gypsum (Ca^{2+} and SO_4^{2-}) enough for supersaturation and precipitation of gypsum to occur is <u>evapotranspiration</u>. Nearly all of the water input to the soil zone through precipitation from April through November is removed by bare ground evaporation and plant transpiration. However, organic sulfur may oxidize even with the short residence time of the water and release H^+ and SO_4^{2-} ions as shown earlier. The H^+ ions would dissolve the carbonates yielding Ca^{2+}, Mg^{2+}, and HCO_3^-. As the soil water is evapotranspirated, these ions (Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}) would become concentrated. Precipitation of calcite, gypsum, and other salts would probably take place. During exceptional infiltration (excessive rainfall) events from April through November or precipitation and snowmelt infiltration during the rest of the year, water will escape below the zone of evapotranspiration and cause recharge to the water table. As the water moves downward through the soil strata and below, the gypsum which had precipitated earlier is dissolved and the water delivered to the water table is very high in its concentration of SO_4^{2-} and Ca^{2+} & Mg^{2+} (or Na^+ if cation exchange is taking place as will be discussed later).

The SO_4^{2-}/HCO_3^- ratio of the 14 till water samples collected for this study range from 1/1 to 6/1 (in equivalent parts per million) but can be much higher. The higher SO_4^{2-} compared with HCO_3^- can be explained by the fact that the dissolution and precipitation of gypsum is not pH dependent whereas calcite and dolomite are pH dependent. Therefore, gypsum would be dissolved more readily than carbonate minerals in the presence of slightly basic water. Also, the coefficient of solubility of gypsum is higher than that of calcite. The following table lists the coefficients of solubility for some common minerals.

Coefficients of solubility in grams/kilogram

of solution at 10°C

$CaCO_3$	0.014	Na2CO3	107
$MgCO_3$	0.1	$MgSO_4$	236
$CaSO_4$	1.926	NaCl	263
$NaHCO_3$	75.8	$MgCl_2$	349
Na_2SO_4	82.5	$CaCl_2$	394

Generally speaking, the higher the coefficient of solubility, the first to be dissolved; the lower the coefficient of solubility, the first to be precipitated (Schoeller, 1967). Therefore if a moderate pH water (pH = 7 to 8) near saturation with respect to calcite and dolomite moves through the zones where the salts had been deposited earlier by the effects of evapotranspiration, gypsum would probably dissolve more readily than calcite or dolomite.

The last major geochemical process to be discussed here is cation exchange. When the process of cation exchange is coupled with the process of the dissolution of carbonate minerals, very high concentrations of Na^+ and HCO_3^- can be acquired in the ground water. When saturation of calcite and dolomite is attained by the processes described earlier, further dissolution of these carbonate minerals will not be obtained unless one or more of the constituents decrease in value. Therefore, if Ca^{2+} & Mg^{2+} are removed from solution, more calcite and dolomite will dissolve if these minerals are present. Cation exchange is the major process by which Ca^{2+} & Mg^{2+} removal occurs. A high concentration of HCO_3^- can be achieved if the concentration of Ca^{2+} or Mg^{2+} is limited by cation–exchange.

The common cation exchange reactions can be expressed as follows:

$$Ca^{2+} + 2NaX \longrightarrow 2Na^+ + CaX_2$$

$$Ca^{2+} + MgX \longrightarrow Mg^{2+} + CaX$$

$$Mg^{2+} + 2NaX \longrightarrow 2Na^+ + MgX_2$$

where the quantities NaX, CaX, and MgX represent cations in the adsorbed state and Na^+, Ca^{2+}, and Mg^{2+} denote these elements in an ionic state in solution (Groenewold, et.al, 1983). Ca^{2+} is selected to exchange sites in strong preference to both Na^+ and Mg^{2+}, and Mg^{2+} is adsorbed in preference to Na^+.

The cation exchange reactions occur as water moves through a clayey sediment such as till. It has been well established by Williams (1984), Falcone (1983), and Groenewold, et al. (1983) that the dominant clay minerals in the till throughout North Dakota are a Na–montmorillonitic (smectite) type. Montmorillonitic clays have relatively large cation exchange capacities. In materials with appreciable cation exchange capacities, the cations contained on the exchange sites represent an extremely large cation source relative to the cation concentration in the pore waters (Groenewold, et.al., 1983). If water with appreciable concentrations of Ca^{2+} and/or Mg^{2+} comes into contact with the Na–montmorillonitic clays, the water will acquire Na^{+} as the dominant cation.

To summarize, the following eight processes appear to be those dominating the system and controlling the water chemistry.

1) carbonic acid forms in the soil zone because of increased CO_2 production due to organic decay
2) oxidation of organic sulfur adds H^{+} and SO_4^{2-} to solution
3) oxidation of pyrite adds H^{+} and SO_4^{2-} to solution
4) carbonate mineral dissolution adds Ca^{2+}, Mg^{2+}, and HCO_3^{-} and buffers the pH
5) evapotranspiration concentrates the ions in the soil pore waters throughout the weathered zone
6) precipitation of gypsum and other salts occur in the weathered zone as the water becomes saturated with respect to those minerals
7) dissolution of gypsum during surplus rainfall events and excess infiltration carries concentrated Ca^{2+} and SO_4^{2-} water to the water table
8) cation exchange of Ca^{2+} and Mg^{2+} for Na^{+} allows further carbonate dissolution and elevated concentrations of Na^{+} and HCO_3^{-} is achieved.

Discussion of till water chemistry

The results of the major cation/anion analyses of all water samples collected for this study are presented in table 5 (pp. 85–88). A statistical compilation of the major cations and anions of water samples collected from wells screened in till is presented in table 6 (p. 89). The mean and range of the major cations and anions of these samples is shown on a Schoeller (1967) diagram (fig. 12). In addition, percent values of major cations and anions of the till water samples are shown in a Piper (1944) diagram (fig. 13). Both the Schoeller diagram (fig.

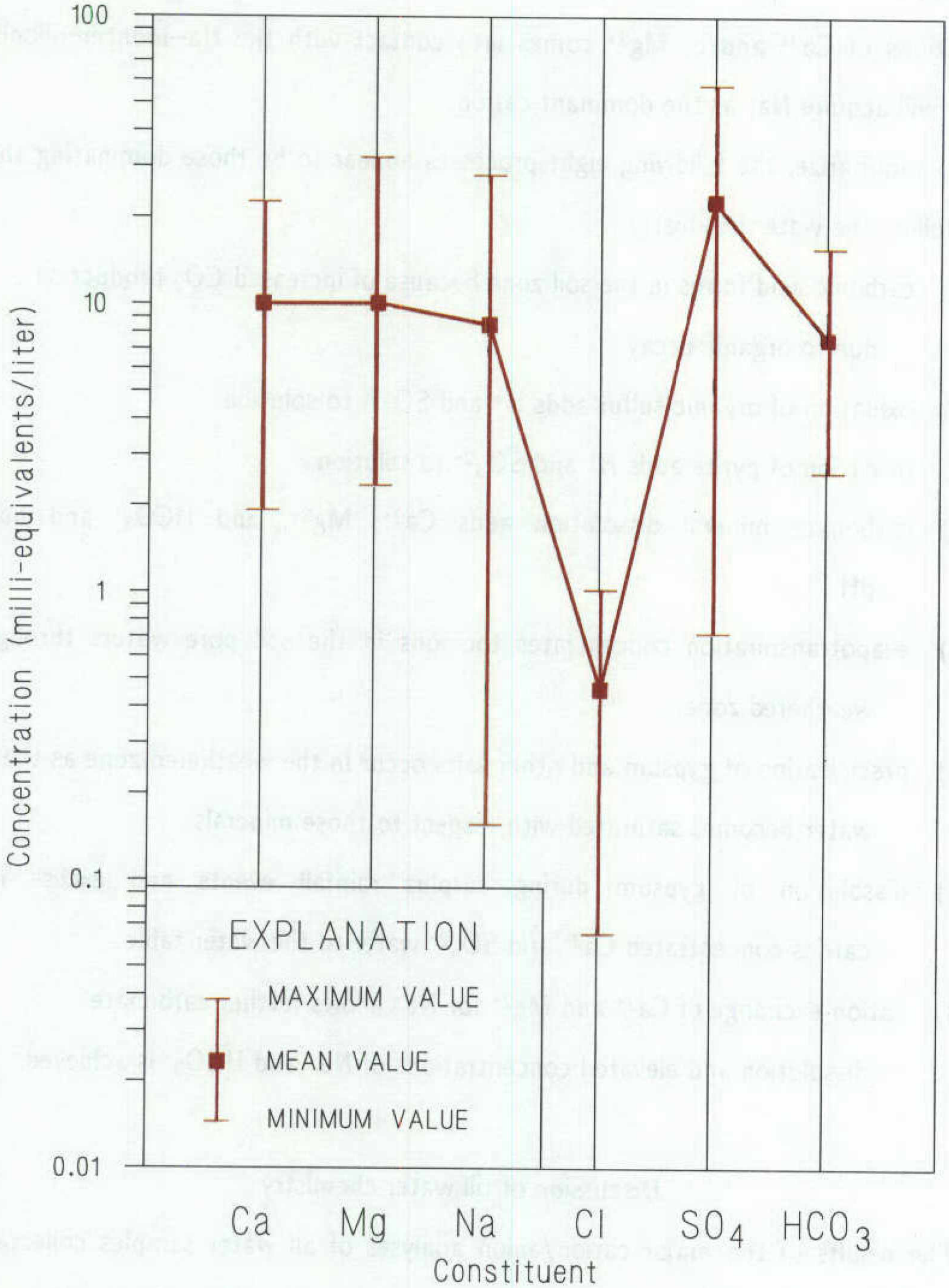

FIGURE 12. Schoeller diagram of statistical compilation of till water samples.

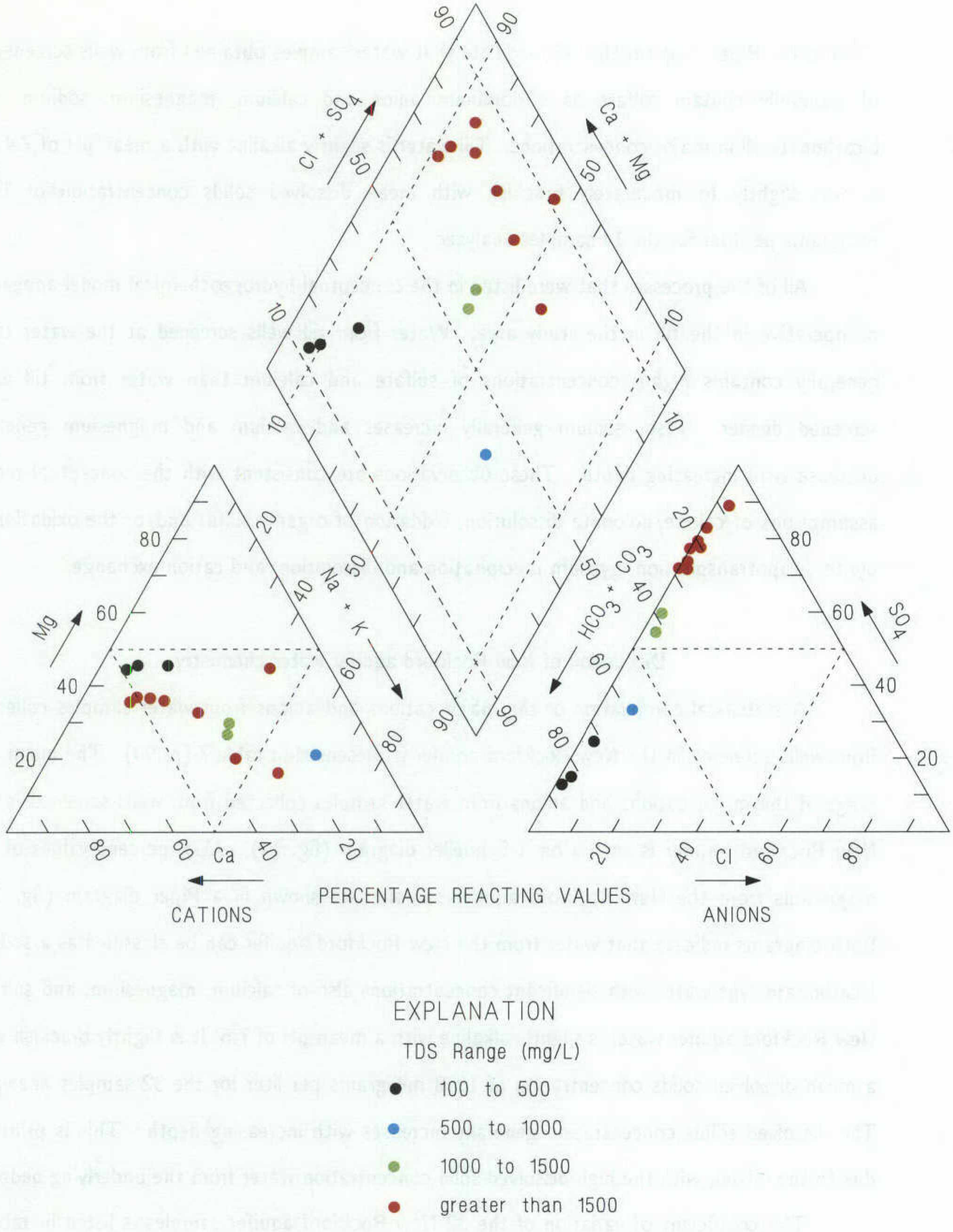

FIGURE 13. Piper diagram with all till samples and range of TDS.

12) and the Piper diagram (fig. 13) indicate that water samples obtained from wells screened in till generally contain sulfate as a dominant anion and calcium, magnesium, sodium, and bicarbonate all in major concentrations. Till water is slightly alkaline with a mean pH of 7.4. It is also slightly to moderately brackish with mean dissolved solids concentration of 1816 milligrams per liter for the 14 samples analyzed.

All of the processes that were listed in the conceptual hydrogeochemical model appear to be operative in the till in the study area. Water from till wells screened at the water table generally contains higher concentrations of sulfate and calcium than water from till wells screened deeper. Also, sodium generally increases and calcium and magnesium generally decrease with increasing depth. These observations are consistent with the conceptual model assumptions of calcite/dolomite dissolution, oxidation of organic sulfur and/or the oxidation of pyrite, evapotranspiration, gypsum precipitation and dissolution, and cation exchange.

Discussion of New Rockford aquifer water chemistry

A statistical compilation of the major cations and anions from water samples collected from wells screened in the New Rockford aquifer is presented in table 7 (p. 90). The mean and range of the major cations and anions from water samples collected from wells screened in the New Rockford aquifer is shown on a Schoeller diagram (fig. 14). Also, percent values of the major ions from the New Rockford aquifer samples are shown in a Piper diagram (fig. 15). Both diagrams indicate that water from the New Rockford aquifer can be classified as a sodium bicarbonate type water with significant concentrations also of calcium, magnesium, and sulfate. New Rockford aquifer water is slightly alkaline with a mean pH of 7.6 It is slightly brackish with a mean dissolved solids concentration of 1273 milligrams per liter for the 32 samples analyzed. The dissolved solids concentration generally increases with increasing depth. This is primarily due to the mixing with the high dissolved solid concentration water from the underlying bedrock

The coefficient of variation of the 32 New Rockford aquifer samples is listed in table 7 (p. 90). The coefficient of variation is used to compare the relative variations of the analyte

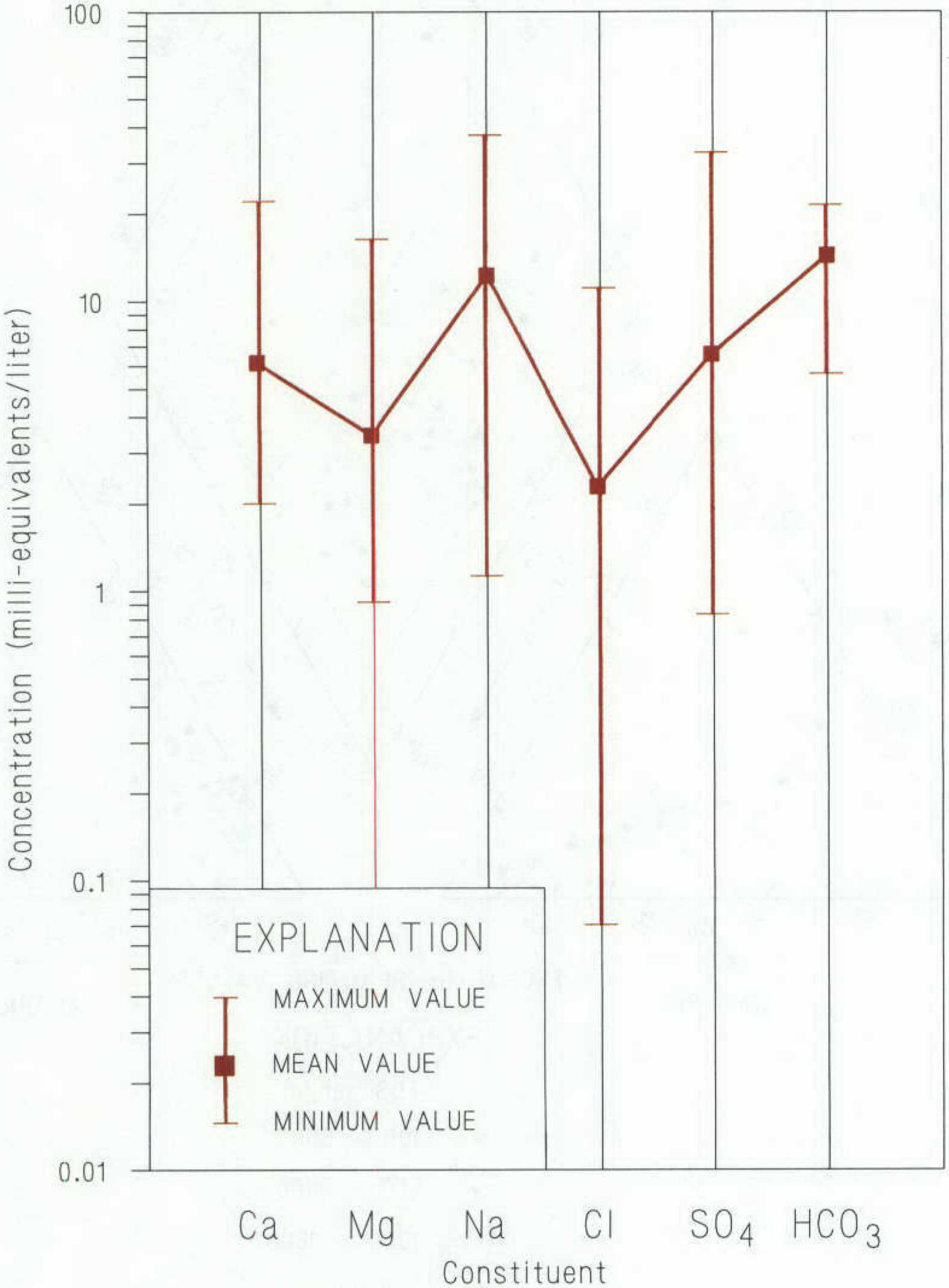

FIGURE 14. Schoeller diagram of statistical compilation of New Rockford aquifer water samples.

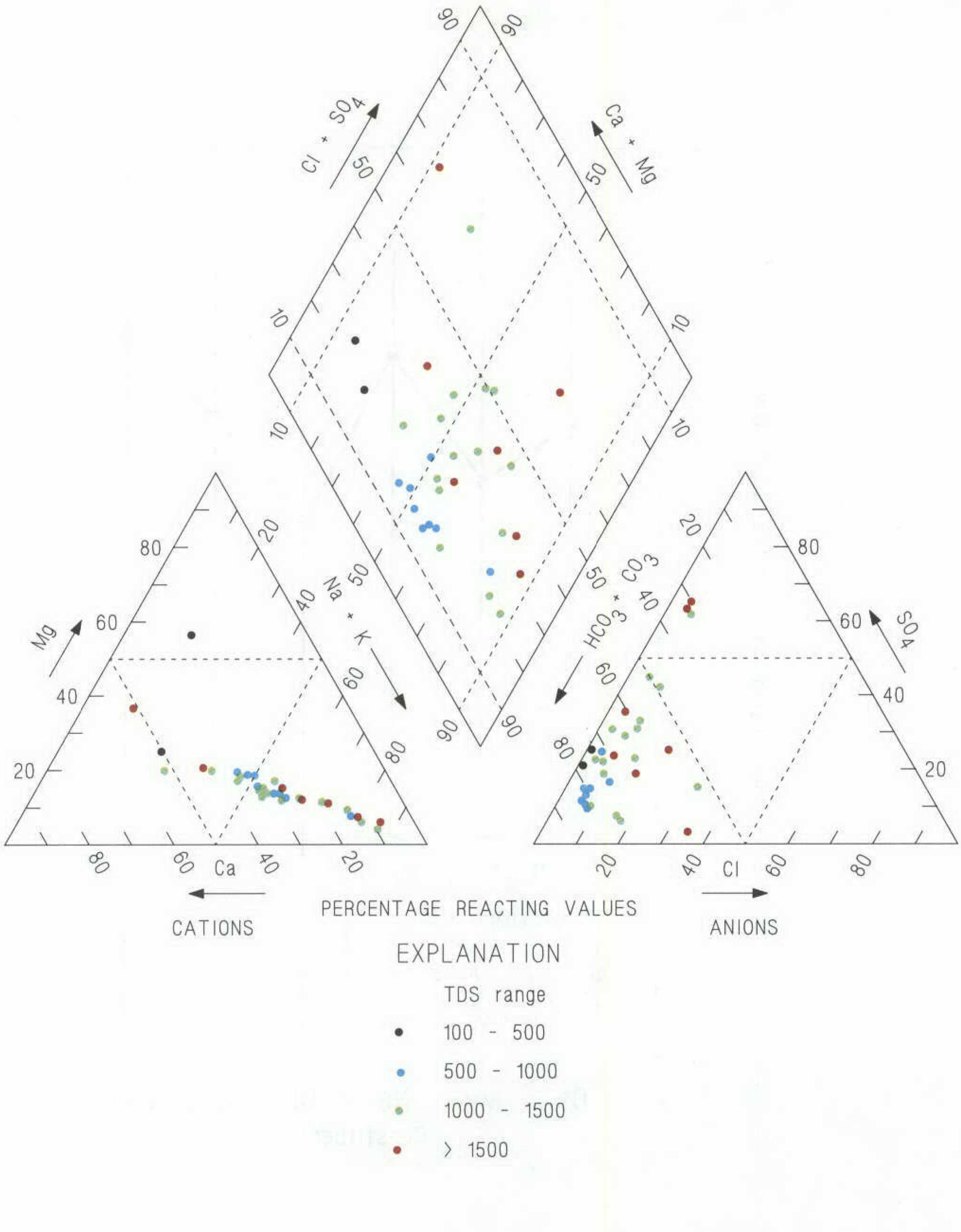

FIGURE 15. Piper diagram with all New Rockford aquifer water samples and range of TDS.

without respect to the units or range of value (Huntsberger, 1961). A smaller coefficient of variation indicates a closer grouping of data about the mean. Nitrate (NO_3 as N) has the greatest variation with a coefficient of variation of 600%. The least variation is dissolved silica (SiO_2) with a coefficient of variation of 19.5%.

Values for dissolved silica (SiO_2), compiled from thousands of ground water analyses from various areas in the United States, typically range from 10 to 30 milligrams per liter, with an average value of 17 milligrams per liter (Freeze and Cherry, 1979). Values for dissolved silica (SiO_2) in New Rockford aquifer samples range from 27.9 milligrams per liter to 53.0 milligrams per liter with an average value of 37.5 milligrams per liter (table 7, p. 90). This relatively high dissolved silica content in the New Rockford aquifer may indicate a relatively long residence time. Ground water containing relatively high amounts of silica generally are in or near equilibrium with respect to feldspar minerals which require long periods of time and sluggish flow conditions for the dissolution of silica (Freeze and Cherry, 1979). A possible source of the high dissolved silica water might be mixing with older bedrock waters from the Fox Hills Formation. However, Thorstenson et al. (1979) analyzed several water samples from the Fox Hills aquifer for dissolved silica and found the range to be 9 to 15 milligrams per liter.

Three samples from observation wells screened near the bottom of the New Rockford aquifer (149–69–10DCC, 150–70–25CCC, and 150–70–34CCC) contain relatively high chloride levels (143 mg/l, 167 mg/l, and 388 mg/l, respectively). Since water from the underlying Pierre Formation is typically high in chlorides (Burtula, 1970), this suggests that some recharge to the aquifer is derived from upward flow through underlying Pierre Formation.

Discussion of water chemistry at each nest site

Nest site 149–69–4BBB

Four wells were constructed at nest site 149–69–4BBB. The vertical distribution of the water chemistry is shown by a Schoeller diagram (fig. 16) and a Piper trilinear diagram (fig. 17). All samples collected at this nest site are classified as sodium–bicarbonate ($Na–HCO_3$) type

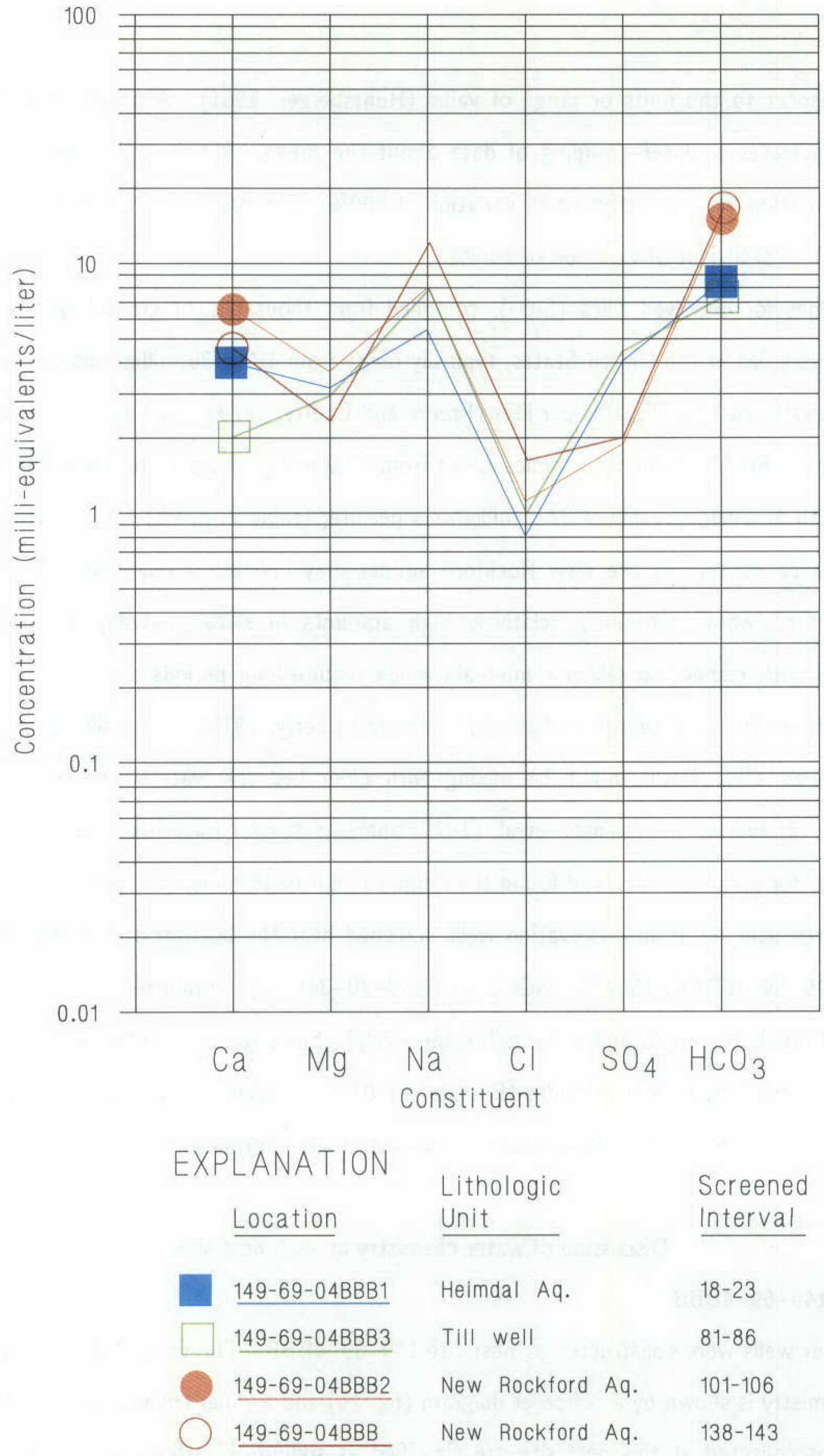

FIGURE 16. Schoeller diagram of all wells at nest site 149-69-04BBB.

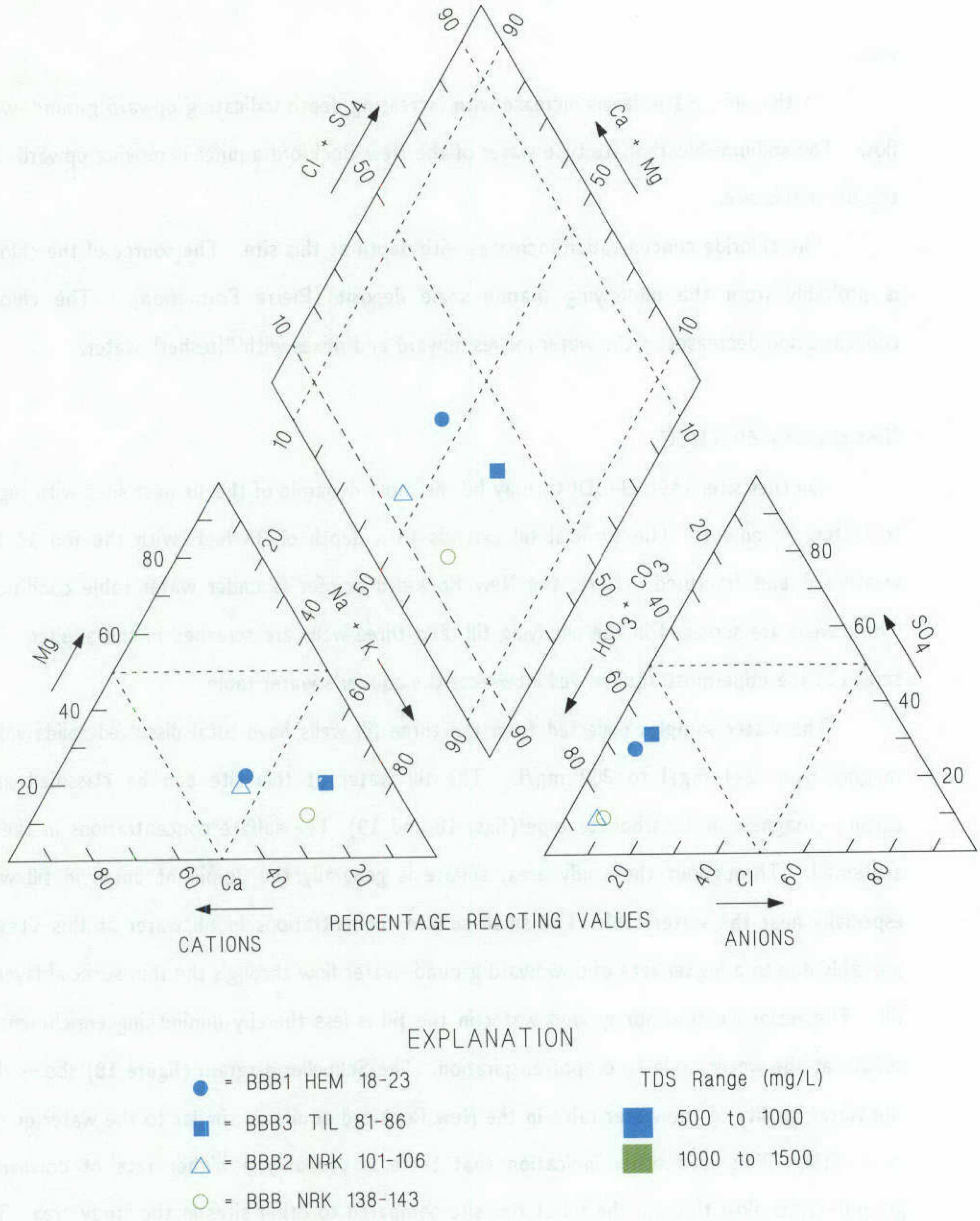

FIGURE 17. Piper diagram of all wells at nest site 149-69-04BBB.

water.

At this site, water levels increase with increasing depth indicating upward ground–water flow. The sodium–bicarbonate type water of the New Rockford aquifer is moving upward into the till at this site.

The chloride concentration increases with depth at this site. The source of the chloride is probably from the underlying marine shale deposit (Pierre Formation). The chloride concentration decreases as the water moves upward and mixes with "fresher" water.

Nest site 149–69–6DCC

Another site, 149–69–6DCC, may be the most dynamic of the six nest sites with regard to water movement. The surficial till extends to a depth of 33 feet, with the top 16 feet weathered and fractured. Here, the New Rockford aquifer is under water table conditions. Three wells are screened in the overlying till, and three wells are screened in the aquifer. The screen of the uppermost aquifer well intersects the aquifer's water table.

The water samples collected from the three till wells have total dissolved solids values ranging from 244 mg/l to 300 mg/l. The till water at this site can be classified as a calcium–magnesium–bicarbonate type (figs. 18 and 19). The sulfate concentrations in the till are small. Throughout the study area, sulfate is generally the dominant anion in till wells especially near the water table. The small sulfate concentrations in till water at this site are probably due to a higher rate of downward ground–water flow through the thin surficial layer of till. The residence time for ground water in the till is less thereby diminishing enrichment of sulfate at the water table by evapotranspiration. .The Schoeller diagram (figure 18) shows that the water quality of the water table in the New Rockford aquifer is similar to the water quality in the till. This is another indication that there is probably a higher rate of downward ground–water flow through the till at this site compared to other sites in the study area. The two deeper wells in the New Rockford aquifer are a sodium–calcium–bicarbonate type and are typical of the water found throughout the New Rockford aquifer in the study area. The

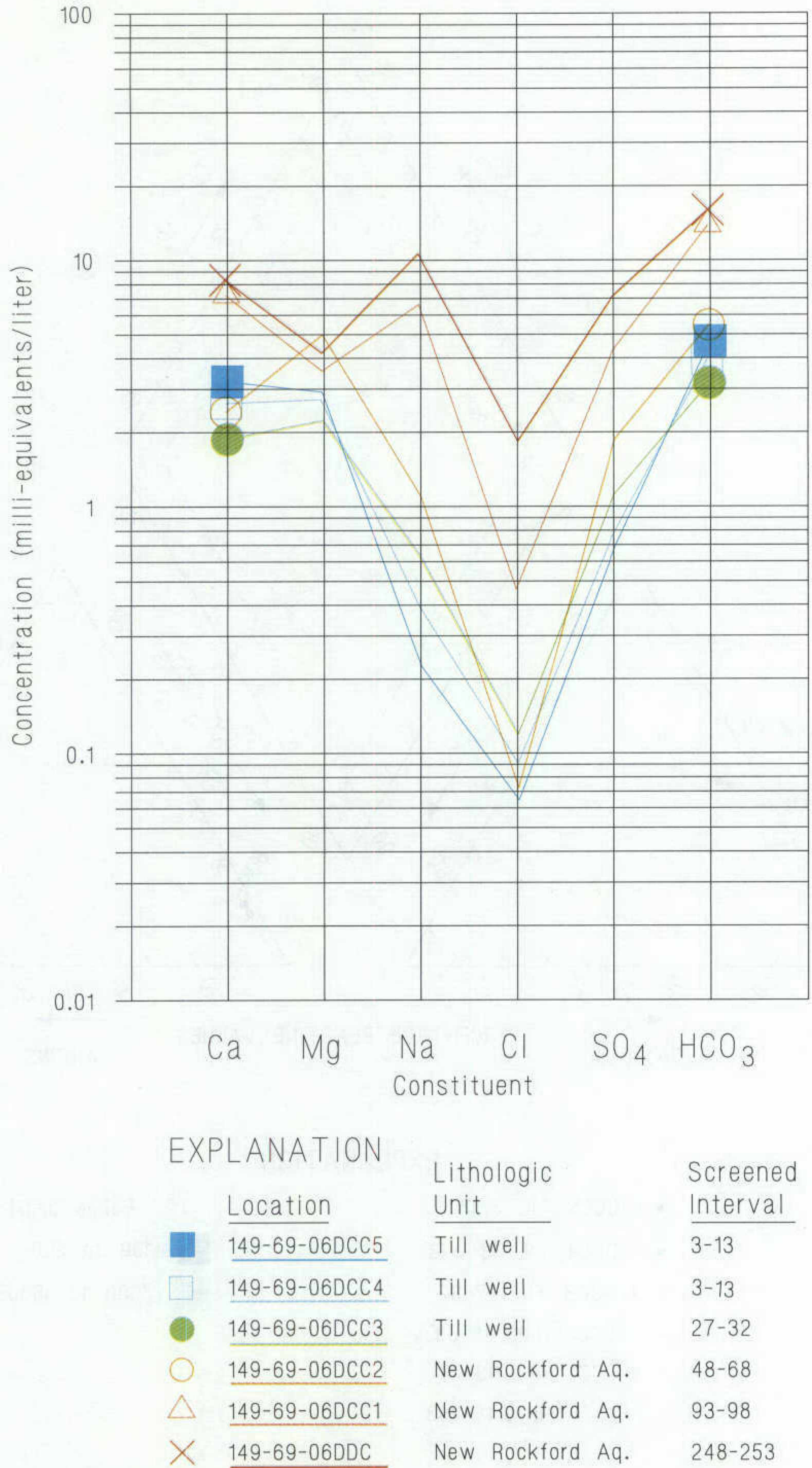

FIGURE 18. Schoeller diagram of all wells at nest site 149-69-06DCC.

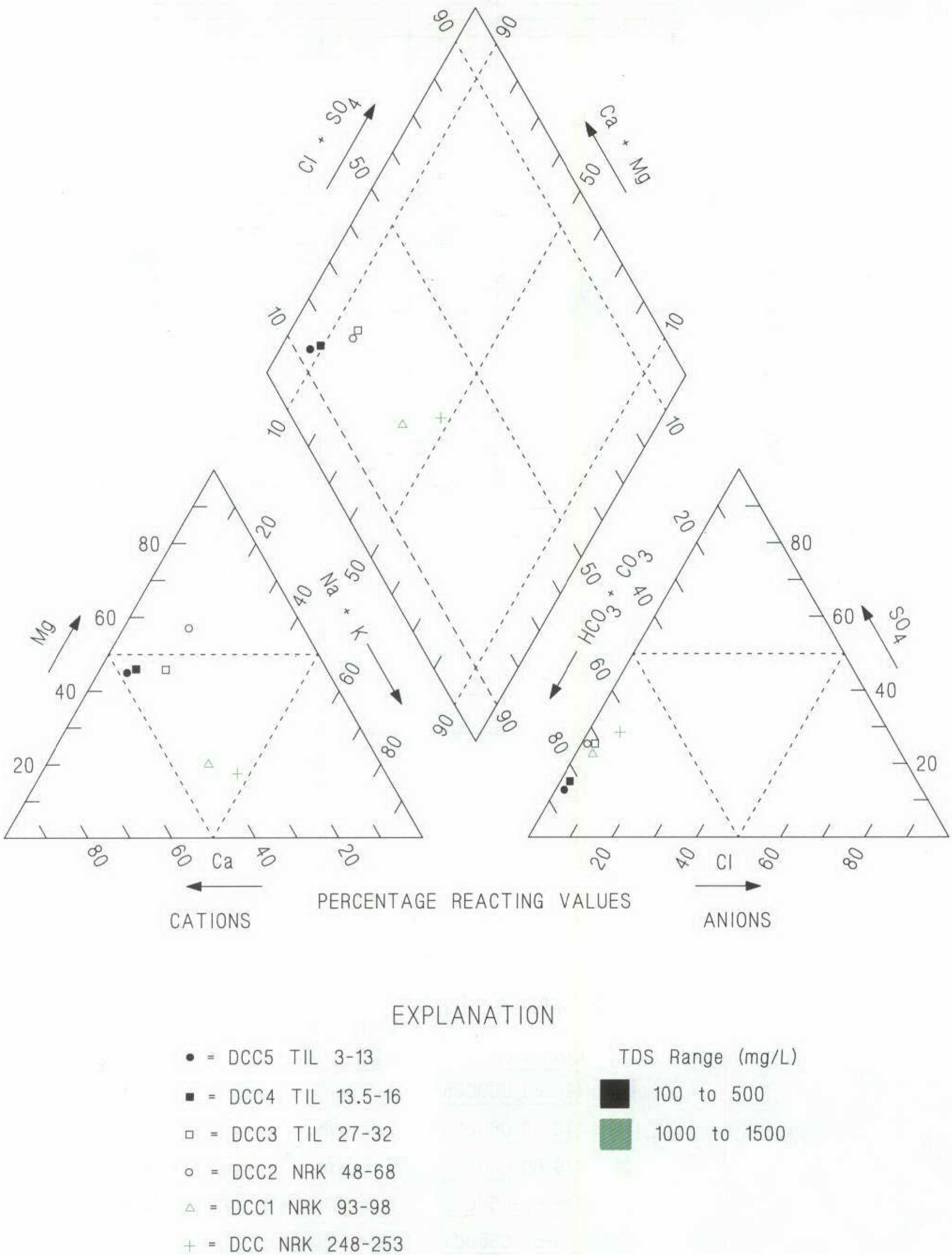

FIGURE 19. Piper diagram of all wells at nest site 149-69-06DCC.

dissolved solids concentration in the aquifer at this site ranges from 406 to 1360 milligrams per liter and increases with depth.

Sodium, chloride, and sulfate increase with increasing depth (fig. 18). The increase in sulfates is probably a result of dissolution of gypsum in the glacial drift and/or the oxidation of organics (lignites) and/or pyrite (Hendry, 1984). The increase in chloride is probably due to mixing with water derived from underlying marine bedrock deposits. The increase in sodium is probably due to cation exchange with clay minerals in the till and mixing with bedrock derived water in the aquifer.

Nest site 149–69–09CBB

Six wells were constructed at this site, two screened in the New Rockford aquifer, and four screened in the overlying till. The Schoeller diagram (fig. 20), show the similarity between all the till water samples collected. At this site the till water near the water table can be classified as a calcium–magnesium–sulfate type water and becomes a sodium–sulfate type with depth. The dissolved solids in the concentration in the till at this site ranges from 1830 to 3070 mg/l and decreases with depth. The Piper trilinear diagram (figure 21) shows a distinct difference in hydrochemical facies between the till and underlying New Rockford aquifer. The dominant anion in the till is sulfate and the dominant anion in the New Rockford aquifer is bicarbonate. The dissolved solids concentration is 937 milligrams per liter in the 153 foot well and 1260 milligrams per liter in the 262 foot well. The hydrochemical distinction between the till and the aquifer suggest that there is not much water movement downward from the till to the aquifer.

Nest site 149–69–24BCC

Five wells were constructed at this nest site: two in the New Rockford aquifer, one in a 15 foot thick inter–till sand and gravel layer, and two in the overlying till. The Schoeller and Piper diagrams (figs. 22 and 23) indicate that water from the two till wells and the inter–till

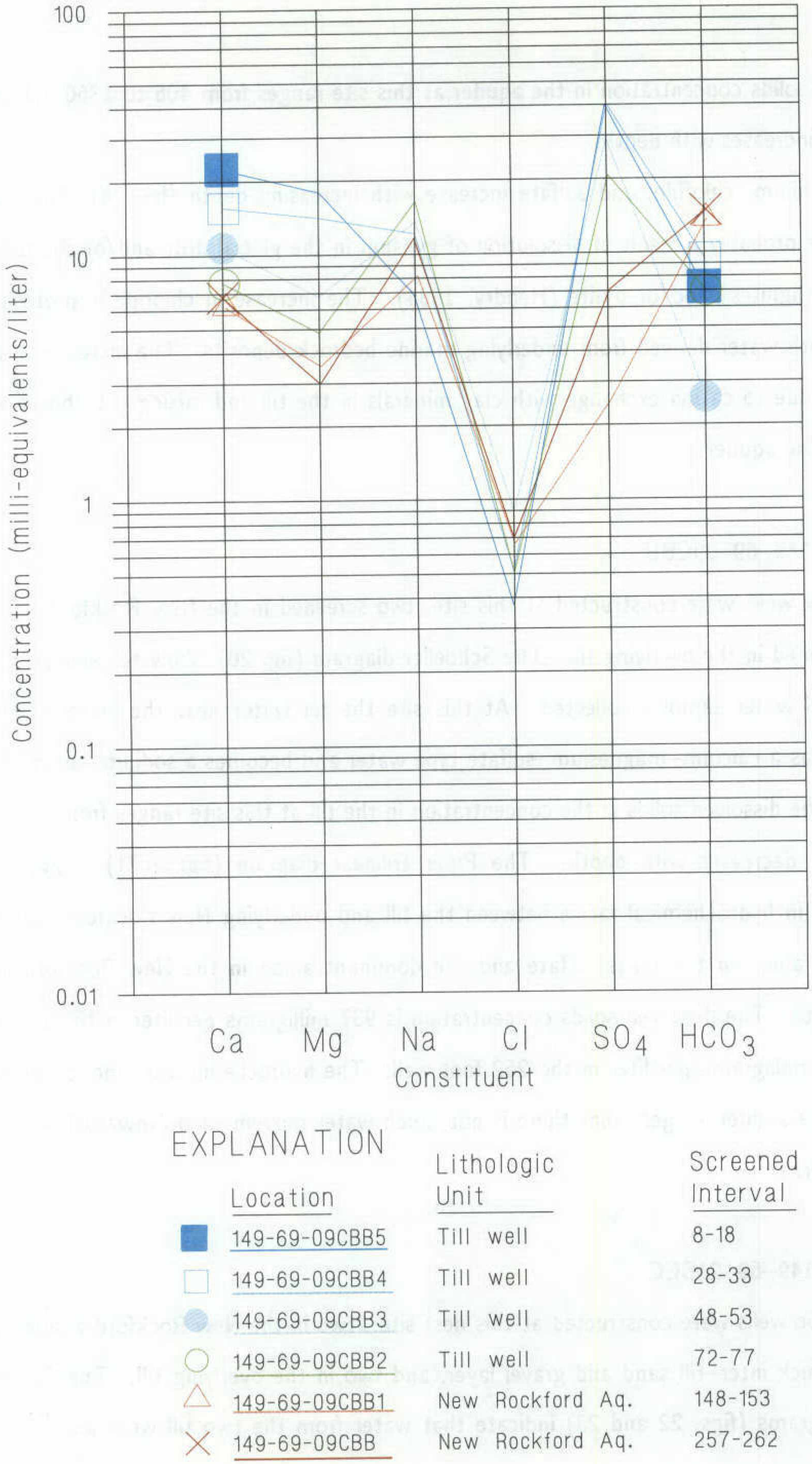

FIGURE 20. Schoeller diagram of all wells at nest site 149-69-09CBB.

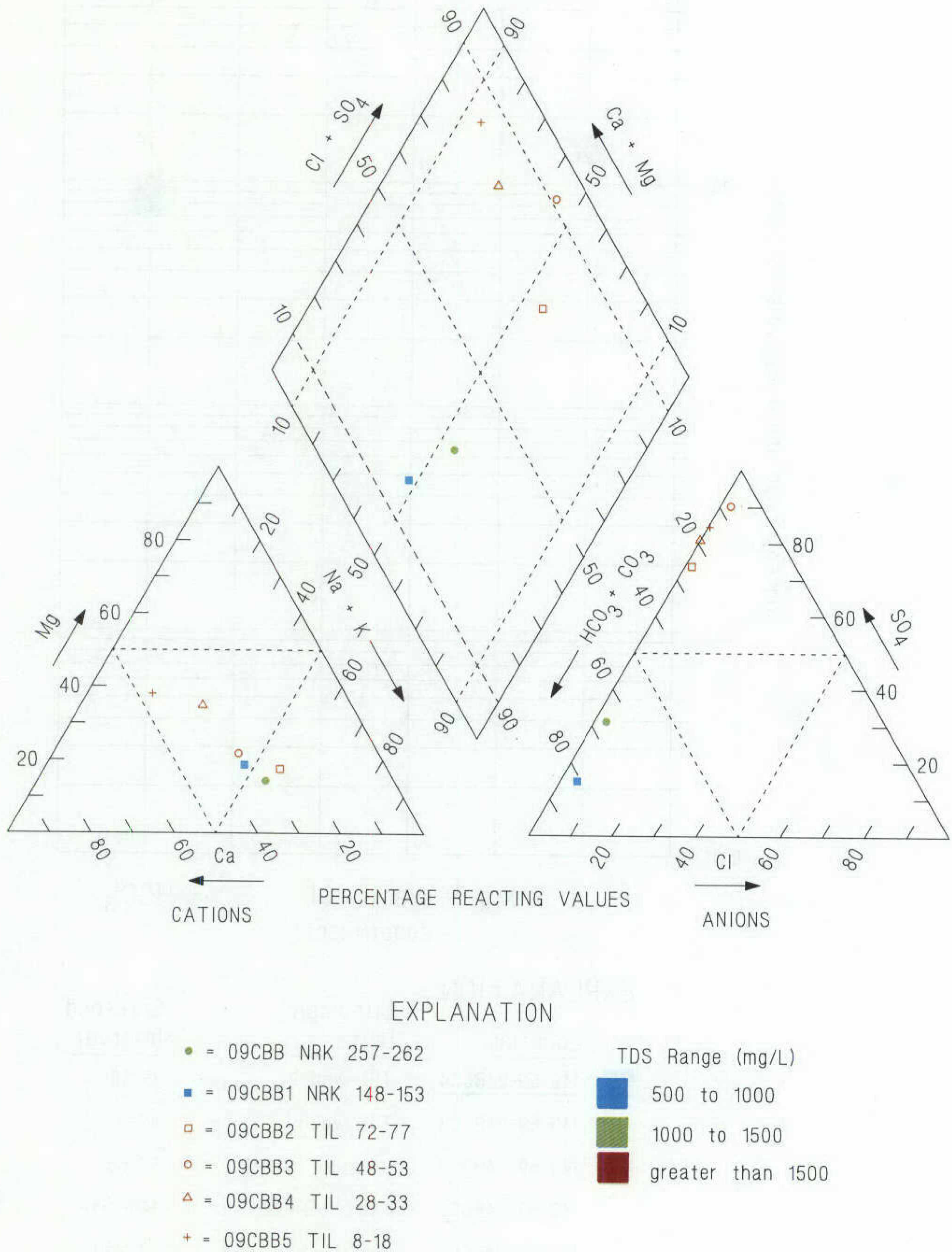

FIGURE 21. Piper diagram of all wells at nest site 149-69-09CBB.

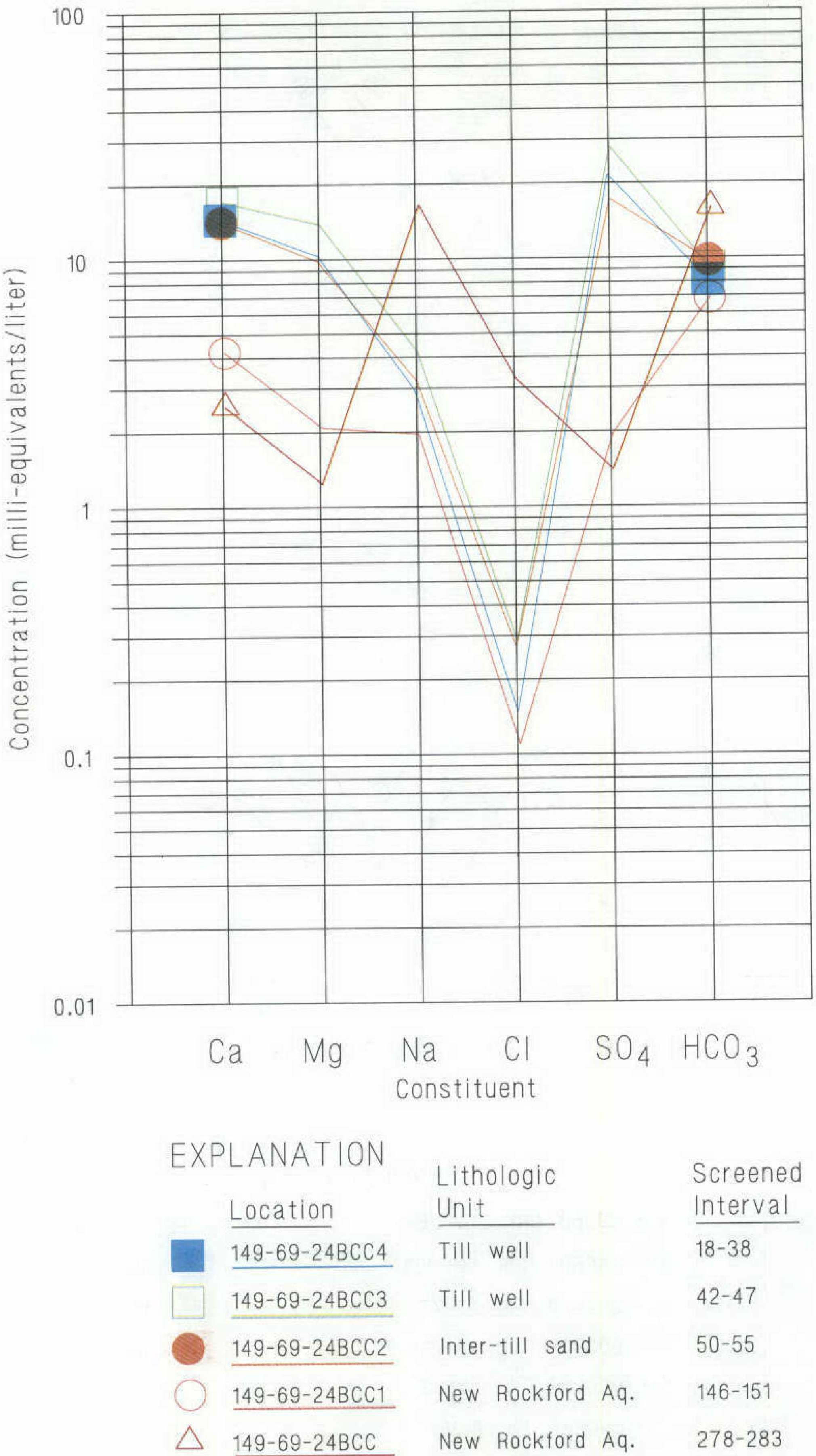

FIGURE 22. Schoeller diagram of all wells at nest site 149-69-24BCC.

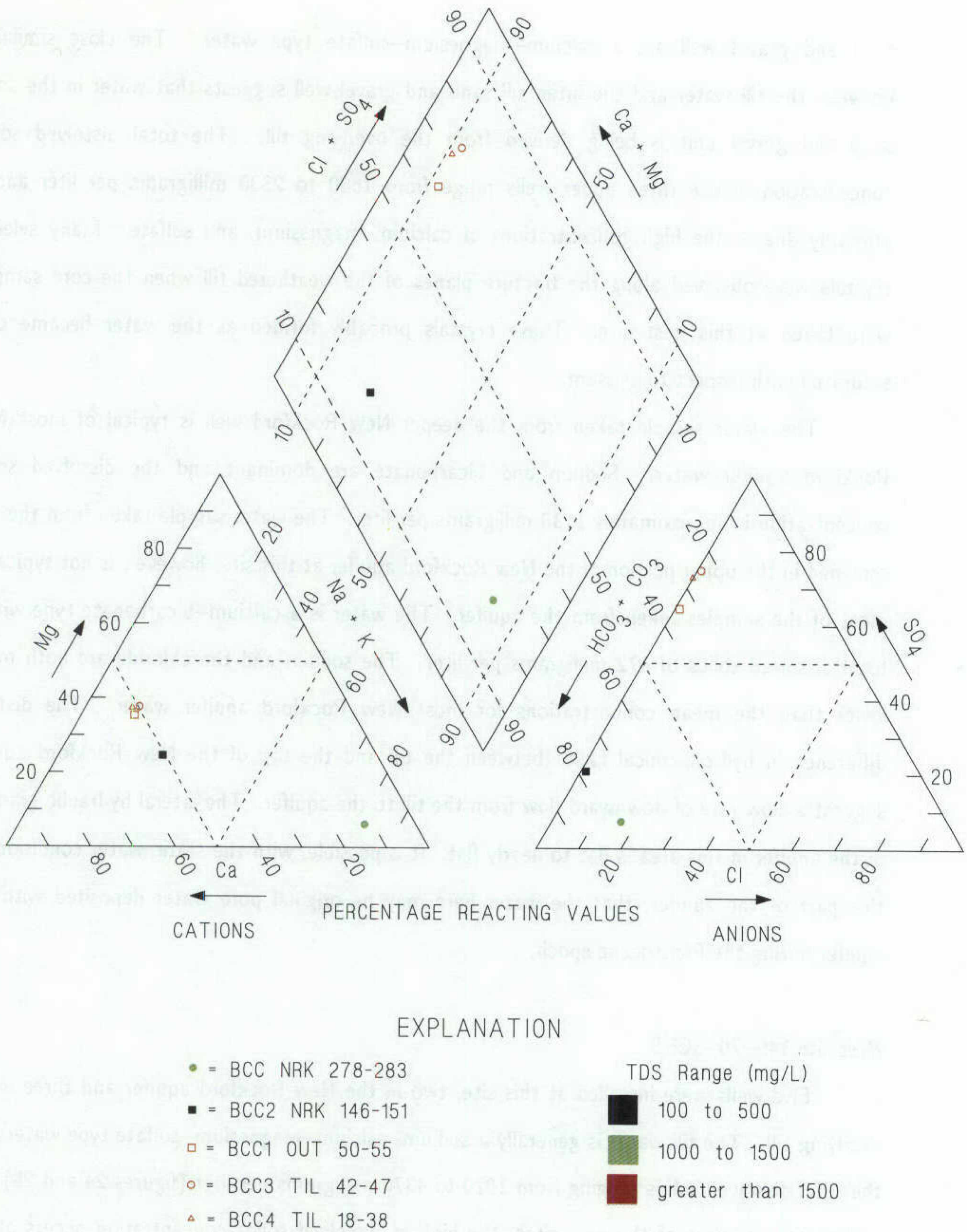

FIGURE 23. Piper diagram of all wells at nest site 149-69-24BCC.

sand and gravel well are a calcium–magnesium–sulfate type water. The close similarity between the till water and the inter–till sand and gravel well suggests that water in the small sand and gravel unit is being derived from the overlying till. The total dissolved solids concentration in the three upper wells range from 1680 to 2330 milligrams per liter and is primarily due to the high concentrations of calcium, magnesium, and sulfate. Many selenite crystals were observed along the fracture planes of the weathered till when the core samples were taken at this nest site. These crystals probably formed as the water became over saturated with respect to gypsum.

The water sample taken from the deeper New Rockford well is typical of most New Rockford aquifer water. Sodium and bicarbonate are dominant and the dissolved solids concentration is approximately 1130 milligrams per liter. The water sample taken from the well screened in the upper portion of the New Rockford aquifer at this site, however, is not typical of most of the samples taken from the aquifer. The water is a calcium–bicarbonate type with a total dissolved solids of 472 milligrams per liter. The sodium and the chloride are both much lower than the mean concentrations for most New Rockford aquifer water. The distinct difference in hydrochemical facies between the till and the top of the New Rockford aquifer suggest a slow rate of downward flow from the till to the aquifer. The lateral hydraulic gradient of the aquifer in this area is flat to nearly flat. It is possible, with the static water conditions in this part of the aquifer, that the water here may be original pore water deposited with the aquifer during the Pleistocene epoch.

Nest site 149–70–3CBB

Five wells were installed at this site, two in the New Rockford aquifer and three in the overlying till. The till water is generally a sodium–calcium–magnesium–sulfate type water with the total dissolved solids ranging from 1020 to 4370 milligrams per liter (figures 24 and 25). As is the case at most of the nest sites, the highest dissolved solids concentration occurs at the water table due to the concentrating mechanism of evapotranspiration.

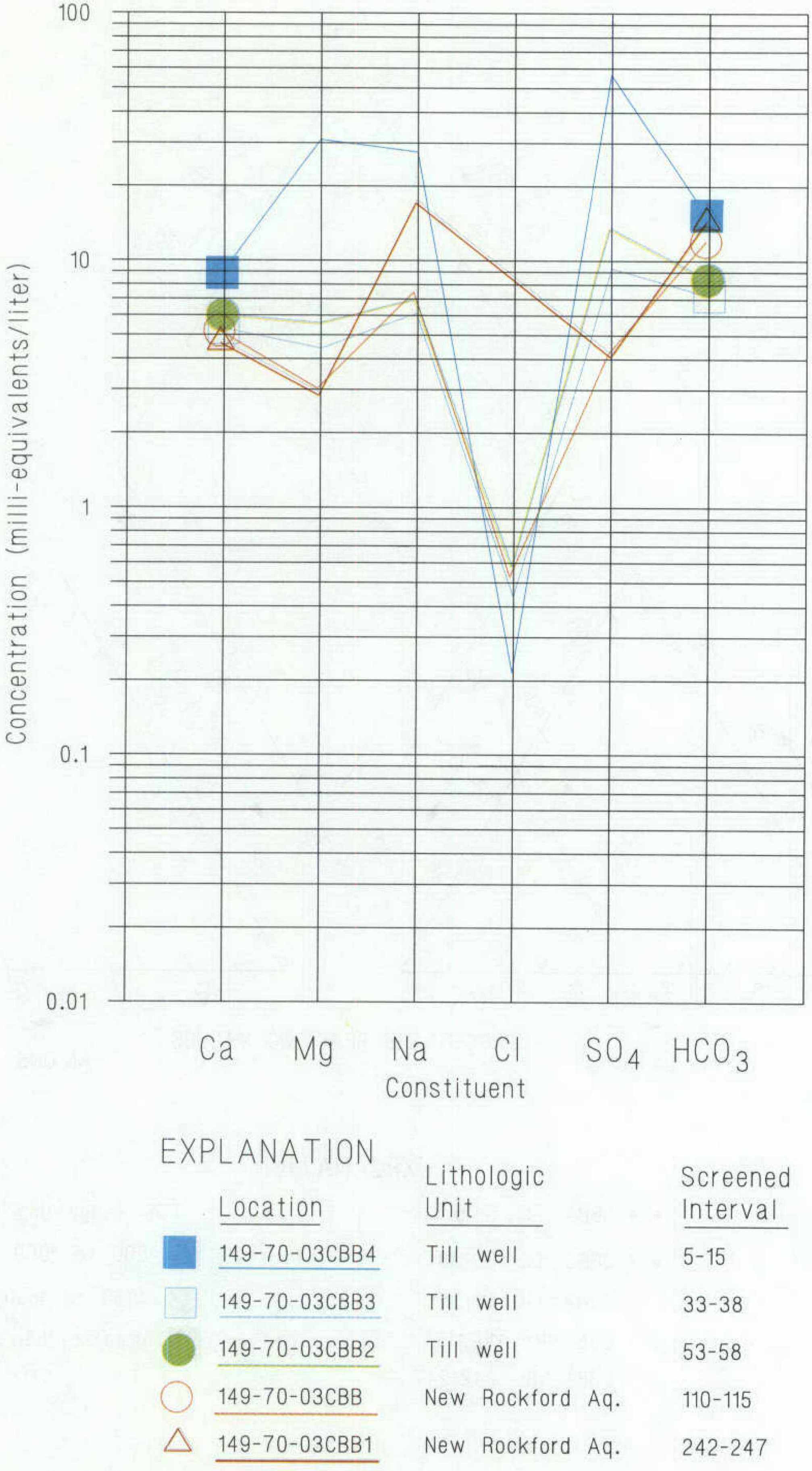

FIGURE 24. Schoeller diagram of all wells at nest site 149-70-3CBB.

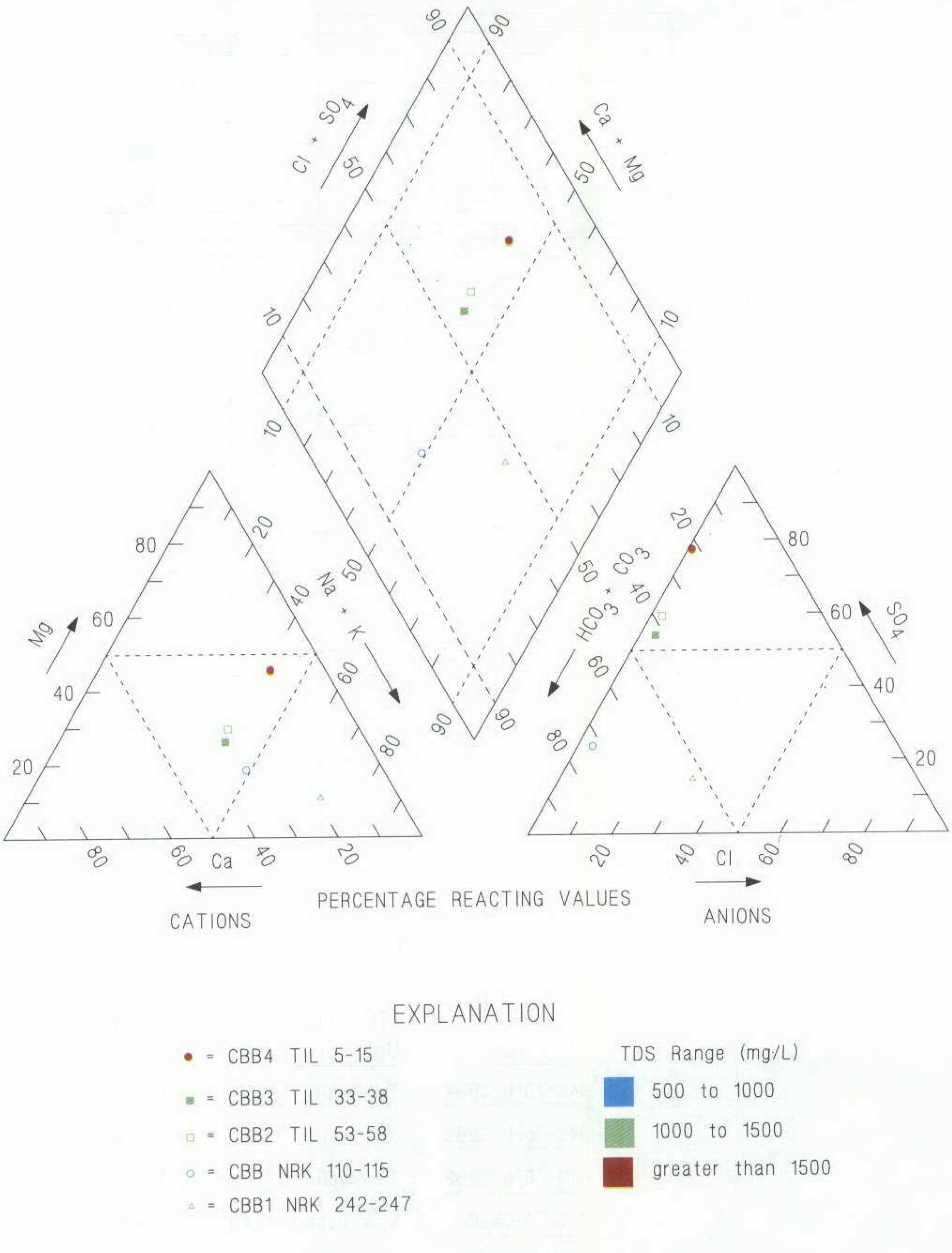

FIGURE 25. Piper diagram of all wells at nest site 149-70-03CBB.

The water from wells completed in the New Rockford aquifer are classified as a sodium–bicarbonate type. The upper New Rockford aquifer sample is similar to the water from the overlying till with the exception of a lower sulfate content. The dissolved solids concentration is 922 milligrams per liter. The city of Fessenden had been withdrawing water from this vicinity for its municipal supply for several years prior to 1987. Pumping has created a larger vertical gradient thereby inducing leakage from the overlying till.

Water from the well screened in the lower part of the New Rockford aquifer has a relatively high concentration of sodium and chloride as compared to water in the upper New Rockford aquifer. Upward ground–water flow from the underlying Pierre Formation is the probable source of elevated sodium and chloride concentrations and hence the higher dissolved solid concentration of 1490 milligrams per liter.

Nest site 150–70–32ABB

Five wells were constructed at this site. One in the New Rockford aquifer, three in an overlying thick sequence of glacio–lacustrine silt and clay and one in the overlying till. All water samples at this site are a calcium–sulfate type water (figures 26 and 27). The hydrochemical facies of the water from the wells screened in the aquifer and in the glacio–lacustrine sediments are similar. The total dissolved solids values of these four wells range from 1070 to 1360 milligrams per liter. Water level measurements from these wells increase with increasing depth indicating upward ground–water flow. Also, the water level in the well screened in the New Rockford aquifer is approximately 35 to 40 feet higher than other New Rockford wells in this area. At this site, there is no distinct separation of the sulfate facies of the overlying sediments and bicarbonate facies in the aquifer which is common elsewhere. The water level and hydrochemical anomalies associated with the New Rockford aquifer in this area suggest this is an an isolated deposit of sand and gravel, not in direct hydraulic connection with the New Rockford aquifer elsewhere.

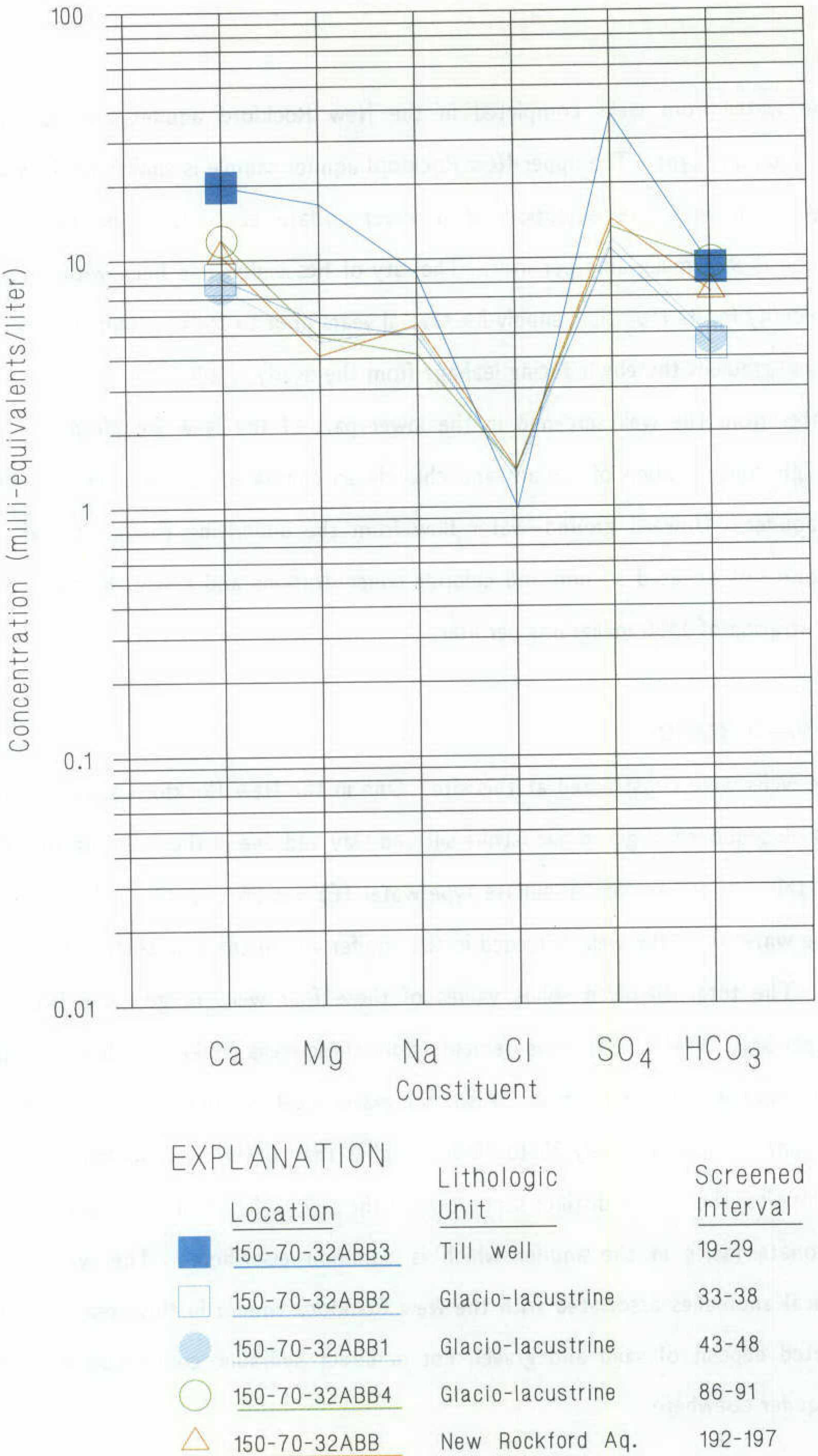

FIGURE 26. Scholler diagram of all wells at nest site 150-70-32ABB.

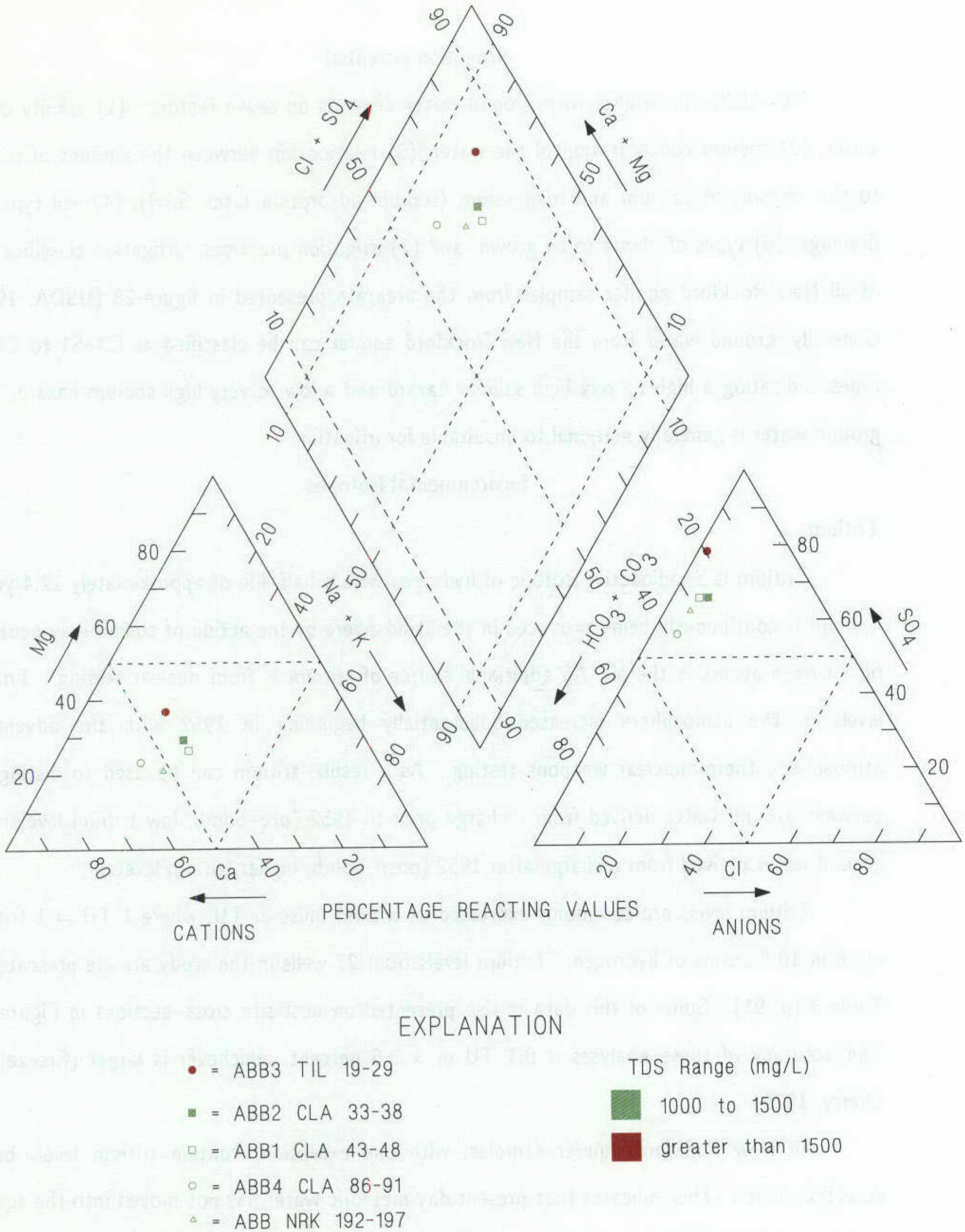

FIGURE 27. Piper diagram of all wells at nest site 150-70-32ABB.

Irrigation potential

The ability to irrigate with ground water depends on seven factors: (1) salinity of the water, (2) sodium concentration of the water, (3) relationship between the amount of sodium to the amount of calcium and magnesium (sodium adsorption ratio, SAR), (4) soil type, (5) drainage, (6) types of plants to be grown, and (7) irrigation practices. Irrigation classifications of all New Rockford aquifer samples from the area are presented in figure 28 (USDA, 1954). Generally, ground water from the New Rockford aquifer can be classified as C3–S1 to C4–S4 types, indicating a high to very high salinity hazard and a low to very high sodium hazard. The ground water is generally marginal to unsuitable for irrigation.

Environmental Isotopes

Tritium

Tritium is a radioactive isotope of hydrogen with a half–life of approximately 12.4 years. Tritium is continuously being produced in the atmosphere by the action of cosmic–ray neutrons on nitrogen atoms in the air. An additional source of tritium is from nuclear testing. Tritium levels in the atmosphere increased substantially beginning in 1952 with the advent of atmospheric thermonuclear weapons testing. As a result, tritium can be used to distinguish between ground water derived from recharge prior to 1952 (pre–bomb, low tritium levels) and ground water derived from recharge after 1952 (post–bomb, higher tritium levels).

Tritium levels are commonly expressed as tritium units or TU, where 1 TU = 1 tritium atom in 10^{18} atoms of hydrogen. Tritium levels from 27 wells in the study are are presented in Table 8 (p. 91). Some of this data is also presented on nest site cross–sections in Figure 11. The accuracy of these analyses is 0.1 TU or ± 3.5 percent, whichever is larger (Freeze and Cherry, 1979).

All New Rockford aquifer samples, with one exception, contain tritium levels below detection limits. This indicates that present day meteoric water has not moved into the aquifer in the past 50 years (Gaspar and Onceseu, 1972). The exception occurs at the nest site located at 149–69–06DCC. A sample from the uppermost saturated sand and gravel at this site

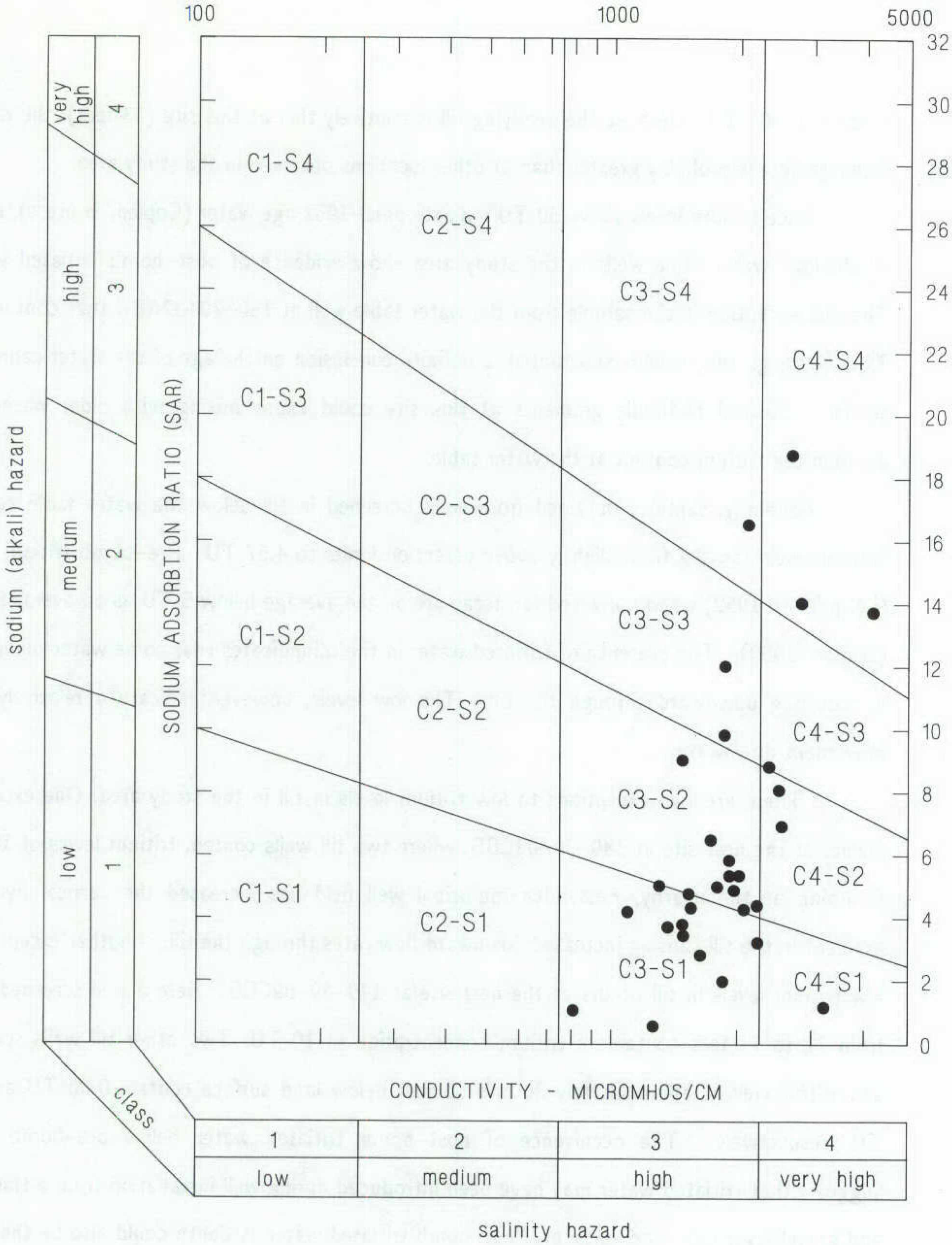

FIGURE 28. Irrigation classification diagram.

contained 1.05 TU. Because the overlying till is relatively thin at this site (33 feet), the rate of recharge here is probably greater than at other locations observed in the study area.

Since tritium levels above 50 TU indicate post–1952 age water (Coplen, in press), nearly all shallow, water table wells in the study area show evidence of post–bomb tritiated water. The one exception is the sample from the water table well at 150–70–32ABB that contains 25 TU. Although this value is substantial, a definite conclusion on the age of the water cannot be stated. Upward hydraulic gradients at this site could cause mixing with older water and dampen the tritium content at the water table.

Generally, samples obtained from wells screened in till below the water table contain tritium levels ranging from slightly above detection limits to 4.57 TU. Pre–bomb tritium levels (i.e. prior to 1952) when corrected for decay are on the average below 5 TU as an average value (Fontes, 1980). The presence of tritiated water in the till indicates that some water movement is occurring downward through the till. The low levels, however, indicate a relatively slow movement downward.

There are two exceptions to low tritium levels in till in the study area. One exception occurs at the nest site at 149–70–03CBB, where two till wells contain tritium levels of 10 TU. Pumping at the nearby, Fessenden municipal well field has increased the vertical hydraulic gradient in the till causing increased downward flow rates through the till. Another exception to low tritium levels in till occurs at the nest site at 149–69–09CBB. Here a well screened in till from 72 to 77 feet contains a tritium concentration of 10 TU. Two other till wells screened above this well at approximately 30 and 50 feet below land surface contain 0.06 TU and 0.2 TU, respectively. The occurrence of post–bomb tritiated water below pre–bomb water suggests that tritiated water may have been introduced during well installation from a thin sand and gravel layer near land surface. Post–bomb tritiated water at depth could also be the result of relatively rapid downward ground–water flow through fractures and/or sand and gravel layers within the till, however, these were not detected during the continuous core sampling at this site.

Stable isotopes of oxygen and hydrogen

Thirty–two samples were collected and analyzed for the relative concentration of two environmental isotopes, ^{18}O (oxygen 18) and ^{2}H (deuterium or D). Twenty–six are ground–water samples, three are surface water, and three are precipitation samples (table 9, p. 92). The relative concentration of these isotopes when compared with Standard Mean Ocean Water (SMOW), can indicate the climatic environment at the time the water was exposed to the atmosphere. The deviation from SMOW is expressed as either $\delta\,^{18}O$ or δ D in units per thousand ($^{0}/_{00}$). Evaporation and condensation within a cloud mass will cause enrichment and depletion of ^{18}O and D. The lighter water molecules ($^{1}H_2{}^{16}O$) are selectively evaporated and the heavier water molecules ($^{2}H^{1}H^{16}O$ and $^{1}H_2{}^{18}O$) are selectively condensed in larger vapor cloud masses. Therefore air temperature plays a key role in the enrichment or depletion process. Summer rains are isotopically heavier since the water droplets are being re–evaporated as they fall from the cloud mass. Spring and fall rains and winter snowfall would tend to be isotopically lighter because the condensed water droplets in a cloud mass would not be re–evaporated as they fall (Gat, 1971).

A linear relationship exists between the $\delta\,^{18}O$ and δ deuterium (D) in precipitation samples. On a global basis, the relationship is defined by Craig (1961) as:

$$\delta D = 8\,\delta\,^{18}O + 10$$

The above equation describes the Meteoric Water Line (MWL). Three precipitation samples collected in the study area during the summer and fall were analyzed for their ^{18}O and D content. These values plot very close to the Meteoric Water Line (figure 29). Precipitation samples collected in the Falkirk, ND area by Hwang (1982) were plotted along with the three precipitation samples collected for this study to determine a Meteoric Water Line for this region. The equation derived from ten samples collected from central North Dakota is:

$$\delta D = 8.4\,\delta\,^{18}O + 17.6$$

Several factors affect the deuterium and ^{18}O content of precipitation. The latitude and

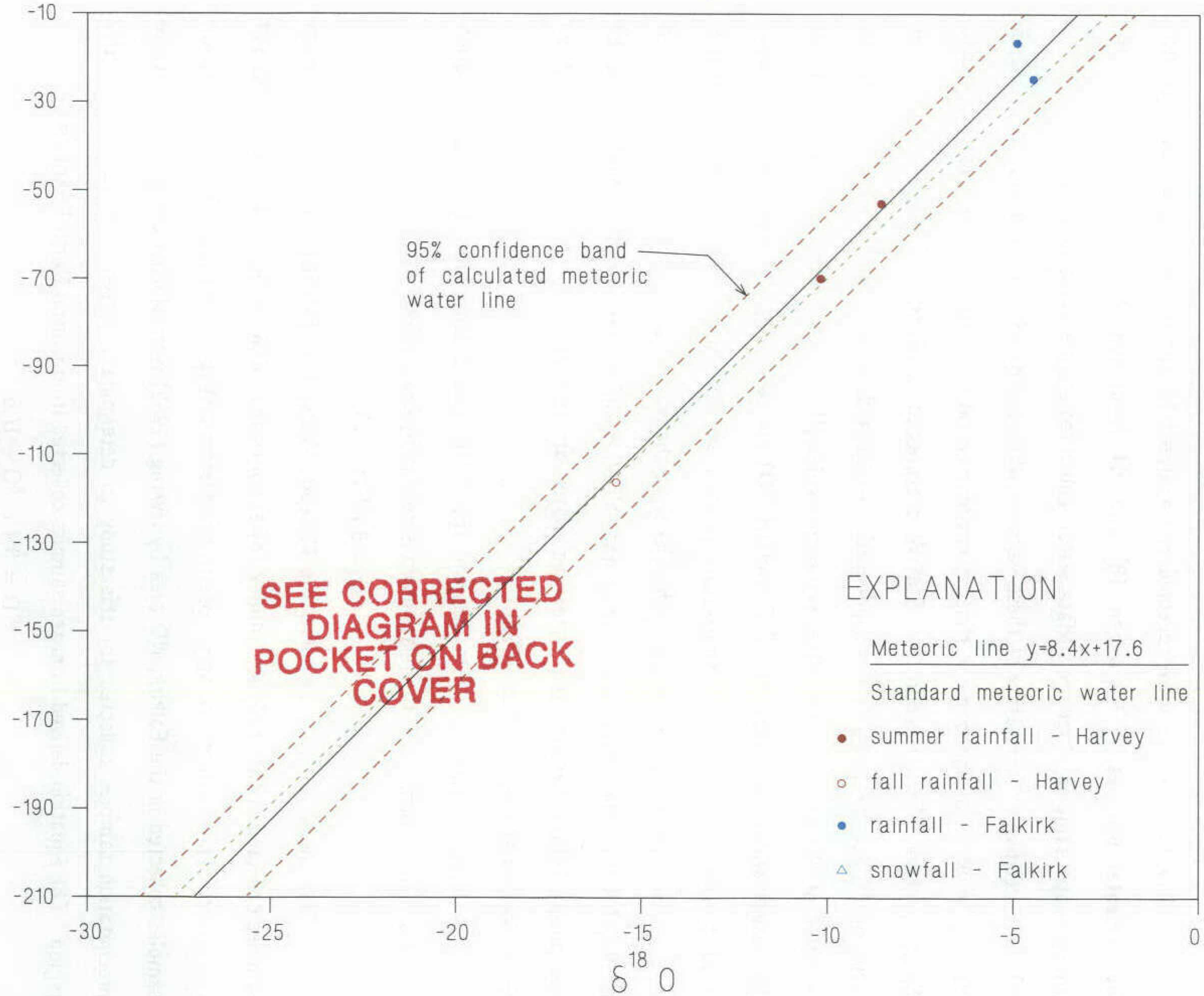

FIGURE 29. Meteoric water line determination from precipitation samples.

altitude of the collection point represent the two major factors. The variations with latitude and altitude are primarily attributed to the history of isotope fractionation that occurred during changes of state between vapor, liquid, and solid. In general, the extent of fractionation is affected by the following factors (Hwang, 1982):

1) Temperature at which evaporation from the ocean originally occurred.
2) History of the vapor mass between the time it leaves the ocean and the time of condensation at the point of interest.
3) Condensation temperature in the air mass.
4) Evaporation and isotopic exchange between the time the moisture was precipitated and the time it was collected at the ground.
5) Amount of precipitation of a single event (heavy rainfalls may cause a "rainout" of the heavier water molecules).

The results of the stable isotope analysis are listed in table 6 and presented in figure 30. Values of $\delta\,^{18}O$ and $\delta\,D$ which plot toward the lower left end of the meteoric water line are more depleted of these isotopes and hence are more likely to have been derived from precipitation in a relatively cooler environment. Higher values of $\delta\,^{18}O$ and $\delta\,D$ plot further up on the Meteoric Water Line. These values are not as depleted of stable isotope content and hence are likely to have been derived from precipitation in a warmer climate. Ten precipitation samples collected in central North Dakota verify these relationships (figure 29).

Evaporation of surface and subsurface water can cause a displacement upward and to the right of the meteoric line. The line developed by this shift is referred to as the evaporation line. The evaporation line will start at the meteoric line and have a slope of generally 3 to 6 (Fritz, 1983).

All but one of the ground–water samples fall to the right of the meteoric water line. A linear regression analysis (fig. 31) was done on the ground–water samples and a line was produced with the equation:

$$\delta\,D = 6.1\,\delta\,^{18}O - 24.5$$

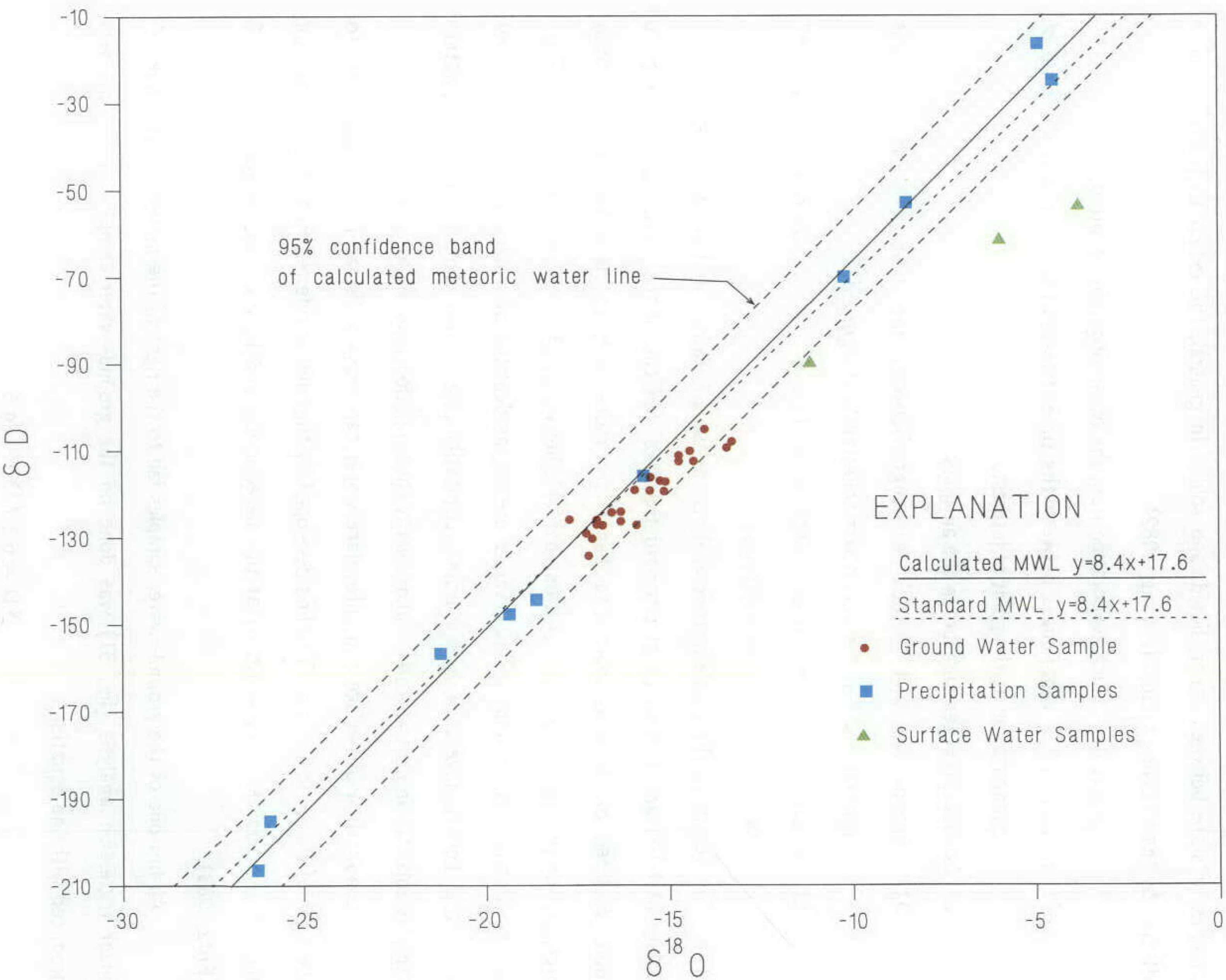

FIGURE 30. Stable isotope analysis of ^{18}O and D.

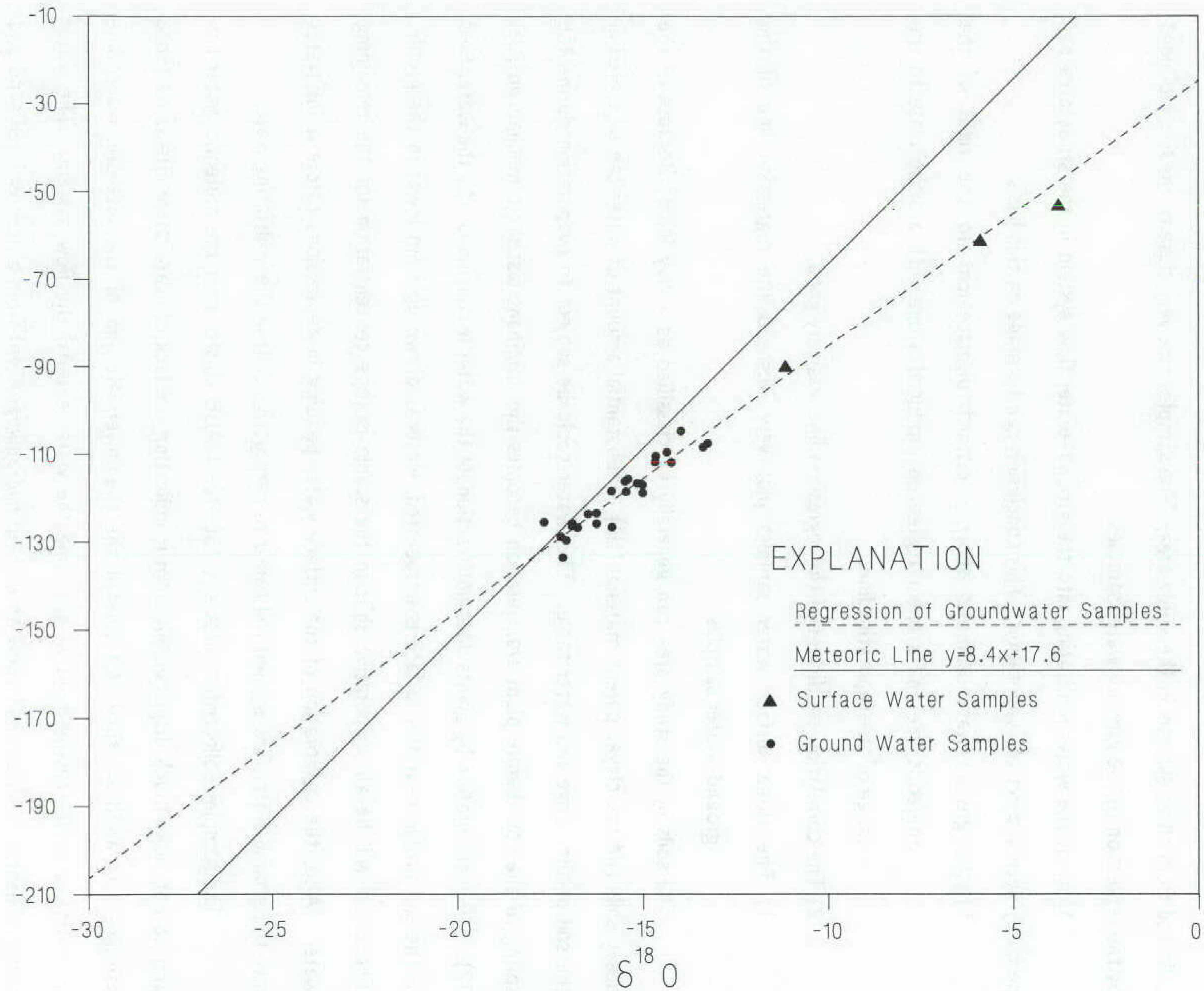

FIGURE 31. Regression line of ^{18}O and D analysis of ground water samples.

The correlation coefficient of these 26 values is 0.9370.

Surface water samples, which would definitely have been subject to evaporation, were collected from three sloughs in the study area. The samples plot very close to the line produced by the regression of the ground–water samples.

Most of the water infiltrating into the ground–water flow system in the study area has probably been subject to evaporation. This conclusion can be made on this basis:

1) the ground–water samples show a distinct displacement to the right of the meteoric line and a linear regression produced a line with a slope close to the range of an evaporative line.

2) The correlation coefficient of the regression line was very good.

3) The three surface water samples plot very close to the regression line of the ground–water samples.

The soils in the study area can generally be classified as a clay loam. Because of the heavy soils and the clayey parent material (till), a substantial amount of water can be stored in the soil profile above the water table. This water could be subject to evaporation during the spring of the year before plant transpiration becomes the dominant discharge mechanism (fig. 32). The transpiration by plants does not fractionate the water it consumes. As the water held in the soil profile near the surface is evaporated, water is drawn up from lower in the profile. The effect will be an evaporative shift in the stable isotope concentration for the remaining water. Also, the evaporation of the surface water ponding in depressions before it infiltrates into the ground water flow system will cause an evaporative shift in the infiltrating water.

The samples collected at nest site 150–70–32ABB cluster near the meteoric water line and do not show much displacement from it indicating the lack of evaporative effects on those samples. In addition, they plot toward the the lower left end of the meteoric water line indicating a cooler environment at the time the water entered the flow system. The water levels measured in these wells show an upward hydraulic gradient from a deep isolated sand and gravel unit. This suggests the water here is different than the till water and may be of

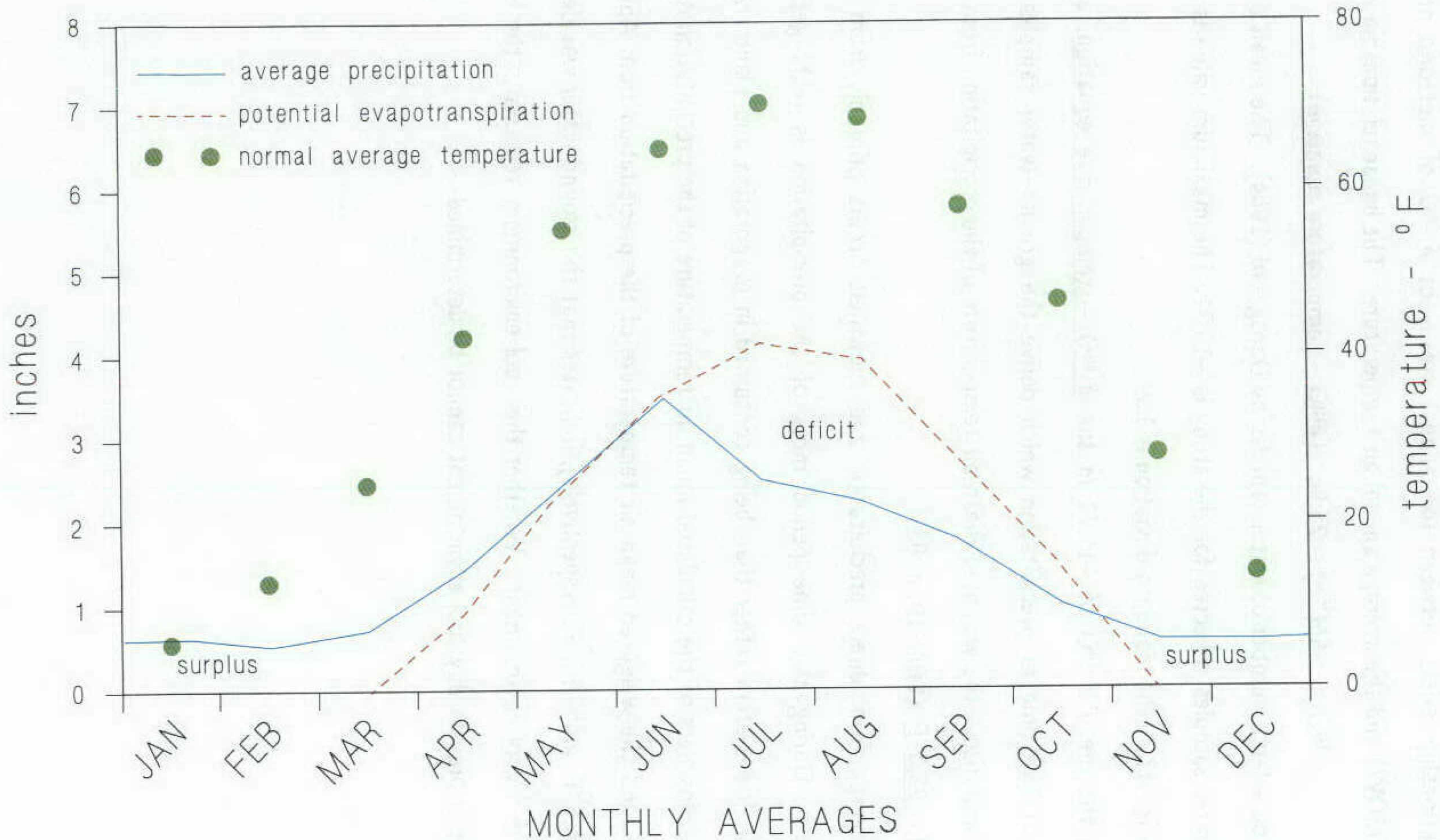

FIGURE 32. Climatic and soil water balance diagram.

Pleistocene age.

A relationship exists between the annual means of $\delta\,^{18}O$ of meteoric precipitation (relative to SMOW) and the average annual air temperature. The linear relationship is

$$\delta\,^{18}O = .386(^{o}F) - 25.96 \quad (\underline{\delta^{18}O - \text{temperature equation}})$$

and is based on a large number of water samples by Dansgaard (1964). The mean $\delta\,^{18}O$ of the 26 ground–water samples collected for the study is –15.71. The maximum value is –13.3 and the minimum is –17.7; the standard deviation is 1.24.

Using the mean $\delta\,^{18}O$ of –15.71 in the **$\delta\,^{18}O$ – temperature equation**, a mean air temperature at the time of precipitation which derive the ground–water samples would be **$26.5^{o}F$**. In comparison, the weighted mean air temperature of the precipitation from November through April is **$25.3^{o}F$**. (table 10, p. 93).

Recharge from direct precipitation and snowmelt occurs primarily from November through April. During this time period most of the precipitation is recharged into the ground–water flow system rather than being consumed in evaporation and plant transpiration (fig. 32). The closeness of the calculated mean air temperature of the precipitation deriving the ground water, and the weighted mean air temperature of the precipitation from April through November ($26.5^{o}F$. and $25.3^{o}F$. respectively), indicates that the ground water was derived from precipitation in a cool environment. Whether this cool environment represents the Pleistocene Epoch or that of present day cool environment cannot be determined.

SUMMARY AND CONCLUSIONS

The New Rockford aquifer is a buried valley deposit that extends generally east–west from western McHenry County to eastern Foster County in North Dakota. The aquifer occupies a valley incised during Pleistocene glaciation. It is buried by generally 50 to 150 feet of glacial till.

Two other aquifers exist within the study area. The Heimdal aquifer occupies a surficial glacial meltwater channel that overlies the New Rockford aquifer for much of its reach, and the Manfred aquifer is a shallow buried valley deposit that may have been a tributary channel to the ancient New Rockford valley. Water level data suggests that both the Heimdal and Manfred aquifers are not in direct hydraulic connection with the New Rockford aquifer.

The lateral hydraulic gradients in the New Rockford aquifer within the study area are small. The rate of ground water flow is small. The New Rockford aquifer consists of a number of discrete hydrogeologic segments. Two such segments occur within the study area. In the western portion, the flow is generally toward the Sheyenne River where it overlies the aquifer. In the eastern portion, the flow is generally to the east. The two flow systems are separated by a low–transmissivity barrier consisting of glacial till and lacustrine clay and silt.

There does not appear to be any direct hydraulic connection with any surface water body or surficial aquifer in the study area. Recharge is probably the result of water slowly moving downward through the till over most of the study area as indicated by the large vertical gradients measured in several nested piezometer sites. Discharge occurs where the vertical gradient is upward through the till into the Heimdal aquifer and Sheyenne River valley.

Hydraulic conductivity values of the unweathered, unfractured till range from 10^{-4} to 10^{-3} feet per day. The hydraulic conductivity of the fractured till is substantially higher ranging from 10^{-2} to 10^{-1} feet per day. However, since no fractures were observed more than 8 feet below the weathered till zone, fractures do not appear to be an important control affecting the rate of downward ground water movement into the New Rockford aquifer in the study area.

Water in the New Rockford aquifer is generally a sodium–bicarbonate but includes calcium–bicarbonate and sodium–bicarbonate–sulfate water also. Water from wells screened near the base of the aquifer show a relatively high chloride concentration which indicates upward movement of water from the underlying Pierre Formation. The dissolved solids concentration typically increases with depth. Relatively high dissolved silica concentrations in the aquifer indicate a relatively long residence time for the ground water contained in the aquifer.

Water samples obtained from the till have sulfate as the dominant anion with sodium, calcium, and magnesium in large concentrations. Generally, water from shallow till wells, especially water table wells, contain higher concentrations of sulfate than water from wells screened deeper in the till. The elevated sulfate and dissolved solids concentration of the water table is due to the concentrating mechanism of evapotranspiration. The dissolved solids concentration in the till typically decreases with depth.

All water samples from the New Rockford aquifer, with one exception, contain tritium levels below detection limits. This indicates an age of recharge for the aquifer water of more than 50 years. Nearly all shallow, water table wells in the study area show evidence of post–bomb tritiated water. The lack of post–bomb age water in most of the deeper till wells implies a relatively slow rate of vertical water movement through the till in the study area. Detectable tritium from the water table New Rockford aquifer well in 149–69–06DCC2 indicates a higher rate of recharge at this site.

The stable isotope analysis showed that most of the ground water in the study area is probably derived from precipitation during cool periods. The ground water located near land surface is probably derived from snowmelt and fall or spring rains. Most of the precipitation in the summer (warmer) months is probably taken up in evaporation and plant consumption. In addition, nearly all of the ground–water samples collected show a displacement to the right of the meteoric water line. This indicates that the water has been subject to evaporative effects before it moves down to the water table. Whether the ground–water samples collected at greater depths are derived from present day fall–winter–spring precipitation or from the Pleistocene epoch is not apparent.

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SUPPLEMENTAL DATA

SUPPLEMENT I – Tables

Table 1 – Chemical parameters and methods of analysis

Major anions/cations*	Method of analysis
Silica	Inductively coupled plasma
Calcium	Inductively coupled plasma
Magnesium	Inductively coupled plasma
Sodium	Inductively coupled plasma
Potassium	Inductively coupled plasma
Iron	Inductively coupled plasma
Manganese	Inductively coupled plasma
Sulfate (total sulfur as sulfate)	Inductively coupled plasma
Carbonate	Potentiometric titration
Bicarbonate	Potentiometric titration
Total alkalinity	Potentiometric titration
Conductivity	Measure resistance
Total hardness	Calculation
pH	Glass electrode
Nitrate	Automated cadmium reduction
Fluoride	Ion selective electrode
Chloride	Automated ferocynide
TDS	Ion summation
Environmental isotope analysis	
Tritium (^{3}H)**	Electrolytic enrichment–liquid scintillation method
$^{18}O/^{16}O$***	Mass spectrometer
$^{1}H/^{2}H$ (Deuterium)***	Mass spectrometer

*Analyses was performed at the Laboratory Services Section, Division of Chemistry, North Dakota State Department of Health

**Analyses performed by the University of Miami Tritium Laboratory, Miami, Florida

***Analyses performed by the Global Geochemistry Corporation, Canoga Park, California

Table 2 — Particle Size Analysis Results*

Location	Type of Sediment	Depth (ft)	Percent Sand	Percent Silt	Percent Clay
149–70–3CBB	weathered till	6.0	7.6	70.5	21.9
	unweathered till	14.0	36.3	36.9	26.8
	unweathered till	35.0	39.7	39.6	20.8
	unweathered till	56.0	37.6	39.0	23.4
149–69–06DCC	sl.weathered till	14.0	46.4	40.5	3.1
149–69–09CBB	weathered till	13.0	44.0	40.6	15.4
	unweathered till	31.0	38.3	39.8	21.9
	unweathered till	50.0	36.4	37.7	25.9
	unweathered till	70.0	41.0	34.3	24.7
149–69–24BCC	sl.weathered till	30.0	40.3	37.4	22.3
	unweathered till	41.0	35.6	44.6	19.8
150–70–32ABB	unweathered till	23.0	37.4	38.7	23.9
	lacustrine	36.0	13.2	74.7	12.1
	lacustrine	45.0	10.5	76.4	13.1
	lacustrine	53.0	7.2	78.7	14.1
	lacustrine	57.0	80.8	17.5	1.7
	lacustrine	90.0	91.0	8.8	0.2

*Analysis were conducted by the North Dakota State University Soils Department using the pipette method

Table 3 — Values of hydraulic conductivity from slug test analysis

Location	Types of Sediments Screened	Hydraulic conductivity (ft/day)	
		Hvorslev Method	Cooper Method
149–69–09CBB4	Till	7.00×10^{-4}	3.84×10^{-4}
149–69–24BCC3	Till	1.60×10^{-3}	2.17×10^{-3}
149–70–03CBB2	Till	9.00×10^{-4}	8.24×10^{-4}
149–69–06DCC4	Fractured till	2.13×10^{-1}	3.08×10^{-1}
150–70–32ABB3	Fractured till	5.39×10^{-2}	2.96×10^{-2}
150–70–32ABB2	Clay & silt	2.89×10^{-2}	4.81×10^{-2}
149–69–24BCC3	Sand; intertill sand	water level recovered in less than 45 seconds	
150–70–27DDA	Sand and gravel; Heimdal aq.	water level recovered in less than 25 seconds	
150–70–27DDA1	Sand and gravel; New Rockford aq.	1.44×10^{-2}	

Table 4. Nested monitoring piezometers

Location	Screened interval (ft.)	Material screened
149–69–04BBB1	18–23	sand & gravel (Heimdal aquifer)
149–69–04BBB3	81–86	till
149–69–04BBB2	101–106	sand & gravel (New Rockford aquifer)
149–69–06DCC5	3–13	till
149–69–06DCC4	13.5–16	till
149–69–06DCC3	27–32	till
149–69–06DCC2	48–68	sand & gravel (New Rockford aquifer)
149–69–06DCC1	93–98	sand & gravel (New Rockford aquifer)
149–69–06DCC	248–253	sand & gravel (New Rockford aquifer)
149–69–09CBB5	8–18	till
149–69–09CBB4	28–33	till
149–69–09CBB3	48–53	till
149–69–09CBB2	72–77	till
149–69–09CBB1	148–153	sand & gravel (New Rockford aquifer)
149–69–09CBB	257–262	sand & gravel (New Rockford aquifer)
149–69–24BCC4	18–38	till
149–69–24BCC3	42–47	till
149–69–24BCC1	50–55	sand (intertill sand layer)
149–69–24BCC2	146–151	sand & gravel (New Rockford aquifer)
149–69–24BCC	278–283	sand & gravel (New Rockford aquifer)
149–70–03CBB4	5–15	till
149–70–03CBB3	33–38	till
149–70–03CBB2	53–58	till
149–70–03CBB	110–115	sand & gravel (New Rockford aquifer)
149–70–03CBB1	242–247	sand & gravel (New Rockford aquifer)
150–70–32ABB3	19–29	till
150–70–32ABB2	33–38	silt & clay (lacustrine sediments)
150–70–32ABB1	43–48	silt & clay (lacustrine sediments)
150–70–32ABB4	86–91	silt & clay (lacustrine sediments)
150–70–32ABB	192–197	sand & gravel (New Rockford aquifer)

Table 5. Chemical analyses of water samples

Explanation of abbreviations, codes, and units:

Location	–Township, range, section, and quarters(s) identifier
Well depth	–Depth of the bottom of the lowest screen; 'S' indicates a surface water sample
Date sampled	–Date sample was gathered in the field
SiO_2	–Dissolved silica in milligrams per liter
Fe	–Dissolved iron in milligrams per liter
Mn	–Dissolved manganese in milligrams per liter
Ca	–Dissolved calcium in milligrams per liter
Mg	–Dissolved magnesium in milligrams per liter
Na	–Dissolved sodium in milligrams per liter
K	–Dissolved potassium in milligrams per liter
HCO_3	–Dissolved bicarbonate in milligrams per liter
CO_3	–Dissolved carbonate in milligrams per liter
SO_4	–Dissolved sulfate in milligrams per liter
Cl	–Dissolved chloride in milligrams per liter
F	–Dissolved fluoride in milligrams per liter
NO_3	–Dissolved nitrate in milligrams per liter
B	–Dissolved boron in milligrams per liter
TDS	–Total dissolved solids calculated from the summation of the ions
Hardness:	
as $CaCO_3$	–Milligrams per liter as calcium carbonate ($CaCO_3$) hardness
as NCH	–Milligrams per liter as noncarbonate hardness
% Na	–Percent sodium
SAR	–Sodium adsorption ratio
Spec Cond	–Field measurement of specific conductance in micromhos per centimeter corrected to 25 ^0C
Temp	–Temperature in ^0C
pH	–pH in standard units

Location	Well Depth (ft)	Date Sampled	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 (°C)	pH
			(milligrams per liter)																					
149-069-04BBB	143	09-17-86	34	3.09	0.27	92	28	279	9	1040	0	97	57	0.2	0		1108	346		63	6.5	1181	8.4	7.5
149-069-04BBB1	23	09-17-86	34	0.34	0.18	82	38	126	6	525	0	196	29	0.2	0		770	360		43	2.8	835	9.1	7.5
149-069-04BBB2	106	10-28-86	29	6.59	0.39	135	45	185	15	949	0	96	39	0.2	0		1019	523		43	3.5	1019	8.2	7.3
149-069-04BBB3	86	12-11-86	18	1.03	0.41	40	36	186	17	461	0	211	35	0.3	0		771	245		62	5.1		8.0	7.2
149-069-05	S	-72	6	0.04	0.09	26	23	54	11	219		89	10	0.1	1	0.29	328	161		40	1.9			
149-069-05	S	04-30-73	5	0.2	0.14	38	53	144	21	422		238	36	0.1	3	0.03	747	313		48	3.5		9.5	
149-069-05ADA	S	09-18-86	1	0.02	0.1	18	76	246	22	377	130	324	35	0.2	0		1042	359		59	5.6	1123	9.8	9.4
149-069-05DDD	200	08-04-66	25	2.8		180	82	195	14	657		616	25	0.4	6	0.33	1470	786	248	35	3.0	1700	8.3	
149-069-06AAA	S	09-18-86	37	0.0	0.0	41	79	206	19	662	26	271	30	0.2	0		1035	429		50	4.3	1138	11.1	8.4
149-069-06DCC	253	09-11-86	36	3.57	0.34	166	50	245	10	972	0	343	64	0.2	0		1400	621		46	4.2	1355	8.3	7.4
149-069-06DCC1	98	09-11-86	37	3.37	0.13	146	43	153	10	863	0	208	23	0.2	0		1051	540		38	2.8	1062	8.0	7.1
149-069-06DCC2	68	12-10-86	33	4.48	1.05	48	61	26	9	340	0	89	3	0.1	1		444	369		13	0.5			
149-069-06DCC3	32	12-09-86	18	0.0	0.2	38	28	15	8	199	0	54	4	0.3	0		263	210		13	0.4			7.6
149-069-06DCC4	16	12-10-86	25	0.02	0.52	53	33	9	6	247	0	36	3	0.3	0		288	269		6	0.2		7.9	7.5
149-069-06DCC5	13	12-09-86	26	0.0	0.06	64	36	5	8	295	0	34	2	0.2	1		326	307		3	0.1		5.6	7.2
149-069-09CBB	262	09-10-86	36	2.16	0.37	136	37	269	8	906	0	342	24	0.2	0		1299	491		54	5.2	1246	7.9	7.4
149-069-09CBB1	153	10-28-86	28	4.69	0.81	121	41	187	15	822	0	116	23	0.4	0		971	471		46	3.7	948	7.5	7.5
149-069-09CBB2	77	12-11-86	4	0.05	1.22	152	58	371	12	424	0	1010	25	0.4	0			619		56	6.4		7.5	7.5
149-069-09CBB3	53	12-11-86	29	0.0	0.12	213	81	314	21	156	0	1430	30	0.2	0		2189	866		44	4.6		6.5	9.1
149-069-09CBB4	33	12-11-86	2	0.0	0.53	320	178	286	15	575	0	1960	18	0.2	0		3073	1530		28	3.1		6.6	7.2
149-069-09CBB5	18	12-09-86	25	0.0	0.15	440	216	159	15	441	0	1980	13	0.4	1		3066	1990		14	1.5		4.2	7.3
149-069-10DCC	275	09-09-86	33	1.1	0.1	40	11	457	8	1120	0	63	143	0.4	0		1304	145		87	16.5	1385	8.0	7.7
149-069-11CCA	176	06-01-67	21	2.1		56	15	364	9	1010		14	100	0.5		0.23	1080	200		79	11.0		7.8	
149-069-13BCC	220	09-09-86	32	2.58	0.29	96	28	206	10	876	0	83	46	0.2	0		935	355		55	4.7	1004	8.0	7.5
149-069-16BCC	255	09-09-86	37	0.43	0.38	111	34	203	9	928	0	105	30	0.2	0		986	416		51	4.3	1035	8.0	7.3
149-069-18BBB	280	05-28-87	24	0.11	0.47	85	30	500	11	788		520	90	0.2	1	0.55	1650	340		76	12.0			
149-069-18BBC		08-03-67	25	6.3		142	34	232	15	798		284	49	0.3		0.16	1180	495		50	4.5			
149-069-24BCC	283	10-19-65	27	0.85		38	16	375	7	899		63	141	0.3		0.25	1110	160		83	13.0			
149-069-24BCC	283	08-20-70	23	1.6		25	11	405	7	879		67	144	0.5	2	0.16	1120	107		88	17.0	1700	7.0	
149-069-24BCC	283	08-29-85	23	0.2	0.05	26	14	400	9	869	19	13	150	0.3	1	0.23	1080	120		87	16.0	1700	8.0	8.0
149-069-24BCC	283	09-12-86	32	0.03	0.18	50	15	375	7	966	0	68	118	0.3	0		1143	186		81	12.0			
149-069-24BCC1	55	10-21-86	30	0.57	0.9	320	120	72	16	548		960	10	0.2	1	0.23	1800	1300	840	11	0.9	1409	8.2	7.2
149-069-24BCC1	55	10-27-86	28	0.87	0.77	287	122	73	15	595	0	884	10	0.2	0		1710	1220		11	0.9	1409	8.2	7.2
149-069-24BCC2	151	10-27-86	29	2.68	0.73	86	25	45	7	433	0	92	4	0.4	0		504	318		23	1.0	551	7.8	7.6
149-069-24BCC3	47	12-10-86	30	0.01	0.52	353	169	100	13	576	0	1400	10	0.2			2360	1580		12	1.1		7.5	6.9
149-069-24BCC4	38	12-10-86	29	0.0	0.06	291	125	69	13	498	0	1060	5	0.3	7		1869	1240		10	0.8		7.6	6.9
149-070-02AAA	81	10-21-65	27	8.9		207	137	100	13	496		810	17		1	0.43	1570	1080	673	17	1.3		7.2	
149-070-02AAA	81	09-12-86	29	1.22	1.65	442	194	118	15	775	0	1360	84	0.1	0		2632	1900		11	1.1			
149-070-02AAA1	223	09-10-86	36	5.21	0.21	149	52	386	10	1280	0	352	81	0.4	0		1701	584		58	6.9	1634	8.1	7.4
149-070-03CBB	115	09-16-86	33	4.87	0.16	104	36	174	9	753	0	208	19	0.3	0		961	410		48	3.7	971	7.8	7.5
149-070-03CBB1	247	10-29-86	33	0.76	0.65	97	35	398	17	890	0	203	305	0.2	0		1524	385		69	8.8	1756	7.7	7.2
149-070-03CBB2	58	12-10-86	10	0.17	3.15	121	69	165	13	514	0	653	20	0.2	0		1304	589		37	2.9		7.4	7.1
149-070-03CBB3	38	12-10-86	7	0.39	2.43	107	54	146	10	450	0	464	16	0.3	0		1030	490		39	2.8		7.9	7.1
149-070-03CBB4	15	12-10-86	3	0.0	0.88	178	383	627	12	939	0	2700	8	0.2			4375	2020		40	6.0		8.1	7.1
149-070-03DDD	263	05-28-87	23	0.22	0.12	140	40	760	15	1120		890	83	0.1	1	0.2	2500	510		76	15.0			
149-070-04ADD	207	07-22-65	20	5.2		119	31	276	12	986		188	24	0.3	4	0.25	1170	426		58	5.8		10.0	
149-070-04DAA	170	08-28-86	48	4.82	0.24	116	44	266	10	1050	0	216	57	0.6	0		1284	471		55	5.3	1380	8.4	7.3
149-070-09DAA1	203	05-16-66	24	0.16		92	43	432	5	842		351	202	0.1	1	0.12	1560	408		69	9.0	1635	7.9	7.8
149-070-09DAA1	203	08-20-70	22	1.9	0.02	8	32	448	11	478	43	426	192	0.2	3	0.08	1420	153		85	16.0	1635	7.9	7.8
149-070-09DAA1	203	07-22-80	25	0.18	0.43	140	32	440	11	852		390	200	0.1	1	0.31	1660	480		66	8.7	1635	7.9	7.8

Location	Well Depth (ft)	Date Sampled	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 (°C)	pH
			|<-------	(milligrams per liter)															------->|					
149-070-09DAA1	203	08-29-85	23	0.48	0.46	140	43	430	14	721		390	200	0.2	5	0.22	1600	880	290	63	6.3	1635	7.9	7.8
149-070-09DAA1	203	09-10-86	30	0.12	0.18	128	39	407	10	942	0	330	194	0.2	0		1601	481		64	8.0	1635	7.9	7.8
149-070-09DAA2	103	08-20-70	21	2.7	0.01	221	230	246	13	455		1610	46	0.4	1	0.22	2620	1500	1130	26	2.8	3000	7.0	
149-070-12BCC	295	09-11-86	35	5.45	0.35	177	52	260	10	940	0	423	84	0.2	0		1511	656		46	4.4	1455	8.6	7.4
149-070-16AAD	209	08-28-86	46	2.04	0.48	116	29	271	10	799	0	330	73	0.6	0			408		59	5.8	1359	8.8	7.4
149-071-01ADD	263	08-28-86	42	3.74	0.41	129	37	249	7	976	0	229	36	0.6	0		1217	476		53	4.9	1288	8.9	7.5
149-071-19CDD	160	07-16-66	28	1.4		129	43	150	11	606		302	18	0.4	1	0.27	982	499	3	39	2.9	1300	8.3	
149-071-19CDD	160	07-23-80	27	0.13	0.89	140	44	110	9	543		290	16	0.3	1	0.14	905	530	85	31	2.1	1350	8.5	
149-071-19CDD	160	09-12-86	39	1.55	0.6	129	38	132	9	606	0	287	19	0.3	0		954	480		37	2.6			
149-071-28ADC		05-03-66	17	0.16		74	90	213	17	680		400	39	0.4	16	3.2	1200	555		45	3.9	1600	6.1	
149-071-31CCB	128	09-12-86	37	0.8	0.81	153	42	261	13	422	0	734	41	0.3	0		1489	555		50	4.8			
149-071-31CCC		06-05-67	24	2.4		174	39	273	15	405		764	43	0.3	3	0.94	1540	595	263	49	4.9		6.1	
150-069-05	S	-64		1.51				696		968	60							50						
150-069-31CBC	103	09-12-86	36	12.6	0.36	212	66	211	12	1010	0	468	40	0.1	0		1559	802		36	3.2	1473	7.3	7.1
150-069-32CCC	19	10-28-86	30	2.59	0.35	107	53	264	15	934	0	215	51	0.2'	0		1203	486		54	5.2	1223	9.5	7.3
150-070-07A		-64		1.4						324		376	5		3			500		22	1.3			
150-070-17ADA		11-06-65	26	0.31		278	143	115	10	352		1080	54	0.2	7	0.11	1890	1280	991	16	1.4			
150-070-20DAD		05-04-66	20	1.1		109	44	46	8	394		198	19	0.2	4	0.23	643	453	130	18	0.9	920	4.4	
150-070-20DAD2		08-20-70	19	5.1	0.01	56	56	59	8	250		270	26	0.1	1	0.54	624	369	164	25	1.3	1120	7.5	
150-070-25CCC	223	08-29-86	45	0.71	0.05	46	23	622	10	1260	0	289	167	0.6	0		1826	208		86	18.7	1802	8.3	7.9
150-070-26CCB	S	09-18-86	45	0.02	0.23	50	81	74	19	539	13	180	16	0.2	0		744	458		25	1.5	863	11.7	8.4
150-070-27DDA	20	09-17-86	34	0.0	0.04	75	57	27	4	439	0	91	4	0.2	12			422		12	0.5	610	9.0	7.6
150-070-27DDA1	170	09-17-86	32	5.48	0.36	178	66	844	17	995	0	1540	90	0.2	0		3220	716		71	13.7	2610	7.6	7.4
150-070-28ADA	29	10-28-86	29	6.51	0.63	143	51	48	6	426	0	304	12	0.1	0		810	569		15	0.8	750	6.8	7.3
150-070-31CDD		07-27-66	27	0.3		110	33	326	11	568		522	80	0.6	1	0.55	1390	410		63	7.0			
150-070-32ABB	197	08-28-86	53	0.37	1.75	210	50	124	10	436	0	672	47	0.5	0		1386	728		27	2.0	1287	7.9	7.3
150-070-32ABB1	48	12-05-86	31	0.92	0.86	152	56	118	11	281	0	547	45	0.2	0			611		29	2.0		6.9	7.0
150-070-32ABB2	38	12-05-86		1.38	0.88	163	65	115	11	273	0	541	50	0.2	0		1082	675		26	1.9		6.5	7.3
150-070-32ABB3	29	12-05-86	28	0.0	0.2	385	201	200	11	559	0	1800	35	0.3	0		2938	1790		19	2.0		5.6	7.5
150-070-32ABB4	91	12-05-86	31	6.35	1.18	234	59	93	9	567	0	639	47	0.2	0		1399	829		19	1.4		6.8	7.3
150-070-32CCC	163	05-27-87	29	0.06	0.71	150	37	260	18	352		720	42	0.2	1	0.45	1430	530	240	51	4.9			
150-070-32DCC	277	05-27-87	24	0.07	0.23	110	34	350	15	712		130	210	0.2		0.33	1220	410		64	7.5			
150-070-33CDD	163	05-27-87	30	0.17	1.3	230	63	100	13	393		550	22	0.1	1	0.28	1200	830	510	20	1.5			
150-070-34CCC	315	09-10-86	37	1.61	0.18	71	24	532	11	1170	0	40	388	0.3	0		1679	274		80	14.0	1820	8.3	7.4
150-070-35AAA	S	09-18-86	30	0.07	0.24	81	68	52	10	590	0	144	6	0.2	0		682	484		18	1.0	800	10.7	7.7
150-070-35AAD	23	10-28-86	31	5.83	0.7	240	101	243	18	745	0	873	47	0.2	0		1928	1020		34	3.3	1593	7.5	7.2
150-071-04BAA		07-20-65	21	4.0		78	20	160	8	622		81	25	0.3	2		706	276		55	4.2		8.9	
150-071-04DDD	280	11-09-65	26	1.4		40	28	203	9	621		114	25	0.2		0.01	751	216		67	6.0	887	7.9	7.7
150-071-04DDD	280	08-20-70	24	1.7	0.01	34	9	207	8	479	18	119	26	0.1	1	0.33	684	123		77	8.1	887	7.9	7.7
150-071-04DDD	280	07-21-80	26	0.07	0.31	83	25	210	8	708		120	29	0.2	1	0.27	851	310		59	5.2	887	7.9	7.7
150-071-04DDD	280	08-29-85	25	0.36	0.34	89	25	200	10	548		140	27	0.2	1	0.16	788	330		56	4.8	887	7.9	7.7
150-071-04DDD	280	09-09-86	33	0.34	0.22	79	23	199	8	717	0	106	26	0.3	0		827	291		59	5.0	887	7.9	7.7
150-071-06DDD	183	05-27-87	25	0.11	0.46	120	25	270	12	581		340	60	0.1		0.21	1140	400		58	5.9			
150-071-16BBA1		08-26-86	51	1.26	0.25	69	20	155	6	628	0	84	23	0.6	0		720	254		56	4.2			
150-071-21CBB	234	08-26-86	43	0.61	0.51	55	22	343	6	830	0	230	93	0.9	0		1205	229		76	9.8	1190	8.3	7.6
150-071-21CBB1	95	09-12-86	32	0.0	0.04	85	50	470	46	387	0	1050	52	0.2	0		1972	419		70	9.9	1893	9.4	8.6
150-071-22BBB	303	08-27-86	47	0.43	0.2	46	15	276	6	765	0	133	51	0.6	0		953	176		77	9.0	1035	9.0	7.6
150-071-22DAA	235	08-27-86	50	3.42	0.44	137	38	252	10	693	0	488	42	0.5	0		1364	500		52	4.9	1329	8.6	7.4
150-071-26ABB	257	10-28-65	27	3.3		114	52	208	11	435		552	32	0.1	3	0.15	1220	497	140	47	4.1			
150-071-26ABB	257	08-20-70	25	3.2	0.01	112	38	197	10	361		520	30	0.4	1	0.27	1120	435	139	49	4.1	1680	7.0	

Location	Well Depth (ft)	Date Sampled	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 (°C)	pH
			(milligrams per liter)																					
150-071-26ABB	257	07-22-80	28	0.08	0.93	200	44	220	10	563		600	35	0.1	1	0.38	1420	680	220	41	3.7	1950	9.0	
150-071-26DCC	338	05-27-87	28	0.17	0.76	120	31	380	12	521		560	75	0.1	1	0.41	1470	430		65	8.0			
150-071-29AAB	103	07-25-66	28	0.4		118	38	208	13	655		267	76	0.4		0.74	1070	451		49	4.3	1156	7.6	7.7
150-071-29AAB	103	08-29-85	22	1.3	0.66	160	42	200	14	496		280	73	0.1	4	0.25	1040	570	170	42	3.6	1156	7.6	7.7
150-071-29AAB	103	09-09-86	33	0.01	0.55	143	39	203	11	728	0	237	80	0.2	0		1103	518		45	3.8	1156	7.6	7.7
150-071-32BCC	235	09-17-86	34	3.74	0.15	83	33	395	11	1070	0	289	52	0.4	0			343		71	9.2	1438	8.1	7.6
150-071-32BCC1	110	09-17-86	32	2.45	0.24	116	46	248	9	887	0	329	19	0.4	0			478		52	4.9	1207	7.7	7.5
150-071-36ADD	291	08-27-86	47	2.43	0.66	145	34	277	10	704	0	466	71	0.5	0		1401	-504		54	5.3	1379	8.2	7.2

Table 6. Statistical parameters of the chemical constituents in the till water samples (n=14 samples)

	Mean x	Standard Deviation s	Minimum Value	Maximum Value	Coefficient of Variation $s/x \times 100$
HCO_3(mg/l)	452.4	196.9	156.0	939.0	43.5%
CO_3(mg/l)	0.0	0.0	0.0	0.0	0.0%
Cl(mg/l)	16.0	11.5	2.3	35.1	72.2%
Fl(mg/l)	0.3	0.1	0.2	0.4	26.8%
N(mg/l)	0.7	1.7	0.0	6.5	271.2%
SiO_2(mg/l)	18.1	10.7	1.9	29.5	58.9%
Ca(mg/l)	196.7	138.0	37.9	440.0	70.2%
Fe(mg/l)	0.12	0.28	0.0	1.0	229.2%
Mg(mg/l)	119.0	101.2	28.0	383.0	85.0%
Mn(mg/l)	0.7	0.9	0.1	3.1	124.8%
K(mg/l)	12.5	4.0	5.83	21.1	32.0%
Na(mg/l)	189.4	169.2	5.20	627.0	89.3%
SO_4(mg/l)	1056.5	855.0	34.0	2700.00	80.9%
Hard(mg/l)	981.7	685.8	210.0	2020.0	69.8%
pH	7.4	0.2	7.0	8.0	3.4%
TDS(mg/l)	1815.5	1252.7	244.0	4370.0	68.9%

Table 7. Statistical parameters of the chemical constituents in the New Rockford aquifer water samples(n = 32 samples)

	Mean x	Standard Deviation s	Minimum Value	Maximum Value	Coefficient of Variation s/x × 100
HCO_3(mg/l)	869.6	217.4	340.0	1280.0	25.0%
Cl(mg/l)	79.5	83.6	2.5	388.0	105.2%
Fl(mg/l)	0.4	0.2	0.1	0.9	50.0%
NO_3(mg/l)	0.02	0.12	0.0	0.7	600.0%
SiO_2(mg/l)	37.5	7.3	27.9	53.0	19.5%
Ca(mg/l)	122.9	74.8	39.6	442.0	60.9%
Fe(mg/l)	2.9	2.6	0.04	12.6	89.7%
Mg(mg/l)	41.1	31.3	11.1	194.0	76.2%
Mn(mg/l)	0.45	0.4	0.05	1.75	88.9%
K(mg/l)	9.9	2.9	5.5	17.0	29.3%
Na(mg/l)	281.0	164.8	25.8	844.0	58.6%
SO_4(mg/l)	308.4	337.7	40.0	1540.0	109.5%
Hardness(mg/l)	476.1	308.9	145.0	1900.0	64.9%
pH	7.6	0.3	6.9	8.2	3.9%
TDS(mg/l)	1272.6	544.7	406.0	322.0	42.8%

Table 8 – Tritium analyses results

Location	Screen interval (ft)	Well type	TU (tritium units)
149–69–04BBB1	18–23	Heimdal aquifer	77.9 ± 1.8
149–69–04BBB3	81–86	till	0.08 ± 0.09
149–69–04BBB2	101–106	New Rockford aq.	–0.02 ± 0.09
149–69–06DCC5	3–13	water table, till	124. ± 3.
149–69–06DCC3	27–32	till	0.67 ± 0.10
149–69–06DCC2	48–68	New Rockford aq.	1.05 ± 0.10
149–69–06DCC1	93–98	New Rockford aq.	–0.27 ± 0.09
149–69–09CBB5	8–18	water table,till & sand	57.6 ± 1.6
149–69–09CBB4	28–33	till	0.06 ± 0.09
149–69–09CBB3	48–53	till	0.12 ± 0.09
149–69–09CBB2	72–77	till	10.0 ± 0.03
149–69–09CBB1	148–153	New Rockford aq.	–0.17 ± 0.11
149–69–24BCC4	18–38	water table, till	93.6 ± 2.2
149–69–24BCC3	42–47	till	4.57 ± 0.13
149–69–24BCC1	50–55	intertill sand	0.71 ± 0.10
149–69–24BCC2	146–151	New Rockford aq.	–0.10 ± 0.09
149–70–03CBB4	5–15	water table,till	61.7 ± 1.6
149–70–03CBB3	33–38	till	13.7 ± 0.04
149–70–03CBB2	53–58	till	12.1 ± 0.04
149–70–03CBB	110–115	New Rockford aq.	–0.07 ± 0.09
150–69–3ICBC	98–103	New Rockford aq.	–0.19 ± 0.09
150–70–32ABB3	19–29	water table, till	25.0 ± 0.7
150–70–32ABB4	86–91	lacustrine sed.	–0.21 ± 0.10
150–70–32ABB	192–197	New Rockford aq.	–0.03 ± 0.10
150–70–35AAAD	18–23	Heimdal aq.	7.2 ± 1.2
150–7I–21CBB1	92–97	Manfred aq.	0.09 ± 0.09
150–71–21CBB	229–234	New Rockford aq.	0.04 ± 0.11

Table 9 — Stable Isotope Analyses

Location	Type of Water	$\delta^{18}O$*	δD*
149–69–06AAB	surface water	–5.9	–61
149–69–06DCC1	ground water	–15.5	–116
149–69–06DCC2	ground water	–13.3	–108
149–69–06DCC3	ground water	–13.4	–109
149–69–06DCC4	ground water	–14.3	–112
149–69–06DCC5	ground water	–15.1	–119
149–69–04BBB1	ground water	–15.5	–116
149–69–04BBB2	ground water	–16.3	–126
149–69–04BBB3	ground water	–16.3	–124
149–69–09CBB1	ground water	–15.2	–117
149–69–09CBB2	ground water	–15.5	–119
149–69–09CBB3	ground water	–15.9	–119
149–69–09CBB4	ground water	–14.7	–112
149–69–09CBB5	ground water	–14.7	–111
149–69–24BCC1	ground water	–14.0	–105
149–69–24BCC2	ground water	–15.9	–127
149–69–24BCC3	ground water	–14.4	–110
149–69–24BCC4	ground water	–15.1	–117
149–70–03CBBX	precipitation	–8.5	–53
149–70–03CBB	ground water	–17.2	–134
149–70–03CBB2	ground water	–16.9	–127
149–70–03CBB3	ground water	–17.7	–126
149–70–03CBB4	ground water	–17.1	–130
150–70–35AAA	surface water	–11.1	–90
150–70–32ABB	ground water	–16.5	–124
150–70–32ABB1	ground water	–17.2	–129
150–70–32AAB2	ground water	–16.9	–126
150–70–32ABB3	ground water	–17.1	–130
150–70–32ABB4	ground water	–16.8	–127
150–70–27ACB1	precipitation	–10.2	–70
150–70–27ACB2	precipitation	–15.7	–116
150–70–26CCB	surface water	–3.8	–53

*Relative to Standard Mean Ocean Water (SMOW)

Table 10 – Mean Air Temperatures and Precipitation Amounts at Fessenden*

Month	Mean Monthly Air Temp. (^{0}F)	Normal Monthly Precipitation (inches)	% of Annual precip.	% of Nov–Apr precip.
Jan	5.4	.61	3.4	13.6
Feb	12.6	.54	3.0	12.0
Mar	24.4	.74	4.1	16.4
Apr	41.9	1.48	8.2	32.9
May	55.1	2.49	13.8	–
Jun	64.4	3.49	19.4	–
Jul	69.9	2.50	13.9	–
Aug	68.3	2.24	12.5	–
Sep	57.6	1.76	9.8	–
Oct	46.3	1.00	5.6	–
Nov	28.0	.56	3.1	12.4
Dec	13.8	.57	3.2	12.7
	$\bar{x} = 40.6^0$F	Σ annual = 17.98" Σ Nov–Apr = 4.50"	$\Sigma = 100.0\%$	$\Sigma = 100.0\%$

*Supplied by the National Weather Service, Bismarck, ND

SUPPLEMENT II – Lithologic Logs

Explanation of Codes:

Casing type:
- abs – acylonitrile–butediene–styrene
- pvc – polyvinyl chloride
- steel – steel

Source of data:
- SWC(jcp) – ND State Water Commission (Jon C. Patch)
- USGS – U.S. Geological Survey

Principal aquifer:
- NRK – New Rockford aquifer
- HEM – Heimdal aquifer
- MAN – Manfred aquifer

Land surface altitude:

If expressed as an integer value (i.e. 1580), altitude was taken from a topographic map

If expressed as a decimal value (i.e. 1582.91), altitude was established by differential leveling

Note: Most of the test holes drilled have a geophysical log on file at the N.D. State Water Commission

149-069-03AAA
NDSWC 2654

Date completed: 05/31/67 Purpose: TEST HOLE
Depth drilled (ft): 160 Source of data: USGS
Land surface altitude (ft): 1548

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
TILL, silty, dusky-yellow to moderate-brown, oxidized	1-20
TILL, very silty, olive-gray	20-54
CLAY, very sandy, noncalcareous, moderate-yellowish-brown, (Fox Hills erratic?)	54-59
TILL, silty, olive-gray	59-85
GRAVEL, medium to coarse, fairly clean	85-92
TILL, olive-gray	92-123
GRAVEL, medium	123-126
TILL, silty, olive-gray	126-149
SHALE (Pierre Fm.), olive-black, noncalcareous	149-160

149-069-04BBB
NDSWC 11849

Date completed: 09/02/86 Well type: OBSERVATION
Depth drilled (ft): 180 Source of data: SWC(jcp)
Screened interval (ft): 138-143 Principal aquifer: NRK
Casing size (in) & Type: 2.0 pvc Land surface altitude (ft): 1537.30

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), yellow grayish brown, silty, sl. sandy, oxidized	1-3
SAND & GRAVEL, medium sand to 25mm gravel, oxidized (Heimdal aq)	3-7
SAND & GRAVEL, as above, unoxidized (Heimdal aq)	7-24
CLAY (Till), silty, dk. to med. gray, sand & gravel inclusions in silty clay matrix, interbedded sand & gravel lenses 1-2 feet thick from 48-57 feet	24-92
SAND, very fine to coarse, predominantly medium, quartz, shale, carbonates, and lignite (New Rockford Aq).	92-140
SAND & GRAVEL, fine sand to 2mm gravel, mainly very coarse sand, poorly sorted, quartz, shale, carbonates, lignite (New Rockford Aq).	140-148
CLAY, dk. gray to black, firm, no silt content, moderatly indurated, firm slow drilling (Bedrock Pierre formation).	148-180

149-069-04BBB1
NDSWC 11849a

Date completed:	09/03/86	Well type:	OBSERVATION
Depth drilled (ft):	30	Source of data:	SWC(jcp)
Screened interval (ft):	18-23	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.30

See lithologic description for 4bbb

149-069-04BBB2
NDSWC 11926

Date completed:	10/10/86	Well type:	OBSERVATION
Depth drilled (ft):	110	Source of data:	SWC(jcp)
Screened interval (ft):	101-106	Principal aquifer:	NRA
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.72

See lithologic description for 4bbb

149-069-04BBB3
NDSWC 11953 & nra04a

Date completed:	11/26/86	Well type:	OBSERVATION
Depth drilled (ft):	86	Source of data:	SWC(jcp)
Screened interval (ft):	81-86	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.75

Lithologic Log

Unit description	Depth (ft)
TOPSOIL & SAND & GRAVEL, see log for 4bbb	
CLAY (till), see log for 4bbbb	

149-069-05DDD
NDSWC 2564

Date drilled:	07/27/66	Purpose:	TEST HOLE
Depth drilled (ft):	252	Source of data:	USGS
Land surface altitude (ft):	1582		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, dusky brown	0-1
TILL, silty and sandy, dusky-yellow, oxidized	1-10
SAND, medium to coarse, gravelly, clayey, oxidized	10-20
TILL, silty to moderately sandy, olive-gray	20-115
SAND, medium to coarse, poorly sorted, large amount of lignite	115-252

149-069-06DCC
NDSWC 11844

Date completed:	08/26/86	Well type:	OBSERVATION
Depth drilled (ft):	295	Source of data:	SWC(jcp)
Screened interval (ft):	248-253	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.00

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), sl. silty, with sand and gravel inclusions, yellow to yellow brown, weathered, iron stained streaks (possible fractures), becomes less oxidized downward	1-18
CLAY (till), as above, medium to dk gray, unoxidized, moderately firm, moderately cohesive	18-33
SAND & GRAVEL, medium sand to 3mm gravel, generally brownish gray, poorly sorted, sub-angular to sub-round, iron staining on most fragments, 60% quartz & igneous, 20% carbonates, 10% shale, & 10% lignite	33-42
SAND & GRAVEL, coarse sand to 40mm gravel, poorly sorted, predominantly sub-round, still some iron staining, detrital lignite lenses at 49'-72'	42-72
SAND & GRAVEL, as above, unoxidized, poorly sorted	72-283
CLAY (Bedrock Pierre Formation), dark gray, no inclusions, no silt, very firm, tight slow drilling	283-295

149-069-06DCC1
NDSWC 11844a

Date completed:	08/27/86	Well type:	OBSERVATION
Depth drilled (ft):	100	Source of data:	SWC(jcp)
Screened interval (ft):	93-98	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.50

See sample description for 06dcc

149-069-06DCC2
NDSWC nra06a

Date completed:	11/22/86	Well type:	OBSERVATION
Depth drilled (ft):	69	Source of data:	SWC(jcp)
Screened interval (ft):	48-68	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.50

See sample description for 06dcc

149-069-06DCC3
NDSWC nra06b

Date completed:	11/22/86	Well type:	OBSERVATION
Depth drilled (ft):	32	Source of data:	SWC(jcp)
Screened interval (ft):	27-32	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.38

See sample description for 06dcc

149-069-06DCC4
NDSWC nra06c

Date completed:	11/23/86	Well type:	OBSERVATION
Depth drilled (ft):	16	Source of data:	SWC(jcp)
Screened interval (ft):	13.5-16	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.50

See sample description for 06dcc

149-069-06DCC5
NDSWC nra06d

Date completed:	11/23/86	Well type:	OBSERVATION
Depth drilled (ft):	13	Source of data:	SWC(jcp)
Screened interval (ft):	3-13	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.23

See sample description for 06dcc

149-069-09CBB
NDSWC 11845

Date completed:	08/27/86	Well type:	OBSERVATION
Depth drilled (ft):	320	Source of data:	SWC(jcp)
Screened interval (ft):	257-262	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.10

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), sl. silty, with sand and gravel inclusions, yellow to yellow brown, weathered, iron stained streaks (possible fractures), becomes less oxidized downward, sand and gravel lenses from 5-6' and 10-11'	1-16
SAND & GRAVEL, medium sand to 3mm gravel, generally coarse sand, medium sorting, angular to round predominantly sub-round, 60% quartz & igneous, 20% carbonates, 10% shale, & 10% lignite, partially oxidized (iron staining on some grains)	16-18
CLAY (Till), silty, with sand and gravel inclusions (partially weathered)	18-22
CLAY, as above, unoxidized, very firm, medium to dark gray, some small interbedded sand & gravel lenses from 100-134'	22-134
SAND & GRAVEL, medium sand to 3mm gravel, generally coarse sand, medium sorting, angular to round predominantly sub-round, 35% quartz & igneous, 35% shale, 20% lignite, & 10% carbonates	134-295
CLAY (Bedrock Pierre Formation), dark gray, no inclusions, no silt, very firm, tight slow drilling	295-320

149-069-09CBB1
NDSWC 11927

Date completed:	10/13/86	Well type:	OBSERVATION
Depth drilled (ft):	160	Source of data:	SWC(jcp)
Screened interval (ft):	148-153	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.30

See sample description for 09cbb

149-069-09CBB2
NDSWC nra09a

Date completed:	11/17/86	Well type:	OBSERVATION
Depth drilled (ft):	79	Source of data:	SWC(jcp)
Screened interval (ft):	72-77	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.31

See sample description for 09cbb

149-069-09CBB3
NDSWC nra09b

Date completed:	11/18/86	Well type:	OBSERVATION
Depth drilled (ft):	55	Source of data:	SWC(jcp)
Screened interval (ft):	48-53	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.32

See sample description for 09cbb

149-069-09CBB4
NDSWC nra09c

Date completed:	11/19/86	Well type:	OBSERVATION
Depth drilled (ft):	35	Source of data:	SWC(jcp)
Screened interval (ft):	28-33	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.41

See sample description for 09cbb

149-069-09CBB5
NDSWC nra09d

Date completed:	11/19/86	Well type:	OBSERVATION
Depth drilled (ft):	20	Source of data:	SWC(jcp)
Screened interval (ft):	8-18	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.45

See sample description for 09cbb

149-069-10DDC
NDSWC 11846

Date completed:	08/28/86	Well type:	OBSERVATION
Depth drilled (ft):	300	Source of data:	SWC(jcp)
Screened interval (ft):	270-275	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1584.60

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-2
CLAY (till), very silty, yellow to yellow brown, weathered, soft, mottled with dark yellow brown color, some small interbedded sand and gravel lenses from 20-23'	2-30
CLAY (Till), as above, unoxidized, very firm, medium to dark gray, some small interbedded sand & gravel lenses from 100-134'	30-133
SILT, sl. clayey, sl. cohesive, some interbedded very fine sand, carbonaceous	133-146
SAND, very fine to fine, silty, moderately well sorted, sub-round to round, much interbedded detrital lignite	146-162
SAND, medium to very coarse, medium sorting, sub-round to round, 75% quartz & igneous, 15% carbonates 10% shale & lignite 162-191	162-191
SAND & GRAVEL, coarse sand to 20mm gravel, generally 2-4mm size, poorly sorted, angular to sub-round predominantly sub-round, 50% quartz & igneous, 20% carbonates, 20% lignite, & 10% shale	191-285
CLAY (Bedrock Pierre Formation), dark gray, no silt, very firm, mod. indurated, waxy, firm slow drilling	285-300

149-069-11CCA
NDSWC 2655

Date completed:	5/31/67	Purpose:	TEST HOLE
Depth drilled (ft):	200	Source of data:	USGS
Land surface altitude (ft):	1577		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
TILL, silty to sandy, gravelly, dusky-yellow, oxidized	1-15
TILL, silty, olive-gray, moderately rocky	15-136
SAND, medium to coarse, fairly well sorted, subangular to subrounded	136-151
CLAY, olive-gray	151-152
SAND, very coarse, gravelly, subangular to subrounded, very clean, some lignite chips present	152-182
SAND, medium to coarse, clayey	182-187
SHALE, grayish-olive-green	187-200

149-069-12BBC
NDSWC 2462

Date completed:	10/15/65	Purpose:	TEST HOLE
Depth drilled (ft):	210	Source of data:	USGS
Land surface altitude (ft):	1545		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
SAND, very coarse, gravelly	1-3
TILL, very sandy, dusky-yellow	3-11
TILL, silty, olive-gray	11-17
SAND, medium to coarse	17-19
TILL, silty, olive-gray	19-122
SAND, fine to medium, silty	122-131
TILL, olive-gray	131-160
SAND, fine to medium, silty	160-164
CLAY, silty, olive-gray with greenish tint, H2S odor	164-170
GRAVEL, fine to medium, clayey, poorly sorted	170-185
SHALE, greenish-gray	185-210

149-069-13BCC
NDSWC 11847

Date completed:	08/28/86	Well type:	OBSERVATION
Depth drilled (ft):	260	Source of data:	SWC(aec)
Screened interval (ft):	215-220	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1577.90

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-2
CLAY (till), v. silty, v. sandy, pebbly, soft, sl. plastic, yellow to yellow brown, weathered, mottled with orangish brown	2-16
CLAY (Till), as above, unoxidized, olive-gray	16-21
SAND, very fine to coarse, sub-round to round, 90% quartz, 10% limestone	21-22
CLAY (Till), as above, gravel lense at 35-36'	22-136
SAND & GRAVEL, medium sand to fine pebbles, angular to round, 40% quartz, 35% shale, 20% lignite, & 10% carbonates	136-156
CLAY, gray, plastic	156-158
SAND AND GRAVEL, as above	158-182
SAND AND GRAVEL, becoming coarser	182-244
CLAY (Bedrock Pierre Formation), dark gray, very firm, moderately well indurated	244-260

149-069-16BCC
NDSWC 11848

Date completed:	08/29/86	Well type:	OBSERVATION
Depth drilled (ft):	300	Source of data:	SWC(jcp)
Screened interval (ft):	250-255	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1588.50

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-2
CLAY (till), v. silty, with sand and gravel inclusions (very weathered), yellow to yellow brown, oxidized, soft	2-18
CLAY (till), as above, unoxidized, mod. firm, gray	18-23
SAND & GRAVEL, medium sand to 3mm gravel, medium sorting, sub-angular to sub-round, 70% quartz & igneous, also shale, lignite, & carbonates	23-24
CLAY (till), as above, unoxidized	24-191
CLAY AND SILT, no inclusions, soft, drilled fast	191-224
SAND, medium to very coarse, poorly sorted, angular to sub-round, predominantly sub-round, 35% quartz & igneous, 35% shale, 20% lignite, & 10% carbonates	224-248
SAND & GRAVEL, coarse sand to 25mm gravel, poorly sorted, angular to sub-round, 40% carbonates, 20% 20%, shale, 20% quartz & igneous, 10% lignite	244-296
CLAY (Bedrock Pierre Formation), dark gray, very firm, waxy	296-300

149-069-18BBB
NDSWC 11962

Date completed:	05/14/87	Well type:	OBSERVATION
Depth drilled (ft):	320	Source of data:	SWC(jcp)
Screened interval (ft):	275-280	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 pvc	Land surface altitude (ft):	1589.87

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), silty, sandy, pebbly, oxidized, yellow	1-16
CLAY (till), as above, unoxidized, mod. firm, gray	16-33
SAND & GRAVEL, medium sand to 15mm gravel, poorly sorted, sub-angular to sub-round, mainly shale & carbonates	33-38
CLAY (till), as above, unoxidized	38-123
SAND, very fine to very coarse, medium sorting, mainly rounded quartz grains	123-137
SAND & GRAVEL, v. fine sand to 15mm gravel, poorly sorted, sub-angular to sub-round, quartz and igneous, also some carbonates, lignite, and shale	137-213
CLAY, with interbedded sand and gravel lenses, poor sample recovery	213-220
SAND & GRAVEL, as above, some interbedded clay lenses	220-277
GRAVEL, 5mm to 25mm, generally angular carbonate and rock fragments, rough drilling	277-284
CLAY (Bedrock Pierre Formation), dark gray, very firm, greasy when smeared, bentonitic	284-320

149-069-20DDA
NDSWC 2565

Date completed:	8/01/66	Purpose:	TEST HOLE
Depth drilled (ft):	242	Source of data:	SWC
Land surface altitude (ft):	1595		

Lithologic Log

Unit description	Depth (ft)
TILL, silty to sandy, dusky-yellow, oxidized	0-20
TILL, very sandy, dusky-yellow, oxidized	20-31
TILL, silty, with a few sand lenses, olive-gray	31-98
GRAVEL, sandy, poorly sorted, rough drilling	98-108
TILL, silty to gravelly, olive-gray	108-148
TILL, silty to sandy, olive-gray	148-157
SAND, clayey, olive-gray, poorly sorted, large amount lignite	157-180
GRAVEL, sandy to clayey, large amount of shale and lignite	180-209
SHALE, olive-black	209-242

149-069-24BCC
NDSWC 2463

Date completed:	10/15/65	Well type:	OBSERVATION
Depth drilled (ft):	304	Source of data:	USGS
Screened interval (ft):	275-280	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1574.80

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, silty, yellowish-brown	1-4
SAND, medium to coarse	4-11
TILL, silty, yellowish-brown, rocky	11-30
TILL, olive-gray	30-44
SAND, fine to medium, clayey	44-60
TILL, olive-gray	60-138
SAND, mediun to coarse, clayey, sub-angular to sub-round, shale and lignite chips present	138-152
SAND, mediun to coarse, sub-angular to sub-round, shale and lignite chips present	152-283
SHALE (Bedrock Pierre Formation), olive-gray, non-calcareous	283-305

149-069-24BCC1
NDSWC 11929

Date completed:	10/14/86	Well type:	OBSERVATION
Depth drilled (ft):	60	Source of data:	SWC(jcp)
Screened interval (ft):	50-55	Well sreened in outwash s&g	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1573.61

See sample description for 24bcc

149-069-24BCC2
NDSWC 11928

Date completed:	10/14/86	Well type:	OBSERVATION
Depth drilled (ft):	158	Source of data:	SWC(jcp)
Screened interval (ft):	146-151	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1573.46

See sample description for 24bcc

149-069-24BCC3
NDSWC nra24b

Date completed:	11/21/86	Well type:	OBSERVATION
Depth drilled (ft):	48	Source of data:	SWC(jcp)
Screened interval (ft):	42-47	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1573.73

See sample description for 24bcc

149-069-24BCC4
NDSWC nra24c

Date completed:	11/21/86	Well type:	OBSERVATION
Depth drilled (ft):	38	Source of data:	SWC(jcp)
Screened interval (ft):	18-38	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1574.02

See sample description for 24bcc

149-070-02AAA
NDSWC 2466

Date completed:	10/20/65	Well type:	OBSERVATION
Depth drilled (ft):	115	Source of data:	USGS
Screened interval (ft):	75-80	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1594.10

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
TILL, sandy to silty, dusky-yellow, oxidized	1-44
TILL, gravelly, dusky-yellow	44-51
SAND, medium to coarse, fairly well sorted, subangular to sub-rounded, very clean, takes water fast	51-70
GRAVEL, medium to coarse, large amounts of quartz and chert, clean	70-80
CLAY, sandy, light blueish-gray	80-103
CLAY, sandy, grayish-olive, calcareous, indurated	103-115

149-070-02AAA1
NDSWC 11850

Date completed:	09/03/86	Well type:	OBSERVATION
Depth drilled (ft):	285	Source of data:	SWC(jcp)
Screened interval (ft):	218-223	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1592.10

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), v. silty, v. sandy, yellow to yellow brown, weathered, soft	1-17
CLAY (Till), as above, unoxidized, mod. firm, medium to dark gray	17-44
SAND, SILT, & CLAY, interbedded, some carbonaceous clay and silt and some lignite	44-58
CLAY (Till), unoxidized, mod. firm, medium gray	58-62
CLAY, black & light gray, very carbonaceous clay with abundant lignite, very soft, (Fox Hills Fm.?)	62-70
SAND, fine to v. coarse, poorly sorted, sub-rounded to round, 65% quartz & igneous, 10% shale, 20% carbonates, 5% lignite	70-114
CLAY (Till), unoxidized, mod. firm, medium gray	114-121
SAND & GRAVEL, medium sand to 15mm gravel, interbedded clay at 124-125', 70% quartz & igneous, 5% shale, 5% lignite, & 20% carbonates	121-182
CLAY, silty and sandy, no inclusions, mod. soft to mod. firm	182-201
SAND & GRAVEL, as above, 15% lignite	201-271
CLAY (Bedrock Pierre Formation), dark gray, waxy, no silt, very firm, tight slow drilling	271-285

149-070-03CBB
NDSWC 11855

Date completed: 09/10/86
Depth drilled (ft): 338
Screened interval (ft): 110-115
Casing size (in) & Type: 2.0 pvc
Well type: OBSERVATION
Source of data: SWC(jcp)
Principal aquifer: NRK
Land surface altitude (ft): 1582.90

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), yellow brown becoming brownish gray, very silty, sandy, weathered	1-12
CLAY (Till), unoxidized, mod. firm, medium gray	12-96
SAND, fine to coarse, medium sorting, subrounded to subangular, 60% quartz, 20% carbonates, 10% shale, 10% lignite	96-116
SAND & GRAVEL, medium sand to 6mm gravel, medium sorting, sub-angular to sub-round, 60% quartz & igneous, 20% carbonates, 10% shale, 10% lignite	116-193
CLAY AND SILT, med. to dark gray, very firm, well indurated, some cuttings look brecciated, some very shalified (Pierre Fm. shove block)	193-240
SAND & GRAVEL, coarse sand to boulders, poorly sorted interbedded clay from 273-277'	240-326
CLAY (Bedrock Pierre Formation), dark gray, no inclusions, no silt, very firm, tight slow drilling	326-338

149-070-03CBB1
NDSWC 11924

Date completed: 10/09/86
Depth drilled (ft): 260
Screened interval (ft): 242-247
Casing size (in) & Type: 2.0 pvc
Well type: OBSERVATION
Source of data: SWC(jcp)
Principal aquifer: NRK
Land surface altitude (ft): 1582.62

See sample description for 03cbb

149-070-03CBB2
NDSWC nra03a

Date completed: 11/06/86
Depth drilled (ft): 59
Screened interval (ft): 53-58
Casing size (in) & Type: 2.0 pvc
Well type: OBSERVATION
Source of data: SWC(jcp)
Well screened in till
Land surface altitude (ft): 1582.76

See sample description for 03cbb

149-070-03CBB3
NDSWC nra03b

Date completed:	11/07/86	Well type:	OBSERVATION
Depth drilled (ft):	39	Source of data:	SWC(jcp)
Screened interval (ft):	33-38	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1582.86

See sample description for 03cbb

149-070-03CBB4
NDSWC nra03c

Date completed:	11/07/86	Well type:	OBSERVATION
Depth drilled (ft):	15	Source of data:	SWC(jcp)
Screened interval (ft):	5-15	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1582.91

See sample description for 03cbb

149-070-03DDD
NDSWC 11961

Date completed:	05/14/87	Well type:	OBSERVATION
Depth drilled (ft):	320	Source of data:	SWC(jcp)
Screened interval (ft):	258-263	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1597.47

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), silty, sandy, pebbly, yellow to yellow brown, oxidized	1-32
CLAY (till), silty, sandy, pebbly, brown to brownish gray, oxidation on some cuttings	32-42
CLAY (Till), unoxidized, mod. firm, medium gray many bedrock Pierre inclusions	42-59
CLAY, med. gray, soft, silty, no inclusions, drilled smooth (lacustine?)	59-62
CLAY (Till), as above, interbedded with gravel lenses	62-77
SAND, very fine to very coarse, poorly sorted, subround to round, 60% quartz, 20% carbonates and shale, 20% lignite	77-103
SAND AND GRAVEL, very fine sand to 15mm gravel, poorly sorted, subround to subangular, 40% quartz, 30% rock fragments, 20% carbonates, 20% shale & coal	103-144
CLAY AND SILT, much detrital lignite also, very carbonaceous, soft, greasy	144-156
SAND & GRAVEL, as above	156-270
CLAY (Bedrock Pierre Formation), dark gray, tight firm, somewhat greasy, firm slow drilling	270-320

149-070-04BBB
NDSWC 11958

Date completed:	5/12/87	Purpose:	TEST HOLE
Depth drilled (ft):	350	Source of data:	SWC(jcp)
Land surface altitude (ft):	1590		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
CLAY (Till), yellow-brown to brownish gray, oxidized, silty, sandy, pebbly	1-13
CLAY (Till), medium gray, firm, silty, sandy, pebbly, unoxidized	13-14
SAND & GRAVEL, fine sand to 10mm gravel, poorly sorted, subangular to round, most grains have iron stain, predominantly quartz & igneous rk fragments	14-21
CLAY (Till), as above	21-162
CLAY, sl silty, no inclusions, mod. soft to mod. firm, med. gray, some possible lamenations noticed, (lacustrine)	162-171
CLAY (Till), as above, poor sample recovery	171-173
CLAY (Lacustrine), as above, gennerally massive structure, possiblly interbedded with some till	173-254
CLAY (Till), as above	254-265
SAND AND GRAVEL, interbedded with clay lenses, poor sample recovery , drilled faster with chatter	265-276
CLAY (Till), as above, firm drilling	276-344
CLAY (Bedrock Pierre Formation), dark gray, no silt, tight	344-350

149-070-06DDD
NDSWC 2656

Date completed:	06/01/67	Purpose:	TEST HOLE
Depth drilled (ft):	260	Source of data:	USGS
Land surface altitude (ft): 1600			

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
TILL, silty, moderate-brown	1-20
TILL, very silty, olive-gray	20-45
GRAVEL, coarse to very coarse, rough drilling	45-59
TILL, olive-gray	59-60
SAND, medium to coarse, silty	60-66
TILL, gravelly, olive-gray	66-79
GRAVEL, coarse, angular	79-87
TILL, very silty, olive-gray	87-160
TILL, rocky, olive-black	160-187
GRAVEL, rocky	187-190
TILL, olive-gray	190-195
GRAVEL, rocky, angular	195-202
TILL, olive-gray	202-209
SILT, light-gray	209-215
TILL, olive-gray, with silt layers	215-235
SHALE, olive-black, noncalcareous	235-260

149-070-09AAD
NDSWC 11835

Date completed:	8/13/86	Purpose:	TEST HOLE
Depth drilled (ft):	280	Source of data:	SWC(jcp)
Land surface altitude (ft):	1605		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
CLAY (Till), yellow-brown to brownish gray, oxidized, silty, sandy, pebbly, interbedded sand and gravel at 5-6'	1-17
SAND & GRAVEL, very fine sand to 3mm gravel, poorly sorted, angular to subround, some oxidized grains	17-22
CLAY (Till), medium gray, firm, silty, sandy, pebbly, unoxidized, interbedded at 36-37	22-44
CLAY, sl silty, very few inclusions, tight drilling, firm, cohesive	44-62
CLAY (Bedrock Pierre Formation), dark gray to black, well indurated, waxy	62-280

149-070-09DAA1
NDSWC 2503

Date completed:	05/12/66	Well type:	OBSERVATION
Depth drilled (ft):	284	Source of data:	USGS
Screened interval (ft):	180-200	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1612.70

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, very silty, dusky-yellow, oxidized, rocky	1-31
GRAVEL, fine to medium, angular to subrounded	31-33
TILL, olive-gray	33-57
SAND, medium to fine, silty, subrounded, much lignite	57-69
SAND, coarse, well-sorted, subrounded to rounded	69-105
SAND, very coarse, gravelly, large amount of lignite	105-209
GRAVEL, medium to coarse, subangular, mostly limestone	209-237
GRAVEL, with clay layers	237-263
SHALE (Bedrock Pierre Fm.), olive-black, noncalcareous	263-284

149-070-09DAA2
NDSWC 2503

Date completed:	05/12/66	Well type:	OBSERVATION
Depth drilled (ft):	284	Source of data:	USGS
Screened interval (ft):	80-100	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1612.70

See sample description for 09daa1

149-070-12BCC
NDSWC 11843

Date completed:	08/25/86	Well type:	OBSERVATION
Depth drilled (ft):	315	Source of data:	SWC(jcp)
Screened interval (ft):	290-295	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1597.70

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brownish black, silty loam	0-1
CLAY (till), silty, sandy, pebbly, soft, yellow to yellow brown	1-22
CLAY (Till), as above, unoxidized, olive-gray	22-62
SAND AND GRAVEL, coarse sand to 6mm gravel	62-64
CLAY AND SILT, well sorted, soft, some possible lamenations noticed, (lacustrine?)	64-166
GRAVEL, 2mm to 5mm gravel, poor recovery	166-168
CLAY (Till), silty, very firm, medium gray	168-203
SAND & GRAVEL, medium sand to 5mm gravel, poorly sorted, subangular to round, 50% quartz & igneous, 20% carbonates, 20% shale, 10% lignite	203-301
CLAY (Bedrock Pierre Formation), dark gray, waxy, bentonitic lenses present drilling	301-315

149-070-16AAD
NDSWC 11836

Date completed:	08/13/86	Well type:	OBSERVATION
Depth drilled (ft):	285	Source of data:	SWC(jcp)
Screened interval (ft):	204-209	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1597.20

Lithologic Log

Unit description	Depth (ft)
SILT, soft, oxidized. yelow-orange	0-5
CLAY (Till), silty , pebbly, soft, yellow-brown	5-14
CLAY (Till), sl. silty, sl. sandy, sl. pebbly, med. to dark gray, unoxidized	14-112
GRAVEL, angular to round, 45% limestone, 45% shale, 10% igneous	112-115
CLAY (Till), as above	115-120
SAND & GRAVEL, very coarse sand to 5mm gravel, poorly sorted, angular to subround, 90% shale, 10% carbonates and quartz & igneous rock fragments	120-137
CLAY (Till), as above	137-143
SAND & GRAVEL, very coarse sand to 20mm gravel, poorly sorted, angular to subround, 50% shale, 30% carbonates, 20% quartz & igneous rock fragments	143-149
CLAY (Till), as above	149-160
SAND & GRAVEL, as above	160-167
CLAY (Till), as above	167-186
CLAY, no inclusions noticed, light to med. gray	186-203
SAND & GRAVEL, coarse sand to 4mm gravel, medium sorted, subangular to subround, 50% shale, 30% carbonates, 20% quartz & igneous rock fragments	203-256
CLAY AND SILT, fairly clean, fast drilling	256-262
CLAY (Till), as above, with some interbedded sand and gravel lenses	262-270
BOULDER, carbonate	270-271
CLAY (Bedrock Pierre Formation), dark gray, very firm, waxy	271-285

149-070-16DDD
NDSWC 2504

Date completed: 06/01/67
Depth drilled (ft): 273
Land surface altitude (ft): 1597
Purpose: TEST HOLE
Source of data: USGS

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, silty, dusky-yellow, oxidized	1-12
TILL, rocky, olive-gray	12-23
TILL, with gravel layers,	23-41
GRAVEL, very clayey, angular	41-51
TILL, olive-gray, mod. hard, many coal fragments	51-56
SAND, fine to medium	56-58
TILL, silty, olive-gray, mod. hard	58-176
TILL, rocky, gravelly	176-256
SHALE, olive-black, noncalcareous	256-273

149-070-24BBA
NDSWC 2465

Date completed: 10/19/65
Depth drilled (ft): 252
Land surface altitude (ft): 1600
Purpose: TEST HOLE
Source of data: USGS

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
TILL, very sandy, dusky-yellow	1-17
TILL, olive-gray	17-23
GRAVEL, fine to medium	23-33
TILL, gravelly, olive-gray	33-36
GRAVEL, medium to coarse, poorly sorted, large percentage of limestone pebbles	36-42
TILL, silty, olive-gray	42-144
GRAVEL, medium to coarse, poorly sorted, large percentage of limestone pebbles	144-153
TILL, gravelly, olive-gray	153-157
TILL, silty, olive-gray	157-205
GRAVEL, fine to medium, poorly sorted, limestone and shale dominant minerals	205-219
TILL, silty, olive-gray	219-223
SHALE, olive-gray	223-252

149-071-01AAA
NDSWC 11829

Date completed:	08/06/86	Purpose:	TEST HOLE
Depth drilled (ft):	330	Source of data:	SWC(jcp)
Land surface altitude (ft): 1600			

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-2
CLAY (Till), yellow to yellow brown, soft, v. silty sandy, pebbly, oxidized	2-17
CLAY (Till), gray mottled with reddish brown, silty sandy, pebbly, partially oxidized	17-38
CLAY, silty, sl. laminated, soft, plastic, med. gray, intebedded with carbonaceous material	38-45
SAND, v. fine to medium, mod. sorted, subangular to round, 95% quartz	45-62
CLAY (Till), med. gray, unoxidized, silty, sandy	62-159
CLAY, v. silty, drills fast, no inclusions, crumbly	159-165
CLAY (Till), as above	165-187
SAND & GRAVEL, medium sand to 15mm gravel, poorly sorted, subangular to subround, 40% quartz & rk frags, 30% carbonates, 20% shale, and 10% lignite	187-312
CLAY (Bedrock Pierre Fm.), dark gray, tight, no silt	312-330

149-071-01ADD
NDSWC 11830

Date completed:	08/06/86	Well type:	OBSERVATION
Depth drilled (ft):	320	Source of data:	SWC(jcp)
Screened interval (ft):	258-263	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1606.90

Lithologic Log

Unit description	Depth (ft)
CLAY (Till), silty, sl. sandy, yellow brown turning grayish downward, oxidized, iron stained streaks (possible fractures)	0-26
SAND AND SILT, medium sorting, mainly quartz	26-31
CLAY (Till), med. gray, unoxidized, silty, sandy	31-56
SAND & GRAVEL, fine sand to 10mm gravel, poorly sorted, subangular to subround, mainly quartz	56-61
CLAY (Till), as above	61-123
SAND, fine to v. coarse, poorly sorted, mainly quartz	123-137
CLAY (Till), as above	137-151
SAND & GRAVEL, medium to 8mm gravel, poorly sorted, subangular to subround, mainly quartz, with up to 30% carbonates, rk. frags, lignite	151-306
CLAY (Bedrock Pierre Fm.), dark gray, waxy, firm	306-320

149-071-01DDD
NDSWC 11932

Date completed:	10/16/86	Purpose:	TEST HOLE
Depth drilled (ft):	270	Source of data:	SWC(jcp)
Land surface altitude (ft):	1600		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty	0-2
CLAY (Till), yellow to yellow brown, soft, v. silty sandy, pebbly, oxidized	2-26
CLAY (Till), med. gray, unoxidized, silty, sandy	26-56
SAND & GRAVEL, medium sand to 10mm gravel, poorly sorted, angular to round, 40% quartz & rk frags, 30% carbonates, 20% shale, and 10% lignite	51-54
CLAY (Till), as above	54-251
CLAY (Bedrock Pierre Fm.), dark gray, waxy, firm	251-270

149-071-04ABA
NDSWC 2468

Date completed:	10/21/65	Purpose:	TEST HOLE
Depth drilled (ft):	94	Source of data:	USGS
Land surface altitude (ft):	1620		

Lithologic Log

Unit description	Depth (ft)
TILL, silty to sandy, dusky-yellow	0-10
TILL, silty to sandy, dusky-yellow, rocky	10-19
TILL, silty to sl. sandy, olive-gray, rocky	19-50
TILL, gravelly, olive-gray	50-60
CLAY (Bedrock Fox Hills Fm.), sandy, light-blueish-green, sandstone, fine grained, calcareous	60-94

149-071-06DCC
NDSWC 2547

Date completed:	07/13/66	Purpose:	TEST HOLE
Depth drilled (ft):	336	Source of data:	USGS
Land surface altitude (ft):	1610		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, very silty to sandy, dusky-yellow, oxidized	1-15
TILL, silty, olive-gray, rocky	15-52
ROCKS	52-55
SAND, medium to coarse, subrounded, fairly well-sorted, silty	55-95
CLAY, sandy, olive-gray	95-104
SAND, medium to coarse, subrounded, much lignite	104-117
CLAY, sandy, olive-gray	117-124
SAND, medium to coarse, subrounded, fairly well-sorted, silty, much lignite	124-198
CLAY, very silty, olive-gray	198-204
SAND, fine to medium, not as much lignite as above	204-219
GRAVEL, fine to medium, very sandy, poorly sorted, subrounded to rounded, chert present	219-225
CLAY, olive-gray to light brown, calcareous	225-312
SHALE (Bedrock Pierre Fm.), olive-black, bentonitic	312-336

149-071-09DDD
NDSWC 2502

Date completed:	05/12/66	Purpose:	TEST HOLE
Depth drilled (ft):	63	Source of data:	USGS
Land surface altitude (ft):	1605		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, rocky, dusky-yellow, oxidized	1-33
TILL, rocky, olive-gray	33-42
CLAY (Fox Hills Fm.), v. silty, dk-greenish-gray, calc.	42-63

149-071-19CDD
NDSWC 2548

Date completed:	07/14/66	Well type:	OBSERVATION
Depth drilled (ft):	189	Source of data:	USGS
Screened interval (ft):	140-160	Principal aquifer:	MAN
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1605.00

Lithologic Log

Unit description	Depth (ft)
SAND, medium, well-sorted, angular to subangular	0-4
CLAY, very silty, dusky-yellow	4-11
TILL, very silty, olive-gray	11-29
CLAY, silty, olive-black, calcareous	29-46
SAND, medium-grained, subrounded, mostly quartz	46-62
SILT, olive-gray to olive-black, very hard	62-68
SAND, fine to medium, very silty	68-72
SILT, sandy, olive-gray	72-78
SAND, medium to coarse, gravelly, subrounded to rounded	78-85
SAND, fine, silty	85-89
SAND, fine to medium, very silty, some lignite present	89-167
CLAY (Fox Hills Fm.), very sandy, brownish-greenish gray	167-189

149-071-20CAC
NDSWC 2501

Date completed:	05/12/66	Purpose:	TEST HOLE
Depth drilled (ft):	63	Source of data:	USGS
Land surface altitude (ft): 1597			

Lithologic Log

Unit description	Depth (ft)
TILL, very silty and sandy, light-olive-brown, oxidized	0-10
ROCK, siltstone	10-12
CLAY (Fox Hills Fm.), silty, greenish-black, calcareous	12-32

149-071-27CBC
NDSWC 2473

Date completed:	10/28/65	Purpose:	TEST HOLE
Depth drilled (ft):	42	Source of data:	USGS
Land surface altitude (ft):	1605		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
TILL, silty, dusky-yellow, oxidized	1-9
SAND, fine grained, very silty	9-15
TILL, silty, olive-gray	15-19
CLAY (Fox Hills Fm.), sandy, greenish-gray, noncalcareous	19-42

149-071-31CCB
NDSWC 2659

Date completed:	06/05/67	Well type:	OBSERVATION
Depth drilled (ft):	160	Source of data:	USGS
Screened interval (ft):	125-130	Principal aquifer:	MAN
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1605.00

Comments:

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
TILL, gravelly, dusky-yellow, oxidized	1-15
TILL, silty, olive-gray	15-49
GRAVEL, medium, angular	49-51
TILL, silty, olive-gray	51-60
GRAVEL, coarse to very coarse, rocky, angular, to subangular, poorly sorted, no coal	60-100
GRAVEL, medium to coarse, sandy subangular, poorly sorted, no coal	100-129
TILL, silty, olive-gray	129-160

150-069-20AAA
NDSWC 2623

Date completed: 11/04/66
Depth drilled (ft): 221
Land surface altitude (ft): 1587
Purpose: TEST HOLE
Source of data: USGS

Lithologic Log

Unit description	Depth (ft)
TILL, silty, dusky-yellow, oxidized	0-16
TILL, silty, olive-gray	16-21
SAND, medium to coarse, subangular to subrounded	21-23
TILL, silty, olive-gray	23-25
SAND, fine to medium, subangular to subrounded	25-28
TILL, silty, olive-gray	28-29
SAND, fine to medium, subangular to subrounded	29-45
TILL, silty, olive-gray, some gravel lenses	45-117
GRAVEL, fine to medium, drills rough	117-121
TILL, olive-gray	121-122
GRAVEL, fine to medium, driils rough	122-126
TILL, silty, olive-gray	126-186
SHALE, olive-black, noncalcareous, drills tight	186-221

150-069-24DCC
NDSWC 2653

Date completed: 05/31/67
Depth drilled (ft): 180
Land surface altitude (ft): 1580
Purpose: TEST HOLE
Source of data: USGS

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black	0-1
TILL, silty, dusky-yellow, rocky, oxidized	1-18
GRAVEL, fine to medium, angular	18-20
TILL, silty, olive-gray	20-26
GRAVEL, fine to medium, subangular to subrounded, some shale gravel present	26-36
TILL, silty to sandy, olive-gray	36-104
GRAVEL, medium to coarse, subangular to subrounded	104-114
TILL, silty, olive-black	114-155
TILL, silty, olive-gray, very rocky	155-159
SHALE, olive-black, noncalcareous, hard, blocky	159-180

150-069-31CBC
NDSWC 11842

Date completed:	08/21/86	Well type:	OBSERVATION
Depth drilled (ft):	280	Source of data:	SWC(jcp)
Screened interval (ft):	98-103	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.80

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, brown, silty	0-1
GRAVEL, 2mm to boulders, poorly sorted, oxidized	1-4
CLAY (Till), silty, yellow brown, oxidized	4-10
CLAY (Till), silty, med. gray, firm, unoxidized	10-19
SAND AND GRAVEL, coarse sand to 10mm gravel, poorly sorted, subangular to round, 60% lignite & shale, 30% carbonates, 10% quartz & igneous	19-23
CLAY (Till), as above	23-61
SAND AND GRAVEL, fine sand to 5mm gravel, poorly sorted, subangular to round, 50% quartz & igneous, 20% lignite, 20% shale, 10% carbonates	61-260
CLAY (Bedrock Pierre Formation), dark gray, no silt, very firm, tight slow drilling	260-280

150-069-31CBC1
NDSWC 11842a

Date completed:	08/22/86	Well type:	OBSERVATION
Depth drilled (ft):	38	Source of data:	SWC(jcp)
Screened interval (ft):	18-38	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.90

See sample description for 31cbc

150-069-32AAA
NDSWC 2563

Date completed:	07/27/66	Purpose:	TEST HOLE
Depth drilled (ft):	42	Source of data:	USGS
Land surface altitude (ft):	1560		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, dusky-brown	0-1
SAND, medium to coarse, gravelly, oxidized	1-10
SAND, medium to coarse, gravelly, saturated	10-21
TILL, gravelly, olive-gray	21-42

150-069-32CCC
NDSWC 11930

Date completed:	10/16/86	Well type:	OBSERVATION
Depth drilled (ft):	30	Source of data:	SWC(jcp)
Screened interval (ft):	14-19	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.66

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty and sandy	0-1
CLAY, silty, yellowish brown, oxidized (Alluvium)	1-2
SAND & GRAVEL, fine sand to 3mm gravel, poorly sorted, subangular to round, 80% quartz, 5% shale, 5% lignite, & 10% carbonates	2-20
SAND & GRAVEL, coarse sand to 15mm gravel, poorly sorted, subangular to round, 50% quartz & igneous, 20% shale & lignite, & 30% carbonates	20-23
CLAY (Till), silty, med. gray, firm, unoxidized	23-30

150-069-32DAA
NDSWC 11933

Date completed:	10/17/86	Purpose:	TEST HOLE
Depth drilled (ft):	120	Source of data:	SWC(jcp)
Land surface altitude (ft):	1550		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
SAND & GRAVEL, fine sand to 3mm gravel, poorly sorted, subangular to round, 50% quartz, 20% shale & lignite, 30% carbonates, some oxidation	1-9
CLAY (Till), silty, yellowish brown, oxidized, soft	9-11
CLAY (Till), silty, med. gray, firm, unoxidized	11-57
CLAY (Bedrock Pierre Formation), dark gray, waxy, no silt, very firm	57-120

150-070-04BBB
NDSWC 2471

Date completed:	10/27/65	Purpose:	TEST HOLE
Depth drilled (ft):	42	Source of data:	USGS
Land surface altitude (ft):	1595		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, dusky-yellow	1-12
TILL, olive-gray	12-23
SHALE (Bedrock Pierre Fm.) olive-black, noncalcareous	23-42

150-070-08DCC
NDSWC 2472

Date completed:	10/28/65	Purpose:	TEST HOLE
Depth drilled (ft):	115	Source of data:	USGS
Land surface altitude (ft):	1570		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
TILL, sandy, dusky-yellow	1-9
TILL, silty, olive-gray	9-32
ROCKS AND GRAVEL	32-35
SAND, medium to coarse, moderatly well sorted, subangular to subrounded	35-40
TILL, silty, olive-gray	40-85
CLAY (Bedrock Fox Hills), sandy, blueish-green to light gray, noncalcareous	85-115

150-070-19CBB
NDSWC 11833

Date completed:	08/12/86	Purpose:	TEST HOLE
Depth drilled (ft):	280	Source of data:	SWC(jcp)
Land surface altitude (ft):	1590		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (till), sl. silty, very sandy, gravelly, yellow, oxidized	1-10
CLAY (till), as above, grayish brown, oxidized	10-23
CLAY (till), medium gray, unoxidized, firm	23-132
CLAY, silty, no inclusions noticed, no structure	132-141
CLAY & SILT & SAND, light gray, carbonaceous, faint greenish hue, mod. indurated (Fox Hills Fm.)	141-237
CLAY (Till), as above, unoxidized	237-268
CLAY (Bedrock Pierre Formation), dark gray, no silt, very firm, waxy, tight slow drilling	268-280

150-070-21ADA
NDSWC 11838

Date completed:	08/19/86	Purpose:	TEST HOLE
Depth drilled (ft):	240	Source of data:	SWC(jcp)
Land surface altitude (ft):	1590		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (till), silty, sandy, gravelly, yellow, oxidized	1-17
SAND AND GRAVEL, fine sand to 25mm gravel, poorly sorted, angular to rounded, 35% carbonates, 50% silicates, 15% shale & lignite	17-23
CLAY (till), as above, oxidized	23-24
CLAY (till), medium gray, unoxidized, firm	24-77
SAND, very fine to very coarse, angular to subround, medium sorting, 70% shale and lignite, 20% carbonates, 10% quartz and igneous rock fragments	77-84
CLAY (till), as above, unoxidized	84-183
CLAY & SILT & SAND, light gray, faint greenish hue, no stucture (Fox Hills Fm.)	183-225
CLAY (Bedrock Pierre Formation), dark gray, no silt, very firm, waxy, tight slow drilling	225-240

150-070-25CCC
NDSWC 11841

Date completed:	08/20/86	Well type:	OBSERVATION
Depth drilled (ft):	250	Source of data:	SWC(jcp)
Screened interval (ft):	218-223	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1540.60

Comments:

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, dark brown, silty	0-2
SAND, very fine to very coarse, mod. well sorted, subround, mainly quartz, oxidized	2-7
CLAY (Till), silty, dk brown to browish gray, no inclusions noticed, oxidized streaks	7-11
SAND AND GRAVEL, fine sand to 40mm gravel, poorly sorted, mainly igneous rk. fragments, oxidized	11-15
CLAY, as above, light gray, partly oxidized to 20', interbedded with sandy clay (lacustine?)	15-149
CLAY (Till), dark gray, much Pierre shale in both matrix and inclusions	149-170
SAND AND GRAVEL, medium sand to 3mm gravel, poorly sorted, round to subround, 80% quartz and igneous, 10% carbonates, 10% shale and lignite	170-227
CLAY (Bedrock Pierre Formation), dark gray, no inclusions, no silt, very firm, tight slow drilling, waxy	227-250

150-070-27CCC
NDSWC 11852

Date completed:	09/14/86	Purpose:	TEST HOLE
Depth drilled (ft):	300	Source of data:	SWC(jcp)
Land surface altitude (ft):	1590		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), yellow, oxidized, silty, soft	1-27
CLAY (Till), med. gray, unoxidized, silty, firm	27-34
SAND AND GRAVEL, coarse sand to 25mm gravel, poorly sorted, angular to subround, mainly quartz	34-42
CLAY (Till), as above, unoxidized	42-62
SAND AND GRAVEL, coarse sand to cobbles, poorly sorted, angular to subround, 35% quartz and igneous; 35% shale, 30% carbonates	62-74
CLAY (Till), as above	74-78
CLAY, light gray, silty, sticky, gummy, mod. soft, massive structure (Lacustrine?)	78-124
CLAY (Till), as above	124-237
CLAY, sl. silty, mod. soft, faint blueish hue, sticky, possible bedrock block?	237-246
CLAY (Till), as above	246-274
CLAY (Bedrock Pierre Fm.), dk. gray, waxy, very firm	274-300

150-070-27DDA
NDSWC 11837

Date completed:	08/15/86	Well type:	OBSERVATION
Depth drilled (ft):	40	Source of data:	SWC(jcp)
Screened interval (ft):	15-20	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1541.70

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, blackish brown	0-1
CLAY AND SILT, dk. brown, much organic material, oxidized	1-3
SAND AND GRAVEL, fine sand to cobbles, poorly sorted, subangular to round, 40% quartz and silicates, 20% carbonates, 30% igneous, 10% shale and lignite, partially oxidized	3-22
CLAY (Till), silty, med. gray, unoxidized, firm	22-40

150-070-27DDA1
NDSWC 11837a

Date completed:	08/18/86	Well type:	OBSERVATION
Depth drilled (ft):	220	Source of data:	SWC(jcp)
Screened interval (ft):	165-170	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1542.20

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY AND SILT, dk. brown, much organics (Alluvium)	1-3
SAND AND GRAVEL, fine sand to cobbles, poorly sorted, subangular to round, 40% quartz and silicates, 25% carbonates, 25% igneous, 10% shale and lignite, partially oxidized	3-17
CLAY, silty, med. gray, unoxidized, firm	17-87
SAND, very fine to very coarse, med. sorting, angular to subround, 65% lignite and shale, 25% carbonates, 10% quartz & igneous, drilled fast	87-98
CLAY, silty, sandy, generally massive, med. gray, not many inclusions noticed (Lacustrine? Till?)	98-103
SAND, as above, with some gravel, 50% lignite and shale, 25% carbonates, 25% quart & igneous, drilled fast & quiet	103-174
CLAY & SILT & SAND (Bedrock Fox Hills Fm.), no inclusions, generally massive, med. gray, slight greenish hue, light colored sand grains	174-203
CLAY (Bedrock Pierre Fm.), no silt, dark gray, no inclusions, firm, waxy, tight drilling	203-220

150-070-28AAA
NDSWC 11840

Date completed:	8/20/86	Purpose:	TEST HOLE
Depth drilled (ft):	280	Source of data:	SWC(jcp)
Land surface altitude (ft):	1570		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
SAND AND GRAVEL, mainly silicates, oxidized	1-5
CLAY (Till), silty, sandy, pebbly, oxidized, weathered	5-20
SAND, mainly quartz, oxidized	20-23
CLAY (Till), as above, oxidized	23-34
CLAY (Till), med gray, firm, unoxidized	34-37
SAND AND GRAVEL, angular to subround, 10% shale and lignite, 25% carbonates, 65% quartz and igneous	37-50
CLAY (Till), as above, unoxidized	50-83
SAND AND GRAVEL, angular to subround, 10% shale and lignite, 25% carbonates, 65% quartz and igneous	83-89
CLAY (Till), as above, unoxidized	89-163
SILT, clayey, med gray, soft, drilled fast (lacustrine)	163-176
CLAY (Till), as above, unoxidized	176-185
SILT & CLAY, med gray, soft, drilled fast (lacustrine)	185-196
CLAY (Till), as above, unoxidized	196-204
SILT & CLAY, as above	204-207
CLAY (Till), as above, unoxidized	207-213
SAND AND GRAVEL, poorly sorted, angular to subround, 60% shale and lignite, 30% carbonates, 10% quartz and igneous	213-224
CLAY (Till), as above, unoxidized	224-248
SAND AND GRAVEL, as above	248-256
CLAY (Till), as above, appears partially oxidated?	256-266
CLAY (Bedrock Pierre Fm.), no silt, dark gray, firm, waxy, tight drilling	266-280

150-070-28ADA
NDSWC

Date completed:	10/08/86	Well type:	OBSERVATION
Depth drilled (ft):	220	Source of data:	SWC(jcp)
Screened interval (ft):	24-29	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1540.42

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam	0-3
CLAY, silty, yellow brown, oxidized, (Alluvium)	3-4
SAND AND GRAVEL, fine sand to 10mm gravel, poorly sorted, subrounded, oxidized	4-7
SAND AND GRAVEL, as above, unoxidized	7-30
CLAY (Till), medium gray, silty, sandy, unoxidized	30-139
CLAY & SILT, white sand grains present, (Fox Hills block)	139-144
CLAY, dk. gray, waxy, firm, possible Pierre block	144-156
CLAY (Till), as above	156-206
CLAY (Bedrock Pierre Fm.), no silt, dark gray, firm, waxy, tight drilling	206-220

150-070-28CCC
NDSWC 2467

Date completed:	10/20/65	Purpose:	TEST HOLE
Depth drilled (ft):	347	Source of data:	USGS
Land surface altitude (ft):	1595		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam, black	0-1
SAND, fine to medium	1-3
TILL, sandy, dusky-yellow	3-31
TILL, silty, olive-gray	31-35
SAND, very fine to medium, fairly well-sorted	35-40
TILL, silty, olive-gray	40-300
GRAVEL, fine to medium, subrounded, mostly limestone	300-306
TILL, olive-gray	306-327
SHALE (Bedrock Pierre Fm.), olive-black, noncalcareous	327-347

150-070-31CDD
NDSWC 2562

Date completed:	07/26/66	Purpose:	TEST HOLE
Depth drilled (ft):	354	Source of data:	USGS
Land surface altitude (ft):	1600		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, clayey, dusky-brown	0-1
TILL, sandy, dusky-yellow to moderate-olive-brown	1-31
TILL, silty, olive-gray	31-112
SILT, clayey, olive-gray, drills tight	112-118
TILL, silty, olive-gray	118-157
SAND, medium to coarse, gravelly, much lignite	157-329
SHALE (Bedrock Pierre Fm.), olive-black, noncalcareous	329-354

150-070-32ABB
NDSWC 11834

Date completed:	08/12/86	Well type:	OBSERVATION
Depth drilled (ft):	345	Source of data:	SWC(jcp)
Screened interval (ft):	192-197	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1579.30

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), silty, sandy, pebbly, yellow brown, oxidized	1-20
CLAY (Till), silty, sandy, pebbly, med. gray, unoxidized	20-22
SAND AND GRAVEL, medium sand to 3mm gravel, medium sorted, subangular to round, mainly quartz	22-26
CLAY (Till), as above, unoxidized	26-33
CLAY AND SILT, silty, sandy clays interbedded with clayey silts and very fine sands, laminations present, drills smooth and fast	33-191
SAND AND GRAVEL, interbedded with clay and boulders, very rough drilling, poor recovery	191-215
CLAY, poor recovery, drilled smooth, quiet	215-217
SAND AND GRAVEL, interbedded with clay and boulders, very rough drilling, poor recovery, much white calcareous material present, some very weathered indurated till cutting coming up	217-289
CLAY, slighty silty, no inclusions, induated, dark gray, very tight slow drilling 289-332	289-332
CLAY (Bedrock Pierre Fm.), no silt, dark gray (darker than above), waxy, tight drilling, very firm	332-345

150-070-32ABB1
NDSWC nra32a

Date completed:	11/05/86	Well type:	OBSERVATION
Depth drilled (ft):	49	Source of data:	SWC(jcp)
Screened interval (ft):	43-48	Well screened in lacustrine material	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.48

See sample description for 32AAB

150-070-32ABB2
NDSWC nra32b

Date completed:	11/05/86	Well type:	OBSERVATION
Depth drilled (ft):	39	Source of data:	SWC(jcp)
Screened interval (ft):	33-38	Well screened in lacustrine material	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.29

See sample description for 32AAB

150-070-32ABB3
NDSWC nra32c

Date completed:	11/05/86	Well type:	OBSERVATION
Depth drilled (ft):	29	Source of data:	SWC(jcp)
Screened interval (ft):	19-29	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.39

See sample description for 32AAB

150-070-32ABB4
NDSWC nra32d

Date completed:	11/11/86	Well type:	OBSERVATION
Depth drilled (ft):	93	Source of data:	SWC(jcp)
Screened interval (ft):	86-91	Well screened in lacustrine material	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1583.39

See sample description for 32AAB

150-070-32CCC
NDSWC 11959

Date completed:	05/13/87	Well type:	OBSERVATION
Depth drilled (ft):	360	Source of data:	SWC(jcp)
Screened interval (ft):	158-163	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1598.13

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam	0-1
CLAY (Till), yellow, silty, sandy, pebbly, oxidized	1-27
CLAY (Till), gray, silty, sandy, pebbly, unoxidized	27-123
SAND AND GRAVEL, fine sand to 5mm gravel, poorly sorted, angular to subround, mainly shale and carbonates	123-135
CLAY (Till), as above, unoxidized, interbedded with shaley sand and gravel lenses from 143-157'	135-157
SAND AND GRAVEL, fine sand to 25+mm gravel, poorly sorted, angular to round, mainly shale and carbonates	157-176
CLAY (Till), as above	176-233
SHALE AND SILT, green to greenish black, glauçonitic shale with silty laminae, moderatly well induated, possible Fox Hills Formation shove block	233-236
CLAY (Till), as above	236-348
CLAY (Bedrock Pierre Fm.), greasy, firm, no silt, slow drilling	348-360

150-070-32DCC
NDSWC 11965

Date completed:	05/19/87	Well type:	OBSERVATION
Depth drilled (ft):	300	Source of data:	SWC(jcp)
Screened interval (ft):	272-277	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1595.19

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam	0-1
CLAY (Till), yellow, silty, sandy, pebbly, oxidized	1-18
CLAY (Till), gray, silty, sandy, pebbly, unoxidized	18-110
SAND AND GRAVEL, medium sand to 15mm gravel, poorly sorted, angular to round, 30% shale, 30% carbonates, 30% quartz and igneous rock fragments	110-176
CLAY (Till), as above	176-251
SAND AND GRAVEL, coarse sand to cobbles, poorly sorted, angular to round, 25% shale, 5% lignite, 25% carbonates, 45% quartz and igneous rock fragments	251-282
CLAY (Bedrock Pierre Fm.), no silt, no inclusions, mod. well indurated	282-300

150-070-33CDD
NDSWC 11966

Date completed:	05/20/87	Well type:	OBSERVATION
Depth drilled (ft):	320	Source of data:	SWC(jcp)
Screened interval (ft):	158-163	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1581.15

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty loam	0-1
CLAY (Till), yellow, silty, sandy, pebbly, oxidized	1-22
CLAY (Till), gray, silty, sandy, pebbly, unoxidized	22-98
SAND, very fine to very coarse, mod. sorted, subround, mainly quartz with much shale and carbonates	98-107
SAND AND GRAVEL, medium sand to cobbles, poorly sorted, angular to round, 35% shale, 5% lignite, 30% carbonates, 30% quartz and igneous rock fragments	107-168
CLAY (Till), as above, with interbedded sand and gravel lenses from 268-290'	168-310
CLAY (Bedrock Pierre Fm.), no silt, no inclusions, mod. well indurated, drills firm	310-320

150-070-34CCC
NDSWC 11851

Date completed:	09/03/86	Well type:	OBSERVATION
Depth drilled (ft):	340	Source of data:	SWC(jcp)
Screened interval (ft):	310-315	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1591.60

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), yellow brown, silty, weathered, oxidized	1-21
CLAY (Till), med. gray, silty, unweathered, unoxidized	21-191
SAND AND GRAVEL, medium sand to 3mm gravel, poorly sorted, angular to round, 40% quartz and igneous fragments, 30% shale & lignite, 30% carbonates	191-330
CLAY (Bedrock Pierre Fm.), no silt, no inclusions, mod. well indurated, drills firm	330-340

150-070-35AAD
NDSWC 11931

Date completed:	10/16/86	Well type:	OBSERVATION
Depth drilled (ft):	30	Source of data:	SWC(jcp)
Screened interval (ft):	18-23	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1537.56

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, Silty loam	0-1
SILT AND CLAY, oxidized, yellow brown, (Alluvium)	1-6
SAND, fine to coarse, moderatly well sorted, round to subangular, 75% quartz, 15% carbonates, 10% shale and lignite, yellow brown, oxidized	6-11
SAND, as above, unoxidized	11-19
GRAVEL, 2mm to 25mm, poorly sorted, angular to subround, 45% quartz and rock fragments, 30% carbonates, 25% shale and lignite	19-23
CLAY (Till), unoxidized, medium to dark gray	23-30

150-070-35CCC
NDSWC 11960

Date completed:	05/13/87	Well type:	OBSERVATION
Depth drilled (ft):	360	Source of data:	SWC(jcp)
Screened interval (ft):	228-233	Principal aquifer:	HEM
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1592.70

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, Silty loam	0-1
CLAY (Till), oxidized, yellow brown, silty, sandy	1-25
CLAY (Till), unoxidized, medium gray	25-41
CLAY & LIGNITES, poor sample recovery, fast drilling	41-46
SAND AND GRAVEL, fine sand to 5mm gravel, poorly sorted, round to subangular, 60% quartz, 20% carbonates, 20% shale and lignite	46-101
CLAY AND SILT, some laminations, some brown carbonaceous	101-118
SAND AND GRAVEL, fine sand to 15mm gravel, poorly sorted, round to subangular	118-162
CLAY AND SILT, as above	162-186
CLAY (Till), as above, unoxidized, medium gray	186-223
SAND AND GRAVEL, as above	223-245
CLAY, silty, soft, massive, some cuttings have the appearence of Fox Hills	245-300
CLAY, soft, greasy, dk, gray, some fragments more indurated, possibly till with Pierre as matrix and inclusions	300-344
CLAY (Bedrock Pierre Fm.), firm, dk, gray, tight slow drilling, waxy	344-360

150-070-36AAA
NDSWC 2624

Date completed:	11/08/66	Purpose:	TEST HOLE
Depth drilled (ft):	189	Source of data:	USGS
Land surface altitude (ft):	1586		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, black	0-1
TILL, very silty to sl. sandy, dusky-yellow to moderate-olive-brown, oxidized	1-25
TILL, silty, olive-gray, drills moderatly rough	25-38
TILL, silty to very sandy, olive-gray	38-42
SAND, fine to medium	42-44
GRAVEL, fine to medium, subangular to subrounded	44-47
TILL, silty, dark-olive-gray, drills moderatly rough	47-92
SAND, medium to coarse, gravelly, drills rough	92-99
TILL, silty, olive-gray	99-103
SAND, medium to coarse, gravelly, much shale and lignite	103-137
CLAY (Bedrock Fox Hills Fm.), very sandy, light-gray to green	137-189

150-071-04BBB
NDSWC 11824

Date completed:	07/28/86	Purpose:	TEST HOLE
Depth drilled (ft):	300	Source of data:	SWC(jcp)
Land surface altitude (ft): 1580			

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), yellow brown, oxidized	1-2
GRAVEL, oxidized	2-5
CLAY (Till), as above, oxidized	5-7
CLAY (Till), light gray, unoxidized, unweathered	7-18
SAND, fine to very coarse, medium sorting, subangular, mainly quartz and granitic rock fragments	18-20
CLAY (Till), as above, unoxidized, rock at 25-26'	20-45
SAND, fine to coarse, medium sorting, subrounded	45-51
CLAY (Till), as above, unoxidized	51-63
SAND AND GRAVEL, medium sorting, subrounded, quartzitic	63-80
CLAY, soft, carbonaceous	80-85
SAND AND GRAVEL, as above	85-91
CLAY (Till), as above, unoxidized	91-102
SAND AND GRAVEL, as above	102-105
CLAY (Till), as above, unoxidized	105-108
SAND AND GRAVEL, as above only slightly coarser	108-110
SAND & GRAVEL AND CLAY, very interbedded, poor sample recovery due to rock bit, much detrital lignite, some very carbonaceous material also	110-280
CLAY (Bedrock Fox Hills Fm.), silty, olive-gray, firm	280-300

150-071-04DDD
NDSWC 2470

Date completed:	10/26/65	Well type:	OBSERVATION
Depth drilled (ft):	304	Source of data:	UGSG
Screened interval (ft):	260-280	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1576.40

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, sandy loam, black	0-1
TILL, silty, dusky-yellow, oxidized	1-11
TILL, silty to sandy, olive-gray	11-15
SAND, fine to medium	11-18
TILL, silty, olive-gray	18-52
CLAY, sandy, light-greenish-gray, noncalcareous	52-56
TILL, gravelly, olive-gray	56-157
TILL, silty, olive-gray, rock at 177'	157-177
SAND, coarse to very coarse, subrounded to subangular, much coal and shale	177-250
GRAVEL, sandy, subrounded, poorly sorted, much coal	250-282
SHALE (Pierre Fm.), olive-black, noncalcareous	282-304

150-071-06DDD
NDSWC 11964

Date completed:	05/18/87	Well type:	OBSERVATION
Depth drilled (ft):	240	Source of data:	SWC(jcp)
Screened interval (ft):	178-183	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 pvc	Land surface altitude (ft):	1603.39

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, loamy	0-2
CLAY (Till), silty, sandy, pebbly, oxidized, yellowish	2-14
CLAY (Till), silty, sandy, pebbly, unoxidized, med. gray	14-88
CLAY, silty, medium gray, laminations present, soft	88-112
SAND AND GRAVEL, fine sand to 10mm gravel, poorly sorted, 70% quartzitics, 30% carbonates & shale & lignite	112-188
CLAY (Till), as above, unoxidized	188-227
CLAY (Bedrock Pierre Fm.), firm, no silt, well-indurated	227-240

150-071-08BBB
NDSWC 2485

Date completed:	11/05/65	Purpose:	TEST HOLE
Depth drilled (ft):	263	Source of data:	USGS
Land surface altitude (ft):	1610		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, sandy loam, black	0-1
SAND, fine to medium, light brown	1-5
TILL, very sandy, dusky-yellow	5-13
TILL, very sandy, rocky, moderate-olive-brown	13-24
TILL, very rocky, olive-gray	24-96
CLAY, silty with interbedded lenses of silt, some sand and gravel lenses, light to olive-gray	96-135
GRAVEL, fine to coarse, very sandy, brownish color, large amount of chert and shale, takes water	135-181
GRAVEL, fine to coarse, clayey, poorly sorted	181-187
TILL, silty to sandy, olive-gray, rough drilling	187-211
SHALE (Fox Hills Fm.), silty, light gray to greenish gray	211-245
CLAY (Pierre Fm.), olive-black, noncalcareous	245-263

150-071-11ABB
NDSWC 2561

Date completed:	07/25/66	Purpose:	TEST HOLE
Depth drilled (ft):	231	Source of data:	USGS
Land surface altitude (ft):	1600		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, silty, dusky-yellow-brown	0-1
TILL, silty, dusky-yellow, oxidized	1-37
TILL, silty, olive-gray, with few sand lenses	37-63
SAND, fine to medium, clayey	63-75
TILL, silty, olive-gray	75-95
TILL, gravelly, olive-gray	95-116
TILL, silty, olive-gray	116-175
TILL, silty to gravelly, olive-gray	175-192
SILT, olive-gray, drills tight	192-199
TILL, silty, olive-gray	199-205
SHALE (Pierre Fm.), silty, olive-black	205-231

150-071-16BAA
NDSWC 11825

Date completed:	07/29/86	Well type:	OBSERVATION
Depth drilled (ft):	60	Source of data:	SWC(jcp)
Screened interval (ft):	55-60	Well screened in till	
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1589.50

See sample description for 16baal

150-071-16BAA1
NDSWC 11825a

Date completed:	07/29/86	Well type:	OBSERVATION
Depth drilled (ft):	335	Source of data:	SWC(jcp)
Screened interval (ft):	273-278	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1589.80

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), oxidized	1-4
SAND, very fine to medium, oxidized, mainly quartz	4-6
CLAY (Till), as above, oxidized	6-18
CLAY (Till), gray, silty, sandy, unoxidized	18-132
CLAY, sandy, soft, carbonaceous, much detrital coal	132-152
SAND, medium to very coarse, medium sorting, subrounded, mainly quartz, some zones of detrital lignite	152-222
CLAY (Till), as above, unoxidized	222-272
GRAVEL, angular to round, mainly quartz, carbonates, coal	272-279
CLAY, slighty silty, soft, laminated	279-300
CLAY (Till), rough drilling, interbedded gravels	300-321
CLAY (Bedrock Pierre Fm.), waxy, poorly indurated	321-335

150-071-16CCC
NDSWC 2559

Date completed:	07/22/66	Purpose:	TEST HOLE
Depth drilled (ft):	315	Source of data:	USGS
Land surface altitude (ft):	1595		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, sandy	0-1
TILL, sandy to gravelly, dusky-yellow, oxidized	1-23
TILL, silty, olive-gray	23-30
GRAVEL, sandy	30-32
TILL, silty to sandy, olive-gray	32-42
SAND, medium to coarse, gravelly	42-50
TILL, silty, olive-gray	50-88
GRAVEL, sandy, drills rough	88-96
TILL, silty, olive-gray	96-149
TILL, sandy to gravelly, drills rough	149-178
GRAVEL, sandy	178-191
SAND, poorly sorted, gravelly, much lignite present	191-292
SHALE (Pierre Fm.), silty, olive-black	292-315

150-071-21CBB
NDSWC 11826

Date completed:	07/30/86	Well type:	OBSERVATION
Depth drilled (ft):	260	Source of data:	SWC(jcp)
Screened interval (ft):	229-234	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1585.60

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), very sandy, silty, yellow brown, oxidized	1-16
CLAY (Till), sandy, silty, gray, unoxidized	16-36
SAND AND GRAVEL, fine sand to 3mm gravel, poorly sorted, subround, mainly quartz	36-40
CLAY (Till), as above, unoxidized	40-81
SAND, medium to very coarse, medium sorted, subrounded	81-94
SAND AND GRAVEL, poorly sorted, mainly igneous fragments	94-121
CLAY (Till), as above, unoxidized	121-127
SAND AND GRAVEL, as above	127-134
CLAY, very tight, dark gray, some laminations	134-139
CLAY (Till), as above, unoxidized	139-146
SAND, fine to coarse, well sorted, mainly quartz	146-176
CLAY, slighty silty, carbonaceous, soft	176-178
SAND, as above	178-190
SAND AND GRAVEL, medium sand to 20mm gravel, poorly sorted, subangular, 40% quartz, 30% carbonates, 30%, shale and coal, interbedded clays from 211-213' and 215-221'	190-231
GRAVEL, 2mm to 40mm, poorly sorted, carbonates, shale, and igneous rock fragments	231-246
CLAY (Till), as above, unoxidized	246-250
CLAY (Bedrock Pierre Fm.), dark gray, greasy, tight	250-260

150-071-21CBB1
NDSWC

Date completed:	07/30/86	Well type:	OBSERVATION
Depth drilled (ft):	100	Source of data:	SWC(jcp)
Screened interval (ft):	90-95	Principal aquifer:	MAN
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1585.80

See sample description for 21cbb

150-071-22BBB
NDSWC 11827

Date completed:	07/31/86	Well type:	OBSERVATION
Depth drilled (ft):	360	Source of data:	SWC(jcp)
Screened interval (ft):	298-3030	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1576.40

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
BOULDERS AND COBBLES	1-3
CLAY (Till), silty, yellow brown, oxidized	3-13
SAND, medium to very coarse	13-14
CLAY (Till), as above	14-24
SAND AND GRAVEL, poorly sorted, subrounded, mainly quartz	24-40
CLAY (Till), slighty sandy, silty, pebbly, browish gray	40-48
CLAY (Till), as above, unoxidized, gravel at 91-94'	48-117
SAND AND GRAVEL, medium sand to 10mm gravel, poorly sorted, interbedded with clay lenses from 120-130'	117-337
CLAY (Bedrock Pierre Fm.), very tight, medium gray	337-360

150-071-22DAA
NDSWC 11828a

Date completed:	08/01/86	Well type:	OBSERVATION
Depth drilled (ft):	260	Source of data:	SWC(jcp)
Screened interval (ft):	230-235	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1581.70

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), oxidized, yellow	1-2
SAND AND GRAVEL, poorly sorted, oxidized	2-3
CLAY (Till), oxidized, yellow	3-11
SAND AND GRAVEL, as above	11-15
CLAY (Till), unoxidized, medium gray	15-116
SAND AND GRAVEL, coarse sand to 10mm, poorly sorted	116-123
CLAY (Till), as above	123-127
SAND AND GRAVEL, as above	127-130
CLAY (Till), as above	130-182
CLAY, soft, slighty silty, massive (lacustine?)	182-211
CLAY (Till), as above	211-219
GRAVEL AND COBBLES, rough drilling	219-223
SAND AND GRAVEL, medium sand to 10mm, poorly sorted	223-248
CLAY (Bedrock Pierre Fm.), very tight, medium gray	248-260

150-071-25DAD
NDSWC 11832

Date completed:	08/11/86	Purpose:	TEST HOLE
Depth drilled (ft):	350	Source of data:	SWC(jcp)
Land surface altitude (ft):	1590		

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), yellow brown, silty, sandy, oxidized	1-8
SAND AND GRAVEL, medium sand to 25mm gravel, poorly sorted, subangular	8-16
CLAY (Till), as above	16-20
SAND AND GRAVEL, as above	20-22
CLAY (Till), as above, turning light brownish gray	22-29
SAND AND GRAVEL, as above	29-33
CLAY (Till), as above, still slightly oxidized	33-46
CLAY (Till), gray, unoxidized	46-106
SAND AND GRAVEL, poorly sorted, mainly shale	106-108
CLAY (Till), gray, unoxidized	46-106
SILT, medium gray, few laminations, crumbly	113-122
CLAY, silty, sandy, medium gray (Lacustrine)	122-260
CLAY (Till), as above	260-312
CLAY, as above (Lacustrine)	312-330
CLAY (Bedrock Pierre Fm.), dark gray, waxy, firm	330-350

150-071-26ABB
NDSWC 2469

Date completed: 10/21/65 Purpose: TEST HOLE
Depth drilled (ft): 283 Source of data: USGS
Land surface altitude (ft): 1585

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, sandy, yellowish brown	0-2
SAND, medium to coarse	2-29
TILL, silty, gravelly, olive-gray	29-42
GRAVEL, medium to coarse, mainly shale and limestone	42-47
TILL, silty to sandy, very gravelly, olive-gray	47-73
SAND, medium to coarse, fairly well-sorted	73-78
TILL, gravelly, olive-gray	78-86
GRAVEL, fine to coarse, poorly sorted	86-94
ROCK, granite	94-97
TILL, silty, olive-gray	97-146
SAND, coarse to very coarse	146-198
GRAVEL, fine to medium, poorly sorted	198-210
CLAY, gravelly, rocky	210-218
SANDSTONE, fine to medium, blueish green	218-220
GRAVEL, fine to medium, subrounded mod-well sorted	220-231
CLAY, silty, olive-gray, heavy H2S smell	231-233
GRAVEL, fine to medium, drilled like cement	233-259
CLAY (Fox Hills Fm.), sandy, light blueish gray to light-brown	259-283

150-071-26DCC
NDSWC 11963

Date completed:	05/14/87	Well type:	OBSERVATION
Depth drilled (ft):	360	Source of data:	SWC(jcp)
Screened interval (ft):	333-338	Principal aquifer:	NRK
Casing size (in) & Type:	1.25 pvc	Land surface altitude (ft):	1603.04

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, black, silty loam	0-1
CLAY (Till), silty, sandy, yellow brown, oxidized	1-16
CLAY (Till), medium gray, unoxidized, firm, tight	16-49
CLAY & SILT & SAND, interbedded, gray, mod. firm, (Lacustrine?, Fox Hills block?)	49-171
SAND AND GRAVEL, poorly sorted, 30% quartz, 30% rock fragments, 30% lignite, 10% shale	171-343
CLAY (Bedrock Pierre), dark gray, greasy, tight, bentonitic	343-360

150-071-29AAB
NDSWC 2560

Date completed:	07/25/66	Well type:	OBSERVATION
Depth drilled (ft):	147	Source of data:	USGS
Screened interval (ft):	100-105	Principal aquifer:	MAN
Casing size (in) & Type:	1.25 abs	Land surface altitude (ft):	1599.30

Lithologic Log

Unit description	Depth (ft)
TOPSOIL, clayey, black	0-1
TILL, silty to sandy, dusky-yellow to brown	1-21
TILL, silty, olive-gray	21-42
SAND, medium to very coarse, gravelly	42-48
TILL, silty, olive-gray	48-54
SAND, medium to very coarse, gravelly, some chalcedony	54-63
GRAVEL, sandy, lignite, shale and chalcedony	63-86
TILL, silty, olive-gray	86-96
SAND, medium to very coarse, gravelly	96-147

150-071-32BCC
NDSWC 11854

Date completed: 09/05/86
Depth drilled (ft): 350
Screened interval (ft): 230-235
Casing size (in) & Type: 2.0 pvc
Well type: OBSERVATION
Source of data: SWC(jcp)
Principal aquifer: MAN
Land surface altitude (ft): 1612.10

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
SILT AND CLAY, oxidized, yellow, soft	1-3
CLAY (Till), silty, yellow brownish gray, oxidized	3-16
CLAY (Till), silty, medium gray, unoxidized	16-73
CLAY AND SILT, some carbonaceous, soft (lacustrine)	73-81
SAND, very fine to fine, well sorted, mainly quartz	81-87
CLAY AND SILT, as above	87-101
SAND, very fine to coarse, poorly sorted, mainly quartz	101-111
SAND AND GRAVEL, coarse sand to 25mm gravel, poorly sorted, mainly igneous rock fragments	111-116
CLAY, lt. gray, firm	116-121
CLAY (Till), silty, medium gray	121-128
CLAY & SHALE & SILTSTONE, indurated, (Fox Hills block)	128-141
CLAY (Till), breccia, matrix dark gray with inclusions primarily dark gray shale	141-157
CLAY & SILT & SAND, slight greenish hue, white sand grains in darker matrix, (Bedrock Fox Hills block)	157-221
SAND, very fine to medium, mainly quartz	221-246
SAND AND GRAVEL, coarse sand to 20mm, poorly sorted, mainly igneos rock fragments	246-253
CLAY (Till), breccia, as above	253-330
CLAY (Bedrock Pierre Fm.), firm, waxy, dk gray	330-350

150-071-32BCC1
NDSWC 11854a

Date completed: 09/08/86
Depth drilled (ft): 120
Screened interval (ft): 105-110
Casing size (in) & Type: 2.0 pvc
Well type: OBSERVATION
Source of data: SWC(jcp)
Principal aquifer: MAN
Land surface altitude (ft): 1612.30

See sample description for 32bcc

150-071-36ADD
NDSWC 11831

Date completed:	08/07/86	Well type:	OBSERVATION
Depth drilled (ft):	327	Source of data:	SWC(jcp)
Screened interval (ft):	286-291	Principal aquifer:	NRK
Casing size (in) & Type:	2.0 pvc	Land surface altitude (ft):	1594.80

Lithologic Log

Unit description	Depth (ft)
TOPSOIL	0-1
CLAY (Till), silty, sandy, yellow brown, oxidized, sand lense from 24-25'	1-29
CLAY (Till), silty, sandy, medium gray, unoxidized	29-108
SAND AND GRAVEL, medium sand to 15mm gravel, poorly sorted, subangular, mainly shale and carbonates	108-117
CLAY (Till), as above	117-168
SAND AND GRAVEL, as above, mainly igneous rock particles	168-214
CLAY, very carbonaceous, soft	214-222
SAND AND GRAVEL, as above, boulder at 241'	222-245
CLAY, interbedded with sand and gravel from 250-285'	245-297
CLAY (Till), as above	297-315
CLAY (Bedrock Pierre Fm.), dark gray, very firm, waxy	315-327

SUPPLEMENT III – Water level data

149-069-04BBB
New Rockford aquifer — LS Elev (msl,ft)= 1537.30 — SI (ft)= 138-143

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/19/86	2.24	1535.06
12/10/86	2.30	1535.00
01/08/87	2.44	1534.86
05/06/87	1.31	1535.99
05/28/87	1.19	1536.11
07/13/87	1.57	1535.73
09/10/87	1.85	1535.45
10/13/87	1.84	1535.46
11/10/87	2.02	1535.28

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/03/87	1.86	1535.44
04/13/88	1.95	1535.35
05/27/88	1.75	1535.55
07/07/88	2.53	1534.77
07/28/88	3.21	1534.09
09/02/88	4.09	1533.21
10/05/88	4.55	1532.75
11/02/88	4.37	1532.93

149-069-04BBB1
Heimdal aquifer — LS Elev (msl,ft)= 1537.30 — SI (ft)= 18-23

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/19/86	3.17	1534.13
12/10/86	3.04	1534.26
01/08/87	3.30	1534.00
01/28/87	3.55	1533.75
02/10/87	3.13	1534.17
05/06/87	1.70	1535.60
05/28/87	1.80	1535.50
07/13/87	2.03	1535.27
09/10/87	2.39	1534.91
10/13/87	2.59	1534.71

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	2.59	1534.71
12/03/87	2.63	1534.67
04/13/88	1.99	1535.31
05/27/88	2.48	1534.82
07/07/88	4.12	1533.18
07/28/88	5.00	1532.30
09/02/88	5.77	1531.53
10/05/88	6.08	1531.22
11/02/88	5.94	1531.36

149-069-04BBB2
New Rockford aquifer — LS Elev (msl,ft)= 1537.72 — SI (ft)= 101-106

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/19/86	2.65	1535.07
12/10/86	2.75	1534.97
01/08/87	2.91	1534.81
05/06/87	1.67	1536.05
05/28/87	1.56	1536.16
07/13/87	1.95	1535.77
09/10/87	2.19	1535.53
10/13/87	2.20	1535.52

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	2.43	1535.29
12/03/87	2.22	1535.50
05/27/88	2.14	1535.58
07/07/88	2.90	1534.82
07/28/88	3.60	1534.12
09/02/88	4.01	1533.71
10/05/88	4.94	1532.78
11/02/88	4.76	1532.96

149-069-04BBB3
Till

LS Elev (msl,ft)= 1537.75 SI (ft)= 81-86

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	11.91	1525.84
01/28/87	6.16	1531.59
02/10/87	4.81	1532.94
03/26/87	3.33	1534.42
05/06/87	2.86	1534.89
05/28/87	2.61	1535.14
07/13/87	2.41	1535.34
09/10/87	2.39	1535.36
10/13/87	2.44	1535.31
11/10/87	2.54	1535.21
12/03/87	2.58	1535.17
04/13/88	2.76	1534.99
05/27/88	2.77	1534.98
07/07/88	2.85	1534.90
07/28/88	3.11	1534.64
09/02/88	4.08	1533.67
10/05/88	4.21	1533.54
11/02/88	4.59	1533.16

149-069-06DCC
New Rockford aquifer

LS Elev (msl,ft)= 1588.00 SI (ft)= 248-253

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	53.27	1534.73
10/21/86	53.13	1534.87
11/21/86	52.87	1535.13
12/10/86	52.69	1535.31
01/08/87	53.11	1534.89
01/28/87	53.05	1534.95
02/10/87	53.11	1534.89
03/26/87	52.64	1535.36
05/06/87	52.19	1535.81
05/28/87	51.86	1536.14
07/13/87	52.40	1535.60
09/10/87	52.49	1535.51
10/13/87	52.44	1535.56
11/10/87	52.66	1535.34
12/03/87	52.66	1535.34
04/13/88	52.48	1535.52
05/27/88	52.32	1535.68
07/07/88	52.94	1535.06
07/28/88	53.44	1534.56
09/02/88	54.47	1533.53
10/05/88	55.13	1532.87
11/02/88	54.88	1533.12

149-069-06DCC1
New Rockford aquifer

LS Elev (msl,ft)= 1588.50 SI (ft)= 93-98

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	53.76	1534.74
10/21/86	53.58	1534.92
11/21/86	53.33	1535.17
12/10/86	53.14	1535.36
01/08/87	53.59	1534.91
01/28/87	53.50	1535.00
02/10/87	53.59	1534.91
03/26/87	53.12	1535.38
05/06/87	52.66	1535.84
05/28/87	52.34	1536.16
07/13/87	52.87	1535.63
09/10/87	52.95	1535.55
10/13/87	52.93	1535.57
11/10/87	53.12	1535.38
12/03/87	53.15	1535.35
04/13/88	52.95	1535.55
05/27/88	52.79	1535.71
07/07/88	53.39	1535.11
07/28/88	53.92	1534.58
09/02/88	54.92	1533.58
10/05/88	55.58	1532.92
11/02/88	55.34	1533.16

149-069-06DCC2

New Rockford aquifer — LS Elev (msl,ft)= 1588.50 — SI (ft)= 48-68

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	53.54	1534.96
01/28/87	53.44	1535.06
02/10/87	53.55	1534.95
03/26/87	53.10	1535.40
05/06/87	52.61	1535.89
05/28/87	52.31	1536.19
07/13/87	52.80	1535.70
09/10/87	52.91	1535.59
10/13/87	52.88	1535.62
11/10/87	53.11	1535.39
12/03/87	53.14	1535.36
04/13/88	52.93	1535.57
05/27/88	52.80	1535.70
07/07/88	53.39	1535.11
07/28/88	53.87	1534.63
09/02/88	54.88	1533.62
10/05/88	55.56	1532.94
11/02/88	55.33	1533.17

149-069-06DCC3

Till — LS Elev (msl,ft)= 1588.38 — SI (ft)= 27-32

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	18.25	1570.13
01/28/87	15.63	1572.75
02/10/87	15.40	1572.98
03/26/87	12.77	1575.61
05/06/87	8.39	1579.99
05/28/87	9.17	1579.21
07/13/87	10.20	1578.18
09/10/87	11.32	1577.06
10/13/87	12.70	1575.68
11/10/87	13.51	1574.87
12/03/87	13.99	1574.39
04/13/88	15.95	1572.43
05/27/88	15.83	1572.55
07/07/88	16.25	1572.13
07/28/88	16.21	1572.17
09/02/88	16.56	1571.82
10/05/88	16.95	1571.43
11/02/88	17.15	1571.23

149-069-06DCC4

Till — LS Elev (msl,ft)= 1588.50 — SI (ft)= 14-16

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	11.12	1577.38
01/28/87	11.28	1577.22
02/10/87	11.33	1577.17
03/26/87	2.96	1585.54
05/06/87	4.28	1584.22
05/28/87	4.09	1584.41
07/13/87	4.42	1584.08
09/10/87	7.08	1581.42
10/13/87	8.01	1580.49
11/10/87	8.32	1580.18
12/03/87	8.68	1579.82
04/13/88	8.40	1580.10
05/27/88	8.50	1580.00
07/07/88	9.44	1579.06
07/28/88	9.99	1578.51
09/02/88	10.98	1577.52
10/05/88	11.55	1576.95
11/02/88	11.85	1576.65

149-069-06DCC5
Till — LS Elev (msl,ft)= 1588.23 — SI (ft)= 3-13

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	10.83	1577.40
01/28/87	11.00	1577.23
02/10/87	11.07	1577.16
03/26/87	2.72	1585.51
05/06/87	3.98	1584.25
05/28/87	3.72	1584.51
07/13/87	4.21	1584.02
09/10/87	6.86	1581.37
10/13/87	7.74	1580.49
11/10/87	8.02	1580.21

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/03/87	8.35	1579.88
04/13/88	8.14	1580.09
05/27/88	8.19	1580.04
07/07/88	9.13	1579.10
07/28/88	9.64	1578.59
09/02/88	10.65	1577.58
10/05/88	11.23	1577.00
11/02/88	11.55	1576.68

149-069-09CBB
New Rockford aquifer — LS Elev (msl,ft)= 1583.10 — SI (ft)= 257-262

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	48.29	1534.81
11/19/86	48.03	1535.07
12/10/86	48.04	1535.06
01/08/87	48.17	1534.93
01/28/87	48.11	1534.99
02/10/87	48.16	1534.94
03/26/87	47.39	1535.71
05/06/87	47.12	1535.98
05/28/87	47.03	1536.07
07/13/87	47.54	1535.56
09/10/87	47.63	1535.47

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	47.61	1535.49
11/10/87	47.83	1535.27
12/03/87	47.58	1535.52
04/13/88	47.49	1535.61
05/27/88	47.47	1535.63
07/07/88	48.26	1534.84
07/28/88	48.91	1534.19
09/02/88	49.87	1533.23
10/05/88	50.30	1532.80
11/02/88	50.06	1533.04

149-069-09CBB1
New Rockford aquifer — LS Elev (msl,ft)= 1583.30 — SI (ft)= 148-153

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	48.47	1534.83
11/19/86	48.20	1535.10
12/10/86	48.22	1535.08
01/08/87	48.37	1534.93
01/28/87	48.34	1534.96
02/10/87	48.38	1534.92
03/26/87	47.60	1535.70
05/06/87	47.31	1535.99
05/28/87	47.22	1536.08
07/13/87	47.72	1535.58
09/10/87	47.56	1535.74

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	47.80	1535.50
11/10/87	48.02	1535.28
12/03/87	47.76	1535.54
04/13/88	47.69	1535.61
05/27/88	47.65	1535.65
07/07/88	47.50	1535.80
07/28/88	49.08	1534.22
09/02/88	50.05	1533.25
10/05/88	50.48	1532.82
11/02/88	50.23	1533.07

149-069-09CBB2
Till — LS Elev (msl,ft)= 1583.31 — SI (ft)= 72-77

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	33.22	1550.09	12/03/87	13.87	1569.44
01/28/87	24.37	1558.94			
02/10/87	21.32	1561.99	04/13/88	13.85	1569.46
03/26/87	16.59	1566.72	05/27/88	14.08	1569.23
05/06/87	15.10	1568.21	07/07/88	14.33	1568.98
05/28/87	14.57	1568.74	07/28/88	14.50	1568.81
07/13/87	14.11	1569.20	09/02/88	14.75	1568.56
09/10/87	14.01	1569.30	10/05/88	14.96	1568.35
10/13/87	13.95	1569.36	11/02/88	15.05	1568.26
11/10/87	13.90	1569.41			

149-069-09CBB3
Till — LS Elev (msl,ft)= 1583.32 — SI (ft)= 48-53

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	12.75	1570.57	12/03/87	11.78	1571.54
01/28/87	12.58	1570.74			
02/10/87	12.38	1570.94	04/13/88	12.65	1570.67
03/26/87	12.17	1571.15	05/27/88	13.02	1570.30
05/06/87	12.18	1571.14	07/07/88	13.46	1569.86
05/28/87	12.10	1571.22	07/28/88	13.66	1569.66
07/13/87	12.40	1570.92	09/02/88	13.72	1569.60
09/10/87	12.12	1571.20	10/05/88	13.71	1569.61
10/13/87	11.96	1571.36	11/02/88	13.58	1569.74
11/10/87	11.88	1571.44			

149-069-09CBB4
Till — LS Elev (msl,ft)= 1583.41 — SI (ft)= 28-33

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	12.85	1570.56	12/03/87	11.54	1571.87
01/28/87	12.25	1571.16			
02/10/87	12.27	1571.14	04/13/88	12.73	1570.68
03/26/87	12.16	1571.25	05/27/88	13.07	1570.34
05/06/87	12.11	1571.30	07/07/88	13.36	1570.05
05/28/87	11.93	1571.48	07/28/88	13.51	1569.90
07/13/87	12.23	1571.18	09/02/88	13.45	1569.96
09/10/87	11.73	1571.68	10/05/88	13.39	1570.02
10/13/87	11.58	1571.83	11/02/88	13.28	1570.13
11/10/87	11.59	1571.82			

149-069-09CBB5
Till — LS Elev (msl,ft)= 1583.45 — SI (ft)= 8-18

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	12.18	1571.27
01/28/87	10.74	1572.71
02/10/87	10.34	1573.11
03/26/87	7.80	1575.65
05/06/87	6.48	1576.97
05/28/87	6.50	1576.95
07/13/87	7.60	1575.85
09/10/87	7.40	1576.05
10/13/87	8.03	1575.42
11/10/87	8.57	1574.88
12/03/87	8.71	1574.74
04/13/88	9.81	1573.64
05/27/88	9.57	1573.88
07/07/88	9.69	1573.76
07/28/88	9.81	1573.64
09/02/88	9.99	1573.46
10/05/88	10.21	1573.24
11/02/88	10.34	1573.11

149-069-10DCC
New Rockford aquifer — LS Elev (msl,ft)= 1584.60 — SI (ft)= 270-275

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	49.69	1534.91
11/21/86	49.37	1535.23
12/10/86	49.37	1535.23
01/08/87	49.46	1535.14
01/28/87	49.39	1535.21
02/10/87	49.47	1535.13
03/26/87	48.87	1535.73
05/06/87	48.52	1536.08
05/28/87	48.69	1535.91
07/13/87	49.20	1535.40
09/10/87	49.30	1535.30
10/13/87	49.12	1535.48
11/10/87	49.21	1535.39
12/03/87	48.93	1535.67
04/13/88	48.87	1535.73
05/27/88	48.81	1535.79
07/07/88	49.88	1534.72
07/28/88	50.64	1533.96
09/02/88	51.78	1532.82
10/05/88	51.75	1532.85
11/02/88	51.44	1533.16

149-069-13BCC
New Rockford aquifer — LS Elev (msl,ft)= 1577.90 — SI (ft)= 215-220

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	42.96	1534.94
11/21/86	42.62	1535.28
12/10/86	42.59	1535.31
01/08/87	42.68	1535.22
01/28/87	42.60	1535.30
02/10/87	42.69	1535.21
03/26/87	42.11	1535.79
05/06/87	41.83	1536.07
05/28/87	42.19	1535.71
07/13/87	42.77	1535.13
09/10/87	42.83	1535.07
10/13/87	42.43	1535.47
11/10/87	42.43	1535.47
12/03/87	42.21	1535.69
04/13/88	42.04	1535.86
05/27/88	41.99	1535.91
07/07/88	43.50	1534.40
07/28/88	44.34	1533.56
09/02/88	45.64	1532.26
10/05/88	45.17	1532.73
11/02/88	44.72	1533.18

149-069-16BCC
New Rockford aquifer LS Elev (msl,ft)= 1588.50 SI (ft)= 250-255

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	53.68	1534.82
11/21/86	53.38	1535.12
12/10/86	53.40	1535.10
01/08/87	53.51	1534.99
01/28/87	53.45	1535.05
02/10/87	53.52	1534.98
03/26/87	52.85	1535.65
05/06/87	52.51	1535.99
05/28/87	52.50	1536.00
07/13/87	52.98	1535.52
09/10/87	53.11	1535.39

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	53.04	1535.46
11/10/87	53.19	1535.31
12/03/87	52.91	1535.59
04/13/88	52.90	1535.60
05/27/88	52.81	1535.69
07/07/88	53.68	1534.82
07/28/88	54.35	1534.15
09/02/88	55.38	1533.12
10/05/88	55.69	1532.81
11/02/88	55.43	1533.07

149-069-18BBB
New Rockford aquifer LS Elev (msl,ft)= 1589.74 SI (ft)= 275-280

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/28/87	53.63	1536.11
06/08/87	54.34	1535.40
07/13/87	54.28	1535.46
09/10/87	54.23	1535.51
10/13/87	54.16	1535.58
11/10/87	54.58	1535.16
12/03/87	54.33	1535.41

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/88	54.36	1535.38
05/27/88	54.14	1535.60
07/07/88	54.68	1535.06
07/28/88	55.18	1534.56
09/02/88	56.12	1533.62
10/05/88	56.94	1532.80
11/02/88	56.61	1533.13

149-069-24BCC
New Rockford aquifer   LS Elev (msl,ft)= 1574.80   SI (ft)= 278-283

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/19/67	38.75	1536.05
08/16/67	38.99	1535.81
10/26/67	39.43	1535.37
12/28/67	39.23	1535.57
01/30/68	39.67	1535.13
02/13/68	40.03	1534.77
03/12/68	40.06	1534.74
04/16/68	39.73	1535.07
05/01/68	39.63	1535.17
05/28/68	39.46	1535.34
06/27/68	39.31	1535.49
07/25/68	39.52	1535.28
09/27/68	39.56	1535.24
10/25/68	39.70	1535.10
01/29/69	39.74	1535.06
05/26/69	39.21	1535.59
07/25/69	39.05	1535.75
12/20/69	39.46	1535.34
03/11/70	39.36	1535.44
06/10/70	38.60	1536.20
09/03/70	39.19	1535.61
12/01/70	39.28	1535.52
03/04/71	39.71	1535.09
06/08/71	39.07	1535.73
09/09/71	38.95	1535.85
12/01/71	39.13	1535.67
03/07/72	39.42	1535.38
06/07/72	38.71	1536.09
08/31/72	39.09	1535.71
12/06/72	39.39	1535.41
04/03/73	39.58	1535.22
06/01/73	39.47	1535.33
09/06/73	39.92	1534.88
12/04/73	39.60	1535.20
03/04/74	39.84	1534.96
05/22/74	39.06	1535.74
08/30/74	39.19	1535.61
12/02/74	39.61	1535.19
12/03/75	38.50	1536.30

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/30/76	40.05	1534.75
11/30/77	40.64	1534.16
11/30/78	40.20	1534.60
11/28/79	39.30	1535.50
12/02/80	39.16	1535.64
12/01/81	38.61	1536.19
12/01/82	38.20	1536.60
11/29/83	38.99	1535.81
11/28/84	39.86	1534.94
12/02/85	39.82	1534.98
07/10/86	39.26	1535.54
10/21/86	39.89	1534.91
11/21/86	39.51	1535.29
12/03/86	38.51	1536.29
12/10/86	39.42	1535.38
01/08/87	39.61	1535.19
01/28/87	39.51	1535.29
02/10/87	39.60	1535.20
03/26/87	39.03	1535.77
05/06/87	38.78	1536.02
05/28/87	39.05	1535.75
07/13/87	39.68	1535.12
09/10/87	39.76	1535.04
10/13/87	39.36	1535.44
11/10/87	39.41	1535.39
12/03/87	39.24	1535.56
04/13/88	39.05	1535.75
05/27/88	38.93	1535.87
07/07/88	40.36	1534.44
07/28/88	41.20	1533.60
09/02/88	42.53	1532.27
10/05/88	42.14	1532.66
11/02/88	41.65	1533.15

149-069-24BCC1
Undefined aquifer — LS Elev (msl,ft)= 1573.61 — SI (ft)= 50-55

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	38.53	1535.08
11/21/86	38.14	1535.47
12/10/86	37.93	1535.68
01/08/87	38.24	1535.37
01/28/87	38.14	1535.47
02/10/87	38.29	1535.32
03/26/87	37.73	1535.88
05/06/87	37.51	1536.10
05/28/87	37.66	1535.95
07/13/87	38.32	1535.29
09/10/87	38.47	1535.14

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	38.06	1535.55
11/10/87	38.08	1535.53
12/03/87	38.04	1535.57
04/13/88	37.75	1535.86
05/27/88	37.59	1536.02
07/07/88	38.87	1534.74
07/28/88	39.44	1534.17
09/02/88	41.11	1532.50
10/05/88	40.85	1532.76
11/02/88	40.29	1533.32

149-069-24BCC2
New Rockford aquifer — LS Elev (msl,ft)= 1573.46 — SI (ft)= 146-151

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	38.37	1535.09
11/21/86	38.00	1535.46
12/10/86	37.88	1535.58
01/08/87	38.10	1535.36
01/28/87	38.02	1535.44
02/10/87	38.11	1535.35
03/26/87	37.52	1535.94
05/06/87	37.30	1536.16
05/28/87	37.55	1535.91
07/13/87	38.18	1535.28
09/10/87	38.29	1535.17

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	37.89	1535.57
11/10/87	37.93	1535.53
12/03/87	37.75	1535.71
04/13/88	37.56	1535.90
05/27/88	37.45	1536.01
07/07/88	38.83	1534.63
07/28/88	39.67	1533.79
09/02/88	41.00	1532.46
10/05/88	40.65	1532.81
11/02/88	40.16	1533.30

149-069-24BCC3
Till — LS Elev (msl,ft)= 1573.73 — SI (ft)= 42-47

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	25.89	1547.84
01/28/87	26.00	1547.73
02/10/87	26.20	1547.53
03/26/87	25.60	1548.13
05/06/87	24.93	1548.80
05/28/87	24.95	1548.78
07/13/87	25.39	1548.34
09/10/87	25.73	1548.00
10/13/87	25.76	1547.97
11/10/87	26.00	1547.73

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/03/87	25.97	1547.76
04/13/88	25.72	1548.01
05/27/88	26.86	1546.87
07/07/88	27.62	1546.11
07/28/88	28.14	1545.59
09/02/88	29.00	1544.73
10/05/88	29.12	1544.61
11/02/88	28.99	1544.74

149-069-24BCC4
Till — LS Elev (msl,ft)= 1574.02 — SI (ft)= 18-38

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	10.48	1563.54
01/28/87	10.69	1563.33
02/10/87	10.85	1563.17
03/26/87	9.71	1564.31
05/06/87	9.38	1564.64
05/28/87	9.13	1564.89
07/13/87	9.96	1564.06
09/10/87	10.43	1563.59
10/13/87	10.62	1563.40
11/10/87	11.22	1562.80
12/03/87	11.48	1562.54
04/13/88	12.66	1561.36
05/27/88	12.82	1561.20
07/07/88	13.07	1560.95
07/28/88	13.23	1560.79
09/02/88	13.63	1560.39
10/05/88	14.20	1559.82
11/02/88	14.42	1559.60

149-070-02AAA
New Rockford aquifer — LS Elev (msl,ft)= 1594.10 — SI (ft)= 78-81

Date	Depth to Water (ft)	WL Elev (msl,ft)
08/16/67	57.56	1536.54
10/26/67	57.73	1536.37
12/28/67	58.07	1536.03
01/30/68	57.74	1536.36
02/13/68	58.06	1536.04
03/12/68	58.00	1536.10
04/16/68	57.92	1536.18
05/01/68	57.87	1536.23
05/28/68	57.91	1536.19
06/27/68	57.60	1536.50
07/26/68	57.84	1536.26
09/27/68	-60.64	1654.74
10/25/68	57.99	1536.11
07/25/69	57.50	1536.60
12/20/69	57.36	1536.74
11/30/70	57.02	1537.08
12/01/71	57.49	1536.61
12/06/72	57.44	1536.66
12/04/73	57.78	1536.32
12/02/74	57.69	1536.41
12/03/75	57.65	1536.45
11/30/76	57.44	1536.66
11/30/77	57.84	1536.26
11/30/78	57.88	1536.22
11/28/79	57.44	1536.66
12/02/80	57.32	1536.78
12/01/81	56.51	1537.59
12/01/82	56.36	1537.74
11/29/83	56.18	1537.92
11/28/84	56.37	1537.73
12/02/85	56.34	1537.76
07/10/86	56.16	1537.94
10/21/86	56.49	1537.61
11/19/86	56.29	1537.81
12/03/86	56.20	1537.90
12/10/86	56.15	1537.95
01/08/87	56.59	1537.51
01/28/87	56.48	1537.62
02/10/87	56.58	1537.52
03/26/87	56.42	1537.68
05/06/87	56.59	1537.51
05/27/87	56.14	1537.96
07/13/87	56.44	1537.66
09/10/87	56.29	1537.81
10/13/87	56.14	1537.96
11/10/87	56.30	1537.80
12/03/87	56.42	1537.68
04/13/88	56.40	1537.70
05/27/88	56.20	1537.90
07/07/88	56.32	1537.78
07/28/88	56.44	1537.66
09/02/88	56.80	1537.30
10/05/88	57.10	1537.00
11/02/88	56.93	1537.17

149-070-02AAA1
New Rockford aquifer — LS Elev (msl,ft)= 1592.10 — SI (ft)= 218-223

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	55.76	1536.34
11/19/86	55.41	1536.69
12/10/86	55.53	1536.57
01/08/87	55.87	1536.23
01/28/87	55.82	1536.28
02/10/87	55.76	1536.34
03/26/87	55.22	1536.88
05/06/87	55.34	1536.76
05/27/87	54.86	1537.24
07/13/87	55.23	1536.87
09/10/87	55.16	1536.94

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	54.97	1537.13
11/10/87	55.40	1536.70
12/03/87	55.20	1536.90
04/13/88	55.31	1536.79
05/27/88	55.19	1536.91
07/07/88	55.65	1536.45
07/28/88	56.49	1535.61
09/02/88	56.58	1535.52
10/05/88	57.20	1534.90
11/02/88	56.90	1535.20

149-070-03CBB
New Rockford aquifer — LS Elev (msl,ft)= 1582.90 — SI (ft)= 110-115

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	55.81	1527.09
10/22/86	56.28	1526.62
11/21/86	55.16	1527.74
12/10/86	54.59	1528.31
01/08/87	53.45	1529.45
01/28/87	51.91	1530.99
02/11/87	51.31	1531.59
03/26/87	49.49	1533.41
05/06/87	48.78	1534.12
05/28/87	47.46	1535.44
07/13/87	46.91	1535.99

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/10/87	45.72	1537.18
10/13/87	45.02	1537.88
11/10/87	45.00	1537.90
12/03/87	44.39	1538.51
04/13/88	42.77	1540.13
05/27/88	42.21	1540.69
07/07/88	41.78	1541.12
07/28/88	41.76	1541.14
09/02/88	41.58	1541.32
10/05/88	41.88	1541.02
11/02/88	41.06	1541.84

149-070-03CBB1
New Rockford aquifer — LS Elev (msl,ft)= 1582.62 — SI (ft)= 242-247

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/22/86	33.90	1548.72
11/21/86	33.51	1549.11
12/10/86	33.67	1548.95
01/08/87	33.99	1548.63
01/28/87	33.81	1548.81
02/11/87	33.86	1548.76
03/26/87	33.74	1548.88
05/06/87	34.25	1548.37
05/28/87	33.53	1549.09
07/13/87	34.03	1548.59
09/10/87	33.89	1548.73

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	33.65	1548.97
11/10/87	34.13	1548.49
12/03/87	33.72	1548.90
04/13/88	33.90	1548.72
05/27/88	33.78	1548.84
07/07/88	33.66	1548.96
07/28/88	33.80	1548.82
09/02/88	33.84	1548.78
10/05/88	34.43	1548.19
11/02/88	33.81	1548.81

149-070-03CBB2
Till

LS Elev (msl,ft)= 1582.76 SI (ft)= 53-58

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	11.02	1571.74
01/28/87	9.97	1572.79
02/11/87	9.80	1572.96
03/26/87	8.56	1574.20
05/06/87	7.73	1575.03
05/28/87	7.69	1575.07
07/13/87	7.17	1575.59
09/10/87	6.47	1576.29
10/13/87	6.83	1575.93
11/10/87	7.06	1575.70
12/03/87	7.11	1575.65
04/13/88	8.44	1574.32
05/27/88	8.21	1574.55
07/07/88	8.29	1574.47
07/28/88	8.60	1574.16
09/02/88	9.40	1573.36
10/05/88	10.22	1572.54
11/02/88	10.56	1572.20

149-070-03CBB3
Till

LS Elev (msl,ft)= 1582.86 SI (ft)= 33-38

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	8.42	1574.44
01/28/87	7.88	1574.98
02/11/87	7.38	1575.48
03/26/87	6.32	1576.54
05/06/87	5.66	1577.20
05/28/87	5.62	1577.24
07/13/87	5.08	1577.78
09/10/87	4.43	1578.43
10/13/87	4.94	1577.92
11/10/87	5.20	1577.66
12/03/87	5.30	1577.56
04/13/88	6.85	1576.01
05/27/88	6.60	1576.26
07/07/88	7.74	1575.12
07/28/88	7.22	1575.64
09/02/88	8.16	1574.70
10/05/88	8.95	1573.91
11/02/88	9.25	1573.61

149-070-03CBB4
Till

LS Elev (msl,ft)= 1582.91 SI (ft)= 5-15

Date	Depth to Water (ft)	WL Elev (msl,ft)
01/08/87	6.29	1576.62
01/28/87	6.43	1576.48
02/11/87	3.86	1579.05
03/26/87	3.75	1579.16
05/06/87	3.97	1578.94
05/28/87	3.39	1579.52
07/13/87	2.91	1580.00
09/10/87	3.58	1579.33
10/13/87	4.06	1578.85
11/10/87	4.20	1578.71
12/03/87	4.44	1578.47
04/13/88	5.18	1577.73
05/27/88	4.98	1577.93
07/07/88	5.59	1577.32
07/28/88	6.56	1576.35
09/02/88	7.90	1575.01
10/05/88	8.67	1574.24
11/02/88	8.85	1574.06

149-070-03DDD

New Rockford aquifer — LS Elev (msl,ft)= 1597.31 — SI (ft)= 258-263

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/28/87	48.65	1548.66
06/08/87	49.26	1548.05
07/13/87	49.07	1548.24
09/10/87	48.97	1548.34
10/13/87	48.69	1548.62
11/10/87	49.06	1548.25
12/03/87	48.86	1548.45
04/13/88	48.94	1548.37
05/27/88	48.80	1548.51
07/07/88	48.94	1548.37
07/28/88	48.84	1548.47
09/02/88	48.97	1548.34
10/05/88	49.33	1547.98
11/02/88	48.91	1548.40

149-070-09DAA1

New Rockford aquifer — LS Elev (msl,ft)= 1612.70 — SI (ft)= 200-203

Date	Depth to Water (ft)	WL Elev (msl,ft)
08/01/67	56.76	1555.94
07/26/68	65.81	1546.89
07/25/69	65.33	1547.37
12/20/69	65.14	1547.56
11/30/70	65.34	1547.36
12/01/71	65.84	1546.86
12/06/72	65.58	1547.12
12/04/73	65.32	1547.38
12/02/74	65.43	1547.27
12/02/75	65.25	1547.45
11/30/76	65.05	1547.65
03/02/77	65.14	1547.56
04/06/77	65.11	1547.59
05/31/77	65.11	1547.59
08/24/77	64.94	1547.76
11/29/77	64.50	1548.20
03/01/78	65.14	1547.56
05/31/78	64.90	1547.80
09/06/78	64.88	1547.82
11/29/78	64.92	1547.78
02/26/79	64.65	1548.05
06/04/79	64.87	1547.83
09/04/79	64.42	1548.28
11/28/79	65.30	1547.40
06/11/80	64.62	1548.08
09/11/80	64.79	1547.91
12/02/80	65.33	1547.37
06/03/81	64.77	1547.93
09/03/81	65.01	1547.69
12/01/81	64.24	1548.46
07/07/82	64.81	1547.89
10/19/82	65.07	1547.63
12/01/82	64.20	1548.50
03/30/83	64.38	1548.32
06/20/83	64.43	1548.27
09/07/83	64.83	1547.87
11/29/83	64.36	1548.34
07/09/84	64.75	1547.95
11/28/84	63.98	1548.72
05/13/85	64.32	1548.38
07/29/85	64.74	1547.96
12/02/85	64.49	1548.21
06/03/86	64.06	1548.64
07/10/86	64.01	1548.69
08/18/86	64.31	1548.39
10/01/86	64.12	1548.58
10/22/86	64.13	1548.57
11/21/86	64.59	1548.11
12/03/86	64.10	1548.60
12/10/86	63.66	1549.04
01/08/87	64.19	1548.51
01/28/87	63.95	1548.75
02/10/87	64.19	1548.51
03/26/87	63.88	1548.82
05/06/87	64.49	1548.21
05/11/87	64.09	1548.61
05/28/87	63.72	1548.98
07/13/87	64.29	1548.41
09/10/87	64.15	1548.55
10/13/87	63.95	1548.75
11/10/87	64.35	1548.35
12/03/87	64.04	1548.66
04/13/88	64.12	1548.58
05/27/88	64.00	1548.70
07/07/88	63.91	1548.79
07/28/88	64.11	1548.59
09/02/88	64.17	1548.53
10/05/88	64.74	1547.96
11/02/88	64.04	1548.66

149-070-09DAA2
New Rockford aquifer — LS Elev (msl,ft)= 1612.70 — SI (ft)= 100-103

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/10/86	63.99	1548.71
10/01/86	64.11	1548.59
10/22/86	64.13	1548.57
11/21/86	63.69	1549.01
12/10/86	63.65	1549.05
01/08/87	64.14	1548.56
01/28/87	63.94	1548.76
02/10/87	64.16	1548.54
03/26/87	63.85	1548.85
05/06/87	64.48	1548.22
07/13/87	64.27	1548.43
09/10/87	64.09	1548.61
11/10/87	64.33	1548.37
12/03/87	64.03	1548.67
04/13/88	64.14	1548.56
05/27/88	63.99	1548.71
07/07/88	63.90	1548.80
07/28/88	64.02	1548.68
09/02/88	64.18	1548.52
10/05/88	64.71	1547.99
11/02/88	64.03	1548.67

149-070-12BCC
New Rockford aquifer — LS Elev (msl,ft)= 1597.70 — SI (ft)= 290-295

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	58.52	1539.18
10/22/86	58.42	1539.28
11/21/86	58.12	1539.58
12/10/86	58.15	1539.55
01/08/87	58.26	1539.44
01/28/87	58.15	1539.55
02/10/87	58.21	1539.49
03/26/87	58.09	1539.61
05/06/87	58.42	1539.28
05/28/87	58.13	1539.57
07/13/87	58.20	1539.50
09/10/87	58.27	1539.43
10/13/87	58.25	1539.45
11/10/87	58.32	1539.38
12/03/87	58.22	1539.48
04/13/88	58.04	1539.66
05/27/88	58.13	1539.57
07/07/88	58.22	1539.48
07/28/88	58.14	1539.56
09/02/88	58.32	1539.38
10/05/88	58.49	1539.21
11/02/88	58.33	1539.37

149-070-16AAD
New Rockford aquifer — LS Elev (msl,ft)= 1597.20 — SI (ft)= 204-209

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	74.80	1522.40
10/22/86	74.90	1522.30
11/21/86	74.65	1522.55
12/10/86	74.69	1522.51
01/08/87	74.88	1522.32
01/28/87	74.74	1522.46
02/10/87	74.84	1522.36
05/28/87	74.48	1522.72
07/13/87	74.85	1522.35
09/10/87	75.12	1522.08
11/10/87	75.39	1521.81
12/03/87	75.14	1522.06
04/13/88	75.16	1522.04
05/27/88	75.03	1522.17
07/07/88	75.21	1521.99
07/28/88	75.48	1521.72
09/02/88	75.79	1521.41
10/05/88	76.45	1520.75
11/02/88	76.27	1520.93

149-071-01ADD
New Rockford aquifer LS Elev (msl,ft)= 1606.90 SI (ft)= 258-263

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	89.51	1517.39
10/22/86	89.44	1517.46
11/19/86	89.09	1517.81
12/10/86	89.04	1517.86
01/08/87	89.05	1517.85
01/28/87	88.96	1517.94
02/10/87	88.95	1517.95
03/26/87	88.77	1518.13
05/06/87	89.16	1517.74
05/27/87	89.30	1517.60
07/13/87	89.87	1517.03
09/10/87	90.03	1516.87
10/13/87	89.90	1517.00
11/10/87	89.92	1516.98
12/03/87	89.73	1517.17
04/13/88	89.36	1517.54
05/27/88	89.73	1517.17
07/07/88	90.80	1516.10
07/28/88	91.26	1515.64
09/02/88	91.92	1514.98
10/05/88	92.04	1514.86
11/02/88	91.73	1515.17

149-071-19CDD
Manfred aquifer

LS Elev (msl,ft)= 1605.00 SI (ft)= 140-160

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/19/67	7.25	1597.75
08/16/67	8.35	1596.65
10/26/67	8.73	1596.27
12/28/67	8.92	1596.08
01/30/68	8.98	1596.02
02/14/68	9.14	1595.86
03/15/68	8.87	1596.13
04/15/68	8.50	1596.50
05/28/68	7.60	1597.40
07/26/68	7.81	1597.19
10/25/68	7.90	1597.10
05/26/69	5.77	1599.23
07/26/69	7.86	1597.14
12/20/69	7.54	1597.46
03/11/70	8.26	1596.74
06/11/70	4.93	1600.07
09/03/70	6.98	1598.02
11/30/70	6.66	1598.34
03/04/71	7.40	1597.60
06/08/71	4.38	1600.62
09/07/71	6.71	1598.29
12/01/71	6.64	1598.36
03/07/72	6.82	1598.18
06/05/72	6.03	1598.97
08/31/72	8.06	1596.94
12/06/72	8.35	1596.65
04/03/73	8.74	1596.26
06/01/73	8.14	1596.86
09/06/73	10.00	1595.00
12/04/73	10.20	1594.80
03/04/74	10.41	1594.59
05/22/74	8.07	1596.93
09/03/74	9.57	1595.43
12/02/74	8.93	1596.07
04/15/75	9.19	1595.81
07/11/75	6.78	1598.22
09/05/75	8.86	1596.14
12/02/75	9.40	1595.60
02/23/76	9.66	1595.34
06/01/76	7.56	1597.44

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/07/76	10.16	1594.84
11/29/76	10.76	1594.24
03/02/77	11.19	1593.81
05/31/77	11.17	1593.83
08/29/77	12.05	1592.95
11/28/77	11.80	1593.20
11/29/78	10.60	1594.40
11/27/79	8.94	1596.06
12/01/80	8.28	1596.72
12/01/81	9.09	1595.91
12/02/82	5.76	1599.24
11/29/83	7.54	1597.46
11/28/84	6.69	1598.31
12/03/85	6.31	1598.69
07/10/86	5.58	1599.42
10/01/86	7.08	1597.92
10/22/86	7.00	1598.00
11/19/86	6.92	1598.08
12/03/86	7.10	1597.90
12/10/86	7.03	1597.97
01/08/87	7.35	1597.65
01/28/87	7.43	1597.57
02/11/87	7.24	1597.76
03/26/87	5.98	1599.02
05/06/87	5.51	1599.49
07/13/87	6.77	1598.23
09/11/87	7.17	1597.83
10/13/87	7.32	1597.68
11/10/87	7.58	1597.42
12/03/87	7.62	1597.38
04/13/88	7.32	1597.68
05/27/88	7.35	1597.65
07/07/88	8.49	1596.51
07/28/88	9.02	1595.98
09/02/88	9.69	1595.31
10/05/88	10.02	1594.98
11/02/88	9.91	1595.09

149-071-31CCB

Manfred aquifer — LS Elev (msl,ft)= 1605.00 — SI (ft)= 125-128

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	15.91	1589.09
10/22/86	15.14	1589.86
11/19/86	14.20	1590.80
12/10/86	13.98	1591.02
01/08/87	13.77	1591.23
01/28/87	13.58	1591.42
02/11/87	13.60	1591.40
03/26/87	13.16	1591.84
05/06/87	12.71	1592.29
07/13/87	12.10	1592.90
09/11/87	11.64	1593.36

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	11.51	1593.49
11/10/87	11.53	1593.47
12/03/87	11.51	1593.49
04/13/88	12.34	1592.66
05/27/88	12.17	1592.83
07/07/88	12.14	1592.86
07/28/88	12.30	1592.70
09/02/88	12.55	1592.45
10/05/88	12.74	1592.26
11/02/88	12.78	1592.22

150-069-31CBC

New Rockford aquifer — LS Elev (msl,ft)= 1537.80 — SI (ft)= 98-103

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	2.97	1534.83
12/10/86	2.74	1535.06
01/08/87	2.90	1534.90
01/28/87	3.02	1534.78
02/10/87	2.68	1535.12
05/06/87	1.79	1536.01
05/28/87	1.70	1536.10
07/13/87	1.92	1535.88
09/10/87	2.19	1535.61
10/13/87	2.25	1535.55

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	2.41	1535.39
12/03/87	2.33	1535.47
04/13/88	1.96	1535.84
05/27/88	2.21	1535.59
07/07/88	3.55	1534.25
07/28/88	4.30	1533.50
09/02/88	4.98	1532.82
10/05/88	5.21	1532.59
11/02/88	4.96	1532.84

150-069-31CBC1

Till — LS Elev (msl,ft)= 1537.90 — SI (ft)= 18-38

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	4.52	1533.38
12/10/86	5.28	1532.62
01/08/87	6.03	1531.87
01/28/87	6.24	1531.66
02/10/87	4.45	1533.45
03/26/87	2.13	1535.77
05/06/87	3.80	1534.10
05/28/87	3.76	1534.14
07/13/87	3.71	1534.19
09/10/87	4.75	1533.15

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	5.30	1532.60
11/10/87	5.58	1532.32
12/03/87	5.65	1532.25
04/13/88	5.17	1532.73
05/27/88	5.14	1532.76
07/07/88	5.98	1531.92
07/28/88	6.57	1531.33
09/02/88	7.20	1530.70
10/05/88	7.79	1530.11
11/02/88	7.97	1529.93

150-069-32CCC
Heimdal aquifer

LS Elev (msl,ft)= 1537.66 SI (ft)= 14-19

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	3.36	1534.30
11/19/86	3.17	1534.49
12/10/86	3.12	1534.54
01/08/87	3.16	1534.50
01/28/87	3.39	1534.27
02/10/87	2.87	1534.79
03/26/87	0.62	1537.04
05/06/87	1.86	1535.80
05/28/87	1.84	1535.82
07/13/87	1.94	1535.72
09/10/87	2.66	1535.00

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	2.75	1534.91
11/10/87	2.71	1534.95
12/03/87	2.69	1534.97
04/13/88	2.03	1535.63
05/27/88	2.76	1534.90
07/07/88	3.81	1533.85
07/28/88	4.75	1532.91
09/02/88	5.40	1532.26
10/05/88	5.68	1531.98
11/02/88	5.55	1532.11

150-070-25CCC
New Rockford aquifer

LS Elev (msl,ft)= 1540.60 SI (ft)= 218-223

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	3.10	1537.50
11/19/86	2.87	1537.73
12/10/86	2.92	1537.68
01/08/87	3.13	1537.47
01/28/87	3.16	1537.44
02/10/87	3.04	1537.56
03/26/87	1.95	1538.65
05/06/87	2.11	1538.49
05/27/87	1.86	1538.74
07/13/87	2.01	1538.59
09/10/87	2.16	1538.44

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	2.19	1538.41
11/10/87	2.47	1538.13
12/03/87	2.28	1538.32
04/13/88	2.12	1538.48
05/27/88	2.36	1538.24
07/07/88	3.10	1537.50
07/28/88	3.67	1536.93
09/02/88	4.24	1536.36
10/05/88	4.78	1535.82
11/02/88	4.62	1535.98

150-070-27DDA
Heimdal aquifer

LS Elev (msl,ft)= 1541.70 SI (ft)= 15-20

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	6.58	1535.12
11/19/86	6.44	1535.26
12/10/86	6.39	1535.31
01/08/87	6.54	1535.16
01/28/87	6.73	1534.97
02/10/87	6.38	1535.32
03/26/87	3.12	1538.58
05/06/87	5.40	1536.30
05/27/87	5.33	1536.37
07/13/87	5.40	1536.30
09/10/87	5.75	1535.95

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	5.83	1535.87
11/10/87	5.77	1535.93
12/03/87	5.76	1535.94
04/13/88	6.45	1535.25
05/27/88	5.62	1536.08
07/07/88	6.69	1535.01
07/28/88	7.77	1533.93
09/02/88	9.32	1532.38
10/05/88	10.52	1531.18
11/02/88	10.47	1531.23

150-070-27DDA1
New Rockford aquifer — LS Elev (msl,ft)= 1542.20 — SI (ft)= 165-170

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	7.22	1534.98
11/19/86	7.03	1535.17
12/10/86	7.04	1535.16
01/08/87	7.21	1534.99
01/28/87	7.43	1534.77
02/10/87	7.10	1535.10
03/26/87	3.93	1538.27
05/06/87	6.06	1536.14
05/27/87	5.96	1536.24
07/13/87	6.03	1536.17
09/10/87	6.20	1536.00

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	6.42	1535.78
11/10/87	6.40	1535.80
12/03/87	6.37	1535.83
04/13/88	5.90	1536.30
05/27/88	6.31	1535.89
07/07/88	7.34	1534.86
07/28/88	8.45	1533.75
09/02/88	9.79	1532.41
10/05/88	11.07	1531.13
11/02/88	11.09	1531.11

150-070-28ADA
Heimdal aquifer — LS Elev (msl,ft)= 1540.42 — SI (ft)= 24-29

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	5.11	1535.31
11/19/86	5.07	1535.35
12/10/86	5.13	1535.29
01/08/87	5.48	1534.94
01/28/87	5.81	1534.61
02/10/87	5.20	1535.22
05/06/87	3.81	1536.61
05/27/87	3.75	1536.67
07/13/87	3.80	1536.62
09/10/87	4.16	1536.26

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	4.36	1536.06
11/10/87	4.08	1536.34
12/03/87	4.12	1536.30
04/13/88	3.93	1536.49
05/27/88	3.88	1536.54
07/07/88	5.81	1534.61
07/28/88	7.19	1533.23
09/02/88	7.88	1532.54
10/05/88	8.15	1532.27
11/02/88	8.20	1532.22

150-070-32ABB
New Rockford aquifer — LS Elev (msl,ft)= 1579.30 — SI (ft)= 192-197

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	5.83	1573.47
10/21/86	5.48	1573.82
11/19/86	5.47	1573.83
12/10/86	5.24	1574.06
01/08/87	5.33	1573.97
01/28/87	5.33	1573.97
02/10/87	5.38	1573.92
03/26/87	5.18	1574.12
05/06/87	5.30	1574.00
05/27/87	5.13	1574.17
07/13/87	5.04	1574.26

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/10/87	4.64	1574.66
10/13/87	4.58	1574.72
11/10/87	4.58	1574.72
12/03/87	4.52	1574.78
04/13/88	4.98	1574.32
05/27/88	5.16	1574.14
07/07/88	5.55	1573.75
07/28/88	5.82	1573.48
09/02/88	6.09	1573.21
10/05/88	6.34	1572.96
11/02/88	6.36	1572.94

150-070-32ABB1
Lake clay sediments — LS Elev (msl,ft)= 1583.48 — SI (ft)= 43-48

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/10/86	11.03	1572.45
01/08/87	10.92	1572.56
01/28/87	10.96	1572.52
02/10/87	10.95	1572.53
03/26/87	10.36	1573.12
05/06/87	10.28	1573.20
05/27/87	10.20	1573.28
07/13/87	9.90	1573.58
09/10/87	9.50	1573.98
10/13/87	9.69	1573.79

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	9.81	1573.67
12/03/87	9.81	1573.67
04/13/88	9.94	1573.54
05/27/88	10.45	1573.03
07/07/88	11.19	1572.29
07/28/88	11.58	1571.90
09/02/88	11.97	1571.51
10/05/88	12.28	1571.20
11/02/88	12.31	1571.17

150-070-32ABB2
Lake clay sediments — LS Elev (msl,ft)= 1583.29 — SI (ft)= 33-38

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/10/86	11.03	1572.26
01/08/87	10.85	1572.44
01/28/87	10.91	1572.38
02/10/87	11.90	1571.39
03/26/87	10.23	1573.06
05/06/87	10.15	1573.14
05/27/87	10.20	1573.09
07/13/87	9.74	1573.55
09/10/87	9.35	1573.94
10/13/87	9.58	1573.71

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	9.72	1573.57
12/03/87	9.72	1573.57
04/13/88	10.08	1573.21
05/27/88	10.35	1572.94
07/07/88	11.14	1572.15
07/28/88	11.53	1571.76
09/02/88	11.93	1571.36
10/05/88	12.24	1571.05
11/02/88	12.28	1571.01

150-070-32ABB3
Till — LS Elev (msl,ft)= 1583.39 — SI (ft)= 19-29

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/10/86	13.43	1569.96
01/08/87	13.20	1570.19
01/28/87	13.32	1570.07
02/10/87	13.33	1570.06
03/26/87	6.90	1576.49
05/06/87	7.67	1575.72
05/27/87	8.20	1575.19
07/13/87	9.77	1573.62
09/10/87	11.08	1572.31
10/13/87	11.88	1571.51

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	12.12	1571.27
12/03/87	12.43	1570.96
04/13/88	10.93	1572.46
05/27/88	11.18	1572.21
07/07/88	13.11	1570.28
07/28/88	13.95	1569.44
09/02/88	14.92	1568.47
10/05/88	15.54	1567.85
11/02/88	15.73	1567.66

150-070-32ABB4

Lake clay sediments — LS Elev (msl,ft)= 1583.39 — SI (ft)= 86-91

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/10/86	9.84	1573.55
01/08/87	9.86	1573.53
01/28/87	9.84	1573.55
02/10/87	9.88	1573.51
03/26/87	9.59	1573.80
05/06/87	9.71	1573.68
05/27/87	9.43	1573.96
07/13/87	9.28	1574.11
09/10/87	8.97	1574.42
10/13/87	8.91	1574.48

Date	Depth to Water (ft)	WL Elev (msl,ft)
11/10/87	8.91	1574.48
12/03/87	8.87	1574.52
04/13/88	9.77	1573.62
05/27/88	9.51	1573.88
07/07/88	9.95	1573.44
07/28/88	10.25	1573.14
09/02/88	10.53	1572.86
10/05/88	10.78	1572.61
11/02/88	10.78	1572.61

150-070-32CCC

New Rockford aquifer — LS Elev (msl,ft)= 1598.08 — SI (ft)= 158-163

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/27/87	77.11	1520.97
06/08/87	77.63	1520.45
07/13/87	77.68	1520.40
09/10/87	77.81	1520.27
10/13/87	77.74	1520.34
11/10/87	78.17	1519.91
12/03/87	77.74	1520.34

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/88	77.74	1520.34
05/27/88	77.69	1520.39
07/07/88	77.99	1520.09
07/28/88	78.38	1519.70
09/02/88	78.91	1519.17
10/05/88	79.71	1518.37
11/02/88	79.33	1518.75

150-070-32DCC

New Rockford aquifer — LS Elev (msl,ft)= 1595.19 — SI (ft)= 272-277

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/28/87	84.80	1510.39
06/08/87	76.60	1518.59
07/13/87	74.28	1520.91
09/10/87	74.23	1520.96
10/13/87	74.25	1520.94
11/10/87	74.39	1520.80
12/03/87	74.33	1520.86

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/88	74.43	1520.76
05/27/88	74.43	1520.76
07/07/88	75.61	1519.58
07/28/88	74.80	1520.39
09/02/88	75.09	1520.10
10/05/88	75.49	1519.70
11/02/88	75.49	1519.70

150-070-33CDD
New Rockford aquifer — LS Elev (msl,ft)= 1581.13 — SI (ft)= 158-163

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/28/87	5.57	1575.56
06/08/87	5.84	1575.29
07/13/87	5.65	1575.48
09/10/87	5.59	1575.54
10/13/87	5.53	1575.60
11/10/87	5.52	1575.61
12/03/87	5.40	1575.73
04/13/88	5.21	1575.92
05/27/88	5.29	1575.84
07/07/88	5.53	1575.60
07/28/88	5.73	1575.40
09/02/88	5.84	1575.29
10/05/88	6.02	1575.11
11/02/88	5.97	1575.16

150-070-34CCC
New Rockford aquifer — LS Elev (msl,ft)= 1591.60 — SI (ft)= 310-315

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	58.56	1533.04
10/22/86	58.61	1532.99
11/21/86	58.23	1533.37
12/10/86	58.36	1533.24
01/08/87	58.40	1533.20
01/28/87	58.10	1533.50
02/11/87	57.97	1533.63
03/26/87	57.38	1534.22
05/06/87	57.31	1534.29
05/27/87	56.23	1535.37
07/13/87	56.23	1535.37
09/10/87	55.39	1536.21
10/13/87	54.82	1536.78
11/10/87	54.95	1536.65
12/03/87	54.15	1537.45
04/13/88	52.75	1538.85
05/27/88	52.15	1539.45
07/07/88	51.64	1539.96
07/28/88	51.63	1539.97
09/02/88	51.27	1540.33
10/05/88	51.60	1540.00
11/02/88	50.79	1540.81

150-070-35AAD
Heimdal aquifer — LS Elev (msl,ft)= 1537.56 — SI (ft)= 18-23

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/21/86	2.26	1535.30
11/19/86	2.08	1535.48
12/10/86	1.95	1535.61
01/08/87	1.90	1535.66
01/28/87	2.03	1535.53
02/10/87	1.68	1535.88
05/06/87	1.35	1536.21
05/27/87	1.33	1536.23
07/13/87	1.36	1536.20
09/10/87	1.74	1535.82
10/13/87	1.77	1535.79
11/10/87	1.73	1535.83
12/03/87	1.67	1535.89
05/27/88	1.78	1535.78
07/07/88	3.22	1534.34
07/28/88	4.70	1532.86
09/02/88	5.96	1531.60
10/05/88	5.96	1531.60
11/02/88	5.41	1532.15

150-070-35CCC

New Rockford aquifer — LS Elev (msl,ft)= 1592.63 — SI (ft)= 228-233

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/27/87	44.07	1548.56
06/08/87	44.47	1548.16
07/13/87	44.38	1548.25
09/10/87	44.21	1548.42
10/13/87	44.09	1548.54
11/10/87	44.46	1548.17
12/03/87	44.05	1548.58

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/88	44.22	1548.41
05/27/88	44.17	1548.46
07/07/88	44.13	1548.50
07/28/88	44.22	1548.41
09/02/88	44.19	1548.44
10/05/88	44.63	1548.00
11/02/88	44.24	1548.39

150-071-04DDD

New Rockford aquifer — LS Elev (msl,ft)= 1576.40 — SI (ft)= 260-280

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/19/67	54.51	1521.89
08/16/67	53.87	1522.53
10/26/67	53.41	1522.99
12/28/67	53.27	1523.13
01/30/68	53.29	1523.11
02/14/68	53.21	1523.19
03/15/68	53.09	1523.31
04/16/68	53.35	1523.05
05/01/68	53.07	1523.33
05/28/68	53.07	1523.33
06/27/68	53.09	1523.31
07/26/68	53.24	1523.16
07/25/69	52.87	1523.53
12/20/69	53.00	1523.40
11/30/70	51.75	1524.65
12/01/71	51.27	1525.13
12/05/72	50.17	1526.23
12/04/73	50.88	1525.52
12/02/74	50.65	1525.75
12/02/75	50.24	1526.16
11/30/76	49.51	1526.89
11/29/77	49.33	1527.07
11/29/78	51.19	1525.21
12/02/80	55.10	1521.30

Date	Depth to Water (ft)	WL Elev (msl,ft)
12/02/81	56.46	1519.94
12/01/82	57.16	1519.24
11/29/83	56.66	1519.74
11/28/84	55.60	1520.80
12/03/85	57.79	1518.61
07/10/86	59.52	1516.88
10/01/86	58.40	1518.00
10/21/86	58.26	1518.14
11/19/86	57.87	1518.53
12/03/86	57.92	1518.48
12/10/86	57.82	1518.58
01/08/87	57.82	1518.58
01/28/87	57.72	1518.68
02/11/87	57.71	1518.69
03/26/87	57.51	1518.89
05/06/87	58.11	1518.29
05/27/87	58.37	1518.03
07/13/87	58.87	1517.53
09/11/87	58.95	1517.45
10/13/87	58.79	1517.61
11/10/87	58.75	1517.65
12/03/87	58.51	1517.89
04/13/88	58.26	1518.14
05/27/88	58.89	1517.51
07/07/88	60.20	1516.20
07/28/88	60.80	1515.60
09/02/88	61.35	1515.05
10/05/88	61.27	1515.13
11/02/88	60.76	1515.64

150-071-06DDD
New Rockford aquifer — LS Elev (msl,ft)= 1603.39 — SI (ft)= 178-183

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
05/27/87	84.51	1518.88	04/13/88	84.43	1518.96
06/08/87	84.76	1518.63	05/27/88	85.03	1518.36
07/13/87	85.03	1518.36	07/07/88	86.32	1517.07
09/11/87	85.09	1518.30	07/28/88	86.92	1516.47
10/13/87	84.91	1518.48	09/02/88	87.58	1515.81
11/10/87	84.85	1518.54	10/05/88	87.50	1515.89
12/03/87	84.67	1518.72	11/02/88	87.11	1516.28

150-071-16BAA
Till — LS Elev (msl,ft)= 1589.50 — SI (ft)= 55-60

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	19.04	1570.46	09/11/87	18.23	1571.27
10/21/86	18.92	1570.58	10/13/87	19.96	1569.54
11/19/86	19.29	1570.21	11/10/87	17.99	1571.51
12/10/86	18.99	1570.51	12/03/87	17.95	1571.55
01/08/87	18.92	1570.58	04/13/88	18.37	1571.13
01/28/87	18.90	1570.60	05/27/88	18.27	1571.23
02/11/87	18.94	1570.56	07/07/88	18.35	1571.15
03/26/87	18.79	1570.71	07/28/88	18.59	1570.91
05/06/87	18.73	1570.77	09/02/88	18.81	1570.69
05/27/87	18.47	1571.03	10/05/88	19.17	1570.33
07/13/87	18.48	1571.02	11/02/88	19.35	1570.15

150-071-16BAA1
New Rockford aquifer — LS Elev (msl,ft)= 1589.80 — SI (ft)= 273-278

Date	Depth to Water (ft)	WL Elev (msl,ft)	Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	71.77	1518.03	09/11/87	72.86	1516.94
10/21/86	72.12	1517.68	10/13/87	72.66	1517.14
11/19/86	71.74	1518.06	11/10/87	72.61	1517.19
12/10/86	71.70	1518.10	12/03/87	72.42	1517.38
01/08/87	71.69	1518.11	04/13/88	72.05	1517.75
01/28/87	71.60	1518.20	05/27/88	72.70	1517.10
02/11/87	71.58	1518.22	07/07/88	73.97	1515.83
03/26/87	71.50	1518.30	07/28/88	74.53	1515.27
05/06/87	71.96	1517.84	09/02/88	75.13	1514.67
05/27/87	72.21	1517.59	10/05/88	75.02	1514.78
07/13/87	72.70	1517.10	11/02/88	74.64	1515.16

150-071-21CBB
New Rockford aquifer — LS Elev (msl,ft)= 1585.60 — SI (ft)= 229-234

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	68.68	1516.92
10/21/86	68.49	1517.11
11/19/86	68.10	1517.50
12/10/86	68.11	1517.49
01/08/87	68.15	1517.45
01/28/87	68.04	1517.56
02/11/87	68.00	1517.60
03/26/87	67.85	1517.75
05/06/87	68.37	1517.23
05/27/87	68.51	1517.09
07/13/87	69.08	1516.52

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/11/87	69.25	1516.35
10/13/87	69.00	1516.60
11/10/87	69.05	1516.55
12/03/87	68.81	1516.79
04/13/88	68.48	1517.12
05/27/88	68.89	1516.71
07/07/88	70.16	1515.44
07/28/88	70.73	1514.87
09/02/88	71.36	1514.24
10/05/88	71.41	1514.19
11/02/88	70.92	1514.68

150-071-21CBB1
New Rockford aquifer — LS Elev (msl,ft)= 1585.80 — SI (ft)= 90-95

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	68.01	1517.79
10/21/86	67.88	1517.92
11/19/86	67.37	1518.43
12/10/86	67.54	1518.26
01/08/87	67.86	1517.94
01/28/87	67.60	1518.20
02/11/87	67.54	1518.26
03/26/87	67.54	1518.26
05/06/87	67.98	1517.82
05/27/87	67.35	1518.45
07/13/87	68.17	1517.63

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/11/87	68.36	1517.44
10/13/87	67.94	1517.86
11/10/87	67.90	1517.90
12/03/87	68.10	1517.70
04/13/88	68.06	1517.74
05/27/88	68.06	1517.74
07/07/88	68.48	1517.32
07/28/88	68.87	1516.93
09/02/88	68.67	1517.13
10/05/88	70.28	1515.52
11/02/88	69.66	1516.14

150-071-22BBB
New Rockford aquifer — LS Elev (msl,ft)= 1576.40 — SI (ft)= 298-303

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/22/86	59.26	1517.14
11/19/86	58.93	1517.47
12/10/86	58.87	1517.53
01/08/87	58.89	1517.51
01/28/87	58.77	1517.63
02/11/87	58.77	1517.63
03/26/87	58.57	1517.83
05/06/87	59.11	1517.29
05/27/87	59.34	1517.06
07/13/87	59.82	1516.58
09/11/87	60.06	1516.34

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/13/87	59.76	1516.64
11/10/87	59.75	1516.65
12/03/87	59.59	1516.81
04/13/88	59.23	1517.17
05/27/88	59.78	1516.62
07/07/88	60.87	1515.53
07/28/88	61.48	1514.92
09/02/88	62.12	1514.28
10/05/88	62.08	1514.32
11/02/88	61.65	1514.75

150-071-22DAA
New Rockford aquifer — LS Elev (msl,ft)= 1581.70 — SI (ft)= 230-235

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	64.65	1517.05
10/22/86	64.56	1517.14
12/10/86	64.15	1517.55
01/08/87	64.15	1517.55
02/10/87	64.06	1517.64
03/26/87	63.86	1517.84
05/06/87	64.34	1517.36
05/27/87	64.53	1517.17
07/13/87	65.04	1516.66
09/11/87	65.23	1516.47
10/13/87	65.07	1516.63
11/10/87	65.03	1516.67
12/03/87	64.81	1516.89
04/13/88	64.51	1517.19
05/27/88	64.97	1516.73
07/07/88	66.14	1515.56
07/28/88	66.63	1515.07
09/02/88	67.27	1514.43
10/05/88	67.30	1514.40
11/02/88	66.96	1514.74

150-071-26DCC
New Rockford aquifer — LS Elev (msl,ft)= 1603.04 — SI (ft)= 333-338

Date	Depth to Water (ft)	WL Elev (msl,ft)
05/27/87	85.50	1517.54
06/08/87	85.78	1517.26
07/13/87	86.08	1516.96
09/11/87	86.20	1516.84
10/13/87	86.09	1516.95
11/10/87	86.07	1516.97
12/03/87	85.92	1517.12
04/13/88	85.58	1517.46
05/27/88	85.92	1517.12
07/07/88	87.04	1516.00
07/28/88	87.49	1515.55
09/02/88	88.17	1514.87
10/05/88	88.21	1514.83
11/02/88	87.92	1515.12

150-071-29AAB
Manfred aquifer LS Elev (msl,ft)= 1599.30 SI (ft)= 100-103

Date	Depth to Water (ft)	WL Elev (msl,ft)
07/19/67	7.68	1591.62
08/16/67	8.17	1591.13
10/26/67	7.58	1591.72
12/28/67	7.62	1591.68
01/30/68	8.02	1591.28
02/14/68	7.79	1591.51
03/15/68	7.91	1591.39
04/16/68	8.15	1591.15
05/01/68	8.17	1591.13
05/28/68	8.22	1591.08
06/27/68	8.31	1590.99
07/26/68	8.47	1590.83
09/27/68	8.25	1591.05
10/25/68	8.19	1591.11
01/30/69	7.99	1591.31
05/26/69	8.29	1591.01
07/25/69	8.29	1591.01
12/20/69	8.07	1591.23
03/11/70	8.30	1591.00
06/11/70	8.01	1591.29
07/20/70	8.06	1591.24
09/03/70	8.00	1591.30
11/30/70	7.48	1591.82
03/04/71	7.51	1591.79
06/08/71	7.76	1591.54
09/07/71	7.28	1592.02
12/01/71	6.74	1592.56
03/07/72	6.41	1592.89
06/05/72	7.25	1592.05
08/31/72	7.36	1591.94
12/06/72	7.15	1592.15
04/03/73	7.96	1591.34
06/01/73	8.12	1591.18
09/06/73	8.49	1590.81
12/04/73	8.34	1590.96
03/04/74	8.36	1590.94
05/21/74	8.45	1590.85
09/03/74	8.42	1590.88
12/02/74	7.81	1591.49
07/11/75	7.65	1591.65
09/05/75	7.82	1591.48
12/02/75	7.37	1591.93
02/23/76	7.29	1592.01
06/01/76	7.92	1591.38
09/07/76	7.84	1591.46
11/30/76	7.85	1591.45
03/02/77	7.84	1591.46
05/31/77	8.54	1590.76
08/29/77	8.91	1590.39
11/29/77	8.50	1590.80
01/03/78	8.39	1590.91
02/09/78	8.58	1590.72
03/01/78	8.62	1590.68

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/78	8.81	1590.49
05/31/78	8.93	1590.37
07/06/78	10.08	1589.22
07/31/78	9.81	1589.49
09/06/78	9.54	1589.76
10/06/78	9.26	1590.04
11/01/78	9.03	1590.27
11/29/78	8.80	1590.50
01/03/79	8.64	1590.66
02/02/79	8.54	1590.76
02/26/79	8.41	1590.89
03/29/79	8.39	1590.91
04/30/79	8.40	1590.90
06/04/79	8.25	1591.05
07/02/79	8.03	1591.27
08/07/79	8.06	1591.24
09/04/79	7.94	1591.36
10/04/79	7.91	1591.39
11/09/79	7.75	1591.55
11/27/79	7.65	1591.65
03/12/80	7.66	1591.64
04/03/80	7.92	1591.38
05/02/80	8.15	1591.15
06/11/80	8.46	1590.84
08/14/80	8.83	1590.47
09/11/80	8.53	1590.77
10/01/80	8.41	1590.89
11/03/80	8.04	1591.26
12/02/80	7.81	1591.49
03/05/81	7.47	1591.83
04/16/81	7.61	1591.69
06/04/81	7.56	1591.74
07/16/81	7.38	1591.92
09/03/81	7.56	1591.74
10/19/81	7.08	1592.22
12/02/81	7.25	1592.05
06/09/82	7.88	1591.42
07/07/82	6.70	1592.60
08/10/82	6.62	1592.68
10/19/82	8.38	1590.92
12/01/82	6.31	1592.99
02/14/83	6.48	1592.82
03/30/83	6.49	1592.81
05/02/83	6.65	1592.65
06/20/83	6.56	1592.74
07/19/83	6.53	1592.77
09/07/83	6.80	1592.50
10/18/83	6.61	1592.69
11/29/83	6.18	1593.12
03/12/84	6.41	1592.89
04/23/84	6.56	1592.74
06/04/84	6.39	1592.91
07/19/84	6.69	1592.61
08/30/84	7.01	1592.29
10/22/84	6.97	1592.33
11/28/84	7.09	1592.21
05/13/85	7.59	1591.71

150-071-29AAB (continued)
Manfred aquifer

LS Elev (msl,ft)= 1599.30 SI (ft)= 100-103

Date	Depth to Water (ft)	WL Elev (msl,ft)
06/85/85	7.78	1591.52
07/29/85	8.14	1591.16
09/17/85	7.83	1591.47
12/03/85	7.57	1591.73
06/03/86	7.17	1592.13
07/10/86	7.18	1592.12
08/18/86	7.37	1591.93
10/01/86	7.30	1592.00
10/08/86	7.31	1591.99
10/22/86	7.24	1592.06
11/19/86	7.03	1592.27
12/03/86	7.34	1591.96
12/10/86	7.04	1592.26
01/08/87	7.08	1592.22
01/28/87	7.04	1592.26
02/11/87	7.07	1592.23
03/26/87	7.05	1592.25
05/06/87	7.23	1592.07
05/27/87	7.11	1592.19
07/13/87	7.24	1592.06
09/11/87	7.02	1592.28
10/13/87	6.97	1592.33
11/10/87	6.97	1592.33
12/03/87	6.88	1592.42
04/13/88	7.35	1591.95
05/27/88	8.17	1591.13
07/07/88	8.34	1590.96
07/28/88	8.44	1590.86
09/02/88	8.55	1590.75
10/05/88	8.68	1590.62
11/02/88	8.65	1590.65

150-071-32BCC
Manfred aquifer

LS Elev (msl,ft)= 1612.10 SI (ft)= 230-235

Date	Depth to Water (ft)	WL Elev (msl,ft)
04/13/88	12.65	1599.45
05/27/88	12.80	1599.30
07/07/88	13.02	1599.08
07/28/88	13.24	1598.86
09/02/88	13.45	1598.65
10/05/88	13.62	1598.48
11/02/88	13.56	1598.54

150-071-32BCC1
Manfred aquifer

LS Elev (msl,ft)= 1612.30 SI (ft)= 105-110

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	12.63	1599.67
10/01/86	12.53	1599.77
10/22/86	12.51	1599.79
10/22/86	12.52	1599.78
12/10/86	12.29	1600.01
12/10/86	12.33	1599.97
01/08/87	12.41	1599.89
01/08/87	12.35	1599.95
01/28/87	12.43	1599.87
01/28/87	12.30	1600.00
02/11/87	12.47	1599.83
02/11/87	12.33	1599.97
03/26/87	12.41	1599.89
03/26/87	12.28	1600.02
05/06/87	12.73	1599.57
05/06/87	12.62	1599.68
05/27/87	12.60	1599.70
05/27/87	12.47	1599.83
07/13/87	12.81	1599.49
07/13/87	12.61	1599.69
09/11/87	12.95	1599.35
09/11/87	12.70	1599.60
10/13/87	12.90	1599.40
10/13/87	12.60	1599.70
11/10/87	12.97	1599.33
11/10/87	12.64	1599.66
12/03/87	12.86	1599.44
12/03/87	12.59	1599.71
04/13/88	12.92	1599.38
05/27/88	13.15	1599.15
07/07/88	13.37	1598.93
07/28/88	13.60	1598.70
09/02/88	13.77	1598.53
10/05/88	13.89	1598.41
11/02/88	13.83	1598.47

150-071-36ADD

New Rockford aquifer — LS Elev (msl,ft)= 1594.80 — SI (ft)= 286-291

Date	Depth to Water (ft)	WL Elev (msl,ft)
10/01/86	77.25	1517.55
10/22/86	77.16	1517.64
11/19/86	76.82	1517.98
12/10/86	76.75	1518.05
01/08/87	76.77	1518.03
01/28/87	76.66	1518.14
02/10/87	76.68	1518.12
03/26/87	76.16	1518.64
05/06/87	76.58	1518.22
05/27/87	76.69	1518.11
07/13/87	77.30	1517.50

Date	Depth to Water (ft)	WL Elev (msl,ft)
09/11/87	77.45	1517.35
10/13/87	77.32	1517.48
11/10/87	77.30	1517.50
12/03/87	77.07	1517.73
04/13/88	76.79	1518.01
05/27/88	77.15	1517.65
07/07/88	78.16	1516.64
07/28/88	78.64	1516.16
09/02/88	79.32	1515.48
10/05/88	79.43	1515.37
11/02/88	79.11	1515.69