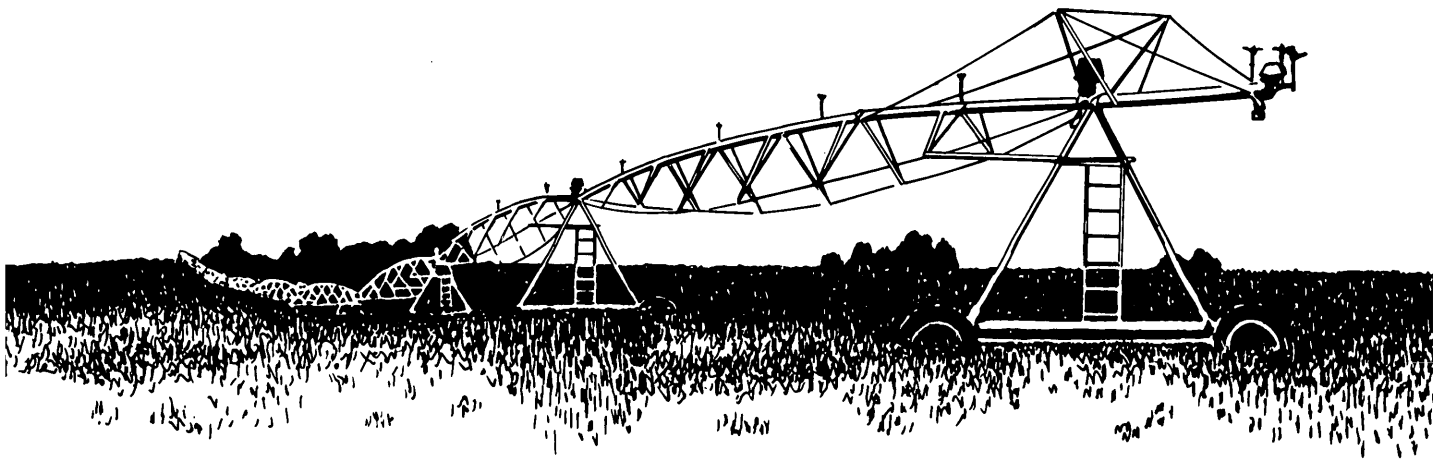
BURIED AQUIFERS IN THE BROOTEN-BELGRADE AND LAKE EMILY AREAS, WEST-CENTRAL MINNESOTA---FACTORS RELATED TO DEVELOPING WATER FOR IRRIGATION



U. S. GEOLOGICAL SURVEY

Water–Resources Investigations 76–100

Open–File Report

Prepared in cooperation with the WesMin Resource Conservation and Development Project Committee and the Minnesota Department of Natural Resources Division of Waters

BURIED AQUIFERS IN THE BROOTEN-BELGRADE AND LAKE EMILY AREAS, WEST-CENTRAL MINNESOTA--FACTORS RELATED TO DEVELOPING WATER FOR IRRIGATION

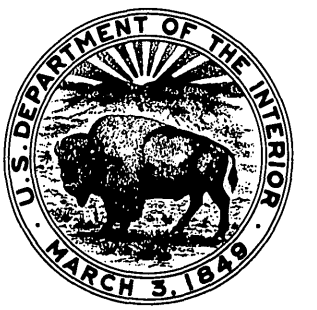
By Ronald J. Wolf

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-100

Open-File Report

Prepared in cooperation with the
WesMin Resource Conservation and
Development Project Committee and
the Minnesota Department of Natural
Resources Division of Waters



September 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

Open-File Report

For additional information write to:

U.S. Geological Survey
1033 Post Office Building
St. Paul, Minnesota 55101

CONTENTS

ILLUSTRATIONS

(Plates are in pocket)

Page

TABLES

CONVERSION FACTORS

For the convenience of those who prefer to use International System (metric) units rather than English units, the conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
feet (ft)	0.3048	metres (m)
miles (mi)	1.609	kilometres (km)
acres	0.4047	hectares (ha)
square miles (mi^2)	2.590	square kilometres (km^2)
gallons per minute (gal/min)	0.06309	litres per second (l/s)
feet per day ($ft\ day^{-1}$)	0.3048	metres per day ($m\ day^{-1}$)
feet squared per day ($ft^2\ day^{-1}$)	0.0929	metres squared per day ($m^2\ day^{-1}$)

BURIED AQUIFERS IN THE BROOTEN-BELGRADE AND LAKE EMILY AREAS, WEST-CENTRAL MINNESOTA--FACTORS RELATED TO DEVELOPING WATER FOR IRRIGATION

By Ronald J. Wolf

ABSTRACT

Irrigation has given a substantial boost to the economy in the Brooten-Belgrade and Lake Emily areas. The surficial outwash aquifer is capable of yielding sufficient quantities of water for irrigation over half of its area; the remaining part may be supplied by deep aquifers. Buried glacial outwash and Cretaceous sand aquifers, as thick as 50 feet (15 metres) occur to depths of 300 feet (91 metres). In places, the buried aquifers are sufficiently thick and permeable to yield large quantities of water to wells. The buried aquifers are probably narrow, elongate, truncated bodies enclosed by clay till. The Precambrian surface, ranging from 190 to 350 feet (58 to 107 metres) below the land surface, is the lower limit of the buried aquifers.

Water in the buried-drift aquifers is a very hard calcium magnesium bicarbonate type, suitable for irrigation needs. Water in Cretaceous aquifers, although untested, is expected to be higher in dissolved solids.

Potential water problems include slow rate of recharge to buried aquifers, and head loss caused by screening of the surficial and buried aquifers in the same well, and by allowing wells to flow unabated. Another potential problem is possible pollution of the buried aquifers through the boreholes of multiaquifer wells.

INTRODUCTION

Irrigation has given a substantial boost to the agricultural economy in the Brooten-Belgrade and Lake Emily areas, popularly known as the Bonanza Valley, in west-central Minnesota. Surficial sand and gravel aquifers, described by Van Voast (1971 a, b), provide a ready source of water for irrigation in much of the area where droughty soils yield marginal crops during dry years. Although wells tapping the surficial aquifer yield 100 to 1,000 gal/min (6 to 60 l/s) over about half its areal extent, yields in the remainder of the area are lower. In places, buried aquifers occur beneath the surficial aquifer, and they may provide a source for irrigation water in areas where the surficial aquifer is inadequate.

Purpose and Scope

The purpose of this report is to determine, as far as possible, the occurrence of buried aquifers and to describe their hydrologic characteristics

and water-yielding capability. The evaluation is based mainly on 44 test holes drilled specifically for this investigation. These test holes are too widely spaced to correlate individual aquifers. Such correlation must await more detailed closely spaced test drilling. Forty-two test holes were drilled in the Brooten-Belgrade area; hence the mapping is restricted to this part. Two test holes were drilled in the Lake Emily area, allowing only one geologic section to be presented. Plan-view mapping would require considerable additional test drilling.

The investigation was conducted in cooperation with the WesMin Resource Conservation and Development Project Committee and the Minnesota Department of Natural Resources, Division of Waters.

Location and Extent

The project area is in west-central Minnesota about 125 miles (200 km) west of Minneapolis and St. Paul. It coincides with areas of previous investigations (Van Voast, 1971 a, b) of the surficial aquifer in the Brooten-Belgrade and Lake Emily sand-plain areas (fig. 1). The Brooten-Belgrade part of the area includes about 300 square miles (780 sq km) in eastern Pope County, northern Kandiyohi County, and southwestern Stearns County. The Lake Emily part includes about 35 square miles (91 sq km) in southwestern Pope County.

Previous Reports

An early investigation of the general geology by Upham (1888) included the Brooten-Belgrade and Lake Emily areas; some well data were included. Reports on the geology and underground waters of southern Minnesota by Hall, Meinzer, and Fuller (1911) and by Thiel (1944) describe the part of Kandiyohi County included in this study. The parts of Pope and Stearns Counties included in the study area are described in a report by Allison (1932) on the geology and water resources of northwestern Minnesota. The area was briefly mentioned in Leverett's (1932) report on the glacial geology of Minnesota and adjacent States. A general description of the geology and water resources of the study area is presented in the hydrologic atlases of the Chippewa River watershed by Cotter and others (1968), the Crow River watershed by Lindholm and others (1974, and the Mississippi and Sauk Rivers watershed by Helgesen and others (1975). Van Voast (1971 a, b) presented a more detailed study of the hydrology of the area, with emphasis on ground-water availability for irrigation from the surficial aquifer.

Methods of Investigation

Fieldwork started in 1973 and consisted of collecting geologic and hydrologic information. Selected deep irrigation and domestic wells were inventoried, and 44 test holes were drilled in the glacial deposits and Cretaceous sedimentary rocks. The test holes, drilled by the hydraulic rotary method, averaged about 275 feet (85 m) deep. More than 1,000 samples were collected from the drill cuttings, and selected samples were analyzed for particle-size distribution. Electric logs, run in each hole after drilling, supplied

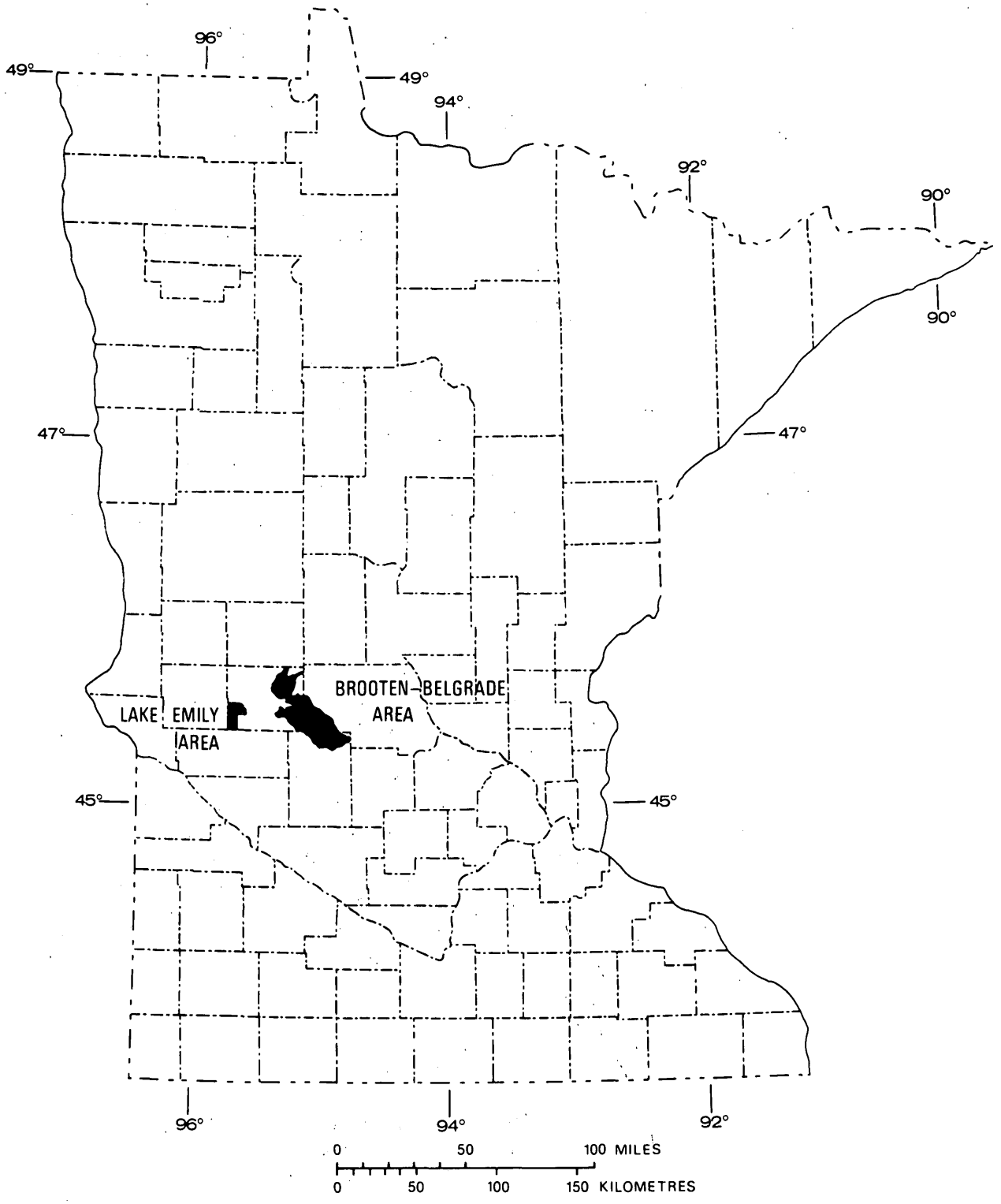


Figure 1.--Map of Minnesota showing location of areas discussed in this report.

additional information about thicknesses and geologic characteristics of the strata penetrated. A 24-hour pumping test involving irrigation wells finished in a buried sand bed at a site about 2½ miles (4 km) northwest of Brooten was made to determine aquifer characteristics. Chemical analyses were made of water from three deep wells in the area, and previously published and unpublished chemical analyses were assembled.

Test-Hole Numbering System

The system of numbering test holes and wells in Minnesota is based on the U.S. Bureau of Land Management's system of subdivision of the public lands. The Brooten-Belgrade and Lake Emily areas are in the fifth-principal-meridian and base-line system. The first segment of a test hole or well number indicates the township north of the base line; the second, the range west of the principal meridian; and the third, the section in which the test hole is situated. The lowercase letters, a, b, c, and d, following the section number, locate the well within the section. The first letter denotes the 160-acre (65 ha) tract, the second the 40-acre (16 ha) tract, and the third the 10-acre (4 ha) tract as shown in figure 2. The letters are assigned in a counterclockwise direction beginning in the northeast quarter. Within one 10-acre (4 ha) tract, successive well numbers, beginning with 1, are added as suffixes. Figure 2 illustrates the method of numbering a test hole or well. The number 123.35.4dad1 indicates the first test hole or well located in the SE¼NE¼SE¼ sec.4, T.123 N., R.35 W.

Sequential project test-hole numbers were assigned to each hole as drilling progressed. For readability and convenience, the project numbers are used in the text and illustrations. The location numbers, as described in the preceding paragraph, and the project test-hole numbers are given in table 1 (p. 36), so that each test hole may be located to the nearest 10-acre (4 ha) tract.

Acknowledgments

The author is grateful for information provided by property owners and well drillers. Special acknowledgment is given to those who permitted the drilling of test holes on their land and to irrigators who permitted use of their wells and equipment for measurement of water levels and for aquifer testing.

GEOLOGY

The rocks underlying the Brooten-Belgrade and Lake Emily areas are of Precambrian, Cretaceous, and Quaternary ages. Precambrian and Cretaceous bedrock lie buried by 125 to 350 feet (38 to 107 m) of Quaternary drift deposits, which form the present land surface.

Precambrian

Crystalline rocks of Precambrian age form the basement complex. The rocks are mostly granitic, and their upper surface is weathered to a soft,

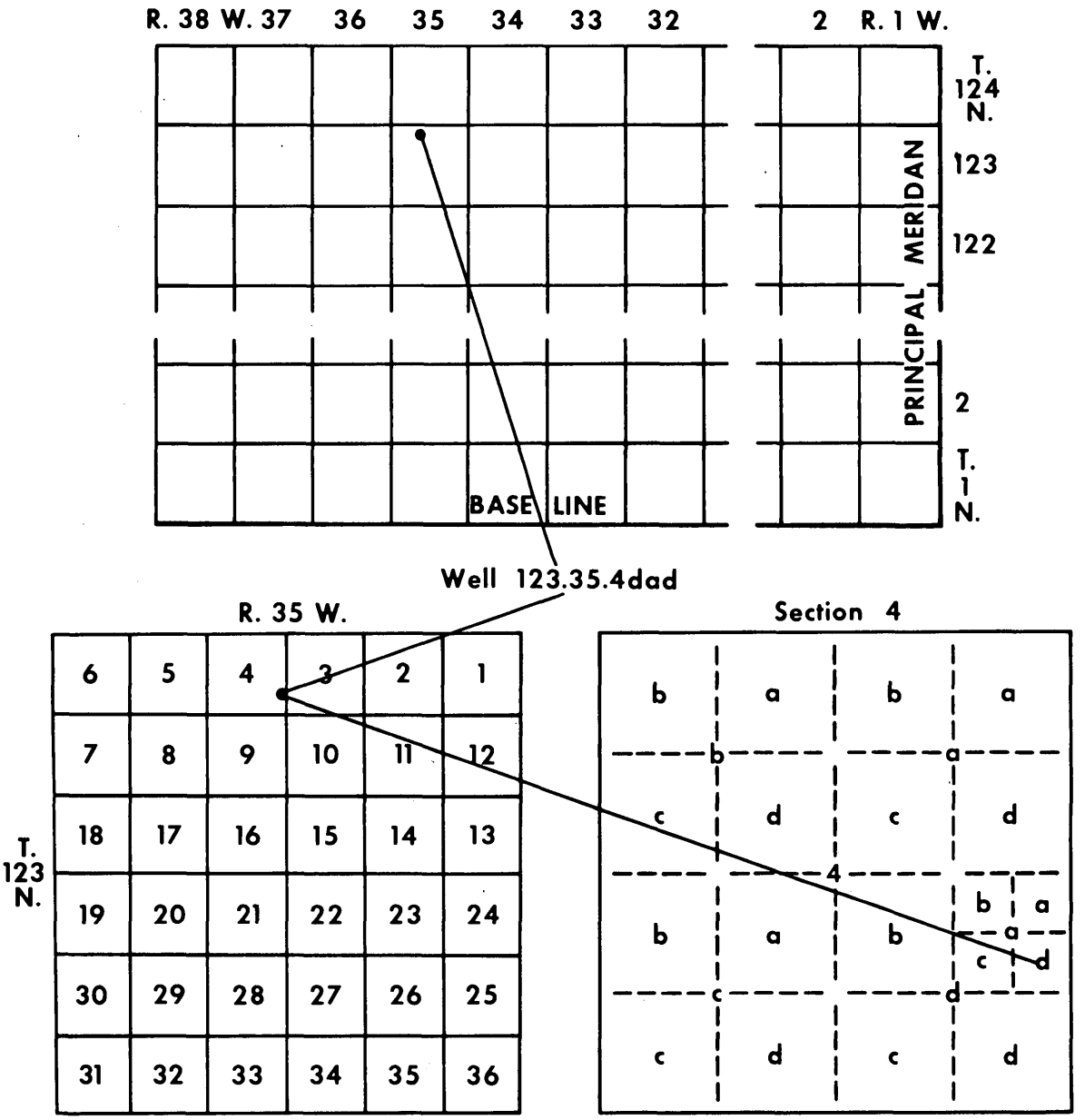


Figure 2.--Test-hole and well numbering system.

kaolinitic clay, containing an abundance of quartz grains and, in places, minor amounts of mica and feldspar. This weathered zone is recognized by most local drillers as "decomposed" granite. The Precambrian is not mapped in the Lake Emily area. Plate 1 shows the configuration of the Precambrian surface in the Brooten-Belgrade area. This surface has a total relief of over 200 feet (61 m) and ranges from about 190 to 350 feet (58 to 107 m) below the present land surface. A prominent feature of the Precambrian surface is a valley network eroded into the rocks by an ancient drainage system. The main valley extends eastward from Tamarack Lake. Tributary valleys extend from the main valley northwestward along the axis of the study area, northward from Belgrade, and southward from Regal. Divides of the ancient drainage appear as highs on the buried surface along the northeast side of the area, west of Brooten, south of Georgeville, and on the southeast edge of the area.

Cretaceous

Sedimentary rocks of Cretaceous age overlie the Precambrian basement complex and underlie drift. The rocks are generally soft varicolored shale beds interbedded with poorly consolidated or loosely cemented siltstone and sandstone. The Cretaceous rocks are sporadic, and are generally less than 100 feet (30 m) thick. The deposits are absent in several areas, especially where the Precambrian surface is high. Test holes indicated the presence of Cretaceous rocks in the Lake Emily area (fig. 16) and in about half of the Brooten-Belgrade area (pl. 2).

The major feature on the Cretaceous surface is a deep eastward-trending valley, which coalesces with the main valley on the Precambrian surface (pl. 1) in the south-central part of the area. Total relief on the Cretaceous surface is about 160 feet (49 m).

Quaternary

Drift of Wisconsin age is exposed in the project area (pl. 3 and fig. 3). Older pre-Wisconsin drift occurs in the subsurface and is identified by drill cuttings of buried soil zones, outwash deposits, and oxidized till. The drift directly overlies Cretaceous sedimentary or Precambrian crystalline bedrock and ranges in thickness from 125 feet (38 m) to 350 feet (107 m).

Drift consists of both nonstratified and stratified deposits ranging in size from clay to boulders. It is largely till, an unstratified, unsorted mixture of sand-through boulder-size material imbedded in a silty clay matrix. Till is deposited directly by glacial ice. Till occurs at depth throughout much of the area and is exposed southeast of Grove Lake and east of Amelia Lake.

Part of the drift consists of stratified sand and gravel deposits of outwash or ice-contact origin. These are largely composed of poorly sorted to well-sorted sand and gravel deposited adjacent to the ice (ice-contact deposits) or beyond the ice (outwash) by melt-water streams. Wide variations in grain size result from the constantly changing conditions of melt-water flow. In addition, highly irregular shapes and thicknesses of deposits result from continual shifting of the stream courses.

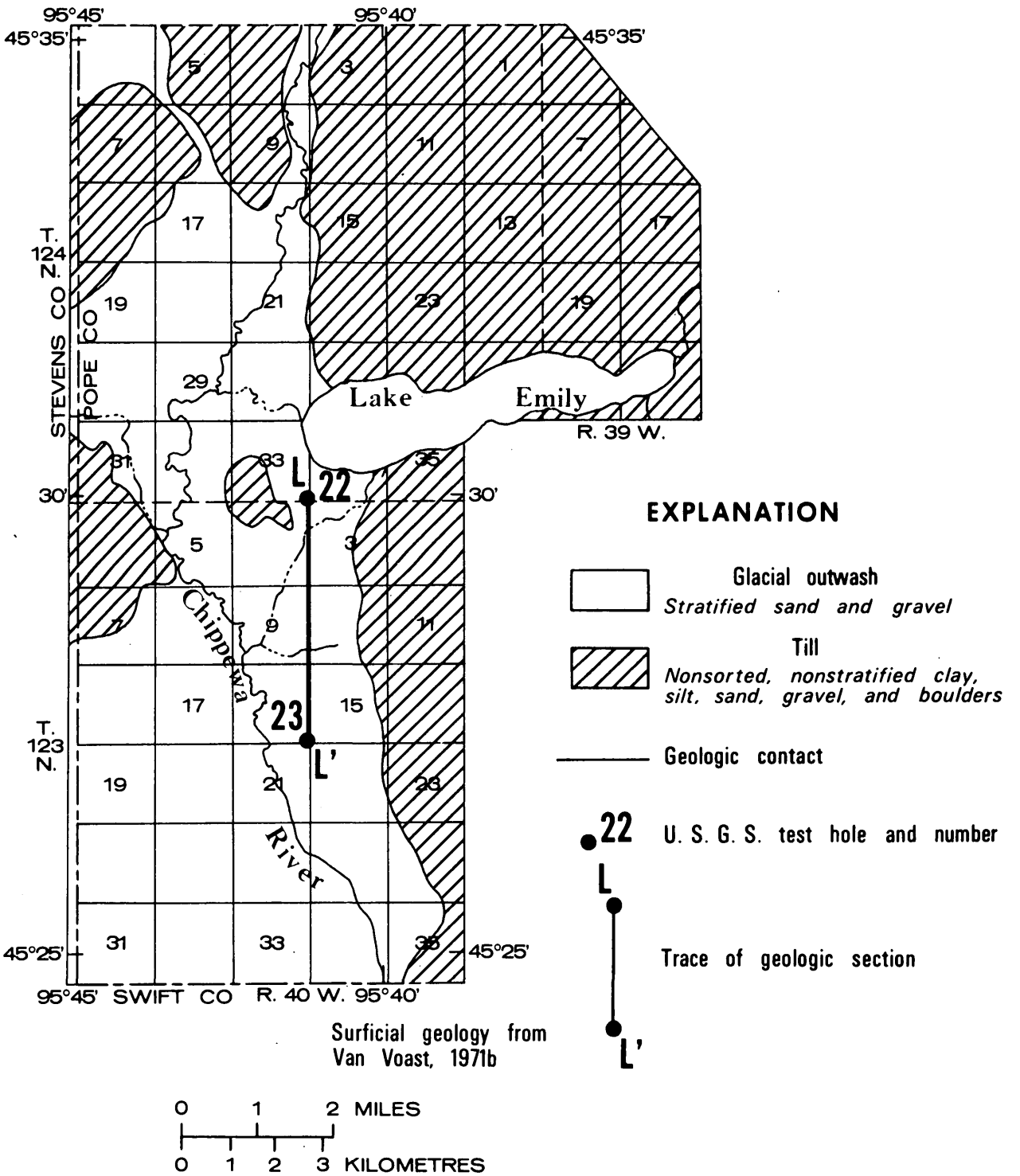


Figure 3.--Generalized surficial geology, location of of test holes, and trace of geologic section in the Lake Emily area.

Outwash forms the surficial materials throughout most of the project area. Ice-contact deposits and outwash occur at depth as isolated deposits throughout the area.

BURIED AQUIFERS IN THE BROOTEN-BELGRADE AND LAKE EMILY AREAS

The most widespread and significant aquifer is the surficial outwash which covers most of the area. Where the surficial outwash is less permeable, thin, or absent, buried aquifers may be an alternative source of water. Buried aquifers, as used in this report, are considered to be those aquifers underlying one or more confining layers of till. The aquifers are composed of sand, gravel, and sandstone, but are sometimes referred to as "sands" in this report.

Precambrian Aquifers

Although no wells finished in the Precambrian rocks are known in the study area, such wells have been drilled outside the area. Some water may occur in the upper part of the Precambrian in fracture zones of the rock or in the highly weathered residual material above the crystalline rock. These water-bearing zones probably do not yield water in quantities sufficient to support irrigation. Therefore, the top of the Precambrian rocks (pl. 1) represents, for all practical purposes, the lower limit of high-yielding aquifers.

Cretaceous and Drift Aquifers

Test drilling indicates that the buried drift and Cretaceous deposits, although differing in age and mode of deposition, are hydrologically similar. Coarse Cretaceous sands resemble the overlying lowermost glacial sands and are practically indistinguishable from them. Also, the lower confining layers of till, although not as indurated, are similar in appearance to the Cretaceous shale. Therefore, the drift and Cretaceous aquifers are discussed together in this section of the report.

Individual drift and Cretaceous aquifers range in depth from about 40 to 300 feet (12 to 91 m) below land surface and are as thick as 50 feet (15 m). Where permeable and thick enough, these aquifers are capable of initially yielding large quantities of water, but the long-term yields are unknown.

Delineation

Drift and Cretaceous deposits extending from the base of the surficial aquifer (pl. 4) to the Precambrian surface (pl. 1) range in thickness from about 160 to 340 feet (49 to 104 m) in the Brooten-Belgrade area, as shown in plate 5. The thickest deposits occur near Tamarack and Crow Lakes and in the central and extreme northwest parts of the area. Thickness of buried deposits in the Lake Emily area are shown in figure 16.

Layers, lenses, and stringers of permeable sand and gravel, interbedded with till in the drift, and sand, interbedded with shale in the Cretaceous

rocks, are potential aquifers. The cumulative thickness of these aquifers in each hole is shown on plate 5. These thicknesses range from 11 to 95 feet (3.4 to 29.0 m).

Composite lithologic logs of test holes are presented in table 1 (p. 36). The logs represent the geologic interpretation of all information available on each test hole, including electric logs. An electric log is a graph of the electrical properties of the strata penetrated by a borehole. As an electrode is lowered down the borehole electrical resistivity and spontaneous potential are recorded against depth. Electric logs are used to identify and correlate geologic strata and delineate thicknesses of water-yielding zones. An example of the electric log for test hole 13 is shown in figure 4.

Geologic interpretation of test-hole data is presented on geologic sections, which represent interpolations and correlations of data between test holes. The sections are shown in figures 5 through 16. Location of test holes and the trace of each section are shown on plate 3 and figure 3. Correlation of the highly variable buried sand and gravel beds between test holes would require a much larger number of closely spaced test holes than were available. Therefore, lines of correlation are shown only for the base of the surficial aquifer, top of the Cretaceous rocks, and the Precambrian surface.

Geologic section A-A' (fig. 5) trending northwest-southeast through the length of the study area, shows the top of the Precambrian crystalline rocks, the variable thickness and discontinuous Cretaceous deposits, and the nearly uniform thickness and the continuity of the Pleistocene surficial-outwash unit. The section also indicates the variable shape of the buried sand units, which occur at different altitudes. Test holes 35, 36, 11, 69-2, and 7 on section A-A' (fig. 5), 13 and 9 on section I-I' (fig. 13), and 15 on section C-C' (fig. 7), all in the vicinity of Brooten, Belgrade, and Georgeville, show thick, permeable sands probably capable of yielding large amounts of water to wells. However, buried sands are thin or absent in some adjacent test holes, such as in test holes 30 (fig. 12), 8 (fig. 5), and 32 (fig. 14). Sections B-B' (fig. 6) and E-E' (fig. 9) indicate the presence of thick, permeable sand units east and south of Villard at test holes 39, 27, and 28. Another promising area is southwest of Hawick, where geologic section K-K' (fig. 15) shows thick sands in test holes 4 and 1. Section L-L' (fig. 16) indicates a thick sand unit in test holes 22 and 23 in the Lake Emily area.

The geologic sections show that many areas are lacking thick sand units. Buried sands are thin or absent in test holes 25 (fig. 5) and 26 (fig. 8), north of Glenwood, and in test holes 40 and 38, southeast of Glenwood (fig. 10). Other areas that have little or no buried sands are east and south of Sedan, as shown in test holes along section G-G' (fig. 11), and north and east of Hawick, as shown by test holes 2 (fig. 5), 3, and 33 (fig. 15). Although the sections show no thick sands in these areas, future drilling may reveal some buried sands missed by the widely spaced test holes drilled for this study.

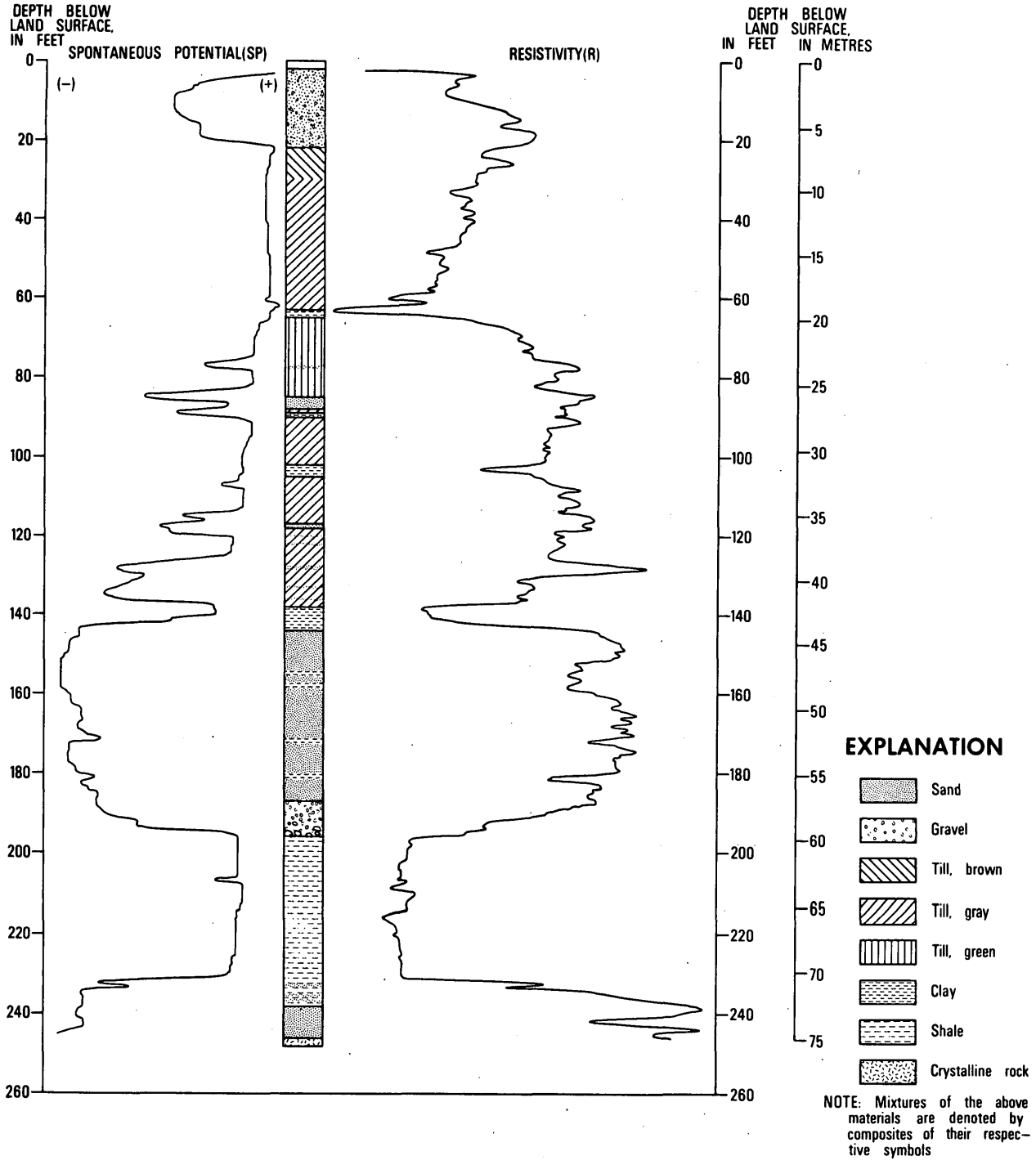


Figure 4.--Electrical responses in drift as shown by electric and composite lithologic strip logs of test hole 13.

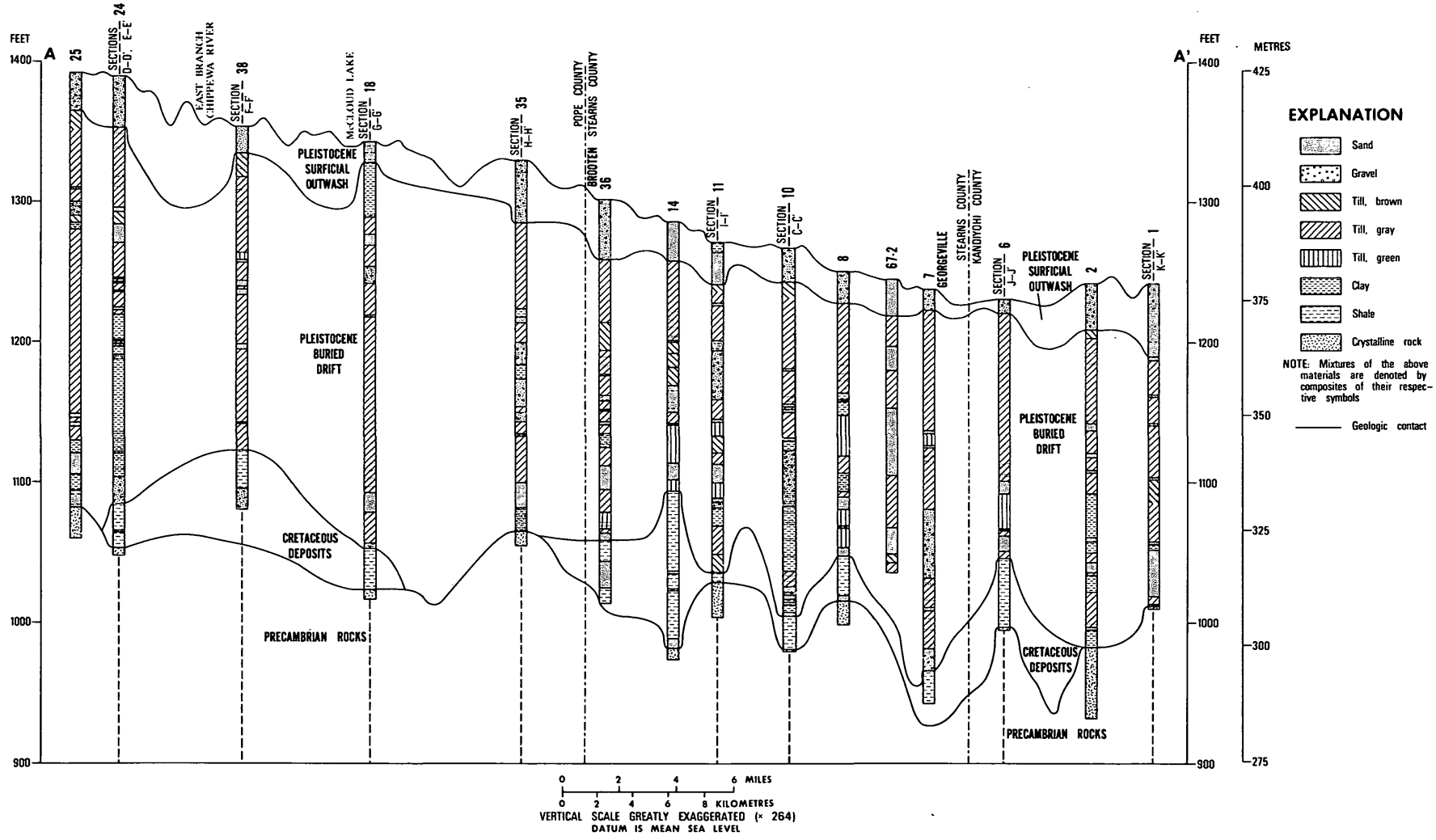


Figure 5.--Geologic section A-A' trending northwest to southeast through Brooten-Belgrade study area.

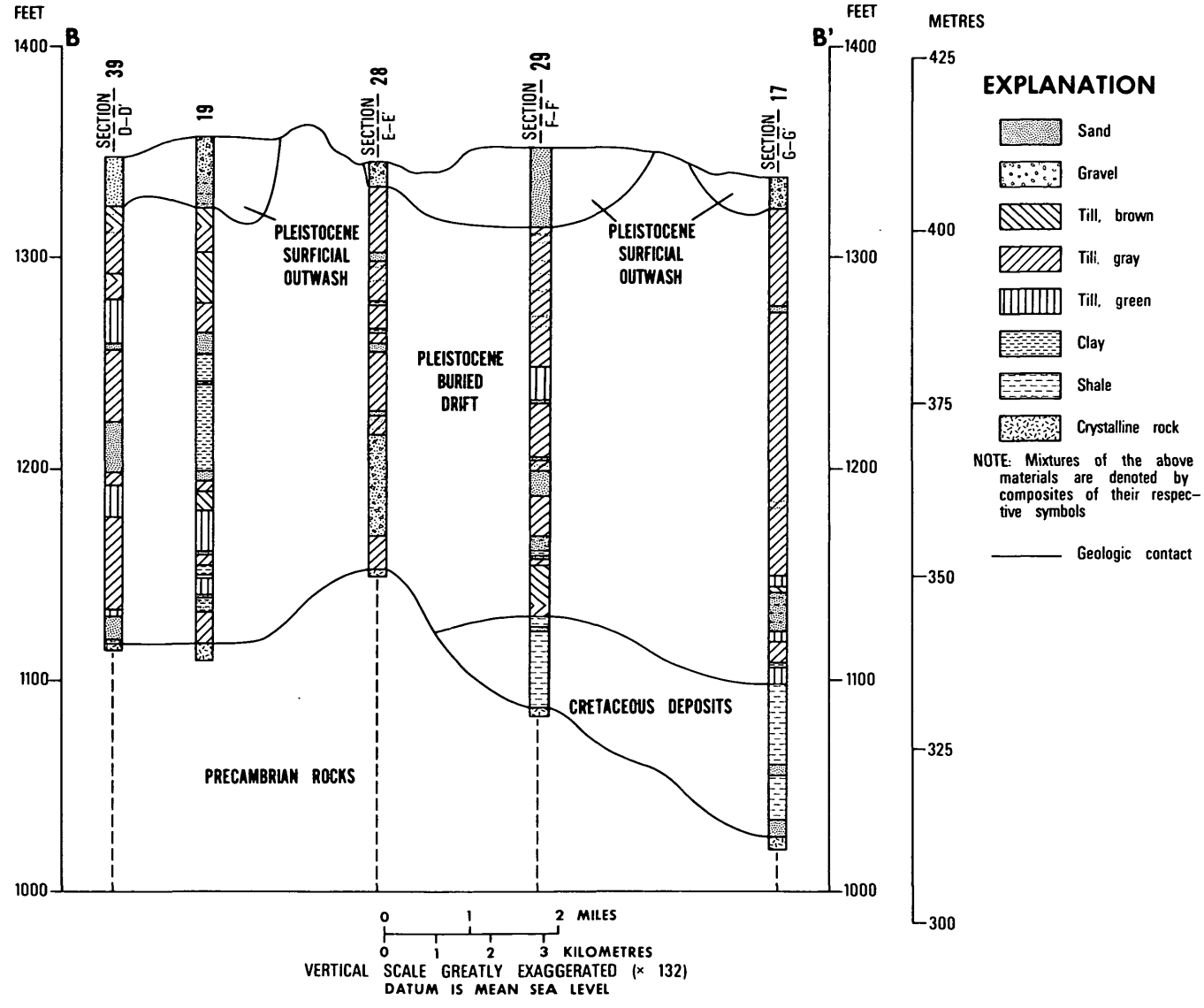


Figure 6.--Geologic section B-B' trending north to south near Westport Lake.

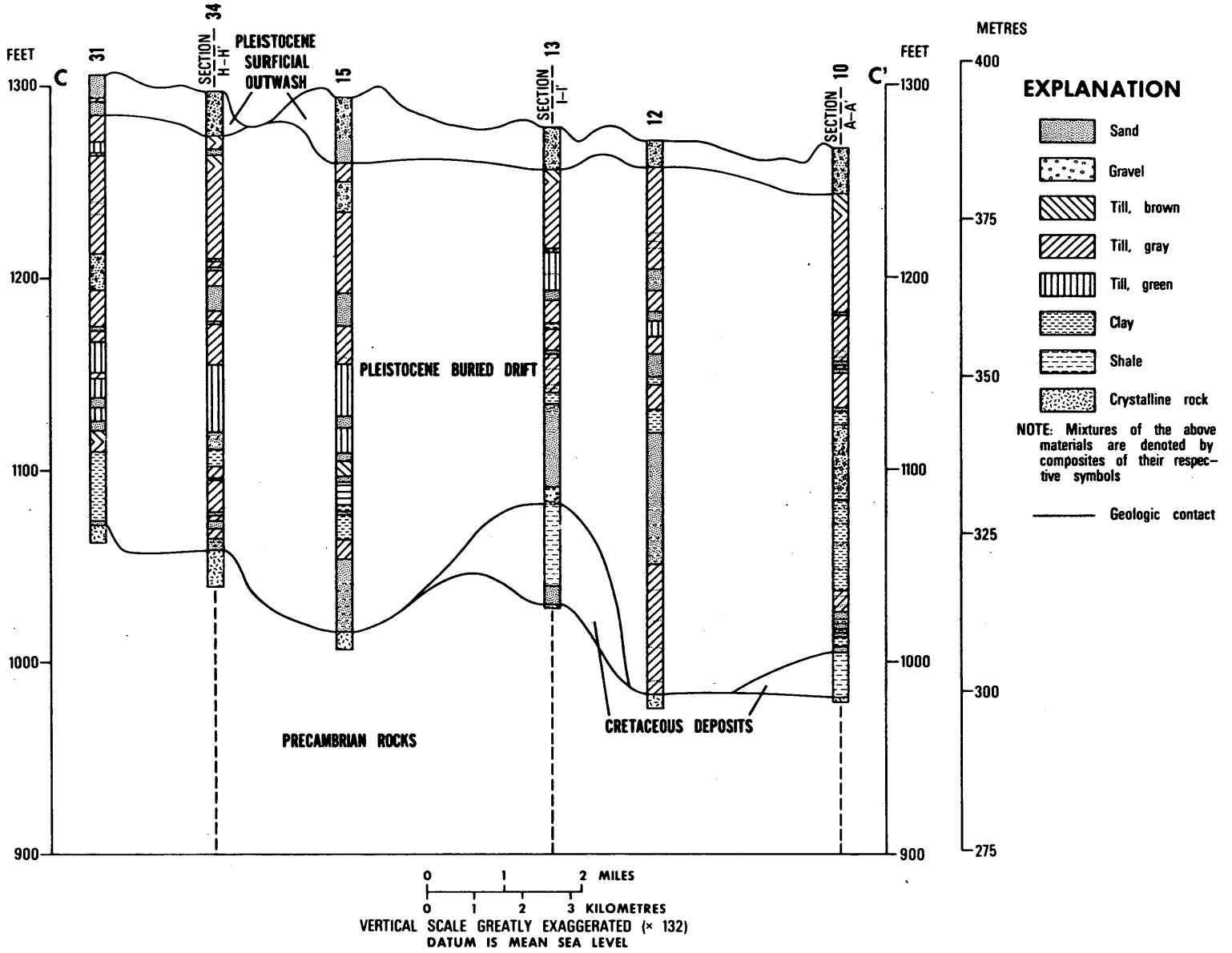


Figure 7.--Geologic section C-C' north of Brooten and Belgrade.

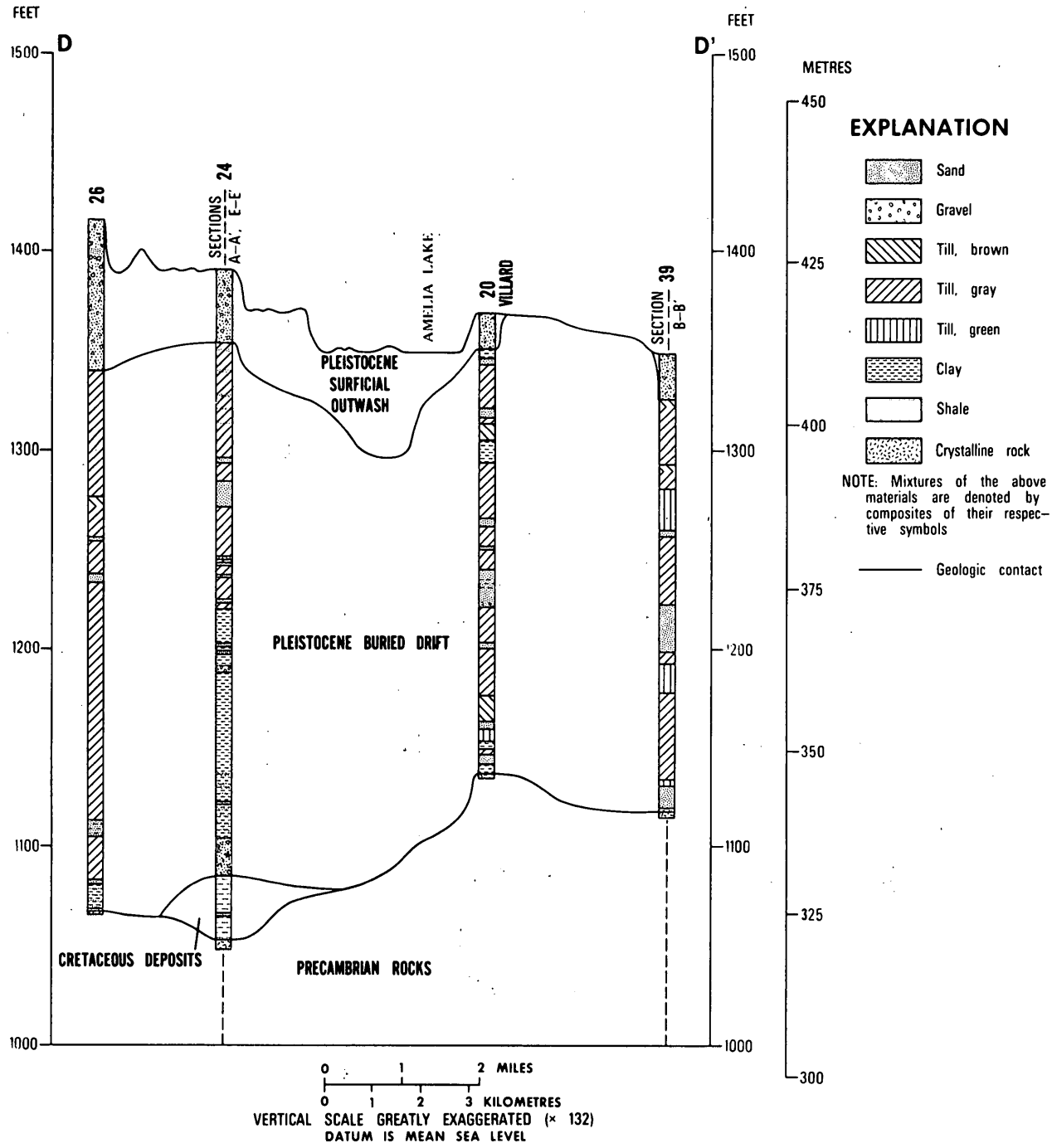


Figure 8.--Geologic section D-D' from Glenwood through Villard.

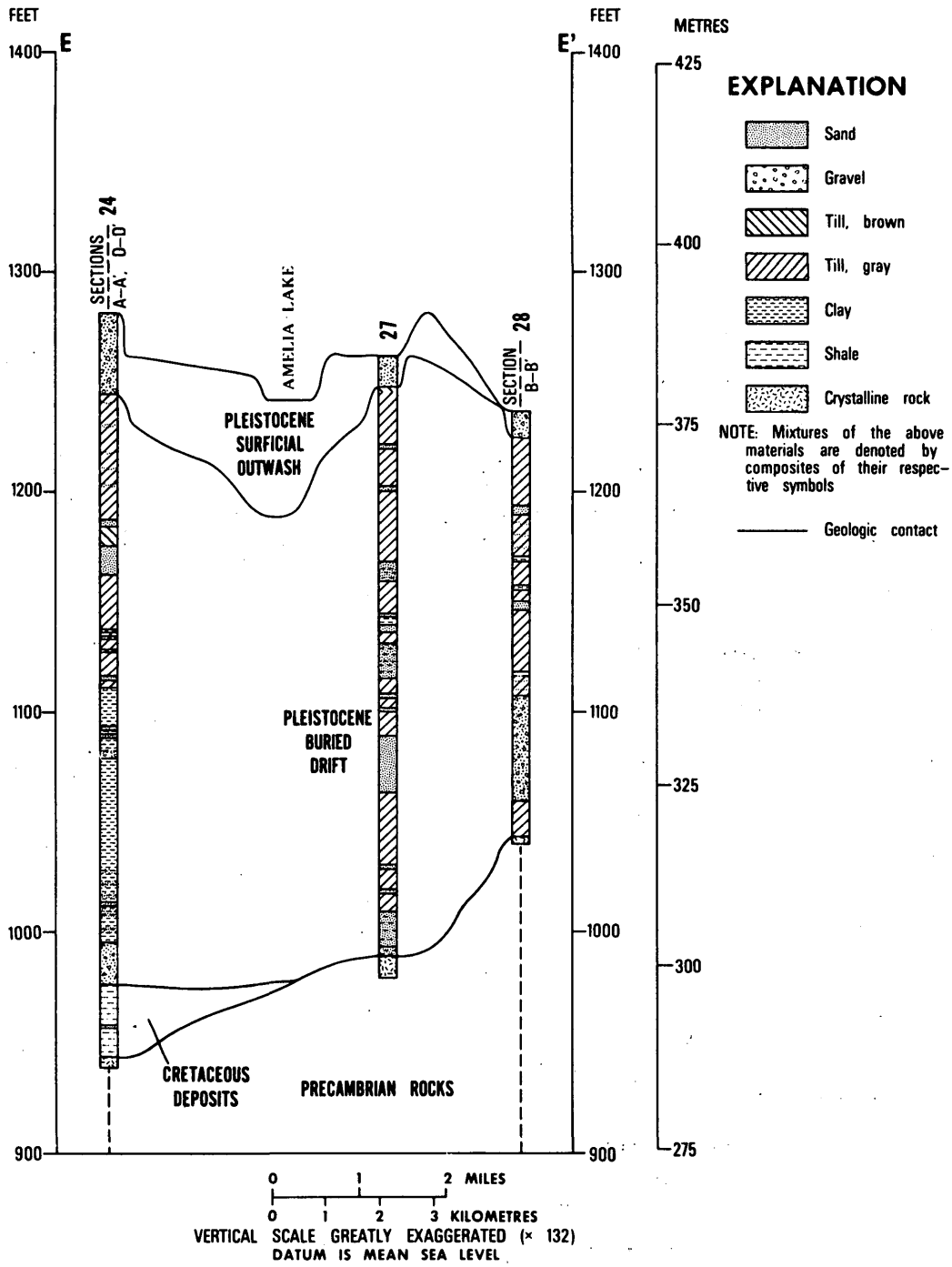


Figure 9.--Geologic section E-E' trending east from near Glenwood.

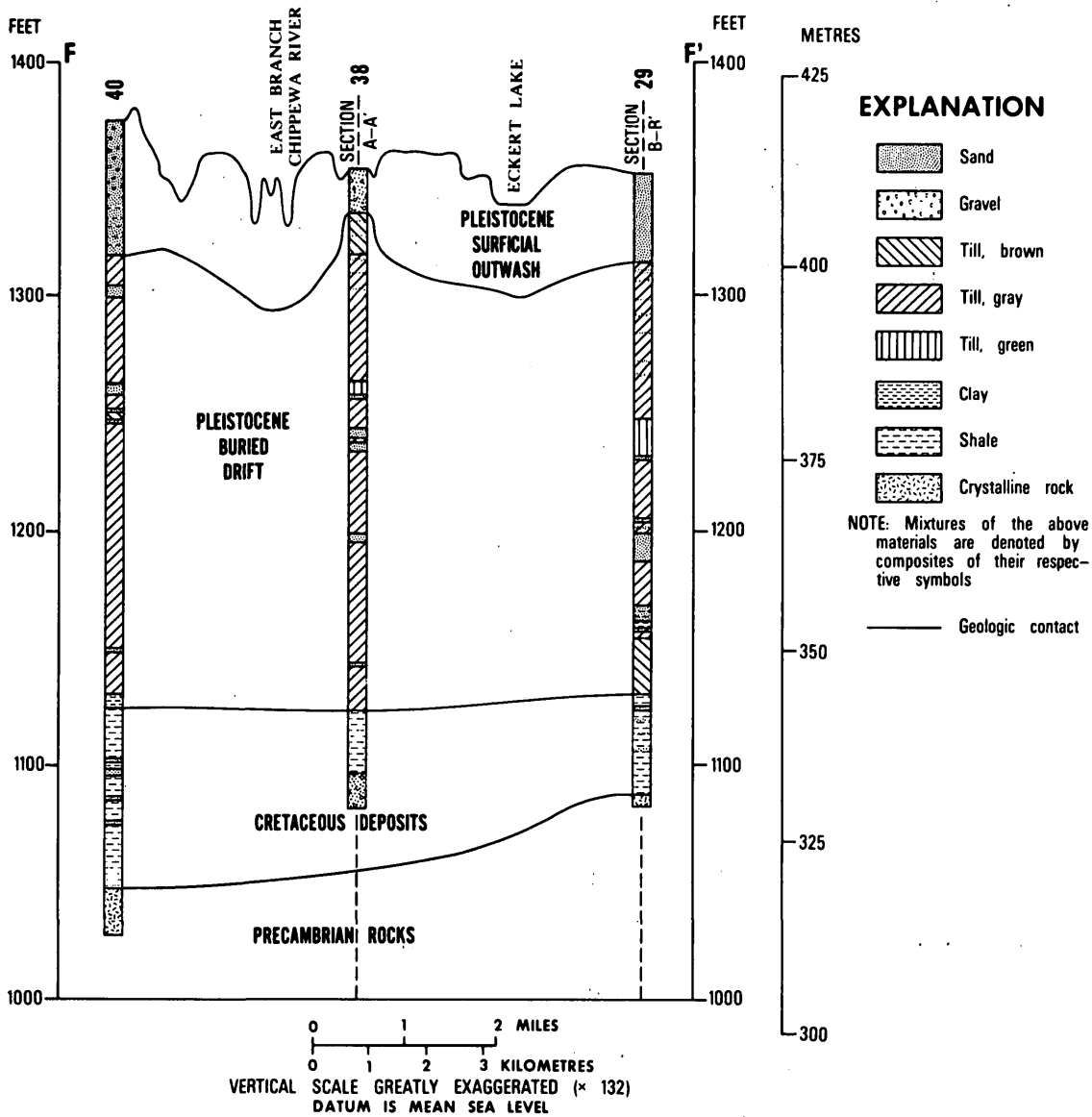


Figure 10.--Geologic section F-F' trending west to east, located between Glenwood and Sedan.

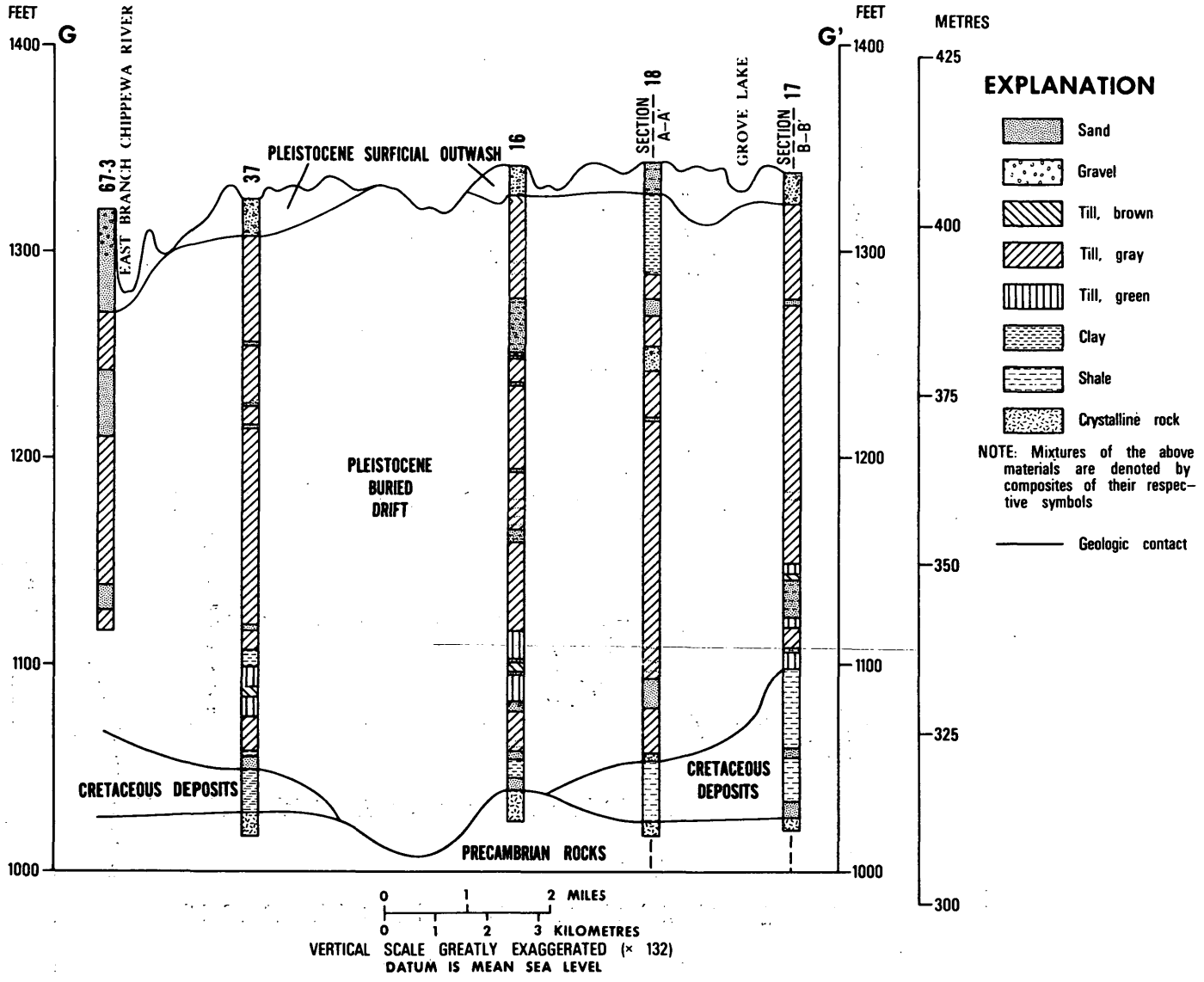


Figure 11.--Geologic section G-G' trending southwest to northeast from Terrace through Sedan.

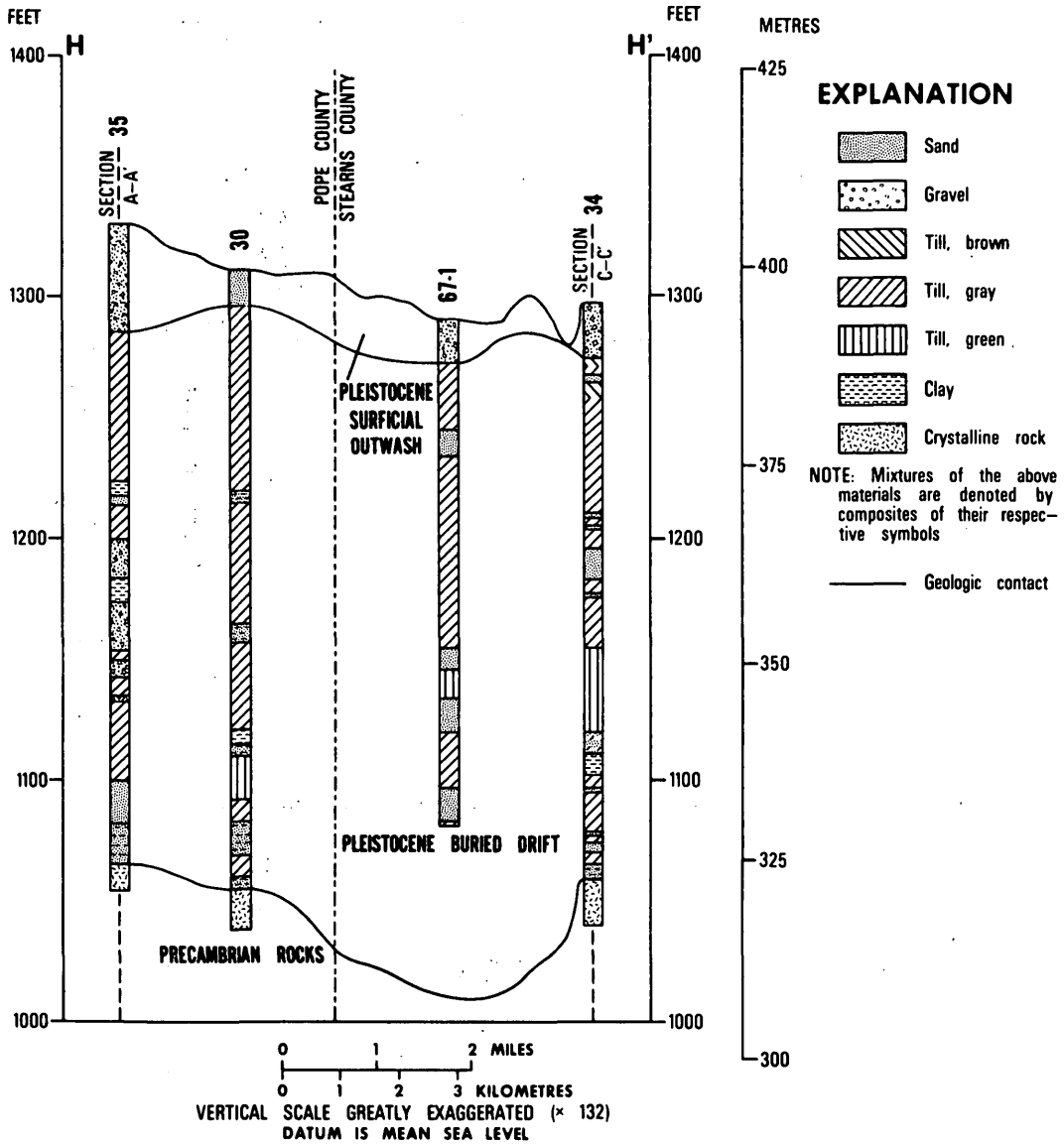


Figure 12.--Geologic section H-H' trending southwest to northeast located between Brooten and Sedan.

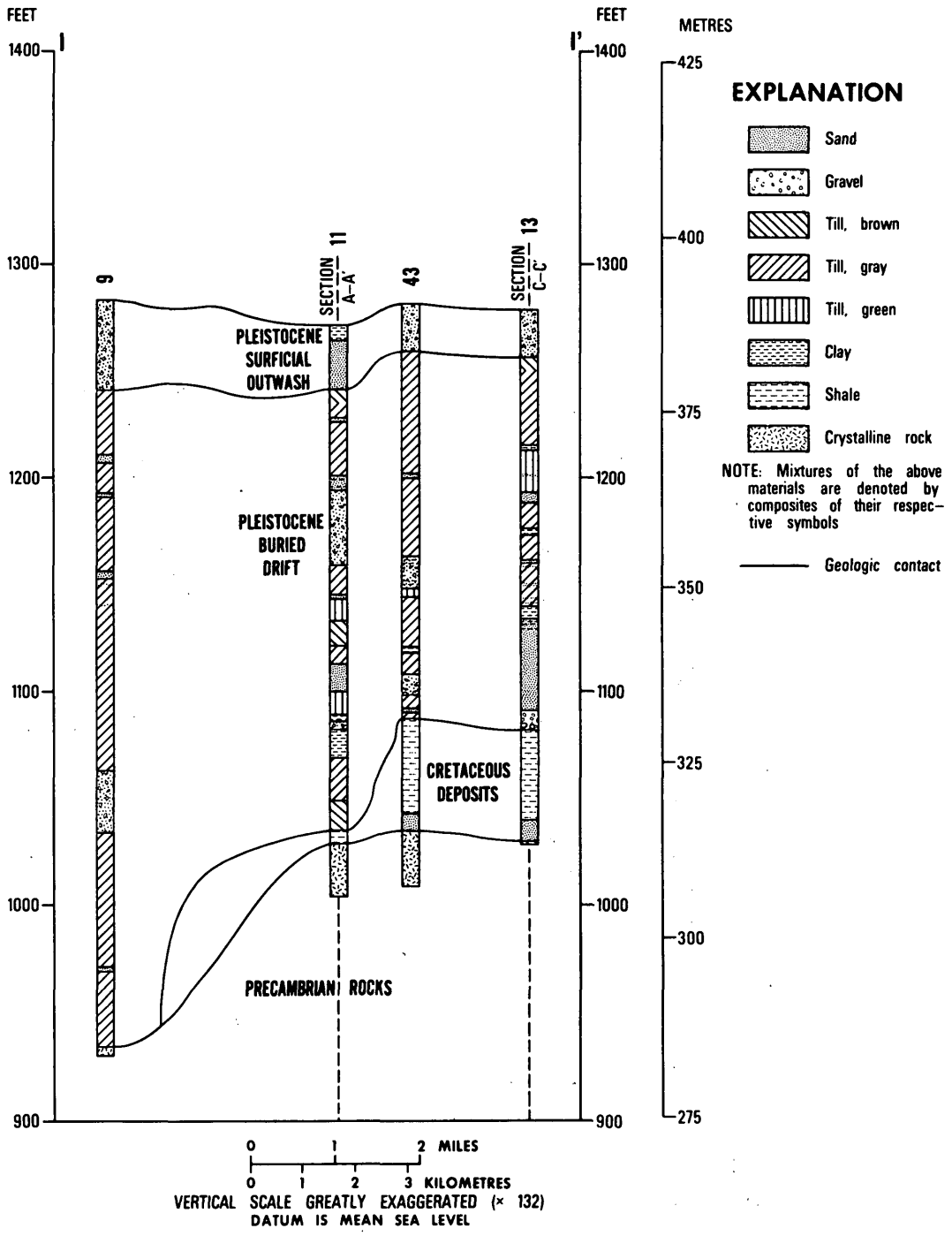


Figure 13.--Geologic section I-I' trending southwest to northeast, located between Brooten and Belgrade.

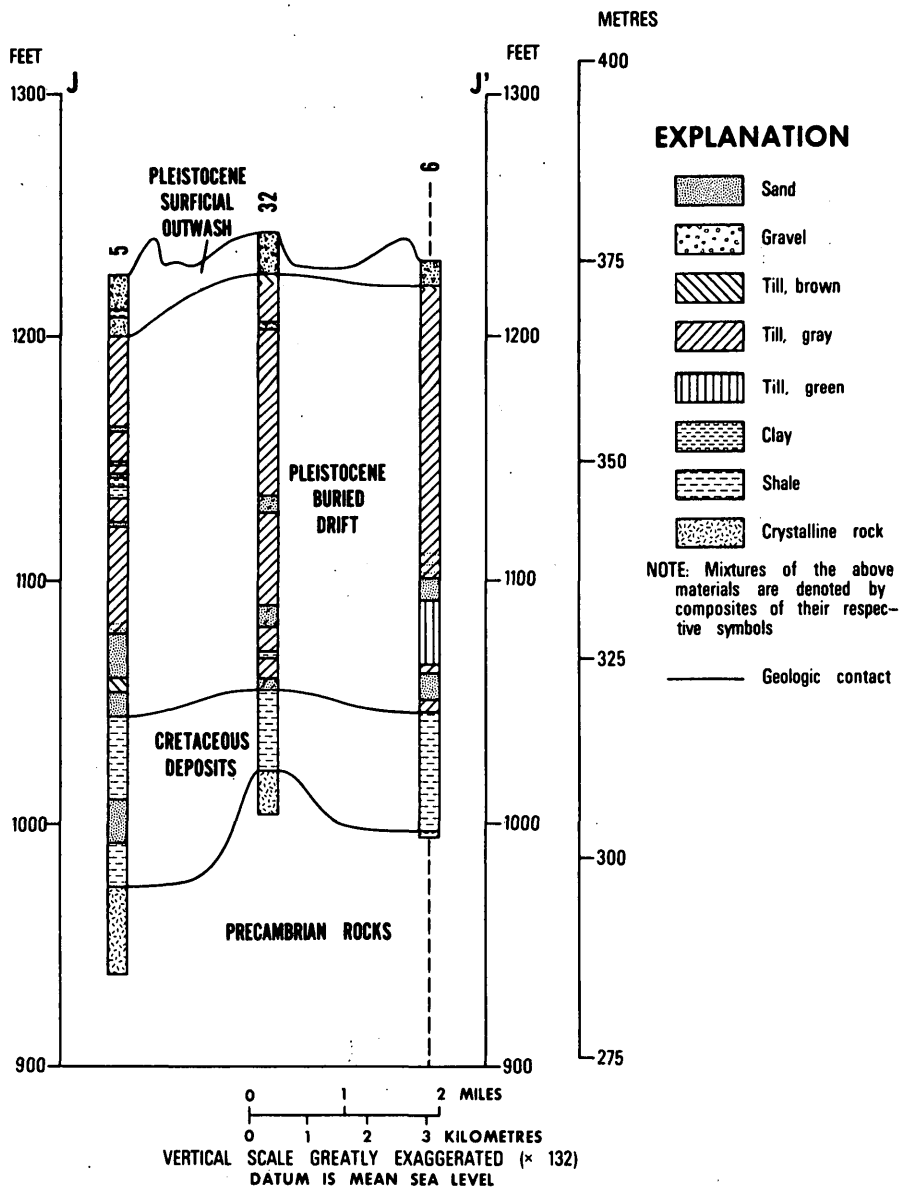


Figure 14.--Geologic section J-J' south of Georgeville.

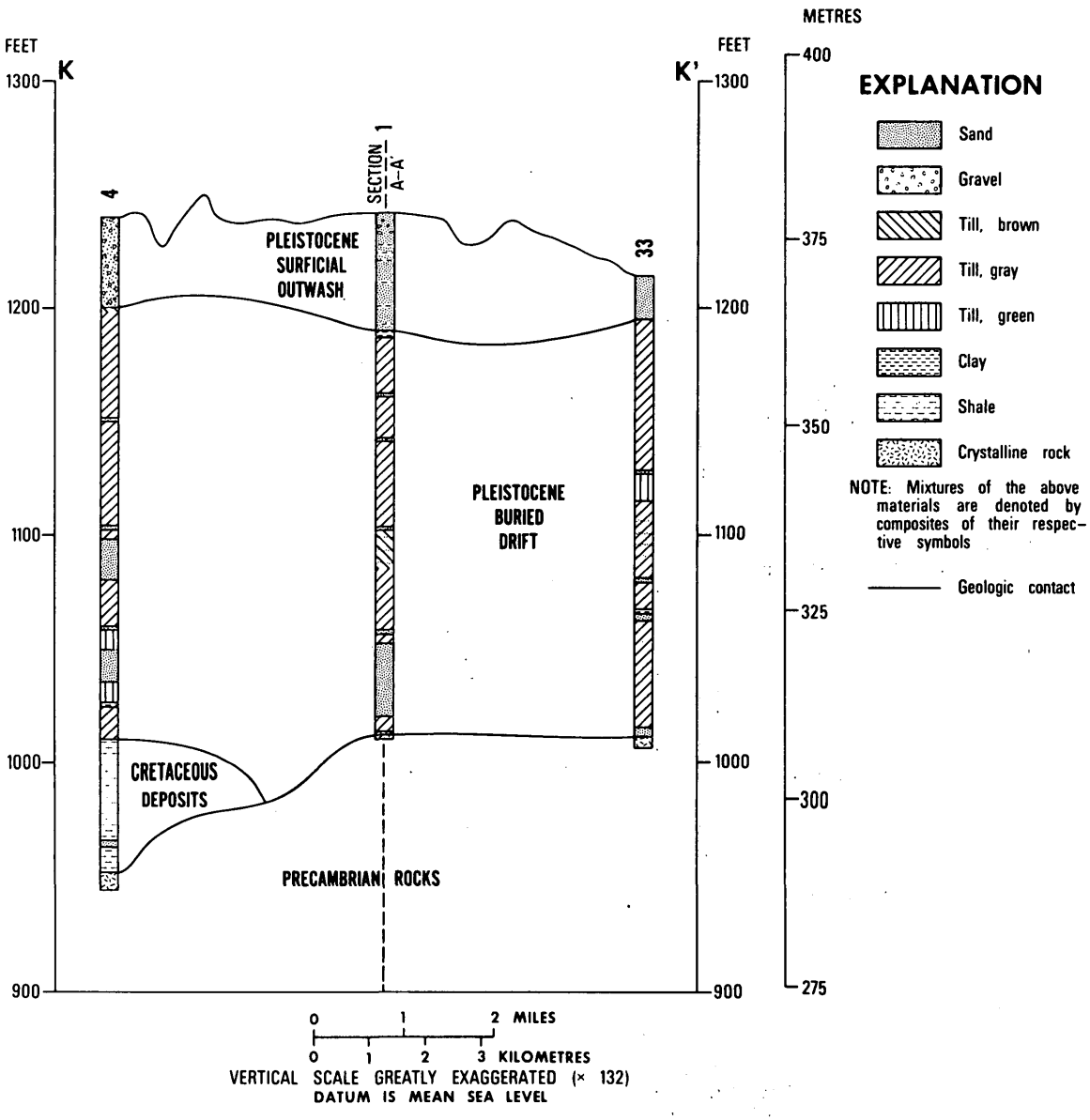


Figure 15.--Geologic section K-K' near Hawick.

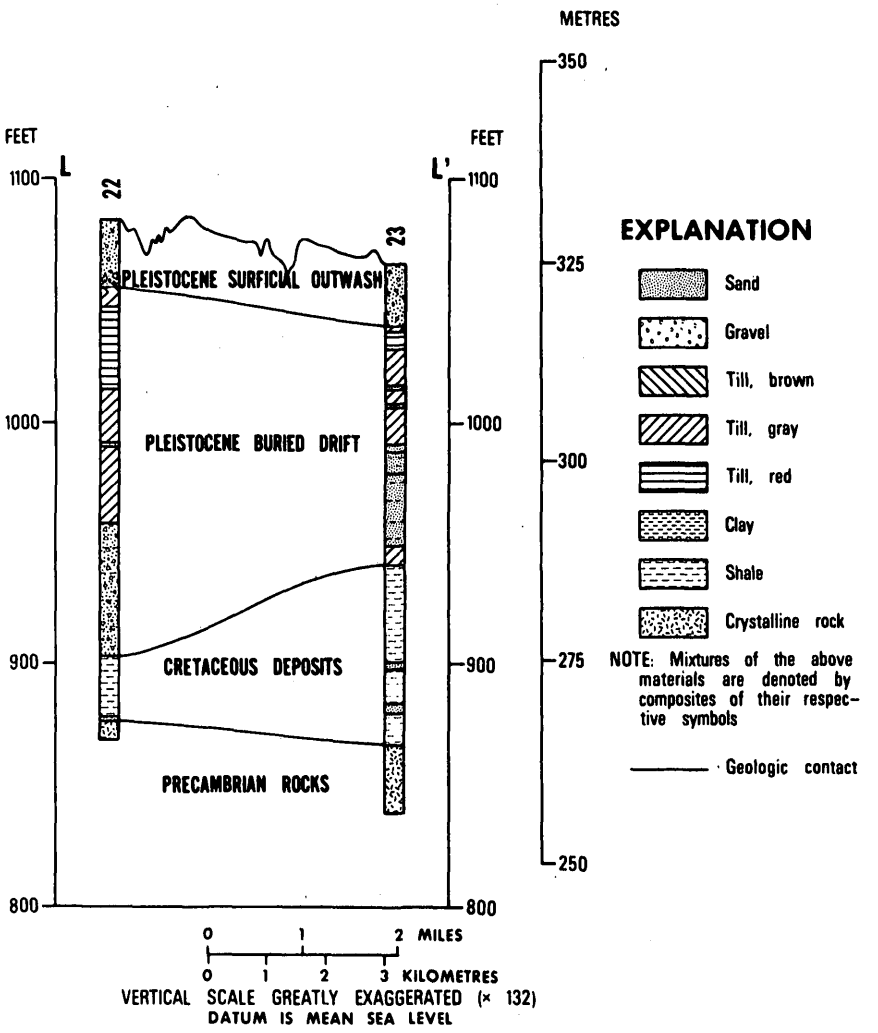


Figure 16.--Geologic section L-L' south of Lake Emily.

Thickness and Extent

Analysis of the geologic sections and other data reveals a great contrast between the geometry of the surficial sand and the buried sands. The surficial sand is a widespread outwash plain of relatively uniform thickness extending over a 300-square mile (800-km^2) area. In contrast, the buried sands occur as thick to thin, discontinuous bodies, which are probably elongate. The sands were probably laid down as outwash in glacial melt-water stream channels and as marine sand accumulations in Cretaceous deposits.

Because test holes drilled for this study are widely spaced, the thickness and areal extent of the buried sands cannot be mapped accurately. To correlate and map these buried sands, test holes would have to be spaced less than 1/8 mile (0.2 km) apart.

Some buried deposits, although thick vertically, are small areally, and isolated. Therefore, a well completed in this type of deposit may have an initial high yield but may not receive adequate recharge to sustain the yield, or storage may be so small that the yield may decline rapidly.

Statistical Approach to Mapping the Distribution of Buried Sand Beds

Locating and delineating buried-drift aquifers poses a major problem. Having no surface expression, and being elongate and sinuous, makes mapping of them difficult and costly by test drilling. Using a statistical technique developed by Krumbein and Libby (1957), Winter (1975) presented a statistical approach to mapping buried-drift aquifers, which objectively considers the distribution of all sands in a geologic section. Using this approach, statistical-parameter maps were prepared for the Brooten-Belgrade area.

The method results in a single map, which depicts the areal and vertical distribution of sand within the entire volume of deposits studied. The technique involves computation of the weighted mean vertical position and of the spread of all sand units in a drill hole. The map thus developed is based on statistical moments that express the position of the sand units as a continuous variable. The first moment, termed the center of gravity, expresses the average position of sand units in a drill hole as a distance, in feet, from the land surface. The center of gravity is also the weighted (as to thickness of individual sands) arithmetic average position of the sands. The second moment is the average dispersion, or the standard deviation, of the sands about the center of gravity. The standard deviation is that interval, expressed in feet, which, when added to and subtracted from the center of gravity, provides a range that contains, on the average, the bulk (about two-thirds) of the sand occurrences in the section. A composite map of center of gravity and dispersion may show any combination of center of gravity and spread of buried sand units.

Basic data for calculation of the statistical measures are: (1) the distance from the top of the hole to the center point of the sand unit and (2) the thickness of that sand unit. Equations for the calculations are given by Winter (1975, p. 143). For this study, where the surficial sand

thickness and areal extent has already been mapped (Van Voast, 1971a), consideration was given only to the section below the surficial sand down to the Precambrian rock. The surficial sand was not included in the calculations. Also, only units 4 or more feet (1.2 m) thick, consisting of sands of fine sizes or greater, were used. Silty fine sand and smaller sized materials were not considered aquifer material.

A plot of the center of gravity and standard deviation of sand units 4 or more feet (1.2 m) thick for each test hole in the study area shows several possible groupings. Three arbitrary groupings seem convenient and reasonable, although different groupings could be chosen. The three groupings used for the center of gravity or average position of sand units, expressed in feet below land surface, are: shallow, 92-146 feet (28.0-44.5 m); medium, 152-182 feet (46.3-55.5 m); and deep, 191-273 feet (58.2-83.2 m). For standard deviation or spread of the sand units, expressed in feet above and below the center of gravity, the groupings used are: narrow, 1-27 feet (0.3-8.2 m); moderate, 30-69 feet (9.1-21.0 m); and wide, 82-101 feet (25.0-30.8 m). Values of the groupings and terms applied to each group are strictly arbitrary, rather than being inherent in the method; therefore, other values or terms could be chosen instead of those used.

A vertical-variability map (pl. 6) was developed from groupings of the two parameters. Areas were delineated on the map where at least two adjacent locations showed the same grouping; that is, they had the same combination of center of gravity and dispersion. It is emphasized that the patterns shown on a vertical-variability map do not necessarily represent specific aquifers but represent only a qualitative statement that the sands in an area exhibit a similar vertical statistical distribution.

The vertical-variability map is a useful guide for further prospecting. For example, prime target areas for potential ground-water supplies are areas where the center of gravity is shallow and the standard deviation is narrow. These conditions indicate an area where the majority of buried sands are clustered within a fairly narrow zone just beneath the surficial sand. Other areas show clustered medium-depth sands or closely grouped deep sands that might be good prospects for water supplies.

Because this study is concerned mainly with high-yield buried aquifers, another vertical-variability map (pl. 7) was prepared using only sand units 10 feet (3.0 m) or more thick. A plot of the center of gravity and standard deviation of the sand units for each test hole shows different possible groupings. Those groupings, arbitrarily chosen, are shown on the map (pl. 7). This map has fewer patterned areas than plate 6 and is probably a good general guide to the location of thick, permeable, high yielding buried aquifers.

A drawback of the vertical-variability map is that it does not indicate the total thickness of sand or the number of sand units that were penetrated by the test hole. Therefore, the number of sand units and the percentage of sand in the total section is noted on the maps for each test hole. With this information the maps show the most advantageous areas for penetrating an

aquifer--those where percentage of sand is great, standard deviation is narrow, and center of gravity is at a medium or greater depth. For practical purposes, deep sands with plenty of available head may be better with regard to long-term yield than shallow buried sands.

Hydrology

Generalized ground-water-flow system.--Ground-water movement in the buried aquifers is controlled by the distribution of hydraulic potential within the flow system. Hydraulic potential is related to recharge-discharge relationships and hydraulic conductivity of geologic materials. Recharge generally occurs in uplands and discharge in lowlands.

Although the predominant direction of deep regional ground-water movement through the area is southwestward, most of the shallow water moves only within local flow systems, and is discharged to lakes, wetlands, and streams in lowlands adjacent to recharge areas. Part of the water in the system follows an intermediate-depth path through buried aquifers and is discharged to large streams. Two such streams, the East Branch Chippewa River and the North Fork Crow River, which flow through the Brooten-Belgrade area, are probable discharge areas for the buried aquifers. The Chippewa River, which flows through the Lake Emily area, is also a probable discharge area for the buried aquifers. These flow relationships are shown by differences in hydraulic head in shallow and deep wells. The water table is above the hydraulic head in the buried aquifers over much of the study area. Therefore, because of this hydraulic potential, some water moves downward from the surficial sand through the confining till to the buried sands below. Water levels in deep wells in these recharge areas tend to be relatively deep. Conversely, near large streams, such as the North Fork Crow River, the hydraulic head in the buried sands is higher than the water table. Therefore, water is discharged from the buried sand upward through the confining till to the surficial sand and thence to the stream. Deep wells drilled in these discharge areas near the larger streams have very shallow water levels or may flow above land surface.

Hydraulic characteristics.--The principal hydraulic characteristics of an aquifer are its hydraulic conductivity, saturated thickness, and storage coefficient. Hydraulic conductivity and saturated thickness can be expressed as transmissivity (hydraulic conductivity times saturated thickness). These parameters can be used to determine rates and magnitudes of water-level declines resulting from withdrawal of water from an aquifer.

An aquifer test was conducted near Brooten to furnish data for determining hydraulic characteristics of a buried aquifer. After the growing season, a 113-foot (34.4-m) irrigation well was pumped at a constant rate of 637 gal/min (40.2 l/s) for 24 hours, while water levels were monitored in the pumped well and in an adjacent irrigation well. Analysis of the test data indicates a transmissivity of 1,350 ft^2 day^{-1} (125 m^2 day^{-1}) and a storage coefficient of 3.4×10^{-5}. Dividing by the aquifer thickness of 15 feet (4.6 m) at the test site, gives an average hydraulic conductivity of 90 ft day^{-1} (27.4 m day^{-1}) for this buried aquifer.

Values of aquifer properties determined by this aquifer test may be valid only in the immediate vicinity of the test location. At each test-hole location aquifer properties were estimated (using aquifer-test results as a guide) based on descriptions of drill cuttings, laboratory analyses of drill cuttings, and published data for similar materials. Selected samples of drill cuttings from aquifer zones in the test holes were analyzed for particle-size distribution. The range and average of particle-size distribution curves for samples of buried sands in the study area are shown graphically on figure 17. Median grain size (the 50 percent line) of all samples ranges from medium sand to fine gravel and averages very coarse sand. Estimates of hydraulic conductivity for each buried aquifer are shown in table 1 (p. 36). These estimates were assigned from values for various particle sizes shown in table 2. Lower hydraulic conductivity values in each range were assigned to relatively poorly sorted material, and higher conductivity values to well-sorted material. Transmissivity can be estimated by multiplying the saturated thickness of each buried aquifer by the hydraulic conductivity (table 1, p. 36). The higher the transmissivity value the greater the probability of obtaining a high-yield well.

It should be understood that the hydraulic characteristics discussed above indicate only the ability of the aquifer to transmit water; they do not indicate the long-term water-yielding capabilities of the aquifer.

Water Quality

Water from the buried-drift aquifers in the study area is predominantly a very hard calcium magnesium bicarbonate type. Chemical constituents and other properties of water samples for buried aquifers in the Brooten-Belgrade area are given in table 3. Chemical analyses for buried aquifers in and near the Lake Emily area were given by Van Voast (1971b, p. 24). The quality of water in the buried-drift aquifers is similar to that in the surficial-outwash aquifer.

The chemical suitability of water for irrigation depends upon the type and concentrations of dissolved mineral constituents in the water. Salinity and sodium-adsorption-ratio are two factors that may be critical if they are high enough to result in accumulation of salts in the soil or to be toxic to plants. If sodium is present in large amounts, it may be exchanged for calcium and magnesium in the soil, with possible damage to soil structure. Water from buried aquifers in the project area has a low sodium hazard, as shown in figure 18. The salinity hazard is medium to high. However, this should not be a problem in the Brooten-Belgrade and Lake Emily areas because good drainage characteristics of most of the soils and the amount and distribution of precipitation permit a flushing or leaching of the root zone. Potentially hazardous amounts of salt should not accumulate.

Boron is essential in trace amounts to the normal growth of all plants, but is exceedingly toxic at concentrations only slightly above optimum (U.S. Salinity Laboratory Staff, 1954, p. 75, 81). Boron in water samples from buried aquifers, as shown in table 3, is below critical concentrations, even for sensitive crops.

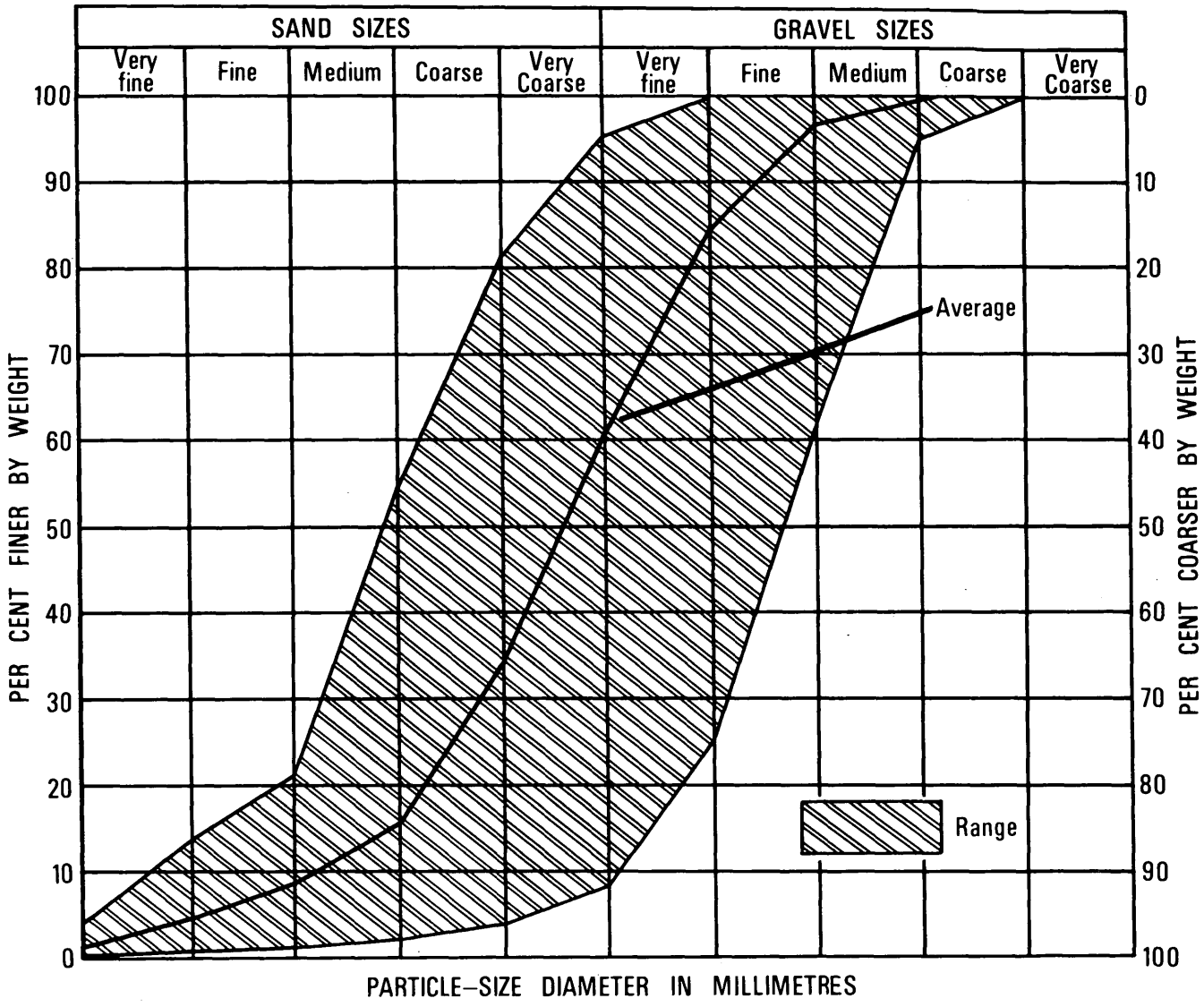


Figure 17.--Range and average of particle-size distribution curves of 49 samples from buried aquifers in test holes in the Brooten-Belgrade and Lake Emily areas.

Table 2.--*Values of hydraulic conductivity used in the estimation of hydraulic conductivity of buried sands in test holes in the Brooten-Belgrade and Lake Emily areas*

[Modified from Emery (1966)]

Material (Based on Wentworth scale of grain sizes)	Hydraulic conductivity (feet per day)
Clay and silt	0- 15
Sand, very fine, silty	15- 40
Sand, fine to medium	40- 60
Sand, medium	60- 80
Sand, medium to coarse	80-100
Sand, coarse	100-120
Sand, very coarse	120-130
Sand and gravel	130-270

Table 3.--Laboratory chemical analyses of water from buried-drift aquifers in the Brooten-Belgrade area

(Values are in milligrams per litre (mg/l) except for pH and other properties as indicated)

Well location	Depth of well (feet)	Date of collection of sample	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$) total	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate nitrogen	Phosphorus as P, total	Boron (B)	Dissolved solids, residue	Dissolved solids, calculated	Hardness (as $CaCO_3$) (Ca, Mg)	Noncarbonate hardness	Percent sodium (%)	Sodium absorption ratio (SAR)	Specific conductance (micromhos at 25° C)	pH (units)	Temperature (° Celsius)	Color (platinum-cobalt units)
122.34.12acb	150	May 1, 1975	24	1.6	0.10	87	33	19	3.0	478	0	392	12	1.8	0.3	11	0.03	0.10	416	416	350	0	10	0.4	700	7.4	7.5	5
122.36.14dcb	83	Aug. 26, 1965		1.6	.24	99	26	13	5.4	447	0		16	.4	.3	.47		.12	412		356	0		.3	669	8.1	8.0	
123.34.19bb	200	June 23, 1964	28	1.3	.02	76	17	18	1.9	363	0		.2	1.2	.3	.07	.02	.09	334		261	0	13	.5	542	7.7		3
123.34.19cbd	182	Jan. 5, 1972	28	1.3	.03	66	21	17	2.2	369	0	303	2.9	1.1	.4		.09	.11	324	322	250	0	13	.5	543	7.4		20
124.34.29a	222	Aug. 14, 1925	13	4.5		97	41	29	20	549				1.8			3.6		464		411			.6				
124.35.31cda	205	Mar. 1972		.68	.37	130		19	2.0			270	<5.0	2.0	1.6	.32			290		270					7.8		
124.36.6c	-	Before 1932	22			83	32	9.0		354			23	14					358		338			.2				
124.36.22dbc	113	Nov. 13, 1974	26	.93	.15	64	17	7.9	1.4	307	0	252	5.3	1.5	.1	2.8	.27	.06	271	275	230	0	7	.2	420	6.7	8.0	3
124.37.6aad	237	Aug. 28, 1965		1.3	.10	44	29	31	1.8	339	9		1.2	2.0	.4	1.5		.15	317		229	0		.9	519	8.4		
125.37.7baa	273	June 23, 1964	27	1.0	.02	48	30	33	1.5	383	0		1.0	1.6	.5	.07	.13		340		245		23	.9	582	7.2		13
126.36.32cbc	150	May 1, 1975	23	1.2	.21	86	31	8.5	2.4	435	0	357	2.3	1.5	.3	2.3	.08	.05	363	370	340	0	5	.2	630	7.6	9.0	3
126.37.24abd	224	June 4, 1971	24	9.0	.13	91	35	26	2.7	519	0	426	30	1.6	.3		.40	.12	382	475	370	0	13	.6	774	7.3		

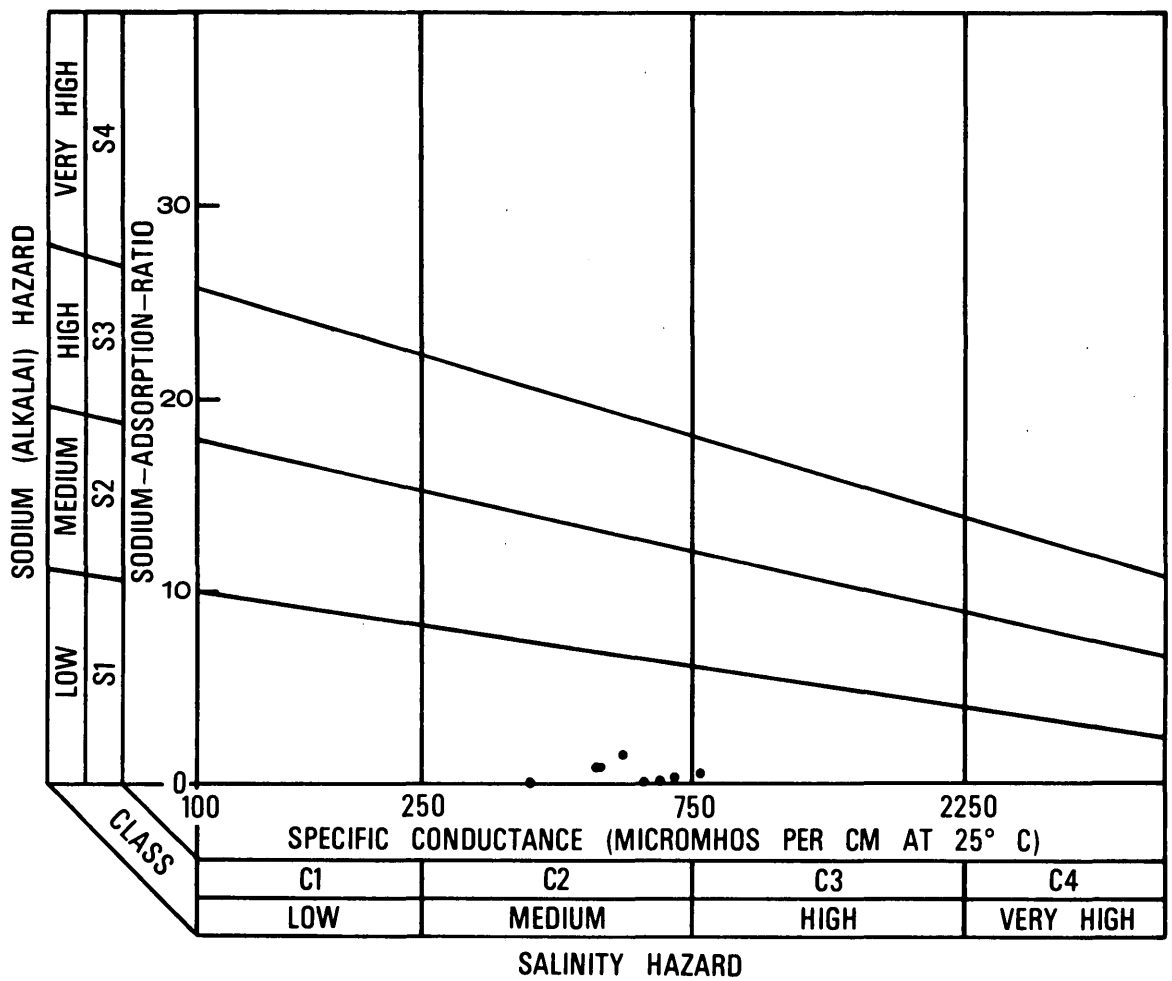


Figure 18.--Suitability of water from buried aquifers for irrigation in terms of sodium-adsorption-ratio and conductivity.

Cretaceous aquifers in the project area were not sampled because no wells tapping them were found. However, on the basis of analyses from outside the project area, dissolved mineral concentrations are probably higher in water from the Cretaceous aquifers than from the buried-drift aquifers. Boron, for example, is known to be relatively high in water pumped from Cretaceous deposits elsewhere in southwestern Minnesota.

Water Problems

A principal problem in the study area is the probable slow rate of recharge to the buried aquifers. Recharge, from precipitation, must infiltrate through overlying, poorly permeable layers of till and clay. Thus, although initially the buried aquifers may yield sufficient quantities of water for irrigation, they may not be able to sustain it. Monitoring water levels in wells in the buried aquifers could be useful in estimating the long-term supply.

Other potential problems concern loss of hydraulic head with large-scale development of ground water. Interference from closely spaced wells in the surficial outwash has already occurred in the study area. Interference may be even greater in the buried aquifers because the cones of depression around pumped wells spread more rapidly in the confined aquifers than in the surficial outwash. Lowering of heads may be excessive in some areas.

Although lowering of heads with increased ground-water development is inevitable, some practices lower heads more than others. A particular case is the common practice of screening deep wells in both the surficial and buried aquifers and gravel packing from the well bottoms to the land surface. Throughout most of the study area a head difference exists between the surficial and buried aquifers. In upland recharge areas, heads in the surficial aquifer are generally higher than those in the buried aquifers. Under nonpumping conditions, water enters such a well (through the screen or gravel pack) from the surficial aquifer, flows down the well, and discharges into the lower aquifer, resulting in overall lowering of the water table. Similarly, the lower aquifer may be polluted by such leakage. The hydraulics of a multiaquifer well are discussed by Bennett and Patten (1960, 1962).

Conversely, in discharge areas, where head in the buried aquifers may be higher than that in the surficial aquifer, multi-screened or completely gravel-packed wells may allow buildup of the water table locally and lowering of the head in the buried aquifer.

Another source of head loss is caused by allowing wells to flow unabated. This can be avoided by capping flowing wells when they are not in use.

CONCLUSIONS

Buried, confined sand and gravel aquifers as thick as 50 feet (15 m) occur in the Brooten-Belgrade and Lake Emily areas. In places, such as south of Hawick, at Georgeville, north of Belgrade, northwest of and at

Brooten, east of Villard, and southwest of Lake Emily, test holes show that buried aquifers are sufficiently thick and permeable to yield enough water initially to support irrigation. However, test holes nearby penetrated only thin aquifers or none at similar altitudes or depths, indicating that the buried aquifers are probably narrow and elongate rather than similar to the sheet-like surficial sand. Closely spaced test drilling would be required to delineate buried aquifers. The Precambrian surface, ranging from about 190 to 350 feet (58 to 107 m) below the land surface, is the lower limit of the buried aquifers.

Quality of water in the buried drift aquifers is of the hard, calcium magnesium bicarbonate type similar to that of the surficial outwash. Sodium and boron concentrations are low, but the salinity hazard can be medium to high. However, this should not be a problem because the good drainage characteristics of the soils and ample precipitation permit flushing or leaching of the root zone. Water from the Cretaceous aquifers, although unsampled, is expected to be higher in dissolved-mineral concentration than water from the drift aquifers, and it may be high in boron.

A principal problem is the probable slow rate of recharge to buried aquifers, contributing to the reduction of well yields over the long term. Observation wells could be used to indicate the long-term supply. Other potential problems include loss of head because of well interference, by screening surficial and buried aquifers in the same well, and allowing wells to flow unabated.

TEST-HOLE LOGS

Table 1 contains logs of 44 test holes drilled during this investigation. Many of the test holes are referred to in the text. Electric logs for most of the test holes are on file at the U.S. Geological Survey, Water Resources Division, St. Paul, Minnesota 55101.

SELECTED REFERENCES

Allison, I. S., 1932, The geology and water resources of northwestern Minnesota: Minnesota Geol. Survey Bull. 22, 245 p.

Bennett, G. D., and Patten, E. P., Jr., 1960, Borehole geophysical methods for analyzing specific capacity of multiaquifer wells: U.S. Geol. Survey Water-Supply Paper 1536-A, p. 1-25.

_____, 1962, Constant-head pumping test of a multiaquifer well to determine characteristics of individual aquifers: U.S. Geol. Survey Water-Supply Paper 1536-G, p. 181-203.

Cotter, R. D., Bidwell, L. E., Van Voast, W. A., and Novitzki, R. P., 1968, Water resources of the Chippewa River watershed, west-central Minnesota: U.S. Geol. Survey Hydrol. Inv. Atlas HA-286.

Emery, P. A., 1966, Use of analog model to predict streamflow depletion, Big and Little Blue River basin, Nebraska: Ground Water, v. 4, no. 4, p. 13-19.

Hall, C. W., Meinzer, O. E., and Fuller, M. L., 1911, Geology and underground waters of southern Minnesota: U.S. Geol. Survey Water-Supply Paper 256, 406 p.

Helgesen, J. O., Ericson, D. W., and Lindholm, G. F., 1975, Water resources of the Mississippi and Sauk Rivers watershed, central Minnesota: U.S. Geol. Survey Hydrol. Inv. Atlas HA-534.

Krumbein, W. C., and Libby, W. G., 1957, Application of moments to vertical variability maps of stratigraphic units: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 2, p. 197-211.

Leverett, Frank, 1932, Quaternary geology of Minnesota and parts of adjacent States, with contributions by F. W. Sardeson: U.S. Geol. Survey Prof. Paper 161, 149 p.

Lindholm, G. F., Farrell, D. F., and Helgesen, J. O., 1974, Water resources of the Crow River watershed, south-central Minnesota: U.S. Geol. Survey Hydrol. Inv. Atlas HA-528.

Thiel, G. A., 1944, The geology and underground waters of southern Minnesota: Minnesota Geol. Survey Bull. 31, 506 p.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agri. Handb. 60, 160 p.

Upham, Warren, 1888, The geology of Kandiyohi and Meeker Counties, and The geology of Stearns County, in Winchell, N. H., Geology of Minnesota: Minnesota Geol. and Nat. History Survey Final Rept., v. 2, p. 220-242, 445-470.

Van Voast, W. A., 1971a, Ground water for irrigation in the Brooten-Belgrade area, west-central Minnesota: U.S. Geol. Survey Water-Supply Paper 1899-E, 24 p.

_____, 1971b, Ground water for irrigation near Lake Emily, Pope County, west-central Minnesota: U.S. Geol. Survey Water-Supply Paper 1899-J, 28 p.

Winter, T. C., 1975, Delineation of buried glacial-drift aquifers: U.S. Geol. Survey Jour. Research, v. 3, no. 2, p. 137-148.

Table 1.--*Logs of test holes penetrating buried aquifers*

Project test hole 1
Location number 122.33.33abb
Altitude 1242 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0 - 2	Soil	2	
2 - 10	Sand and gravel, brown; sand fine to medium, gravel fine	8	
10 - 17	Sand, yellow-brown, with clay layers	7	
17 - 52	Sand, brown, fine to coarse; with some clay layers	35	
52 - 55	Clay, gray	3	
55 - 80	Till, gray, silty, clayey	25	
80 - 80½	Sand	½	70
80½-100	Till, gray, sandy, pebbly	19½	
100 -101	Boulder or cobbles	1	
101 -139	Till, gray, sandy, pebbly	38	
139 -140	Sand	1	70
140 -157	Till, yellowish buff, silty, sandy, pebbly; with sandy layers	17	
157 -184	Till, gray, silty, sandy	27	
184 -186	Sand, very fine	2	10
186 -190	Till, gray, sandy	4	
190 -222	Sand, gray; very fine to fine, grading to medium at 202 feet	32	120
222 -223	Boulders	1	
223 -229	Till or clay, gray	6	
229 -230	Sand	1	80
	PRECAMBRIAN		
230 -232	Granite, unweathered	2	

Project test hole 2
Location number 122.33.20cbb
Altitude 1242 feet

	PLEISTOCENE		
0 - 2	Soil, brown	2	
2 - 33	Sand and gravel, brown; sand medium to coarse, gravel medium to coarse	31	
33 - 39	Till, buff, soft, sandy, clayey	6	
39 - 93	Till, gray, sandy, silty; with sandy or gravelly layers at 42, 47 and 55 feet	54	
93 -100	Till, with sandy layers	7	
100 -105	Sand, gray, medium to coarse	5	100
105 -121	Till, gray, sandy, clayey	16	
121 -124	Sand	3	70

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 2--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
124-133	Till, gray, sandy, silty, clayey.....	9	
133-135	Sand, gray, coarse.....	2	120
135-150	Till, gray, clayey, silty, sandy.....	15	
150-162	Clay, dark gray, hard; with no pebbles or sand	12	
162-165	Clay, greenish-gray.....	3	
165-175	Clay, yellow.....	10	
175-181	Clay, light tan.....	6	
181-184	Sand, brown, medium to coarse.....	3	100
184-192	Clay, light brown, silty.....	8	
192-199	Till, light gray, sandy.....	7	
199-206	Sand, gray, medium to coarse.....	7	130
206-208	Till, gray.....	2	
208-211	Clay, black.....	3	
211-215	Clay, green.....	4	
215-220	Clay, yellowish brown.....	5	
220-245	Till, gray, silty, clayey; with sandy layers at 238 and 243 feet.....	25	
245-247	Sand.....	2	70
247-259	Clay, drak brown.....	12	
259-260	Boulder, black, crystalline.....	1	
	PRECAMBRIAN		
260-310	Highly weathered crystalline rock; clay, whitish-gray with increase of quartz grains (white, grading to pink) with depth.....	50	

Project test hole 3
Location number 122.33.22bbb
Altitude 1233 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 5	Sand and gravel, brown, medium to coarse.....	4	
5- 22	Sand, brown, medium to coarse, with some gravel.....	17	
22- 26	Sand, brown, fine to medium.....	4	
26-129	Till, brown at very top, gray below; silty, sandy, clayey.....	103	
129-131	Sand.....	2	70
131-145	Till, gray, sandy, silty, clayey.....	14	
145-175	Till, pale green, sandy, silty.....	30	
175-177	Sand, gray, fine.....	2	40
177-187	Till, gray-green, soft.....	10	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 3--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
187-190	Sand, fine	3	40
190-197	Till, gray-green	7	
197-201	Clay, brown	4	
201-219	Till, grayish-green	18	
219-220	Sand	1	70
220-247	Till, reddish-gray above grading to gray below; silty, sandy, clayey	27	
247-257	Sand, fine to coarse, mostly medium	10	130
257-273	Till, grayish green	16	
	PRECAMBRIAN		
273-302	Highly weathered crystalline rock; greenish-white clay with some mica and abundant quartz	29	

Project test hole 4
Location number 122.34.25dcc
Altitude 1240 feet

	PLEISTOCENE		
0- 1	Soil, brown, dark	1	
1- 40	Sand and gravel; sand medium to coarse, gravel fine to very coarse	39	
40- 42	Till, brown, clayey, sandy	2	
42- 89	Till, gray, sandy, silty	47	
89- 90	Sand	1	70
90-136	Till, gray, sandy, silty	46	
136-138	Sand	2	70
138-142	Till, gray, sandy, silty	4	
142-160	Sand, gray, medium to coarse, with fine gravel.	18	160
160-181	Till, gray above, light gray below, sandy, silty	21	
181-182	Sand	1	70
182-191	Till, greenish tint, sandy, silty	9	
191-205	Sand, gray, fine to medium	14	100
205-206	Boulder	1	
206-214	Till, greenish white, sandy, clayey	8	
214-216	Clay, dark	2	
216-230	Till, dark, becomes lighter with depth; pieces of wood at 216'	14	
	CRETACEOUS		
230-233	Clay, green, soft	3	
233-258	Clay, yellowish tan	25	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 4--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	CRETACEOUS--Continued		
258-273	Clay, light gray	15	
273-276	Sand and gravel	3	130
276-280	Boulder, red granite	4	
280-285	Clay, gray	5	
285-287	Boulder	2	
	PRECAMBRIAN		
287-295	Highly-weathered crystalline rock; whitish clay with quartz grains	8	

Project test hole 5
Location number 122.34.9acc
Altitude 1225 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 14	Sand and gravel	13	
14- 17	Clay	3	
17- 25	Sand and gravel, medium to coarse	8	
25- 62	Till, brown at very top, blue-gray below; sandy, silty	37	
62- 63	Sand	1	70
63- 76	Till, gray	13	
76- 77	Sand	1	70
77- 81	Till	4	
81- 82	Sand	1	70
82- 86	Clay, light gray above, green below	4	
86- 91	Sand, with clay layers	5	50
91-101	Till, gray, sandy, silty	10	
101-102	Sand	1	70
102-142	Till, gray, sandy, silty	40	
142-147	Till, with sandy layers	5	
147-165	Sand, gray, fine to coarse	18	100
165-171	Till, reddish-brown, sandy, silty; pieces of wood at bottom (171 feet)	6	
171-181	Sand, gray, coarse	10	110
	CRETACEOUS		
181-186	Clay, light greenish-gray	5	
186-202	Clay, light yellowish-tan	16	
202-215	Clay, light gray-brown	13	
215-233	Sand, with some clay layers; gravel and coarse sand in bottom 5 feet	18	130
233-251	Clay, gray with sandy layers	18	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 5--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PRECAMBRIAN		
251-287	Highly weathered crystalline rock; consists of clay, whitish-pink to pink, with mica and quartz grains from 251-257 feet; clay, light green to gray above, darker gray below, with quartz grains from 257-287 feet..	36	

Project test hole 6
Location number 122.34.1cdd
Altitude 1231 feet

	PLEISTOCENE		
0- 2	Soil.....	2	
2- 10	Sand and gravel, brown, medium to coarse.....	8	
10-117	Till, brown at top two feet, gray below, sandy, silty.....	107	
117-130	Till, gray, with some layers of sand.....	13	
130-139	Sand, gray, medium to coarse, with fine gravel	9	130
139-154	Till, light greenish-gray, sandy, clayey.....	15	
154-164	Till, light gray, sandy, silty.....	10	
164-165	Sand, coarse.....	1	120
165-169	Till, gray, sandy, silty.....	4	
169-180	Sand, gray, fine to coarse, mostly medium.....	11	80
180-185	Till, gray, sandy, silty.....	5	
	CRETACEOUS		
185-202	Clay, light yellowish-brown.....	17	
202-212	Clay, light greenish-white.....	10	
212-226	Clay, greenish-brown.....	14	
226-234	Clay, light brown.....	8	
	PRECAMBRIAN		
234-236	Crystalline rock	2	

Project test hole 7
Location number 123.34.27dcd
Altitude 1238 feet

	PLEISTOCENE		
0- 2	Soil, brown.....	2	
2- 15	Sand and gravel, medium.....	13	
15- 33	Till, brown at top foot, gray below, sandy, silty; with sandy layers.....	18	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 7--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
33-101	Till, gray, sandy, silty, containing white limestone and red pebbles.....	68	
101-103	Sand.....	2	70
103-112	Till, greenish gray at top, light gray below..	9	
112-113	Sand, gray, medium to coarse.....	1	100
113-145	Till, gray, sandy, silty; with thin sand layers between 118-127 feet.....	32	
145-157	Till, gray.....	12	
157-206	Sand and gravel, gray; sand fine to coarse, coarser with depth; gravel fine to medium, cobbles or boulder at bottom foot.....	49	190
206-226	Till, gray, sandy, silty; with sandy layers....	20	
226-228	Sand.....	2	70
228-255	Till, sandy, with layers of sand.....	27	
255-256	Till, gray.....	1	
256-259	Boulders and sand.....	3	200
259-260	Sand.....	1	70
260-272	Sand and gravel, multi-colored.....	12	230
	CRETACEOUS		
272-277	Clay, green.....	5	
277-282	Clay, gray.....	5	
282-292	Clay, reddish brown.....	10	
292-295	Clay, greenish-blue.....	3	

Project test hole 8
Location number 123.34.16dbb
Altitude 1251 feet

	PLEISTOCENE		
0- 1	Soil, brown.....	1	
1- 23	Sand and gravel, brown at top, gray with depth; sand medium to coarse; gravel fine to coarse.....	22	
23- 66	Till, gray, sandy, silty.....	43	
66- 87	Till, gray, with sandy layers.....	21	
87- 92	Clay, gray.....	5	
92- 93	Sand.....	1	70
93-103	Clay, light greenish-gray above, light gray below.....	10	
103-132	Till, dark reddish-gray.....	29	
132-144	Till, gray.....	12	
144-145	Sand.....	1	70

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 8--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
145-148	Clay	3	
148-149	Sand	1	70
149-150	Clay	1	
150-151	Sand	1	70
151-152	Clay	1	
152-153	Sand, coarse	1	120
153-156	Clay	3	
156-157	Sand	1	70
157-161	Till, gray, sandy	4	
161-170	Sand, gray, fine to medium	9	120
170-182	Till, dark greenish-gray above, gray below, sandy, silty	12	
182-183	Clay, dark brown	1	
183-197	Till, gray above, dark green to light green in middle, light greenish gray below; pieces of wood at 183 feet	14	
197-203	Sand, multi-colored, fine to medium	6	50
	CRETACEOUS		
203-212	Clay, greenish-olive above, to greenish gray in middle and gray below	9	
212-222	Clay, gray	10	
222-231	Clay, reddish brown	9	
231-235	Sand, multi-colored, medium to coarse	4	100
	PRECAMBRIAN		
235-252	Highly weathered crystalline rock; clay, whitish-gray	17	

Project test hole 9
Location number 123.35.23bcc
Altitude 1283 feet

	PLEISTOCENE		
0- 1	Soil, brown	1	
1- 42	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse	41	
42- 72	Till, gray, with sandy layers	30	
72- 76	Sand, gray, fine to coarse, mostly medium	4	80
76- 91	Till, gray	15	
91- 92	Sand, medium	1	70
92-107	Till, gray, with sandy layers at 105	15	
107-117	Till, whitish-gray, weathered	10	
117-127	Till, light gray	10	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 9--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
127-130	Sand, fine to medium, mostly fine.....	3	40
130-165	Till, gray, sandy, with thin sand lens at 132 and 142.....	35	
165-220	Till, gray, sandy, silty.....	55	
220-247	Sand and gravel, gray; sand medium to coarse, gravel fine to medium.....	27	150
247-249	Boulder.....	2	
249-271	Till, gray, silty, clayey.....	22	
271-312	Till, dark gray, sandy, silty.....	41	
312-314	Sand, gray, fine to medium.....	2	50
314-348	Till, gray, very sandy; with sand lens at 322.	34	
	PRECAMBRIAN		
348-352	Weathered crystalline rock; clay, white, overlying granite.....	4	

Project test hole 10
Location number 123.34.7daa
Altitude 1267 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 24	Sand and gravel, brown; sand fine to coarse, gravel fine to medium.....	23	
24- 63	Till, brown at top, gray below, sandy, silty..	39	
63- 86	Till, gray.....	23	
86- 87	Sand.....	1	70
87-111	Till, whitish-gray above, light gray below, sandy, silty; with sandy layers near bottom.....	24	
111-113	Sand, gray.....	2	70
113-115	Till, light gray.....	2	
115-117	Sand, gray.....	2	70
117-122	Till, light gray, sandy, silty.....	5	
122-135	Till, gray, sandy, silty.....	13	
135-137	Sand, gray.....	2	70
137-144	Clay.....	7	
144-153	Sand and gravel.....	9	200
153-160	Sand and gravel with clay layers.....	7	100
160-168	Sand and gravel.....	8	200
168-184	Sand and gravel and clay layers interbedded; less sand and more clay with depth.....	16	100
184-225	Clay, gray, with some sand layers.....	41	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 10--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
225-230	Clay	5	
230-241	Till, gray, with some sandy layers	11	
241-245	Sand	4	70
245-247	Clay	2	
247-250	Sand, gray, fine to coarse	3	80
250-262	Clay, whitish-gray, with sandy layers at 252-254 and 259-262	12	
	CRETACEOUS		
262-286	Clay, gray	24	
	PRECAMBRIAN		
286-287	Crystalline rock, blue, weathered, with black chips	1	

Project test hole 11
Location number 123.35.2dcc
Altitude 1271 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 7	Peat or swamp deposits, dark brown, clayey	6	
7- 30	Sand, brown, fine to medium	23	
30- 43	Till, brown at top, gray below	13	
43- 45	Sand	2	70
45- 67	Till, gray, sandy, silty	22	
67- 70	Till, gray, with some sandy layers	3	
70- 77	Sand, gray, fine to medium, with some clay layers	7	50
77-112	Sand and gravel, gray; sand medium to coarse, with gravel, medium and coarse toward bottom	35	200
112-126	Till, gray, sandy, silty	14	
126-128	Sand, gray	2	70
128-138	Till, gray above, light green below	10	
138-150	Till, light yellowish-brown above, light brown or tan below	12	
150-158	Till, gray to gray-brown	8	
158-171	Sand, gray, medium to coarse, gravelly	13	120
171-182	Till, green above, to greenish-gray, to gray below, sandy, silty	11	
182-185	Clay, dark reddish gray-brown	3	
185-189	Cobbles, gravel and sand	4	270
189-202	Clay, light yellowish-brown, sandy	13	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 11--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
202-222	Till, gray, sandy	20	
222-235	Till, yellowish-brown	13	
	CRETACEOUS		
235-239	Clay, grayish-brown	4	
239-242	Clay, brown, very soft	3	
	PRECAMBRIAN		
242-267	Highly weathered crystalline rock; clay greenish-white	25	

Project test hole 12
Location number 124.34.31abc
Altitude 1271 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 14	Sand and gravel, brown; sand fine to coarse, gravel fine to coarse	13	
14- 16	Till, gravelly	2	
16- 47	Till, gray, sandy, silty	31	
47- 58	Till, with sandy layers	11	
58- 59	Boulder, granite	1	
59- 67	Till, gray, sandy	8	
67- 73	Sand, gray, fine to coarse	6	80
73- 74	Clay	1	
74- 78	Sand, gray, fine to coarse	4	80
78- 89	Till, gray	11	
89- 94	Sand, gray	5	70
94-102	Till, green, soft, very sandy	8	
102-111	Till, light gray, sandy, silty	9	
111-123	Sand and gravel	12	130
123-127	Clay, gray, no pebbles	4	
127-140	Till, gray, sandy; with wood pieces	13	
140-152	Clay, gray, soft, no pebbles	12	
152-167	Sand, gray, fine to coarse; with gravel, medium to coarse	15	130
167-220	Sand, with clay layers; clay layers increase with depth, sand decreases and becomes finer with depth	53	20
220-288	Till, gray, with streaks of fine sand	68	
	PRECAMBRIAN		
288-295	Weathered crystalline rock; clay, greenish-white	7	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 13
Location number 124.35.36bba
Altitude 1278 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic Conductivity (ft day^{-1})
	PLEISTOCENE		
0- 2	Soil	2	
2- 22	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	20	
22- 63	Till, brown above, gray below, sandy, silty	41	
63- 65	Clay, dark brown, soft, no pebbles	2	
65- 85	Till, light green above, light gray below, sandy, silty; with sand lens at 78'	20	
85- 88	Sand, gray, fine to coarse; mostly medium	3	80
88- 89	Till	1	
89- 90	Sand, gray	1	70
90-102	Till, light gray, sandy, silty	12	
102-105	Clay, soft	3	
105-117	Till, light gray, sandy silty	12	
117-118	Sand, gray	1	70
118-131	Till, gray with sand layers at 120 and 129 feet	13	
131-134	Till, gray, sandy	3	
134-138	Till, with sand layers	4	
138-144	Clay, gray	6	
144-149	Sand and clay layers	5	50
149-187	Sand, gray, medium to coarse	38	240
187-196	Gravel, medium to coarse, very coarse near bottom	9	270
	CRETACEOUS		
196-201	Clay, light yellowish-brown, sandy	5	
201-209	Clay, gray, sandy	8	
209-233	Clay, reddish gray-brown	24	
233-238	Clay, sandy	5	
238-248	Sand, multi-colored, medium to coarse	10	120
	PRECAMBRIAN		
248-249	Crystalline rock	1	

Project test hole 14
Location number 123.35.4dad
Altitude 1286 feet

	PLEISTOCENE		
0- 2	Soil	2	
2- 28	Sand, brown, fine to coarse, gravelly	26	
28- 64	Till, gray, sandy	36	
64- 85	Till, with sandy layers	21	
85- 86	Sand, gray	1	70
86- 94	Till, salmon-colored	8	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 14--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
94-104	Till, light tan	10	
104-117	Till, light tan to gray, with several sand layers	13	
117-136	Sand, multi-colored, fine to coarse, with many clay lens	19	60
136-144	Till, gray	8	
144-145	Sand, gray	1	70
145-172	Till, light greenish-gray	27	
172-184	Sand, gray, fine to coarse	12	120
184-192	Till, green at top, light gray below	8	
	CRETACEOUS		
192-197	Clay, gray	5	
197-202	Clay, tan	5	
202-217	Clay, salmon-colored	15	
217-222	Clay, light brown	5	
222-227	Clay, gray-brown	5	
227-249	Clay, gray	22	
249-251	Sand	2	70
251-262	Clay, gray	11	
262-263	Sand	1	70
263-297	Clay, gray	34	
297-304	Sand, multi-colored	7	80
	PRECAMBRIAN		
304-312	Highly weathered crystalline rock; clay, greenish-white	8	

Project test hole 15
Location number 124.35.28abd
Altitude 1294 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 19	Sand and gravel, brown; sand fine to coarse, gravel fine to coarse	18	
19- 21	Sand, greenish gray, fine, silty	2	
21- 22	Boulder or cobbles	1	
22- 34	Sand, greenish gray, fine, silty	12	
34- 44	Till, gray	10	
44- 52	Sand and gravel, gray; sand medium to coarse with medium to coarse gravel	8	200
52- 60	Sand and gravel, with clay layers	8	120
60-102	Till, gray, sandy, silty	42	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 15--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
102-119	Sand, gray, with some gravel.....	17	150
119-139	Till, gray, with sandy layer at 136.....	20	
139-166	Till, light greenish-gray.....	27	
166-172	Sand, gray.....	6	70
172-185	Till, light greenish-gray above, light yellowish-brown below, silty, clayey.....	13	
185-189	Sand, gray, fine to medium.....	4	50
189-197	Till, light brown.....	8	
197-200	Sand, gray.....	3	70
200-212	Till, whitish-green at very top, gray-brown below.....	12	
212-215	Clay, dark gray, smooth.....	3	
215-217	Cobbles, gravel and pebbles.....	2	100
217-230	Clay, dark gray, smooth.....	13	
230-240	Till, dark gray, sandy.....	10	
240-252	Sand, gray.....	12	70
252-278	Sand, gray, with clay layers.....	26	50
	PRECAMBRIAN		
278-285	Highly weathered crystalline rock.....	7	
285-287	Crystalline rock, unweathered.....	2	

Project test hole 16
Location number 124.36.8bdd
Altitude 1341 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 14	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse.....	13	
14- 17	Till, brown, sandy, silty, clayey.....	3	
17- 46	Till, gray, sandy, silty, clayey.....	29	
46- 53	Till, with sandy layers.....	7	
53- 64	Till, gray, sandy, silty, clayey.....	11	
64- 68	Sand, gray, with clay layers.....	4	50
68- 77	Sand, gray, fine to medium; with clay layers..	9	80
77- 82	Sand and gravel, gray; sand medium to coarse, gravel medium; with clay layers.....	5	160
82- 90	Sand, gray, fine to medium; with clay layers..	8	50
90- 92	Clay, light brown.....	2	
92- 93	Sand.....	1	70
93-105	Till, gray, sandy, silty, clayey.....	12	
105-106	Sand.....	1	70

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 16--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
106-147	Till, gray, sandy, silty, clayey.....	41	
147-148	Sand, gray.....	1	70
148-160	Till, gray, sandy, clayey.....	12	
160-176	Till, with sandy layers.....	16	
176-177	Sand, gray.....	1	70
177-182	Sand, gray, with clay layers.....	5	60
182-225	Till, gray, sandy, silty.....	43	
225-239	Till, light green; with sandy layers.....	14	
239-240	Sand, gray, medium to coarse; with pebbles of white granite.....	1	100
240-245	Till, reddish-gray, sandy.....	5	
245-246	Sand, gray.....	1	70
246-259	Till, dark green at top, light green below....	13	
259-264	Boulders, cobbles, and clay layers.....	5	80
264-277	Till, gray.....	13	
277-283	Till, with sandy layers.....	6	
283-287	Sand, gray, fine to coarse.....	4	80
287-296	Clay, dark brown; pieces of wood at 288 feet..	9	
296-302	Sand, gray, medium to coarse.....	6	110
	PRECAMBRIAN		
302-317	Highly weathered crystalline rock; greenish-white clay with abundant quartz grains.....	15	

Project test hole 17
Location number 125.36.27bcc
Altitude 1338 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 15	Sand and gravel, brown; sand fine to coarse, gravel fine to medium.....	14	
15- 26	Till, gray, sandy, silty, clayey.....	11	
26- 61	Till, light gray, sandy, clayey.....	35	
61- 64	Sand, gray.....	3	70
64-153	Till, gray, sandy, clayey.....	89	
153-158	Till, gray with sandy layers.....	5	
158-189	Till, gray, sandy, silty, clayey.....	31	
189-194	Till, light green, sandy, silty.....	5	
194-197	Till, dark brown.....	3	
197-215	Sand, gray, medium to coarse; with some clay lens.....	18	120
215-220	Till, green.....	5	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 17--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
220-230	Till, gray	10	
230-232	Clay, very dark	2	
232-240	Till, light green	8	
	CRETACEOUS		
240-251	Clay, gray, sandy	11	
251-253	Clay, dark brown	2	
253-278	Clay, gray	25	
278-283	Sand, multi-colored, with clayey layers	5	70
283-300	Clay, pinkish light-brown to gray	17	
300-304	Clay, dark brown	4	
304-312	Sand, gravel, and boulders, with clayey layers	8	120
	PRECAMBRIAN		
312-318	Highly weathered crystalline rock; clay, greenish-white with abundant quartz grains and small pieces of granite	6	

Project test hole 18
Location number 125.36.33ccd
Altitude 1343 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 15	Sand, with clay layers	14	
15- 51	Clay, brown at top, gray below	36	
51- 54	Clay, with sandy layers	3	
54- 66	Till, gray	12	
66- 74	Sand, gray	8	70
74- 89	Till, light gray above, dark gray below, sandy	15	
89-101	Sand and gravel, gray, medium to coarse	12	200
101-115	Till, light gray, sandy	14	
115-124	Till, gray	9	
124-125	Sand	1	70
125-234	Till, gray, sandy, with white limestone pebbles	109	
234-250	Till, with sandy layers	16	
250-264	Sand, gray	14	160
264-286	Till, gray	22	
286-290	Boulders, gravel, and sand	4	130

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 18--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	CRETACEOUS		
290-296	Clay, gray	6	
296-312	Clay, green, weathered at top, dark below	16	
312-319	Clay, dark gray	7	
	PRECAMBRIAN		
319-326	Highly weathered crystalline rocks; clay, greenish-white, soft, silvery	7	

Project test hole 19
Location number 126.36.29dbb
Altitude 1357 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 17	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse	16	
17- 34	Sand, with clay layers	17	
34- 55	Till, brown at top, gray below; sandy, silty, clayey	21	
55- 79	Till, buff-colored	24	
79- 93	Till, gray, sandy, silty, clayey	14	
93-103	Sand, brown, fine to coarse, mostly medium	10	100
103-116	Clay, gray, soft, no pebbles	13	
116-117	Sand, gray	1	70
117-158	Clay, gray	41	
158-163	Sand	5	70
163-168	Till, gray, sandy, clayey	5	
168-177	Till, light brown, sandy, clayey	9	
177-178	Boulder	1	
178-197	Till, light green, sandy, clayey	19	
197-198	Sand	1	70
198-203	Till, gray, silty, clayey	5	
203-208	Clay, dark brown	5	
208-209	Sand	1	70
209-217	Till, green, silty, clayey	8	
217-218	Sand	1	70
218-225	Clay and sand lenses	7	50
225-240	Till, gray, silty, clayey	15	
	PRECAMBRIAN		
240-248	Highly weathered crystalline rock; clay, silvery-white, soft	8	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 20
Location number 126.37.24cba
Altitude 1368 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0- 1	Soil	1	
1- 18	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse	17	
18- 23	Clay	5	
23- 26	Sand, brown	3	70
26- 48	Till, gray, sandy, clayey	22	
48- 53	Sand, fine, with wood pieces	5	40
53- 56	Till, gray, sandy, clayey	3	
56- 64	Till, dark brown, sandy, clayey	8	
64- 75	Clay, white above, gray below	11	
75-103	Till, light gray, silty, clayey	28	
103-107	Sand, gray, medium to coarse, with fine gravel	4	120
107-117	Till, gray, clayey	10	
117-118	Sand	1	70
118-128	Sand and clay layers	10	60
128-133	Sand, gray	5	70
133-138	Sand, gray, with some clay layers	5	60
138-147	Sand and gravel, gray; sand mostly medium to coarse, gravel fine to medium	9	160
147-158	Till, gray, sandy, clayey	11	
158-165	Till, light gray, sandy, clayey	7	
165-168	Sand, gray, medium to coarse, with black pebbles	3	110
168-179	Till, gray, sandy, clayey	11	
179-192	Till, light gray, clayey	13	
192-202	Till, light brown, clayey	10	
202-205	Till, yellowish brown, clayey	3	
205-209	Sand, gray, medium to coarse	4	110
209-215	Till, light green above, light gray below; sandy, clayey	6	
215-219	Clay, dark brown	4	
219-222	Till, dark gray, clayey	3	
222-227	Sand, medium to coarse, with fine to medium gravel	5	140
227-232	Clay	5	
	PRECAMBRIAN		
232-234	Crystalline rock	2	

Table 1.-- *Logs of test holes penetrating buried aquifers--Continued*

Project test hole 21
Location number 126.37.25cdd
Altitude 1350 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0- 1	Soil	1	
1- 18	Sand and gravel, brown; sand medium to coarse, gravel fine to medium	17	
18- 35	Till, brown at top 2 feet, gray below; sandy, clayey	17	
35- 41	Sand layers in till	6	40
41- 55	Till, gray, sandy, clayey; with some sandy layers	14	
55- 61	Till, gray, clayey	6	
61- 64	Sand	3	70
64- 80	Till, light brown, sandy, clayey	16	
80- 90	Sand and clay layers	10	40
90- 94	Sand, gray	4	120
94-115	Till, gray, clayey	21	
115-119	Sand and clay layers	4	40
119-145	Till, gray, clayey	26	
145-146	Sand	1	70
146-155	Till, gray	9	
155-156	Sand	1	70
156-244	Till, brown at very top, gray below; sandy, silty, rocky, clayey	88	
244-249	Sand	5	70
249-258	Till, gray	9	
258-263	Sand	5	70
	PRECAMBRIAN		
263-265	Crystalline rock	2	

Project test hole 22
Location number 124.40.33ddd
Altitude 1084 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 21	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	20	
21- 28	Boulder, cobbles, gravel, and sand	7	
28- 36	Till, gray, sandy	8	
36- 70	Till, reddish-gray; sandy	34	
70- 93	Till, gray, sandy	23	
93- 94	Sand	1	70
94-126	Till, gray	32	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 22--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
126-181	Sand, gray, medium to coarse, with some fine gravel and some clay layers.....	55	130
	CRETACEOUS		
181-206	Clay, gray.....	25	
206-207	Sand.....	1	80
	PRECAMBRIAN		
207-215	Highly weathered crystalline rock; greenish-white clay with a "sheen" containing quartz grains and pink feldspar grains.....	8	

Project test hole 23
Location number 123.40.16ddd
Altitude 1066 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 26	Sand and gravel.....	25	
26- 28	Till, gray, sandy.....	2	
28- 35	Till, reddish-brown.....	7	
35- 51	Till, gray.....	16	
51- 52	Sand.....	1	70
52- 58	Till, gray, sandy, silty.....	6	
58- 59	Sand.....	1	70
59- 75	Till, gray.....	16	
75- 78	Sand, fine.....	3	70
78- 87	Till, with sandy layers.....	9	
87-117	Sand, gray, fine to coarse, mostly medium; with some clay layers.....	30	120
117-118	Boulder.....	1	
118-125	Till, gray, sandy, silty.....	7	
	CRETACEOUS		
125-138	Clay, gray.....	13	
138-165	Clay, pink, turns to dark brown to gray-brown to light gray with depth.....	27	
165-168	Sand.....	3	80
168-182	Clay, gray-green to brown.....	14	
182-186	Sand.....	4	80
186-199	Clay, whitish-gray at top, turns gray with depth.....	13	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 23--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day-1)
	PRECAMBRIAN		
199-227	Highly weathered crystalline rock; consists of	28	
	Clay, whitish, silvery 199-205		
	Clay, multi-colored 205-207		
	Clay, light green 207-209		
	Clay, whitish, silvery, with quartz grains 209-214		
	Clay, blue-green, with quartz grains 214-222		
	Clay, dark blue-gray, with quartz grains 222-227		

Project test hole 24
Location number 126.37.33dbb
Altitude 1390 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 37	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse	36	
37- 80	Till, gray, sandy, clayey; with sandy layers	43	
80- 94	Till, gray, clayey	14	
94- 97	Sand, fine to coarse	3	80
97-106	Till, light brown, sandy, clayey	9	
106-119	Sand, brown above, gray below; medium to coarse with some fine gravel	13	120
119-144	Till, light brown at top, gray below; sandy, silty, clayey	25	
144-145	Sand	1	70
145-147	Till, gray clayey	2	
147-148	Sand	1	70
148-153	Till, gray	5	
153-154	Sand and gravel	1	140
154-165	Till, gray	11	
165-167	Sand, gray, with gravel layers	2	120
167-170	Till, gray, sandy, silty, clayey	3	
170-188	Clay, gray	18	
188-189	Sand	1	70
189-191	Clay, gray	2	
191-193	Gravel and cobbles	2	170
193-199	Clay	6	
199-202	Gravel and cobbles	3	170
202-227	Clay, gray	25	
227-228	Boulder	1	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 24--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
228 -253	Clay, gray, sandy	25	
253 -268	Clay, with sandy layers from 263-268	15	
268 -269	Sand	1	40
269 -283	Clay with sandy layers	14	
283 -286	Clay	3	
286 -305	Gravel, sand, and cobbles, multi-colored; with clay layers	19	140
	CRETACEOUS		
305 -320	Clay, green at top foot, gray below	15	
320 -322	Clay, dark brown	2	
322 -324	Clay, light gray-brown	2	
324 -324½	Sand	½	60
324½-331	Clay, light gray-brown	6½	
331 -337	Clay, light greenish-white at top, light green below	6	
	PRECAMBRIAN		
337 -342	Weathered granite	5	

Project test hole 25
Location number 126.37.29caa
Altitude 1392 feet

	PLEISTOCENE		
0 - 1	Soil	1	
1 - 16	Sand and gravel, brown; sand medium to coarse, gravel fine	15	
16 - 27	Sand and gravel, brown, with some clay layers	11	
27 - 40	Till, brown, soft, sandy, silty, clayey	13	
40 - 82	Till, gray, sandy, silty, clayey	42	
82 - 83	Sand	1	70
83 - 92	Till, gray	9	
92 -102	Sand and gravel, with clay layers	10	150
102 -107	Till, light brown, clayey	5	
107 -112	Sand, with some clay layers	5	50
112 -243	Till, gray, sandy, silty, clayey	131	
243 -246	Sand	3	70
246 -249	Till or clay	3	
249 -252	Sand	3	70
252 -262	Till, whitish-colored at top, gray below, clayey	10	
262 -266	Clay, gray, soft	4	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 25--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
266-271	Clay, green, silty	5	
271-286	Sand, multi-colored, coarse; interbedded with green silty clay	15	100
286-298	Clay, gray above, dark gray-brown to brown below	12	
298-310	Sand, gray, fossiliferous, wood pieces present; with interbedded clay	12	50
	PRECAMBRIAN		
310-332	Highly weathered crystalline rock; clay, white	22	

Project test hole 26
Location number 125.37.6aaa
Altitude 1415 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 14	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	13	
14- 18	Sand, fine	4	
18- 20	Cobbles and boulders	2	
20- 34	Cobbles, gravel, and sand with some interbedded clay	14	
34- 76	Sand and gravel, with some interbedded clay	42	
76-139	Till, brown, clayey at top 2 feet; gray, sandy silty, clayey	63	
139-144	Till, brown, sandy, clayey	5	
144-159	Till, gray, sandy	15	
159-161	Sand and gravel	2	130
161-177	Till, gray, sandy, silty, clayey	16	
177-182	Sand	5	70
182-302	Till, gray, sandy, silty, clayey	120	
302-310	Sand, interbedded with clay	8	50
310-332	Till, gray, clayey	22	
332-334	Sand	2	70
334-347	Clay and interbedded sand	13	
347-348	Sand	1	70
	PRECAMBRIAN		
348-349	Crystalline rock	1	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 27
Location number 125.37.1dbb
Altitude 1370 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0- 1	Soil	1	
1- 14	Sand and gravel, brown; sand medium to coarse, with fine to medium gravel	13	
14- 40	Till, brown at top 2 feet, gray below; silty, clayey	26	
40- 42	Sand	2	70
42- 59	Till, gray, silty, clayey	17	
59- 61	Sand	2	70
61- 93	Till, gray, sandy, clayey	32	
93-102	Sand layers interbedded with greenish-gray silty clay	9	50
102-117	Till, gray, silty, clayey	15	
117-118	Sand	1	70
118-122	Clay, dark brown, silty	4	
122-125	Sand and clay layers	3	50
125-130	Till, gray, clayey	5	
130-146	Sand interbedded with clay layers	16	100
146-153	Till, light gray, silty, clayey	7	
153-155	Sand	2	70
155-160	Till, light gray, silty, clayey	5	
160-161	Sand	1	70
161-172	Till, light gray, silty, clayey	11	
172-198	Sand, gray, with gravel toward bottom	26	130
198-231	Till, gray, sandy, silty, clayey	33	
231-233	Sand	2	70
233-242	Till, gray, sandy, silty, clayey	9	
242-244	Sand	2	70
244-252	Till, gray, sandy, silty, clayey	8	
252-268	Sand, gray; with some white, weathered clay associated with some boulders above, and light gray clay layers below	16	50
268-272	Clay, gray, and sand, multi-colored, pyritiferous	4	
	PRECAMBRIAN		
272-282	Highly weathered crystalline rock; clay, white above, pink near bottom	10	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 28
Location number 125.36.5bcc
Altitude 1345 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0 - 1	Soil	1	
1 - 12	Sand and gravel, brown; sand medium to coarse, gravel fine to medium	11	
12 - 43	Till, gray, silty, clayey	31	
43 - 47	Sand	4	70
47 - 62	Till, gray, with some sandy layers	15	
62 - 66	Till, gray, sandy, silty clayey	4	
66 - 68	Clay, olive-brown	2	
68 - 79	Till, gray, silty, clayey	11	
79 - 81	Clay, dark gray	2	
81 - 86	Till, gray	5	
86 - 90	Sand, fine to coarse, mostly medium	4	80
90 -118	Till, white above, light gray below, silty, clayey	28	
118 -120	Sand, brown above, gray below; fine to coarse, mostly medium	2	80
120 -129	Till, gray, with some sandy layers	9	
129 -177	Sand and gravel, gray; sand medium to coarse, gravel fine; interbedded with some clay layers	48	130
177 -193	Till, gray	16	
	PRECAMBRIAN		
193 -196	Granite	3	

Project test hole 29
Location number 125.36.17aaa
Altitude 1352 feet

	PLEISTOCENE		
0 - 1	Soil	1	
1 - 38	Sand, brown, fine to coarse, with fine gravel	37	
38 - 87	Till, gray, silty, clayey, with some sandy layers	49	
87 -104	Till, gray, soft	17	
104 -120	Till, greenish gray at top to olive to light grayish-white to light gray at bottom; gravelly, sandy, clayey	16	
120 -120½	Sand	½	60
120½-147	Till, gray, clayey	26½	
147 -148	Sand, medium	1	70
148 -153	Till, gray, sandy, clayey; with sand layers	5	
153 -165	Sand, gray, medium to coarse	12	120
165 -184	Till, gray	19	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 29--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
184-191	Sand and clay interbedded	7	50
191-194	Clay	3	
194-195	Sand, medium	1	70
195-198	Till, gray, clayey, hard	3	
198-222	Till, olive-gray at top, to tan to brownish-gray to light brownish-gray to light gray below	24	
	CRETACEOUS		
222-227	Silt, blue-gray	5	
227-229	Sand	2	70
229-249	Silt, blue, gray, with some multi-colored sand layers	20	
249-253	Boulder, black, with associated dark blue-green clay	4	
253-256	Clay, light green-gray	3	
256-265	Silt, vivid olive green-brown	9	
	PRECAMBRIAN		
265-269	Rock, granitic, weathered, with whitish clay material	4	

Project test hole 30
Location number 124.36.24ccc
Altitude 1311 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 15	Sand, mostly brown, gray at very bottom; medium to coarse, with fine gravel	14	
15- 91	Till, gray, silty, clayey	76	
91- 96	Sand and clay layers	5	50
96-146	Till, gray, silty, clayey	50	
146-154	Sand and clay layers	8	50
154-190	Till, gray, sandy, silty, clayey	36	
190-196	Clay, dark brown	6	
196-201	Sand and clay layers	5	50
201-219	Till, light greenish tint, sandy	18	
219-228	Till, gray	9	
228-242	Sand, interbedded with some clay layers	14	100
242-251	Till, dark gray	9	
251-256	Sand, interbedded with clay layers	5	50

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 30--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PRECAMBRIAN		
256-273	Highly weathered crystalline rock; clay, dark green to bluish-green, contains many quartz grains and black, white and other-colored pebbles.....	17	

Project test hole 31
Location number 124.35.8acc
Altitude 1306 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 3	Sand, dark brown, fine, clayey.....	2	
3- 12	Sand, brown, medium to coarse.....	9	
12- 14	Till, gray, silty, clayey.....	2	
14- 21	Sand, gray, clayey.....	7	
21- 35	Till, gray, clayey.....	14	
35- 41	Till, olive-buff above, grey-buff below; silty, clayey.....	6	
41- 42	Sand.....	1	70
42- 65	Till, gray-buff at top, to light gray to gray below; sandy, silty, clayey.....	23	
65- 74	Till, gray, with sandy layers.....	9	
74- 76	Boulder.....	2	
76- 93	Till, gray, clayey.....	17	
93-108	Sand and gravel, gray; sand fine to coarse, gravel fine.....	15	120
108-112	Sand and gravel; gray; sand coarse, gravel fine to medium.....	4	70
112-131	Till, gray, clayey.....	19	70
131-133	Sand.....	2	
133-139	Till, gray, clayey; with boulders or cobbles at 136 feet and 138 feet.....	6	
139-155	Till, greenish-gray above to light gray to greenish-gray below; clayey.....	16	
155-158	Till, dark gray, clayey.....	3	
158-168	Till, gray-green, clayey.....	10	
168-173	Sand and gravel, coarse.....	5	200
173-180	Till, green-gray, clayey.....	7	
180-185	Sand.....	5	70
185-196	Till, bright salmon-colored above, gray below; silty, clayey.....	11	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 31--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic Conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
196 -210	Clay, dark gray, hard.....	14	
210 -232	Clay, mostly light gray, some blue-gray; silty, with some sandy layers.....	22	
232 -234	Sand, multi-colored.....	2	80
	PRECAMBRIAN		
234 -243	Highly weathered crystalline rock; clay, white to greenish-white, with chips of quartz, orthoclase and olivine with depth.	9	

Project test hole 32
Location number 122.34.11ccc
Altitude 1243 feet

	PLEISTOCENE		
0 - 1	Soil.....	1	
1 - 17	Sand and gravel, brown; sand medium to coarse, gravel fine.....	16	
17 - 37	Till, brown at top, grey below, clayey.....	20	
37 - 39½	Boulder, with cobbles, gravel, and sand.....	2½	
39½-108	Till, gray, sandy, silty, clayey.....	68½	
108 -115	Sand interbedded with till.....	7	50
115 -153	Till, gray, sandy, clayey.....	38	
153 -157	Sand interbedded with till.....	4	50
157 -159	Sand, gray.....	2	70
159 -162	Sand interbedded with till.....	3	50
162 -172	Till, light gray at top, gray below; sandy, clayey.....	10	
172 -175	Clay, dark gray.....	3	
175 -183	Till, gray.....	8	
183 -188	Sand interbedded with till.....	5	50
	CRETACEOUS		
188 -191	Clay, light blue-gray.....	3	
191 -202	Clay, olive above, light tan below.....	11	
202 -221	Clay, orange-brown above to light brown or buff below.....	19	
	PRECAMBRIAN		
221 -239	Highly weathered crystalline rock; clay, white and gray, with many quartz grains.....	18	
239 -	Rock, solid		

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 33
Location number 122.33.23daa
Altitude 1214 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0- 1	Soil	1	
1- 19	Sand, brown; fine to medium, with fine to medium gravel in bottom half	18	
19- 86	Till, gray, silty, sandy, clayey	67	
86- 87	Sand, gray	1	70
87- 99	Till, light greenish-gray; sandy, clayey	12	
99-117	Till, light gray, very silty	18	
117-124	Till, gray; with thin sand layers	7	
124-133	Till, gray, clayey	9	
133-135	Sand, gray	2	70
135-147	Till, gray, clayey	12	
147-149	Clay, dark gray	2	
149-152	Sand and clay layers	3	50
152-162	Till, light blue-gray, very silty	10	
162-170	Till, light gray with slight greenish tint, clayey	8	
170-198	Till, gray, clayey	28	
198-203	Sand and gravel	5	160
	PRECAMBRIAN		
203-208	Highly weathered crystalline rock; clay, light greenish-gray with small pieces of granite	5	

Project test hole 34
Location number 124.35.16cad
Altitude 1297 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 23	Sand and gravel, brown; sand medium to coarse; gravel fine to medium	22	
23- 24	Boulder	1	
24- 30	Till, brown at top, gray below; clayey	6	
30- 33	Sand, gray, fine	3	40
33- 39	Till, light yellow-brown with greenish tint above, to darker yellow to light buff below; clayey	6	
39- 87	Till, light gray above, gray below; sandy, clayey	48	
87- 87½	Sand	½	60

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 34--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
87½- 92	Till, gray	4½	
92 - 93	Sand	1	70
93 -101	Till, gray	8	
101 -114	Sand, gray, fine to coarse, with some fine gravel	13	120
114 -120	Till, light gray, soft above; gray, clayey below	6	
120 -120½	Sand	½	60
120½-142	Till, gray, clayey	21½	
142 -177	Till, greenish-gray at top, light blue-gray below	35	
177 -186	Sand interbedded with till	9	
186 -195	Clay, light blue-gray, soft	9	
195 -201	Till, gray, clayey	6	
201 -202	Sand, gray, with white pebbles and other colors; fine to coarse	1	80
202 -219	Till, gray to dark gray, gray-brown near bottom; soft, clayey	17	
219 -219½	Sand	½	60
219½-223	Till, gray, clayey	3½	
223 -227	Sand	4	70
227 -232	Till, gray, clayey	5	
232 -238	Sand, multi-colored, with clay beds	6	80
	PRECAMBRIAN		
238 -257	Highly weathered crystalline rock; clay green above, gray below; quartz and pink feldspar grains abundant	19	

Project test hole 35
Location number 124.36.26cbc
Altitude 1330 feet

	PLEISTOCENE		
0 - 1	Soil	1	
1 - 45	Sand and gravel, brown; sand fine to coarse, gravel fine to medium; with some clay layers	44	
45 -106	Till, gray, sandy, silty, clayey	61	
106 -112	Clay, dark gray	6	
112 -116	Sand, gray; fine to coarse, with fine gravel	4	150
116 -130	Till, light gray, sandy, clayey	14	
130 -146	Sand, gray, medium to coarse, with fine to medium gravel	16	160

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 35--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
146-156	Clay, or till	10	
156-176	Sand and gravel, gray; sand medium to coarse, gravel fine to medium	20	190
176-180	Till, gray, sandy, clayey	4	
180-187	Cobbles, gravel, and sand, coarse	7	200
187-195	Till, gray, clayey	8	
195-197	Sand	2	70
197-230	Till, gray, sandy, clayey	33	
230-248	Sand, gray, medium to coarse, with fine gravel	18	150
248-265	Sand and clay interbedded	17	50
	PRECAMBRIAN		
265-274	Highly weathered crystalline rock; clay gray above, greenish brown below	9	
274-275	Rock, solid, pink, granitic	1	

Project test hole 36
Location number 124.35.31dcd
Altitude 1302 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 43	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	42	
43- 88	Till, gray, silty, clayey	45	
88-108	Till, light orange-brown above, buff-colored below; sandy, clayey	20	
108-120	Till, light gray, clayey, with some sandy layers	12	
120-125	Till, gray	5	
125-126	Sand, gray, medium to coarse	1	100
126-140	Till, sandy, silty, clayey, hard	14	
140-144	Gravel, sand, and clay layers, with white limestone pebbles	4	80
144-150	Till, gray, clayey	6	
150-151	Sand	1	70
151-159	Till, gray, clayey	8	
159-161	Sand and gravel	2	70
161-167	Till, gray	6	
167-169	Sand	2	70
169-171	Till, gray, clayey	2	
171-172	Sand	1	70
172-173	Clay	1	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 36--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
173 -177	Sand	4	50
177 -190	Till, gray, clayey	13	
190 -197	Sand, multi-colored, with some interbedded green to gray clay	7	70
197 -207	Sand	10	100
207 -223	Till, gray	16	
223 -235	Till, light blue-green, clayey; with sandy layers near bottom	12	
235 -238	Till, light gray	3	
238 -243	Sand, multi-colored, medium to coarse	5	100
	CRETACEOUS		
243 -258	Clay, greenish-brown	15	
258 -277	Sand and gravel, multi-colored; sand medium to coarse, gravel fine to medium, with boulders, cobbles, and very coarse gravel in bottom few feet	19	240
277 -288	Clay, brown above, gray below	11	

Project test hole 37
Location number 124.37.24dcc
Altitude 1325 feet

	PLEISTOCENE		
0 - 2	Soil	2	
2 - 18	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	16	
18 - 70	Till, brown at very top, gray below; sandy, soft	52	
70 - 71	Sand	1	70
71 - 99	Till, gray, sandy	28	
99 -100	Sand	1	70
100 -110	Till, gray, sandy	10	
110 -110½	Sand	½	60
110½-123	Till, light gray, grading to light greenish-brown to light gray with depth; silty	12½	
123 -160	Till, gray, sandy, silty	37	
160 -161	Boulder	1	
161 -206	Till, gray, sandy, silty; clayey 188' to 198'	45	
206 -209	Sand layers in till	3	50
209 -218	Till, gray	9	
218 -226	Clay, dark gray	8	
226 -236	Till, light greenish-brown	10	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 37--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
236 -241	Till, yellowish-brown	5	
241 -250	Till, light greenish gray	9	
250 -250½	Boulder	½	
250½-267	Till, gray, silty	16½	
267 -270	Clay, light brown to buff	3	
270 -276	Sand, multi-colored, fine to coarse; with fine gravel and clay lens	6	100
	CRETACEOUS		
276 -288	Clay, brown	12	
288 -297	Clay, reddish-gray and blue-gray	9	
	PRECAMBRIAN		
297 -308	Highly weathered crystalline rock; pinkish-white clay with quartz grains	11	

Project test hole 38
Location number 125.37.13ccc
Altitude 1354 feet

	PLEISTOCENE		
0 - 1	Soil	1	
1 - 19	Sand and gravel, brown	18	
19 - 36	Till, brown; with sandy layers	17	
36 - 55	Till, gray, soft, with sandy layers	19	
55 - 90	Till, gray, sandy, silty, clayey	35	
90 - 95	Till, light greenish-gray above to tan to green below; clayey	5	
95 - 97	Sand	2	70
97 -110	Till, light gray above to dark gray to light gray below; clayey	13	
110 -114	Sand	4	70
114 -116	Till, gray	2	
116 -120	Sand	4	70
120 -155	Till, gray, sandy, silty, clayey	35	
155 -159	Sand with some clay layers	4	50
159 -211	Till, gray, sandy, silty, clayey	52	
211 -212	Sand	1	70
212 -231	Till, gray, sandy, silty, clayey	19	
	CRETACEOUS		
231 -258	Clay, green above, to light greenish-gray to olive to brown below	27	
258 -273	Sand, gravel, & cobbles, multi-colored, with clay layers	15	130

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 39
Location number 126.36.20bdd
Altitude 1347 feet

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE		
0- 1	Soil	1	
1- 23	Sand and gravel, brown; sand fine to coarse, gravel fine to medium	22	
23- 38	Till, brown at top, gray below, clayey; with some sandy layers	15	
38- 55	Till, light gray above, gray below; sandy, silty, clayey	17	
55- 58	Till, dark brown, clayey	3	
58- 67	Till, gray above, light gray below; clayey	9	
67- 88	Till, greenish-gray above, to light gray to gray below; sandy, clayey	21	
88- 91	Sand, gray	3	70
91-125	Till, gray, silty, clayey	34	
125-149	Sand, gray, medium to coarse, with fine gravel	24	150
149-155	Till, gray, clayey	6	
155-170	Till, greenish-yellow above, bluish-green below; silty, clayey	15	
170-198	Till, gray; sandy, silty, clayey	28	
198-214	Till, dark gray; clayey, sticky	16	
214-217	Till, greenish tint; with sandy layers	3	
217-228	Sand, multi-colored; gravelly, with some cobbles and some clay layers	11	130
228-230	Clay, gray	2	
	PRECAMBRIAN		
230-233	Rock, granitic, solid	3	

Project test hole 40
Location number 125.37.21bdd
Altitude 1375 feet

	PLEISTOCENE		
0- 1	Soil	1	
1- 34	Sand and gravel, brown; sand fine to coarse, gravel fine to coarse	33	
34- 58	Sand and clay interbedded	24	
58- 71	Till, gray, soft, sandy, clayey above; hard, silty, clayey below	13	
71- 76	Sand	5	70
76-112	Till, gray, silty, clayey	36	
112-116	Sand	4	70

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 40--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
116 -123	Till, light gray, with brownish tint; sandy, silty, clayey	7	
123 -124	Sand	1	70
124 -128	Till, light brown to buff, clayey	4	
128 -129	Sand	1	70
129 -190	Till, light gray above, gray below; clayey	61	
190 -191	Boulder	1	
191 -226	Till, gray, sandy, silty, clayey	35	
226 -227	Sand	1	70
227 -245	Till, gray, sandy, silty, clayey	18	
245 -251	Clay, dark, sticky	6	
	CRETACEOUS		
251 -271	Clay, greenish blue above, to olive, to brown, to brownish-gray below	20	
271 -273	Clay, buff	2	
273 -274	Sand	1	70
274 -277	Clay	3	
277 -280	Sand, multi-colored	3	70
280 -289	Clay, reddish-brown, silty, sandy	9	
289 -290	Sand	1	70
290 -300	Clay, gray-brown	10	
300 -301	Sand	1	70
301 -325	Clay, gray, hard	24	
325 -328	Clay, greenish-brown	3	
	PRECAMBRIAN		
328 -348	Highly weathered crystalline rock; clay white above, light gray below	20	

Project test hole 41
Location number 124.37.36daa
Altitude 1334 feet

	PLEISTOCENE		
0 - 1	Soil	1	
1 - 30	Sand, brown, fine to coarse, with fine gravel	29	
30 - 39	Till, brown at top, gray below, silty, clayey	9	
39 - 52	Sand and gravel, with some clay layers	13	170
52 - 83	Till, gray, clayey	31	
83 -128	Till, gray, sandy, silty, clayey	45	
128 -133	Sand, ochre-colored	5	70
133 -136	Till, gray	3	
136 -137	Sand	1	70
137 -148	Till, gray, silty, clayey, hard	11	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 41--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
148 -148½	Sand	½	60
148½-207	Till, gray, silty, clayey, hard above, soft below	58½	
207 -230	Till	23	
230 -239	Clay, dark gray	9	
239 -260	Clay, light gray at top, light greenish-gray below	21	
	CRETACEOUS		
260 -266	Silt, brown-gray above, to olive-gray, to olive-brown below; clayey, hard	6	
266 -287	Clay, light gray above, gray below, silty	21	
287 -293	Sand, with some gravel	6	70
	PRECAMBRIAN		
293 -298	Highly weathered crystalline rock; clay, white	5	

Project test hole 42
Location number 123.35.12ddd
Altitude 1264 feet

	PLEISTOCENE		
0 - 3	Soil and dark clay	3	
3 - 14	Sand and gravel, brown; sand fine to coarse, gravel fine	11	
14 - 26	Sand and clay layers	12	
26 - 68	Till, gray, light at top; sandy, silty, clayey; hard	42	
68 - 72	Till, gray, soft	4	
72 - 73	Sand, gray, medium to coarse	1	100
73 - 78	Till, gray	5	
78 - 85	Sand, gravel, and cobbles; coarser near bottom 2 feet	7	200
85 - 98	Till, light brown to buff; sandy, silty	13	
98 -109	Till, gray, silty	11	
109 -109½	Sand	½	60
109½-142	Till, gray, clayey	32½	
142 -152	Sand with some clay layers	10	50
152 -157	Clay	5	
157 -164	Sand and gravel, gray	7	160
164 -167	Till, gray	3	
167 -172	Sand, fine to coarse, with fine gravel	5	150
172 -176	Clay	4	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 42--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
176 -180	Sand, medium to coarse.....	4	100
180 -195	Till, gray, sandy, silty, clayey.....	15	
195 -195½	Sand.....	½	60
195½-217	Till, gray, sandy, silty, hard.....	21½	
	CRETACEOUS		
217 -219	Clay, olive-brown.....	2	70
219 -221	Sand, gray, fine to coarse, mostly medium....	2	
221 -228	Clay, olive at top, to tan, to gray-brown, to gray below; hard.....	7	
228 -232	Clay, gray.....	4	
232 -234	Clay, dark brown, soft.....	2	
	PRECAMBRIAN		
234 -250	Highly weathered crystalline rock; clay, whitish gray.....	16	

Project test hole 43
Location number 123.35.1bcb
Altitude 1281 feet

	PLEISTOCENE		
0 - 1	Soil.....	1	
1 22	Sand and gravel, brown; sand medium to coarse, gravel fine to coarse; orange-colored iron oxide stained layer at 14-15 feet	21	
22 - 79	Till, gray, sandy, silty, clayey.....	57	
79 - 81	Sand, gray-brown.....	2	70
81 - 84	Till, gray, sandy, silty, clayey.....	3	
84 -100	Till, light gray, silty.....	16	
100 -118	Till, gray sandy, silty, clayey.....	18	
118 -122	Sand and clay layers.....	4	50
122 -127	Sand, with some gravel.....	5	120
127 -133	Clay and sand layers.....	6	50
133 -137	Till, gray at top, to light gray with greenish tint, to buff with greenish tint below; clayey.....	4	
137 -160	Till, light gray above to gray below; clayey	23	
160 -163	Clay, dark brownish-gray.....	3	
163 -173	Till, gray, silty, clayey.....	10	
173 -183	Sand, gravel, cobbles, and boulders; coarser toward bottom; some clay layers present...	10	200
183 -187	Till, gray, silty, clayey.....	4	

Table 1.--*Logs of test holes penetrating buried aquifers--Continued*

Project test hole 43--Continued

Depth (feet)	Lithologic description and geologic age	Thickness (feet)	Estimated hydraulic conductivity (ft day^{-1})
	PLEISTOCENE--Continued		
187-189	Till, light greenish-gray, sandy, silty, clayey.....	2	
189-191	Sand, green, medium to coarse.....	2	90
191-194	Till, gray.....	3	
	CRETACEOUS		
194-211	Clay, bright green above, to dull olive, to brown below.....	17	
211-238	Clay, dark grayish-brown.....	27	
238-246	Sand, multi-colored; with clay layers at top..	8	80
	PRECAMBRIAN		
246-272	Highly weathered crystalline rock; clay, turquoise above, to white, to whitish-gray below; pink-tinted quartz grains abundant; pink feldspar grains toward bottom.....	26	

Project test hole 44
Location number 124.37.2dbc
Altitude 1332 feet

	PLEISTOCENE		
0- 1	Soil.....	1	
1- 5	Sand, brown.....	4	
5- 12	Till, brown.....	7	
12- 45	Till, gray silty, clayey, soft.....	33	
45- 48	Till, gray, soft; with sand and gravel layers.	3	
48- 60	Sand and gravel, gray; sand medium, gravel medium; with some clay layers.....	12	200
60- 63	Till, gray, soft.....	3	
63- 73	Sand and gravel.....	10	270
73- 83	Clay.....	10	
83- 92	Clay, with sandy layers.....	9	
92-102	Sand interbedded with clay layers.....	10	50
102-108	Till, gray above, light gray below.....	6	

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976--670050/1 REGION NO. 6