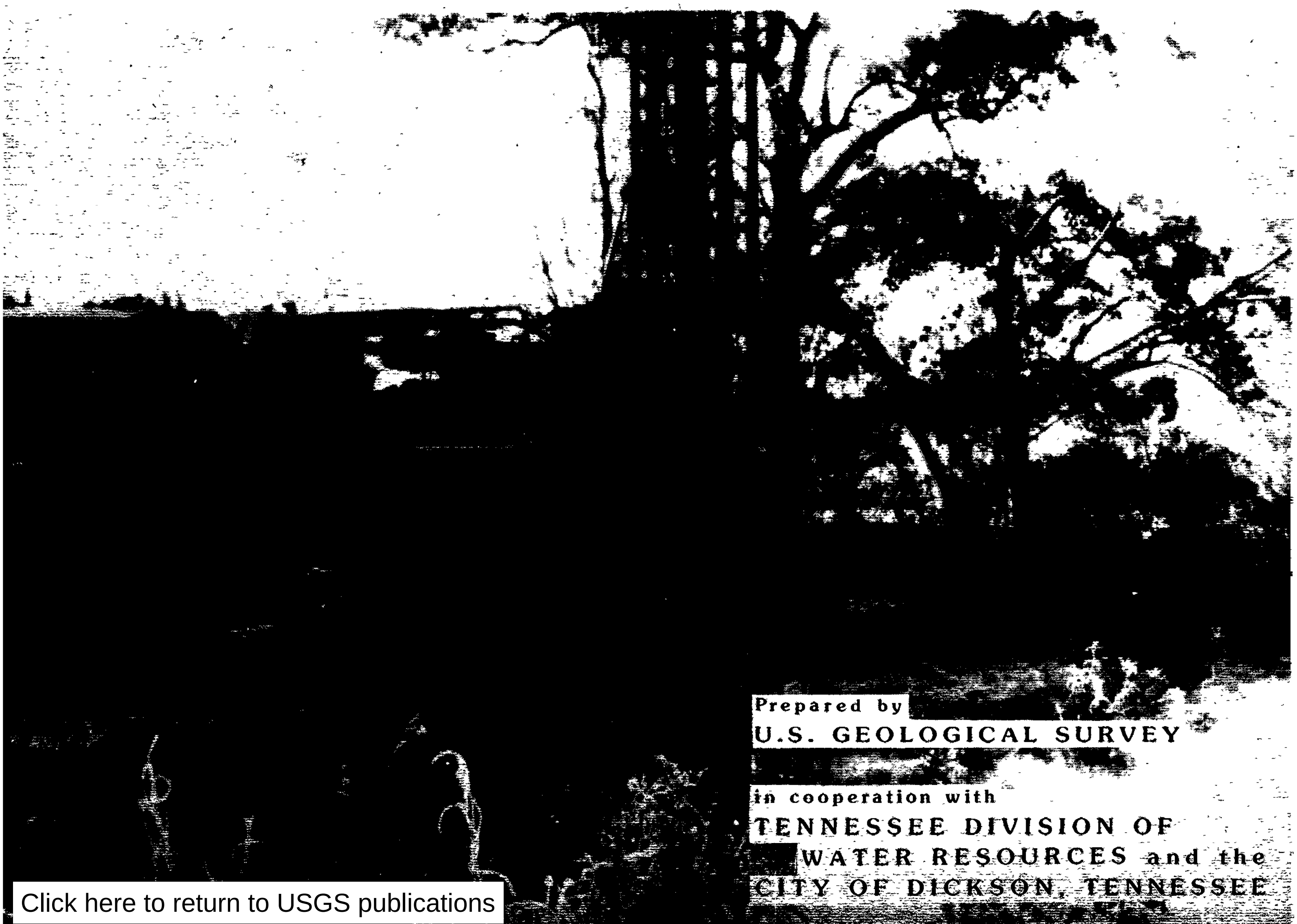
WATER-RESOURCES INVESTIGATIONS REPORT 82-4088

GROUND WATER IN THE DICKSON AREA OF THE WESTERN HIGHLAND RIM OF TENNESSEE



Prepared by
U.S. GEOLOGICAL SURVEY

in cooperation with
TENNESSEE DIVISION OF
WATER RESOURCES and the
CITY OF DICKSON, TENNESSEE

GROUND WATER IN THE DICKSON AREA OF THE WESTERN HIGHLAND RIM OF TENNESSEE

Michael W. Bradley

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-4088

Prepared in cooperation with the

TENNESSEE DIVISION OF WATER RESOURCES and the

CITY OF DICKSON, TENNESSEE

Nashville, Tennessee

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
A-413 Federal Building
U.S. Courthouse
Nashville, Tennessee 37203

Copies of this report can be
purchased from:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey
Box 25425, Federal Center
Lakewood, Colorado 80225
(Telephone: (303) 236-7476)

CONTENTS

	Page
Abstract	1
Introduction	1
Description of the study area	2
Geology	2
Hydrology	7
Concept of ground-water occurrence	7
Well records	9
Ground-water levels	11
Spring data	14
Streamflow data	14
Results of drilling	20
Test well data	20
Specific capacity tests	26
Yield-specific capacity tests	26
Tests at the Dk-17 site	26
Test at the Dk-21 site	32
Additional drilling near the Dk-21 site	35
Water quality	36
Summary and conclusions	39
Selected references	41

ILLUSTRATIONS

		Page
Figure 1.	Map showing location of the Dickson area, Tennessee......	3
2.	Graph showing mean monthly air temperature measured at the Dickson station (temperature data from National Oceanic and Atmospheric Adminstration, 1979)..	4
3.	Graph showing mean monthly precipitation measured at the Dickson station (precipitation data from National Oceanic and Atmospheric Administration, 1979..	4
4.	Map showing geology and structure of the Dickson area....	5
5.	Geologic cross section of the Dickson area...............	6
6.	Concept of ground-water occurrence and flow in the Dickson area..	8
7.	Bar graph showing frequency distribution of reported well yields in the Dickson area.......................	9
8.	Map showing reported well yields in the Dickson area.....	10
9.	Bar graph showing frequency distribution of casing lengths in wells in the Dickson area............	11
10-15.	Maps showing:	
	10. Regolith thickness based on casing length...........	12
	11. Ground-water levels and direction of flow...........	13
	12. Location of springs in the Dickson area.............	15
	13. Discharge measurements in the Dickson area..........	18
	14. Low-flow sites in the Dickson area..................	19
	15. Location of test wells..............................	21
16.	Bar graph showing frequency distribution of casing length in the test wells.............................	22
17.	Bar graph showing frequency distribution of yields of the test wells while blowing with compressed air....	22
18.	Graph showing regolith thickness versus yield for the test wells..................................	23
19.	Geologic cross section of the Dk-17 site with location map..	27
20.	Hydrograph and yield for the 72-hour test at Dk-17.......	28
21.	Semilogarithmic plot of drawdown versus distance from the pumped well for the 72-hour test of Dk-17.....	30
22.	Hydrograph and yield for the 8-hour test at Dk-17........	31
23.	Geologic cross section of the Dk-21 site with location map..	33
24.	Hydrograph and yield during the 72-hour test of well Dk-21...	34
25.	Semilogarithmic graph of drawdown versus distance from the pumped well for the test of Dk-21.............	35
26.	Hydrograph for well Dk-14 during May 5-May 7, 1981.......	36
27.	Comparisons of major cations and anions in water from wells Dk-21, Dk-17, and Fv-13...............	39

TABLES

		Page
Table 1.	Discharge, specific conductance, temperature, and pH of water from springs in the Dickson area	16
2.	Discharge measurements - Fielder Spring and Bruce Spring	17
3.	Low-flow discharge measurements for streams in the study area	20
4.	Test-well data and water occurrence	24
5.	Specific capacity test data	26
6.	Drawdown and recovery in wells at the Dk-17 site during the 72-hour test	29
7.	Drawdown and recovery in Dk-17, Dk-18, and Dk-19 during the 8-hour test	32
8.	Drawdown and recovery in wells Dk-13, Dk-14, Dk-20, and Dk-21 site during the 72-hour test	34
9.	Specific conductance of water from test wells	37
10.	Analyses of water from Dk-17 and Dk-21 compared with standards for maximum levels of constituents in finished drinking water	38

ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to International System of units (SI) and abbreviation of units:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.59	square kilometer (km^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound (lb)	0.4536	kilogram (kg)
ton	0.9072	megagram (Mg)
micromho per centimeter (μmho/cm)	1	microsiemens per centimeter (μS/cm)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°F = 1.8°C + 32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

GROUND WATER IN THE DICKSON AREA OF THE WESTERN HIGHLAND RIM OF TENNESSEE

Michael W. Bradley

ABSTRACT

A hydrologic study of the Dickson, Tenn., area provided additional information on the occurrence of ground water in the Mississippian carbonate rocks of the western Highland Rim. Twenty-six wells were drilled to determine the occurrence of ground water in relation to topographic position, regolith thickness, streamflow gains or losses, lithology of the underlying formations, and linear features.

Yields of 26 test wells ranged from 0 to about 300 gallons per minute and averaged about 68 gallons per minute. Nine wells yielded 80 to about 300 gallons per minute; specific capacities ranged from about 0.71 to 12.7 gallons per minute per foot of drawdown. Seven of these nine wells yielded water from solution openings in the Warsaw Limestone. The other two wells yielded water from gravel and sand in the regolith. Aquifer tests were conducted on two wells. One well was pumped at an average rate of 350 gallons per minute for 72 hours with 39.77 feet of drawdown. The second well was pumped for 8 hours at 120 gallons per minute with 20.86 feet of drawdown. The water from both wells was of generally good quality. Water from one well had a dissolved solids concentration of 170 milligrams per liter. The dissolved solids in the water from a second well was estimated from specific conductance as about 160 milligrams per liter.

Thick regolith and the presence of fine-grained limestone interbedded with coarse-grained limestone near the base of the regolith appear to be significant conditions for the development of solution openings that yield large amounts of water. Seventy percent of the test wells in which these conditions occurred yielded 80 gallons per minute or more.

INTRODUCTION

The need for alternative sources of water has emphasized the need for additional information on the occurrence of ground water in carbonate rocks. In the past, these aquifers have been used, for the most part, as rural domestic water sources. Development of these aquifers for municipal and industrial purposes is deterred by their highly variable water-bearing properties; low-yielding wells are common and the occurrence of large supplies is unpredictable. A three phase study was conducted near Dickson, Tenn., to acquire a better understanding of the ground-water system.

The study had three objectives:

- To describe the ground-water hydrology of the western Highland Rim in the vicinity of Dickson,

- To test concepts of ground-water occurrence by drilling test wells at sites selected on the basis of hydrologic criteria, and
- To acquire and interpret data on the quantity and quality of ground water and on the geologic environment in which it occurs.

To accomplish these objectives the first phase of the study included interpretation of well and spring records, water-quality data, streamflow measurements, aerial photographs, and geologic data. During the second phase, test sites were selected and a total of 26 wells was drilled. In the third phase, aquifer tests were conducted to determine aquifer properties. Water samples were collected for water-quality analyses.

This study was conducted by the U.S. Geological Survey, in cooperation with the city of Dickson and the Tennessee Division of Water Resources and is part of a larger study of the carbonate rocks of the Highland Rim in which the concept of ground-water occurrence is being tested in specific areas.

DESCRIPTION OF THE STUDY AREA

The Dickson area lies on the rolling plateau of the western Highland Rim, a section of the Interior Low Plateaus physiographic province. The study area is within Dickson County and approximately 40 miles west of Nashville (fig. 1). The 104-square-mile area lies along the drainage divide between the Tennessee and Cumberland River basins. The major streams are the East and West Piney Rivers which drain the western and southern part of the area and Jones Creek which drains the northeastern part. These streams are deeply incised into the plateau providing about 300 feet of relief. Altitudes range from near 600 feet in the valley of Piney River to about 900 feet above sea level.

The Dickson area has a temperate climate, mean monthly temperature ranges from 39°F in January to 79°F in July (fig. 2). The mean annual temperature is 59°F. The Dickson area receives about 50 inches of precipitation in a normal year. However, most of the precipitation falls during the late winter and early spring. Mean monthly precipitation ranges from 2.54 inches in October to 5.52 inches in March (fig. 3).

GEOLOGY

Formations exposed on the northwestern Highland Rim in the Dickson area include, in descending order, the Tuscaloosa Gravel of the Cretaceous Period and the St. Louis Limestone, the Warsaw Limestone, and the Fort Payne Formation of the Mississippian Period (fig. 4). The regional dip of the formations is toward the northwest (Marcher, 1962a). Local structural features include lows to the southwest and northeast parts of the study area that are separated by an east-west trending anticline under the city of Dickson (figs. 4 and 5).

The Tuscaloosa Gravel consists of chert gravel, sand, silt, and clay. The chert gravel is composed of well-rounded fragments up to 6 inches in diameter, and was derived from the Camden Chert of Devonian age or locally from the St. Louis, Warsaw, and Fort Payne. Because of its isolated nature and limited distribution, the Tuscaloosa is not a significant source of ground water.

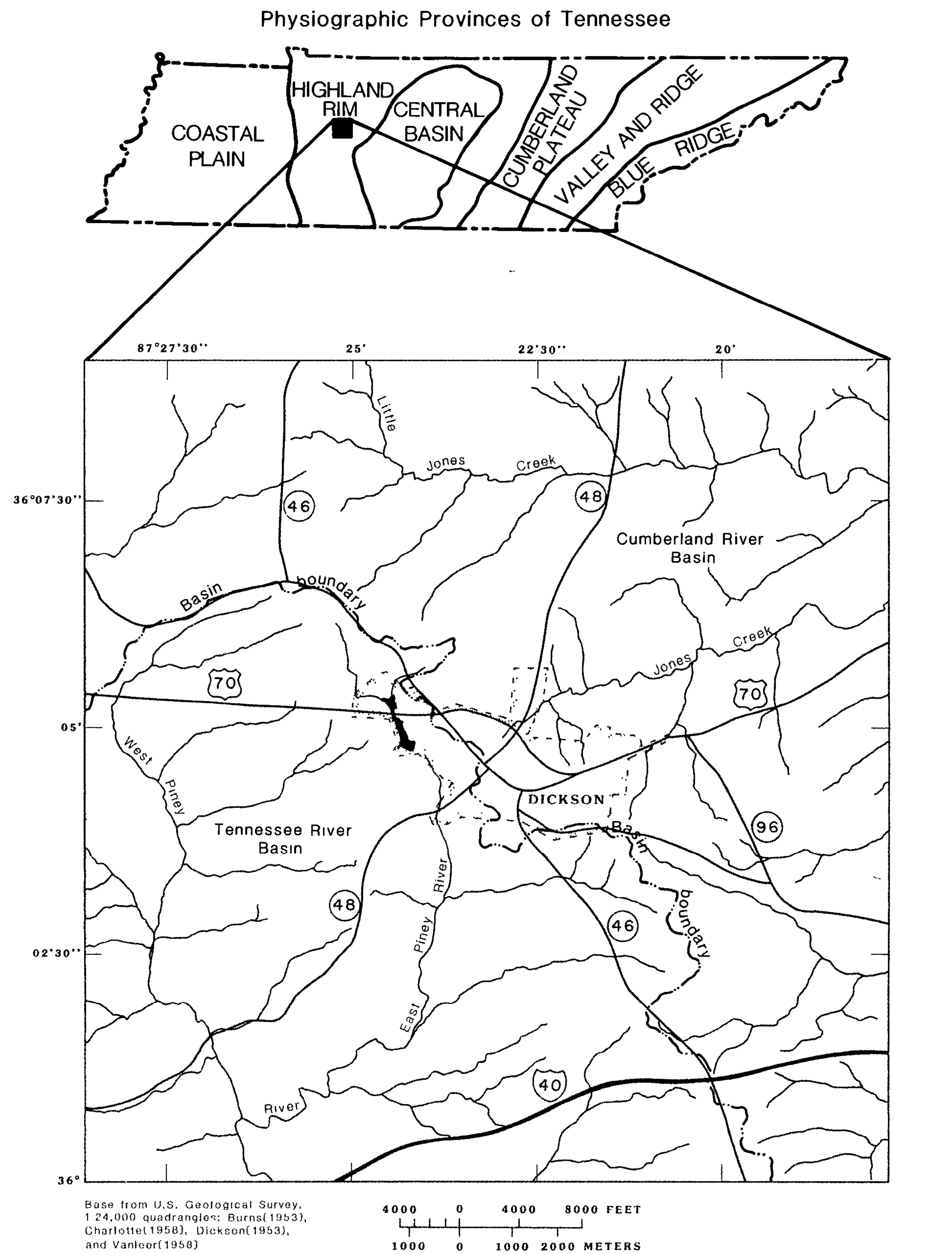


Figure 1.-- Location of the Dickson area, Tennessee.

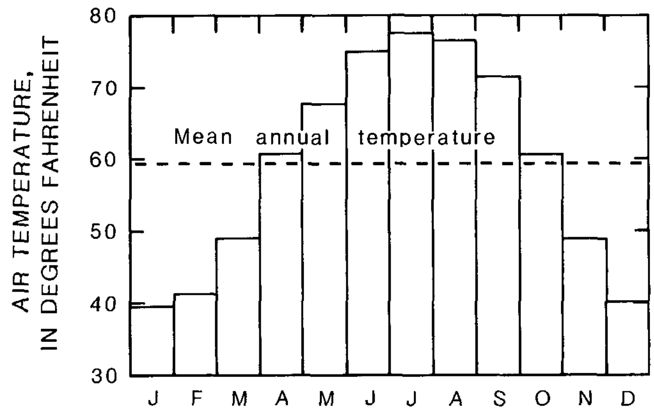


Figure 2.--Mean monthly air temperature measured at the Dickson station (temperature data from National Oceanic and Atmospheric Administration, 1979).

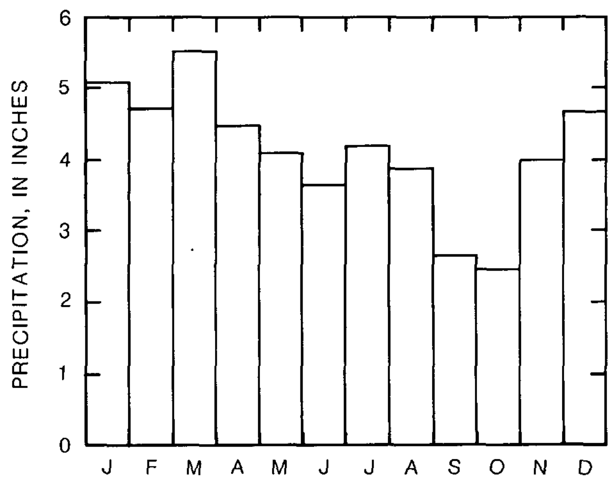
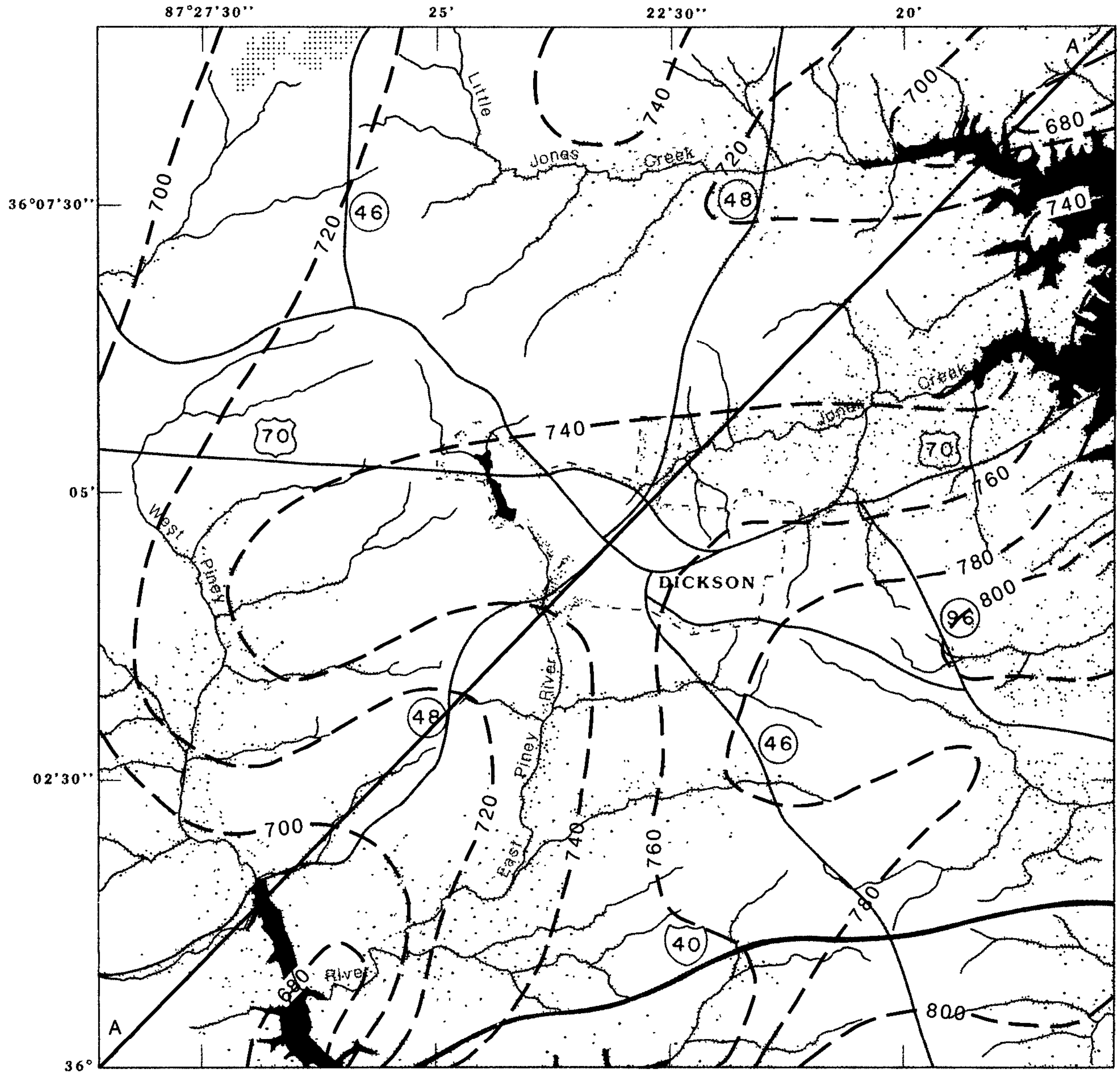


Figure 3.--Mean monthly precipitation measured at the Dickson station (precipitation data from National Oceanic and Atmospheric Administration, 1979).



Base from U.S. Geological Survey, 1:24,000 quadrangles, Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

Geology modified from Marcher, Bingham, and Lounsbury (1964)

EXPLANATION

CRETACEOUS

Tuscaloosa Gravel

MISSISSIPPIAN

ST. Louis Limestone

Warsaw Limestone

Fort Payne Formation

—720— Structural contours on top of the Warsaw Limestone. Contour interval 20 feet. Dashed where approximately located. National Geodetic Vertical Datum of 1929

A ——— A' Line of cross section (See figure 5)

Figure 4.-- Geology and structure of the Dickson area.

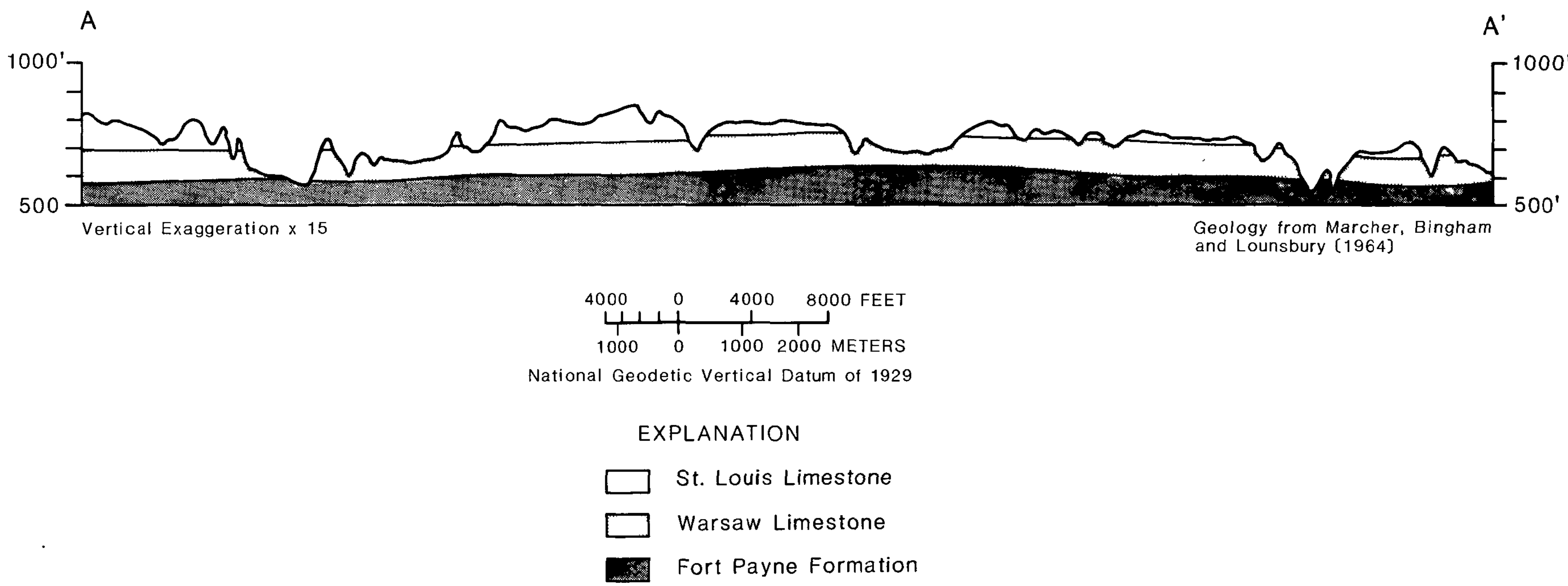


Figure 5.-- Geologic cross section of the Dickson area.

The St. Louis Limestone, which caps most of the uplands, is generally represented at land surface only by a residual clay soil containing blocks and nodules of chert. The St. Louis is a yellowish-brown fine-grained cherty limestone which locally includes beds of medium- to coarse-grained fossil-fragmental silty limestone similar to the underlying Warsaw Limestone. The St. Louis regolith contains chert which is dark, very dense, and brittle, and in places is characterized by round chert "cannonballs" (Marcher and others, 1964). Regolith is the mantle of unconsolidated material which overlays the bedrock.

The Warsaw Limestone is typically a thick-bedded, light colored, medium- to coarse-grained, fossil fragmental limestone. In the Dickson area it is approximately 100 feet thick. The sand size fossil fragments were derived primarily from crinoids and bryozoans. Quartz and calcite are the main minerals present, but glauconite and pyrite occur locally in very small amounts. Locally, the Warsaw Limestone contains fine-grained, cherty beds which are typical of the underlying Fort Payne Formation. The Warsaw-Fort Payne contact is generally conformable with gradation and possible inter-tonguing occurring between the two formations.

The Fort Payne Formation is typically a calcareous, dolomitic, very cherty siltstone. Maximum thickness in the Dickson area is approximately 250 feet. Chert occurs throughout the formation in distinct beds, as irregular discontinuous beds or nodules, and within the matrix of the limestone and dolomite. Small cavities (less than 2 inches in diameter) contain quartz or calcite. Some gypsum occurs in the lower part of the Fort Payne. Glauconite and pyrite also occur in small quantities. Some beds in the Fort Payne are medium- to coarse-grained, fossil fragmental limestone similar to the typical Warsaw Limestone.

Underlying the Mississippian formations is the Chattanooga Shale, a fissile black shale approximately 20 feet thick. Below this is a thick sequence of Silurian and older rocks consisting of limestone, dolomite and calcareous siltstone (C. R. Burchett and Ann Zurawski, written commun., 1979). For additional discussion of the geology of the Dickson area, see Marcher and others (1964).

HYDROLOGY

CONCEPT OF GROUND-WATER OCCURRENCE

Carbonate rocks underlying the Dickson area have little intergranular permeability. Secondary permeability features, primarily solution enlarged bedding plane openings, transmit most of the water (fig. 6). Moore and Bingham (1965) reported that the largest amounts of ground water occur in solution openings in soluble limestone, such as some beds in the Warsaw and St. Louis Limestone.

The St. Louis Limestone and locally the upper part of the Warsaw generally have weathered to a clay regolith in the Dickson area. The regolith has low permeability but has an important role in ground-water occurrence in this area. The regolith stores a large amount of water and slowly releases it to solution openings in the underlying limestone. There the solvent action of the water

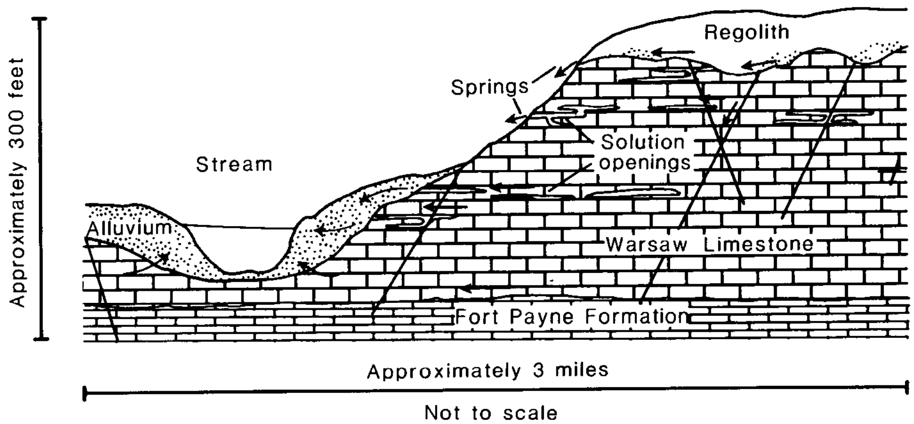


Figure 6.-- Concept of ground-water occurrence and flow in the Dickson area.

enlarges openings and increases permeability. The occurrence of thick regolith over the soluble Warsaw Limestone is conducive to the development of high yielding solution openings.

The ground-water system is recharged primarily from precipitation on the uplands. Water moves down through the regolith and into solution openings and fractures in the limestone. Marcher and others (1964) estimated that about 12 percent of the total precipitation recharges the ground-water system. Once the water is in the limestone, it moves along the solution openings and vertical fractures to discharge points at springs and along streams.

Springs and stream segments which gain flow are positive indicators of the presence of ground-water reservoirs (Rima and Goddard, 1979). The springs in this area, with the exception of Payne Spring, all issue from the Warsaw Limestone. This indicates that the Warsaw is a ground-water reservoir and the dense cherty Fort Payne Formation is generally an underlying confining layer. However, some wells yield water from solution openings in the Fort Payne.

WELL RECORDS

Data on wells in the Dickson area are in the files of the Tennessee Division of Water Resources and U.S. Geological Survey. Since 1963, water-well drillers have been submitting reports to the State on the wells that they drill. Data on yield and casing length were obtained from these driller reports.

Reported well yields for 165 wells in the area (fig. 7) range from less than 1 to about 100 gal/min. Sixty-nine percent of the wells yield less than 10 gal/min. However, 22 percent yield 15 gal/min or more. There is no clear pattern to the distribution of well yield and location (fig. 8). Wells yielding more than 15 gal/min are scattered throughout the area and occur in stream valleys and uplands.

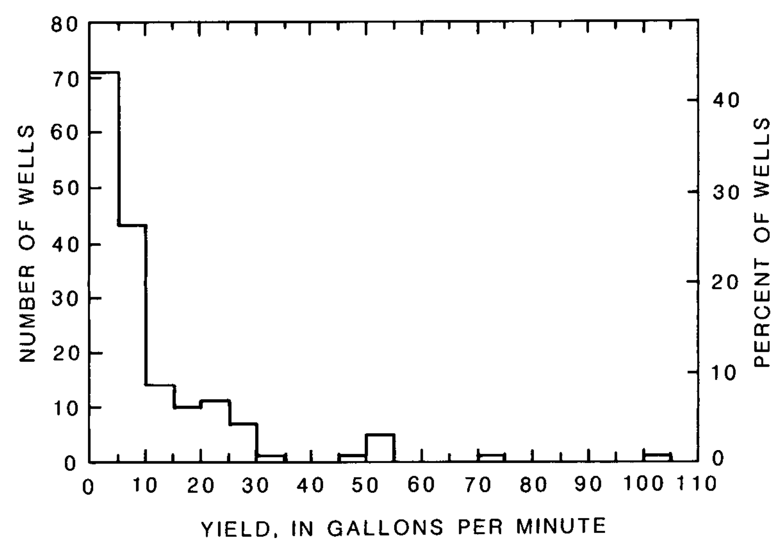


Figure 7.--Frequency distribution of reported well yields (data from Tennessee Division of Water Resources, unpublished data).

Casing lengths have been reported for 226 wells in the Dickson area. The lengths range from a minimum of 6 feet to a maximum of 188 feet. About half of the wells are cased to between 40 and 79 feet (fig. 9). Because State regulations require that well casing be set into bedrock, most reported casing lengths are at least as great as the regolith thickness and may be greater (Burchett and Zurawski, written commun., 1979). Casing lengths were used to approximate the regolith thickness (fig. 10).

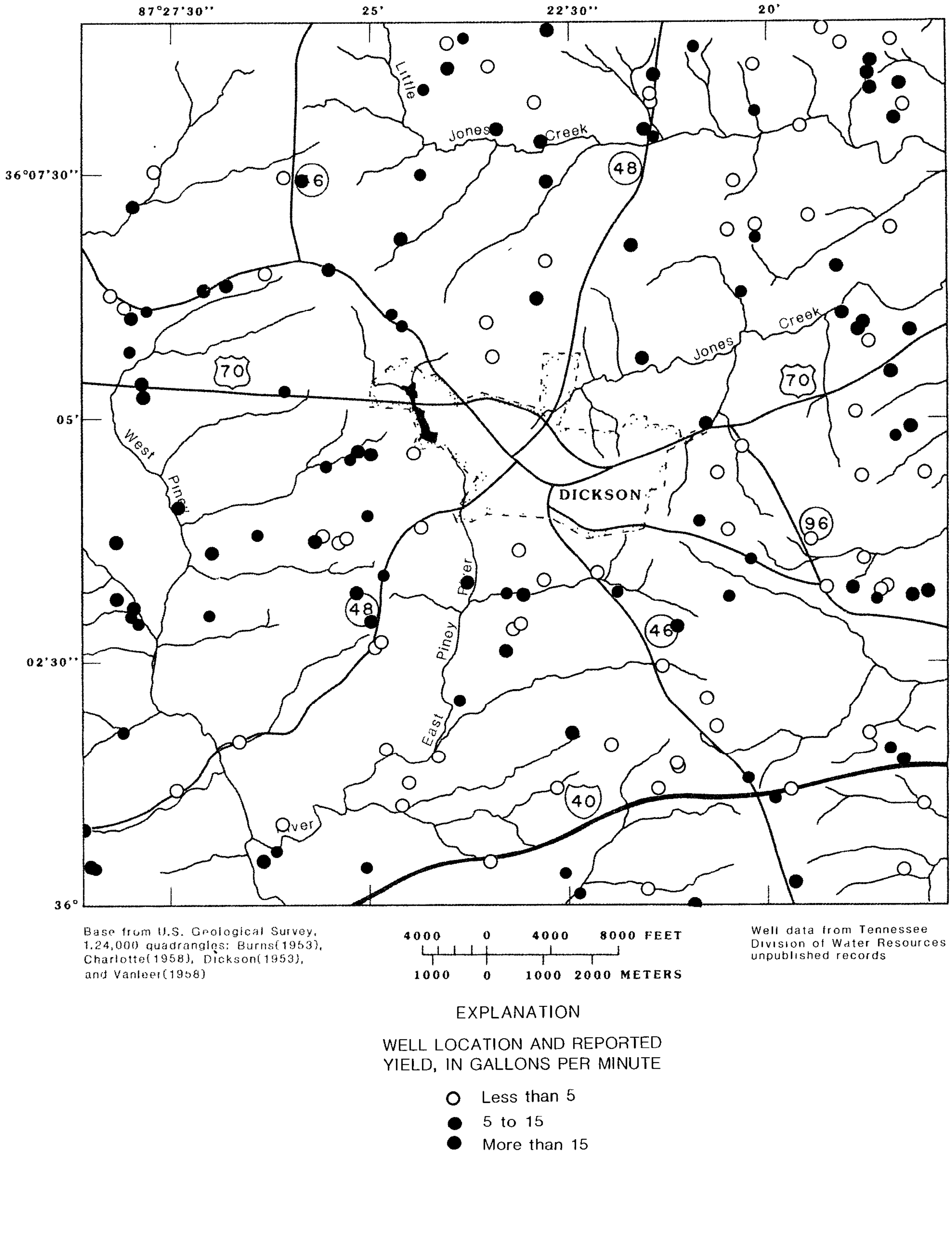


Figure 8.— Reported well yields in the Dickson area.

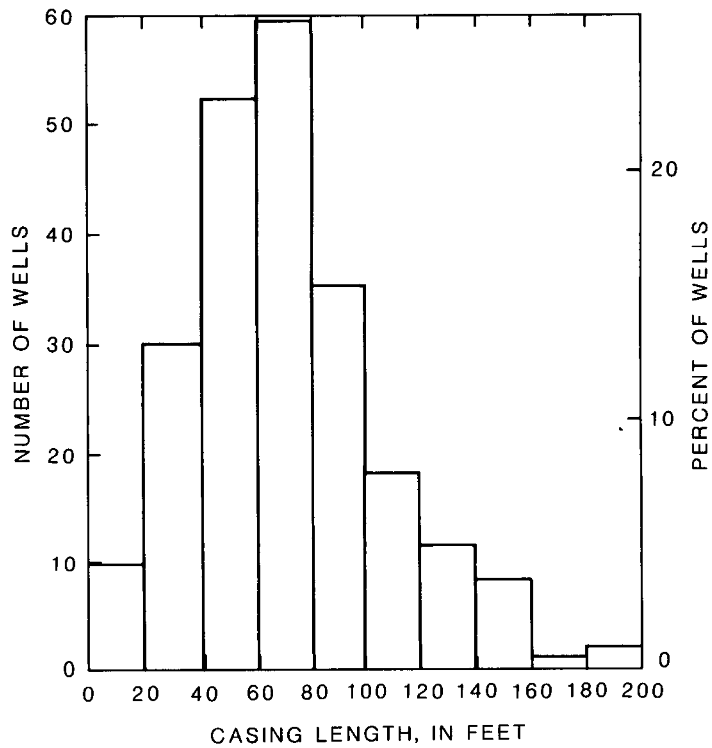


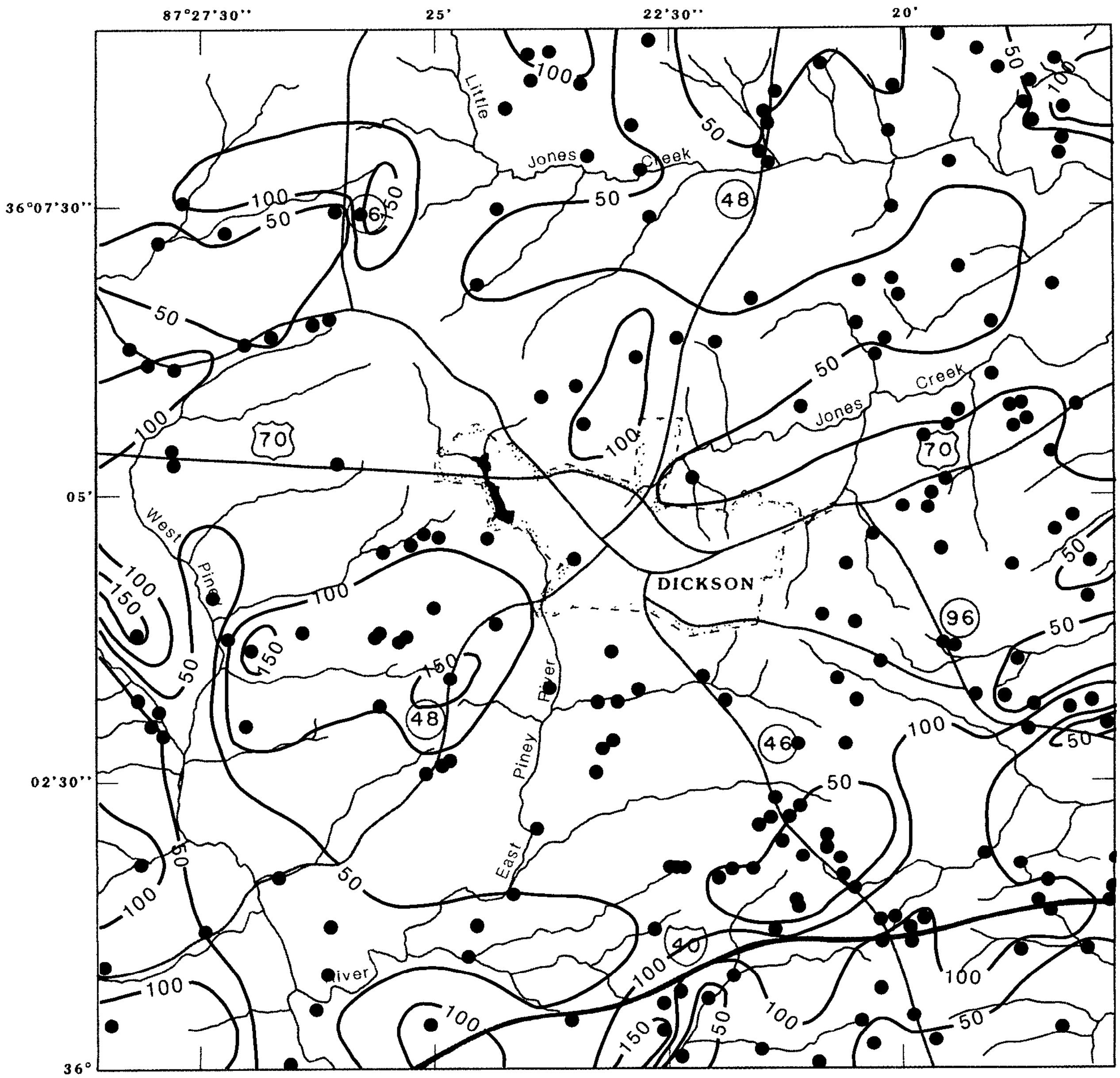
Figure 9.--Frequency distribution of casing lengths in wells in Dickson area (data from Tennessee Division of Water Resources, unpublished data).

Regolith in the uplands is generally about 50 to more than 150 feet thick. One exception is southeast of Dickson along Highway 46, an upland area where, based on casing lengths, the regolith is less than 50 feet thick. In the valleys of the major streams, East and West Piney Rivers, Jones Creek, and Little Jones Creek, the regolith is less than 50 feet thick (fig. 10).

GROUND-WATER LEVELS

Ground water in the Dickson area flows from recharge areas where water level elevations are high, to discharge points at lower elevations. Water levels in 59 wells were measured in March 1960 (Marcher and others, 1964) and ranged from 0 to 110 feet below land surface. It is likely that water levels are similar now (1980) as ground-water pumpage in the area has not changed greatly.

A water level contour map modified from Marcher and others (1964) is based on the March 1960 water levels and the altitudes of nine springs (fig. 11). This map shows high water-level altitudes under the drainage divide which runs northwest to southeast through Dickson with the highest water levels northwest



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET
1000 0 1000 2000 METERS

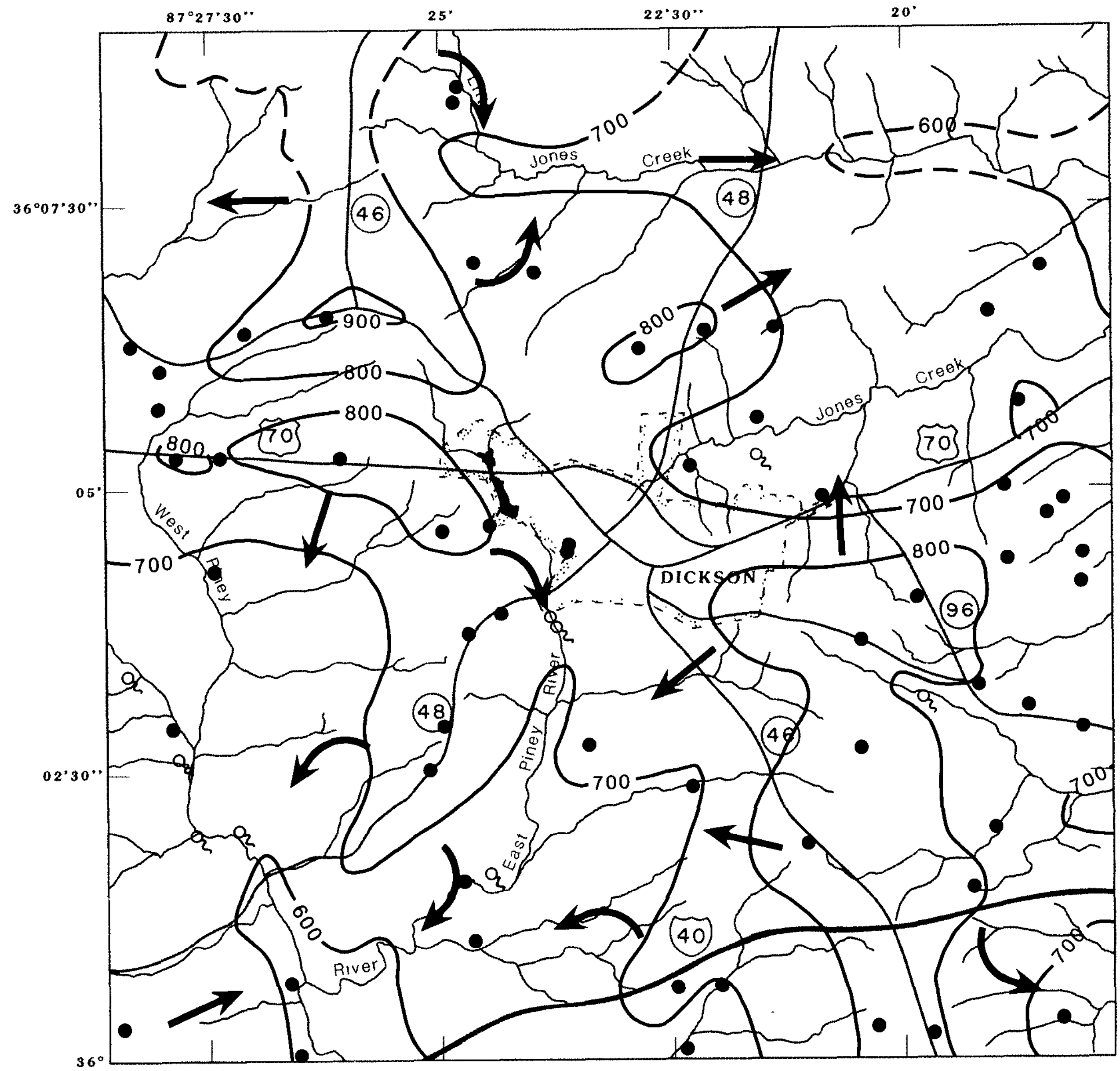
Data from Tennessee Division of Water Resources, unpublished data (1979)

EXPLANATION

—100— LINE OF EQUAL THICKNESS OF REGOLITH-- Interval 50 feet. Datum is land surface

● Well location

Figure 10.-- Regolith thickness based on casing lengths.



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

Hydrology modified from Marcher, Bingham, and Lounsbury (1964)

EXPLANATION

— 600 — — POTENTIOMETRIC CONTOUR — Shows altitude of water table, March 1960. Dashed where approximately located. Contour interval 100 feet. National Geodetic Vertical Datum of 1929

● Wells with water levels measured March, 1960

Springs

Direction of ground-water flow

Figure 11.-- Ground-water levels and direction of flow.

of Dickson. The water table is as much as 300 feet lower in altitude in the valleys of the major streams (Burchett and Zurawski, written commun., 1979). The direction of ground-water flow is similar to the surface drainage; flow is away from uplands and toward lower water-level altitudes in the valleys.

SPRING DATA

Springs are natural outlets for ground water and occur where land surface intersects the water table. Most of the large springs in the Dickson area (fig. 12) discharge from near the bottom of deeply incised hollows (Marcher and others, 1964).

Discharge measurements were made during July 1979 at six springs in the Dickson area. Two springs, Walnut Grove Spring and Grassy Spring, had the lowest discharge of the six springs measured (table 1). The measured yield of the four springs along West Piney River ranged from 0.57 to 1.78 cubic feet per second (ft^3/s). Payne Spring was measured in September 1978, with a flow of 0.20 ft^3/s. Eight discharge measurements ranging from 0.13 to 0.79 ft^3/s were made at Tice Spring from September 1980 through June 1981. Specific conductance of water from the springs ranged from 175 to 295 micromhos per centimeter (μmhos/cm) and pH ranged from 7.0 to 7.7 (table 1).

Discharge measurements have been made periodically from 1931 through 1979 at Fielder and Bruce Springs (table 2). Fifty-seven measurements have been made at Fielder Spring; Bruce Spring has been measured 17 times during the same period as Fielder Spring. Discharge from Bruce Spring is consistently lower than discharge from Fielder Spring.

STREAMFLOW DATA

Streamflow measurements were made on July 19, 1979, at 96 sites along streams in the study area (fig. 13). The streams were dry at 27 of the sites. All but two of the dry sites have drainage areas of less than 1 square mile. The largest drainage area was 1.68 square miles. The average streamflow for all 96 sites was 0.26 cubic foot per second per square mile. If the 27 dry sites were omitted, the average was 0.36 cubic foot per second per square mile.

The change in streamflow per additional square mile of drainage area between sites was determined for each site in order to delineate stream reaches which are gaining more ground water than other stream reaches (fig. 13). The gaining reaches of the streams are generally draining upland areas which have some relatively high reported well yields. The gaining reaches of streams, similar to springs, indicate discharge from the ground-water reservoir.

Low-flow discharge measurements have been published (Gold, 1980) for 10 sites within the study area (fig. 14 and table 3). Low-flow measurements are made at a time when there is no overland runoff from precipitation, and flow is sustained by discharge from the ground-water system.

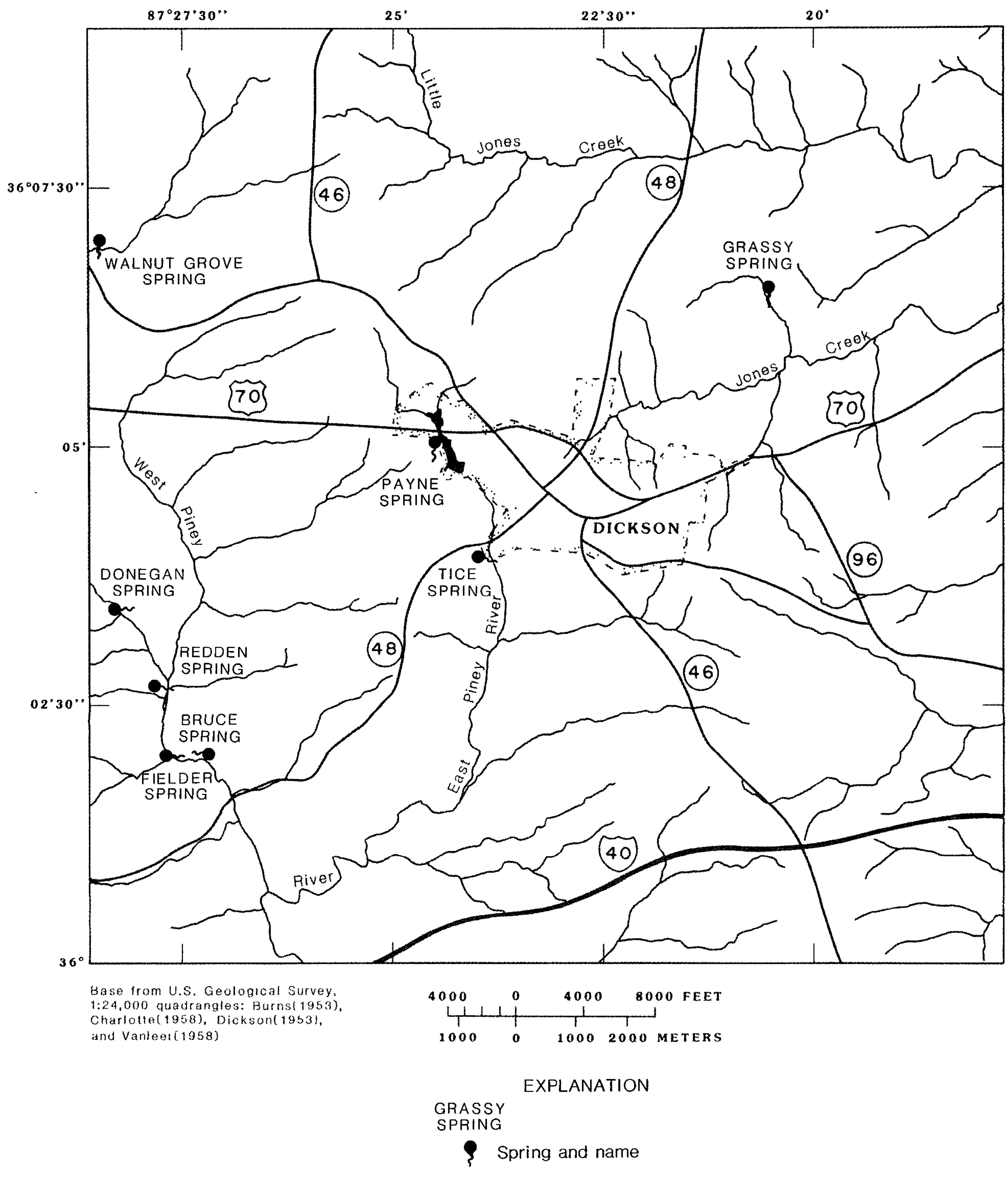


Figure 12.— Springs in the Dickson area.

Table 1.--Discharge, specific conductance, temperature, and pH of water from springs in the Dickson area.

Spring (fig. 12)	Date	Discharge (ft^3/s)	Specific conductance (µmho/cm 25°C)	Temperature (°C)	pH
Walnut Grove Spring	7-11-79	0.05*	245	16.5	7.4
	7-19-79	0.04*	270	16.0	---
Donegan Spring	7-11-79	0.84	270	17.0	7.0
Redden Spring	7-11-79	0.57	220	15.5	7.5
	7-19-79	0.68	230	15.5	---
Fielder Spring	7-11-79	1.78	255	14.5	7.6
Bruce Spring	7-11-79	1.42	240	15.5	7.7
	7- 7-79	1.34	175	14.0	---
Grassy Spring	7-19-79	0.07	---	---	---
Payne Spring	9-29-78	0.20	---	---	---
Tice Spring	9-17-80	0.16	280	14.0	---
	12-22-80	0.13	260	13.0	---
	1-12-81	0.17	280	13.0	---
	2- 2-81	0.18	290	14.0	---
	2-23-81	0.22	270	13.0	---
	4-13-81	0.28	250	14.5	---
	5-21-81	0.79	190	13.0	---
	6-29-81	0.21	295	14.5	---

* Estimated.

Table 2.--Discharge measurements - Fielder Spring and Bruce Spring

Date	Discharge (ft^3/s) Fielder Spring	Bruce Spring	Date	Discharge (ft^3/s) Fielder Spring	Bruce Spring
08-06-31	2.06	1.30	08-29-62	1.93	---
09-29-31	1.72	1.10	09-26-62	1.98	---
07-17-52	2.17	1.68	10-25-62	1.93	---
08-12-52	1.90	1.19	11-28-62	1.78	---
09-23-52	1.86	1.19	01-12-62	1.57	---
10-22-52	2.02	1.12	01-12-63	1.46	---
11-20-52	1.72	1.17	03-27-63	2.01	---
12-08-52	1.62	1.00	04-10-63	1.85	---
01-20-53	1.74	1.08	05-07-63	1.92	---
02-24-53	1.98	1.54	06-05-63	1.91	---
03-18-53	2.18	1.67	07-12-63	1.86	---
04-29-53	1.95	1.46	08-05-63	1.74	---
05-26-53	2.21	1.75	09-10-63	1.78	---
06-23-53	2.09	1.45	10-03-63	1.60	---
06-02-54	1.94	1.31	11-13-63	1.53	---
07-07-61	2.96	---	12-10-63	1.66	---
08-09-61	3.12	---	01-23-64	1.86	---
09-07-61	2.09	---	02-14-64	1.75	---
10-04-61	2.07	---	03-10-64	2.25	---
11-02-61	1.83	---	04-16-64	1.85	---
12-04-61	1.58	---	05-15-64	2.67	---
01-02-62	1.79	---	06-18-64	1.96	---
02-07-62	2.03	---	07-16-64	1.65	---
03-06-62	2.70	---	08-20-64	1.71	---
04-03-62	3.03	---	09-23-64	1.78	---
05-02-62	2.58	---	10-15-64	1.70	---
05-03-62	2.38	---	11-17-64	1.50	---
07-03-62	2.23	---	07-11-79	1.78	1.42
08-02-62	2.30	---	07-19-79	---	1.34

	Mean	Maximum	Minimum
Fielder Spring	1.98	3.12	1.46
Bruce Spring	1.34	1.75	1.00

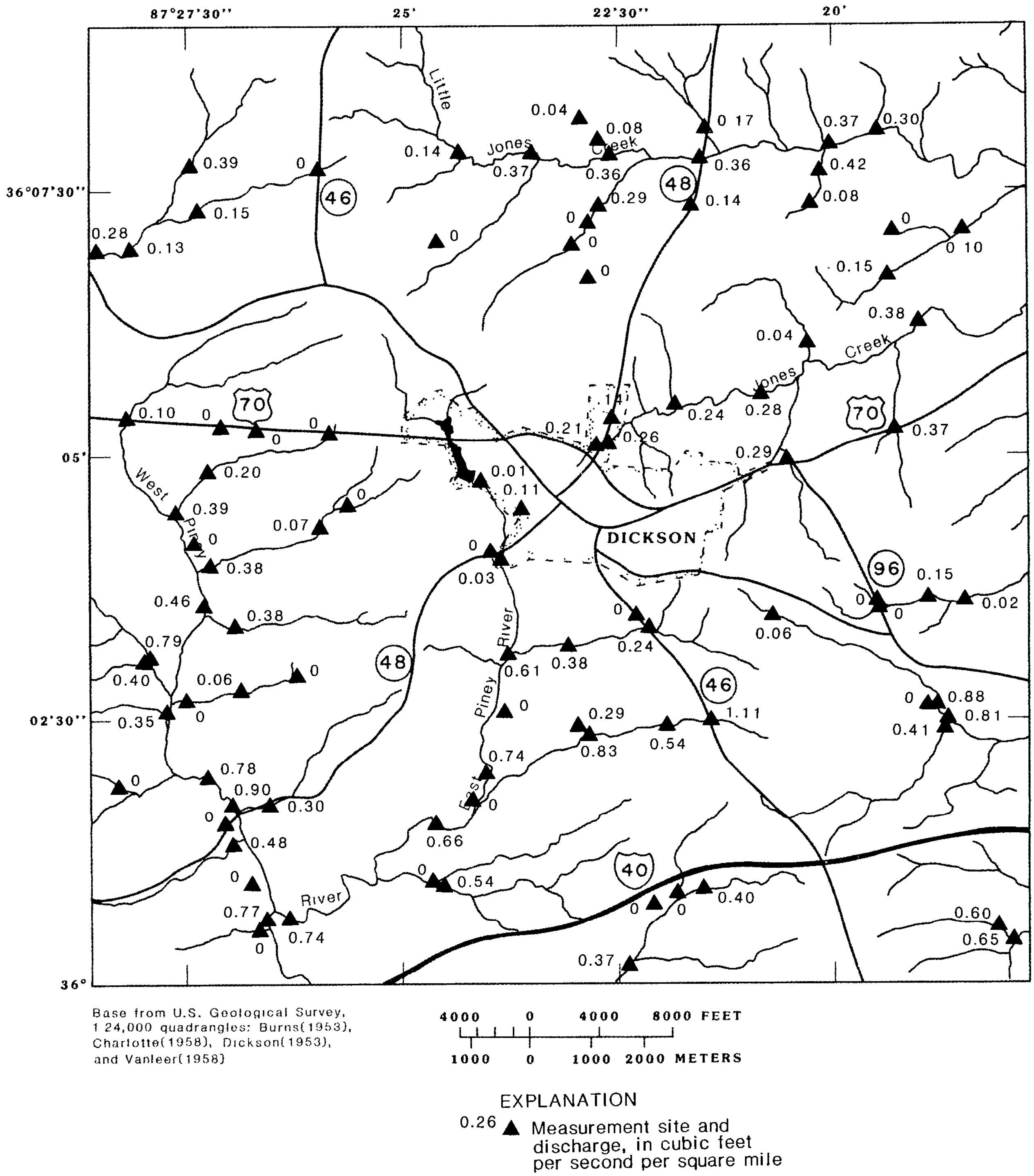
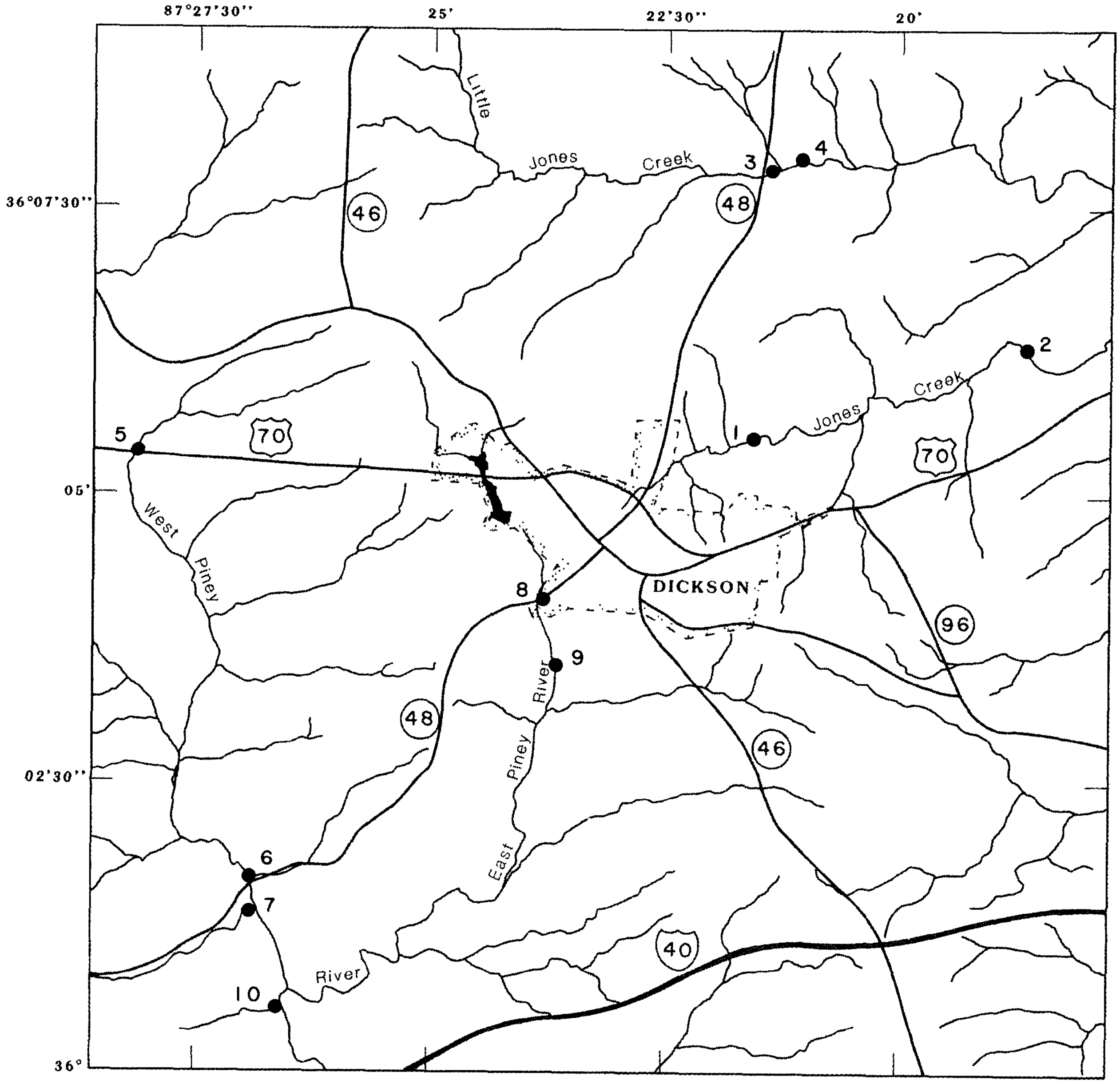


Figure 13.– Discharge measurements in the Dickson area.



Base from U.S. Geological Survey, 1:24,000 quadrangles: Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

EXPLANATION

● 4 Low-flow site and reference number (See table 3)

Figure 14.-- Low-flow sites in the Dickson area.

Table 3.--Low-flow discharge measurements for streams in the study area

Reference no. (fig. 14)	Station no.	Drainage area (mi^2)	Date	Discharge (ft^3/s)	Date	Discharge (ft^3/s)
1	03434585	5.05	10-17-50	0.42	06-24-52	0.57
2	03434590	13.3	07-31-74	2.20	08-21-75	1.8
3	03434593	10.9	07-07-50	3.47		
4	03434595	13.8	09-12-51	0.57		
5	06302170	2.16	10-10-61	0	09-27-63	0.05
			05-15-62	0.56	10-04-64	0
			04-25-63	0.45	08-06-65	0.36
6	03602192	21.2	07-07-50	12.5	05-15-62	22.0
			09-12-51	9.01	04-25-63	17.7
			10-17-51	8.75	09-27-63	9.95
			06-24-52	10.6	10-04-64	9.11
			10-10-61	8.01	08-10-65	12.6
7	03602193	1.95	11-13-52	0		
8	03602196	2.90	10-24-54	0.47		
9	03602200	6.21	10-10-61	1.67	10-04-64	2.38
			05-15-62	5.50	08-10-65	5.57
			04-25-63	4.88	09-03-69	3.16
			09-27-63	2.61		
10	03602210	0.73	11-13-52	0		

Data from Gold, 1980.

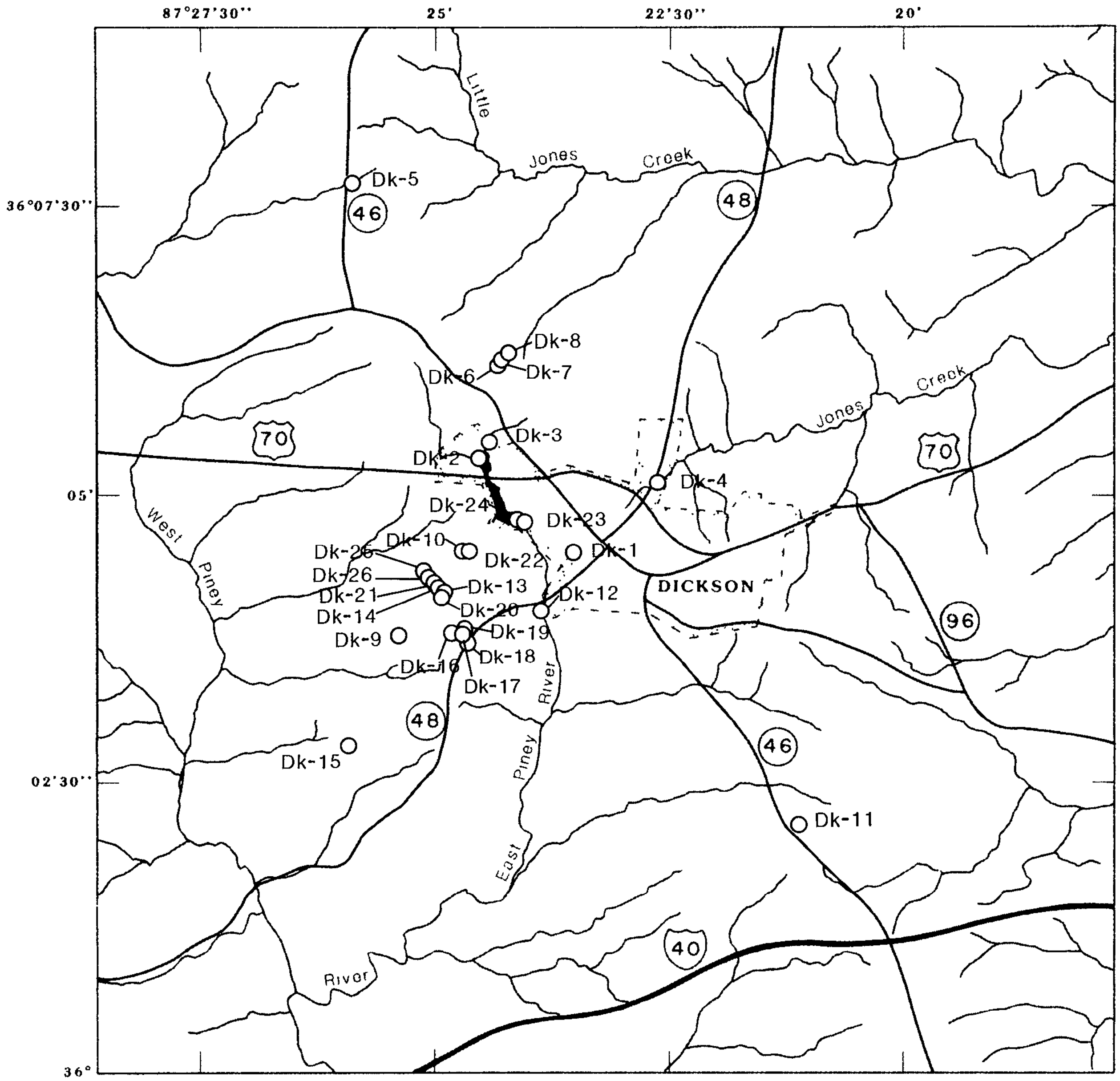
By using low-flow data, the minimum amount of recharge to the ground-water system in the Dickson area can be estimated. Discharge data from the gaging station on the Piney River at Vernon, Tenn., south of the study area, were used for this purpose. During 1980, the minimum discharge of the Piney River at Vernon was 90 ft^3/s. At this site, the Piney is draining 202 square miles. While part of this drainage basin is outside of the study area, it is assumed that the recharge rate for the entire basin is about the same as the recharge rate in the Dickson area.

Assuming that the 90 ft^3/s represents the amount of ground water being discharged to streams and springs, then about 320 acre-feet of water must recharge each square mile annually. This represents a minimum rate of about 6 inches of the annual precipitation that is recharging the ground-water system around Dickson.

RESULTS OF DRILLING

Test Well Data

Twenty-six wells were drilled during the study (fig. 15). Well depths ranged from 21 to 400 feet, and the wells were cased to depths ranging from



Base from U.S. Geological Survey, 1:24,000 quadrangles, Burns(1953), Charlotte(1958), Dickson(1953), and Vanleer(1958)

4000 0 4000 8000 FEET

1000 0 1000 2000 METERS

EXPLANATION

Dk-4

O Test well and field number (See table 4)

Figure 15.– Test wells.

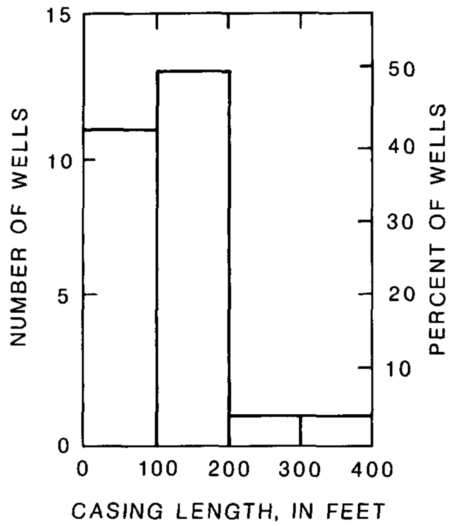


Figure 16.--Frequency distribution of casing lengths in the test wells.

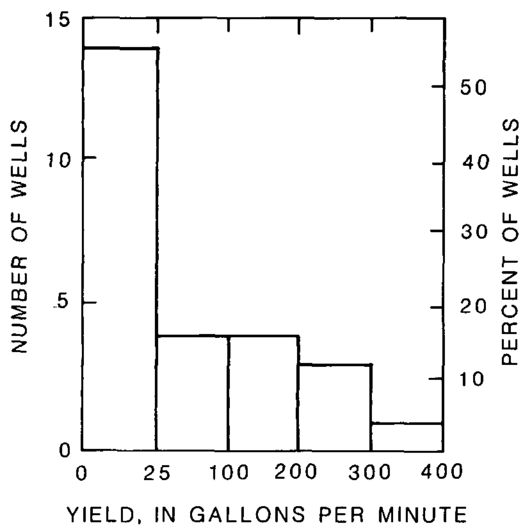


Figure 17.--Frequency distribution of the yields of the test wells while blowing with compressed air.

5 to 317 feet below land surface (fig. 16). Regolith thickness ranged from 4 feet in the valleys to 331 feet in the uplands. Yields during drilling were less than 1 to more than 300 gal/min; only two wells were dry (table 4). Eight wells yielded more than 100 gal/min (fig. 17). Data from the test wells are summarized in table 4.

The regolith at the 26 test wells ranged from 4 to 331 feet thick (table 4) with an average thickness of 88 feet. Fourteen wells penetrated at least 80 feet of regolith and 10 of these wells had fine-grained beds of limestone near the top of rock. Of these 14 wells, 7 (all with fine-grained limestone near the top of rock) yielded 80 gal/min or more from solution openings in bedrock, and 2 wells yielded more than 100 gal/min from the regolith (fig. 18). Well Dk-9 yielded 175 gal/min from an 8-foot layer of chert gravel at the top of bedrock. Well Dk-15 yielded more than 300 gal/min from a 60-foot thick section of calcareous sand. The remaining five wells with at least 80 feet of regolith yielded less than 20 gal/min. For the 12 wells which have less than 80 feet of regolith, 9 yielded less than 20 gal/min. The three remaining wells, all with fine-grained beds of limestone near the top of rock, yielded 30 to 50 gal/min; however, the yield of one of these wells, Dk-24, may be affected by the presence of the city lake which causes local ground-water levels to remain high.

The regolith thickness was highly variable within short lateral distances. For example, wells Dk-17, Dk-18, and Dk-19 are within 200 feet of each other and have regolith thicknesses of 90, 110, and 70 feet, respectively. Well Dk-9 has 331 feet of regolith whereas two domestic wells within about 400 feet of Dk-9

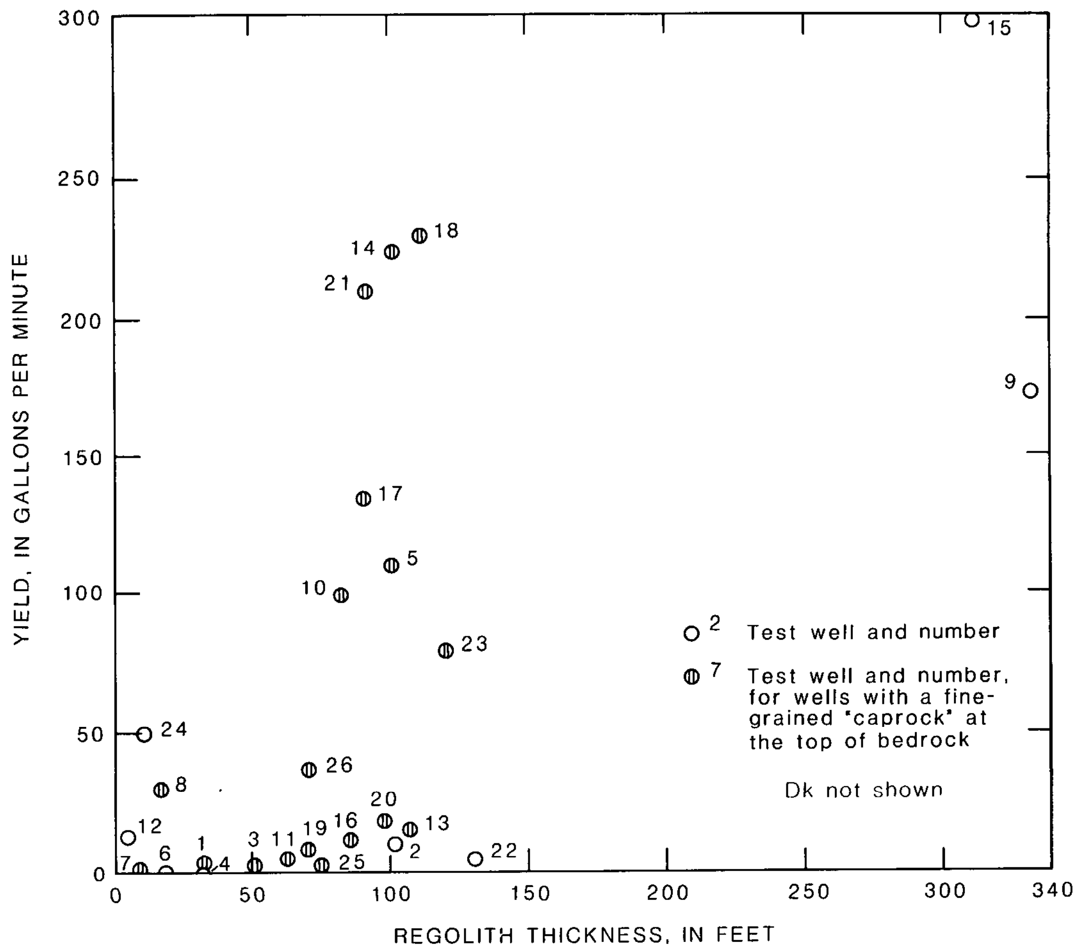


Figure 18.-- Regolith thickness versus yield for test wells.

have reported regolith thicknesses of 98 and 160 feet. Well Dk-23 has approximately 120 feet of regolith and well Dk-24 which is 230 feet away has only 10 feet of regolith. These variations in regolith thickness indicate that the bedrock surface is irregular and may be pinnacled. The analysis of the regolith thickness and yield showed that wells are likely to produce more water in areas of thick regolith.

The primary water-bearing zones are solution openings in the Warsaw Limestone and to some extent in the Fort Payne Formation. The regolith consisted of dense clay and, with two exceptions, yielded very little water. The size of solution openings penetrated during drilling ranged from less than 1 foot to more than 40 feet thick. Generally, the smaller openings were clean, water-bearing zones whereas the larger openings, more than 10 feet, were partially or almost completely filled with clay. Solution openings which occurred below fine-grained "cap rock" near the top of bedrock were more likely to yield large

Table 4.--Test well data and water occurrence

Well no. Field	Well no. Office	Latitude	Longitude	Date Completed	Altitude (ft)	Total depth (ft)	Regolith thickness (ft)	Depth cased (ft)	Water bearing zones, depth (ft)	Final yield by blowing (gal/min)	Water level below land surface (ft)	Water bearing formation*	Finish	Remarks
Dk-1	Di:F-60	36°04'24"	87°23'36"	Nov. 14, 1978	780	400	31	32	56-59 155	3	---	W,FP	Open	In the final yield the hole was losing air to an adjacent well.
Dk-2	Di:F-61	36°05'20"	87°24'35"	Nov. 17, 1978	810	300	100	101	107-109	11	---	W	Open	
Dk-3	Di:F-62	36°05'28"	87°24'30"	Nov. 21, 1978	810	180	45	91	61-65	2	---	W	Destroyed	Casing was leaking.
Dk-4	Di:F-63	36°05'04"	87°22'43"	June 23, 1980	710	222	31	40.5	70	0.5	---	FP	Destroyed	
Dk-5	Di:K-8	36°07'40"	87°25'59"	June 26, 1980	850	400	100	104.8	111-112 113-136 178-179 270-271	110	40.40	W,FP	Open	Hydrogen sulfide was encountered at 270-271 feet.
Dk-6	Di:F-64	36°06'09"	87°24'24"	June 26, 1980	800	21	18	20	None	Dry	---		Destroyed	Well destroyed; hole was slanted.
Dk-7	Di:F-65	36°06'12"	87°24'23"	June 27, 1980	800	240	9	20	None	Dry	---		Destroyed	
Dk-8	Di:F-66	36°06'14"	87°24'19"	June 28, 1980	795	206	16	20	160 180 205-206	30	15.30	FP	Open	The zone at 205-206 feet produced water containing hydrogen sulfide.
Dk-9	Di:F-67	36°03'42"	87°25'28"	July 2, 1980	815	340	331	317	323-331	175	63.70	R	Open	
Dk-10	Di:F-68	36°04'30"	87°24'43"	July 7, 1980	820	280	82	127	100-110 123-131	100	35.20	W	Open	
Dk-11	Di:G-86	36°02'08"	87°21'11"	July 9, 1980	850	400	62	70	295 370	5	55.75	W	Open	
Dk-12	Di:F-69	36°03'59"	87°23'56"	July 9, 1980	710	160	4	5	25 34 116	13	5.45	FP	Destroyed	
Dk-13	Di:F-70	36°04'08"	87°24'54"	July 11, 1980	855	320	106	162	124 225 245-250	15	58.50	W	Open	About 550 feet from Dk-21.
Dk-14	Di:F-71	36°04'11"	87°25'00"	July 14, 1980	845	280	100	126	100-105 139-143	225	60.50	W	Open	330 feet from Dk-21.
Dk-15	Di:F-72	36°02'51"	87°26'00"	July 28, 1980	760	300	300	260	200-260 270-285 287-292	300+	41.26	R	Open	Yields water from sand within the openings.

Table 4.--Test well data and water occurrence--Continued

Well no. Field	Well no. Office	Latitude	Longitude	Date Completed	Altitude (ft)	Total depth (ft)	Regolith thickness (ft)	Depth cased (ft)	Water bearing zones, depth (ft)	Final yield by blowing (gal/min)	Water level below land surface (ft)	Water bearing formation*	Finish	Remarks
Dk-16	Di:F-73	36°03'49"	87°24'56"	July 29, 1980	815	350	84	114	92 102-105 140 300 307	12	54.48	W,FP	Open	About 700 feet from Dk-17.
Dk-17	Di:F-74	36°03'48"	87°24'47"	Aug. 1, 1980	820	300	90	170	89-100 113-116 130-140 178-181	135	59.1	W	Open	The upper 3 zones were cased off due to air bubbling up around the casing when cased to 144 feet.
Dk-18	Di:F-75	36°03'46"	87°24'45"	Oct. 2, 1980	820	250	110	180	165-168	230	66.47	W	Open	200 feet from Dk-17.
Dk-19	Di:F-76	36°03'50"	87°24'46"	Oct. 4, 1980	820	300	70	101	87 150 251-252	8	69.72	W	Open	190 feet from Dk-17.
Dk-20	Di:F-77	36°04'07"	87°25'01"	Oct. 6, 1980	860	250	98	104	117-121 130-135	18	76.81	W	Open	515 feet from Dk-21.
Dk-21	Di:F-78	36°04'12"	87°25'04"	Oct. 8, 1980	840	160	90	104	95-97 126-143	210	68.25	W	Open	
Dk-22	Di:F-80	36°04'31"	87°24'39"	Dec. 1, 1980	820	300	130	134	150	5		W	Open	About 230 feet from Dk-10.
Dk-23	Di:F-81	36°04'46"	87°24'08"	Jan. 8, 1981	750	240	120	124	112 150	80	18.14	W	Open	
Dk-24	Di:F-82	36°04'47"	87°24'11"	Jan. 14, 1981	750	200	10	20	8 135-149	50	5.9	W	Open	215 feet from Dk-23.
Dk-25	Di:F-83	36°04'20"	87°25'11"	May 5, 1981	810	220	75	82	47 97 121-124	4	23.56	W	Open	About 1,150 feet from Dk-21.
Dk-26	Di:F-84	36°04'11"	87°25'07"	May 7, 1981	820	250	70	79	104 132 234	37	38.05	W	Open	About 600 feet from Dk-21.

* R - Regolith
W - Warsaw Limestone
FP - Fort Payne Formation

amounts of water. This "cap rock" is a fine-grained siliceous limestone or dolomite which allowed for the development of solution openings by inhibiting the downward weathering and movement of clay into the solution openings. The size and number of solution openings decreased with depth.

Specific Capacity Tests

Specific capacity tests were conducted on 10 wells. Specific capacity is the discharge of a well expressed as a rate of yield per unit of drawdown and can be used as an indicator of the capacity of the well and aquifer. Average yield for the individual wells during the tests ranged from about 72 gal/min in Dk-24 to 300 gal/min in Dk-15. Specific capacities for the wells ranged from 0.71 to 12.7 gallons per minute per foot [(gal/min)/ft] of drawdown (table 5) and averaged 4.10 (gal/min)/ft. A high specific capacity, such as 12.7 (gal/min)/ft in Dk-21, indicates that the water-bearing zone supplying the well is capable of transmitting ground water more readily than a well with a lower specific capacity, such as 0.71 (gal/min)/ft in Dk-24.

Table 5.--Specific-capacity test data

Well no. Field	Well no. Office	Date of test	Static water level below measuring point (ft)	Drawdown (ft)	Average yield during test (gal/min)	Specific capacity [(gal/min)/ft]	Length of test (h)	Remarks
Dk-5	Di:K-8	6/26/80	49.50	47.35	110	2.32	2.0	Slow and incomplete recovery.
Dk-9	Di:F-67	7/ 2/80	73.10	128.7	175	1.36	1.0	Yields water from regolith.
Dk-10	Di:F-68	7/ 7/80	48.45	54.05	100	1.85	2.0	
Dk-14	Di:F-71	7/14/80	63.07	27.74	225	8.11	1.5	
Dk-15	Di:F-72	7/28/80	51.64	87.89	300	3.41	2.0	Yields water from regolith.
Dk-17	Di:F-74	8/ 1/80	70.77	36.44	135	3.70	2.0	
Dk-18	Di:F-75	10/ 2/80	83.14	46.62	270	5.79	1.5	
Dk-21	Di:F-78	10/ 8/80	70.50	16.53	210	12.7	4.0	
Dk-23	Di:F-81	1/22/81	3.84	83.13	85	1.02	6.4	
Dk-24	Di:F-82	1/13/81	19.42	100.75	72	0.71	4.0	

YIELD-SPECIFIC CAPACITY TESTS

Tests at the Dk-17 Site

Two tests were conducted at the Dk-17 site. A 72-hour test took place in November 1980, and an 8-hour test was conducted in August 1981. Well Dk-17 was pumped during both tests, and water levels were measured at four observation wells. Wells Dk-16, Dk-18, and Dk-19 are 850, 200, and 190 feet, respectively, from the pumped well. Di:F-27 is a domestic well about 415 feet from Dk-17 (fig. 19).

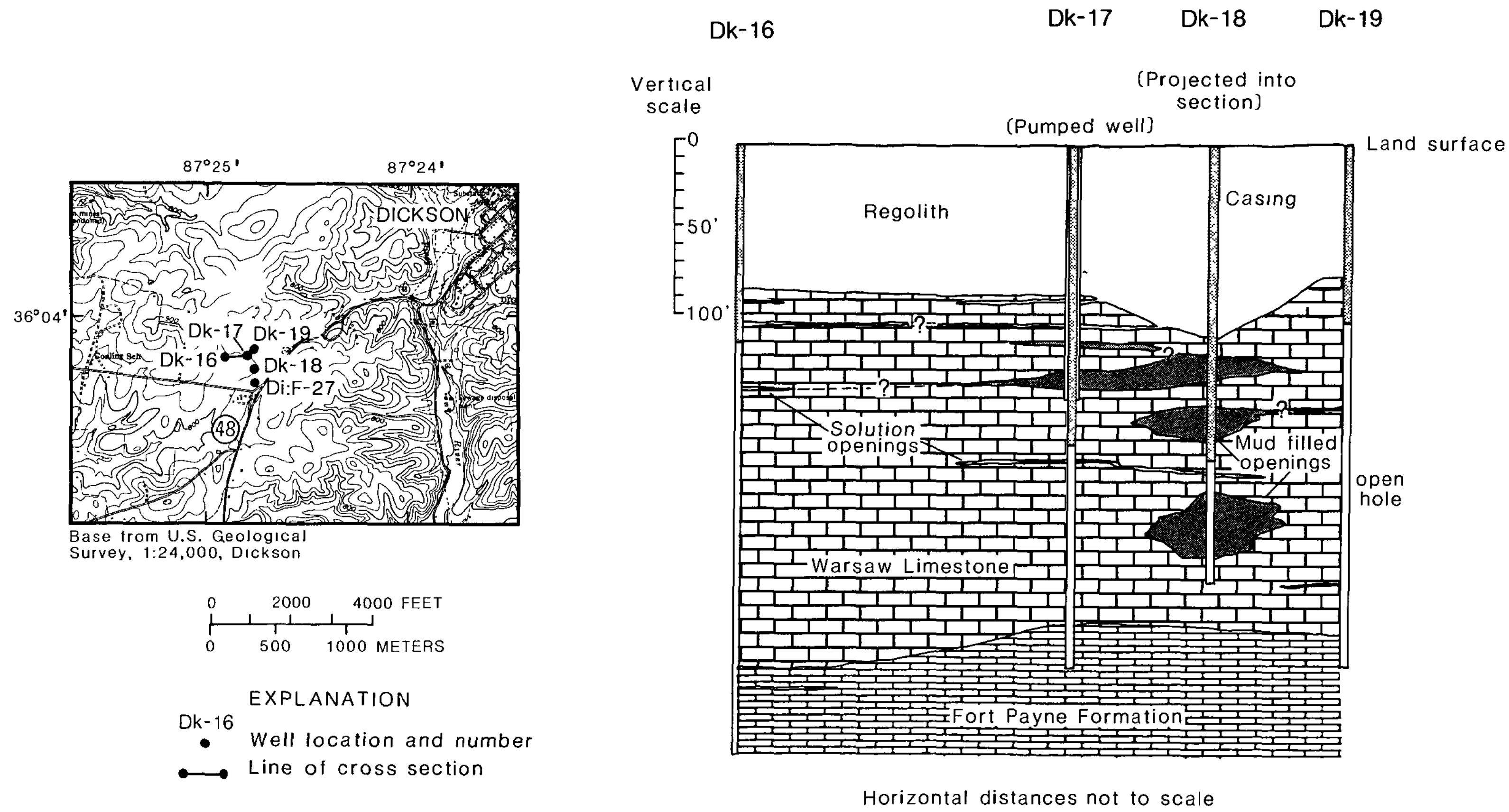


Figure 19.-- Geologic cross section of the Dk-17 site with location map.

The test site is underlain by the St. Louis Limestone, Warsaw Limestone, and Fort Payne Formation. The St. Louis Limestone and the upper part of the Warsaw Limestone have weathered to a clay regolith approximately 90 feet thick (fig. 19). Ground water occurs in solution openings in the Warsaw Limestone and at the contact with the Fort Payne Formation. Many openings penetrated by Dk-17 and Dk-18 were partially or completely filled with clay.

The test began on November 19, 1980, and ended November 22, 1980, after 3 days of pumping. The initial pumping rate was approximately 140 gal/min. Water levels in the observation wells responded to pumping Dk-17 in various degrees (fig. 20). The specific capacity of Dk-17 at the end of the first step was 3.0 (gal/min)/ft of drawdown. At the end of the test, the specific capacity had decreased to 1.8 (gal/min)/ft of drawdown for an average pumping rate of 155 gal/min. The decrease in specific capacity may reflect well losses caused by lower water levels or possible dewatering of some upper water-bearing zones. Water levels in Dk-19 began to rise before pumping stopped. This could occur if the connection between Dk-19 and Dk-17 became blocked. Drawdown in Dk-17 and the observation wells is summarized in table 6. Data from this test were analyzed using a mathematical model, but the results were inconclusive. Because of this, the response of the well to higher pumping rates or to a longer pumping period could not be determined.

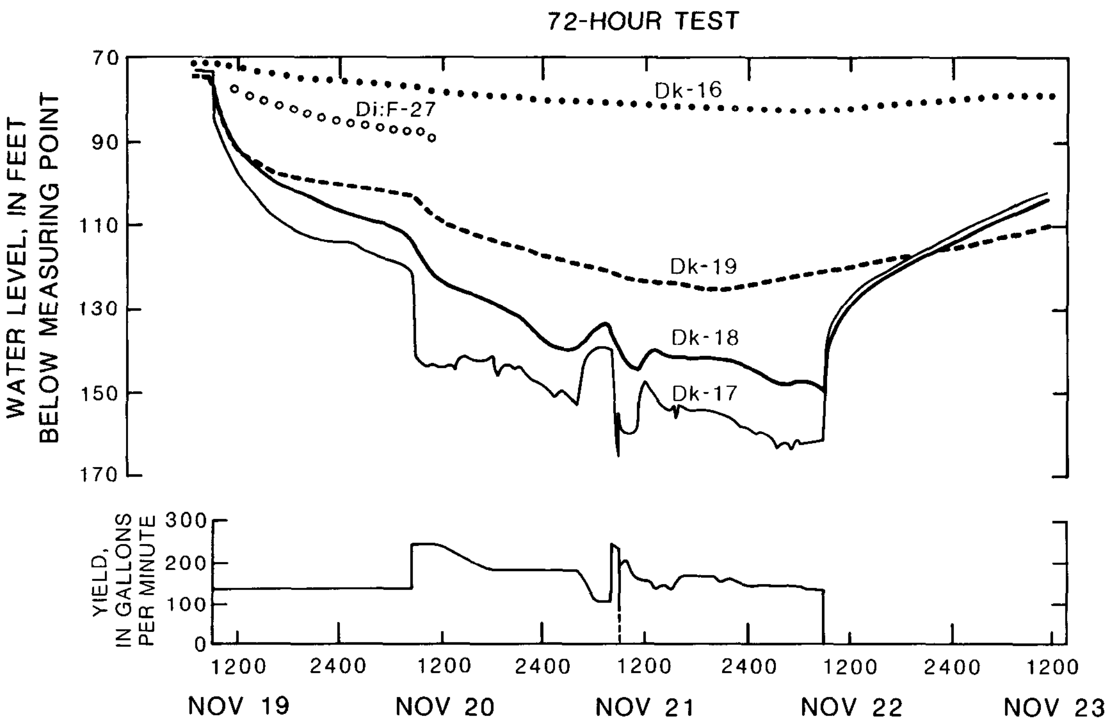


Figure 20.-- Hydrograph and yield of 72-hour test at Dk-17.

Table 6.--Drawdown and recovery in wells at the Dk-17 site during the 72-hour test

	Well no.				
	Dk-17 (pumped well)	Dk-16	Dk-18	Dk-19	Di:F-27
Distance from pumped well, in feet.	--	850	200	190	415
Prepumping water level, in feet below measuring point.	73.49	71.71	74.44	74.80	74 (est)
Drawdown at end of first step, in feet.	46.78	5.20	38.10	27.95	13.6
Drawdown at the end of test, in feet.	87.51	10.68	74.66	46.23	--
Recovery 2 hours after pumping stopped, in feet.	27.51	0.09	14.04	0.89	--

A plot of drawdown versus distance from the pumped well (fig. 21) was used to determine if the observation wells are connected with the water-bearing zones in Dk-17. For observation wells in an aquifer with uniform properties, this type of plot would ideally show a straight line near the pumped well and a smooth curve at the distant observation wells. The slope of curves between Dk-17 and Dk-18 is relatively constant which indicates that these wells have a good hydraulic connection. At times (t = 1,800 and 4,200 minutes) the slope is steeper than earlier in the test. Steepening of the slope may be due to possible dewatering of the aquifer or well entrance losses.

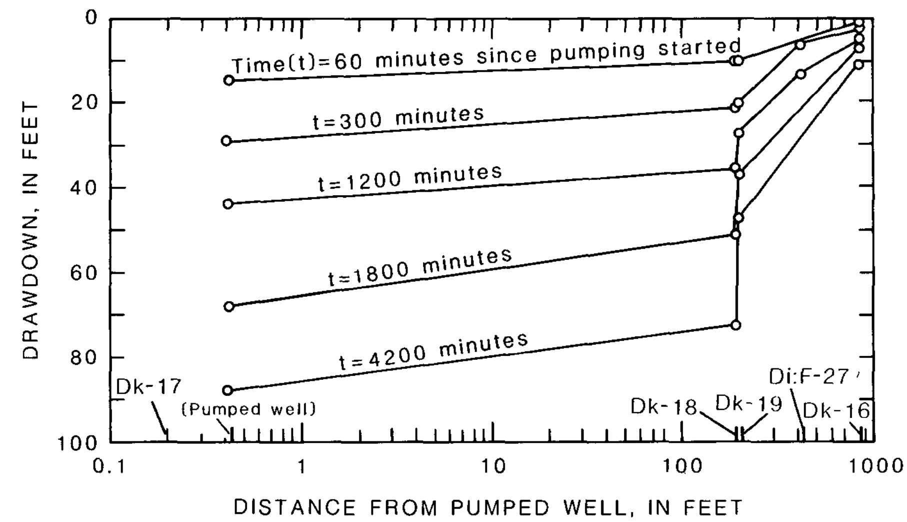


Figure 21.-- Drawdown versus distance from the pumped well for the 72-hour test of Dk-17.

The abrupt changes in slope between Dk-18 and the other wells as time increases indicates that these wells did not penetrate the same water-bearing zone as Dk-17 and Dk-18. The water level in well Di:F-27 was drawn down below the bottom of the well at about 90 feet on November 20 and no further data could be collected. Because the water levels in Di:F-27, Dk-16 and Dk-19 respond to pumping in Dk-17, there is some hydraulic connection with the zone penetrated by Dk-17 and Dk-18.

A caliper log of Dk-17 revealed a large opening at the bottom of the 10-inch casing. This opening was believed to be connected to a water-bearing zone at 130 to 140 feet which caused turbidity by allowing clay to enter the well. During (June or July) 1981, an 8-inch casing was installed to a depth of 170 feet in an effort to seal this opening.

On August 14, 1981, Dk-17 was pumped at a constant rate of 120 gal/min for 8 hours. Wells Dk-18 and Dk-19 were used as observation wells (fig. 22). At the end of the test there was 20.86 feet of drawdown, for a specific capacity of 5.75 (gal/min)/ft. During the 72-hour test, well Dk-17 had a specific capacity of 3.80 (gal/min)/ft of drawdown after 8 hours. The improvement could be due to the development of the water-bearing zone at 180 feet.

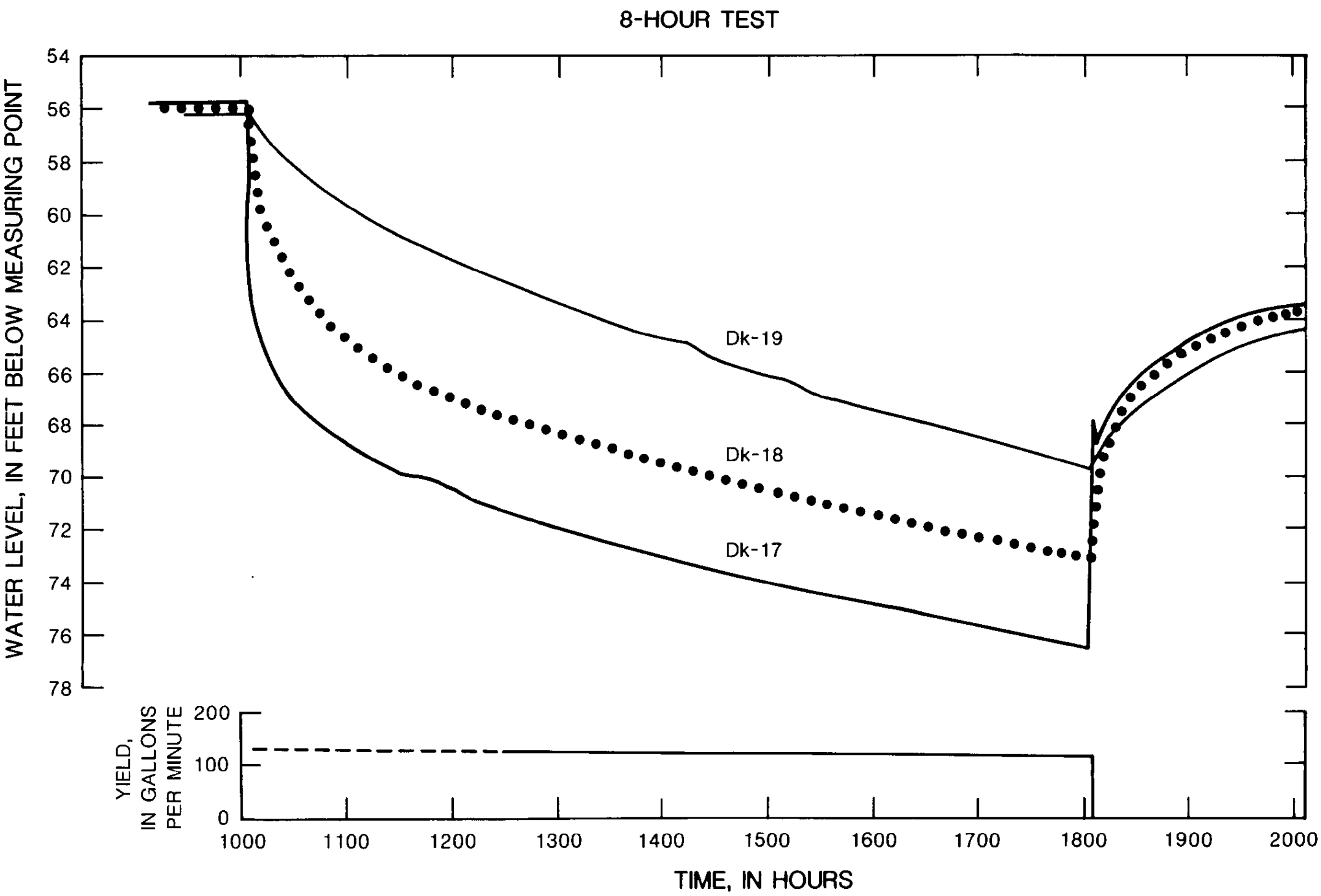


Figure 22.-- Hydrograph and yield for the 8-hour test at Dk-17.

The response of water levels in Dk-18 and Dk-19 are similar to the response during the 72-hour test (fig. 22). Water levels in well Dk-19 showed a much more rapid rate of recovery following the 8-hour test (table 7). It is possible that the connection between Dk-17 and Dk-19 was blocked at the end of the 72-hour test. This could have caused the rise in water level in Dk-19 before pumping stopped during the 72-hour test as well as the slow recovery.

Table 7.--Drawdown and recovery in Dk-17, Dk-18 and Dk-19 during the 8-hour test

	Well no.		
	Dk-17 (pumped well)	Dk-18	Dk-19
Prepumping water level, in feet below measuring point.	55.8	56.00	55.71
Drawdown after 4 hours, in feet.	17.24	13.65	9.23
Drawdown at end of test, in feet.	20.86	17.12	13.44
Recovery 1 hour after pumping stopped, in feet.	11.94	8.12	3.89

Test at the Dk-21 Site

Well Dk-21 was pumped at an average rate of 350 gal/min during a 72-hour aquifer test begun on December 15, 1980. Wells Dk-13, Dk-14 and Dk-20 were within 500 feet of Dk-21 and were used as observation wells. Dk-25 and Dk-26 are also located near the site (fig. 23) but had not been drilled at the time of the test.

The wells at this site began in the lower part of the St. Louis Limestone which, along with the upper part of the Warsaw Limestone, has weathered to form a clay regolith with some scattered chert gravel (fig. 23). The primary water-bearing zone in Dk-21 is a 17-foot high solution opening in the Warsaw Limestone. The opening thins to 4 feet in Dk-14.

The initial rate of pumping was 430 gal/min. Figure 24 shows the response of water levels in the pumping well Dk-21 and the observation wells Dk-13, Dk-14, and Dk-20. When pumping stopped on December 18, water levels in Dk-14 and Dk-21 recovered rapidly. Water levels in wells Dk-13 and Dk-20 responded slowly to the end of pumping (table 8). Specific capacity at the end of the 1,530 minute step was 8.6 (gal/min)/ft of drawdown at 430 gal/min. At the end of the test, specific capacity was approximately the same at 8.8 (gal/min)/ft of drawdown with an average pumping rate of 350 gal/min. This aquifer test was also analyzed and again the results were inconclusive. The response of this well to longer periods of pumping or to a higher rate of pumping could not be determined.

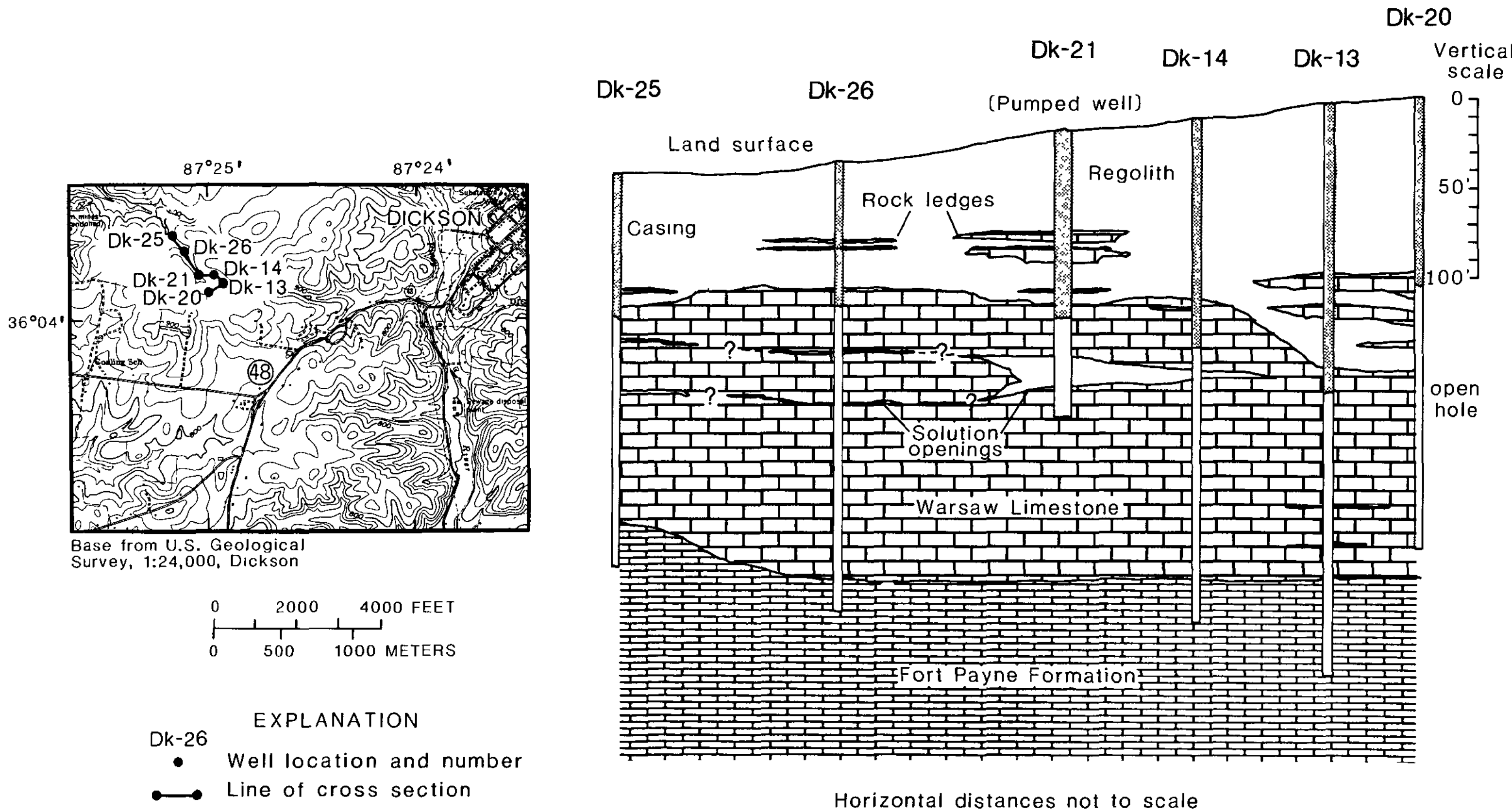


Figure 23.-- Geologic cross section at the Dk-21 site with location map.

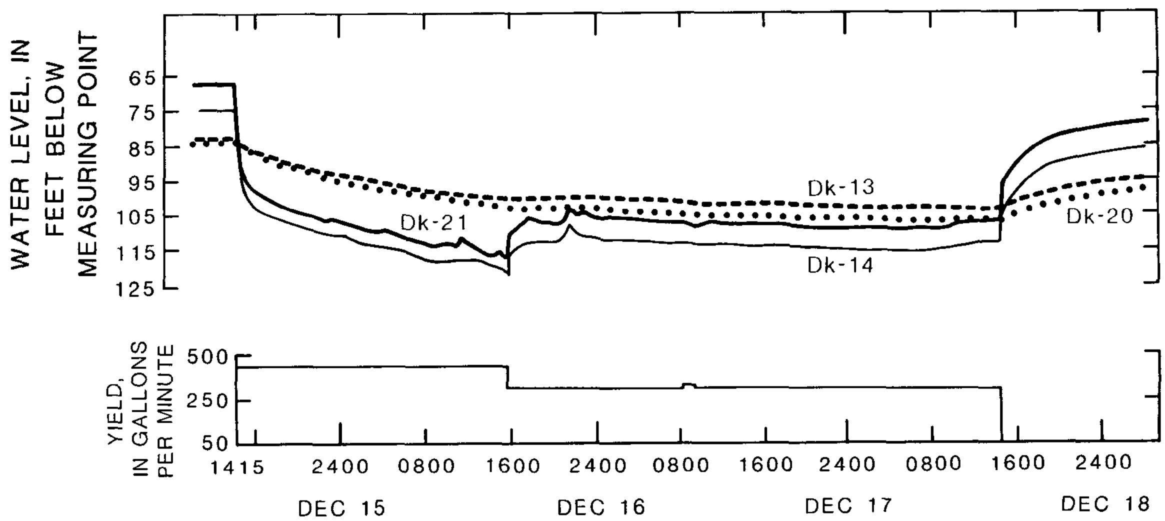


Figure 24.-- Hydrograph and yield during the 72-hour test of well Dk-21.

Table 8.--Drawdown and recovery in wells Dk-13, Dk-14, Dk-20, and Dk-21 during the 72-hour test

	Well no.			
	Dk-21 (pumped well)	Dk-13	Dk-14	Dk-20
Distance from pumped well, in feet.	--	552	330	515
Prepumping water level, in feet below measuring point.	65.43	81.13	76.65	82.29
Drawdown at end of first step, in feet.	49.97	17.65	46.96	19.13
Drawdown at end of test, in feet.	39.77	20.52	38.76	23.04
Recovery 200 minutes after pumping stopped, in feet.	21.29	2.94	20.28	2.55

The response of the water levels in Dk-13 and Dk-20 indicates that the water-bearing zone in Dk-21 and Dk-14 is poorly connected with other zones in Dk-13 and Dk-20. A graph of drawdown versus distance from the pumped well (fig. 25) shows the shape of the cone of depression during pumping. The abrupt change in the slope between Dk-14 and Dk-20 supports the assumption that wells Dk-13 and Dk-20 are open to different water-bearing zones than the main zone in Dk-14 and Dk-21. Because water levels in Dk-20 and Dk-13 respond to pumping in Dk-21, there must be some hydraulic connection between these two wells and the main water-bearing zone.

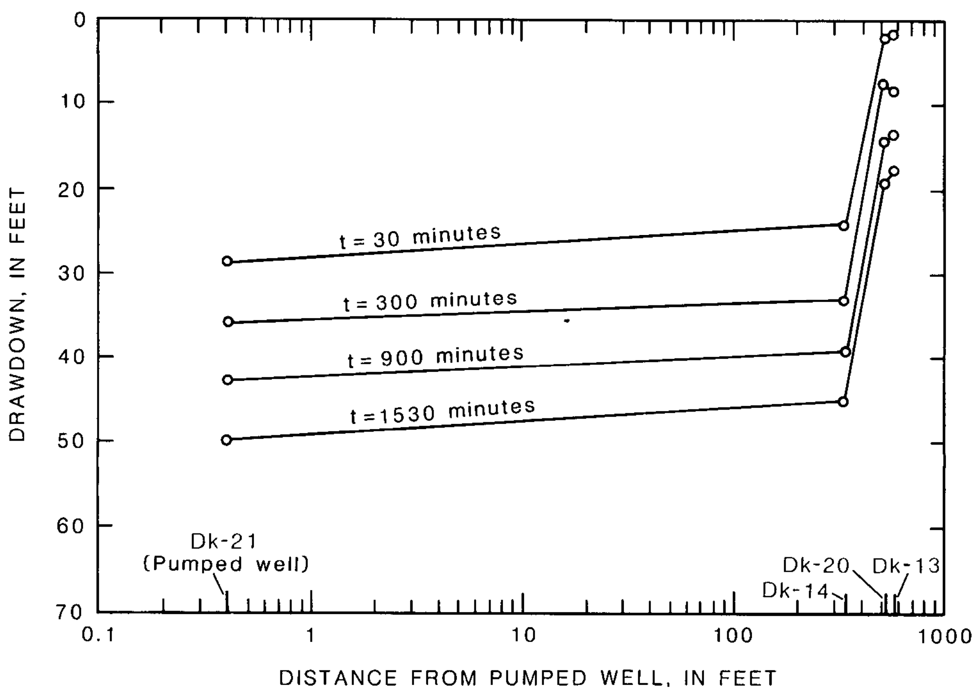


Figure 25.-- Drawdown versus distance from the pumped well for the test of Dk-21.

ADDITIONAL DRILLING NEAR THE DK-21 SITE

Following the 72-hour test, two additional wells, Dk-25 and Dk-26, were drilled in an attempt to determine the lateral extent of the primary water-bearing zone in Dk-21. Well Dk-25 was drilled to a depth of 220 feet. The final yield was 4 gal/min while blowing with compressed air for 15 minutes. Water levels at Dk-14 did not respond to drilling Dk-25 (fig. 26). However, the small yield from Dk-25 and short pumping time would not be expected to effect water levels in Dk-14 which is more than 1,400 feet away.

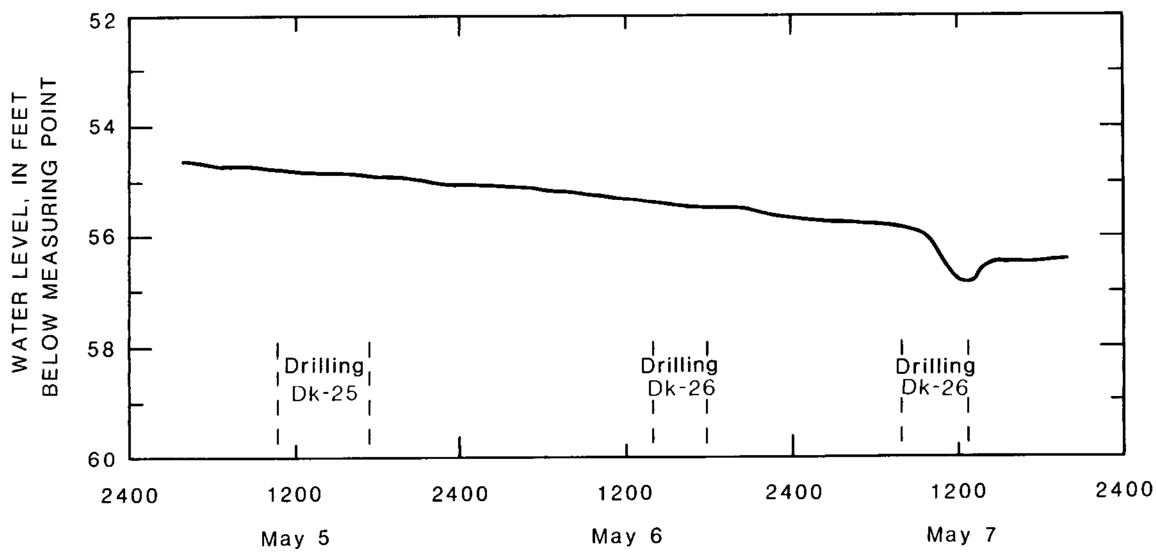


Figure 26.-- Hydrograph for well Dk-14 during May 5-7, 1981.

Well Dk-26, about 900 feet from Dk-14, was completed to a depth of 250 feet. The final yield was 37 gal/min. The hydrograph of Dk-14 (fig. 26) shows an abrupt drop in water level during the drilling of Dk-26 on May 7 indicating a hydraulic connection between these wells. The water-bearing zones at 104 and 132 feet in Dk-26 may correlate with the main water-bearing zone in Dk-21 and Dk-14 (fig. 23).

WATER QUALITY

Specific conductance of ground water from the test wells ranged from 200 to more than 1,500 micromhos per centimeter (μmhos/cm). Most values were between 250 and 350 μmhos/cm (table 9). Generally, the specific conductance increased with depth.

Ground water from the regolith (Dk-9 and Dk-15) and from solution openings in the Warsaw Limestone, such as in Dk-14, Dk-17 and Dk-21, had a specific conductance ranging from 200 to about 400 μmhos/cm. Wells which penetrated solution openings in the Fort Payne Formation (Dk-16 and Dk-26) generally had values within this range. However, in wells Dk-1, Dk-5, and Dk-8, hydrogen sulfide was detected in water from openings in the Fort Payne Formation. After the detection of hydrogen sulfide, the specific conductance ranged from 800 to as much as 1,550 μmhos/cm.

Table 9.--Specific conductance of water from the test wells

Well no.	Depth of well at time of sampling (feet)	Specific conductance (µmho/cm at 25°C)	Well no.	Depth of well at time of sampling (feet)	Specific conductance (µmho/cm at 25°C)
Dk-1	400	850	Dk-15	250	300
				260	300
Dk-2	300	360		290	320
				300	340
Dk-5	110	400			
	120	425	Dk-16	350	320
	210	450			
	265	560	Dk-17	116	270
	270	775		135	400
	300	1,475		145	335
	320	1,550		180	300
	340	1,475		190	300
	390	1,200		200	290
	400	1,400		240	300
				260	305
Dk-8	206	800		275	300
				290	300
Dk-9	315	280			
	330	275	Dk-18	168	290
	340	320		173	300
				211	255
Dk-10	280	320		250	320
Dk-14	156	220	Dk-21	130	280
	180	200			
	270	320	Dk-22	270	330
			Dk-25	220	350
			Dk-26	140	425
				180	420
				220	390
				250	390

Ground water from wells Dk-17 and Dk-21 tapping the Warsaw Limestone was analyzed for 54 parameters. These analyses show no major water-quality problems (table 10). Water from both wells is a hard, calcium bicarbonate type with similar proportions of major mineral constituents (fig. 27). By comparison, well Fv-13 in Fairview, Tenn., yields mineralized water from the Fort Payne Formation. Hydrogen sulfide was also detected in this well, the water type is believed to be similar with water from the Fort Payne in wells Dk-1, Dk-5, and Dk-8.

Table 10.--Analyses of water from Dk-17 and Dk-21 compared with standards for maximum levels of constituents in finished drinking water

Constituent or property	Well nos. Dk-17	Well nos. Dk-21	Tennessee standards for public water supplies[1]: Secondary maximum contaminant level	Tennessee standards for public water supplies[1]: Maximum contaminant level	National drinking-water regulations: Secondary maximum contaminant level[2]	National drinking-water regulations: Primary maximum contaminant level [3]
Alkalinity, total (mg/L as $CaCO_3$)	140	130	--	--	--	--
Aluminum, dissolved (μg/L as Al)	---	100	--	--	--	--
Arsenic, dissolved (μg/L as As)	0	1	--	50	--	50
Barium, dissolved (μg/L as Ba)	30	20	--	1,000	--	1,000
Beryllium, dissolved (μg/L as Be)	0	0	--	--	--	--
Boron, dissolved (μg/L as B)	2	--	--	--	--	--
Cadmium, dissolved (μg/L as Cd)	2	1	--	10	--	10
Calcium, dissolved (Ca in mg/L)	48	41	--	--	--	--
Carbon, dissolved organics (mg/L as C)	--	0.7	--	--	--	--
Carbon, total organic (mg/L as C)	2.9	--	--	--	--	--
Chloride, dissolved (mg/L as Cl)	2.5	1.2	250	--	250	--
Chromium, dissolved (μg/L as Cr)	10	10	--	50	--	50
Cobalt, dissolved (μg/L as Co)	3	7	--	--	--	--
Color (platinum cobalt units)	0	2	15	--	15	--
Copper, dissolved (μg/L as Cu)	21	5	1,000	--	1,000	--
Cyanide, dissolved (mg/L as CN)	0.00	0.00	--	--	--	--
Detergents, MBAS (mg/L)	--	0.0	0.5	--	0.5	--
Dissolved solids, residue at 180°C (mg/L)	170	--	500	--	500	--
Fluoride, dissolved (mg/L as F)	0.1	0.1	1.3	2.0	--	1.8[4]
Hardness, noncarbonate (mg/L as $CaCO_3$)	0	0	--	--	--	--
Hardness, total (mg/L as $CaCO_3$)	140	130	--	--	--	--
Iron, dissolved (μg/L as Fe)	50	0	300	--	300	--
Iron, total (μg/L as Fe)	---	0.43	300	--	300	--
Lead, dissolved (μg/L as Pb)	2	2	--	50	--	50
Lithium, dissolved (μg/L as Li)	2	0	--	--	--	--
Magnesium, dissolved (mg/L as Mg)	4.4	6.2	--	--	--	--
Manganese, dissolved (μg/L as Mn)	8	1	50	--	50	--
Manganese, total (μg/L as Mn)	---	20	50	--	50	--
Mercury, dissolved (μg/L as Hg)	0.1	0.2	--	2	--	2
Molybdenum, dissolved (μg/L as Mo)	--	0	--	--	--	--
Nickel, dissolved (μg/L as Ni)	2	2	--	--	--	--
Nitrate, dissolved (mg/L as N)	0.87	0.18	--	10	--	10
Nitrite, dissolved (mg/L as N)	0.00	0.01	--	--	--	--
Nitrogen, total (mg/L as N)	0.87	0.19	--	--	--	--
pH (units)	8.5	7.9	6.5-8.5	--	6.5-8.5	--
Phenols (μg/L)	0	4	--	--	--	--
Phosphate, dissolved (mg/L as P)	0.04	0.03	--	--	--	--
Potassium, dissolved (mg/L as K)	0.5	0.4	--	--	--	--
Selenium, dissolved (μg/L as Se)	0	0	--	10	--	10
Silica, dissolved (mg/L as SiO_2)	9.4	7.6	--	--	--	--
Silver, dissolved (μg/L as Ag)	0	0	--	50	--	50
Sodium, dissolved (mg/L as Na)	3.6	1.7	--	--	--	--
Sodium adsorption ratio	0.1	0.1	--	--	--	--
Sodium percent	5	3	--	--	--	--
Specific conductivity (μmhos/cm as 25°C)	284	267	--	--	--	--
Strontium, dissolved (μg/L as Sr)	120	60	--	--	--	--
Sulfate, dissolved (mg/L as SO_4)	4.5	2.9	250	--	250	--
Turbidity (NTU)	0.40	2.4	--	1	--	1 [5]
Temperature (°C)	14.0	13.5	--	--	--	--
Zinc, dissolved (μg/L as Zn)	10	30	5,000	--	5,000	--
Coliform, total, immed. (Cols./100 mL)	40	2	--	4 [6]	--	4 [6]
Coliform, fecal, 0.45 UM-MF (Cols./100 mL)	1	2	--	4 [6]	--	4 [6]
Streptococci, fecal, (Cols./100 mL)	1	1	--	4 [6]	--	4 [6]

1 Tennessee Department of Public Health, 1977.
2 U.S. Environmental Protection Agency, 1979.
3 U.S. Environmental Protection Agency, 1976.
4 Based on annual average maximum daily temperatures.
5 A value of five or fewer is allowed if it does not interfere with disinfection or microbiological determination.
6 Maximum limit in more than one sample where less than 20 samples are examined per month.

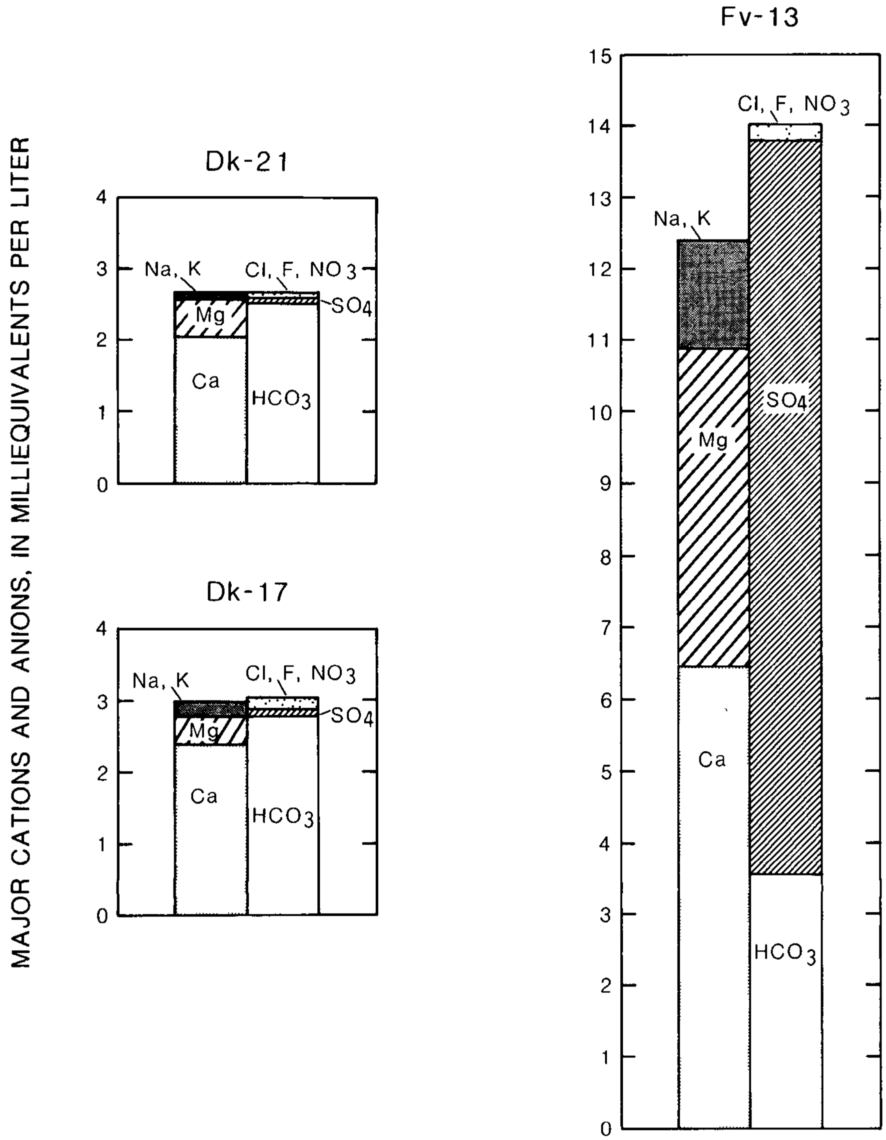


Figure 27.-- Comparison of major cations and anions in wells Dk-21 Dk-17, and Fv-13

SUMMARY AND CONCLUSIONS

Ground water in the Dickson area occurs primarily in the Warsaw Limestone. Secondary permeability, such as solution openings, are the principle avenues of ground-water movement. The underlying Fort Payne Formation is fine-grained and usually acts as the base of the aquifer. Test-well sites were chosen on the basis of topographic position, regolith thickness, and the lithology of the underlying formations. Data from the test wells were analyzed to relate geology and topography to ground-water occurrence. It appears that regolith thickness and the lithology of the bedrock are the main factors influencing the development of high-yielding solution openings.

Ten of the 26 test wells had thick regolith and a fine-grained limestone near the top of the coarse-grained bedrock. Seven of the 10 wells yielded 80 gal/min or more. The specific capacity for these seven wells ranged from 1.02 to 12.7 (gal/min)/ft of drawdown. High-yielding solution openings are more likely to develop in areas where there is thick regolith and a fine-grained limestone is present at the top of rock.

Aquifer tests were conducted at two wells which penetrated high-yielding solution openings. Well Dk-17 was pumped for 72 hours at an average rate of 155 gal/min with a specific capacity of 1.8 (gal/min)/ft. An 8-hour test was conducted at Dk-17 after additional casing was installed to seal off some upper zones. During this test, discharge was 120 gal/min with a specific capacity of 5.75 (gal/min)/ft.

A second well, Dk-21 was pumped at an average yield of 350 gal/min for 72 hours and had a specific capacity of 8.8 (gal/min)/ft. Further drilling at this site indicates that the solution opening may extend about 900 feet laterally. Most of the openings seemed to be very localized.

The Warsaw Limestone in the Dickson area is capable of yielding good quality water for drinking or industrial use. While low-yielding wells are the rule, the development of high-yielding wells is possible.

SELECTED REFERENCES

Burchett, C. R., 1977, Water resources of the upper Duck River basin, central Tennessee: Tennessee Division Water Resources, Water Resources Series No. 12, 103 p.

Burchett, C. R., and Hollyday, E. F., 1974, Tennessee's newest aquifer: Geological Society of America Abstract with Programs, v. 6, no. 4, p. 338.

Gold, R. L., 1980, Low flow measurements of Tennessee streams: Tennessee Division of Water Resources, Water Resources Series No. 14, 362 p.

Lohman, S. W., 1972, Ground-water hydraulics: U.S. Geological Survey Professional Paper 708, 70 p.

Marcher, M. V., 1962a, Stratigraphy and structure of rocks of Mississippian age in the northwestern Highland Rim, Tennessee: Journal of the Tennessee Academy of Science, v. 37, no. 4, p. 111-116.

______1962b, Petrography of Mississippian limestones and cherts from the northwestern Highland Rim, Tennessee: Journal of Sedimentary Petrology, v. 32, no. 4, p. 819-832.

Marcher, M. V., Bingham, R. H., and Lounsbury, R. E., 1964, Ground-water geology of the Dickson, Lawrenceburg, and Waverly areas in the western Highland Rim, Tennessee: U.S. Geological Survey Water-Supply Paper 1764, 50 p.

Moore, G. K., and Bingham, R. H., 1965, Availability of ground water in the western Highland Rim of Tennessee: Journal of the Tennessee Academy of Science, v. 40, no. 1, p. 22-26.

Moore, G. K., and Wilson, J. M., 1972, Water resources of the Center Hill Lake region, Tennessee: Tennessee Division of Water Resources, Water Resources Series No. 9, 77 p.

National Oceanic and Atmospheric Administration, 1979, Climatological Data annual summary Tennessee: National Oceanic and Atmospheric Administration, v. 80, no. 13, 10 p.

Parizek, R. R., and Drew, L. J., 1966, Random drilling for water in carbonate rocks: Pennsylvania State University, Water Resources Research Publication No. 3166, 22 p.

Piper, A. M., 1932, Ground water in north-central Tennessee: U.S. Geological Survey Water Supply Paper 640, 238 p.

Rima, D. R., and Goddard, P. L., 1979, Ground-water resources in the metropolitan region of Nashville, Tennessee: U.S. Army Corps of Engineers, Nashville District, Nashville, Tennessee, 44 p.

Tennessee Division of Water Quality Control, 1977, Public Water System _in_ Rules of Tennessee Department of Public Health - Bureau of Environmental Health Services - Division of Water Quality control: Tennessee Department of Public Health, Bureau of Environmental Health Services, Division of Water Quality control, Chapter 1200-5-1, 29 p.

U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: U.S. Environmental Protection Agency report EPA 570/9 - 76-003, 159 p.

______ 1979, National secondary drinking water regulations: U.S. Environmental Protection Agency report EPA 570/9 - 76-000, 37 p.

White, W. A., 1960, Major folds by solution in the western Highland Rim of Tennessee [abs.]: Geological Society of America Bulletin, v. 71, no. 12, p. 2029.

Zurawski, Ann, 1968, Summary appraisals of the nation's ground-water resources - Tennessee region: U.S. Geological Survey Professional Paper 813-L, 35 p.