

DEC 10 1963

# Geology and Occurrence of Ground Water in Lyon County, Minnesota

---

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-N

*Prepared in cooperation with the Division of Waters, Minnesota Department of Conservation and the Marshall Municipal Utilities, Marshall, Minnesota*





# Geology and Occurrence of Ground Water in Lyon County, Minnesota

By HARRY G. RODIS

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

---

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1619-N

*Prepared in cooperation with the Division of Waters, Minnesota Department of Conservation and the Marshall Municipal Utilities, Marshall, Minnesota*



**UNITED STATES DEPARTMENT OF THE INTERIOR**

**STEWART L. UDALL, *Secretary***

**GEOLOGICAL SURVEY**

**Thomas B. Nolan, *Director***

## CONTENTS

---

	Page
Abstract.....	N1
Introduction.....	2
Purpose and scope of study.....	2
Location of area.....	2
Methods of investigation.....	3
Test-hole numbering system.....	4
Previous reports.....	4
Acknowledgments.....	5
Geography.....	5
Culture.....	5
Topography.....	5
Drainage.....	6
Climate.....	8
Geology.....	8
Summary of stratigraphy and geologic history.....	8
Description of geologic units.....	9
Precambrian rocks.....	9
Cretaceous rocks.....	11
General characteristics.....	11
Sandstone and limestone.....	13
Bedrock topography.....	15
Pleistocene deposits.....	17
General characteristics.....	17
Melt-water deposits.....	17
Till.....	19
Recent deposits.....	19
Physiographic development of Lyon County.....	19
Ground water.....	21
Occurrence and movement.....	22
Recharge, discharge, and fluctuation of water levels.....	22
Hydrologic characteristics of the geologic units.....	22
Precambrian basement rocks.....	22
Cretaceous rocks.....	23
Pleistocene deposits.....	24
Recent deposits.....	25
Relation of ground-water quality to geologic source.....	25
Availability of ground water.....	32
Utilization of ground water.....	32
Logs of wells and test holes.....	33
Water-well data.....	33
Conclusions.....	40
References.....	40

## ILLUSTRATIONS

	Page
PLATE 1. Sections <i>A-A'</i> , <i>B-B'</i> , and <i>C-C'</i> , Lyon County, Minnesota-- In pocket	
FIGURE 1. Map showing location of Lyon County, Minn.....	N3
2. Well-numbering system.....	4
3-6. Maps showing—	
3. Physiographic provinces and watersheds.....	7
4. Precambrian bedrock surface and extent of Cretaceous sandstone.....	10
5. Cretaceous bedrock surface and extent of Cretaceous sandstone and limestone.....	14
6. Glacial geology.....	16
7, 8. Sections near	
7. Green Valley.....	18
8. Cottonwood.....	20
9. Map showing location of wells and test holes.....	26
10. Relation of drawdown to distance in melt-water-channel aquifer.....	28
11. Relation of drawdown to time in melt-water-channel aquifer.....	29
12. Map showing availability of ground water.....	34

## TABLE

	Page
TABLE 1. Summary of physical characteristics, water-bearing properties, and quality of water of geologic units, Lyon County, Minn..	N12
2. Laboratory chemical analyses of ground water in Lyon County..	30
3. Municipal water supplies, 1957-58.....	32
4. Selected logs of wells and test holes in and adjacent to Lyon County.....	36
5. Selected wells in Lyon County.....	39

## CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

---

### GEOLOGY AND OCCURRENCE OF GROUND WATER IN LYON COUNTY, MINNESOTA

---

By HARRY G. RODIS

---

#### ABSTRACT

Lyon County is in southwestern Minnesota, mostly within the drainage basin of the Minnesota River. The basement rocks in the area consist largely of Precambrian granite and quartzite. These are overlain locally by flat-lying Upper Cretaceous strata composed of thick sections of soft dark-bluish-gray shale and some thin beds of loosely consolidated sandstone. The Cretaceous strata are more than 500 feet thick near the center of the county but gradually pinch out toward the northeast and southwest against the highs of the Precambrian bedrock surface. Glacial drift overlies the Precambrian and Cretaceous rocks and forms the surface of the area. The drift consists largely of till and ranges in thickness from about 10 feet in the north and northeast to approximately 550 feet in the southwest. The most prominent surficial glacial deposits are five southeast-trending end moraines, two of which are associated with, and parallel to, relatively extensive belts of outwash. Recent deposits averaging less than 20 feet in thickness overlie the glacial drift in stream valleys.

The principal aquifers in Lyon County are glacial-melt-water deposits of sand and gravel, and sandstone of Cretaceous age. The underlying Precambrian rocks and the Recent alluvium are of only local importance as water sources.

Melt-water deposits composed of stratified clay and silt as well as sand and gravel occur in channels having surficial expression, in buried channels having no direct surface expression, and as small isolated bodies within the till. Well logs of test holes show that the buried melt-water channels are generally parallel to the surficial channels. However, melt-water deposits are not necessarily confined to the area beneath the surficial channel but may extend laterally 1 mile or more beyond its limits. Sand and gravel are commonly interbedded with other melt-water materials. They range in thickness from 10 to 75 feet, are usually less than 1 mile in width, and may be as much as 8 miles in length. Although these aquifers are extensive, they underlie less than 10 percent of the county area. In most places, water from the drift is obtained from small isolated bodies of sand and gravel within the till.

Water in the glacial drift is usually very hard (more than 500 parts per million) and low in chlorides (less than 50 parts per million). Drift wells generally yield from 2 to 30 gallons per minute; however, in areas where wells tap melt-water-channel deposits, sustained yields of as much as 500 gallons per minute are obtained.

The sandstone beds of Cretaceous age occur between the Precambrian bedrock surface and an altitude of 825 feet as a basal sandstone, between altitudes of 890 and 1,020 feet, and between altitudes of 1,050 and 1,160 feet. Water-well data, supplemented by test drilling, show that each of these stratigraphic intervals is developed only in the county. The sandstone beds are of low permeability and are usually less than 2 feet thick, but they may be more than 20 feet thick in places. Water from these aquifers range in quality from soft (less than 60 parts per million) to very hard (more than 500 parts per million) and may contain excessive amounts of chloride (500 to 2,000 parts per million). Wells tapping rocks of Cretaceous age usually yield 2 to 7 gallons per minute, but in areas where the sandstone beds are thicker or hydrologically interrelated with aquifers of other geologic units, yields of as much as 75 gallons per minute have been obtained.

Large quantities of ground water are available from melt-water channels in the county. Moderate quantities, adequate for domestic and small industrial needs, are available from many of the small isolated deposits of sand and gravel in the till. Small quantities of ground water, adequate only for domestic supply, generally can be obtained from Cretaceous sandstone.

## INTRODUCTION

### PURPOSE AND SCOPE OF STUDY

The economic, urban, and industrial growth of Lyon County is dependent on an adequate supply of ground water. It is the purpose of this report to describe all sources capable of yielding ground water of suitable quality and quantity to fulfill long-term demands. Information in this report should be of value to municipalities, industries, and farmers seeking new or additional supplies of ground water.

This description of the geologic and ground-water conditions of Lyon County is the result of a study made by the U.S. Geological Survey in cooperation with the Division of Waters, Minnesota Department of Conservation, and the Marshall Utilities Commission. The investigation was under the direct supervision of Robert Schneider, district geologist for the State of Minnesota.

### LOCATION OF AREA

Lyon County is in southwestern Minnesota, about 150 miles southwest of Minneapolis and St. Paul, between lats.  $44^{\circ}12'$  N. and  $44^{\circ}37'$  N., and longs.  $95^{\circ}36'$  W. and  $96^{\circ}06'$  W. (fig. 1). The county is bounded on the north and northeast by Yellow Medicine County, on the east by Redwood County, on the south by Murray County, on the southwest by Pipestone County, and on the west by Lincoln County. Marshall, which is near the center of the county, is the principal city and the county seat.



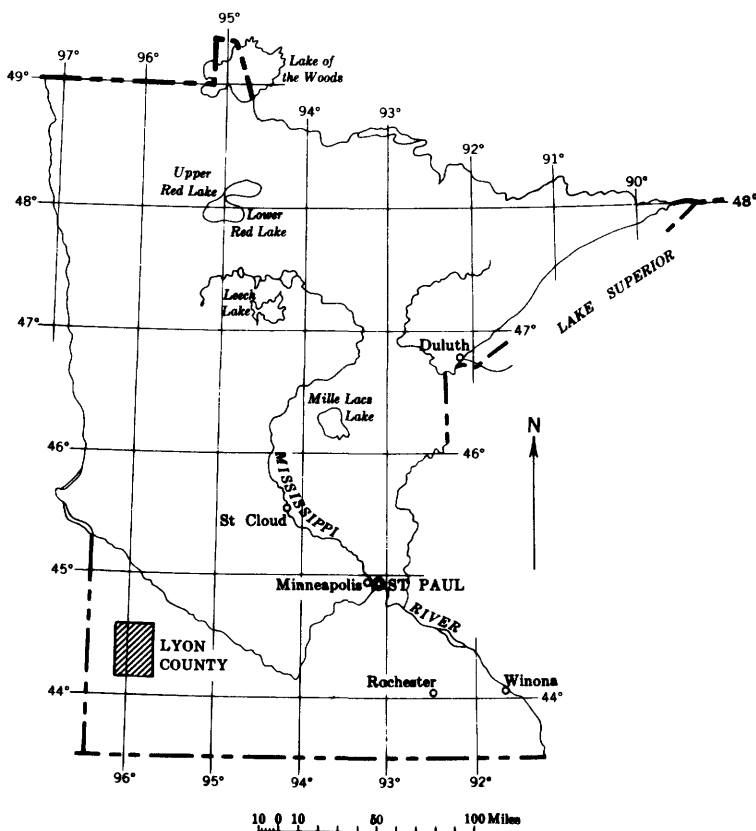


FIGURE 1.—Map of Minnesota showing location of Lyon County.

### METHODS OF INVESTIGATION

Geologic and hydrologic data analyzed and compiled for this report were collected in the field by U.S. Geological Survey personnel during the summers of 1956–58.

The first phase of the investigation included the systematic collection of water-well data from well owners and users, municipal officials, and local well drillers. In addition, water levels and well depths were measured, well yields were estimated, and well water was collected for field and laboratory analysis.

During the next phase of the investigation, surface and subsurface geological data on the occurrence of ground water were collected interviewing well drillers and by mapping surficial features. Information on the physical and water-bearing characteristics of subsurface deposits was obtained from well logs and pumping tests. A geologic map of surficial deposits was prepared in the field and plotted

on a Minnesota State Highway map at a scale of 1 inch equals 1 mile.

Test holes were drilled and logged electrically at selected points throughout the county, and the yield of a glacial aquifer was tested.

#### TEST-HOLE NUMBERING SYSTEM

The numbering of test holes and wells is based on the U.S. Bureau of Land Management's system of subdivision of the public lands. Lyon County is in the fourth-principal-meridian and base-line system. The first segment of a well or test-hole 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. Lowercase letters a, b, c, and d after the section number locate the well within the section. The first small letter denotes the 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract, as shown in figure 2. The letters are assigned in a counterclockwise

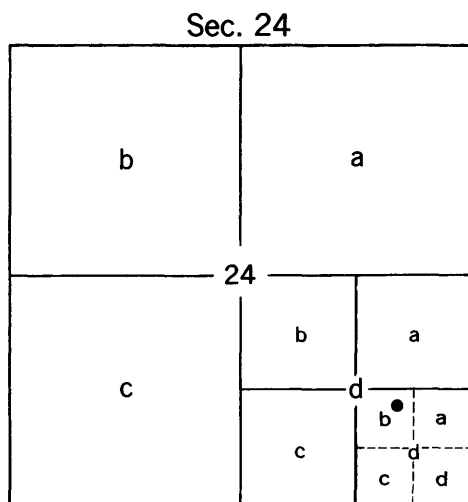


FIGURE 2.—Well-numbering system.

direction, beginning in the northeast quarter. Consecutive numbers (beginning with 1) are added as suffixes to identify additional wells within a 10-acre tract. Thus, the number 111.42.24ddb1 identifies the first well or test hole in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 24, T. 111 N., R. 42 W.

#### PREVIOUS REPORTS

Previous reports include only the broader aspects of the geologic and ground-water condition in Lyon County. Winchell (1884), as-

sisted by Upham, discusses the general and economic geology of the area and describes some of the surface and shallow subsurface features. A report by Leverett (1932) contains a map showing the geographic extent of most of the surficial glacial deposits.

Reports containing both geologic and hydrologic studies of the area were prepared by Hall, Meinzer, and Fuller (1911) and Thiel (1944). These and other references are listed at the end of this report.

### ACKNOWLEDGMENTS

Appreciation is expressed to the many persons who assisted in the collection of field data. The willing cooperation of Lyle Else, Louis Schwartz, and the Marshall Utilities Commission is greatly appreciated. Special acknowledgement is given the local well drillers, who were very helpful in furnishing information on wells.

### GEOGRAPHY

#### CULTURE

The population of Lyon County is 22,655 (1960 census); 60 percent live in urban areas, and 40 percent live on farms. Marshall, the largest city, has a population of 6,681.

Since 1867, the time of the first permanent settlement in this area, the county has grown to be one of the leading farming and food-processing areas in the State. Farms include more than 90 percent of the county's land area and produce mostly corn, flax, soybeans, and oats. Manufacturing and food-processing plants depend almost entirely on local agriculture for raw materials.

#### TOPOGRAPHY

Lyon County is nearly rectangular and comprises about 715 square miles in an area 30 miles long (from north to south) and 24 miles wide. The area has been mapped by the U.S. Army Map Service, and the topography is shown by contour intervals of 25 and 50 feet, respectively, on two maps (Watertown NL-14-12 and New Ulm NL-15-10) published at a scale of 1:250,000.

The U.S. Coast and Geodetic Survey, the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the Minnesota Department of Highways have established bench marks along rail lines and trunk highways and in municipalities and villages in the area. The highest bench mark in the county, at an altitude of 1,727.9 feet, is about 2 miles southwest of Florence, near the Lincoln County line. The lowest bench mark, at an altitude of 1,052 feet, is half a mile north of Lake Cottonwood, near the Yellow Medicine County line.

Lyon County lies in the Western Young Drift section of the Central

Lowland province of the United States (Fenneman, 1938, p. 559). The southwestern part of the county forms a part of the upland and northeast slope of the Coteau des Prairies, an elongated highland extending northwestward through South Dakota, Minnesota, and Iowa. The northeastern part forms part of a lowland plain that extends northeastward to the Minnesota River valley.

The county can be divided into three rather well defined physiographic units: the Upland Plain, the Slope, and the Lowland Plain (fig. 3) (Thiel, 1944, p. 271). The Upland Plain is part of the Coteau des Prairies and occupies the southwestern part of the county. This area, although hilly in places, is for the most part a gently undulating, poorly drained surface containing many small lakes and streams. The Slope, which forms the northeast flank of the Coteau in the area, descends gradually from the Upland Plain to the Lowland Plain. It is well drained and is characterized by numerous small ravines and valleys and the conspicuous absence of lakes. The Lowland Plain is gently rolling and poorly drained and contains numerous small lakes, sloughs, and drainage ditches.

#### DRAINAGE

Most of Lyon County lies within the drainage area of the Minnesota River basin; a small area in the south-central part drains into the Des Moines River basin. The Minnesota basin in this area comprises three watersheds—those of the Yellow Medicine, the Redwood, and the Cottonwood Rivers (fig. 3).

The Yellow Medicine River watershed includes about 155 square miles in the northwestern part of the county. The South Branch of the Yellow Medicine River, which drains most of the watershed in the county, joins the main stream of the Yellow Medicine River near the north county line.

The largest watershed in the county, that drained by the Redwood River, includes approximately 320 square miles. In its course across the county and down the Slope, the Redwood River increases its gradient from 10 to approximately 20 feet per mile; then, where it enters the Lowland Plain, the river changes abruptly to a slow-moving meandering stream whose gradient is less than 7 feet per mile.

The Cottonwood River watershed includes an area of about 210 square miles in the southeastern part of the county. This area is drained by the Big Cottonwood River, which rises at Rock Lake and flows with a moderate gradient until it descends the Slope, where its gradient increases to 19 feet per mile. Where it reaches the Lowland Plain, the river flows eastward into Redwood County and joins with the main stream of the Cottonwood River.

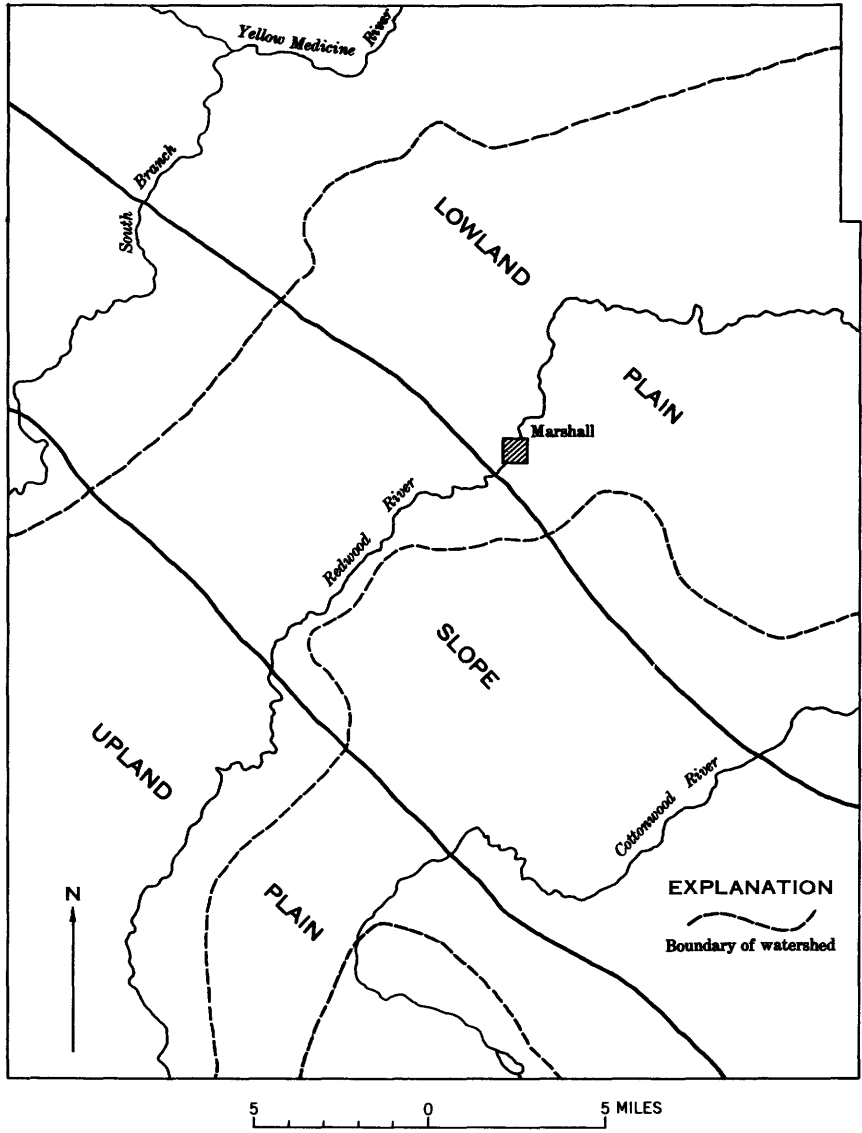


FIGURE 3.—Map of Lyon County showing physiographic provinces and watersheds. After Thiel (1944).

The remainder of the county, about 30 square miles in the south-central part, lies within the Des Moines River basin.

Although the principal direction of drainage in the county is to the northeast, toward the Minnesota River, secondary drainage that trends southeastward has developed in many areas. Part of the secondary drainage system is a group of southeast-trending lake chains; one extends through the northeast corner of the area, another through the areas of Garvin and Balaton in the southwest, and another through the southwest corner of the county.

### CLIMATE

The climate of Lyon County is characteristically continental and is marked by wide seasonal variations. July, the hottest month, has a mean temperature of 74.7° F; and January, the coldest month, has a mean temperature of 12.9° F. The highest temperature recorded in Marshall before 1960 was 107° F; the lowest was -36° F. The average annual temperature is about 45° F. Normally, the growing season is about 132 days; the average date of the last frost is May 8, and that of the first frost, October 6.

The average yearly precipitation for the period 1945-55 was 23.68 inches. Most of the precipitation is rain that falls during the growing season. Even though the monthly average is only 1.81 inches, high-intensity rains of 4 or 5 inches in 24 hours are not uncommon during the spring and summer. During the winter, total snowfall averages 48.2 inches.

Mild breezes that average 3-5 mph (miles per hour), are usually present. The prevailing wind during the summer is from the southwest, and in the winter it is from the northwest.

### GEOLOGY

#### SUMMARY OF STRATIGRAPHY AND GEOLOGIC HISTORY

The rock formations underlying Lyon County were formed during Precambrian, Cretaceous, Pleistocene, and Recent times. The Precambrian rocks consist largely of granite and quartzite. These rocks are overlain in places by Upper Cretaceous strata composed largely of thick sections of soft dark-bluish-gray shale but include thin beds of loosely consolidated sandstone. Pleistocene deposits of glacial drift overlie the Precambrian and Cretaceous rocks and form the surface in the area. Recent deposits consisting mostly of alluvium overlie the glacial drift in valleys and stream channels.

During Precambrian time, more than 1 billion years ago, molten rock from the earth's interior solidified and formed the granite. Later, the area was uplifted, exposed, and the granite underwent an

extensive period of erosion. During late Precambrian time the area was covered by the sea, and silicious sand was deposited on the eroded granite surface. Through silicification, the sand later was changed to quartzite.

From the close of Precambrian time through the Paleozoic and Mesozoic (through Early Cretaceous), a period of more than 500 million years, the area was again above the sea. During this time, the quartzite and granite surfaces were subjected to extensive erosion and became the source of some of the sediments deposited in other areas.

Deposition of rock-forming material in the area did not occur until Late Cretaceous time (about 70 million years ago). Continental seas covered the area during this period and deposited the clay, silt, and sand that later formed shales and sandstones. The area was again exposed at the close of the Cretaceous, and there followed a period of erosion that lasted until the advent of the Pleistocene (about 1 million years ago).

During the Pleistocene (the Great Ice Age), the county was covered by the ice of at least four major glacial advances (the Nebraskan, the Kansan, the Illinoian, and the Wisconsin, from oldest to youngest). Deposits of the first three of these major advances are exposed south of the county. The Wisconsin advance was marked by four stades in Lyon County: the Iowan, the Tazewell, the Cary, and the Mankato. The surface of the county was formed during late Wisconsin time by deposits left by the southeastward-advancing Des Moines ice lobe. The Recent alluvium was deposited after the retreat of the last ice sheet from the area.

## DESCRIPTION OF GEOLOGIC UNITS

### PRECAMBRIAN ROCKS

The Precambrian basement rocks in the county consist of granite and, in the extreme southwest, quartzite. Although the granite does not crop out in Lyon County, it is well exposed along the Minnesota River valley to the north and at a quarry in Yellow Medicine County 5 miles southeast of Cottonwood (fig. 4). The major joint system at this quarry strikes N. 50° W. and dips 73° to the southwest.

Samples of the granite underlying the area, obtained by well drillers and by test drilling, are described briefly in table 1. In most places the granite is deeply weathered, and locally it is covered by a thin regolith consisting in part of weathered materials transported and reworked during the Cretaceous. This zone consists largely of fragments of granite in a matrix of kaolinitic materials. In places, however, the fine-grained kaolinitic materials have been washed out, leav-

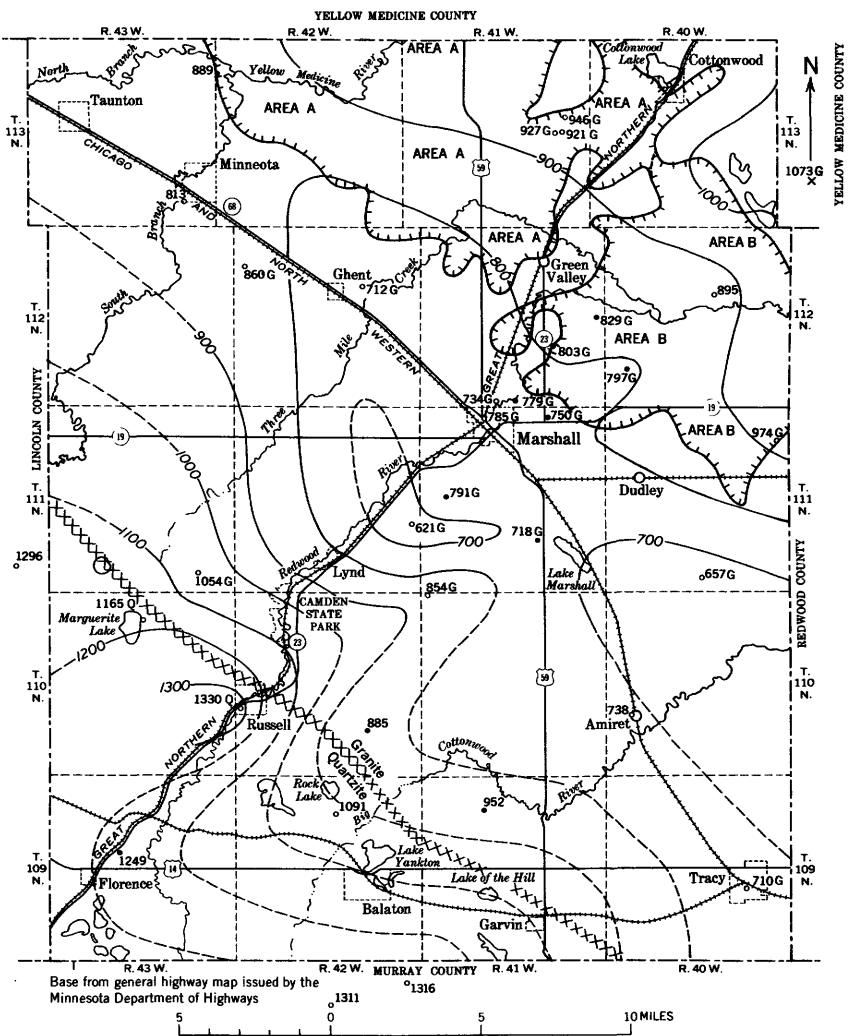


FIGURE 4.—Map of Lyon County showing configuration of the Precambrian bedrock surface and areal extent of Cretaceous sandstone between altitudes of 890 and 1,020 feet.



ing loosely consolidated pockets of granite fragments ranging in size from sand to gravel. The pockets average less than 1 foot in thickness, and in places they are in contact with the overlying Cretaceous strata.

The surface of the granite in the county slopes northeast and forms a broad northwest-trending depression that opens to the southeast (fig. 4). Where penetrated by closely spaced test holes and wells, the surface was found to be steeply undulating. The bedrock topography map can be used in conjunction with surface altitudes to show the approximate thickness of the intervening formations.

Sioux quartzite, which overlies the granite, forms the upper part of the basement rock in southwest Lyon County (fig. 4). Although samples of the quartzite were not recovered during this investigation, drillers report that it is similar to that exposed in Pipestone County. Even though the quartzite is described as virtually impermeable (table 1), secondary permeability is developed in fractures near its surface.

### CRETACEOUS ROCKS

#### GENERAL CHARACTERISTICS

The Cretaceous strata in the area rest on the Precambrian basement surface and are an extension of the Upper Cretaceous of South Dakota (Hall and others, 1911, p. 241). The rocks extend from Redwood and Murray Counties northwestward through central and northeast Lyon County and into Lincoln and Yellow Medicine Counties. In Lyon County, the Cretaceous rocks were deposited in a broad basin in the Precambrian bedrock surface and occur at altitudes

#### EXPLANATION TO FIGURE 4

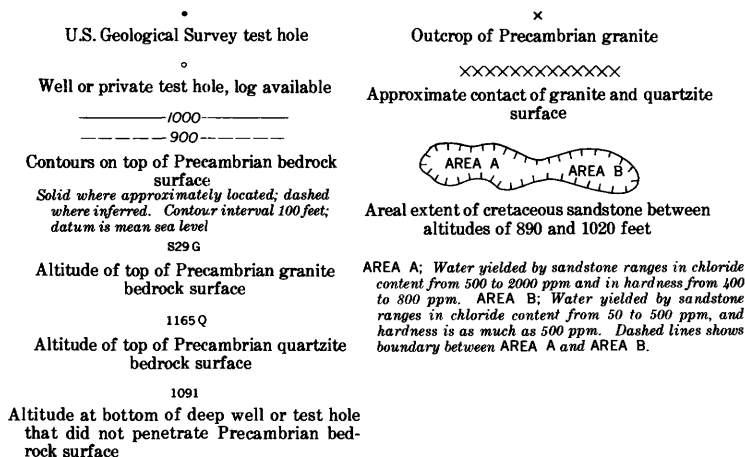


TABLE 1.—*Summary of physical characteristics, water-bearing properties, and quality of water of geologic units, Lyon County, Minn.*

System	Series	Approximate thickness (feet)	Geologic description	Water-bearing and water-yielding characteristics	Geographic and stratigraphic extent of aquifers	Chemical quality of ground water (based on field chemical analyses)	
						Hardness (ppm)	Chloride (ppm)
Quaternary	Recent	0-20 (?)	Alluvium, made up of silt, sand, gravel, and boulders.	Not an important aquifer; permeable sand and gravel yield small to moderate amounts of water to wells.	Restricted mostly to valleys and channels of rivers and streams.	200-500	0-50
	Pleistocene	10-550+	Glacial drift; mostly dark-gray till, yellowish brown where oxidized, made up of unsorted mixtures of clay, silt, sand, and boulders, contains sorted and bedded outwash deposits of sand and gravel deposited in channels and lake basins; till locally contains small lenses and irregularly shaped bodies of silt, sand, and gravel.	Outwash sand and gravel yield as much as 300 gpm to wells; the amount depending on the thickness, extent, and permeability of the deposits.	Occur between altitudes of 950 and 1,200 ft in areas where their areal extent is known (fig. 6).	200-900	0-50
				Till is relatively impermeable; yields of 2-30 gpm are generally obtained from the small bodies of sand and gravel in the till.	Occurs sporadically throughout till.	700-1500	0-50
Cretaceous		0-500+	Shale, soft, fissile, dark-bluish-gray; contains thin, discontinuous beds of interbedded sandstone, limestone, siltstone, and lignite; sandstone is fine grained, loosely consolidated, and generally occurs in beds that are less than 2 ft thick. Limestone is fine grained, thickly bedded, semiconsolidated, creviced and fractured, occurs in beds that are less than 10 feet thick.	Limestone yields moderate supplies of water to wells, from crevices, fractures, and solution cavities.	Occurs between altitudes of 1,240 and 1,260 ft in northwestern part of county (fig. 5).	700-1000	0-50
				Sandstone yields 2-45 gpm to wells, depending on permeability and thickness of bed.	Permeable sandstone generally occurs between the following altitudes: 1. 1,060 and 1,160 ft in northwestern and central parts of county; sporadic in occurrence elsewhere (fig. 5). 2. 890 and 1,020 ft in northeastern part of county; sporadic in occurrence elsewhere (fig. 4). 3. Below 825 ft as basal sandstone largely within area enclosed by 825-ft contour line on fig. 4.	(1) 300-1100 (2) 0-800 (3) 100-900	0-50 50-2000 0-150
	Upper Cretaceous			Shale, siltstone, and lignite virtually impermeable; shale and siltstone will yield 2-7 gpm to wells from cracks and crevices connected to water-bearing sandstone.	Not known except locally.	Not known	Not known
Precambrian	?	?	Quartzite, pink, hard and compact; contains cracks and fractures.	Virtually impermeable; may yield small amounts of water to wells from creviced zones.	Not known except locally.	100-900	0-150
			Granite, pink, red, and gray, coarsely grained, biotitic; weathered and creviced at the top.	Virtually impermeable; may yield small amounts of water to wells, as much as 7 gpm, from weathered and creviced zone.	Not known except locally.		

[gpm, gallons per minute; ppm, parts per million]

of 630 to 1,311 feet (pl. 1; fig. 5). These strata are approximately 550 feet thick near the center of the granitic basin and gradually pinch out against its flanks. In the northeastern and southwestern parts of the county, Cretaceous outliers occur in other depressions in the Precambrian bedrock surface.

The Cretaceous strata are flat lying and are composed largely of thick sections of soft dark-bluish-gray shale, but they also include thin beds of poorly consolidated water-bearing sandstone and limestone (table 1). The beds of sandstone are of small geographic extent and generally occur at each of the following stratigraphic intervals: between the Precambrian bedrock surface and an altitude of 825 feet, at altitudes of 890 to 1,020 feet, and at altitudes of 1,050 to 1,160 feet. Although the beds of sandstone are usually of small geographic and stratigraphic extent, they sometimes occur outside these areas. Limestone was found only in the northwestern part of the county at altitudes of 1,240 to 1,260 feet.

#### SANDSTONE AND LIMESTONE

The basal sandstone, which occurs below an altitude of 825 feet, is usually medium to coarse grained and is associated with, or in contact with, the Precambrian granite surface. In most areas these beds reach a maximum thickness of 4 feet but have been reported to be as much as 100 feet thick. They are locally interbedded with shale and kaolinitic material and are thickest near the center of the granitic depositional basin.

Sandstone strata at altitudes of 890 to 1,020 feet are mostly fine grained, locally fossiliferous, and are confined primarily to an area in the northeastern part of the county (fig. 4). The sandstone is generally in beds less than 2 feet thick but in places may be as much as 20 feet thick. Because of the proximity of the sandstone to the underlying granite bedrock, it may be that in places, such as northeast area B (fig. 4), it is in contact with the granite. These sandstone strata, which were deposited by a transgressing Cretaceous sea, are thinly interbedded with shale and siltstone and overlap one another in a northeast direction (Rodis, 1961a).

Sandstone beds at altitudes of 1,050 to 1,160 feet are fine to medium grained and extend northwestward from the central part of the county into Lincoln and Yellow Medicine Counties (fig. 5). These beds are sometimes absent in the vicinity of a surficial melt-water channel where glacial melt waters eroded the Cretaceous rocks deeply (fig. 6). The strata are as much as 50 feet thick, are locally interbedded with shale and lignite, and in places are tightly cemented with calcium carbonate. Although these sandstone beds are near the surface in the northeastern part of the county, only a few poorly exposed outcrops were found in the area (fig. 5).

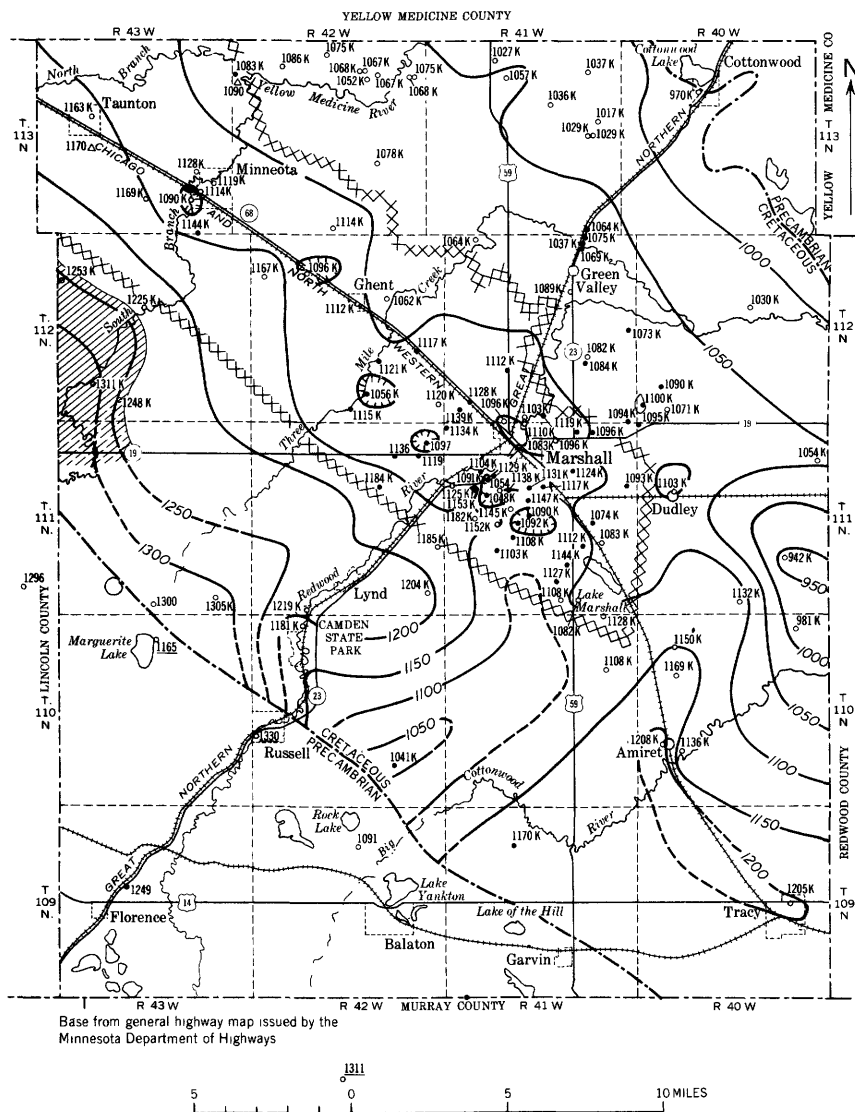


FIGURE 5.—Map of Lyon County showing configuration of the Cretaceous bedrock surface and areal extent of sandstone and limestone between altitudes of 1,050 and 1,260 feet.

The limestone, which occurs only in the northwestern part of the county (fig. 5), is thick bedded and averages 7 feet in thickness. It is characterized by numerous solution cavities and crevices and is locally in contact with thin and discontinuous sandstone beds near its base.

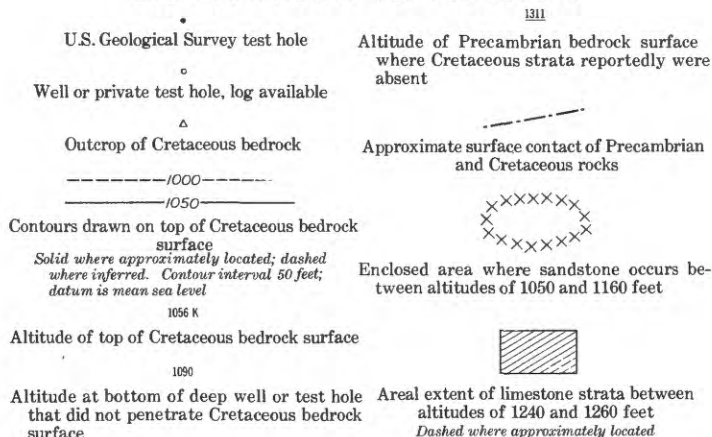
#### BEDROCK TOPOGRAPHY

The configuration of the Cretaceous bedrock surface (fig. 5) is the result of an extended period of erosion that lasted from the close of Cretaceous time through the Pleistocene. A difference between the altitude of the bedrock surface in the northeast (1,000 feet) and in the southwest (1,300 feet) suggests that in places as much as 300 feet of Cretaceous strata has been eroded away.

Glaciation during late Pleistocene time formed some of the minor topographic features of this surface. In the central, northeastern, and northwestern parts of the area the surface contours strike to the southeast parallel to the movement of the Des Moines glacial lobe. This suggests that the surface was probably eroded by the advancing glacial ice. Depressions in the bedrock surface occur mostly along a thin belt that extends from the center of the county, near Marshall, northwest to Minneota. Because these depressions are coincident with the overlying surficial melt-water channel of the Marshall moraine (fig. 6), one can conclude that they probably were formed by the scouring action of glacial melt waters.

The contact of the Cretaceous and Precambrian bedrock surfaces in the northeast is well defined by subsurface data; however, in the southwest there are fewer control points, and the position of the contact is not so well defined (fig. 5).

#### EXPLANATION TO FIGURE 5



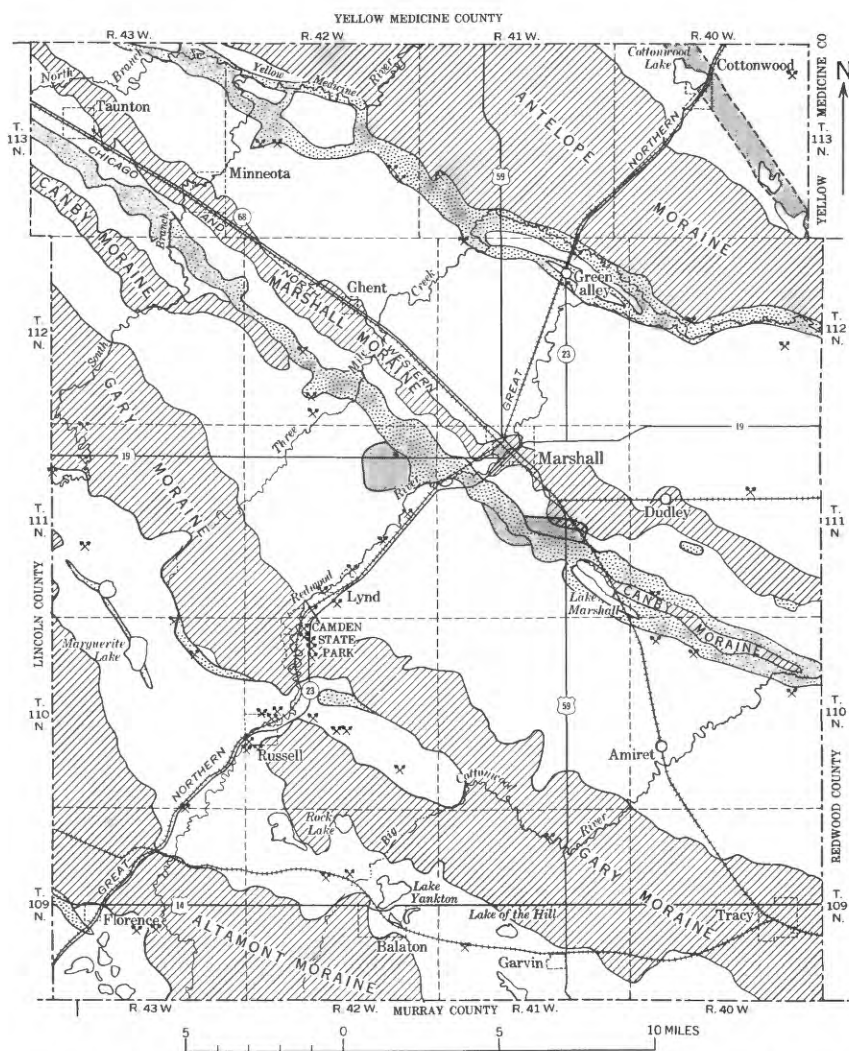


FIGURE 6.—Map of Lyon County showing surficial geology and buried melt-water deposits.

## PLEISTOCENE DEPOSITS

## GENERAL CHARACTERISTICS

Glacial drift overlies Precambrian and Cretaceous rocks and forms the surface of the area. The drift, deposited during successive advances and retreats of the Pleistocene ice sheets, is composed largely of till, although it also includes melt-water deposits.

The drift ranges in thickness from about 10 feet in the northern and northeastern parts of the county to more than 550 feet in the southwest. It consists of as many as four and possibly five, separate drift sheets that in most places are separated by an oxidized layer of till or by buried melt-water deposits (pl. 1, A-A').

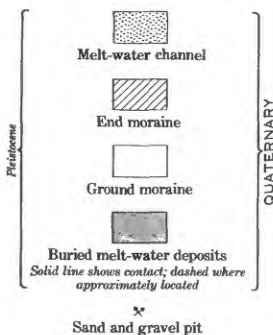
The surficial glacial features (fig. 6) that were formed during the retreat of the last ice sheet from the area consist mainly of five north-west-trending end moraines. The northeasternmost two of these moraines, the Antelope and the Marshall, are flanked on their southwest sides by extensive belts of outwash. The intervening areas are flat to slightly rolling ground moraine. The end moraines in this area are part of a morainal system that extends through South Dakota, Minnesota, and Iowa (Leverett, 1932, pl. 2). These features are subdued in many places, rising less than 25 feet above the surrounding area, and they are composed largely of till but may include some melt-water deposits.

## MELT-WATER DEPOSITS

Melt-water deposits composed of sorted sand, gravel, silt, and clay, occur largely as outwash in southeast-trending melt-water channels or as small isolated deposits within the till. The outwash deposits generally underlie the surficial melt-water channels but occur locally in buried melt-water channels that have little surface expression.

The surficial melt-water deposits associated with the Marshall and Antelope moraines were studied in considerable detail because of their

EXPLANATION TO FIGURE 6



apparent value as sources of ground water. Test drilling in these surficial deposits near Marshall has shown that their subsurface extent is not necessarily confined to an area beneath the surficial melt-water channels but may extend laterally a mile or so beyond the limits of the surficial channels (fig. 6).

Deposits in the channels comprise till, glaciolacustrine deposits, and outwash. In many places the outwash includes thick sections of highly permeable sand and gravel. A cross section of the melt-water channel near Marshall (pl. 1, *B-B'*) shows the outwash sand and gravel to be discontinuous across the width of the channel; however, a section along the long axis of the deposit (pl. 1, *C-C'*) shows that these beds do extend continuously for more than 6 miles. Test drilling of the surficial melt-water deposits in front of the Antelope moraine shows that these deposits are not as extensive as those in front of the Marshall moraine, and that their subsurface extent may generally coincide with the extent of the surface expression (fig. 7). Other surficial melt-water deposits, less extensive than those associated with the Marshall and Antelope moraines, occur in front of the Gary moraine near Marguerite Lake northeast of Russell and in front of the Altamont moraine west of Florence (fig. 6).

Buried melt-water-channel deposits that have no direct surface expression but which coincide with the surficial channels and drain-

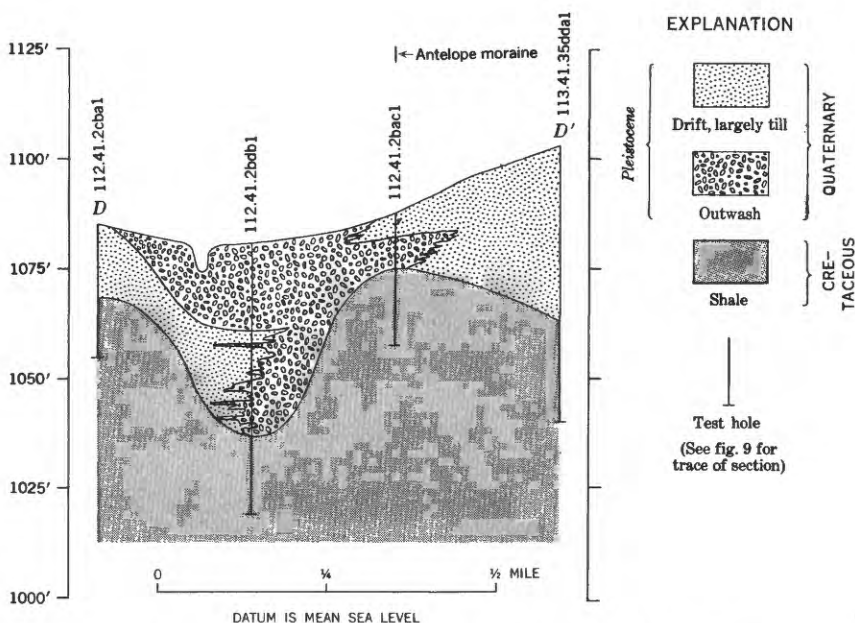


FIGURE 7.—Southwest to northeast section near Green Valley.



ageways occur in other areas of the county. By studying water-well and test-hole data collected in the vicinity of the chain of lakes in the northeast corner of the county, a buried melt-water deposit was found to coincide with the lake chain at the Precambrian-Cretaceous contact (fig. 8). Deposits in this channel include permeable water-bearing sand and gravel. Similar channels in the southwestern part of the county, where the drift is very thick, were located by analysis of subsurface data (Schneider and Rodis, 1961).

The isolated melt-water deposits that occur within the drift differ in size and shape and have no regular lineation. Most of them are lenticular, are as much as 30 feet or more thick, and extend laterally for several hundred feet. Drillers report that in most areas they are less than 10 feet thick and less than 100 feet long. Closely spaced test holes (5 to 100 feet apart) are necessary to outline their boundaries.

#### TILL

Till is a heterogeneous mixture of unconsolidated and unsorted clay, silt, sand, gravel, and boulders. However, it may contain as much as 10 percent small isolated bodies of sorted melt-water deposits. Most of the till is dark gray, but where it is exposed to the atmosphere for long periods its upper zone oxidizes to a yellowish brown. This oxidized zone is less than 30 feet thick in most areas; however, where the surface has been exposed for extremely long periods, the zone may be as much as 150 feet thick (table 4, well 108.42.2dac1).

#### RECENT DEPOSITS

Recent deposits (described in table 1) are largely confined to stream valleys, where they overlie the glacial drift. In most places their contact with the drift is not well defined; however, their maximum thickness is about 20 feet, and their average thickness is about 10 feet. Although these deposits occur to some extent in all stream valleys in the area, they are thickest in valleys near the toe of the Slope province, where the gradients of sediment-laden streams change abruptly. In the flood plain of the Redwood River, between Lynd and Marshall, these deposits are mined commercially for their sand and gravel.

#### PHYSIOGRAPHIC DEVELOPMENT OF LYON COUNTY

The primary physiographic features of Lyon County were formed by Pleistocene glaciation. The high relief in the area of the Upland Plain and the Slope (Coteau des Prairies) is due largely to the thick accumulation of older drift sheets (Schwartz and Thiel, 1954, p. 12-13). The low rolling relief of the Lowland Plain, which is interrupted only by a few low-lying morainal hills (end moraines),

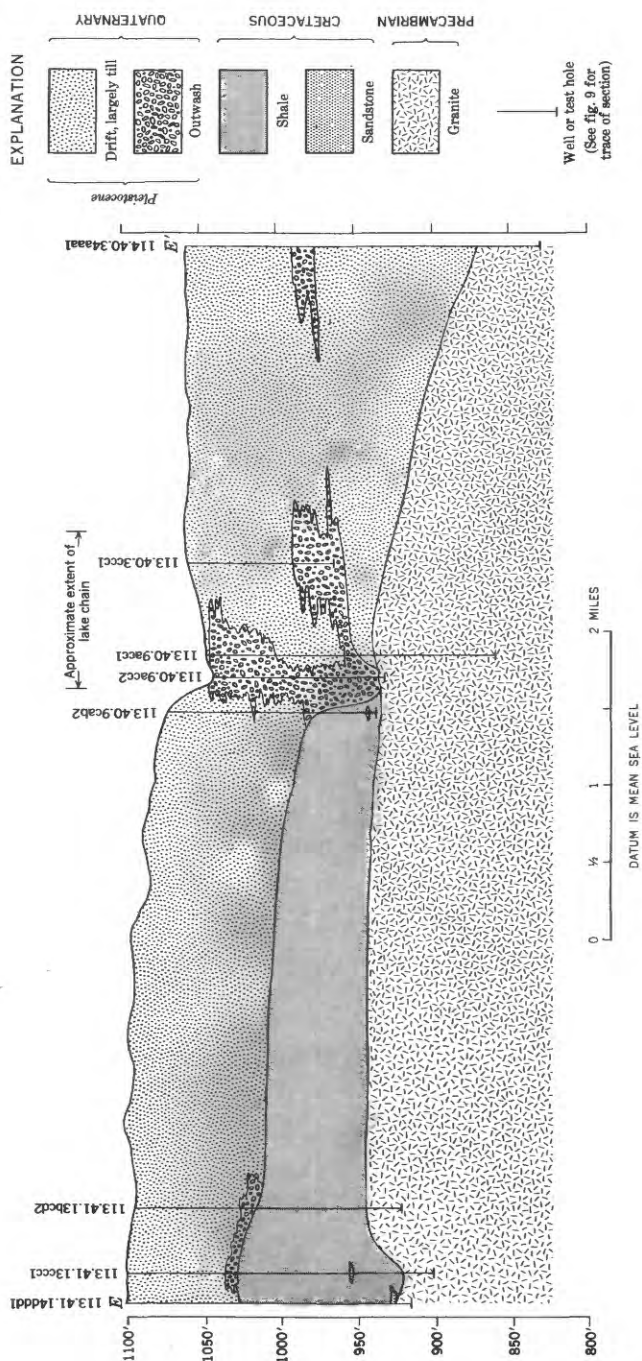


FIGURE 8.—Southwest to northeast section near Cottonwood.

was formed by the deposits of late Pleistocene glaciation. Since Pleistocene time, alteration of the surface in the area has been limited to minor erosion and deposition in stream valleys.

The primary direction of drainage, to the northeast, is a consequence of the slope of the area. Secondary drainage, evidenced by southeast-trending streams and lake chains, is due to the lineation of the retreating ice front during late Wisconsin glaciation (Schneider and Rodis, 1961).

### GROUND WATER

Ground water may be defined as all water that lies within the zone of saturation, the zone in which the rocks are saturated with water under hydrostatic pressure. The ultimate source of this ground water is precipitation in the form of rain or snow, part of which percolates downward through the soil and eventually reaches the water table. The remainder either becomes surface runoff or is retained by the soil and later lost to the atmosphere by evaporation or transpiration.

Geologic strata capable of yielding water to wells are called aquifers. An aquifer usually includes a bed or a series of beds of a geologic unit but may include strata of several geologic units. The rate per unit cross section at which an aquifer can transmit water under pressure is called its permeability. The permeability of a bed is primarily dependent on the degree of interconnection of pore spaces. Materials such as shale and clay have a high porosity, or percentage of open pore space; but because of the lack of interconnection between pore spaces, they are virtually impermeable. In other porous materials, such as unconsolidated sand and gravel and loosely consolidated sandstone, the pore spaces are to some degree interconnected. If the interconnected pore spaces are large, then the material has a high permeability; but if the interconnected pore spaces are so small that it takes an excessive amount of pressure to force water through them, then the material has a low permeability. Rocks such as unweathered granite or quartzite have almost no interconnected pore spaces and are considered to be virtually impermeable.

The piezometric surface of a water-bearing formation or aquifer is the highest surface to which water will rise under its full head. If the aquifer is not confined by an overlying bed and the upper part is exposed to atmospheric conditions, then the piezometric surface is called the water table. If the aquifer is confined above and below by less permeable beds, the water is under artesian conditions, and the piezometric surface is above the base of the overlying bed.

### OCCURRENCE AND MOVEMENT

Ground water in Lyon County occurs under both water-table and artesian conditions. Water-table conditions usually exist at depths

of less than 25 feet in alluvium and shallow glacial melt-water deposits. Ground water under confined or artesian conditions generally exists at depths greater than 25 feet in the deeper melt-water deposits, in the sandstone and limestone, and in the weathered basement rocks.

Ground water in the area moves in the same general direction as the overlying surface drainage except possibly in the northeastern part of the county. Even though the surface drainage in this area is to the northeast, the regional inclination of the underlying Cretaceous sandstone is to the southwest, and ground water in these beds probably moves southwestward also.

#### **RECHARGE, DISCHARGE, AND FLUCTUATION OF WATER LEVELS**

Water levels in wells in the area are affected largely by recharge to the ground-water reservoir by precipitation and by discharge from the ground-water reservoir through evapotranspiration, flow of ground water into effluent streams or both. Minor or local fluctuations of water levels may be due to frost melt, changes in atmospheric pressure, and pumping of nearby wells.

Normally the water table fluctuates more frequently and with a greater amplitude than do the water levels of the artesian aquifers. Water levels of wells tapping water-table aquifers rise almost immediately after an appreciable amount of precipitation, whereas changes in water levels in the deeper, confined aquifers generally lag behind periods of heavy precipitation. During periods of little or no precipitation that are accompanied by rapid ground-water discharge due to evapotranspiration, the water table generally declines more rapidly than the water levels of the deeper, artesian aquifers.

Broad seasonal fluctuations of water levels are reflected in most wells in the area. During a year of normal precipitation, water levels rise in the early spring as a result of heavy rainfall, frost melt, and snow melt. This rise is followed by a gradual decline that continues from late spring until the time of the first killing frost. During fall and winter the rate of decline gradually decreases until it is almost nil.

#### **HYDROLOGIC CHARACTERISTICS OF THE GEOLOGIC UNITS**

##### **PRECAMBRIAN BASEMENT ROCKS**

Although the Precambrian basement rocks are virtually impermeable, ground water occurs locally in the weathered and creviced zone of the granite and in the crevices of the quartzite; however, most attempts to obtain water from these strata fail.

Wells completed in permeable weathered granite are generally limited to areas where adequate amounts of water cannot be obtained from the overlying strata. Usually these wells yield only a few gallons per minute; however, in places where the pockets of permeable weathered granite are hydrologically interconnected with the Cretaceous basal sandstone, higher yields have been obtained.

Ground water in the quartzite occurs only in those crevices that are connected with water-bearing parts of the overlying drift.

#### CRETACEOUS ROCKS

Ground water in Cretaceous strata occurs chiefly in sandstone and limestone but may occur between crevices in the bedding planes of siltstone and shale interbedded with the sandstone (table 1). The sandstone is usually of low permeability and yields water under artesian pressure.

The basal sandstone, which occurs mostly near the center of the county below an altitude of 825 feet, yields water under a very high artesian head. In areas where the basal sandstone has been extensively explored, as in the area of the Marshall well field, it has been found to be hydrologically interconnected locally with the underlying regolith and weathered granite.

The piezometric surface of water in the basal sandstone ranges from 10 to 150 feet below the land surface, and a few flowing wells are found in areas where the altitude of the land surface is below 1,125 feet. Yields of wells that obtain water from these beds usually range from 2 to 7 gpm (gallons per minute). In the Marshall well field, where large-diameter wells obtain water from both the sandstone and the weathered granite, yields of as much as 75 gpm have been obtained.

The thinly bedded sandstone that occurs between altitudes of 890 and 1,020 feet is largely of low permeability and yields water that is softer but higher in chloride content (table 1) than water elsewhere in the county (Rodis and Schneider, 1960). Ground water that is hydrologically interconnected with that in the thinly bedded sandstone sometimes occurs in crevices in bedding planes of the interbedded siltstone and shale. The piezometric surface of water in these beds ranges from 20 to 70 feet below the land surface and yields of wells range from about 2 to 7 gpm. Where the thinly bedded sandstone is in contact with the underlying granite surface, it probably is recharged in part by water percolating downward along the sloping surface of the weathered granite.

Sandstone at altitudes of 1,050 to 1,150 feet is of medium to low permeability and yields very hard water that is derived largely from the overlying drift. Where the sandstone is in contact with melt-

water-channel deposits (pl. 1, *B-B'*), it is hydrologically interconnected with glacial aquifers. The piezometric surface of the water in the sandstone ranges from 10 to 50 feet below the land surface and will yield 2 to 45 gpm of water to wells, the amount depending on the thickness and permeability of the aquifer. In the vicinity of the north entrance to Camden State Park, where an outlier of these strata occurs, several flowing wells yield about 300 gpm each under a high artesian head. A well near the park headquarters flowed at about 1,600 gpm before it was plugged.

The limestone, which is found in the northwestern part of the county, yields a moderate amount of ground water to wells from numerous solution cavities and crevices. The piezometric surface of the ground water usually ranges from 10 to 100 feet below the land surface. Flowing wells occur in places where the altitude of the ground surface is below 1,350 feet.

#### PLEISTOCENE DEPOSITS

Ground water in the glacial drift is found primarily in outwash deposits of sand and gravel associated with the surficial and buried melt-water-channel deposits and in small isolated bodies of sand and gravel that occur sporadically throughout the till. Most of these deposits are highly permeable and will yield water under artesian conditions where they are penetrated at depth, and under water-table conditions where they are near the surface.

The piezometric surface throughout the drift ranges from about 10 to 150 feet below the land surface, but in the vicinity of the surficial melt-water channel near Marshall and the buried melt-water channel near Cottonwood the range is from about 8 to approximately 20 feet below the land surface. Most wells that obtain water from the glacial drift yield from 2 to 30 gpm; however, in the area of the Marshall well field where the melt-water-channel deposits are thick, sustained yields of as much as 500 gpm have been obtained from large-diameter municipal wells.

To obtain additional hydrologic information about an aquifer in the melt-water channel near Marshall, a pumping test was made in October 1958 using well 111.41.8cdd1 (city well no. 8) as the pumped well and wells 111.41.8cdd2, 111.41.8cdd3, 111.41.8cdd4, and 111.41.17abb1 (city well 10) as observation wells. (See inset on fig. 9 for map location.) The observation wells, which penetrate the aquifer at about the same depth as the pumped well, are at distances of 50, 100, 200, and 450 feet from the pumped well. The aquifer was test pumped at a constant rate of 320 gpm for 6 hours and then allowed to recover for the same length of time.

Measurements made in the observation wells during the first 100 minutes of the test showed that the cone of depression developed around the pumping well had intersected several small relatively impermeable bodies or boundaries within the aquifer. Even though the log of the pumped well did not show any thick impermeable beds, the pumping test of several hours duration indicated that there were zones having low permeability near the pumping well. To minimize the effect of these zones of low permeability, wells intended for maximum production should penetrate the thickest part of the aquifer where the fewest of these boundaries occur.

Results of this test show the coefficient of transmissibility of the aquifer (defined as the number of gallons of water per day transmitted through each vertical 1-foot-wide strip extending the height of the aquifer, at the existing temperature, and under a hydraulic gradient of 100 percent) to be 30,000 gpd (gallons per day) per ft. This is within the range of transmissibility of other glacial aquifers that yield similar amounts of water to high-capacity wells.

Using data obtained from the test, curves were computed showing theoretical drawdown at the end of 2, 10, and 100 days of continuous discharge at distances of 50, 500, and 1,000 feet from the well (figs. 10, 11). Drawdown is directly proportional to discharge. Doubling the rate of discharge from a well theoretically doubles the drawdown. Thus the drawdown in a well pumping 640 gpm should be twice that of the well pumping 320 gpm for which the curves were constructed. Boundary conditions, well interference, dewatering of the aquifer, and similar factors have not been considered in the computation of the theoretical drawdown.

Because of the lenticularity of melt-water-channel deposits, well-spacing and -yield estimates in this and other areas of the aquifer should be accompanied by adequate test drilling and test pumping.

#### **RECENT DEPOSITS**

Ground water in the permeable beds of the Recent alluvium occurs under water-table conditions in most areas. Most of these deposits are less than 20 feet thick. Any appreciable decline in the water table leaves many of the permeable beds dry and lowers the water levels in others. The water-yielding properties of these deposits have remained virtually untested.

#### **RELATION OF GROUND-WATER QUALITY TO GEOLOGIC SOURCE**

The relation of the chemical quality of the ground water to geologic source has been determined from chemical data obtained by field and laboratory analyses. The range of hardness (concentration of

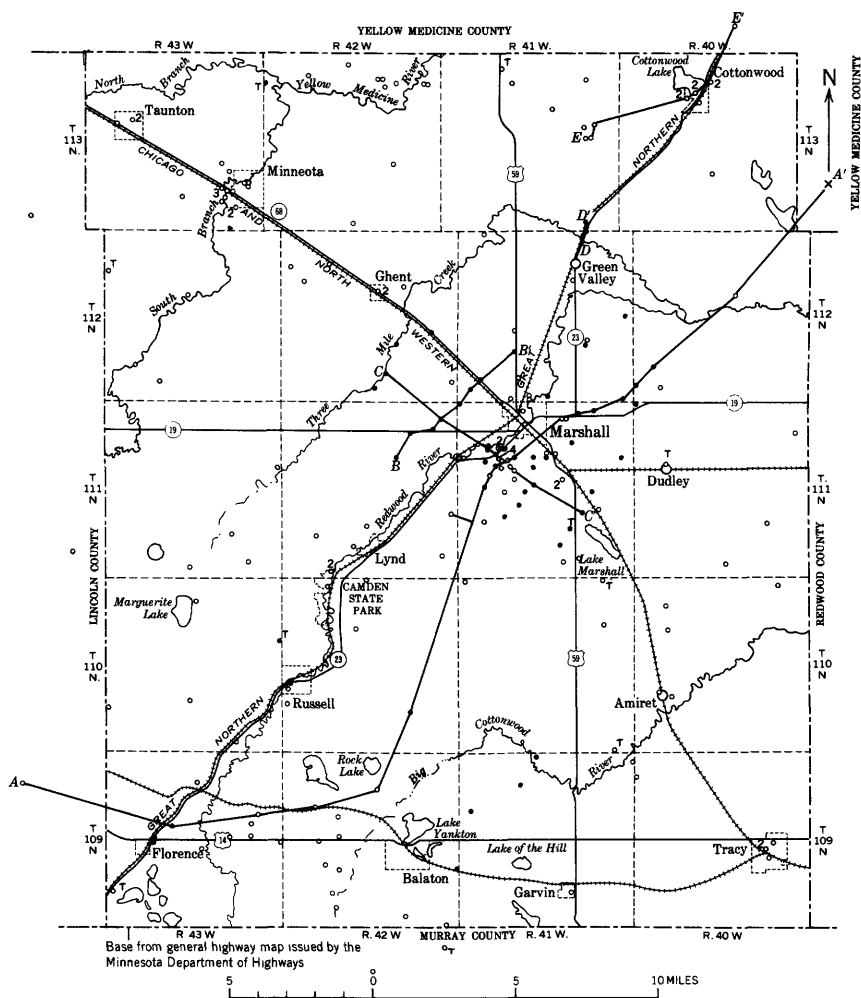


FIGURE 9.—Map of Lyon County showing location of wells, test holes, and lines of geologic sections.



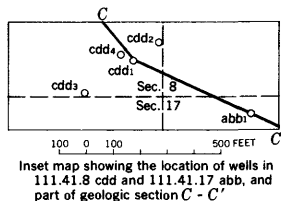
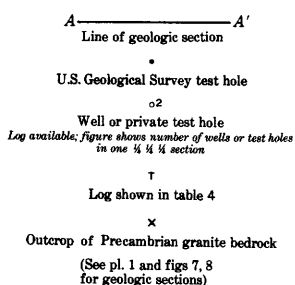
calcium and magnesium) and chloride content of ground water from the principal aquifers in the area is shown in table 1 and is based on field chemical analyses made at approximately 600 locations. Results of many of the field analyses were qualified by comparison with 23 partial and 12 complete laboratory analyses that included determinations for other chemical constituents (table 2).

Ground water obtained from Recent deposits is generally softer (less calcium and magnesium) and is lower in chlorides than water obtained from other units. Representative hardness and chloride determinations are shown by the analyses of water from a spring (110.42.19aca1) on a terrace of the Redwood River near Russell.

Ground water from the glacial drift although low in chloride content, is generally harder than the water obtained from the other geologic units. Exceptions occur in the outwash deposits that receive rapid recharge from precipitation or in those that are hydrologically interconnected with aquifers of other geologic units. This is shown by the lower range of hardness for aquifers in melt-water channels (table 1) and by the high chloride content of water from well 113.40.9acc2 (table 2). The latter well is completed in buried outwash in an area where Cretaceous aquifers yield water of high chloride content.

Ground water from Cretaceous aquifers varies considerably in hardness and chloride content. The quality of water from sandstone at altitudes of 1,050 to 1,160 feet is similar to that of the glacial outwash with which it is in places hydrologically interconnected. Ground water from the 890- to 1,020-foot zone in area A of figure 4 has a hardness of from 400 to 800 ppm as  $\text{CaCO}_3$  and a chloride content of from 500 to 2,000 ppm. In area B of the same zone, the maximum hardness of the water is 500 ppm as  $\text{CaCO}_3$ , and the chloride content ranges from 50 to 500 ppm (Rodis and Schneider, 1960). At one

#### EXPLANATION TO FIGURE 9



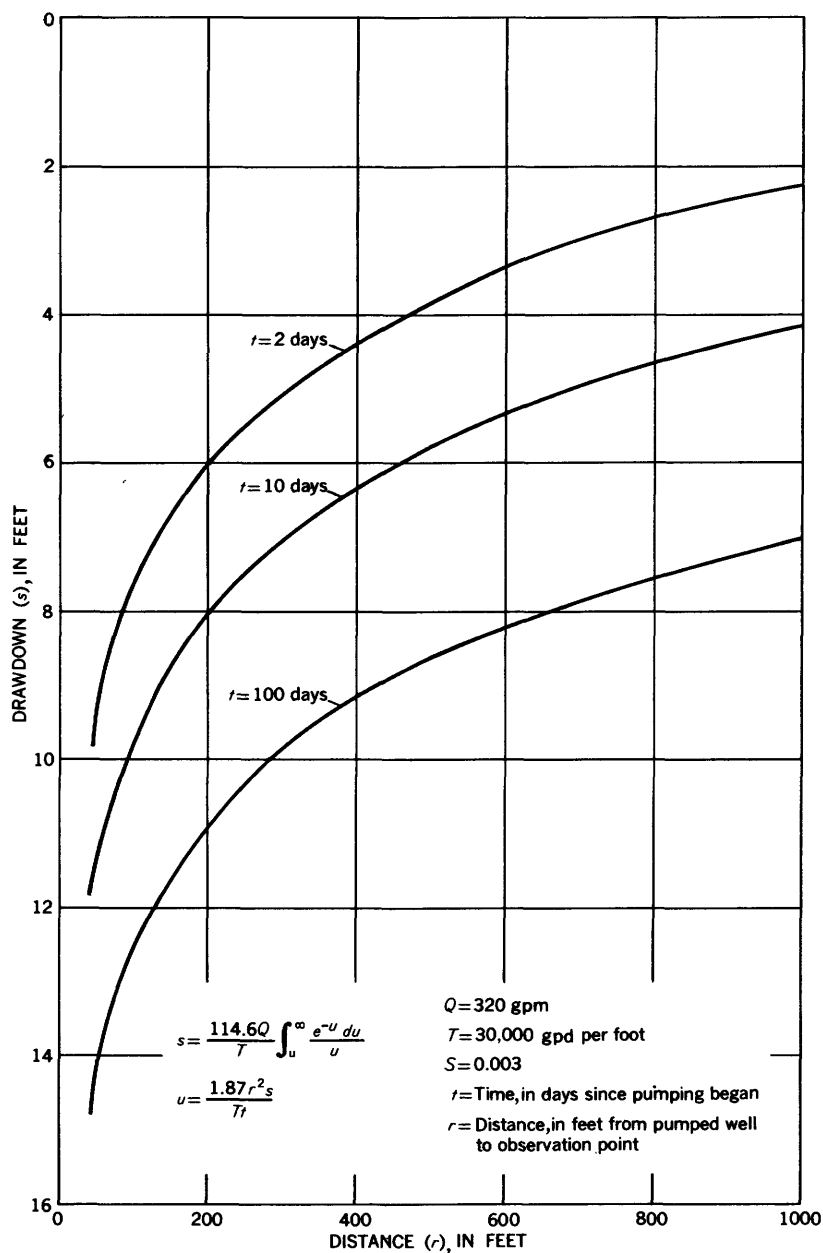


FIGURE 10.—Relation of drawdown to distance from pumped well in melt-water-channel aquifer near Marshall.

time, probably all the water in area B also was high in chloride content. The water was apparently softened through the loss of calcium and magnesium by natural ion exchange with clay minerals. These clay minerals were derived from the weathered granite to the northeast and became saturated with absorbed sodium. The hardness of ground water from the basal sandstone is similar to that in the 890- to 1,020-foot zone but is generally lower in chloride content. Because detailed geologic and hydrologic data on sandstone at this horizon are lacking, no distinction is made for those aquifers that are hydrologically interconnected with permeable weathered granite.

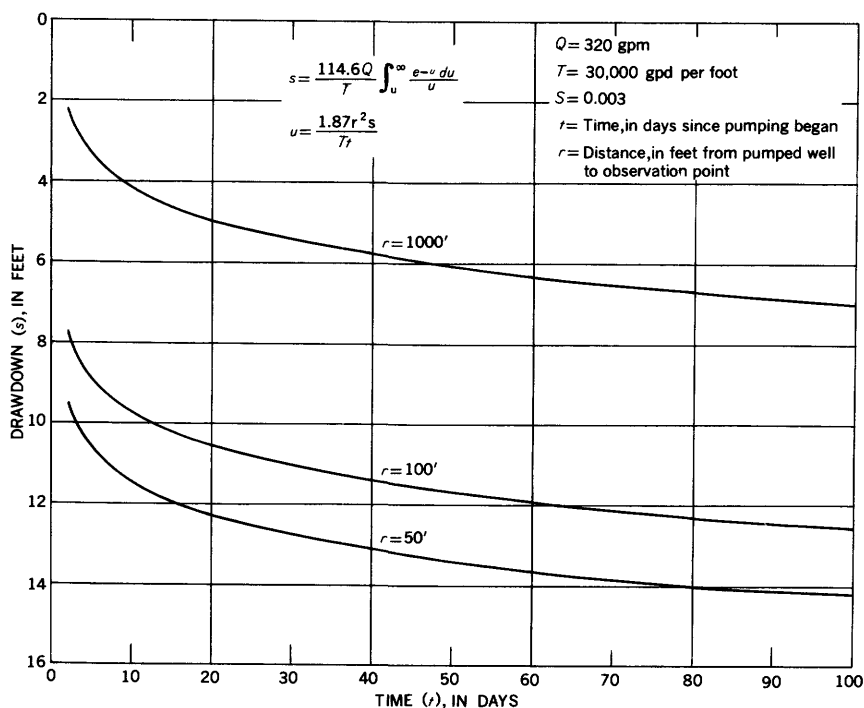


FIGURE 11.—Relation of drawdown to time since discharge began in melt-water-channel aquifer near Marshall.

TABLE 2.—Laboratory chemical analyses of ground water in Lyon County

[Well number: See text for well-numbering system: PS: Public Supply. Depth of well: Measured depths are given in feet and tenths of feet; reported depths are given in feet. M.D.H.: Minnesota Department of Health. Geologic age of aquifer: K, Cretaceous; Kb, Cretaceous basal rocks; P, Pleistocene; R, Recent. Remarks: Asterisk, signifies radiometric analysis available; L, log available (locations plotted on fig. 10). Dissolved solids calculated from the determined constituent. Analytical results in parts per million except as indicated.]

Well	Depth of well (feet)	Analyzing Agency	Date of collection	Geologic age of aquifer	Silica (SiO <sub>2</sub> )	Total Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO <sub>3</sub> )	Carbonate (CO <sub>3</sub> )
108.40.23abai PS	638	U.S.G.S.	8-20-57	Kb	20	2.6	0.17	209	64	62	8.6	374	0
108.40.23bdai PS	620	M.D.H.	9-25-47	Kb	—	2.0	.24	—	—	—	—	—	—
108.40.23bdai PS	640	M.D.H.	do.	Kb	—	1.5	.24	—	—	—	—	—	—
108.42.26cbi	230	U.S.G.S.	6-25-59	P	—	—	—	—	—	—	—	—	—
108.42.10bcb2	470	U.S.G.S.	do.	P	—	—	—	—	—	—	—	—	—
108.42.17aab1	361	U.S.G.S.	6-23-59	P	3.1	5.1	.0	298	164	163	8.9	556	0
108.42.23bca1 PS	35	U.S.G.S.	do.	P	6.3	.00	.0	163	65	38	5.9	400	0
108.43.13bbcb1	112	U.S.G.S.	do.	P	—	—	—	—	—	—	—	—	—
108.43.22bcb1	100	U.S.G.S.	6-24-59	P	—	—	—	—	—	—	—	—	—
108.43.30cbcb1	57	U.S.G.S.	do.	P	—	—	—	—	—	—	—	—	—
110.42.0abcl PS	279	U.S.G.S.	6-23-59	K	—	4.8	.86	277	88	79	7.4	412	0
110.42.19ccal PS	58.8	U.S.G.S.	6-23-59	R	4.8	.00	.0	66	18	3.2	1.8	238	0
110.42.26abcb2	74.5	U.S.G.S.	6-24-59	P	—	—	—	—	—	—	—	—	—
111.41.3dbcb1	41	U.S.G.S.	do.	P	—	—	—	—	—	—	—	—	—
111.41.8caab2	41	U.S.G.S.	6-23-59	P	—	—	—	—	—	—	—	—	—
111.41.8cdcb1 PS	95	U.S.G.S.	6-23-59	P	32	4.2	.17	210	66	98	9.2	463	—
111.41.17abab2 PS	400	M.D.H.	11-19-48	Kb	—	—	—	—	—	—	—	—	—
111.41.17abcb1 PS	428	U.S.G.S.	1-27-56	Kb	9.3	0.8	0.00	122	41	415	14	356	0
111.41.17bcb3 PS	418	M.D.H.	6-23-43	Kb	—	3.0	0.07	—	—	—	—	—	—
111.41.17bcb4 PS	433	M.D.H.	1-19-48	Kb	—	30.35	.12	—	—	—	—	—	—
111.41.17bcb1 PS	424	M.D.H.	2-23-43	Kb	—	.61	.0	15	4.9	322	9.1	288	0
112.40.34cccd1	163.2	U.S.G.S.	6-23-59	K	.9	—	—	—	—	—	—	—	—
121.41.22aaal	260	U.S.G.S.	6-23-59	K	—	17	.0	193	69	126	14	368	0
112.42.36bbcb1	63.7	U.S.G.S.	do.	P	1.5	—	—	—	—	—	—	—	—
112.43.76bbcb1	127	U.S.G.S.	6-24-59	P	—	—	—	—	—	—	—	—	—
113.40.36cccb PS	91	M.D.H.	7-19-56	P	—	5.7	.18	—	—	—	—	—	—
113.40.96cccb PS	111	U.S.G.S.	6-23-59	P	5.0	15	.00	152	55	379	18	294	0
113.40.28daal	115	U.S.G.S.	6-24-59	P	—	—	—	—	—	—	—	—	—
113.41.21bcb1	130.3	U.S.G.S.	do.	K	—	—	—	—	—	—	—	—	—
113.42.34ddcb1	180	U.S.G.S.	do.	K	—	—	—	—	—	—	—	—	—
113.42.65cb1	200	U.S.G.S.	6-22-59	K	1.1	.53	.0	185	66	808	32	95	0
113.42.12abcb1	177	U.S.G.S.	6-24-59	K	—	—	—	—	—	—	—	—	—
113.43.28cccb2	160	U.S.G.S.	6-23-59	K	—	—	—	—	—	—	—	—	—
113.43.26daab1	62	U.S.G.S.	6-24-59	K	—	—	—	—	—	—	—	—	—
113.43.36bbcb2 PS	60	U.S.G.S.	2-11-58	K	23	.03	.10	213	80	103	8.4	385	—

Well	Sul- fate (SO <sub>4</sub> )	Chlo- ride (Cl)	Fluo- ride (F)	Ni- trate (NO <sub>3</sub> )	Boron (B)	Dissolved solids		Hardness as CaCO <sub>3</sub>		Per- cent so- dium (N)	Tur- bidity	Specific cond- uct- ance (micro- mhos at 25° C)	pH	Color	Altra- linity	Re- marks
						Calcu- lated	Residue on evap- oration at 180° C	Cal- cium, magne- sium	Non- car- bonate							
109.40.23bael PS	599	4.0	0.5	0.7		1,150	1,180	784	473	15		1,500	7.1	2		(*)
109.40.23bdal PS	750	4.0	.2					800					7.0	18		31
109.40.23bda2 PS	630	4.0	.2					790					7.0	5		31
109.42.2bcb1	849	5.5						1,040								
109.42.10bhd2	1,070	17						1,060								
109.42.17bael	1,339	4.0	.0	14		2,190	2,390	1,420	982			2,230	7.5	4		
109.42.23bael PS	1,010	45	.0	3.2		857	1,070	1,662	334			2,390	7.8	5		
109.43.13bbbl	1,988	3.5					1,330	1,140				1,890				
109.43.22bael	1,310	3.2					1,330	1,230				2,010				
109.43.30cbdl	1,310	4.0					2,390	1,510				2,320				
110.42.5abcl PS	556	4.0	.3	.0		1,550	1,344	1,050	716	14		1,435	7.2	2		L
110.42.19cael PS	42	2.0	.0	4.5		269	1,540	1,238	44			1,900	7.9	5		*L
110.42.26bae2	1,010	2.0					1,823	1,150				1,220				
111.41.3abbl	1,374	3.5					690	796				1,000				L
111.41.8cael	121	3.5						428				1,650	7.4	2		*L
111.41.8cael2	611	4.0	.3	.0		1,260	1,310		416	21						
111.41.8cdl1 PS	990	100	.8					475	183			2,540	7.5	2		
111.41.17bae2 PS	990	65	.7	9.0	1.4	1,830	1,890	180		0.25				5	23	
111.41.17bael1 PS	910	100	.9					200		65			7.1	9	30	
111.41.17bae3 PS	820	110	.7					120					7.1	5	28	
111.41.17bae4 PS	870	110	.9					130						5		
112.40.34cdl PS	384	100	1.3	2.2		981	1,040	58	0			1,560	8.2	5		
112.41.22cael	618	160					1,380	73				2,120				
112.42.35bbbl	708	6.5	.1	4.6		1,300	1,490	765	464			1,620	7.7	6		
112.43.7cbbl	823	5.0					1,630	932				1,750				
113.40.3ccc2 PS	1,200	27	.2					1,100					7.2	12	40	L
113.40.3ccc2 PS	1,012	200	.2	2.9		1,860	2,090	88	372			2,420	7.7	5		L
113.40.28cael	278	170					2,972	605				430				
113.41.21bael	548	440					1,750	406				2,680				
113.42.34dd1	556	1,180					3,250	728				4,810				L
113.42.54cb1	373	1,480	.4	.8		2,970	3,630	733	655			5,140	7.1	5		L
113.42.12abbl	616	750					2,470	644				3,550				L
113.43.2ccc2	384	1,540					3,820	814				5,330				L
113.43.26dael	711	24					1,470	596				1,940				*L
113.43.36bdc2 PS	741	4.0	.2	.0		1,360	1,460	860	545	20		1,760	7.7	2		

### AVAILABILITY OF GROUND WATER

Division of the county into areas of ground-water availability is based on the amount and the quality of ground water available at various depths from the different geologic units. These map areas are shown and described on figure 12; a more detailed explanation of the availability of ground water in the county is presented in Geological Survey Circular 444 (Rodis, 1961b). The circular, as well as figure 12 of this report, is intended to serve as a guide to residents and well drillers who seek new or additional supplies of ground water.

### UTILIZATION OF GROUND WATER

Estimates show that during 1957 and 1958, approximately 1.5 million gpd of water was pumped from aquifers underlying the area. Approximately two-thirds of this total (1 million gpd) was used by municipalities and villages that have central water systems (table 3). The water for these systems is obtained mostly from large-capacity screened wells that range from about 8 to 16 inches in diameter. Only one municipality (Russell) obtains water from a developed spring.

TABLE 3.—*Municipal water supplies, 1957-58*

Municipality	Population (1950)	Source of supply and geologic age of aquifer(s)	Average pumpage (gpd)
Balaton.....	734	1 dug well (Pleistocene)	25, 000
Cottonwood.....	709	3 drilled wells (Pleistocene) 1 drilled well (Cretaceous)	18, 000
Florence.....	137	1 drilled well (Pleistocene)	1, 000
Marshall.....	5, 923	2 drilled wells (Pleistocene) 5 drilled wells (Cretaceous)	650, 000
Minnesota.....	1, 274	2 drilled wells (Cretaceous)	40, 000
Russell.....	503	1 spring (Recent) 2 drilled wells (Pleistocene)	10, 000
Tracy.....	3, 020	3 drilled wells (Cretaceous)	275, 000

Farm water supplies are obtained from approximately 3,500 wells; 75 percent are small-diameter (2-6 inches) drilled wells, 20 percent are bored, and 5 percent are dug. For a use estimated at 50 gpd per person, a minimum of 500,000 gpd is pumped for general farm use.

Local drillers report that the corrosion of small-diameter wells drilled prior to World War II, together with an increase in water use on farms, has accelerated the number of new wells drilled in recent years.

## LOGS OF WELLS AND TEST HOLES

Selected logs of wells and test holes drilled in Lyon County and adjacent counties are shown in table 4 and in the geologic sections (pl. 1; figs. 7, 8). Logs of most of the private wells and test holes are as reported by local drillers; however, parts of some logs were added by Geological Survey personnel while observing private drilling. Logs of Geological Survey test holes were prepared after an analysis of written field logs and electric logs and an examination of drill cuttings. Most of the private drilling in the county is by the cable-tool method; the Geological Survey test holes were drilled by rotary methods.

A total of 213 logs of wells and test holes were collected and analyzed for this report (fig. 9); 157 are logs of wells and private test holes, and 56 are of Geological Survey test holes.

Logs of representative wells are shown in table 4. Logs of the other wells in the county that were collected during this investigation are on file in the Geological Survey offices, St. Paul, Minn.

## WATER-WELL DATA

Water-well records selected from the more than 2,500 collected for this study are shown in table 5 of this report and table 2 of Geological Survey Circular 444.

Data from most well records were used to interpret the stratigraphic and geographic extent of aquifers and to describe the availability and quality of ground water. Field chemical data from records of wells in northeastern Lyon County were used to describe the occurrence of ground water of low hardness and of high chloride content (Rodis and Schneider, 1960); well-bottom altitudes, interpolated from well depths and surface altitudes, were used to show the lineation of glacial aquifers in the southwest (Schneider and Rodis, 1961) and the extent and depositional environment of Cretaceous sandstone in the northeast (Rodis, 1961a). Field chemical data together with well-bottom altitudes and well yields were used largely to describe the availability and quality of ground water (Rodis, 1961b). In the present report the data were also used to show the extent of Cretaceous aquifers at altitudes of 1,050 to 1,260 feet (fig. 5).

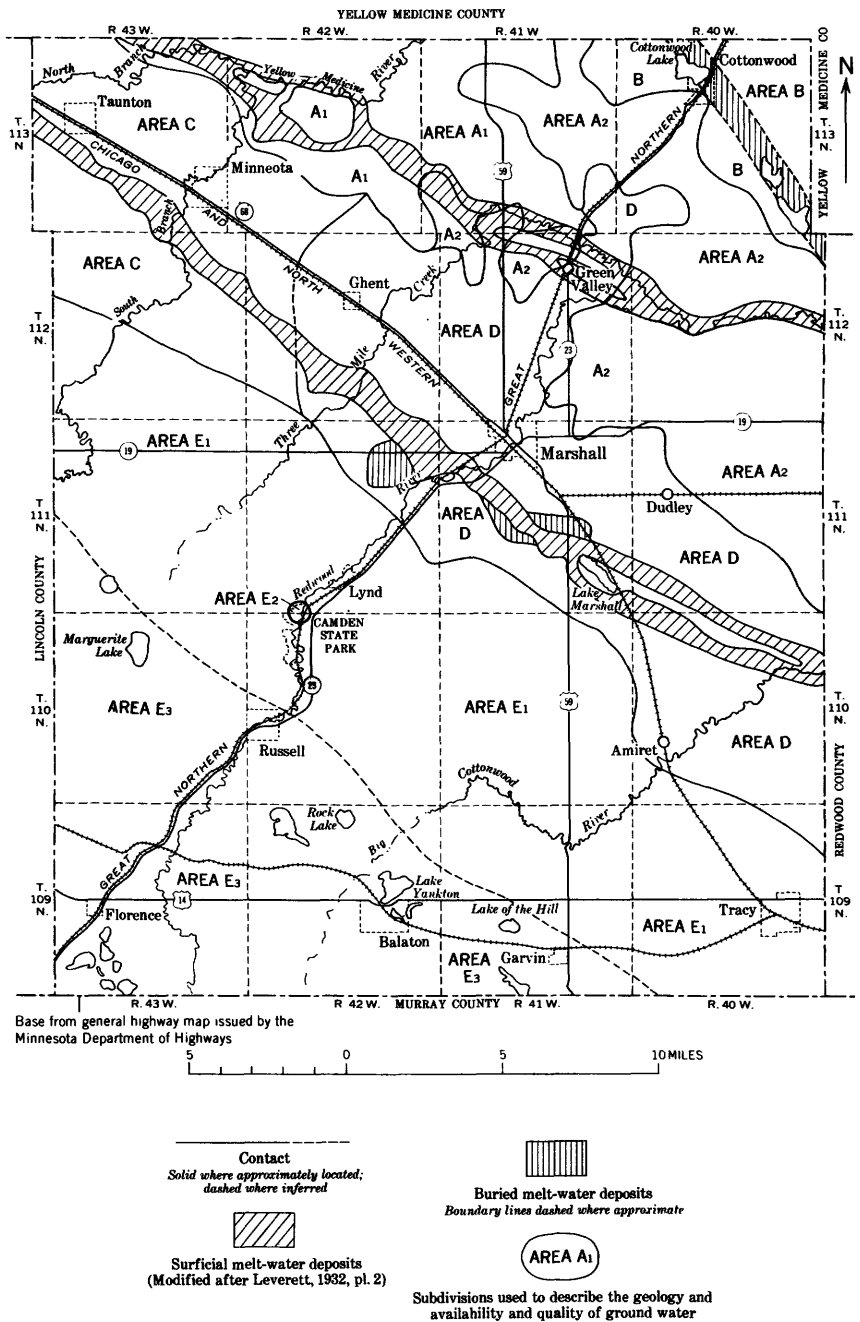


FIGURE 12.—Map of Lyon County showing availability and quality of ground water and distribution of major geologic units.



## EXPLANATION TO FIGURE 12

## Area A

[Glacial drift is underlain by Cretaceous strata]

Most wells obtain water from Cretaceous sandstone at depths of about 100 to 300 feet; some tap the overlying glacial drift at depths of 15 to 75 feet. A few wells obtain small amounts of water from the underlying weathered granite. Yields from sandstone generally range from 2 to 7 gpm.

Where water is obtained from the drift, wells yield from 2 to 30 gpm; higher yields, up to 500 gpm, can be obtained in places where the drift contains melt-water channel deposits. Known melt-water deposits are outlined on the map. The water from the glacial drift usually is very hard (>500 ppm) but is low in chloride content (<50 ppm).

Area A<sub>1</sub>

Water from the Cretaceous sandstone is hard (120–500 ppm) and is high in chloride content (500–>2,000 ppm).

Area A<sub>2</sub>

Water from the Cretaceous sandstone ranges from soft (less than 60 ppm) to hard, and its chloride content usually is moderately high (50–500 ppm).

## Area B

[Glacial drift is underlain by Cretaceous strata or Precambrian granite]

Most wells obtain water from the glacial drift at depths of about 15 to 125 feet. In some places, however, water is obtained from Cretaceous sandstone at depths of 100 to 180 feet, and from the weathered granite at depths of 40 to 250 feet.

Wells in the drift may yield 2 to 30 gpm. Sustained yields of 75 gpm have been obtained in places where the drift contains melt-water deposits. The water is usually very hard but is low in chloride content.

Wells in the Cretaceous sandstone and in the weathered granite normally yield 2 to 7 gpm. The water ranges from moderately hard (60–120 ppm) to very hard and, in places, is moderately high in chloride content.

## Area C

[Glacial drift is underlain by Cretaceous strata]

Very hard water is obtained from the glacial drift at depths of about 15 to 80 feet and from Cretaceous sandstone at depths of about 40 to 120 feet. In places, moderately hard or hard water in smaller quantities is obtained from Cretaceous sandstone at depths of 220 to 280 feet. The weathered granite is of little importance as a water source.

Wells in the drift and in the shallow aquifers of Cretaceous age yield about 2 to 45 gpm, but yields from the deeper Cretaceous aquifers are generally less than 7 gpm. Higher yields may be obtained from melt-water channel deposits in the drift.

## Area D

[Glacial drift is underlain by Cretaceous strata]

Most wells obtain water from Cretaceous strata at 1 of 3 horizons: 40 to 120 feet, 240 to 280 feet, and 325 to 425 feet. Water is obtained also from the overlying glacial drift at depths of about 15 to 175 feet. A few wells obtain water from the weathered granite.

Wells tapping shallow aquifers of Cretaceous age (40–120 ft) generally yield 2 to 20 gpm. Commonly the water is hard to very hard, but it is low in chloride content. Wells in the deeper Cretaceous aquifers (240–280 ft and 325–425 ft) normally yield 2 to 7 gpm. The water is soft to hard and commonly is moderately high in chloride content. Where Cretaceous aquifers are in contact with the underlying regolith or the weathered granite, sustained yields of as much as 75 gpm have been obtained. Several flowing wells in the southwestern half of the area yield up to about 2 gpm from the deeper Cretaceous aquifers.

Water in the drift is very hard but is low in chloride content. Yields usually range from 2 to 30 gpm. Sustained yields of as much as 500 gpm have been obtained in places where the drift contains thick melt-water channel deposits.

## Area E

[Glacial drift is underlain by Cretaceous strata or by Precambrian quartzite or granite]

Most wells obtain water from the glacial drift at depths ranging from 15 to 450 feet, although the majority of the drift wells are less than 250 feet deep. Water in the glacial drift is very hard but low in chloride; yields of wells in drift usually range from 2 to 30 gpm. A few wells obtain small amounts of water from the weathered granite or from quartzite at depths greater than 450 feet.

Area E<sub>1</sub>

[Glacial drift is underlain by Cretaceous strata]

Near the northeast border of this area, wells 200 to 500 feet deep yield 2 to 7 gpm from Cretaceous aquifers. The water from the Cretaceous strata is moderately hard to hard but is low in chloride content.

Area E<sub>2</sub>

[Glacial drift is underlain by Cretaceous strata]

In this area flowing wells yield about 30 to 150 gpm from Cretaceous strata at depths from 225 to 300 feet; the water is very hard but is low in chloride content.

Area E<sub>3</sub>

[Glacial drift is underlain by Precambrian quartzite or granite]

A few wells obtain small amounts of water from the quartzite.

TABLE 4.—Selected logs of wells and test holes in and adjacent to Lyon County

[Sample logs of test holes drilled by a contractor for the Geological Survey in cooperation with the Division of Waters, Minnesota Department of Conservation. \*Indicates reported driller's log. Altitudes determined by altimeter]

Materials	Thickness (feet)	Depth (feet)
<b>Well 108.42.2dac1*</b>		
[Altitude, 1,674± feet above mean sea level]		
Till:		
Yellowish-brown.....	50	50
Dark-gray.....	62	112
Yellowish-brown.....	41	153
Dark-gray.....	22	175
Gravel.....	2	177
Till:		
Dark-gray.....	3	180
Yellowish-brown.....	156	336
Dark-gray.....	19	355
Sand.....	3	358
<b>Well 109.43.30cbd1*</b>		
[Altitude, 1,741± feet above mean sea level]		
Till:		
Yellowish-brown.....	30	30
Dark-gray.....	70	100
Sand:		
Coarse, brown.....	1	101
<b>Well 110.41.2aaa1*</b>		
[Altitude, 1,146± feet above mean sea level]		
Gravel.....	16	16
Till.....	2	18
Shale.....	41	59
Sand.....	1	60
<b>Well 110.41.36cdc1*</b>		
[Altitude, 1,389± feet above mean sea level]		
Soil.....	5	5
Till:		
Yellowish-brown.....	25	30
Dark-gray.....	59	89
Gravel.....	1	90
<b>Test Hole 110.43.13aaa1</b>		
[Altitude, 1,547± feet above mean sea level]		
Sand:		
Coarse and very coarse; very fine to medium gravel.....	16	16
Till:		
Silty, dark-gray, firm.....	60	76
Sand:		
Medium, some fine and coarse; contains beds of silt.....	3	79
Till:		
Silty, dark-gray, firm.....	4	83

TABLE 4.—*Selected logs of wells and test holes in and adjacent to Lyon County—*  
Continued

[Sample logs of test holes drilled by a contractor for the Geological Survey in cooperation with the Division of Waters, Minnesota Department of Conservation. \*Indicates reported driller's log. Altitudes determined by altimeter]

Materials	Thickness (feet)	Depth (feet)
<b>Well 111.40.17bbb1*</b>		
[Altitude, 1,143± feet above mean sea level]		
Till:		
Yellowish-brown.....	15	15
Dark-gray.....	15	30
Sand.....	10	40
Shale:		
Dark-bluish-gray.....	20	60
Rock (consolidated).....	32	92
Dark-bluish-gray.....	48	140
Bluish-gray.....	35	175
Dark-bluish-gray.....	72	247
Sand.....	5	247.5
<b>Test Hole 111.41.27adb1</b>		
[Altitude, 1,151± feet above mean sea level]		
Soil:		
Silty, black.....	1	1
Sand:		
Coarse, some fine, medium, and very coarse.....	6	7
Shale:		
Light yellowish-brown, waxy, firm.....	5	12
Dark-bluish-gray, waxy, firm; contains a few very thin beds of gypsum.....	9	21
Dark-bluish-gray, waxy, firm.....	53	74
Sand:		
Very fine and fine; contains a few thin beds of dark-bluish-gray shale.....	7	81
Shale:		
Dark-bluish-gray, waxy, firm.....	172	253
Sand:		
Medium, some fine and coarse; firm waxy dark-bluish-gray shale; interbedded.....	14	267
Shale:		
Dark-bluish-gray, waxy, firm; contains a few thin beds of a brown consolidated siltstone.....	137	404
Dark-bluish-gray, soft; contains beds of firm shale.....	5	409
Dark-bluish-gray, waxy, very firm.....	4	413
Sand:		
Fine to medium; contains thin beds of firm dark-bluish-gray shale.....	7	420
Fine to medium; firm waxy, dark-bluish-gray shale; interbedded.....	5	425
Medium to coarse, some fine and very coarse.....	8	433
Granite:		
Weathered in kaolinite matrix.....	18	451

TABLE 4.—*Selected logs of wells and test holes in and adjacent to Lyon County—*  
Continued

[Sample logs of test holes drilled by a contractor for the Geological Survey in cooperation with the Division of Waters, Minnesota Department of Conservation. \*Indicates reported driller's log. Altitudes determined by altimeter]

Materials	Thickness (feet)	Depth (feet)
<b>Well 112.43.7cbb1*</b>		
[Altitude, 1,373± feet above mean sea level]		
Till:		
Yellow.....	20	20
Blue.....	60	80
Yellow.....	10	90
Sandy, yellow.....	30	120
Limestone.....	7	127
<b>Well 113.41.4cbb1*</b>		
[Altitude, 1,103± feet above mean sea level]		
Till:		
Yellowish-brown.....	24	24
Dark-gray.....	52	76
Shale:		
Dark-bluish-gray.....	94	170
Sand.....	5	170.5
<b>Test hole 113.42.7bbb1</b>		
[Altitude, 1,105± feet above mean sea level]		
Soil:		
Silty, black.....	1	1
Silt:		
Grayish-brown, soft.....	5	6
Sand:		
Fine to medium, gray; some lignite.....	16	22
Shale:		
Dark-bluish-gray, waxy, firm; contains a few thin beds of grayish-brown siltstone.....	26	48
Sand:		
Fine, some very fine and medium; firm waxy, dark- bluish-gray shale; interbedded.....	4	52
Shale:		
Dark-bluish-gray, waxy, firm.....	115	167
Sand:		
Fine to coarse.....	5	172
Shale:		
Dark-bluish-gray, waxy, firm.....	2	174
Sand:		
Fine to coarse.....	5	179
Shale:		
Dark-bluish-gray, waxy, firm.....	37	216
Granite:		
Weathered, in kaolinite matrix.....	10	226

TABLE 5.—Selected wells in Lyon County

[Well number: See text for description of well-numbering system. Depth of well: Measured depths given in feet and tenths; reported depths given in feet. Type of well: B' bored; D, drilled with cable tool or rotary equipment; Du, dug. Use: D, domestic; PS, public supply; S, stock. Geologic age of aquifer: R, Recent; P, Pleistocene; K, Cretaceous; Kb, Cretaceous basal rocks; P-C, Pre-Cambrian. Measured depths given in feet and tenths; reported depths given in feet. Other data available: Fca, field chemical analyses for hardness and chloride; L, log.]

U.S.G.S. well	Owner or user	Depth below land surface (feet)	Year completed	Type	Diameter (inches)	Use	Geologic age of aquifer	Water level		Other data available
								Depth below land surface (feet)	Date measured or reported	
109.40.26baal	Harry Haney	176	1951	D	4	D, S		60	6-8-57	Fca
109.40.28dcal	C. Carter	114	1957	B	20	D, S		84.3	6-27-57	Fca
109.42.8ccb1	F. Groeneweg	253	1957	D	5	D, S	P	108	6-19-57	Fca, L
109.43.11dbc2	A. Lake	83.1	1933	D	3	D, S	P	32.6	8-12-57	
109.43.20bac1	Village of Florence	100		D	5	PS	P			
110.40.31abb1	V. Ford	83.1		B	12	D, S	P	8.3	6-24-57	
110.42.17abb1	Mrs. H. Kadus	300	1937	D	4	S	K			Fca
110.43.25aad1	E. C. Hodges	33	1949	D	5	D, S	P	22.2	8-17-57	Fca
111.43.3daa1	Mrs. R. Eisenmenger	49.1	1939	B	30	D, S	P	40.3	7-23-57	
111.43.26cab1	H. Jorgenson	134	1957	D	5	D, S	P	61	6-18-57	Fca, L
112.41.2adcl	Hector Louwagie	200		D	4	D, S	K	40	6-5-57	Fca
112.42.26ebb2	R. DeWolf	90	1946	D	4	S	K	30	7-2-56	Fca
113.40.9dbc1	Village of Cottonwood	438	1948	D	8	PS	P-C	58	6-17-57	
113.41.14ddd1	C. Mauland	183.9	1957	D	5	D, S	P-C	57.1	7-25-57	Fca, L
113.42.2ccc1	O. Kompellen	130	1920	D	4.5	D, S	K	30	8-16-57	Fca, L
113.42.32cdc1	Ed. Hennen	100		D	5	D, S	K			Fca
113.43.25ccd1	Village of Minnesota	42	1937	Du	120	PS	K	19	5-22-46	
113.43.25ccd3	do.	96	1948	D	6	PS	K	20	7-6-56	

## CONCLUSIONS

Sand and gravel outwash deposits in melt-water channels are the best source of ground water in the county. These deposits can support additional large withdrawals. Where melt-water deposits are associated with surficial channels as they are near Marshall, or where channels have indirect surface expression as near Cottonwood, their subsurface extent can be outlined by drilling test holes. Additional closely spaced drilling is then necessary to outline the areal extent of the thicker, more permeable beds of sand and gravel. Geologic and hydrologic data collected in these areas show that because the deposits are sinuous, any large ground-water development should be preceded not only by adequate test drilling but also by carefully controlled test pumping.

Additional supplies of ground water in moderate quantities, adequate for domestic and small industrial needs, can be obtained from many of the small, isolated deposits of sand and gravel within the till. The probability of penetrating these deposits is greater in places where the drift is thicker.

Cretaceous sandstone should continue to serve as a source of ground water suitable primarily for domestic and stock supplies. Attempts to develop wells of larger capacity in these strata are limited to areas where the aquifers are very thick or where they are hydraulically connected to aquifers of other geologic units.

Even though ground water in Lyon County may be hard or high in chloride content, it is used for most municipal, industrial, domestic, and stock supplies. Softer water, which commonly has a high chloride content, can be obtained only locally and in small quantities. To insure a dependable supply from sources capable of yielding large quantities of ground water, care should be taken in the construction, development, test pumping, and spacing of wells. Conversely, limitations in the capacity of thin aquifers of low permeability to yield larger quantities of ground water should be realized.

## REFERENCES

- Fenneman, N. M., 1938, *Physiography of eastern United States*: New York, McGraw-Hill Book Co., 714 p.
- 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.
- Leverett, Frank, 1932, *Quaternary geology of Minnesota and parts of adjacent States*: U.S. Geol. Survey Prof. Paper 161, 149 p.
- Rodis, H. G., 1961a, Use of water-well data in interpreting the occurrence of upper Cretaceous aquifers in northeastern Lyon County, Minnesota: *Geol. Soc. America*, v. 72, p. 1275-1278.

- Rodis, H. G., 1961b, Availability of ground water in Lyon County, Minnesota : U.S. Geol. Survey Circ. 444.
- Rodis, H. G., and Schneider, Robert, 1960, Occurrence of ground waters of low hardness and of high chloride content in Lyon County, Minnesota : U.S. Geol. Survey Circ. 423.
- Schneider, Robert, and Rodis, H. G., 1961, Aquifers in melt-water channels along the southwest flank of the Des Moines lobe, Lyon County, southwestern Minnesota : U.S. Geol. Survey Water-Supply Paper 1539-F.
- Schwartz, G. M., and Thiel, G. A., 1954, Minnesota's rocks and waters : Minneapolis, Minnesota Univ. Press, 366 p.
- Thiel, G. A., 1944, Geology and underground waters of southern Minnesota : Minnesota Geol. Survey Bull. 31, 506 p.
- Winchell, N. H., 1884, The geology of Minnesota : Minnesota Geol. Survey, v. 1, Final Rept., p. 589-612.









