TRENDS IN MUNICIPAL-WELL INSTALLATIONS AND AQUIFER UTILIZATION IN SOUTHEASTERN MINNESOTA, 1880-1980

By D. G. Woodward

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
gallon (gal)	0.003785	cubic meter (m^3)
gallon per minute (gal/min)	0.06308	cubic meter per second (m^3/s)
square mile (mi^2)	2.590	square kilometer (km^2)

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ABSTRACT

Water distributed by municipal systems has been the largest off-stream use of water in southeastern Minnesota for the past 100 years. Water pumped by these systems in 1980 totaled 102.3 billion gallons, with 60.1 billion gallons supplied by ground water. Ground water supplies 294 of the 309 municipal systems in the area.

The development of ground-water supplies for municipal use in southeastern Minnesota began around the 1880's as an alternative to supplies from lakes and rivers. After about 4,500 Minnesotans died from typhoid from 1891 to 1900, deep wells became widely used in order to avoid contaminated surface water.

An inventory of 1,244 wells drilled for municipal systems from 1880 to 1980 has been completed. Of the five bedrock aquifers in the study area, the Prairie du Chien-Jordan is the most extensively used for water supply; 537 municipal wells tap it. About half of these wells were drilled in the Twin Cities Metropolitan Area since 1945 to accommodate suburban growth. The undifferentiated drift aquifer ranks second in use with 294 municipal wells tapping it. Most of these wells are completed in aquifers buried in thick drift deposits in the western part of the study area.

Aquifer preference was analyzed to determine whether municipal wells

were completed in the shallowest bedrock aquifer present in an area, in a deeper bedrock aquifer, or in a drift aquifer above the bedrock. Until 1950, there was a strong preference to complete municipal wells in the Upper Carbonate aquifer. Because of poor water quality in parts of the aquifer, most municipal wells drilled in the area since 1950 are cased through the Upper Carbonate and completed in deeper aquifers. The St. Peter aquifer is little used for municipal wells because wells completed in it often pump sand. About 96 percent of the municipal wells drilled in the St. Peter aquifer subcrop area since 1950 were cased through the St. Peter and completed in deeper aquifers. About 64 percent of the municipal wells drilled in the Mount Simon-Hinckley aquifer subcrop area are completed in drift aquifers. The Prairie du Chien-Jordan and Ironton-Galesville aquifers are preferred for municipal wells in their respective areas of occurrence.

Water appropriation in Minnesota is regulated through a permit system based on five water-use priorities. Domestic water supply, excluding industrial and commercial uses of a municipal water supply, is the highest priority (Minnesota Statutes, Chapter 105.41). Under the regulations, uses of a lower priority are not permitted to adversely affect uses of a higher priority. Identification of the aquifer(s) used for municipal supplies is also necessary to safeguard these supplies from adverse effects of competing water users and contamination, and to evaluate the consequences of each.

1.0 INTRODUCTION

1.1 Overview

WATER DISTRIBUTED BY MUNICIPAL SYSTEMS IS LARGEST OFFSTREAM USE OF WATER IN SOUTHEASTERN MINNESOTA SINCE 1880

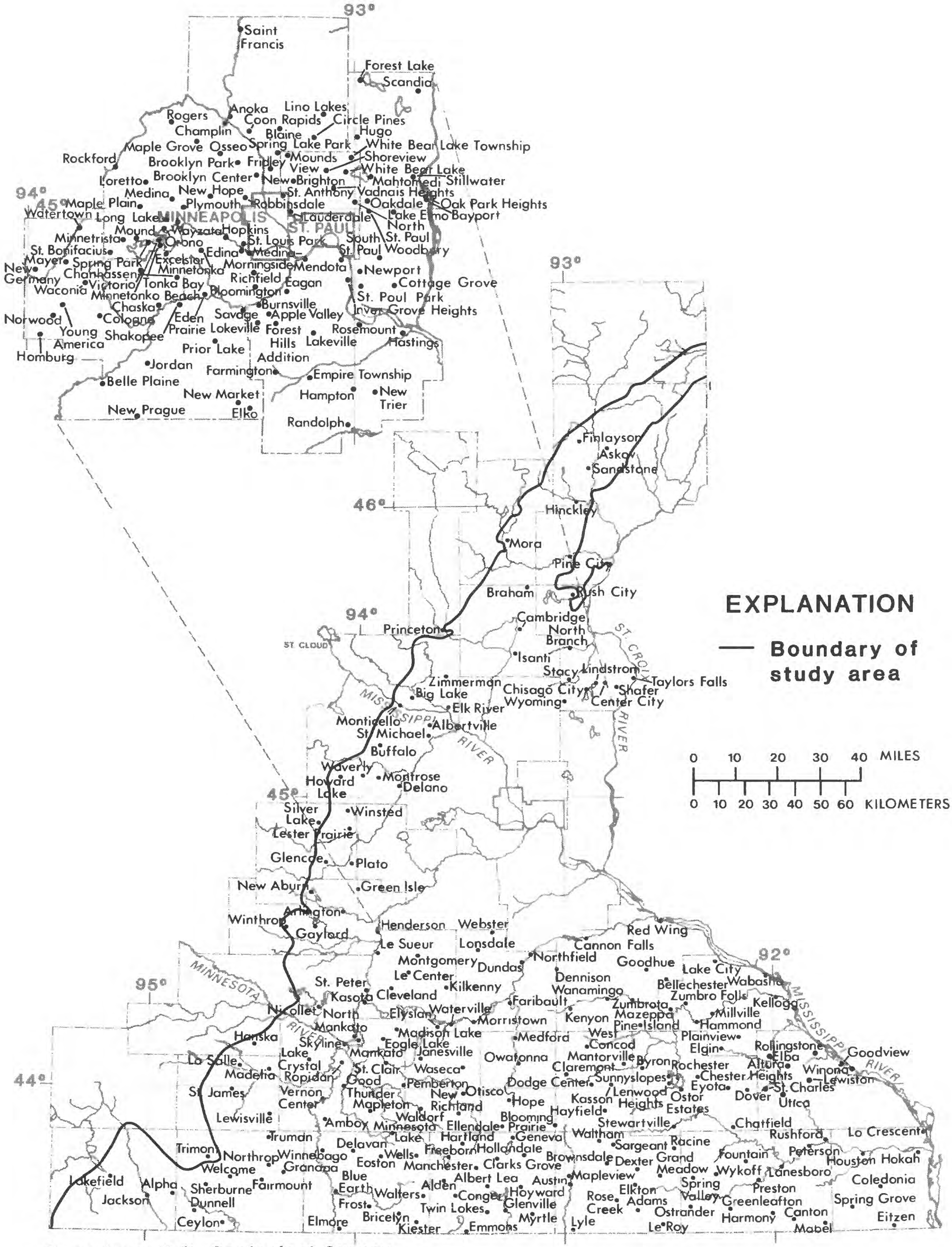
In 1980, municipal systems distributed 60.1 billion gallons of ground water and 42.2 billion gallons of surface water.

Water distributed by municipal systems has been the largest off-stream use of water in southeastern Minnesota since 1880. In 1980, water withdrawn for municipal systems totaled 102.3 billion gallons, with 60.1 billion gallons supplied by ground water and 42.2 billion gallons supplied by surface water (M. A. Horn, U.S. Geological Survey, written commun., 1982). Of the 309 municipal systems in the area, 294 (about 95 percent) use ground water (fig. 1.1-1), and this number is expected to increase in the future.

Municipal water use in the Twin Cities area dominates the water-withdrawal patterns for southeastern Minnesota. In 1980 the Twin Cities area used 78 percent (79.5 billion gallons) of the water used for municipal supply in southeastern Minnesota. This included 99 percent (41.8 billion gallons) of the surface water and 63 percent (37.7 billion gallons) of the ground water used by municipalities (Horn, 1983). Water distributed by the Minneapolis Water Department and the St. Paul Water Utility is supplied primarily by the Mississippi River, although the St. Paul Water Utility obtains some water from the Rice Creek Chain of Lakes. The Minneapolis and St. Paul systems, in turn, distribute water to about 13 other municipalities in the Twin Cities area.

During the drought of the mid 1970's, flow of the Mississippi River was inadequate to both sustain municipal water demands and assimilate treated waste. During this period, the St. Paul Water Utility reactivated standby wells to augment the river supply, and the Minneapolis Water Department experimented with collector wells. An investigation of the ground-water resources of the Minneapolis-St. Paul Metropolitan Area is currently (1985) being done by the U.S. Geological Survey in cooperation with other State agencies (Guswa and others, 1982). A result of this study will be a computer model that will simulate the ground-water system and aid decisions on development of additional water supplies.

A major product of this study is an inventory of municipal wells in southeastern Minnesota that identifies the aquifer(s) in which the wells are completed. Although the area is underlain by six regional aquifers (Delin and Woodward, 1984), many planning and management documents identify sources of municipal water supplies only as surface water or ground water (or dug well, drilled well, or spring) without identifying the aquifer used. Because municipal wells pump the largest volume of ground water in the area, the distribution of withdrawals by aquifer from these wells is an important element in evaluating and managing the ground-water resource.



Base from U.S. Geological Survey
State Base Map, 1965

Figure 1.1-1.--Municipalities in southeastern Minnesota using ground-water

1.0 INTRODUCTION--Continued

1.2 Purpose and Scope

TRENDS IN MUNICIPAL WELL INSTALLATION AND AQUIFER UTILIZATION

Aquifer utilization is described in terms of the distribution of municipal wells.

In 1977, the U.S. Geological Survey began a series of investigations of regional aquifer systems in the United States. These studies will provide quantitative information for use in developing and managing regional ground-water supplies. One of the studies, the Northern Midwest Regional Aquifer-System Analysis (RASA), concerns aquifers of Cambrian and Ordovician age in southeastern Minnesota and in parts of five other states: Illinois, Indiana, Iowa, Missouri, and Wisconsin (fig. 1.2-1). This report describes the trends in municipal-well installations and aquifer utilization in southeastern Minnesota from 1880 to 1980.

The objectives of this report are to: (1) inventory municipal wells drilled in southeastern Minnesota from 1880 to 1980 and identify the aquifer(s) in which the wells are completed, (2) analyze the trends in municipal-well installations with time, location, and aquifer completion, (3) analyze trends in preference for specific aquifers with time and location, and (4) describe aquifer utilization in terms of the distribution of municipal wells. Data collected during the well inventory are given in table 5.0-1 (at the end of report). A series of maps show well location and completion by aquifer during selected time periods. Tables and graphs show trends in well depths, aquifer completions, and aquifer preferences.

Two other reports describing different aspects of the regional aquifers in southeastern Minnesota have been prepared. Delin and Woodward (1984) mapped the potentiometric surface of each regional aquifer and described the regional flow regimes, and Woodward (1985) described the physical framework and hydrologic properties of the aquifers.

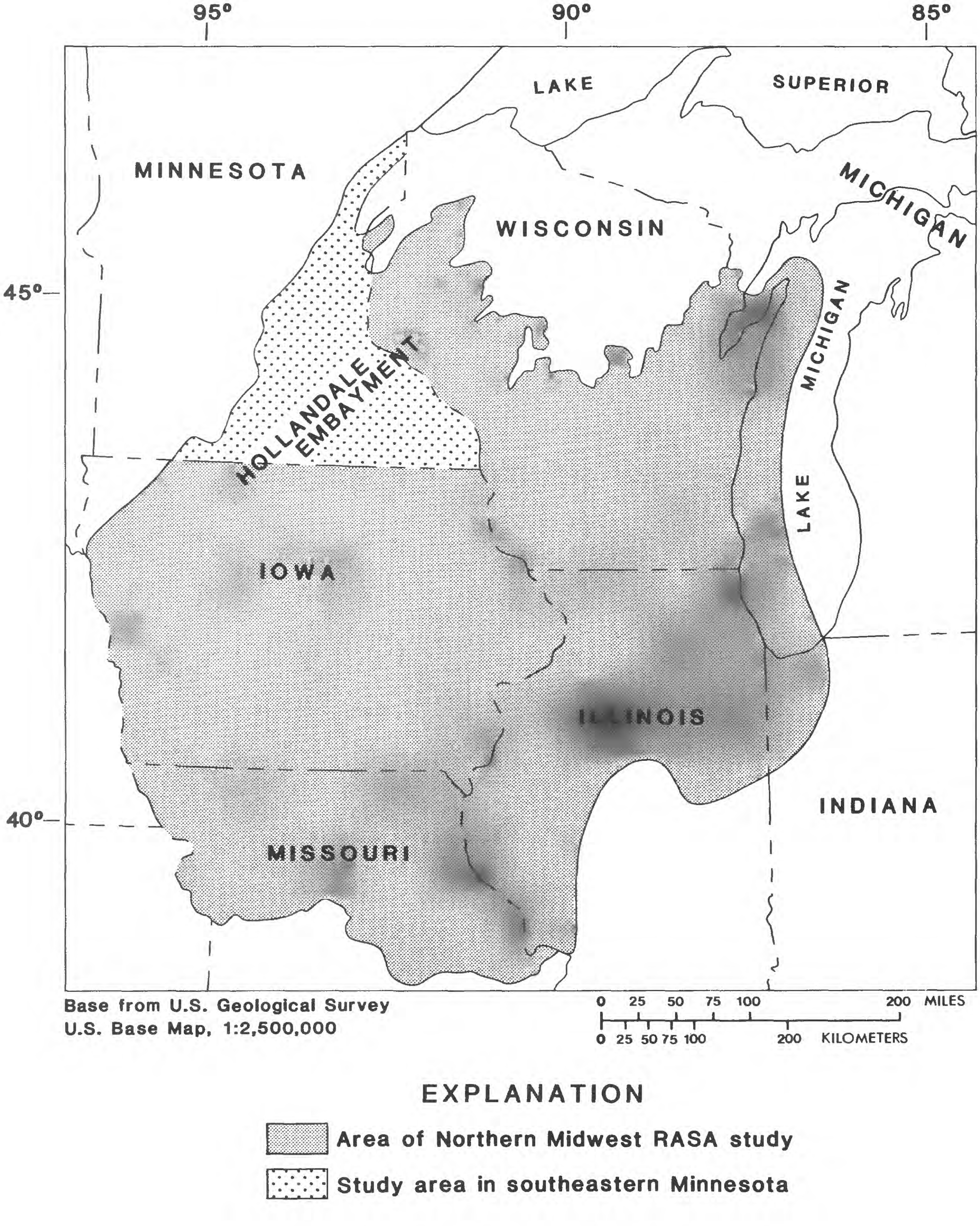


Figure 1.2-1.--Location of study area

1.3 Previous Investigations

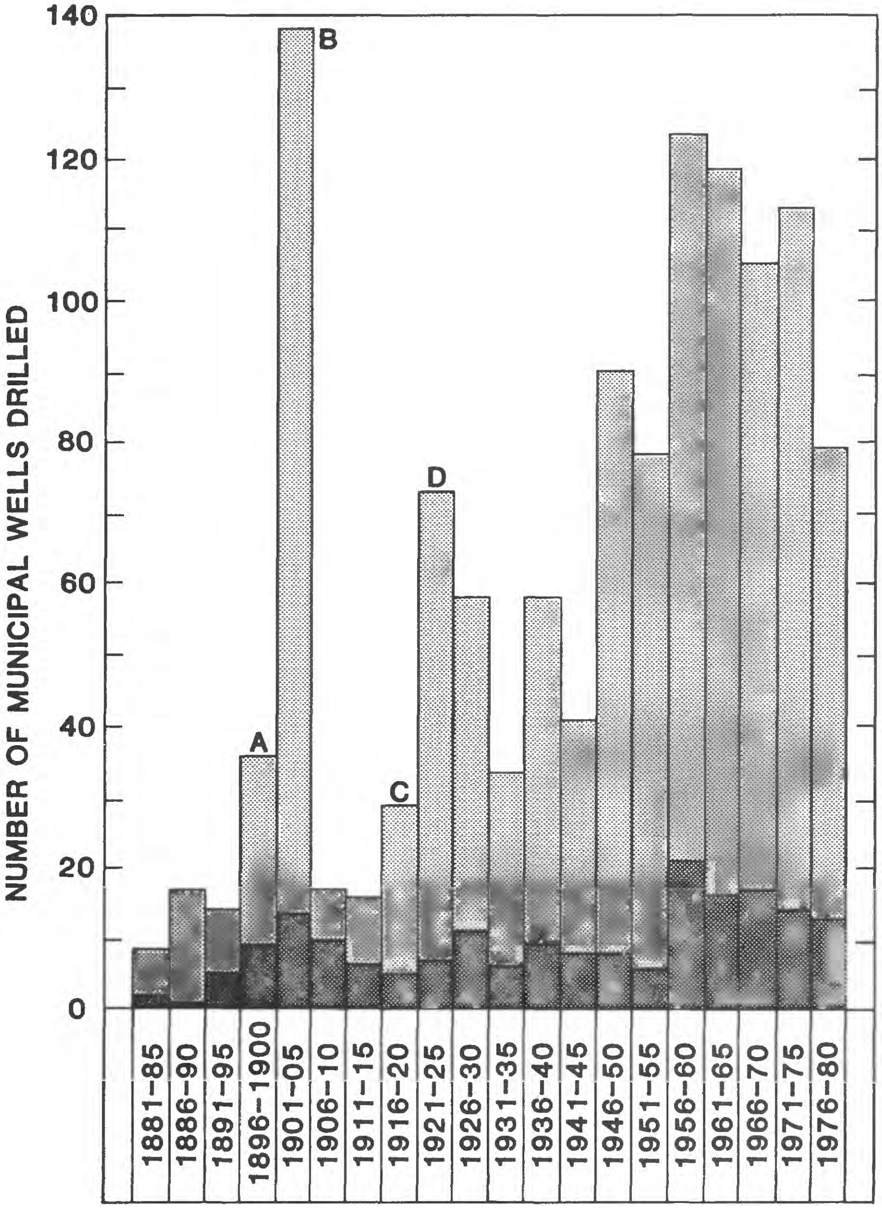
1,244 WELLS DRILLED FOR MUNICIPAL WATER SUPPLY IN SOUTHEASTERN MINNESOTA FROM 1880 TO 1980

Although several surveys and inventories of municipal water systems have been completed, they previously distinguished between source of supply only as surface water or ground water.

Between 1880 and 1980, 1,244 wells were drilled for municipal systems in southeastern Minnesota (fig. 1.3-1). About 17 percent of the municipal wells were drilled from 1881-1905, 15 percent from 1906-30, 25 percent from 1931-55, and 43 percent from 1956-80.

Descriptions of the wells in reports improved markedly over the years. Winchell and Upham (1884; 1888) mention some municipal wells in their early description of the geology of Minnesota. Listings of deep borings (greater than 400 feet) in Minnesota were compiled by Darton (1902, p. 55-56). Listings of shallow and deep wells were compiled by Hall (1904, p. 441-488) with owner, depth of well, depth of principal water supply, and material in which water occurs (drift, rock, sandstone, limestone) among the categories mentioned.

The first survey of municipal water supplies in Minnesota was conducted in 1905 by Dole and Wesbrook (1907); table 84 of their report (p. 147) lists "Places having ground-water supplies" and contains categories such as source of supply (tubular, dug, driven, drilled, or artesian well, or spring), well depth, and diameter. This survey indicated that of the 83 municipalities in southeastern Minnesota, 18 had no municipal water supply, 5 were supplied by surface water, and 60 were supplied by ground water from a total of 82 municipal wells. The first inventory that attempted to identify the aquifer in which municipal wells were completed in southern Minnesota was in 1907 (Hall and others, 1911, p. 98-113), and it listed the geologic formation, well depth and diameter, head, and aver age daily consumption for 196



EXPLANATION

- Total number of single-aquifer wells
- Total number of multiaquifer wells

A Installation dates for 18 wells are unknown, and are dated pre-1900

B Installation dates for 126 wells are unknown, and are dated pre-1906

C Installation dates for 14 wells are unknown, and are dated pre-1918

D Installation dates for 42 wells are unknown, and are dated pre-1924

Figure 1.3-1.--Installation of municipal wells in southeastern Minnesota, 1880-1980

municipal wells. This inventory indicated that of the 109 municipalities in the study area, 10 were supplied by surface water and 99 were supplied by ground water. The report also recommended which aquifers could locally provide sufficient supplies for municipal systems.

In 1917, the Minnesota State Board of Health issued regulation No. 200 stipulating that water-supply systems that potentially affected public health could not be installed, materially altered, nor extended until complete plans and specifications had been approved by the Board. Passage of this regulation enabled the Minnesota Department of Health (MDH) to begin compiling data on every new or altered municipal well in the State. Major emphasis of these records was on sanitary aspects of well construction and on water quality and treat ment; designation of the aquifer was not required. Most of the well information in this report is from MDH records.

An update of the 1907 municipal-well inventory was completed by Thiel for southern Minnesota in 1944 and for northeastern Minnesota in 1947. Geologic information is well represented in these reports, but aquifer designations for many municipal wells are vague or incomplete. The local occurrence of ground water was discussed to guide future water-supply development by municipalities.

The next series of municipal water-supply inventories was generated by the Minnesota Department of Health, primarily for the purpose of identifying the water source (surface or ground water) and treatment type. These municipal inventories were in map format for 1959, 1966, 1971, and 1976; data tables were prepared for 1971, 1973, and 1977. The data tables list categories including source (drilled or dug well, spring, or name of surface source), well number, date well installed, well depth, and water-quality analyses.

The Minnesota Department of Natural Resources, Division of Waters is responsible for maintaining records of annual municipal ground-water withdrawal as a major function of their water-appropriation program. Various reports list municipal wells (Minnesota Department of Natural Resources 1952; 1961), but few mention aquifer completions. An inventory of the municipal water supplies in the Twin Cities Metropolitan Area was compiled by the Metropolitan Council (1979) that lists well number, year, well depth, and depth cased. A list of drillers' logs of municipal wells in the Twin Cities area was compiled by the Minnesota Geological Survey and has been extremely helpful in this study.

The U.S. Geological Survey has inventoried municipal wells in parts of the study area. Norvitch and others (1973) lists the municipalities in the Twin Cities area supplied by ground water in 1970 with the number of wells used. Horn (1983) discusses trends in municipal ground-water withdrawals in the Twin Cities area. U.S. Geological Survey Hydrologic Atlases include tables for municipal water supply by watershed; atlases relevant to this study are listed with the references.

1.4 Methods of Investigation

MUNICIPAL WELLS DRILLED IN SOUTHEASTERN MINNESOTA FROM 1880 THROUGH 1980 ARE IDENTIFIED BY DATE DRILLED, DEPTH, AND AQUIFER

Well-distribution and aquifer-preference trends are determined.

Municipal wells drilled in southeastern Minnesota from 1880 through 1980 were identified and the aquifer in which each well is completed was determined. The distribution of wells was analyzed by time period, location, and aquifer of preference. Five arbitrary time periods were selected for analysis: 1880-1910, 1911-30, 1931-50, 1951-70, and 1971-80. Three major tasks had to be completed before the time-period analyses could be performed: identification of individual municipal wells, identification of the aquifer(s) in which the wells are completed, and development of an aquifer-preference scheme.

Well Identification

The main criteria used to identify an individual municipal well include the name of the municipality, the year the well was drilled or connected to the supply system, well depth, and well location. When discrepancies were found in data for an individual well, the earliest completion date and (or) deepest drilling depth was listed. By treating discrepancies in this manner, it is possible that some municipal wells were not listed in this study.

Many wells drilled for industrial use (creameries, mills, or canneries) have been cross-connected to municipal water systems, some for standby or emergency use, some for temporary use, and some for permanent routine use. Many of these cross connections were banned by the adoption of Minnesota State Board of Health Regulation No. 201 in 1918, and the industrial wells were subsequently disconnected. Because the wells were not originally drilled for a municipal water supply, and because their period of service usually was sporadic, they were not included in this study.

Aquifer Identification

Information required to ascertain the aquifer in which a well is completed includes a log of the geologic formations penetrated and records of well and casing depth. Many of the early (pre-1930) municipal-well inventories included well logs with erroneous geologic information. In many logs, for example, the first sandstone penetrated was assumed to be the St. Peter Sandstone despite the fact that the Jordan Sandstone and Ironton Sandstone are the shallowest sandstones in many areas. Also, it seems that casing depth was mistakenly reported as well depth in some of the early inventories. Discrepancies in aquifer identification sometimes resulted when municipal wells were reconstructed or reconditioned in a different aquifer. The most recent aquifer-completion information has been listed for all wells in this report.

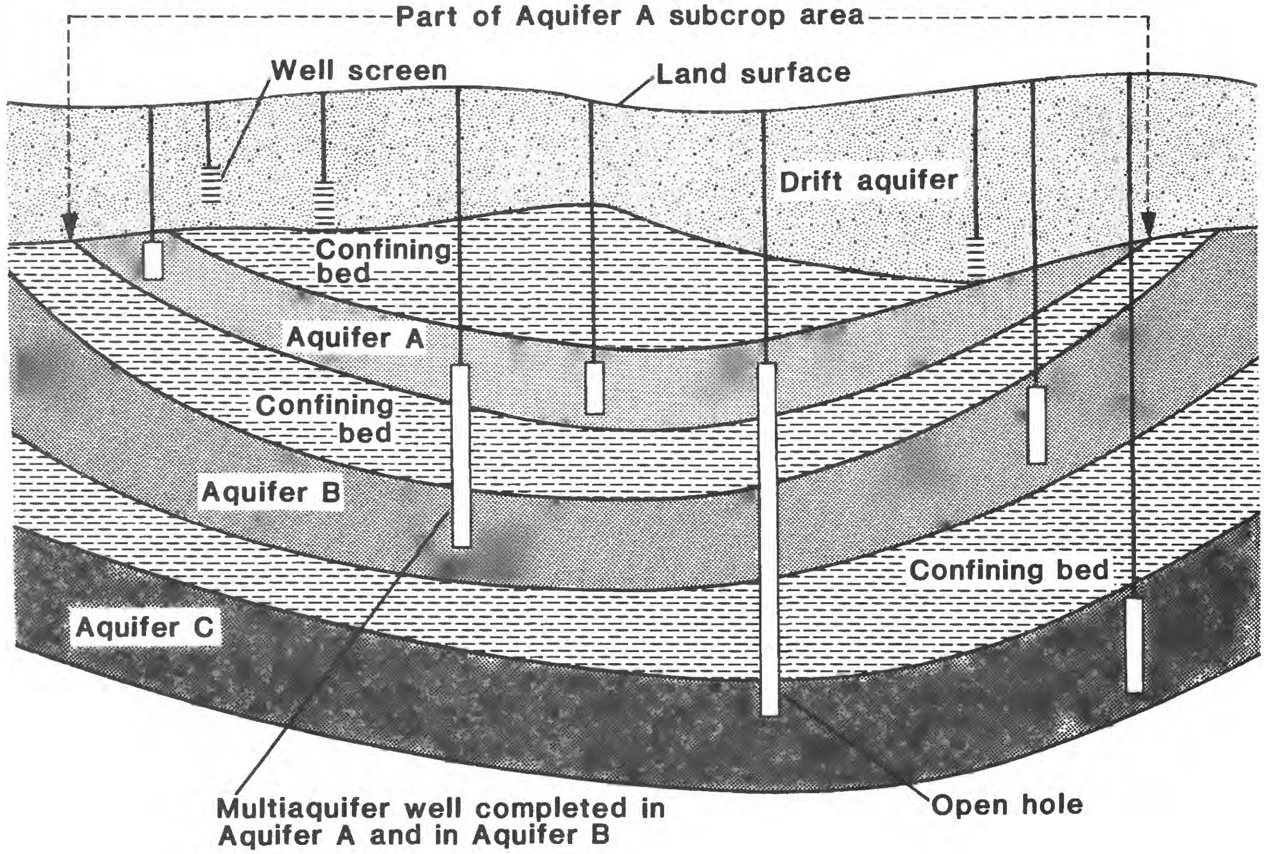
Regional geologic maps were used to confirm or determine aquifer completions for municipal wells. When data for aquifer identification were discrepant or missing, the aquifer penetrated was determined by comparing the well depth with the relevant geologic map. When casing depth was not given, the well was assumed to be completed in the deepest aquifer penetrated. However, multiaquifer completions were assumed when nearby municipal wells of similar depth were known to be multiaquifer completions.

Aquifer Preference

Aquifer preference for municipal wells depends on a number of factors that are based on hydrogeologic assumptions and personal considerations that changed with time. One way to evaluate aquifer preference in an area is to rank the aquifers by the total number of well completions in each. This type of evaluation does not, however, indicate which aquifer in a layered sequence was selected, the first aquifer encountered, the second, third, or fourth.

In this report, aquifer preference is based on the percentage of municipal wells completed in: (1) the shallowest bedrock aquifer, (2) a deeper bedrock aquifer, and (3) a drift aquifer above the bedrock (fig. 1.4-1). An assumption inherent in this analysis is that, in most cases, the shallowest aquifer possible will be used; if this is not the case, then something must be "wrong" with the shallowest aquifer.

In the aquifer-preference scheme, the subcrop area of each bedrock aquifer was used as the basis for comparison. The subcrop area is defined as the area in which a bedrock aquifer or its overlying confining bed occurs directly beneath drift. Therefore, the aquifer subcrop area defines where that aquifer is always the first bedrock aquifer to be penetrated. Completions of municipal wells were compiled by aquifer for each subcrop area, and the aquifer preference within each subcrop area was determined by listing the percent of wells completed in either the drift, shallowest bedrock aquifer, or deeper bedrock aquifers.



Distribution by aquifer subcrop area of municipal wells

Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer		Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
		Single aquifer	Multi-aquifer			
Aquifer A area	9	2	2	45 (4/9)	22 (2/9)	33 (3/9)

Figure 1.4-1.--Conceptualized hydrogeologic section showing how aquifer-preference values are derived

1.5 Development of Municipal Systems Supplied by Ground Water

INITIALLY, MUNICIPAL WATER-SUPPLY SYSTEMS WERE DEVELOPED FOR FIRE PROTECTION AND TO OBTAIN REASONABLE INSURANCE RATES

In 1906, Minnesota State Board of Health passed legislation to eliminate and control typhoid fever. Inventories of municipal water-supply systems prompted by this legislation led to wider use of ground water to avoid contaminated surface water.

Early settlements in southeastern Minnesota were located principally along lakes or rivers. These water courses were used both for domestic water supply and for sewage disposal. A water-supply system was usually one of the first public utilities developed by municipalities because a fire-protection system was needed in order to obtain reasonable insurance rates. Initial municipal water-supply systems in southeastern Minnesota were installed in the 1880's; they commonly were obtained from an adjacent lake or river (Dole and Wesbrook, 1907, p. 150). People often used water from these systems for domestic purposes.

Dole and Wesbrook (1907, p. 26-27) reported the following:

> The value of water as a municipal resource is greatly affected by its liability to transmit disease from one locality to another. Of the diseases which are transmissible by water, typhoid fever merits special attention in Minnesota.

From 1891 to 1900, about 4,500 people died of typhoid fever in Minnesota. In Minneapolis, 350 typhoid deaths occurred in an 1881-82 epidemic, and in 1897 there were 1,534 cases of typhoid fever reported, resulting in 148 deaths. Dr. J. F. Corbett (1904, p. 27-28) attributed these epidemics to the use of unfiltered water from the Mississippi River.

On July 14, 1906, the Minnesota State Board of Health passed certain rules aimed at containing and eliminating typhoid fever. Rule 54 stated that any drinking-water supply shown to be a positive or probable source of disease shall be condemned, and when so condemned, shall not be used again as a drinking-water supply until declared safe.

The passage of Rule 54 led to the development of ground-water supplies for municipal systems in two ways: (1) domestic use of surface water for municipal systems was greatly curtailed, which fostered demand for ground water, and (2) inventories and studies of municipal water-supply systems conducted in cooperation with the State Board of Health recommended use of ground water to avoid contaminated surface water (Dole and Westbrook, 1907, p. 152; Hall and others, 1911, p. 117).

Minnesota Department of Health is the State agency responsible for supervising development of municipal water systems in Minnesota. Legislation emanating from MDH has affected the selection of aquifers that can be used for municipal supplies in some areas of the state (see section 4.1).

The installation of municipal systems supplied by ground water from 1880- 1980 is shown in figure 1.5-1. By 1910, most municipal systems were supplied by ground water. However, since 1910, the choice of aquifer used for municipal wells has changed. Aquifer preferences will be discussed in following sections.

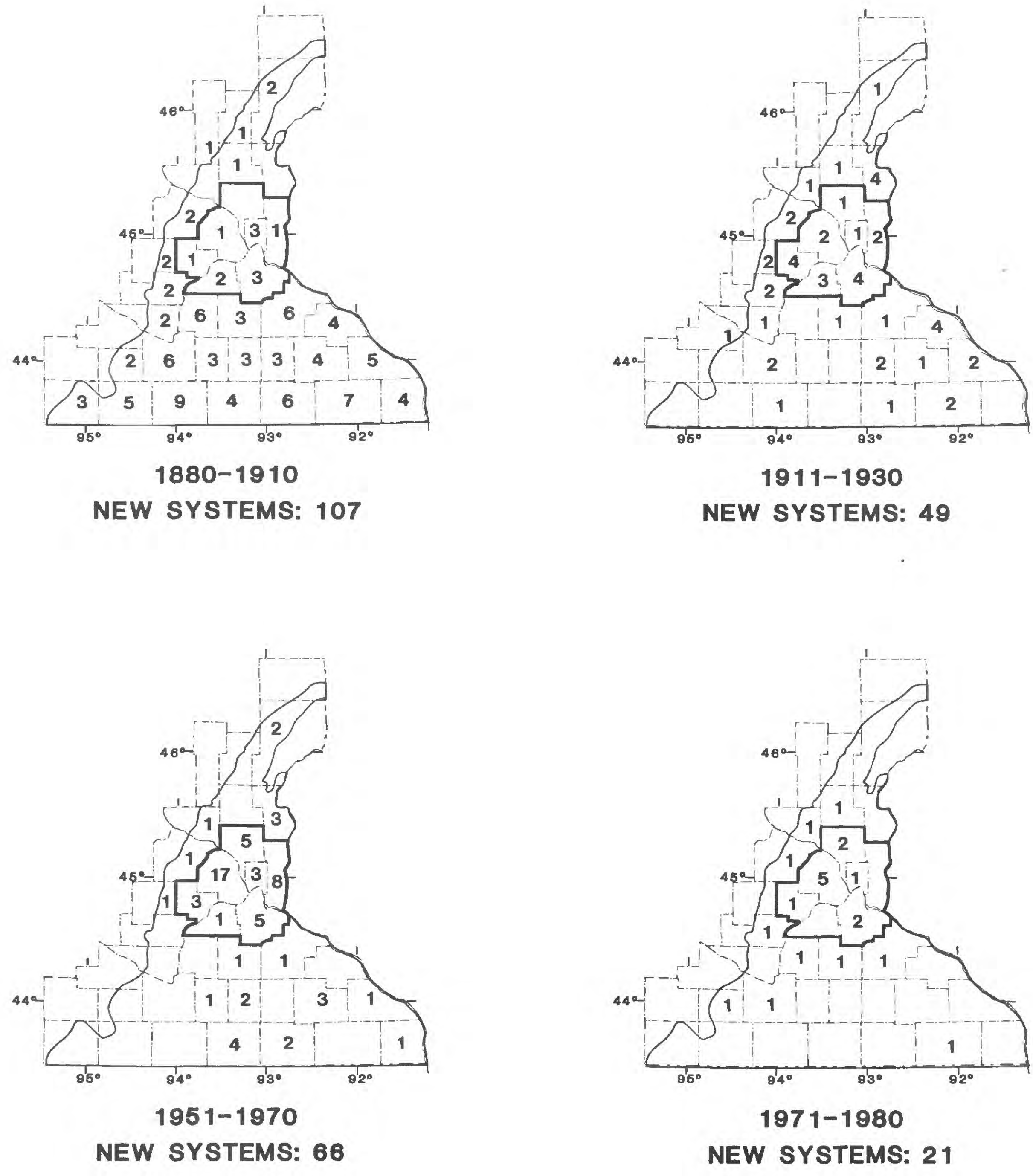
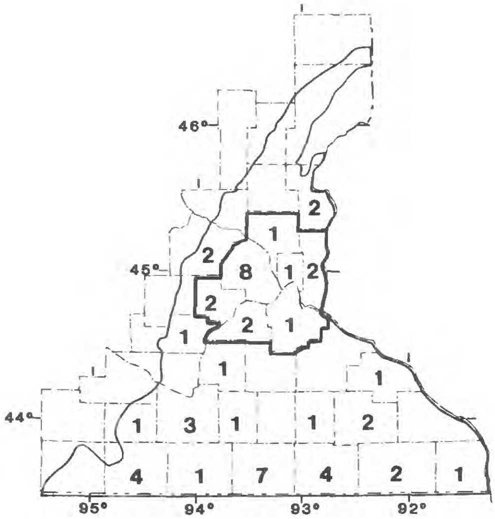


Figure 1.5-1.--Installation of municipal ground-water



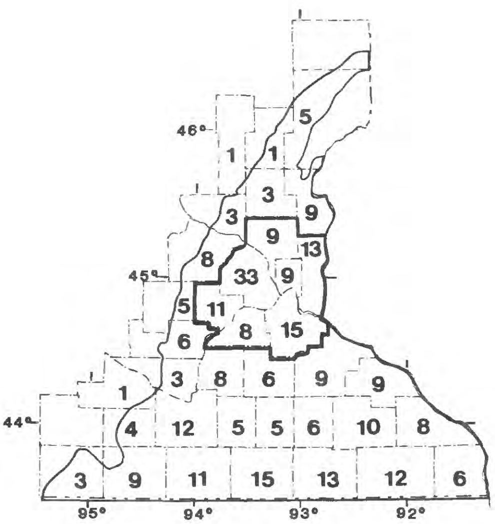
1931–1950
NEW SYSTEMS: 51

EXPLANATION

Boundary of study area

Boundary of Twin Cities Metropolitan Area

8 Number of systems installed in each county during time period



1880–1980
TOTAL SYSTEMS: 294

systems in southeastern Minnesota, 1880-1980

2.0 HYDROGEOLOGIC FRAMEWORK

2.1 Regional Hydrogeologic Classification System

REGIONAL AQUIFERS IN SOUTHEASTERN MINNESOTA ARE THE UNDIFFERENTIATED DRIFT, UPPER CARBONATE, ST. PETER, PRAIRIE DU CHIEN-JORDAN, IRONTON-GALESVILLE, AND MOUNT SIMON-HINCKLEY

Initial appraisals of rocks that comprise the Upper Carbonate and Prairie du Chien aquifers contended that the formations were impervious and contained little or no water.

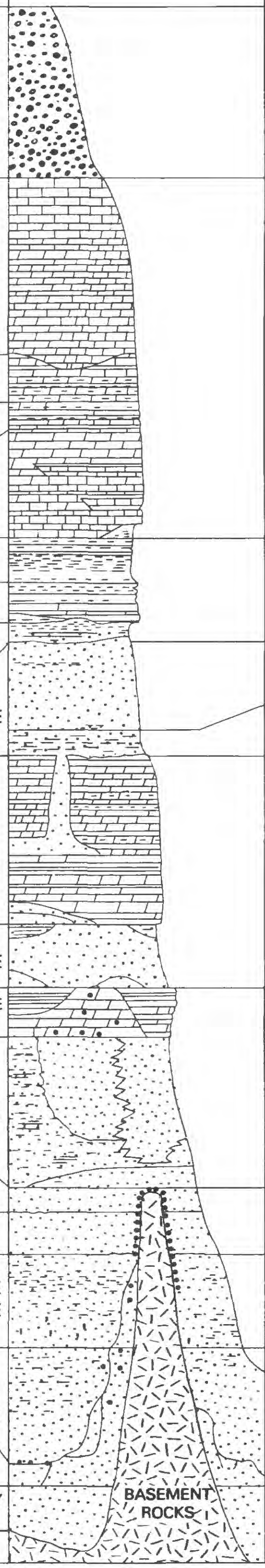
During the Paleozoic Era, nearly 2,000 feet of sandstone, limestone, dolomite, siltstone, and shale was deposited in the Hollandale embayment of southeastern Minnesota. This sedimentary sequence, together with the underlying Proterozoic Hinckley Sandstone and the overlying Quaternary drift, has been divided by Delin and Woodward (1984) into 11 regional hydrogeologic units (fig. 2.1-1). The six regional aquifers in the area are the undifferentiated drift, Upper Carbonate, St. Peter, Prairie du Chien-Jordan, Ironton-Galesville, and Mount Simon-Hinckley.

Opinions about the water-bearing capabilities of these rocks have changed during the past 100 years, as shown in the following examples.

1. The "Basal Cambrian Sandstone" (also termed the "Potsdam, St. Croix, and Dresbach Sandstone") was recognized as a productive water-bearing unit around the turn of the century (Winchell and Upham, 1884, 1888; Mead, 1894; Hall, 1904; Dole and Wesbrook, 1907). Many early wells in Minnesota were completed in what was known as the "Dresbach aquifer". Stauffer and Thiel (1941) divided the "Dresbach Formation" into upper (Ironton-Galesville) and lower (Mount Simon-Hinckley) sandstone members separated by a shale member (the Eau Claire). Consequently, wells completed in the full thickness of what was known formerly as the "Dresbach aquifer" are now considered to be multi-aquifer wells completed in both the Ironton-Galesville and Mount Simon-Hinckley aquifers.

2. The initial appraisals of the Shakopee and Oneota Dolomites contended they were impervious and contained very little or no water (Mead, 1894, p.352; Hall, 1904, p. 441; Dole and Wesbrook, 1907, p. 19). These dolomites form the Prairie du Chien Group, which comprises the bulk of the most widely used aquifer in southeastern Minnesota, the Prairie du Chien-Jordan.

3. The carbonate rocks above the St. Peter Sandstone historically have had a variety of names. Apart from an observation by Winchell (1889, p. 8) that the upper part of the "Trenton" (Galena) is a porous limestone, most initial appraisals contended that these rocks contained little or no water (Hall, 1904, p. 441; Dole and Wesbrook, 1907, p. 19). However, the rocks constitute the Upper Carbonate aquifer, which is now an important source of water supply for southern Minnesota.



EON AND ERA	PERIOD	GEOLOGIC UNIT	WATER-BEARING CHARACTERISTICS
CENOZOIC	QUATERNARY	UNDIFFER- ENTIATED DRIFT	UNDIFFERENTIATED DRIFT AQUIFER—Used primarily for domestic and farm purposes throughout area and for municipalities along the western boundary. The aquifer consists of till, alluvium, buried and surficial outwash, valley train, lake, and ice-contact deposits. Yields are highly variable but up to 5000 gal/min have been obtained from wells in outwash and alluvial deposits.
PALEOZOIC	DEVONIAN	CEDAR VALLEY LIMESTONE	UPPER CARBONATE AQUIFER—Most extensively used aquifer in south-central part of study area. Permeability is attributed to extensive karst development. Well yields range from 200 to 500 gal/min but are highly variable because solution cavities and channels differ in size and distribution.
	ORDOVICIAN	MAQUOKETA SHALE	
		DUBUQUE FORMATION	
		GALENA DOLOMITE	
		DECORAH SHALE	DECORAH-PLATTEVILLE-GLENWOOD CONFINING BED—Small quantities of water from fractures and solution cavities may be obtained locally from the Platteville.
		PLATTEVILLE FORMATION	
		GLENWOOD SHALE	
		ST. PETER SANDSTONE	ST. PETER AQUIFER—Yields typically range from 100 to 250 gal/min, but yields of 1200 gal/min have been obtained. Sandstone is poorly cemented, and wells tend to fill with sand.
			BASAL ST. PETER CONFINING BED—Siltstone and shale in basal St. Peter restricts vertical flow.
		PRAIRIE DU CHIEN GROUP UNDIVIDED	PRAIRIE DU CHIEN-JORDAN AQUIFER—Most extensively used aquifer in the study area. Hydraulic conductivity is due to joints, fractures, and solution cavities in the Prairie du Chien and to coarse-grained sandstone in the Jordan. Yields of wells commonly range from 500 to 1000 gal/min and can exceed 2000 gal/min.
	CAMBRIAN	JORDAN SANDSTONE	
		ST. LAWRENCE FORMATION	ST. LAWRENCE-FRANCONIA CONFINING BED—Vertical hydraulic conductivity is impeded by silty or shaly beds. Small quantities of water may be obtained from the medium- to coarse-grained Mazomanie Member of the Franconia Formation.
		FRANCONIA FORMATION	
		IRONTON SANDSTONE	IRONTON-GALESVILLE AQUIFER—Yields range from 100 to 500 gal/min. Wells are commonly completed through the underlying Mount Simon-Hinckley and are reported as Dresbach.
		GALESVILLE SANDSTONE	
		EAU CLAIRE SANDSTONE	EAU CLAIRE CONFINING BED—Hydraulic conductivity is poorly known. Sandstone beds in extreme southeastern Minnesota may yield small quantities of water.
		MOUNT SIMON SANDSTONE	MOUNT SIMON-HINCKLEY AQUIFER—Only bedrock aquifer used in northern part of study area. Well yields generally range from 200 to 700 gal/min. Locally, as much as 2000 gal/min may be obtained.
		HINCKLEY SANDSTONE	
PROTER-OZOIC		SEDIMENTARY ROCKS	CONFINING BED—Hydraulic characteristics are poorly known.

Figure 2.1-1.--Generalized hydrogeologic column of aquifers and confining beds in southeastern Minnesota (modified from Austin, 1969)

2.2 Bedrock Aquifers

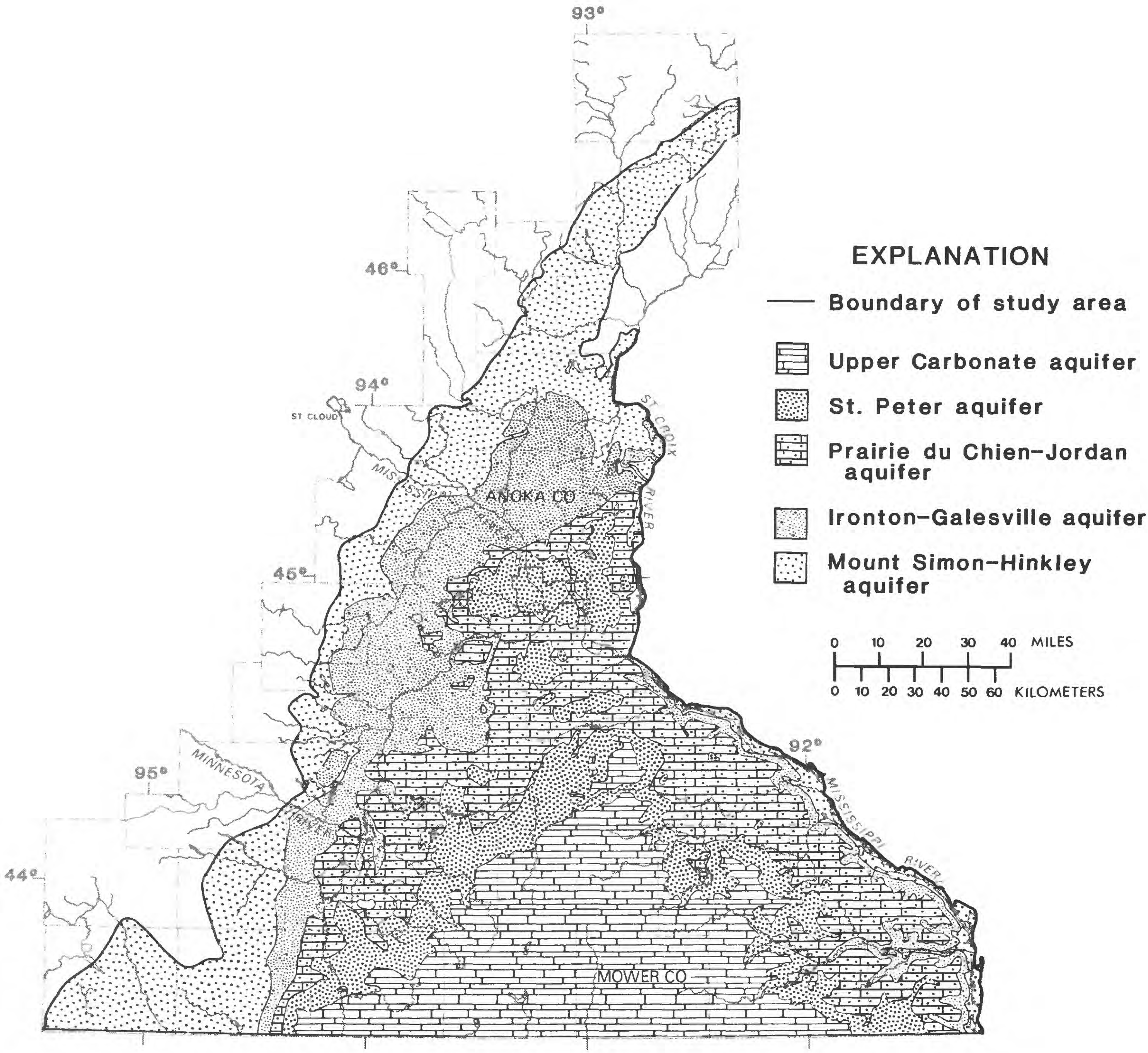
FIVE REGIONAL BEDROCK AQUIFERS OCCUR IN A LAYERED SEQUENCE IN SOUTHEASTERN MINNESOTA

Only the lowest aquifer in the sequence is present in northern and western part of study area; entire sequence is present only in south-central part of area.

Regional bedrock aquifers in southeastern Minnesota have been mapped and the aquifer subcrop areas are shown in figure 2.2-1. The five bedrock aquifers, separated by confining beds, are layered in a spoon-shaped depression called the Hollandale embayment. The geologic structure and stratigraphy of rocks in the Hollandale embayment are summarized by Delin and Woodward (1984).

The Mount Simon-Hinckley aquifer, the oldest and lowest aquifer in the layered sequence, covers about 17,200 mi^2; its subcrop area extends through about 4,200 mi^2 along the northern and western part of the study area. The Ironton-Galesville aquifer covers about 13,200 mi^2 and has a subcrop area of 2,500 mi^2. The Prairie du Chien-Jordan aquifer covers about 10,500 mi^2 and has a horseshoe-shaped subcrop area of 4,200 mi^2. The St. Peter aquifer covers about 6,300 mi^2 of the study area and has a subcrop area of 2,500 mi^2. The Upper Carbonate aquifer covers about 3,800 mi^2, all of which is the subcrop area.

Nondeposition and (or) erosion have limited the extent of the younger bedrock aquifers to the south-central part of the embayment. Thus, a well in Mower County could penetrate all five bedrock aquifers, but only two bedrock aquifers, the Ironton-Galesville and Mount Simon-Hinckley, can be tapped in northern Anoka County.



Base from U.S. Geological Survey
State Base Map, 1965

Geology modified from J.H. Mossler,
1980, Minnesota Geological Survey

Figure 2.2-1.--Location and extent of subcrops of bedrock aquifers in southeastern Minnesota

2.3 Drift Aquifer

DRIFT COVERS NEARLY ALL BEDROCK IN SOUTHEASTERN MINNESOTA

Drift thickness increases from less than 50 feet in the southeastern part of the area to about 500 feet in the western part.

Wisconsin and pre-Wisconsin Drift covers nearly all the bedrock in southeastern Minnesota. The undifferentiated drift aquifer consists of till, surficial and buried outwash, ice-contact and tunnel-valley deposits, glacial and modern-day alluvium, and loess. Thin outliers of unconsolidated Cretaceous deposits occur discontinuously throughout the southern part of the area. Because they have hydraulic characteristics and lithologies similar to drift, these scattered Cretaceous deposits are incorporated into the undifferentiated drift aquifer for this study.

The undifferentiated drift ranges in thickness from 0 to about 500 feet (fig. 2.3-1). Drift in the southeastern part of the area is generally less than 50 feet thick. In most of this area, the water table occurs in the bedrock and the drift is generally unsaturated. Locally, loess less than 20 feet thick directly overlies the bedrock. Drift thickness generally increases toward the west to more than 500 feet. The Mississippi River has eroded deep channels into the bedrock along the southeastern boundary of the area. These channels were filled with alluvium as much as 260 feet thick.

The likelihood of locating buried-drift aquifers is greatest where the drift is thickest. Most of the municipal wells tapping the drift aquifer are in the western part of the area or in alluvial channels of major rivers. Hydrologic properties of the undifferentiated drift aquifer in southeastern Minnesota are summarized in Delin and Woodward (1984).

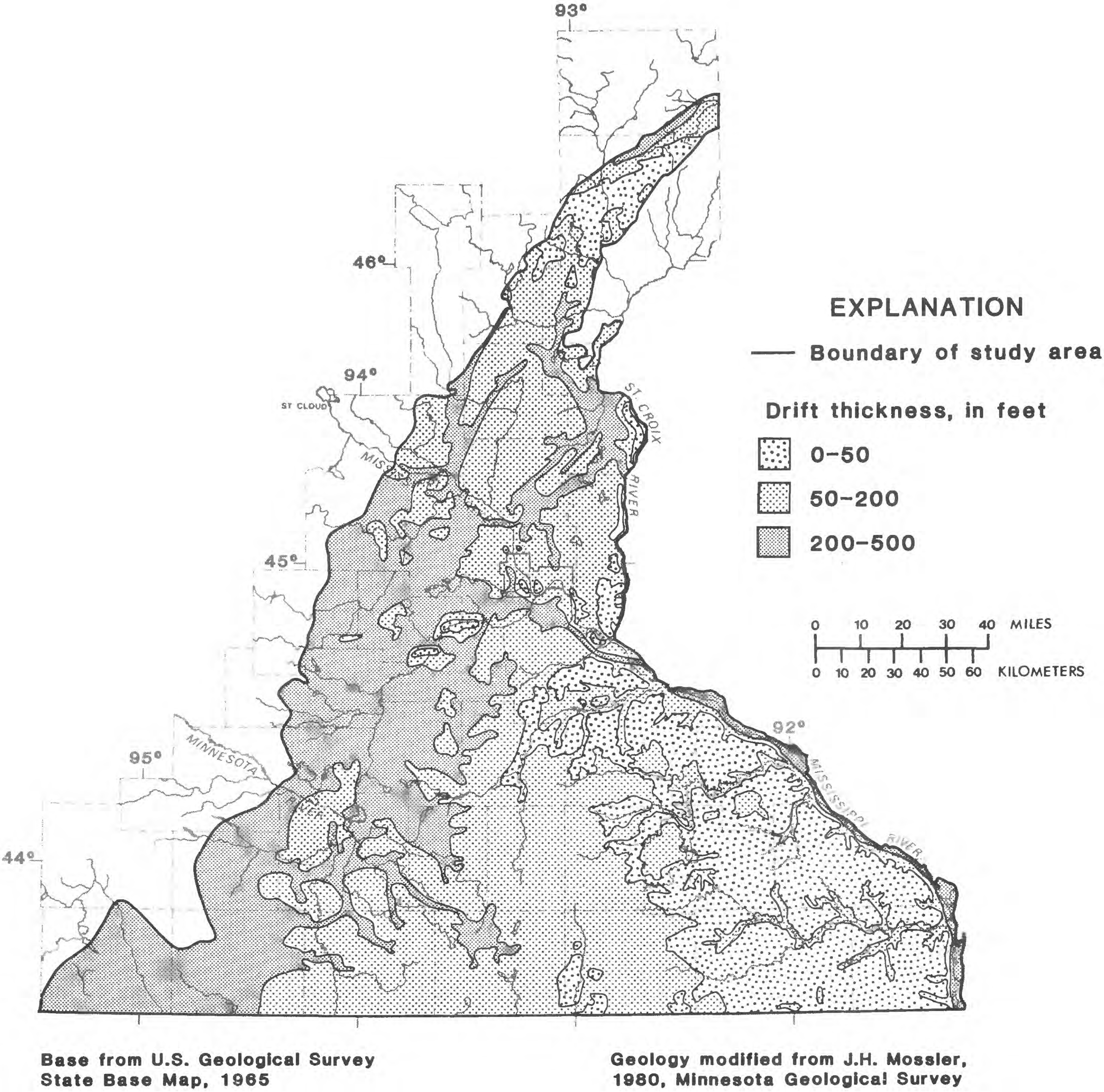


Figure 2.3-1.--Thickness of undifferentiated drift in southeastern Minnesota

3.0 WELL DISTRIBUTION AND ANALYSES

3.1 1880-1910 Time Period

107 MUNICIPAL SYSTEMS SUPPLIED BY GROUND WATER FROM 229 WELLS DRILLED FROM 1880-1910

Municipal wells tapping the drift aquifer were most common, numbering 89, followed by 72 wells in the Prairie du Chien-Jordan aquifer.

By 1910, there were 107 municipalities in southeastern Minnesota with water systems supplied by ground water from 229 wells (fig. 3.1-1). Most of the systems were constructed south of the Twin Cities area (fig. 1.5-1). Depth of municipal wells drilled during this period ranged from 14 to 2,204 feet and averaged 328 feet.

Although most municipal wells drilled during this period were completed in the shallowest aquifer capable of supplying the required quantity of water, a few extremely deep wells were drilled.

Notable failures at attempts to obtain artesian flows from deep municipal wells include a 2,204-foot well drilled at Mankato in 1875, which, according to Winchell and Upham (1884, p. 422), was "One of the deepest drillings ever made in the United States or the world in the hopes of obtaining an artesian well."; a 1,243-foot well drilled in Blue Earth in 1889; a 1,157-foot well drilled in Waseca in 1896; and a 1,640-foot well drilled in Glencoe in 1897.

Aquifer Completions

Municipal wells tapping the drift aquifer were most common, numbering 89 (39 percent of total), and 140 wells were completed in bedrock aquifers. The Prairie du Chien-Jordan aquifer, tapped by 72 wells, was the most used bedrock aquifer. Almost all these wells were completed in the Jordan Sandstone, as the Prairie du Chien at that time was considered to be impervious and to contain little or no water (Mead, 1894, p. 352; Dole and Wesbrook, 1907, p. 19; Hall and others, 1911). A summary of bedrock completions follows:

Bedrock completions: 140

Single-aquifer (SA) wells: 100
Multiple-aquifer (MA) wells: 40

Aquifer completion	Upper Carbonate		St. Peter		Prairie du Chien-Jordan		Ironton-Galesville		Mount Simon-Hinckley	
	SA	MA	SA	MA	SA	MA	SA	MA	SA	MA
Number of wells	30	7	6	13	47	25	3	28	14	17

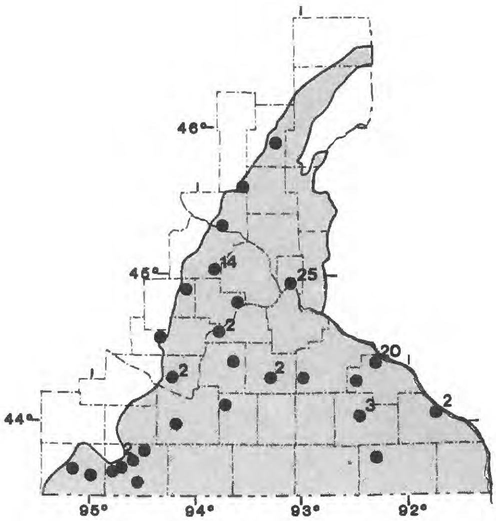
Aquifer Preference

Municipal wells drilled in each aquifer subcrop area from 1880-1910 are listed in table 3.1-1. These data indicate a high preference for drift wells in the Ironton-Galesville and Mount Simon-Hinckley subcrop areas. The drift wells are concentrated primarily in thick drift in the western part of the study area, and in alluvium of the Mississippi River valley in the eastern part (fig. 3.1-1). No drift wells were completed in the Upper Carbonate subcrop area.

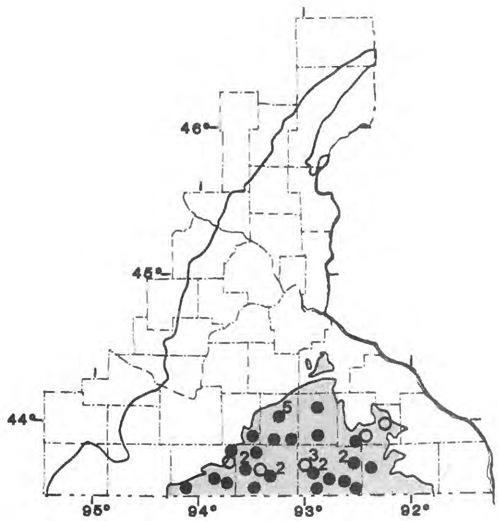
Overall, approximately 41 percent of the municipal wells were completed in the shallowest bedrock aquifer penetrated. High preference is indicated for the Upper Carbonate and Prairie du Chien-Jordan aquifers in which 77 and 74 percent of the wells drilled were completed in each respective subcrop area. A low preference is indicated for the St. Peter aquifer, as only 14 percent of the wells drilled in the St. Peter subcrop area tapped that aquifer, and 40 percent of the wells in the area were drilled and cased into deeper bedrock aquifers.

Table 3.1-1.—Distribution by aquifer subcrop area of municipal wells drilled during 1880-1910

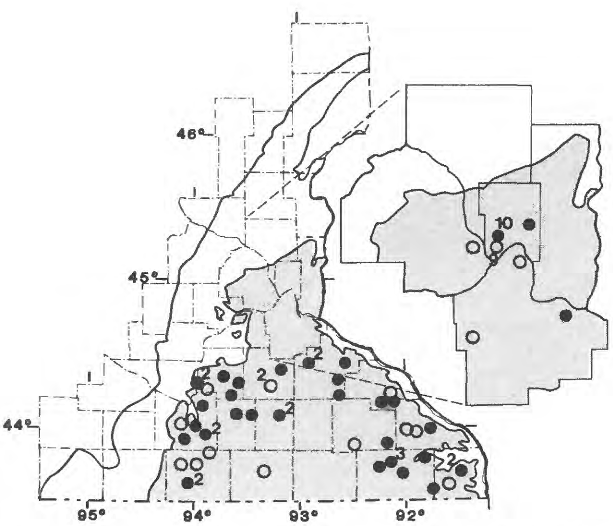
Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer		Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
		Single aquifer	Multi-aquifer			
Upper Carbonate area..........	48	30	7	77	23	0
St. Peter area..........	67	3	6	14	40	46
Prairie du Chien-Jordan area...	39	24	5	74	18	8
Ironton-Galesville area..........	30	3	5	27	3	70
Mount Simon-Hinckley area..........	45	11	-	24	-	76
Totals.........	229	71	23	41	20	39



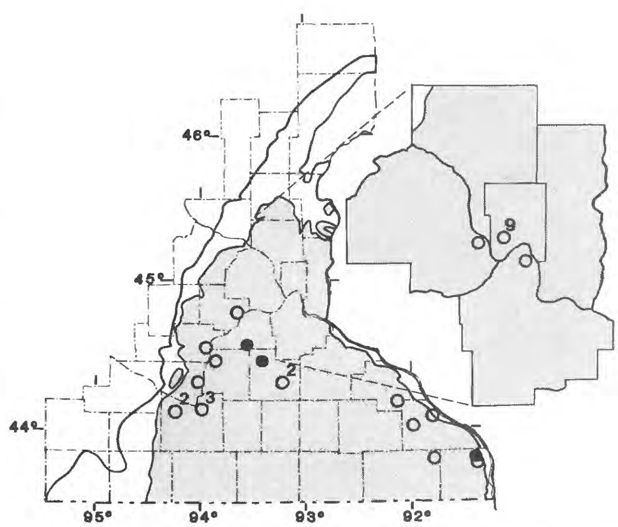
UNDIFFERENTIATED DRIFT AQUIFER



UPPER CARBONATE AQUIFER

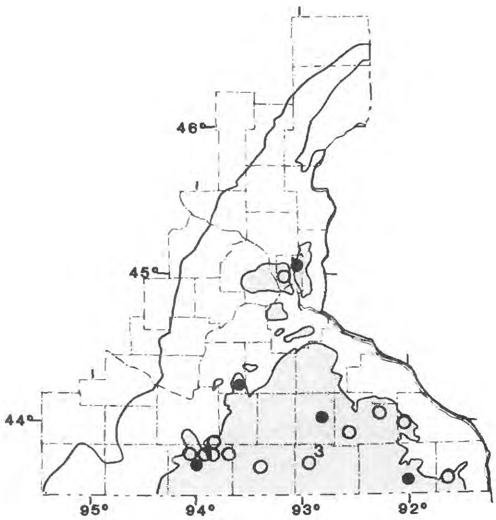


PRAIRIE DU CHIEN-JORDAN AQUIFER

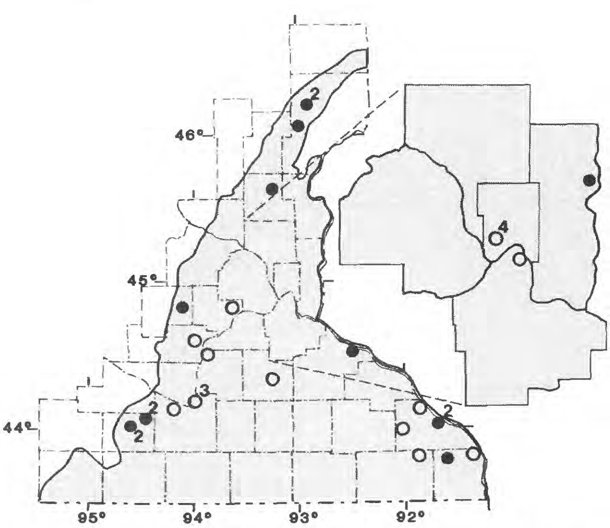


IRONTON-GALESVILLE AQUIFER

Figure 3.1-1.--Municipal wells



ST. PETER AQUIFER



MOUNT SIMON-HINCKLEY AQUIFER

EXPLANATION

——— Boundary of study area

Area of aquifer

●4 Municipality with single-aquifer well, and number of wells if more than one

○4 Municipality with multi-aquifer well, and number of wells if more than one

NOTE: If a **multiaquifer well** is open to three aquifers, the location of that well will be shown as **an open** circle on each of the three aquifer maps.

0 100 200 MILES

0 100 200 KILOMETERS

Installed in each aquifer, 1880-1910

3.2 1911-30 Time Period

49 MUNICIPAL GROUND-WATER SYSTEMS INSTALLED AND 177 MUNICIPAL WELLS DRILLED FROM 1911-30

Municipal wells tapping the drift aquifer were most common, numbering 66, followed by 54 wells in the Prairie du Chien-Jordan aquifer.

During the 1911-1939 period, 49 new municipal water systems supplied by ground water were installed in southeastern Minnesota (bringing the total to 156 systems), and 177 municipal wells were drilled (fig. 3.2-1). Most of these new water systems are located in and north of the Twin Cities area (fig. 1.5-1). Depth of municipal wells drilled during this period ranged from 20 to 1,485 feet and averaged 309 feet.

Municipalities planning to drill water-supply wells during this period had access to a variety of reports and studies that addressed aquifer yield and potential. A report by Hall and others (1911) listed the geology, ground-water conditions, and water supplies for cities, villages, and counties in southeastern Minnesota. This report provided guidance to municipalities on well construction and aquifer selection in the study area. Also, the Minnesota Department of Health began to provide assistance to municipalities for designing water-supply systems.

Aquifer Completions

Municipal wells tapping the drift aquifer were most common, numbering 66 (37 percent of total), and 111 wells were completed in bedrock aquifers. The Prairie du Chien-Jordan aquifer, tapped by 54 new wells, remained the most used bedrock aquifer.

Bedrock completions: 111

Single-aquifer (SA) wells: 82
Multiple-aquifer (MA) wells: 29

Aquifer completion	Upper Carbonate		St. Peter		Prairie du Chien-Jordan		Ironton-Galesville		Mount Simon-Hinckley	
	SA	MA	SA	MA	SA	MA	SA	MA	SA	MA
Number of wells	11	7	4	12	36	18	12	17	19	13

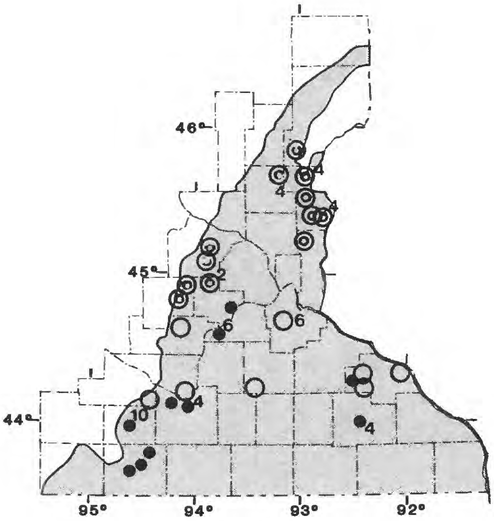
Aquifer Preference

Municipal wells drilled in each aquifer subcrop area from 1911-30 are listed in table 3.2-1. These data indicate a high preference for drift wells in the Mount Simon-Hinckley subcrop area. As in the previous period, no drift wells were completed in the Upper Carbonate subcrop area.

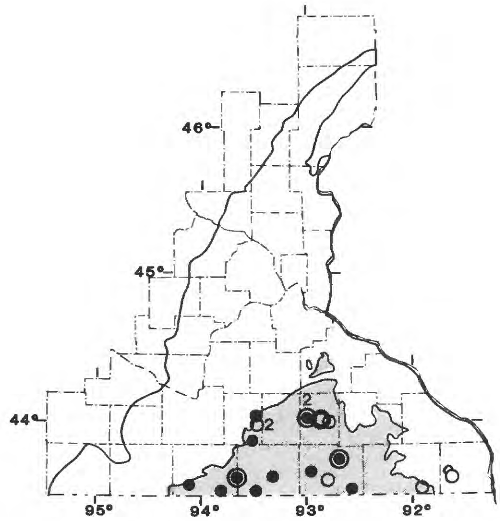
Overall, approximately 47 percent of the municipal wells were completed in the shallowest bedrock aquifer (table 3.2-1). A high preference is indicated for the Upper Carbonate aquifer in which 82 percent of the wells drilled in that subcrop area were completed.

Table 3.2-1.—Distribution by aquifer subcrop area of municipal wells drilled during 1911-30

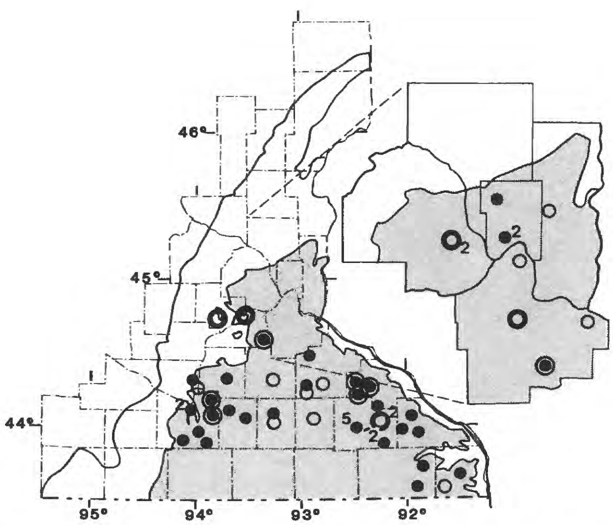
Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer		Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
		Single aquifer	Multi-aquifer			
Upper Carbonate area..........	22	11	7	82	18	0
St. Peter area..........	31	4	5	29	58	13
Prairie du Chien-Jordan area...	41	18	5	56	7	37
Ironton-Galesville area..........	34	22	6	50	9	41
Mount Simon-Hinckley area.	49	16	-	33	-	67
Totals.......	177	60	23	47	16	37



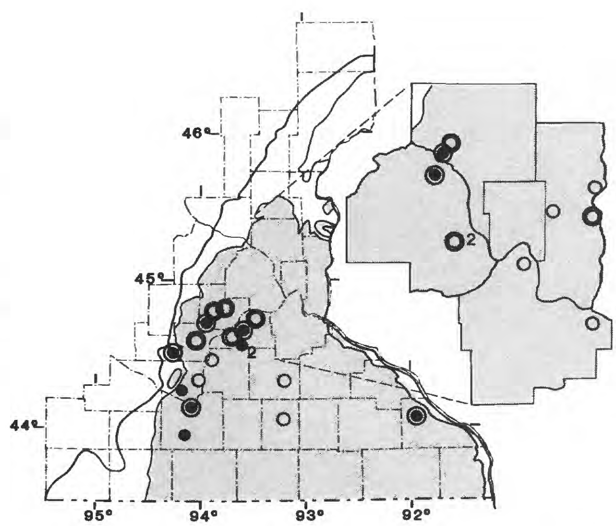
UNDIFFERENTIATED DRIFT AQUIFER



UPPER CARBONATE AQUIFER

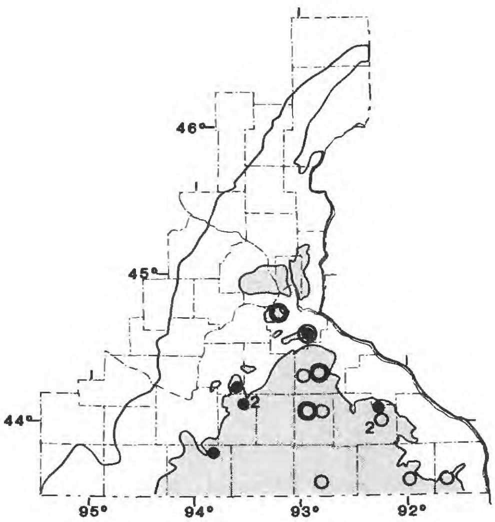


PRAIRIE DU CHIEN-JORDAN AQUIFER

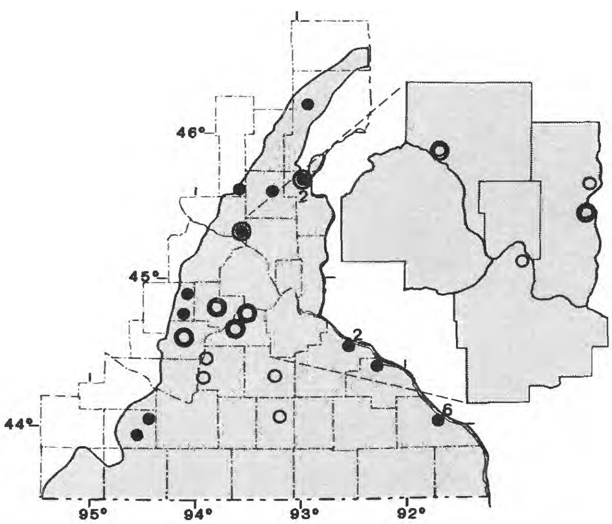


IRONTON-GALESVILLE AQUIFER

Figure 3.2-1.--Municipal wells



ST. PETER AQUIFER



MOUNT SIMON–HINCKLEY AQUIFER

EXPLANATION

—— Boundary of study area

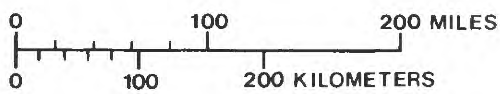
▭ Area of aquifer

•4 Municipality with single-aquifer well, and number of wells if more than one

o4 Municipality with multi-aquifer well, and number of wells if more than one

O Municipal water system started during this time period

NOTE: If a **multiaquifer well** is open to three aquifers, the location of that well will be shown as **an open** circle on each of the three aquifer maps.



Installed in each aquifer, 1911-1930

3.3 1931-50 Time Period

51 MUNICIPAL GROUND-WATER SYSTEMS INSTALLED AND 207 MUNICIPAL WELLS DRILLED FROM 1931-50

Municipal wells tapping the Prairie du Chien-Jordan aquifer were most common, numbering 79, followed by 48 wells in the drift aquifer

During the 1931-50 period, 51 new municipal water systems supplied by ground water were installed in southeastern Minnesota (bringing the total to 207 municipal systems), and 222 municipal wells were drilled (fig. 3.3-1). Most of these new water systems are located in and south of the Twin Cities area (fig. 1.5-1). Depth of municipal wells drilled during this period ranged from 56 to 1,222 feet and averaged 359 feet.

<u>Aquifer Completions</u>

Municipal wells tapping the drift aquifer were the second most common, numbering 48 (22 percent of the total), and 174 wells were completed in bedrock aquifers. The Prairie du Chien-Jordan aquifer, tapped by 79 new wells, was the most used bedrock aquifer. A summary of bedrock completions follows:

<u>Bedrock completions</u>: 174

Single-aquifer (SA) wells: 143
Multiple-aquifer (MA) wells: 31

Aquifer completion	Upper Carbonate		St. Peter		Prairie du Chien-Jordan		Ironton-Galesville		Mount Simon-Hinckley	
	SA	MA	SA	MA	SA	MA	SA	MA	SA	MA
Number of wells	29	4	8	16	59	20	23	16	24	10

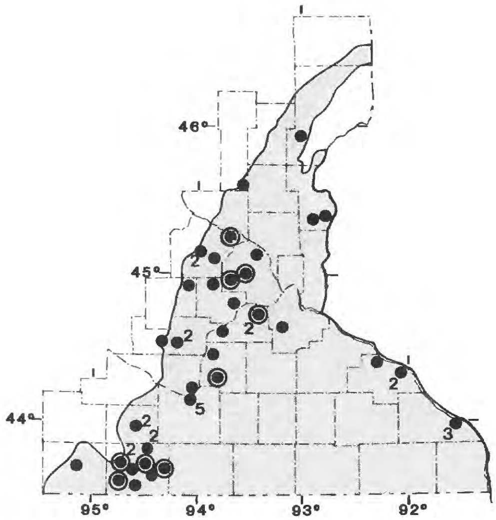
Aquifer Preference

Municipal wells drilled in each aquifer subcrop area from 1931-50 are listed in table 3.3-1. These data indicate a high preference for drift wells in the Mount Simon-Hinckley subcrop area. The drift wells are concentrated primarily in aquifers buried in thick drift along the western part of the area. No drift wells were completed in the Upper Carbonate subcrop area, and one was drilled in the St. Peter subcrop area.

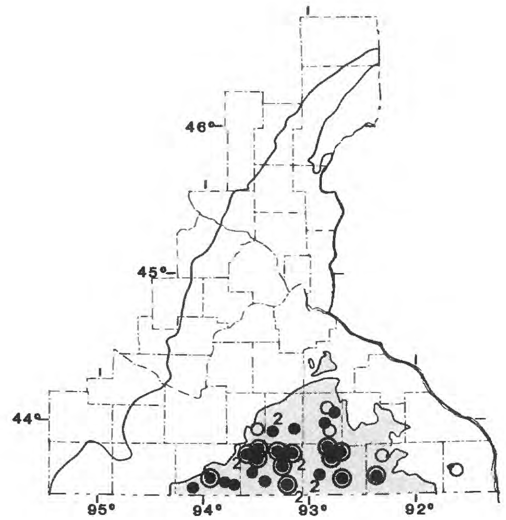
Overall, approximately 55 percent of the municipal wells were completed in the shallowest bedrock aquifer penetrated (table 3.3-1). High preference is indicated for the Upper Carbonate, Prairie du Chien-Jordan, and Ironton-Galesville aquifers in which at least 60 percent of the wells drilled in their respective subcrop areas were completed. In the St. Peter subcrop area, however, about 60 percent of the wells drilled were cased through the St. Peter aquifer and completed in deeper bedrock aquifer.

Table 3.3-1.--Distribution by aquifer subcrop area of municipal wells drilled during 1931-50

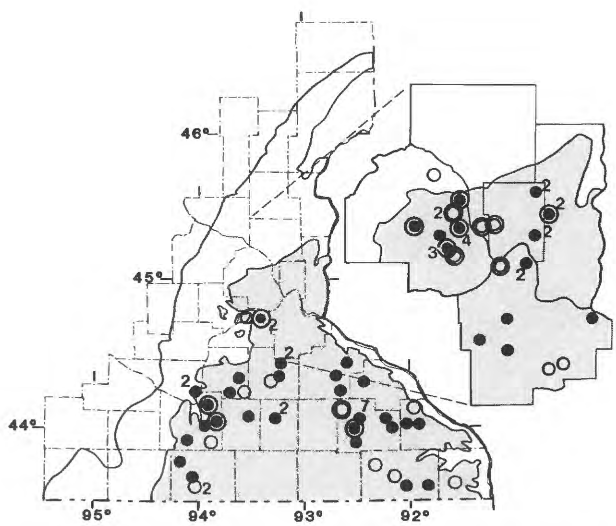
Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer		Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
		Single aquifer	Multi-aquifer			
Upper Carbonate area..........	46	29	4	72	28	0
St. Peter area..........	42	7	9	38	60	2
Prairie du Chien Jordan area...	46	26	4	65	15	20
Ironton-Galesville area..........	47	21	7	60	12	28
Mount Simon-Hinckley area.	41	16	-	39	-	61
Totals.......	222	99	24	55	23	22



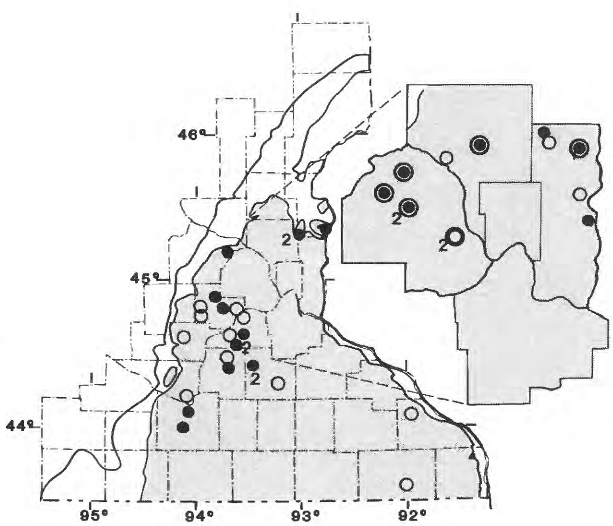
UNDIFFERENTIATED DRIFT AQUIFER



UPPER CARBONATE AQUIFER

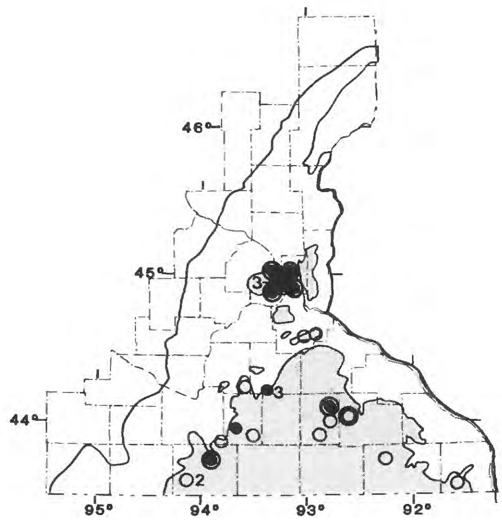


PRAIRIE DU CHIEN–JORDAN AQUIFER

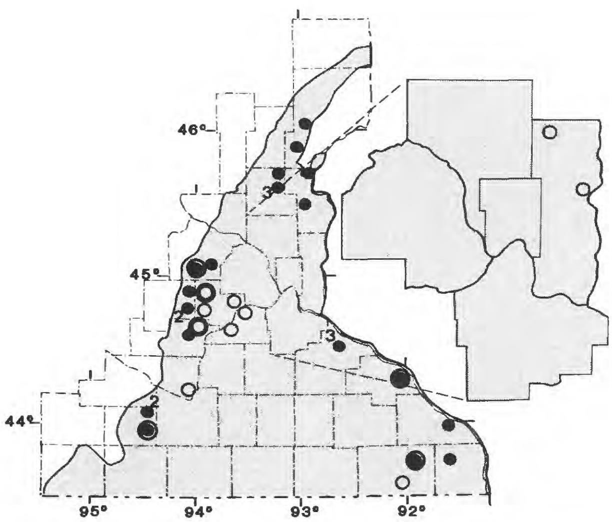


IRONTON–GALESVILLE AQUIFER

Figure 3.3-1.--Municipal wells



ST. PETER AQUIFER



MOUNT SIMON-HINCKLEY AQUIFER

EXPLANATION

Boundary of study area

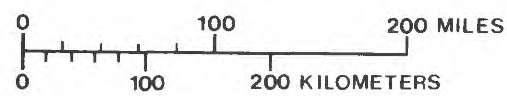
Area of aquifer

●4 Municipality with single-aquifer well, and number of wells if more than one

○4 Municipality with multi-aquifer well, and number of wells if more than one

O Municipal water system started during this time period

NOTE: If a **multiaquifer well** is open to three aquifers, the location of that well will be shown as **an open** circle on each of the three aquifer maps.



Installed in each aquifer, 1931-1950

3.4 1951-70 Time Period

66 MUNICIPAL GROUND-WATER SYSTEMS INSTALLED AND 424 MUNICIPAL WELLS DRILLED FROM 1951-70

Municipal wells tapping the Prairie du Chien-Jordan aquifer were most common, numbering 234, followed by 89 wells in the Mount Simon-Hinckley aquifer.

During the 1951-70 period, 66 new municipal water systems supplied by ground water were installed in southeastern Minnesota (bringing the total to 273 municipal systems), and 424 municipal wells were drilled (fig. 3.4-1). Most of these new water systems are located in the Twin Cities area, with Hennepin County leading with 17 new systems (fig. 1.5-1). Depth of municipal wells drilled during this period ranged from 42 to 1,135 feet and averaged 476 feet.

Aquifer Completions

Municipal wells tapping the drift aquifer were the fourth most common, numbering 55 (13 percent of the total), and 369 wells were completed in bedrock aquifers. The Prairie du Chien-Jordan aquifer, tapped by 234 new wells, was the most used bedrock aquifer. The Mount Simon-Hinckley and Ironton-Galesville were aquifers selected for 89 and 75 completions, respectively. Many of these wells were drilled in the Twin Cities area to cope with increased water demands created by suburban growth. A summary of bedrock completions follows:

Bedrock completions: 369

Single-aquifer (SA) wells: 309
Multiple-aquifer (MA) wells: 60

Aquifer completion	Upper Carbonate		St. Peter		Prairie du Chien-Jordan		Ironton-Galesville		Mount Simon-Hinckley	
	SA	MA	SA	MA	SA	MA	SA	MA	SA	MA
Number of wells	21	4	6	11	207	27	25	50	50	39

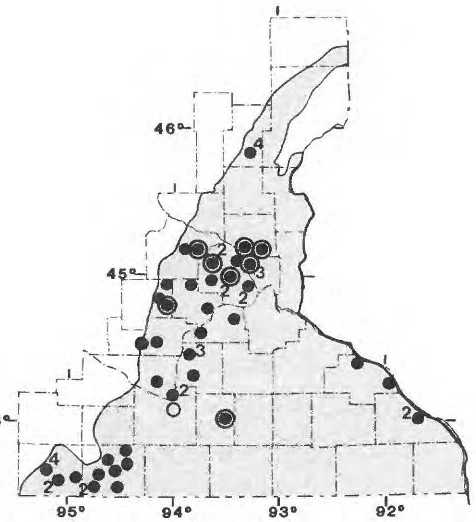
Aquifer Preference

Municipal wells drilled in each aquifer subcrop area from 1951-70 are listed in table 3.4-1. These data indicate a high preference for drift wells in the Mount Simon-Hinckley subcrop area. The drift wells are concentrated primarily in aquifers buried in thick drift along the western part of the area.

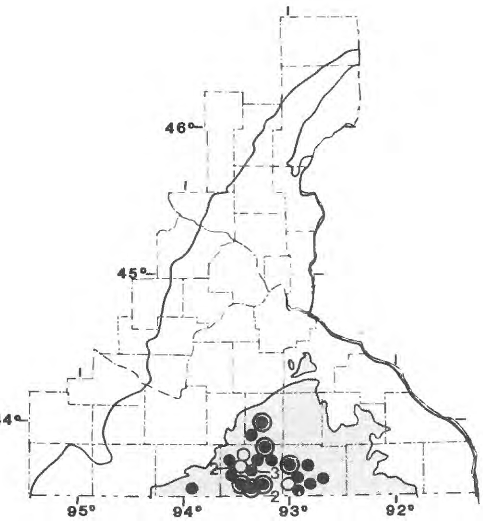
Overall, approximately 43 percent of the municipal wells were completed in the shallowest aquifer penetrated, and 44 percent were completed in deeper aquifers (table 3.4-1). A high preference is indicated for the Prairie du Chien-Jordan and Ironton-Galesville aquifers in which at least 60 percent of the wells drilled in their respective subcrop areas were completed. A very low preference is indicated for the St. Peter aquifer, as only 4 percent of the wells drilled in the St. Peter subcrop area tapped the aquifer. Most (91 percent) of the wells in the area were drilled and cased through the St. Peter into deeper bedrock aquifers.

Table 3.4-1.--Distribution by aquifer subcrop area of municipal wells drilled during 1951-70

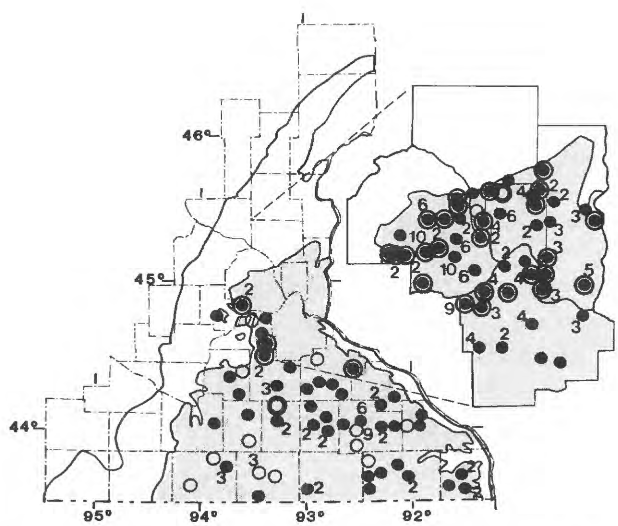
Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer: Single aquifer	Wells completed in shallowest bedrock aquifer: Multi-aquifer	Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
Upper Carbonate area..........	57	21	4	44	54	2
St. Peter area..........	128	3	2	4	91	5
Prairie du Chien Jordan area...	134	92	4	72	24	4
Ironton-Galesville area..........	52	19	12	60	13	27
Mount Simon-Hinckley area.	54	27	-	50	-	50
Totals.......	424	162	22	43	44	13



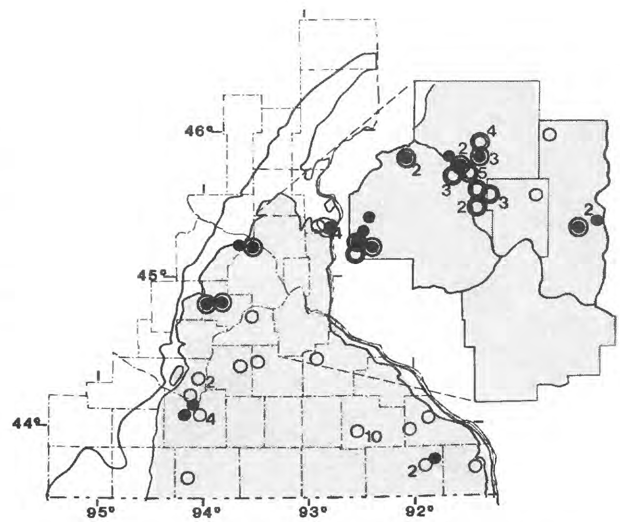
UNDIFFERENTIATED DRIFT AQUIFER



UPPER CARBONATE AQUIFER

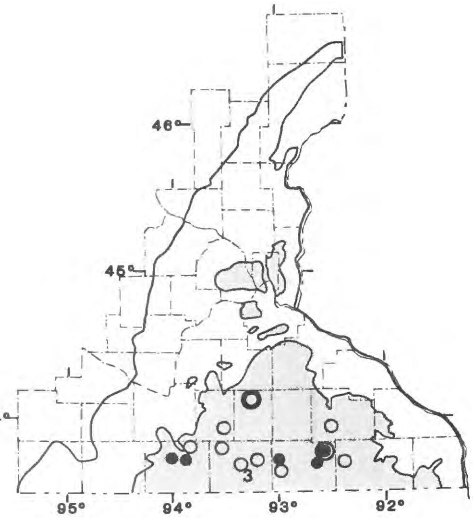


PRAIRIE DU CHIEN-JORDAN AQUIFER



IRONTON-GALESVILLE AQUIFER

Figure 3.4-1.--Municipal wells



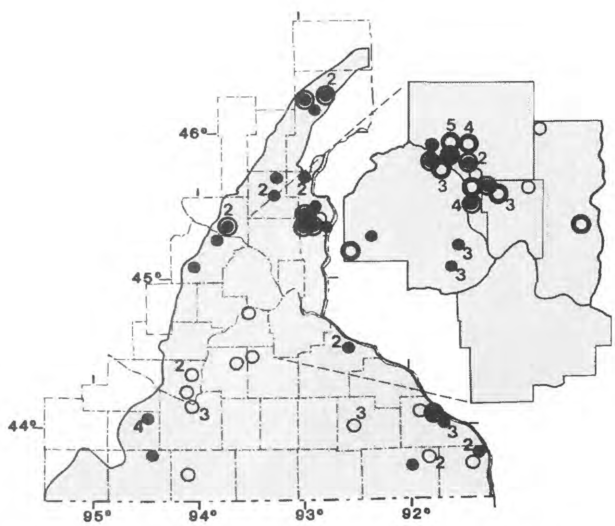
ST. PETER AQUIFER

EXPLANATION

- Boundary of study area
- Area of aquifer
- ●4 Municipality with single-aquifer well, and number of wells if more than one
- ○4 Municipality with multi-aquifer well, and number of wells if more than one
- O Municipal water system started during this time period

NOTE: If a **multiaquifer well** is open to three aquifers, the location of that well will be shown as **an open** circle on each of the three aquifer maps.

0 100 200 MILES
0 100 200 KILOMETERS



MOUNT SIMON-HINCKLEY AQUIFER

Installed in each aquifer, 1951-1970

3.0 WELL DISTRIBUTION AND ANALYSES—Continued

3.5 1971-80 Time Period

20 MUNICIPAL GROUND-WATER SYSTEMS INSTALLED AND 192 MUNICIPAL WELLS DRILLED FROM 1971-80

Municipal wells tapping the Prairie du Chien-Jordan aquifer were most common, numbering 102, followed by 39 wells in the Mount Simon-Hinckley aquifer

During the 1971-80 period, 20 new municipal water systems supplied by ground water were installed in southeastern Minnesota (bringing the total to 293 municipal systems), and 192 municipal wells were drilled (fig. 3.5-1). Most of these new water systems are located in the Twin Cities area (fig. 1.5-1). Depth of municipal wells drilled during this period ranged from 55 to 1,325 feet and averaged 447 feet.

Aquifer Completions

Municipal wells tapping the drift aquifer were the third most common, numbering 36 (19 percent of the total), and 156 wells were completed in bedrock aquifers. The Prairie du Chien-Jordan aquifer, tapped by 102 new wells, was the most used bedrock aquifer. A summary of bedrock completions follows:

Bedrock completions: 156

Single-aquifer (SA) wells: 129
Multiple-aquifer (MA) wells: 27

Aquifer completion	Upper Carbonate		St. Peter		Prairie du Chien-Jordan		Ironton-Galesville		Mount Simon-Hinckley	
	SA	MA	SA	MA	SA	MA	SA	MA	SA	MA
Number of wells	8	-	1	2	95	7	8	25	17	22

Aquifer Preference

Municipal wells drilled in each aquifer subcrop area from 1971-80 are listed in table 3.5-1. These data indicate a continued high preference for drift wells in the Mount Simon-Hinckley subcrop area. The drift wells are concentrated primarily in aquifers buried in thick drift along the western part of the area. No drift wells were completed in the Upper Carbonate or St. Peter subcrop areas.

Overall, approximately 49 percent of the municipal wells were completed in the shallowest becrock aquifer penetrated (table 3.5-1). High preference is indicated for the Prairie du Chien-Jordan aquifer in which 77 percent of the wells drilled in that subcrop area were completed. A very low preference is indicated for the St. Peter aquifer, as only 3 percent of the wells drilled in the St. Peter subcrop area tapped the aquifer. Most (97 percent) of the wells in the area were drilled and cased into deeper bedrock aquifers.

Table 3.5-1.--Distribution by aquifer subcrop area of municipal wells drilled during 1971-80

Aquifer subcrop area	Total number of wells in subcrop	Wells completed in shallowest bedrock aquifer		Percentage of wells completed solely or partly in shallowest bedrock aquifer	Percentage of wells completed solely in deeper bedrock aquifers	Percentage of wells completed in drift aquifer
		Single aquifer	Multi-aquifer			
Upper Carbonate area..........	18	8	0	44	56	0
St. Peter area..........	30	0	1	3	97	0
Prairie du Chien Jordan area...	83	62	2	77	12	11
Ironton-Galesville area..........	35	5	9	40	37	23
Mount Simon-Hinckley area.	26	7	-	27	-	73
Totals.......	192	82	12	49	32	19

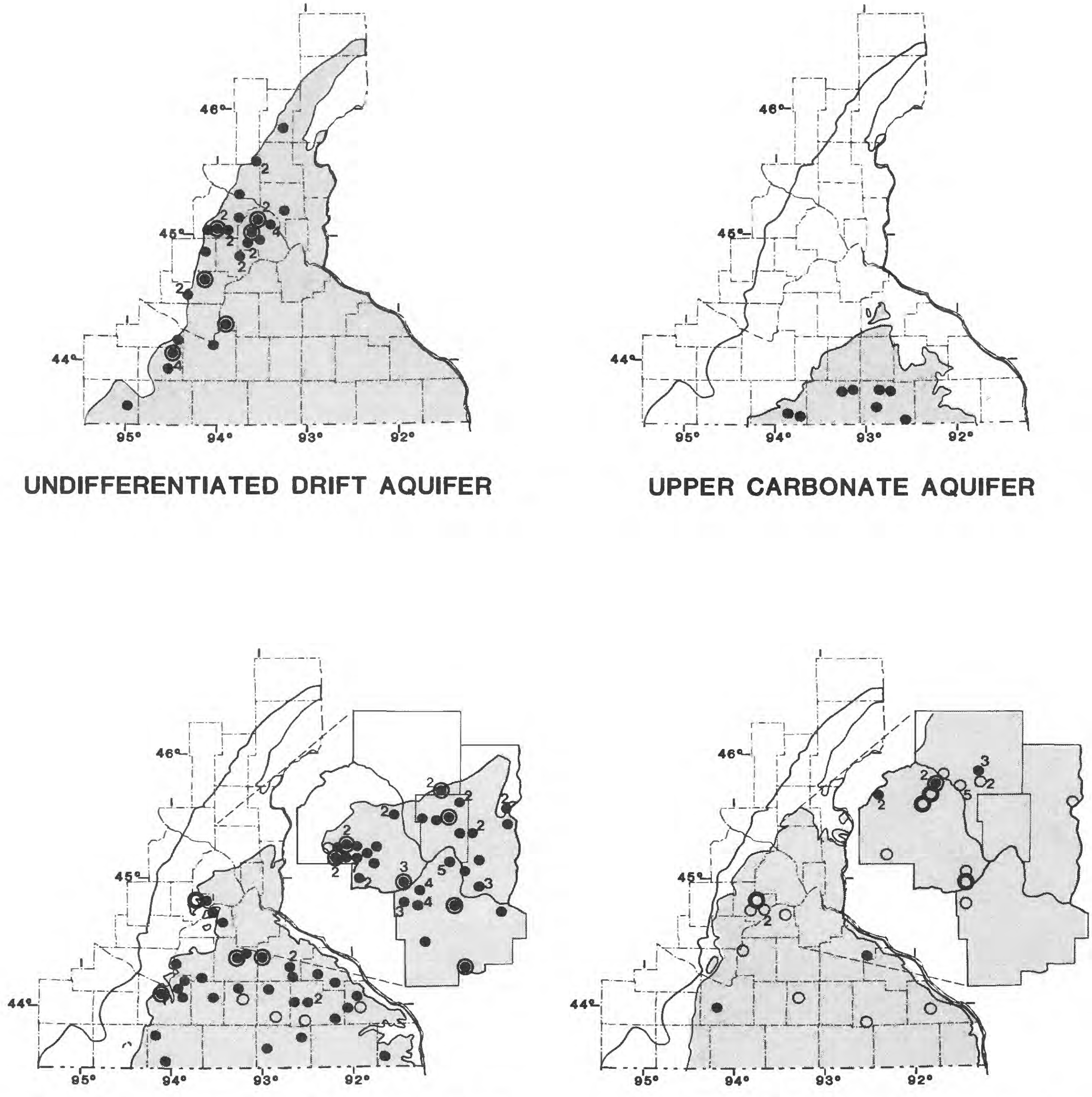
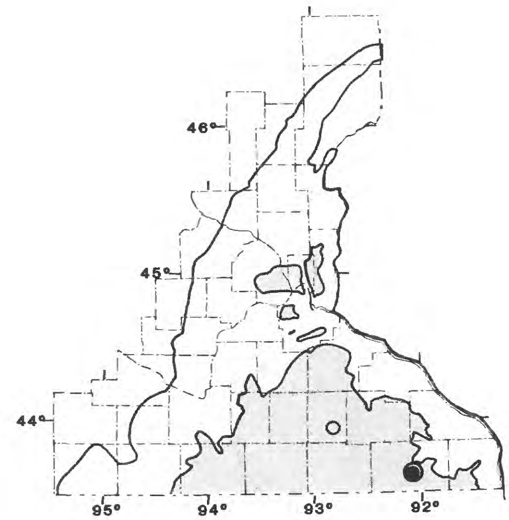
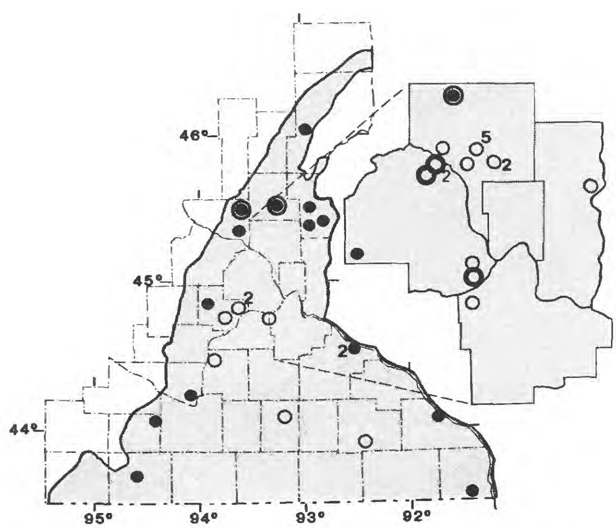


Figure 3.5-1.--Municipal wells



ST. PETER AQUIFER



MOUNT SIMON-HINCKLEY AQUIFER

EXPLANATION

——— Boundary of study area

▭ Area of aquifer

●4 Municipality with single-aquifer well, and number of wells if more than one

○4 Municipality with multi-aquifer well, and number of wells if more than one

◯ Municipal water system started during this time period

NOTE: If a **multiaquifer well** is open to three aquifers, the location of that well will be shown as **an open** circle on each of the three aquifer maps.

0 100 200 MILES

0 100 200 KILOMETERS

installed in each aquifer, 1971-1980

4.0 SUMMARY

4.1 Role of Governmental Legislation

LEGISLATION PASSED TO PROTECT PUBLIC FROM WATER-QUALITY PROBLEMS ASSOCIATED WITH SHALLOW, CARBONATE AQUIFERS

Multiaquifer completions prohibited by Minnesota Department of Health in 1979.

The Minnesota State Board of Health was instrumental in supervising the development of municipal water supplies in Minnesota. The adoption of Rule 54 (in 1906), Regulation 200 (in 1917), and Regulation 201 (in 1918) and their relevance to municipal ground-water supplies were discussed in sections 1.3 and 1.5 of this report. In March 1923, the first edition of "Water Supplies and Sewage Systems for Municipalities" was published by the Board of Health, with subsequent editions published in 1927 and 1933. These publications provided information to officials in charge of municipal water-supply systems concerning the location, construction, and operation of municipal wells. In 1937, the State Board of Health adopted a "Manual of Water Supply Sanitation," which standardized the location, construction, and operation of municipal wells; this manual has been updated periodically.

For many years, the Minnesota Board of Health recognized the water-quality problems associated with obtaining water from shallow, carbonate aquifers. Outbreaks of typhoid fever and gastro-enteritis in some areas of extreme southeastern Minnesota were traced to water supplied by wells completed in shallow, carbonate aquifers (Kingston, 1943). In the 1940's, the Board of Health adopted a policy that approval for construction of municipal wells in carbonate aquifers would be granted only when that aquifer was covered by at least 100 feet of overburden material.

In 1974, the Minnesota Department of Health adopted the Water Well Construction Code (Chapter 15, Minnesota State Regulations) which restricted the use of aquifers in certain areas because of the potential for ground-water contamination. As of July 1974, "Geological formations which are creviced or cavernous (limestone or dolomite) shall not be used as a potable source of ground water unless overlain by at least 50 feet of drift material and (or) by a firm insoluble rock material (sandstone) extending for at least 1 mile horizontal distance from the well in all directions..." (F MCAR Section 1.220 H.1). Thus, municipal wells are not allowed to be completed in the eastern part of the area underlain by the Upper Carbonate aquifer and dolomite formations of the Prairie du Chien-Jordan aquifer (fig. 4.1-1).

As of 1979, multiaquifer wells were prohibited by the Health Department (F MCAR Section 1.220 H.3). The Ironton-Galesville and Mount Simon-Hinckley multiaquifer wells, the fourth most popular completion in the area since 1955 (fig. 4.3-1), will no longer be allowed.

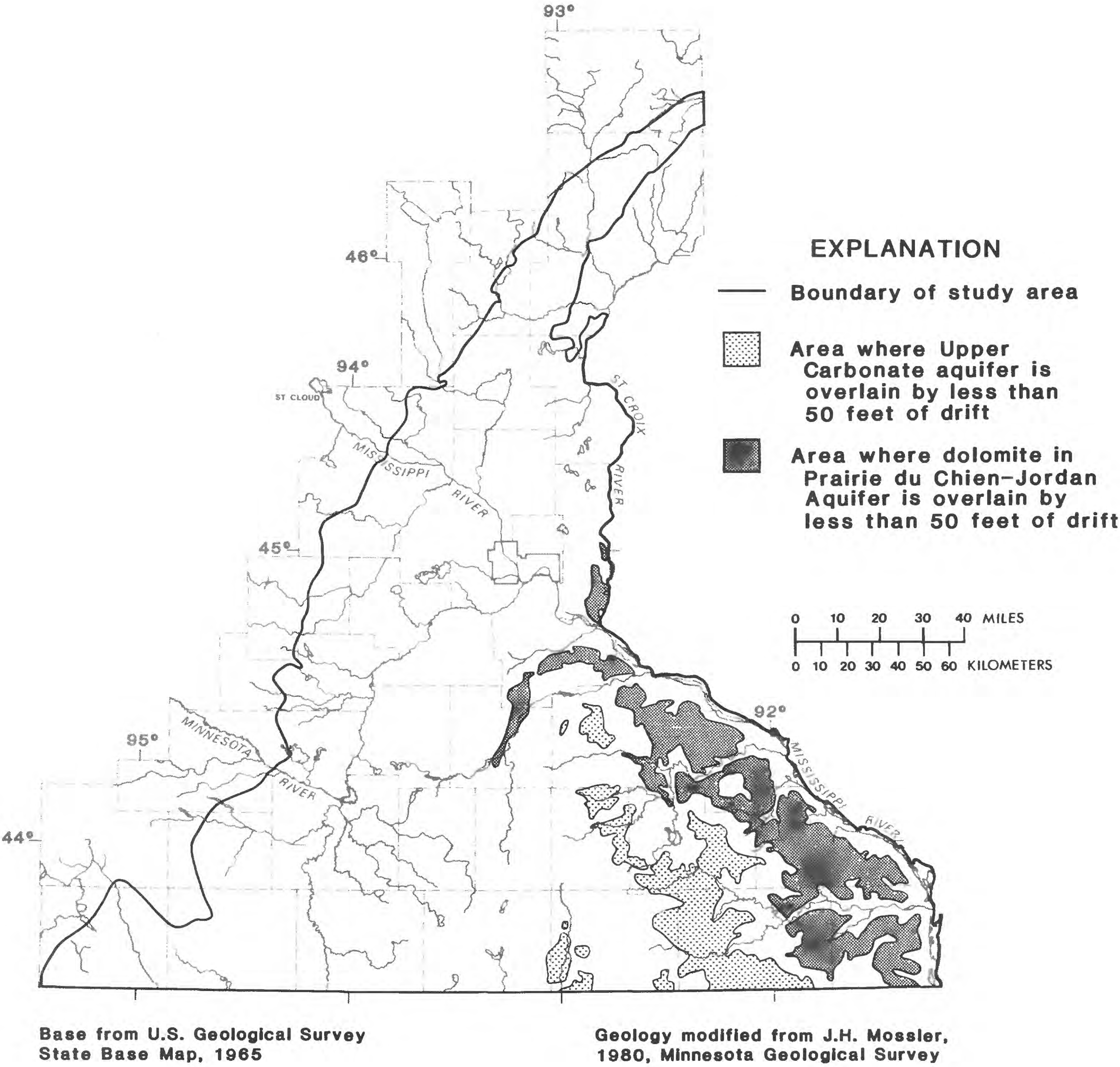


Figure 4.1-1.--Areas in southeastern Minnesota where Department of Health prohibits use of carbonate aquifers for potable water supply

4.2 Municipal Well Depths, 1880 - 1980

FROM 1880 TO 1980, AVERAGE DEPTH OF MUNICIPAL WELLS GENERALLY INCREASED

During 1951-70, the depth of the new municipal wells averaged 476 feet owing to the large number of Prairie du Chien-Jordan, Ironton-Galesville, and Mount Simon-Hinckley wells driled in the Twin Cities area.

The average depth of municipal wells drilled in southeastern Minnesota generally increased during 1880 to 1980 (fig. 4.2-1). Although well depths cannot be directly correlated with aquifers throughout the area, the following generalizations can be made:

1. Most of the wells less than 50 feet deep are completed in alluvial aquifers.

2. Most of the drift wells are less than 200 feet deep.

3. In the Twin Cities area, the Prairie du Chien-Jordan wells range from 158 to 605 feet deep, but are generally between 300 and 500 feet deep; the Ironton-Galesvile wells range from 137 to 638 feet deep, but are generally between 400 and 500 feet deep; and the Mount Simon-Hinckley wells range from 416 to 1,130 feet deep, but are generally more than 700 feet deep.

The higher average well depth during 1951-70 compared to 1971-80 results from the large number of Prairie du Chien-Jordan, Ironton, Galesville, and Mount Simon-Hinckley wells drilled in the Twin Cities area during expansion of the suburbs in the 1960's. The higher average well depth during 1880-1910 compared to 1911-30 results from the futile attempts of some municipalities to obtain flowing wells by drilling extremely deep holes (2,204-foot well at Mankato, 1,728-foot well at Glencoe, etc.).

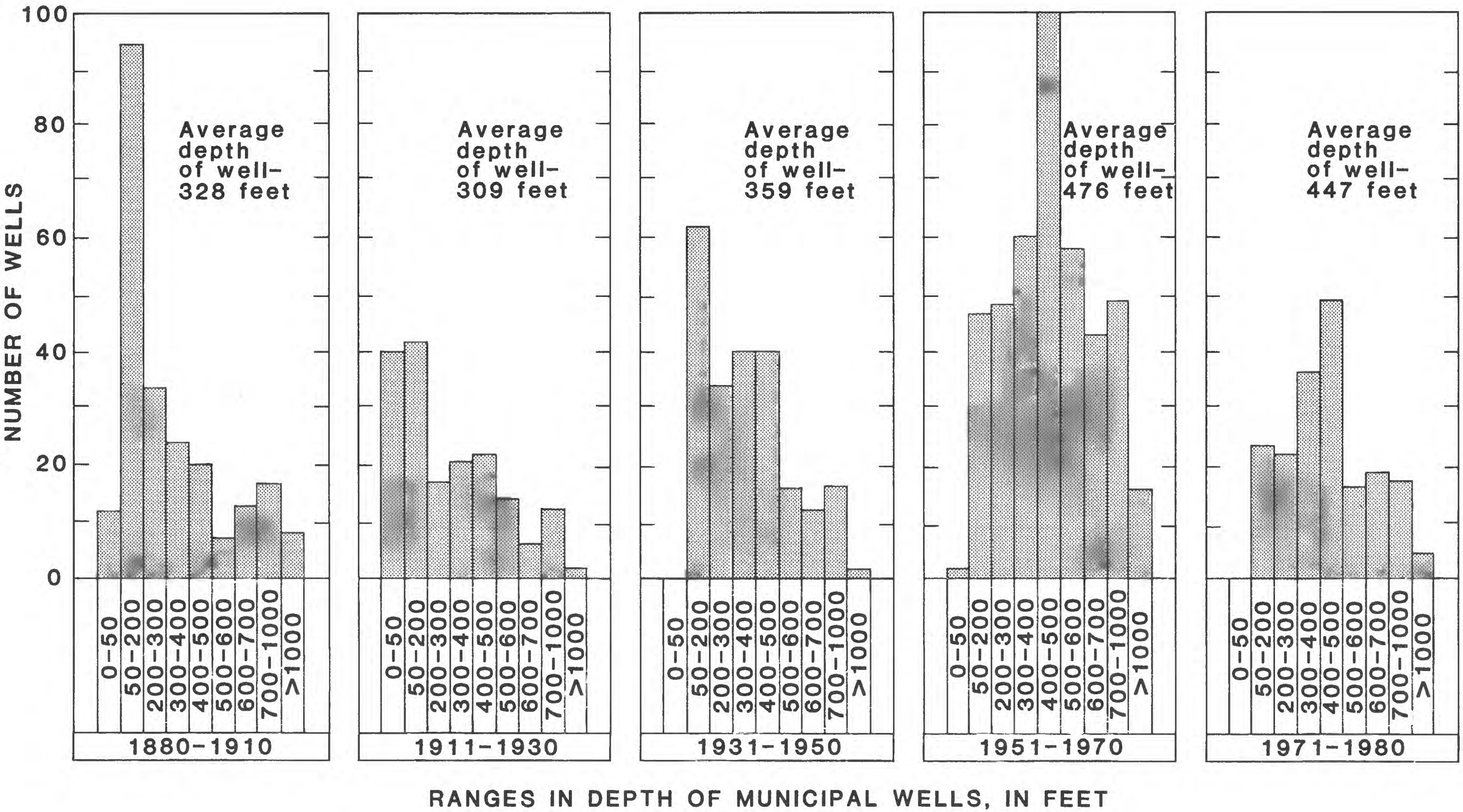


Figure 4.2-1.--Trends in depths of municipal wells

4.3 Aquifer Completions, 1880-1980

950 WELLS COMPLETED IN BEDROCK AQUIFERS AND 294 WELLS COMPLETED IN DRIFT AQUIFERS

About 80 percent of the bedrock wells were single-aquifer completions and 20 percent were multiaquifer completions.

A total of 1,244 municipal wells drilled in southeastern Minnesota during 1880-1980 were inventoried for this report--950 wells were completed in bedrock aquifers and 294 wells tapped the drift aquifer. Of the bedrock wells, 763 were single-aquifer (80 percent of the total) and 187 were multiaquifer. Summaries of the distribution of single-aquifer and multiaquifer wells through time are shown in figure 4.3-1.

The Prairie du Chien-Jordan is the most extensively used aquifer in southeastern Minnesota, with a total of 537 municipal wells. The number of municipal wells tapping this aquifer has increased greatly since 1945 (fig. 4.3-1), due primarily to rapid suburban growth in the Twin Cities area. A total of 248 municipal wells have ben completed in this aquifer (figs. 3.3-1, 3.4-1, and 3.5-1) in the area since 1945.

The undifferentiated drift aquifer ranks second in the number of municipal wells with 294. Although many of the drift wells drilled before 1930 were completed in shallow alluvial aquifers less than 50 feet deep (fig. 4.2-1), most of the wells drilled since 1930 were completed in buried-drift aquifers.

The Mount Simon-Hinckley ranks third in number of municipal wells (225), 101 of which are multiaquifer wells. The number of municipal wells tapping this aquifer has increased greatly since 1955 (fig. 4.3-1), due primarily to the rapid suburban growth in those parts of the Twin Cities area where the Prairie du Chien-Jordan aquifer is absent. In these areas, 72 wells were completed in the Mount Simon-Hinckley between 1955 and 1980 (figs. 3.4-1 and 3.5-1).

The Ironton-Galesville ranks fourth, with 202 municipal wells, 131 of which are multiaquifer wells. Because 76 wells are Ironton-Galesville and Mount Simon-Hinckley multiaquifer wells (fig. 3.4-1), the number of wells tapping the Ironton-Galesville aquifer has also increased greatly since 1955 due to suburban expansion in those parts of the Twin Cities area where the Prairie du Chien-Jordan aquifer is absent.

The Upper Carbonate ranks fifth in aquifer use with 122 municipal wells, 23 of which are multiaquifer wells. The number of municipal wells tapping this aquifer increased during 1935-60 when 53 wells were completed in this aquifer (fig. 4.3-1). However, since 1960 only 13 municipal wells have been completed in the Upper Carbonate.

The St. Peter ranks sixth in aquifer use with 77 municipal wells, 52 of which are multiaquifer wells. There have been no significant changes in use of the St. Peter aquifer since 1880 (fig. 4.3-1).

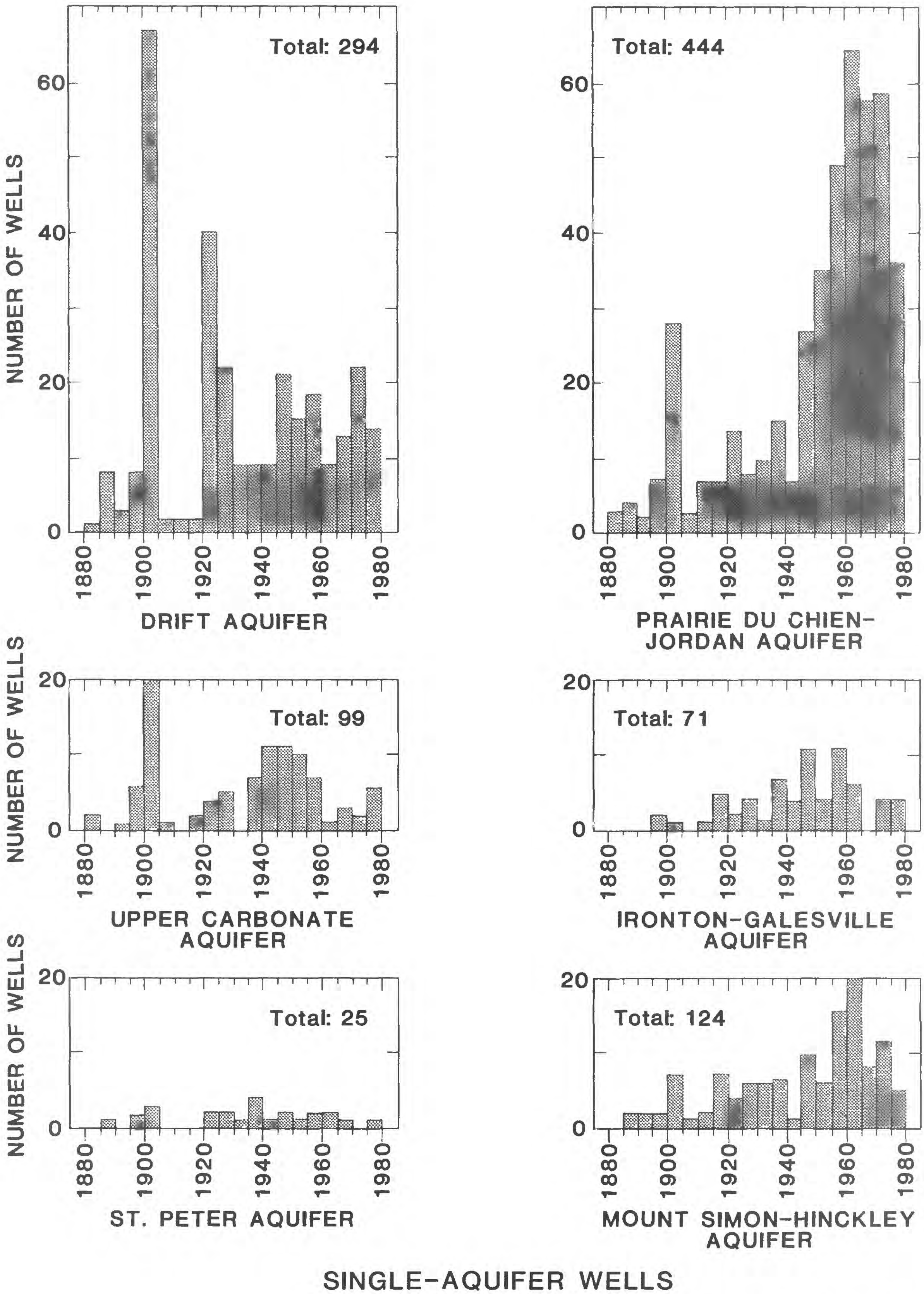
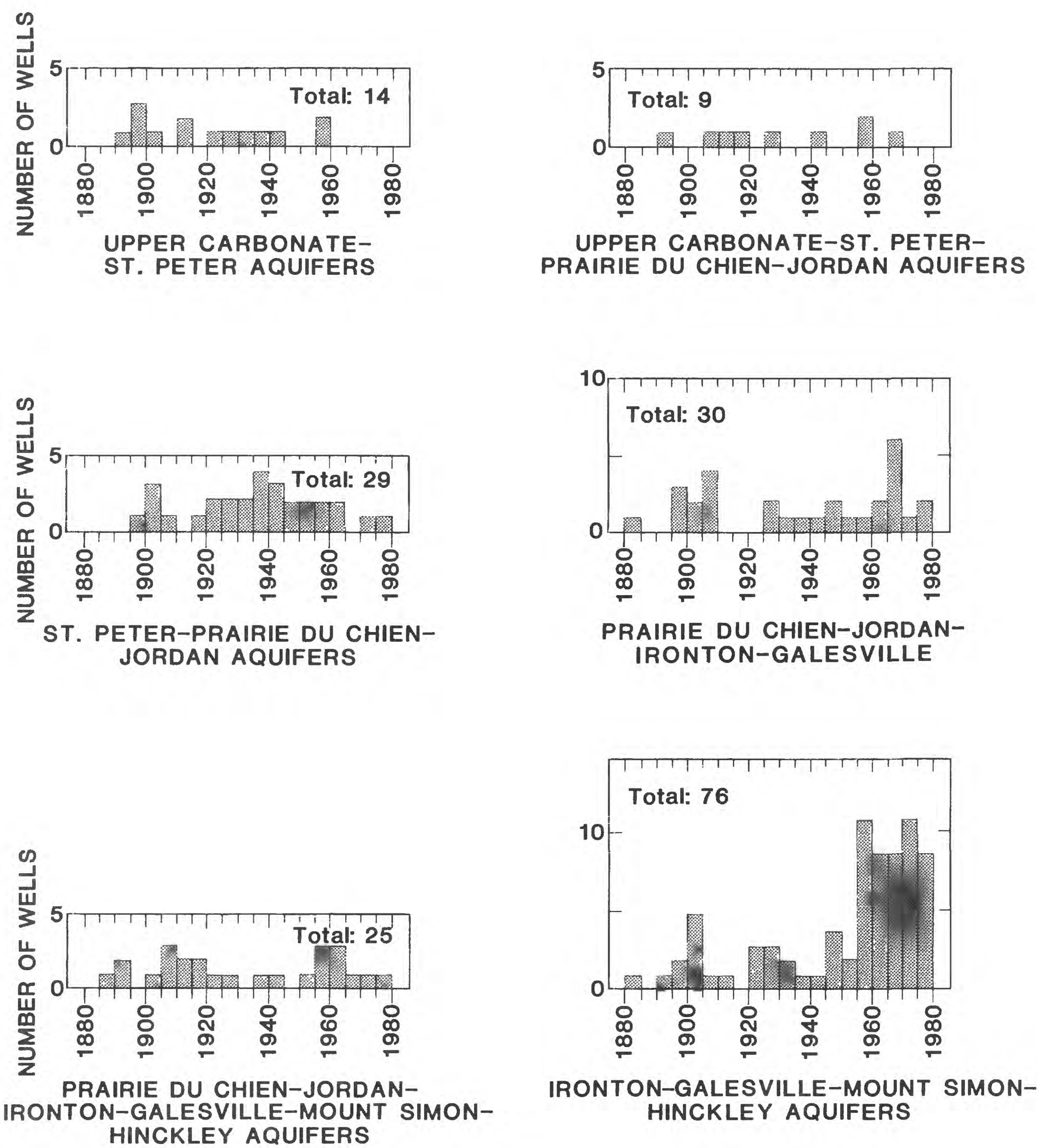


Figure 4.3-1.--Temporal distribution of aquifer



MULTIAQUIFER WELLS

completions for municipal wells, 1880-1980

4.4 Aquifer Preference, 1880-1980

46 PERCENT OF MUNICIPAL WELLS WERE COMPLETED IN SHALLOWEST BEDROCK AQUIFER; 30 PERCENT COMPLETED IN DEEPER BEDROCK AQUIFERS; 24 PERCENT COMPLETED IN DRIFT AQUIFERS

Use of Upper Carbonate aquifer for municipal wells has decreased markedly since 1950.

Of the 1,244 municipal wells inventoried, about 24 percent were completed in the drift aquifer, 46 percent were completed in the shallowest bedrock aquifer, and 30 percent were completed in deeper bedrock aquifers. Aquifer preference for municipal wells in southeastern Minnesota has changed during the last 100 years for a variety of reasons, such as: (1) increased knowledge of aquifer performance, (2) water-quality considerations, (3) increased water demands, (4) new drilling and well-construction technology, and (5) governmental regulations. Summaries of the distribution of aquifer preference through time are shown in table 4.4-1 for each subcrop area, and are discussed below.

Upper Carbonate Subcrop Area

The drift aquifer essentially has not been used in the Upper Carbonate subcrop area, and the Upper Carbonate aquifer has been the preferred completion zone for most municipal wells. Until 1950, about 76 percent of the wells were completed in the Upper Carbonate, and 24 percent were completed in deeper aquifers. However, after 1950, only 44 percent of the wells were completed in the Upper Carbonate, and 56 percent were completed in deeper aquifers. This shift in aquifer preference has resulted from policies developed by the Minnesota Department of Health to protect the public from potentially hazardous water supplied from shallow, carbonate aquifers in southeastern Minnesota.

St. Peter Subcrop Area

The St. Peter has never been the preferred aquifer for municipal wells in its subcrop area, and most of the wells tap more than one aquifer. Because the St. Peter is a poorly-cemented, medium to fine-grained sandstone, most high-capacity wells completed in the aquifer yield sand. The Prairie du Chien-Jordan is the preferred aquifer in the St. Peter subcrop area; it underlies the St. Peter throughout southeastern Minnesota. The St. Peter subcrop area occupies the central part of the Twin Cities area (fig. 2.2-1). Rapid suburban growth in this area was accommodated by municipal wells primarily tapping the Prairie du Chien-Jordan aquifer, which explains the decrease in the percent of wells completed in the St. Peter aquifer since 1950 (table 4.4-1).

Prairie du Chien-Jordan Subcrop Area

The Prairie du Chien-Jordan has always been the preferred aquifer in its subcrop area with 71 percent of all municipal wells completed in it. About 92 percent of the municipal wells tapping the Prairie du Chien-Jordan were single aquifer.

Ironton-Galesville Subcrop Area

Before 1910, about 70 percent of the municipal wells in the Ironton-Galesville subcrop area were completed in the drift aquifer. Between 1911 and 1970, installation of drift wells decreased to 31 percent of the total drilled in the area, and Ironton-Galesville wells increased to 57 percent. However, from 1971-80 installation of Ironton-Galesville wells decreased to 40 percent and installation of wells in deeper aquifers increased to 37 percent.

Mount Simon-Hinckley Subcrop Area

The drift aquifer has always been preferred in the Mount Simon-Hinckley subcrop area with 64 percent of all municipal wells completed in it. Before 1931, many of the drift wells were in alluvium of the Mississippi and Minnesota Rivers, but since 1931 most of the drift wells have been completed in buried-drift aquifers.

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Table 4.4-1.--Distribution of aquifer preference for municipal wells in each aquifer subcrop area, 1880-1980.

Time period	Wells drilled in aquifer subcrop area	Wells completed in drift aquifer	Wells completed in shallowest bedrock aquifer: single-aquifer	Wells completed in shallowest bedrock aquifer: multi-aquifer	Wells completed in deeper aquifer	Drift wells, as percent of total	Shallowest bedrock wells, as percent of total	Deeper bedrock aquifer wells, as percent of total
UPPER CARBONATE AQUIFER SUBCROP AREA								
1880-1910	48	0	30	7	11	0	77	23
1911-1930	22	0	11	7	4	0	82	18
1931-1950	46	0	29	4	13	2	72	28
1951-1970	57	1	21	4	31	2	44	54
1971-1980	18	0	8	0	10	0	44	56
Total	191	1	99	22	69	0	63	47
ST. PETER AQUIFER SUBCROP AREA								
1880-1910	67	531	3	6	27	46	14	40
1911-1930	31	4	4	5	18	13	29	58
1931-1950	42	1	7	9	25	2	38	60
1951-1970	128	7	3	2	116	5	4	91
1971-1980	30	0	0	1	29	0	3	97
Total	298	43	17	23	215	15	13	72
PRAIRIE DU CHIEN-JORDAN AQUIFER SUBCROP AREA								
1880-1910	39	3	24	5	7	8	74	18
1911-1930	41	15	18	5	3	37	56	7
1931-1950	46	9	26	4	7	20	65	15
1951-1970	134	6	92	4	32	4	72	24
1971-1980	83	9	62	2	10	11	77	12
Total	343	42	222	20	59	12	71	17
IRONTON-GALESVILLE AQUIFER SUBCROP AREA								
1880-1910	30	21	3	5	1	70	27	3
1911-1930	34	14	11	6	3	41	50	9
1931-1950	47	13	21	7	6	28	60	12
1951-1970	52	14	19	12	7	27	60	13
1971-1980	35	8	5	9	13	23	40	37
Total	198	70	59	39	30	35	50	15
MOUNT SIMON-HINCKLEY AQUIFER SUBCROP AREA								
1880-1910	45	34	11	-	0	76	24	0
1911-1930	48	33	15	-	0	67	33	0
1931-1950	41	25	16	-	0	61	39	0
1951-1970	54	27	27	-	0	50	50	0
1971-1980	26	19	7	-	0	73	27	0
Total	214	138	76	-	0	64	36	0
Grand Total	1,244	294	473	104	373	24	46	30

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5.0 INVENTORY OF MUNICIPAL WELLS

THE FOLLOWING TABLE LISTS AN INVENTORY OF MUNICIPAL WELLS

DRILLED IN SOUTHEASTERN MINNESOTA

FROM 1880 TO 1980

Included are the city name, date of well completion, well depths, and aquifer completion.

An inventory of the 1,244 municipal wells drilled in southeastern Minnesota from 1880 to 1980 is listed in table 5.0-1. Included in the inventory are the city name, year well drilled, well depth and the aquifer completion. These data are presented in alphabetical order first by county, and then by city.

Information contained in table 5.0-1 comprises the data base from which the analyses of well installations and aquifer utilization were derived.

Table 5.0-1

UC, Upper Carbonate; St.P, St. Peter; PdC-J, Prairie du Chien-Jordan; I-G, Ironton-Galesville; Mt.S-H, Mount Simon-Hinckley; xp, multiaquifer well; p19xx, pre-19xx; 4-x, 4 wells

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
ANOKA COUNTY								
Anoka	1913	420	--	--	--	--	x	--
	1928	520	--	--	--	--	xp	xp
	1947	452	--	--	--	xp	xp	--
	1962	660	--	--	--	--	--	x
	1965	444	--	--	--	--	x	--
	1976	640	--	--	--	--	xp	xp
Blaine	1959	675	--	--	--	--	xp	xp
	1960	665	--	--	--	--	xp	xp
	1960	515	--	--	--	--	x	--
	1964	524	--	--	--	--	x	--
	1966	686	--	--	--	--	xp	xp
	1968	741	--	--	--	--	xp	xp
	1969	487	--	--	--	--	x	--
	1971	500	--	--	--	--	x	--
	1971	480	--	--	--	--	x	--
	1972	480	--	--	--	--	x	--
	1974	735	--	--	--	--	xp	xp
	1977	228	x	--	--	--	--	--
	1977	685	--	--	--	--	xp	xp
Circle Pines	p1948	512	--	--	--	--	x	--
	1959	321	--	--	--	x	--	--
	1967	270	--	--	--	x	--	--
Coon Rapids	1957	472	--	--	--	--	x	--
	1957	684	--	--	--	--	xp	xp
	1958	145	x	--	--	--	--	--
	1960	602	--	--	--	--	xp	xp
	1960	158	--	--	--	x	--	--
	1961	705	--	--	--	--	xp	xp
	1964	632	--	--	--	--	xp	xp
	1965	702	--	--	--	--	--	x
	1969	500	--	--	--	--	x	--
	1970	684	--	--	--	--	xp	xp
	1972	627	--	--	--	--	xp	xp
	1975	604	--	--	--	--	xp	xp

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
ANOKA COUNTY--Continued								
Coon Rapids--Continued	1976	615	--	--	--	--	xp	xp
	1977	613	--	--	--	--	xp	xp
	1978	693	--	--	--	--	xp	xp
Fridley	1957	925	--	--	--	--	xp	xp
	1960	842	--	--	--	--	--	x
	1960	870	--	--	--	--	--	x
	1961	830	--	--	--	--	--	x
	1961	845	--	--	--	--	--	x
	1962	104	x	--	--	--	--	--
	1965/70	102/262	--	--	--	x	--	--
	1969/70	104/265	--	--	--	x	--	--
	1969	119	x	--	--	--	--	--
	1969	199	x	--	--	--	--	--
	1970	669	--	--	--	xp	xp	--
	1970	276	--	--	--	x	--	--
	1970	332	--	--	--	x	--	--
Lexington	1967	306	x	--	--	--	--	--
Lino Lakes	1971	171	--	--	--	x	--	--
	1972	306	--	--	--	x	--	--
St. Francis	1974	416	--	--	--	--	--	x
Spring Lake Park	1961	741	--	--	--	--	xp	xp
	1965	694	--	--	--	--	--	x
	1970	726	--	--	--	--	--	x
BLUE EARTH COUNTY								
Amboy	p1905	485	--	--	--	x	--	--
	1929	584	--	--	--	x	--	--
	1946	503	--	--	--	x	--	--
Eagle Lake	1949	399	--	--	--	x	--	--
	1973	400	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			BLUE EARTH COUNTY--Continued					
Goodthunder	p1905	374	--	--	--	x	--	--
Lake Crystal	1894	737	--	--	--	--	xp	xp
	1896	625	--	--	--	xp	xp	--
	1923	36	x	--	--	--	--	--
	1980	---	--	--	--	--	--	--
Madison Lake	1912	485	--	--	--	x	--	--
	1960	384	x	--	--	--	--	--
	1975	313	--	--	--	x	--	--
Mankato	1875	2204	--	--	--	--	xp	xp
	1889-1906	1450	--	--	--	--	xp	xp
	1889-1906	1365	--	--	--	--	xp	xp
	1889-1906	650?	--	--	--	x	--	--
	1889-1906	650?	--	--	--	x	--	--
	1925	56	4-x	--	--	--	--	--
	1925	320	--	--	--	2-x	--	--
	1932	56	x	--	--	--	--	--
	1934	63	x	--	--	--	--	--
	1939	67	x	--	--	--	--	--
	1939	65	x	--	--	--	--	--
	1947	73	x	--	--	--	--	--
	1953	69	x	--	--	--	--	--
	1954	847	--	--	--	--	xp	xp
	1955	67	x	--	--	--	--	--
	1955	600	--	--	--	--	x	--
	1956	852	--	--	--	--	xp	xp
	1959	715	--	--	--	--	xp	xp
	1971	55	x	--	--	--	--	--
Mapleton	1890's	224	--	--	--	x	--	--
	1890's	265	--	--	--	x	--	--
	p1924	402	--	--	--	x	--	--
	1946	400	--	--	--	x	--	--
Pemberton	1948	248	--	--	--	x	--	--
	1955	263	--	--	--	x	--	--
Rapidan	1950	501	--	--	--	--	x	--
	1959	501	--	--	--	--	x	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
BLUE EARTH COUNTY--Continued								
St. Clair	1913	320	--	--	--	x	--	--
	1978	405	--	--	--	x	--	--
Skyline	1977	501	--	--	--	x	--	--
Vernon Center	1907	129	x	--	--	--	--	--
	1928	255	--	--	--	--	x	--
	1937	318	--	--	--	--	x	--
	1978	351	--	--	--	--	x	--
BROWN COUNTY								
Hanska	p1924	179	x	--	--	--	--	--
	1976	172	x	--	--	--	--	--
CARVER COUNTY								
Chanhassen	1962	518	--	--	--	x	--	--
	1969	471	--	--	--	x	--	--
	1973	500	--	--	--	x	--	--
Chaska	p1911	210	x	--	--	--	--	--
	1908	680	--	--	--	--	xp	xp
	1927	170	x	--	--	--	--	--
	1932	187	x	--	--	--	--	--
	1938	570	--	--	--	--	xp	xp
	1959	112	x	--	--	--	--	--
	1972	813	--	--	--	--	xp	xp
	1975	790	--	--	--	--	xp	xp
Cologne	1934	344	--	--	--	--	x	--
	p1972	725	--	--	--	--	xp	xp
Hamburg	p1924	340	--	--	--	--	x	--
	1943	745	--	--	--	--	xp	xp
Mayer	1961	280	--	--	--	--	x	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
CARVER COUNTY--Continued								
New Germany	1960	460	--	--	--	--	x	--
Norwood	1926	675	--	--	--	xp	xp	--
	1951	450	--	--	--	x	--	--
Victoria	1976	640	--	--	--	xp	xp	--
Waconia	1924	848	--	--	--	--	xp	xp
	1949	480	--	--	--	--	x	--
	1971	283	x	--	--	--	--	--
	1971	285	x	--	--	--	--	--
Watertown	p1923	111	x	--	--	--	--	--
	1927	150	x	--	--	--	--	--
	1945	164	x	--	--	--	--	--
	1953	154	x	--	--	--	--	--
Young America	1946	923	--	--	--	--	xp	xp
	1979	943	--	--	--	--	--	x
CHISAGO COUNTY								
Center City	p1924	100	4-x	--	--	--	--	--
	1949	130	x	--	--	--	--	--
	1966	620	--	--	--	--	xp	xp
Chisago City	1936	451	--	--	--	--	x	--
	1950	401	--	--	--	--	x	--
	1957	602	--	--	--	--	x	--
Lindstrom	p1924	292	x	--	--	--	--	--
	p1941	300	x	--	--	--	--	--
	1953	615	--	--	--	--	--	x
	1972	615	--	--	--	--	--	x
North Branch	1923	20	x	--	--	--	--	--
	1947	762	--	--	--	--	--	x
	1978	360	--	--	--	--	--	x

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
CHISAGO COUNTY--Continued								
Rush City	1918	86	--	--	--	--	--	x
	1924	30	4-x	--	--	--	--	--
	1929	86	--	--	--	--	--	x
	1948	97	--	--	--	--	--	x
	1957	96	--	--	--	--	--	x
	1964	104	--	--	--	--	--	x
Shaefer	1967	550	--	--	--	--	--	x
Stacy	1967	495	--	--	--	--	--	x
Taylors Falls	1942	169	--	--	--	--	x	--
	1955	246	--	--	--	--	x	--
	1957	172	--	--	--	--	x	--
	1957	212	--	--	--	--	x	--
	1961	350	--	--	--	--	x	--
Wyoming	1965	650	--	--	--	--	--	x
	1973	701	--	--	--	--	--	x
DAKOTA COUNTY								
Apple Valley	1963	520	--	--	--	x	--	--
	1964	529	--	--	--	x	--	--
	1969	584	--	--	--	x	--	--
	1971	504	--	--	--	x	--	--
	1974	487	--	--	--	x	--	--
	1976	507	--	--	--	x	--	--
	1977	494	--	--	--	x	--	--
Burnsville	1961	548	--	--	--	x	--	--
	1963	427	--	--	--	x	--	--
	1963	593	--	--	--	x	--	--
	1965	298	--	--	--	x	--	--
	1966	306	--	--	--	x	--	--
	1968	420	--	--	--	x	--	--
	1969	314	--	--	--	x	--	--
	1970	335	--	--	--	x	--	--
	1970	264	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
Burnsville--Continued	1971	356	--	--	--	x	--	--
	1972	357	--	--	--	x	--	--
	1975	948	--	--	--	--	xp	xp
	1975	386	--	--	--	x	--	--
Eagan	1959	447	--	--	--	x	--	--
	1961	505	--	--	--	x	--	--
	1964	444	--	--	--	x	--	--
	1968	425	--	--	--	x	--	--
	1971	440	--	--	--	x	--	--
	1973	408	--	--	--	x	--	--
	1976	414	--	--	--	x	--	--
	1978	500	--	--	--	x	--	--
Empire Township	1973	410	--	--	--	x	--	--
Farmington	p1922	45	6-x	--	--	--	--	--
	1932	62	x	--	--	--	--	--
	1936	402	--	--	--	x	--	--
	1952	400	--	--	--	x	--	--
	1959	424	--	--	--	x	--	--
	1973	477	--	--	--	x	--	--
Forest Hills Addition	1961	605	--	--	--	x	--	--
Hampton	p1924	380	--	--	--	x	--	--
	p1942	286	--	--	xp	xp	--	--
	1965	302	--	--	--	x	--	--
Hastings	p1907	495	--	--	--	x	--	--
	1930	916	--	--	--	xp	xp	xp
	1933	202	--	--	--	x	--	--
	1956	311	--	--	--	x	--	--
	p1963	400	--	--	--	x	--	--
	1970	356	--	--	--	x	--	--
	1972	332	--	--	--	x	--	--
Inver Grove Heights	1956	431	--	--	--	x	--	--
	1960	439	--	--	--	x	--	--
	1970	407	--	--	--	x	--	--
	1970	360	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
DAKOTA COUNTY--Continued								
Lakeville	1882	1085	--	--	--	xp	xp	--
	1932	302	--	--	--	x	--	--
	1964	517	--	--	--	x	--	--
	1965	472	--	--	--	x	--	--
	1968	460	--	--	--	x	--	--
	1969	505	--	--	--	x	--	--
Mendota	1948	264	--	--	xp	xp	--	--
	1956	488	--	--	--	x	--	--
	1960	495	--	--	--	x	--	--
New Trier	p1924	160	--	--	x	--	--	--
	p1942	204	--	--	xp	xp	--	--
	1966	560	--	--	--	x	--	--
Randolph	1979	356	--	--	--	x	--	--
Rosemount	1928	243	--	--	xp	xp	--	--
	1949	450	--	--	--	x	--	--
	1962	471	--	--	--	x	--	--
	1962	520	--	--	--	x	--	--
	1963	490	--	--	--	x	--	--
	1965	485	--	--	--	x	--	--
	1976	490	--	--	--	x	--	--
South St. Paul	p1907	880	--	--	--	xp	xp	xp
	p1922	921	--	--	--	xp	xp	xp
	1937	340	--	--	--	x	--	--
	1948	362	--	--	--	x	--	--
	1961	401	--	--	--	x	--	--
	1972	484	--	--	--	x	--	--
	1972	255	--	--	--	x	--	--
	1973	436	--	--	--	x	--	--
	1975	500	--	--	--	x	--	--
	1975	381	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
DODGE COUNTY								
Claremont	p1917	243	--	x	--	--	--	--
	1927	250	--	x	--	--	--	--
Dodge Center	1911	526	--	xp	xp	xp	--	--
	1962	868	--	--	--	x	--	--
	1966	913	--	--	--	x	--	--
Hayfield	p1905	380	--	x	--	--	--	--
	1931	600	--	xp	xp	--	--	--
	1945	340	--	x	--	--	--	--
	1976	678	--	--	xp	xp	--	--
Kasson	p1900	295	--	--	x	--	--	--
	p1924	325	--	xp	xp	--	--	--
	1937	325	--	xp	xp	--	--	--
	1937	200	x	--	--	--	--	--
	1953	852	--	--	--	x	--	--
	1969	857	--	--	--	x	--	--
Mantorville	p1944	220	--	--	x	--	--	--
	1970	750	--	--	--	x	--	--
West Concord	1900	225	--	x	--	--	--	--
	1970	803	--	--	--	x	--	--
	1971	803	--	--	--	x	--	--
FARIBAULT COUNTY								
Blue Earth	1889	1243	--	--	--	x	--	--
	1904	670	--	--	--	x	--	--
	p1905	375	--	--	x	--	--	--
	1923	198	--	x	--	--	--	--
	1937	384	--	--	xp	xp	--	--
	1941	379	--	--	xp	xp	--	--
	1941	650	--	--	--	x	--	--
	1957	1110	--	--	--	xp	xp	xp

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
FARIBAULT COUNTY--Continued								
Bricelyn	p1905	107	--	x	--	--	--	--
	1930	170	--	x	--	--	--	--
	1944	280	--	x	--	--	--	--
	1972	300	--	x	--	--	--	--
Delavan	p1905	473	--	--	xp	xp	--	--
	1940	185	--	--	x	--	--	--
	1963	200	--	--	x	--	--	--
Easton	p1905	110	--	--	x	--	--	--
	1930	150	--	--	x	--	--	--
	1963	202	--	--	x	--	--	--
Elmore	p1905	110	--	x	--	--	--	--
	1936	117	--	x	--	--	--	--
	1978	550	--	--	--	x	--	--
Frost	1941	214	--	x	--	--	--	--
	1967	216	--	x	--	--	--	--
Kiester	p1905	400	--	x	--	--	--	--
	1941	250	--	x	--	--	--	--
	1977	385	--	x	--	--	--	--
Minnesota Lake	p1905	380	--	--	xp	xp	--	--
	p1924	380	--	--	--	x	--	--
	1937	470	--	--	xp	xp	--	--
	1962	477	--	--	xp	xp	--	--
	1972	477	--	--	xp	xp	--	--
Walters	1924	170	--	x	--	--	--	--
Wells	p1896	266	--	xp	xp	--	--	--
	p1905	216	--	x	--	--	--	--
	1952	700	--	--	--	x	--	--
	1961	670	--	--	--	x	--	--
	1965	705	--	--	--	x	--	--
Winnebago	1896	266	--	--	xp	xp	--	--
	1940	362	--	--	--	x	--	--
	1975	368	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion Drift	UC	St.P	PdC-J	I-G	Mt.S-H
FILLMORE COUNTY								
Canton	1914	404	--	--	--	x	--	--
Fountain	1882	376	--	--	--	x	--	--
	p1905	376	--	--	--	x	--	--
	1906	608	--	--	--	x	--	--
	1951	707	--	--	--	x	--	--
Greenleafton	1978	490	--	--	x	--	--	--
Harmony	p1889	220	--	--	x	--	--	--
	p1930	317	--	xp	xp	--	--	--
	1936	1222	--	--	--	xp	xp	xp
	1950	748	--	--	--	x	--	--
Lanesboro	1939	775	--	--	--	--	--	x
	1957	910	--	--	--	--	--	x
Mabel	p1905	140	--	--	--	x	--	--
	1932	150	--	--	--	x	--	--
Ostrander	p1948	250	--	x	--	--	--	--
	1964	1030	--	--	--	x	--	--
Peterson	p1922	---	--	--	x	--	--	--
	1960	239	--	--	--	--	x	--
Preston	1896	---	--	--	--	x	--	--
	1951	252	--	--	--	x	--	--
	1957	327	--	--	--	x	--	--
Rushford	1887	---	--	--	--	x	--	--
	1901	553	--	--	--	--	xp	xp
Spring Valley	1882	14	--	x	--	--	--	--
	1951	916	--	--	--	x	--	--
	1954	630	--	--	--	--	xp	xp
	1959	931	--	--	xp	xp	--	--
	1970	582	--	--	--	--	xp	xp
Wykoff	1899	600	--	--	--	x	--	--
	1935	450	--	--	xp	xp	--	--
	1958	834	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
FREEBORN COUNTY								
Albert Lea	1885	300	--	x	--	--	--	--
	1892	660	--	xp	xp	xp	--	--
	p1905	448	--	x	--	--	--	--
	1928	305	--	x	--	--	--	--
	1955	1133	--	--	xp	xp	--	--
	1957	319	--	x	--	--	--	--
	1959	688	--	xp	xp	xp	--	--
	1960	680	--	xp	xp	xp	--	--
	1960	300	--	x	--	--	--	--
	1965	350	--	x	--	--	--	--
Alden	1899	100	--	x	--	--	--	--
	p1900	215	--	x	--	--	--	--
	1948	484	--	x	--	--	--	--
	1955	474	--	x	--	--	--	--
Clarks Grove	p1940	340	--	x	--	--	--	--
	1960	350	--	x	--	--	--	--
	1977	350	--	x	--	--	--	--
Congor	p1944	246	--	x	--	--	--	--
	1945	390	--	x	--	--	--	--
Elmwood Terrace	1960	202	--	x	--	--	--	--
Emmons	p1905	160	--	x	--	--	--	--
	p1927	183	--	x	--	--	--	--
	1953/65	270/1165	--	--	--	x	--	--
Freeborn	p1944	142	--	x	--	--	--	--
	p1953	350	--	x	--	--	--	--
	1956	350	--	x	--	--	--	--
Geneva	p1951	432	--	x	--	--	--	--
	1976	365	--	x	--	--	--	--
Glenville	1953	265	--	x	--	--	--	--
	1969	370	--	x	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			FREEBORN COUNTY--Continued					
Hartland	p1905	311	--	x	--	--	--	--
	p1939	255	--	x	--	--	--	--
	1947	386	--	x	--	--	--	--
	1957	597	--	xp	xp	--	--	--
Hayward	1947	379	--	x	--	--	--	--
	1969	1135	--	--	xp	xp	--	--
Hollandale	p1939	180	--	x	--	--	--	--
	1944	219	--	x	--	--	--	--
	1954	220	--	x	--	--	--	--
Manchester	1948	423	--	x	--	--	--	--
Myrtle	p1946	173	--	x	--	--	--	--
Twin Lakes	1960	370	--	x	--	--	--	--
			GOODHUE COUNTY					
Bellechester	1953	243	--	--	--	x	--	--
	1976	450	--	--	--	--	x	--
Cannon Falls	p1905	270	--	--	--	x	--	--
	p1905	400	--	--	--	x	--	--
	p1929	400	--	--	--	x	--	--
	1952	637	--	--	--	xp	xp	--
Dennison	1980	435	--	--	--	x	--	--
Goodhue	p1905	275	--	--	--	x	--	--
	1939	314	--	--	--	x	--	--
Kenyon	p1905	30	x	--	--	--	--	--
	1908	665	--	--	xp	xp	--	--
	1920	480	--	--	--	x	--	--
	1955	710	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
GOODHUE COUNTY--Continued								
Pine Island	p1905	156	--	--	--	x	--	--
	1922	300	--	--	--	x	--	--
	1970	565	--	--	--	x	--	--
	1979	452	--	--	--	x	--	--
Red Wing	1910	436	--	--	--	--	--	x
	1924	475	--	--	--	--	--	x
	1930	718	--	--	--	--	--	x
	1932	495	--	--	--	--	--	x
	p1939	495	--	--	--	--	--	x
	1939	610	--	--	--	--	--	x
	1951	770	--	--	--	--	--	x
	1956	610	--	--	--	--	--	x
	1971	595	--	--	--	--	--	x
	1975	630	--	--	--	--	--	x
Wanamingo	1926	200	--	--	xp	xp	--	--
	1966	590	--	--	--	x	--	--
Zumbrota	1897	210	--	--	--	x	--	--
	p1939	191	--	--	--	x	--	--
	1955	479	--	--	--	x	--	--
	1971	404	--	--	--	x	--	--
	1971	418	--	--	--	x	--	--
HENNEPIN COUNTY								
Bloomington	1973	440	--	--	--	x	--	--
	1973	392	--	--	--	x	--	--
	1974	950	--	--	--	--	xp	xp
	1978	376	--	--	--	x	--	--
Brooklyn Center	1957	310	--	--	--	x	--	--
	1959	340	--	--	--	x	--	--
	1960	319	--	--	--	x	--	--
	1960	316	--	--	--	x	--	--
	1965	316	--	--	--	x	--	--
	1966	317	--	--	--	x	--	--
	1971	317	--	--	--	x	--	--
	1971	316	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
HENNEPIN COUNTY--Continued								
Brooklyn Park	1961	737	--	--	--	--	--	x
	1961	617	--	--	--	--	xp	xp
	1967	655	--	--	--	--	xp	xp
	1967	672	--	--	--	--	xp	xp
	1970	241	--	--	--	x	--	--
	1971	182	x	--	--	--	--	--
	1972	240	x	--	--	--	--	--
	1975	275	x	--	--	--	--	--
	1975	162	x	--	--	--	--	--
Champlin	1974	700	--	--	--	--	xp	xp
	1974	275	--	--	--	--	x	--
	1978	602	--	--	--	--	xp	xp
Eden Prairie	1970	405	--	--	--	x	--	--
	1971	394	--	--	--	x	--	--
	1978	392	--	--	--	x	--	--
Edina	1934	460	--	--	--	x	--	--
	1938	391	--	--	xp	xp	--	--
	1949	469	--	--	--	x	--	--
	1950	500	--	--	--	x	--	--
	1954	443	--	--	--	x	--	--
	1954	503	--	--	--	x	--	--
	1955	547	--	--	--	x	--	--
	1957	1130	--	--	--	--	--	x
	1958	472	--	--	--	x	--	--
	1963	1001	--	--	--	--	--	x
	1963	403	--	--	--	x	--	--
	1964	1081	--	--	--	--	--	x
	1964	494	--	--	--	x	--	--
	1964	420	--	--	--	x	--	--
	1967	405	--	--	--	x	--	--
	1967	380	--	--	--	x	--	--
	1970	461	--	--	--	x	--	--
	1973	450	--	--	--	x	--	--
Excelsior	1957	465	--	--	--	x	--	--
	1959	448	--	--	--	x	--	--
	1974	465	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
HENNEPIN COUNTY--Continued								
Hopkins	1920	780	--	--	--	xp	xp	--
	1926	728	--	--	--	xp	xp	--
	1948	475	--	--	--	x	--	--
	1954	548	--	--	--	x	--	--
	1967	500	--	--	--	x	--	--
	1977	545	--	--	--	x	--	--
Long Lake	1946	340	--	--	--	x	--	--
	1965	448	--	--	--	x	--	--
Loretto	1943	592	--	--	--	--	x	--
	1964	340	--	--	--	--	x	--
Maple Grove	1972	680	--	--	--	--	xp	xp
	1973	267	x	--	--	--	--	--
	1978	157	x	--	--	--	--	--
Maple Plain	1939	418	--	--	--	--	x	--
	1959	435	--	--	--	--	x	--
Medina	1960	205	x	--	--	--	--	--
	1968	310	x	--	--	--	--	--
	1975	240	x	--	--	--	--	--
Medina-Morningside	1961	205	x	--	--	--	--	--
	1968	204	x	--	--	--	--	--
Minnetonka	1955	513	--	--	--	x	--	--
	1956	581	--	--	--	x	--	--
	1957	530	--	--	--	x	--	--
	1958	564	--	--	--	x	--	--
	1962	619	--	--	--	x	--	--
	1963	465	--	--	--	x	--	--
	1967	486	--	--	--	x	--	--
	1968	395	--	--	--	x	--	--
	1969	505	--	--	--	x	--	--
	1970	498	--	--	--	x	--	--
	1971	535	--	--	--	x	--	--
	1972	475	--	--	--	x	--	--
	1972	555	--	--	--	x	--	--
	1974	450	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			HENNEPIN COUNTY--Continued					
Minnetonka--Continued	1978	464	--	--	--	x	--	--
	1978	575	--	--	--	x	--	--
	1978	444	--	--	--	x	--	--
Minnetonka Beach	1958	403	--	--	--	x	--	--
	1958	393	--	--	--	x	--	--
Minnetrista	1958	600	--	--	--	--	x	--
	1973	675	--	--	--	xp	xp	--
Mound	1934	285	x	--	--	--	--	--
	1939	509	--	--	--	--	x	--
	1947	317	--	--	--	--	x	--
	1957	140	x	--	--	--	--	--
	1962	729	--	--	--	--	--	x
	1976	175	x	--	--	--	--	--
	1976	200	x	--	--	--	--	--
New Hope	1959	422	--	--	--	x	--	--
Orono	1971	385	--	--	--	x	--	--
	1971	269	x	--	--	--	--	--
Osseo	1918	537	--	--	--	--	x	--
	1945	235	x	--	--	--	--	--
	1957	235	x	--	--	--	--	--
Plymouth	1961	505	--	--	--	x	--	--
	1962	476	--	--	--	x	--	--
	1962	486	--	--	--	x	--	--
	1962	498	--	--	--	x	--	--
	1966	402	--	--	--	x	--	--
	1970	394	--	--	--	x	--	--
	1972	448	--	--	--	x	--	--
	1975	470	--	--	--	x	--	--
Richfield	1961	437	--	--	--	x	--	--
	1961	437	--	--	--	x	--	--
	1962	412	--	--	--	x	--	--
	1962	405	--	--	--	x	--	--
	1962	421	--	--	--	x	--	--
	1963	408	--	--	--	x	--	--
	1977	1066	--	--	--	--	xp	xp

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
HENNEPIN COUNTY--Continued								
Robbinsdale	1938	624	--	--	xp	xp	xp	--
	1944	624	--	--	--	xp	xp	--
	1948	471	--	--	--	x	--	--
	1953	402	--	--	--	x	--	--
	1956	477	--	--	--	x	--	--
Rockford	1955	142	x	--	--	--	--	--
	1971	130	x	--	--	--	--	--
	1976	210	--	--	--	--	x	--
	1976	310	--	--	--	--	x	--
Rogers	1955	300	--	--	--	--	x	--
	1966	356	--	--	--	--	x	--
St. Anthony	1954	500	--	--	--	x	--	--
	1954	427	--	--	--	x	--	--
St. Bonifacius	1958	880	--	--	--	--	xp	xp
	1972	480	--	--	--	--	--	x
St. Louis Park	1932	540	--	--	--	x	--	--
	1938	290	--	--	x	--	--	--
	1938	290	--	--	x	--	--	--
	1939	286	--	--	x	--	--	--
	1946	503	--	--	--	x	--	--
	1947	465	--	--	--	x	--	--
	1948	480	--	--	--	x	--	--
	1952	446	--	--	--	x	--	--
	1955	507	--	--	--	x	--	--
	1955	500	--	--	--	x	--	--
	1956	473	--	--	--	x	--	--
	1960	1095	--	--	--	--	--	x
	1964	1045	--	--	--	--	--	x
	1965	1095	--	--	--	--	--	x
	1965	485	--	--	--	x	--	--
	1969	503	--	--	--	x	--	--
	1973	500	--	--	--	x	--	--
Spring Park	1964	638	--	--	--	--	x	--
	1964	391	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
HENNEPIN COUNTY--Continued								
Tonka Bay	1972	423	--	--	--	x	--	--
	1973	448	--	--	--	x	--	--
Wayzata	1938	154	x	--	--	--	--	--
	1956	150	x	--	--	--	--	--
	1965	100	x	--	--	--	--	--
	1971	507	--	--	--	x	--	--
West Minneapolis	p1905	600	--	--	xp	xp	xp	--
HOUSTON COUNTY								
Caledonia	1882	270	--	--	--	x	--	--
	1894	320	--	--	--	x	--	--
	p1924	417	--	--	--	x	--	--
	1954	405	--	--	--	x	--	--
	1960	407	--	--	--	x	--	--
Eitzen	p1952	300	--	--	--	x	--	--
	1963	372	--	--	--	x	--	--
	1980	935	--	--	--	--	--	x
Hokah	1897	375	--	--	--	--	x	--
	p1905	544	--	--	--	--	xp	xp
	1957	458	--	--	--	--	xp	xp
Houston	p1905	302	--	--	--	--	--	x
	1948	257	--	--	--	--	--	x
La Crescent	1939	159	--	--	--	--	x	--
	1955	591	--	--	--	--	--	x
	1962	550	--	--	--	--	--	x
Spring Grove	p1905	396	--	--	xp	xp	--	--
	p1920	449	--	xp	xp	xp	--	--
	1941	630	--	xp	xp	xp	--	--
	1954	557	--	--	--	x	--	--
	1974	612	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			ISANTI COUNTY					
Braham	p1921	20	3-x	--	--	--	--	--
	p1921	110	x	--	--	--	--	--
	1938	150	--	--	--	--	--	x
	1967	174	--	--	--	--	--	x
Cambridge	p1905	140	--	--	--	--	--	x
	p1919	225	--	--	--	--	--	x
	1931	175	--	--	--	--	--	x
	1935	150	--	--	--	--	--	x
	1948	369	--	--	--	--	--	x
	1954	323	--	--	--	--	--	x
	1965	630	--	--	--	--	--	x
Isanti	1976	378	--	--	--	--	--	x
			JACKSON COUNTY					
Alpha	1895	96	x	--	--	--	--	--
	1968	96	x	--	--	--	--	--
Jackson	p1905	20	x	--	--	--	--	--
	1958	42	x	--	--	--	--	--
	1959	42	x	--	--	--	--	--
	1978	52	x	--	--	--	--	--
Lakefield	1902	190	x	--	--	--	--	--
	1931	204	x	--	--	--	--	--
	1952	204	x	--	--	--	--	--
	1955	185	x	--	--	--	--	--
	1967	204	x	--	--	--	--	--
	1968	189	x	--	--	--	--	--
			KANABEC COUNTY					
Mora	p1905	210	x	--	--	--	--	--
	1951	180	x	--	--	--	--	--
	1957	170	x	--	--	--	--	--
	1962	200	x	--	--	--	--	--
	1964	190	x	--	--	--	--	--
	1977	203	x	--	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
LE SUEUR COUNTY								
Cleveland	p1939	317	x	--	--	--	--	--
	1953	383	x	--	--	--	--	--
Elysian	p1905	289	--	--	--	x	--	--
	1939	284	--	--	--	x	--	--
	1978	595	--	--	--	x	--	--
Kasota	1975	140	x	--	--	--	--	--
Kilkenny	p1905	250	--	--	--	x	--	--
	1937	380	--	--	--	x	--	--
Le Center	p1905	340	--	--	--	x	--	--
	1926	553	--	--	--	x	--	--
	1967	543	--	--	--	x	--	--
Le Sueur	p1901	668	--	--	--	--	xp	xp
	1929	650	--	--	--	--	xp	xp
	1942	275	x	--	--	--	--	--
	1953	250	x	--	--	--	--	--
	1964	232	x	--	--	--	--	--
	1968	248	x	--	--	--	--	--
	1978	661	--	--	--	--	xp	xp
Montgomery	p1900	246	x	--	--	--	--	--
	1933	598	--	--	--	xp	xp	--
	1950	617	--	--	--	--	x	--
	1964	712	--	--	--	xp	xp	xp
Waterville	p1897	185	--	--	x	--	--	--
	1929	204	--	--	x	--	--	--
	1938	300	--	--	xp	xp	--	--
	1955	240	--	--	x	--	--	--
	1965	615	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
MARTIN COUNTY								
Ceylon	1900	300	x	--	--	--	--	--
	1945	300	x	--	--	--	--	--
	1958	300	x	--	--	--	--	--
Dunnell	1947	168	x	--	--	--	--	--
	1960	182	x	--	--	--	--	--
	1962	168	x	--	--	--	--	--
Fairmount	1894	404	--	--	--	--	--	--
	1941	107	x	--	--	--	--	--
Granada	1950	131	x	--	--	--	--	--
Northrop	p1940	154	x	--	--	--	--	--
	1955	145	x	--	--	--	--	--
Sherburne	1895	248	x	--	--	--	--	--
	p1918	260	x	--	--	--	--	--
	1960	275	x	--	--	--	--	--
Trimont	1940	120	x	--	--	--	--	--
	1946	120	x	--	--	--	--	--
	1968	140	x	--	--	--	--	--
Truman	p1905	104	x	--	--	--	--	--
	1929	100	x	--	--	--	--	--
	1941	95	x	--	--	--	--	--
	1946	96	x	--	--	--	--	--
	1954	100	x	--	--	--	--	--
	1963	590	--	--	--	--	--	x
Welcome	p1901	185	x	--	--	--	--	--
	p1905	150	x	--	--	--	--	--
	p1924	248	x	--	--	--	--	--
	1950	260	x	--	--	--	--	--
	1965	156	x	--	--	--	--	--
	1978	550	--	--	--	--	--	x

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			MC LEOD COUNTY					
Glencoe	1897	1728	--	--	--	--	--	x
	1925	600	--	--	--	--	--	x
	1946	602	--	--	--	--	--	x
	1947	600	--	--	--	--	--	x
Lester Prairie	p1905	22	x	--	--	--	--	--
	p1930	197	--	--	--	--	--	x
	1943	200	--	--	--	--	--	x
Plato	1953	98	x	--	--	--	--	--
Silver Lake	p1933	120	x	--	--	--	--	--
	1965	190	x	--	--	--	--	--
	1974	220	x	--	--	--	--	--
Winsted	p1923	175	x	--	--	--	--	--
	1946	149	x	--	--	--	--	--
	1957	185	x	--	--	--	--	--
			MILLE LACS COUNTY					
Princeton	p1900	187	x	--	--	--	--	--
	1912	271	--	--	--	--	--	x
	1948	162	x	--	--	--	--	--
	1962	155	--	--	--	--	--	x
	1972	158	x	--	--	--	--	--
	1978	165	x	--	--	--	--	--
			MOWER COUNTY					
Adams	1897	291	--	x	--	--	--	--
	1929	756	--	xp	xp	xp	--	--
Austin	1891	175	--	x	--	--	--	--
	p1900	580	--	xp	xp	--	--	--
	p1900	600	--	xp	xp	--	--	--
	p1905	300	--	x	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
MOWER COUNTY--Continued								
Austin--Continued	p1905	710	--	xp	xp	--	--	--
	p1917	150	--	x	--	--	--	--
	1949	125	--	x	--	--	--	--
	1949	132	--	x	--	--	--	--
	1954	375	--	x	--	--	--	--
	1956	575	--	xp	xp	--	--	--
	1956	1075	--	--	--	x	--	--
	1959	558	--	--	x	--	--	--
	1962	1017	--	--	--	x	--	--
	1976	992	--	--	--	x	--	--
	1977	147	--	x	--	--	--	--
Brownsdale	p1938	150	--	x	--	--	--	--
	p1959	171	--	x	--	--	--	--
Dexter	p1922	228	--	x	--	--	--	--
Elkton	1946	324	--	x	--	--	--	--
	1952	306	--	x	--	--	--	--
Grand Meadow	p1900	125	--	x	--	--	--	--
	1908	338	--	x	--	--	--	--
	1959	614	--	--	x	--	--	--
	1978	1035	--	--	--	x	--	--
Le Roy	p1905	422	--	x	--	--	--	--
	p1930	298	--	x	--	--	--	--
	1977	352	--	x	--	--	--	--
Lyle	p1905	240	--	x	--	--	--	--
	1954	252	--	x	--	--	--	--
Mapleview	p1951	426	--	x	--	--	--	--
Racine	1968	512	--	--	x	--	--	--
Rose Creek	1904	179	--	x	--	--	--	--
	1953	192	--	x	--	--	--	--
Sargeant	p1938	340	--	x	--	--	--	--
	1972	400	--	x	--	--	--	--
Waltham	1944	220	--	x	--	--	--	--
	1976	275	--	x	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
NICOLLET COUNTY								
Nicollet	p1905	175	x	--	--	--	--	--
	p1905	175	x	--	--	--	--	--
	p1923	416	--	--	--	--	x	--
	1967	215	x	--	--	--	--	--
North Mankato	p1926	325	--	--	--	--	x	--
	1928	60	2-x	--	--	--	--	--
	1934	76	x	--	--	--	--	--
	1948	680	--	--	--	--	xp	xp
	1959	687	--	--	--	--	xp	xp
	1975	865	--	--	--	--	--	x
St. Peter	p1900	362	--	--	--	xp	xp	--
	p1905	40	--	--	--	x	--	--
	p1917	592	--	--	--	xp	xp	xp
	1928	44	--	--	--	x	--	--
	1933	76	--	--	--	x	--	--
	1948	130	--	--	--	x	--	--
	1951	667	--	--	--	xp	xp	xp
	1957	670	--	--	--	xp	xp	xp
	1972	127	--	--	--	x	--	--
OLMSTED COUNTY								
Byron	1932	510	--	--	xp	xp	--	--
	1963	698	--	--	--	x	--	--
	1978	706	--	--	--	x	--	--
Chatfield	p1905	200	--	--	--	x	--	--
	p1924	230	--	--	--	x	--	--
	1929	478	--	--	--	x	--	--
	1977	624	--	--	--	x	--	--
Chester Heights	1959	600	--	--	--	x	--	--
Dover	p1924	100	--	--	2-xp	2-xp	--	--
	p1924	82	--	--	x	--	--	--
	1937	200	--	--	--	x	--	--
	1970	524	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
OLMSTED COUNTY--Continued								
Eyota	p1900	203	--	xp	xp	--	--	--
	1937	699	--	--	--	x	--	--
	1960	608	--	--	--	x	--	--
	1963	612	--	--	--	x	--	--
Lenwood Heights	1958	531	--	--	--	x	--	--
Ostor Estates	1964	650	--	--	--	x	--	--
Rochester	1890	24	x	--	--	--	--	--
	1890	32	x	--	--	--	--	--
	1890	32	x	--	--	--	--	--
	1914	418	--	--	--	x	--	--
	1917	415	--	--	--	x	--	--
	1918	412	--	--	--	x	--	--
	1918	424	--	--	--	x	--	--
	1922	430	--	--	--	x	--	--
	1926	50	3-x	--	--	--	--	--
	1930	50	x	--	--	--	--	--
	1934	430	--	--	--	x	--	--
	1938	452	--	--	--	x	--	--
	1941	448	--	--	--	x	--	--
	1947	463	--	--	--	x	--	--
	1948	506	--	--	--	x	--	--
	1949	457	--	--	--	x	--	--
	1950	466	--	--	--	x	--	--
	1955	445	--	--	--	x	--	--
	1958	462	--	--	--	x	--	--
	1958	434	--	--	--	x	--	--
	1959	1045	--	--	--	--	xp	xp
	1960	905	--	--	--	xp	xp	--
	1963	806	--	--	--	xp	xp	--
	1963	881	--	--	--	xp	xp	xp
	1964	907	--	--	--	xp	xp	xp
	1965	981	--	--	--	xp	xp	--
	1966	728	--	--	--	xp	xp	--
	1967	806	--	--	--	xp	xp	--
	1968	685	--	--	--	xp	xp	--
	1969	848	--	--	--	xp	xp	--
	1978	624	--	--	--	x	--	--
	1979	448	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
OLMSTED COUNTY--Continued								
Stewartville	p1905	163	--	x	--	--	--	--
	1908	710	--	xp	xp	xp	--	--
	1944	755	--	--	--	x	--	--
	1956	805	--	--	xp	xp	--	--
	1975	1136	--	--	--	xp	xp	xp
Sunnyslopes	1948	296	--	--	--	x	--	--
PINE COUNTY								
Askov	1954	725	--	--	--	--	--	x
	1956	110	--	--	--	--	--	x
Finlayson	p1969	170	--	--	--	--	--	x
Hinckley	p1900	390	--	--	--	--	--	x
	p1934	110	--	--	--	--	--	x
	1975	459	--	--	--	--	--	x
Pine City	1913	134	x	--	--	--	--	--
	1936	135	x	--	--	--	--	--
	1947	385	--	--	--	--	--	x
Sandstone	p1905	750	--	--	--	--	--	x
	p1905	150	--	--	--	--	--	x
	p1917	732	--	--	--	--	--	x
	1969	385	--	--	--	--	--	x
RAMSEY COUNTY								
Lauderdale	1950	552	--	--	xp	xp	--	--
Moundsview	1961	836	--	--	--	--	xp	xp
	1962	835	--	--	--	--	--	x
	1970	317	--	--	--	x	--	--
	1970	680	--	--	--	xp	xp	xp
	1970	350	--	--	--	x	--	--
	1970	679	--	--	--	--	xp	xp

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			Aquifer completion					
RAMSEY COUNTY--Continued								
New Brighton	1918	386	--	--	--	x	--	--
	1954	500	--	--	--	x	--	--
	1955	495	--	--	--	x	--	--
	1961	523	--	--	--	x	--	--
	1963	501	--	--	--	x	--	--
	1968	437	--	--	--	x	--	--
	1970	482	--	--	--	x	--	--
	1971	476	--	--	--	x	--	--
North St. Paul	p1905	400	--	--	--	x	--	--
	p1927	700	--	--	--	xp	xp	--
	1935	470	--	--	--	x	--	--
	1946	522	--	--	--	x	--	--
	1957	468	--	--	--	x	--	--
	1964	475	--	--	--	x	--	--
	1977	531	--	--	--	x	--	--
St. Paul	1890	112av.	5-x	--	--	--	--	--
	1890	865	--	--	--	xp	xp	xp
	1896	112av.	2-x	--	--	--	--	--
	1896	62av.	18-x	--	--	--	--	--
	1896	388av.	--	--	--	10-x	--	--
	1904	659	--	--	--	xp	xp	--
	1904	925	--	--	--	xp	xp	xp
	1910	708av.	--	--	--	4-xp	4-xp	--
	1910	801	--	--	--	xp	xp	xp
	1910	1065	--	--	--	xp	xp	xp
	1911	550	--	--	--	x	--	--
	1911	378	--	--	--	x	--	--
Shoreview	1962	536	--	--	--	x	--	--
	1968	395	--	--	--	x	--	--
	1970	413	--	--	--	x	--	--
	1974	423	--	--	--	x	--	--
Vadnais Heights	1978	476	--	--	--	x	--	--
White Bear Lake	p1905	112	--	--	x	--	--	--
	1944	374	--	--	--	x	--	--
	1944	375	--	--	--	x	--	--
	1956	436	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
RAMSEY COUNTY--Continued								
White Bear Lake--Continued	1959	490	--	--	--	x	--	--
	1962	963	--	--	--	--	xp	xp
	1966	513	--	--	--	x	--	--
	1969	476	--	--	--	x	--	--
White Bear Township	p1956	445	--	--	--	x	--	--
	1961	435	--	--	--	x	--	--
	1976	362	--	--	--	x	--	--
	1976	408	--	--	--	x	--	--
RICE COUNTY								
Dundas	1980	390	--	--	--	x	--	--
Faribault	p1892	30	x	--	--	--	--	--
	p1899	30	x	--	--	--	--	--
	p1895	1000	--	--	--	xp	xp	xp
	p1905	750	--	--	--	xp	xp	--
	1919	1482	--	--	--	xp	xp	xp
	1936	750	--	--	--	xp	xp	--
	1938	450	--	--	--	x	--	--
	1951	410	--	--	--	x	--	--
	1964	407	--	--	--	x	--	--
	1968	407	--	--	--	x	--	--
Lonsdale	p1905	322	--	--	--	--	x	--
	1937	733	--	--	--	--	x	--
	1949	875	--	--	--	--	xp	xp
	1963	773	--	--	--	--	x	--
Morristown	1924	30	x	--	--	--	--	--
	1931	150	--	--	x	--	--	--
	1947	200	--	--	x	--	--	--
Northfield	1895	647	--	--	--	x	--	--
	1944	401	--	--	--	x	--	--
	1950	403	--	--	--	x	--	--
	1969	410	--	--	--	x	--	--
	1977	390	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			RICE COUNTY--Continued					
Webster	p1965	221	--	--	--	x	--	--
	p1965	363	--	--	--	x	--	--
			SCOTT COUNTY					
Belle Plain	1885	93	x	--	--	--	--	--
	p1905	213	x	--	--	--	--	--
	p1924	30	5-x	--	--	--	--	--
	p1928	310	x	--	--	--	--	--
	1946	280	x	--	--	--	--	--
	1956	282	x	--	--	--	--	--
Elko	1969	487	--	--	--	x	--	--
Jordan	p1917	137	--	--	--	--	x	--
	1920	232	--	--	--	--	x	--
	1928	362	--	--	--	--	xp	xp
	1942	350	--	--	--	--	x	--
	1950	542	--	--	--	--	xp	xp
New Market	p1924	412	--	--	--	x	--	--
New Prague	p1900	289	--	--	--	--	x	--
	p1917	317	--	--	--	--	x	--
	1925	596	--	--	--	--	x	--
	1938	400	--	--	--	--	x	--
	1949	398	--	--	--	--	x	--
Prior Lake	p1935	100	x	--	--	--	--	--
	1937	228	x	--	--	--	--	--
	1952	190	x	--	--	--	--	--
	1970	364	--	--	--	x	--	--
	1975	365	--	--	--	x	--	--
Savage	p1947	185	--	--	--	x	--	--
	p1947	165	--	--	--	x	--	--
	1959	250	--	--	--	x	--	--
	1977	846	--	--	--	--	xp	xp

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
SCOTT COUNTY--Continued								
Shakopee	1911	715	--	--	--	xp	xp	xp
	1944	760	--	--	--	xp	xp	xp
	1956	780	--	--	--	xp	xp	xp
	1971	254	--	--	--	x	--	--
	1971	253	--	--	--	x	--	--
SHERBURNE COUNTY								
Big Lake	1957	210	--	--	--	--	--	x
	1967	230	--	--	--	--	--	x
Elk River	1919	308	--	--	--	--	--	x
	1975	313	--	--	--	--	--	x
Zimmerman	1975	345	--	--	--	--	--	x
SIBLEY COUNTY								
Arlington	p1918	154	x	--	--	--	--	--
	1921	671	--	--	--	--	xp	xp
	1938	732	--	--	--	--	--	x
Gaylord	p1917	508	--	--	--	--	x	--
	1942	400	x	--	--	--	--	--
	1948	435	x	--	--	--	--	--
	1969	410	x	--	--	--	--	--
Green Isle	1934	802	--	--	--	--	xp	xp
Henderson	1896	706	--	--	--	--	xp	xp
New Auburn	1974	238	x	--	--	--	--	--
Winthrop	1903	239	x	--	--	--	--	--
	1946	310	x	--	--	--	--	--
	1952	331	x	--	--	--	--	--
	1976	303	x	--	--	--	--	--
	1977	332	x	--	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
STEELE COUNTY								
Blooming Prairie	p1900	245	--	x	--	--	--	--
	1941	250	--	x	--	--	--	--
	1941	250	--	x	--	--	--	--
Ellendale	1901	212	--	x	--	--	--	--
	1943	280	--	x	--	--	--	--
	1953	394	--	x	--	--	--	--
Hope	1952	220	--	x	--	--	--	--
Medford	1951	588	--	--	xp	xp	--	--
	1977	576	--	--	--	x	--	--
Owatonna	1878	387	--	--	--	x	--	--
	1890	640	--	--	--	x	--	--
	p1905	90	--	2-x	--	--	--	--
	p1905	120	--	3-x	--	--	--	--
	1914	1142	--	--	--	xp	xp	xp
	1924	720	--	--	--	x	--	--
	1935/41	1107/695	--	--	--	x	--	--
	1938	720	--	--	--	x	--	--
	1957	700	--	--	--	x	--	--
	1970	767	--	--	--	x	--	--
	1977	1325	--	--	--	xp	xp	xp
WABASHA COUNTY								
Elgin	p1900	275	--	--	--	x	--	--
	p1920	150	--	--	--	x	--	--
	1954	410	--	--	--	x	--	--
	1968	420	--	--	--	x	--	--
Hammond	p1930	225	--	--	--	x	--	--
	p1930	50	x	--	--	--	--	--
	1972	90	--	--	--	x	--	--
Kellogg	p1937	310	--	--	--	--	--	x
	1960	145	x	--	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
WABASHA COUNTY--Continued								
Lake City	p1905	60	20-x	--	--	--	--	--
	p1929	450	--	--	--	--	--	x
	1949	146	x	--	--	--	--	--
	1954	162	x	--	--	--	--	--
Mazeppa	p1905	90	x	--	--	--	--	--
	p1924	158	x	--	--	--	--	--
Millville	p1924	186	--	--	--	x	--	--
Plainview	p1900	690	--	--	--	xp	xp	--
	p1905	325	--	--	--	x	--	--
	1953	419	--	--	--	x	--	--
	1973	444	--	--	--	x	--	--
Wabasha	1913	40	x	--	--	--	--	--
	1950	192	x	--	--	--	--	--
	1950	192	x	--	--	--	--	--
Zumbro Falls	p1924	28	x	--	--	--	--	--
	p1924	192	--	--	--	x	--	--
	1949	86	--	--	--	x	--	--
WASECA COUNTY								
Janesville	p1900	75	x	--	--	--	--	--
	1908	350	--	--	--	x	--	--
	1916	580	--	--	--	x	--	--
New Richland	p1905	160	--	x	--	--	--	--
	1923	160	--	x	--	--	--	--
	1941	427	--	xp	xp	--	--	--
	1963	461	--	--	xp	xp	--	--
Otisco	1953	150	x	--	--	--	--	--
Waldorf	1946	326	--	--	x	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
WASECA COUNTY--Continued								
Waseca	1896	1157	--	--	--	x	--	--
	1911	400	--	xp	xp	--	--	--
	1914	402	--	xp	xp	--	--	--
	1925	762	--	--	--	x	--	--
	1949	725	--	--	--	x	--	--
	1963	725	--	--	--	x	--	--
	1979	723	--	--	--	x	--	--
WASHINGTON COUNTY								
Bayport	1914	691	--	--	--	--	xp	xp
	1947	315	--	--	--	--	x	--
	1953	299	--	--	--	--	x	--
	1967	260	--	--	--	--	x	--
Cottage Grove	1953	325	--	--	--	x	--	--
	1958	350	--	--	--	x	--	--
	1960	388	--	--	--	x	--	--
	1962	418	--	--	--	x	--	--
	1967	358	--	--	--	x	--	--
	1973	427	--	--	--	x	--	--
	1974	370	--	--	--	x	--	--
	1977	396	--	--	--	x	--	--
Forest Lake	p1922	27	x	--	--	--	--	--
	1931	678	--	--	--	--	xp	xp
	1950	404	--	--	--	--	x	--
	1965	630	--	--	--	--	xp	xp
Hugo	1962	320	--	--	--	x	--	--
Lake Elmo	1962	805	--	--	--	--	xp	xp
Mahtomedi	1933	440	--	--	--	x	--	--
	1940	446	--	--	--	x	--	--
	1956	394	--	--	--	x	--	--
	1962	435	--	--	--	x	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
			WASHINGTON COUNTY--Continued					
Newport	1963	261	--	--	--	x	--	--
	1972	285	--	--	--	x	--	--
Oakdale	1958	581	--	--	--	x	--	--
	1964	542	--	--	--	x	--	--
	1969	510	--	--	--	x	--	--
	1975	494	--	--	--	x	--	--
	1978	520	--	--	--	x	--	--
Oak Park Heights	1967	310	--	--	--	x	--	--
	1975	290	--	--	--	x	--	--
St. Paul Park	1954	263	--	--	--	x	--	--
	1957	325	--	--	--	x	--	--
	1964	338	--	--	--	x	--	--
Scandia	1944	301	--	--	--	--	x	--
Stillwater	1889	750	--	--	--	--	--	x
	1925	787	--	--	--	--	xp	xp
	1948	440	--	--	--	--	xp	xp
	1956	243	--	--	--	x	--	--
	1963	225	--	--	--	x	--	--
	1969	271	--	--	--	x	--	--
	1972	840	--	--	--	--	xp	xp
	1974	242	--	--	--	x	--	--
	1978	305	--	--	--	x	--	--
Woodbury	1956	517	--	--	--	x	--	--
	1963	481	--	--	--	x	--	--
	1969	512	--	--	--	x	--	--
	1973	480	--	--	--	x	--	--
			WATONWAN COUNTY					
La Salle	1978	63	x	--	--	--	--	--
Lewisville	p1950	455	--	--	--	--	--	x

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
WATONWAN COUNTY--Continued								
Madelia	p1905	216	--	--	--	--	--	x
	p1905	249	--	--	--	--	--	x
	1927	260	--	--	--	--	--	x
	1931	250	--	--	--	--	--	x
	1947	462	--	--	--	--	--	x
	1953	327	--	--	--	--	--	x
	1957	462	--	--	--	--	--	x
	p1960	543	--	--	--	--	--	x
	p1960	550	--	--	--	--	--	x
	1972	546	--	--	--	--	--	x
St. James	1893	541	--	--	--	--	--	x
	p1907	480	--	--	--	--	--	x
	1924	490	--	--	--	--	--	x
	1928	---	10-x	--	--	--	--	--
	1949	---	x	--	--	--	--	--
	1950	186	x	--	--	--	--	--
	1971	69	x	--	--	--	--	--
	1971	72	x	--	--	--	--	--
	1974	72	x	--	--	--	--	--
	1978	67	x	--	--	--	--	--
WINONA COUNTY								
Altura	p1926	325	--	--	--	x	--	--
	1949	702	--	--	--	xp	xp	--
	1955	375	--	--	--	x	--	--
	1974	370	--	--	--	x	--	--
Elba	1927	326	--	--	--	--	x	--
Goodview	1962	400	--	--	--	--	--	x
	1975	455	--	--	--	--	--	x
Lewiston	p1900	353	--	--	--	x	--	--
	p1921	277	--	--	--	x	--	--
	1945	411	--	--	--	x	--	--
	1971	721	--	--	--	xp	xp	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion					
			Drift	UC	St.P	PdC-J	I-G	Mt.S-H
WINONA COUNTY--Continued								
Rollingstone	1900	340	--	--	--	--	xp	xp
	1966	410	--	--	--	--	xp	xp
St. Charles	1895	940	--	--	--	xp	xp	xp
	p1929	175	--	--	--	x	--	--
	1966	667	--	--	--	xp	xp	--
	1974	405	--	--	--	x	--	--
Utica	p1911	312	--	--	xp	xp	--	--
	p1937	387	--	--	--	x	--	--
	1959	480	--	--	--	x	--	--
Winona	1889	510	--	--	--	--	--	x
	p1905	28	x	--	--	--	--	--
	p1905	38	x	--	--	--	--	--
	p1905	484	--	--	--	--	--	x
	1915	504	--	--	--	--	--	x
	p1918	502	--	--	--	--	--	x
	p1918	503	--	--	--	--	--	x
	p1918	496	--	--	--	--	--	x
	1924	476	--	--	--	--	--	x
	1929	484	--	--	--	--	--	x
	1931	450	--	--	--	--	--	x
	1934	147	x	--	--	--	--	--
	1946	148	x	--	--	--	--	--
	1950	150	x	--	--	--	--	--
	1953	149	x	--	--	--	--	--
	1956	150	x	--	--	--	--	--
	1958	514	--	--	--	--	--	x
	1958	514	--	--	--	--	--	x
	1962	1075	--	--	--	--	--	x
WRIGHT COUNTY								
Albertville	1960	272	--	--	--	--	x	--
Buffalo	1920	339	x	--	--	--	--	--
	1949	334	x	--	--	--	--	--
	1968	330	x	--	--	--	--	--

Table 5.0-1.--Continued

City	Year well completed	Well depth (feet)	Aquifer completion: Drift	UC	St.P	PdC-J	I-G	Mt.S-H
WRIGHT COUNTY--Continued								
Delano	p1905	60	14-x	--	--	--	--	--
	1937	140	x	--	--	--	--	--
	1946	123	x	--	--	--	--	--
Howard Lake	1947	923	--	--	--	--	--	x
	1957	1040	--	--	--	--	--	x
	1972	148	x	--	--	--	--	--
Monticello	p1905	237	x	--	--	--	--	--
	1968	250	--	--	--	--	--	x
	1971	250	x	--	--	--	--	--
Montrose	p1924	120	x	--	--	--	--	--
	1940	693	--	--	--	--	--	x
	1976	184	x	--	--	--	--	--
	1979	186	x	--	--	--	--	--
St. Michael	1941	107	x	--	--	--	--	--
	1947	200	--	--	--	--	x	--
	1959	320	--	--	--	--	x	--
Waverly	1973	174	x	--	--	--	--	--
	1975	143	x	--	--	--	--	--

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