GEOHYDROLOGY AND WATER QUALITY OF THE SAND RIDGE GLACIAL-DRIFT AQUIFER IN OSWEGO COUNTY, NEW YORK

By Todd S. Miller and Donald A. Sherwood

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4042

Prepared in cooperation with the

OWEGO COUNTY HEALTH DEPARTMENT

Ithaca, New York

1993

DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

DALLAS L. PECK, DIRECTOR

For additional information
write to:

Subdistrict Chief
U.S. Geological Survey
521 W. Seneca Street
Ithaca, NY 14850

Copies of this report can be
be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

PLATES
(in pocket)

CONVERSION FACTORS AND VERTICAL DATUM

Multiply inch-pound unit	*By*	*To obtain metric units*
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second
million gallons per day (Mgal/d)	0.003786	cubic meter per day
million gallons per day per square mile [(Mgal/d)/mi^2]	1,460	cubic meter per day per square kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon per day (gal/d)	3.785	liter per day
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.09290	meter squared per day
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight of solute per unit volume of water, and 1,000 micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

GEOHYDROLOGY AND WATER QUALITY OF THE SAND RIDGE GLACIAL-DRIFT AQUIFER IN OSWEGO COUNTY, NEW YORK

By Todd S. Miller and Donald A. Sherwood

Abstract

The Sand Ridge aquifer is a 15-mile-long, 15.9-square-mile ridge of glaciofluvial sediments (eskers, subglacial outwash, and kames) and glaciolacustrine (deltaic and beach) sediments that trend northwestward in the south-central part of Oswego County. The aquifer was deposited during deglaciation of the area 12,000 to 13,000 years before present. Recharge is derived solely from infiltration of precipitation that falls directly on the aquifer and averages from 7.9 to 15.9 million gallons per day. Wetlands are the principal discharge areas for the aquifer; other major discharge areas are the Oneida River to the south, streams whose headwaters originate on the aquifer, the Village of Phoenix well field (which pumps about 82.1 million gallons per year), and springs along the edge of the aquifer. The aquifer supplies water to about 7,000 people. Pumpage from the entire aquifer is estimated to be about 0.63 million gallons per day.

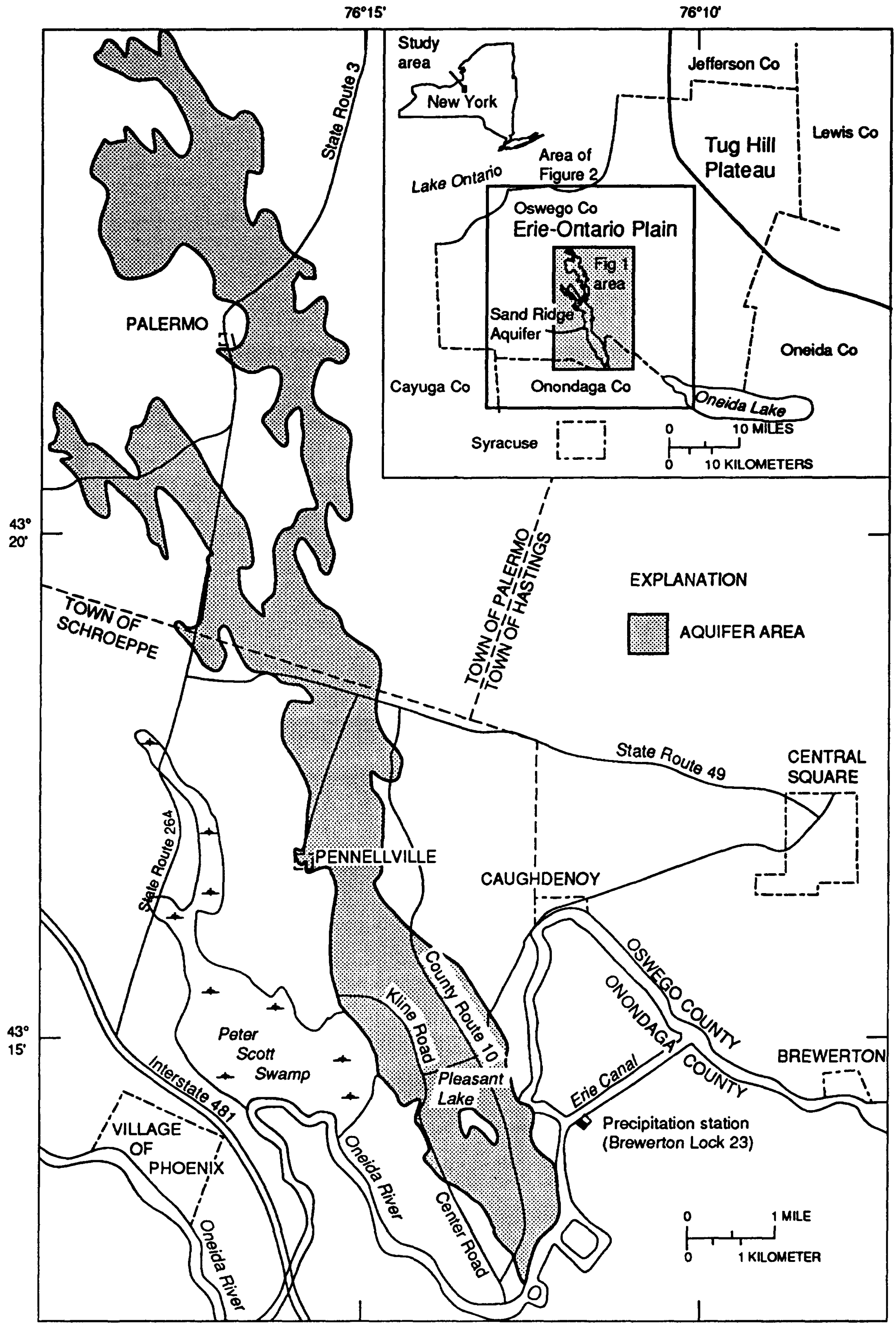
The aquifer is capable of yielding water at a rate of several hundred gallons per minute to large-diameter (greater than 6-inch diameter) screened wells that are properly developed. The two municipal wells for the Village of Phoenix can pump water at rates of 900 and 400 gallons per minute. Transmissivity calculated from laboratory tests of four core samples from one of these wells is 29,000 to 169,000 feet squared per day. Yields reported in drillers' logs for 52 domestic and farm wells that have open-ended, 6-inch-diameter casings ranged from 5 to 50 gallons per minute and averaged 15 gallons per minute.

Chemical analyses of ground-water samples indicate that the quality of water in the aquifer generally meets New York State Department of Health drinking-water standards, although iron concentrations in 9 of the 25 wells sampled exceeded the New York State drinking-water standards. A statistical comparison of median values of pH, specific conductance, and concentrations of common cations and anions indicated insignificant differences among water samples grouped according to the type of bedrock that underlies the aquifer.

INTRODUCTION

The State of New York and its counties and towns share responsibilities for the management and protection of aquifers. These responsibilities are especially important in areas that are undergoing rapid development. Highly permeable, unconfined glacial-drift aquifers are generally the principal sources of drinking water for communities and homeowners who live in areas that overlie the aquifer. Aquifers of this type are highly susceptible to contamination from a variety of sources, such as leaking petroleum-product storage tanks, septic-tank effluent, road salt, and agricultural pesticides and fertilizers. Implementation of land-use controls by the State and local governments can provide a high degree of protection for these aquifers, but formulation of sound regulations requires data on the aquifer boundaries, recharge areas, and other hydrologic characteristics. This information can be obtained through geohydrologic assessments such as the one described herein.

Some of the increasing development of the north Syracuse area, which lies 5 mi south of the Oneida River in Onondaga County (fig. 1 and pl. 1), is spreading north to the area underlain by the Sand Ridge glacial-drift aquifer in southern Oswego County. Several high-density housing developments have been built since the late 1970's, and land-use managers are expecting development in areas that



Base from New York State Department of Transportation, 1980, 1:250,000

Figure 1.--Location and major geographic features of the study area.

overlie the aquifer to continue during the next several years in response to the construction of a shopping mall near the southern part of the study area and a bridge over the Oneida River (part of the New York State Barge Canal system) that will improve access to the area.

In 1986, the U.S. Geological Survey (USGS), in cooperation with the Oswego County Health Department, began a geohydrologic and water-quality investigation of the Sand Ridge aquifer to provide information that can be used in the formulation of aquifer-protection plans. The findings presented herein form a basis for future studies to enable sound ground-water management of the aquifer, and the concepts presented here could be used to interpret the geohydrologic framework of similar aquifers elsewhere.

Purpose and Scope

This report describes the hydrology, geology, and water quality of the Sand Ridge glacial-drift aquifer and provides information on the aquifer properties that State and local governments can use to develop and implement ground-water protection strategies. It describes the extent and geologic framework of the aquifer, gives ground-water withdrawals and water-level fluctuations, depicts locations of recharge and discharge areas and directions of ground-water flow, and summarizes the ground-water quality. Oversize maps (in pocket) depict (1) potentiometric-surface altitude and directions of ground-water flow, (2) bedrock-surface altitude, and (3) surficial geology. Well records and water-quality analyses are summarized in tables.

Physiography and Climate

The Sand Ridge aquifer is a 15-mi-long, 15.9-mi^2 ridge of permeable sand and gravel on the Erie-Ontario plain in south-central Oswego County (see inset, fig. 1). The area has gently undulating topography with elevations that range from 365 to 480 ft above sea level. Land surface slopes generally southward at an average of 9 ft/mi, and most streams flow southward to the Oneida River, which is part of the New York State Barge Canal system and forms the southern boundary of the aquifer (fig. 1).

The surface of underlying bedrock also dips southward and, in the northern part of the study area (fig. 2), forms a relatively low, broad, east-west-trending ridge. This ridge forms a topographic drainage divide that separates streams that flow northward to Lake Ontario from streams that flow southward to the Oneida River. The Sand Ridge aquifer, part of which occupies a buried bedrock valley (fig. 2 and pl. 2), is on the southern slope of the bedrock ridge.

The climate of the area is humid continental with an average annual precipitation of 42 in., based on 55 years of record at the Brewerton Lock 23 precipitation station (National Oceanic and Atmospheric Administration, 1986) (fig. 1). Monthly precipitation is distributed relatively evenly throughout the year and generally is in the form of snow from mid-December to mid-March. The average annual temperature is 48° F, based on 100 years of record at the Syracuse weather station 10 mi south of the study area (not shown on map). Summer temperatures may exceed 90° F, and winter temperatures may drop below -10° F.

Methods of Data Collection

Geohydrologic data were collected in the field and from other sources, such as reports and records provided by drillers, local government agencies, consulting firms, and homeowners. The hydrogeology of the Sand Ridge aquifer was interpreted from data from 102 drillers' logs, 11 test holes, and seismic surveys at 8 sites. Water-quality data were collected at 25 wells.

Well Inventory and Test Drilling

Information on wells, including the location, owner, depth of well, depth to water, yield, and date drilled was compiled from reports and commercial drillers' logs. Additional well data were obtained through visits and interviews with the owners.

Eleven test holes were drilled with an auger rig to the top of bedrock in areas where well data were lacking. Two-inch-inside-diameter wells with screens were installed in nine of the test holes where significant water-bearing zones were penetrated. The test holes provided information on the character of geologic units, depth to bedrock (where penetrated), depth to water, and saturated thickness of the unconsolidated material. Well records are given in table 5 (at end of report).

Seismic Surveys

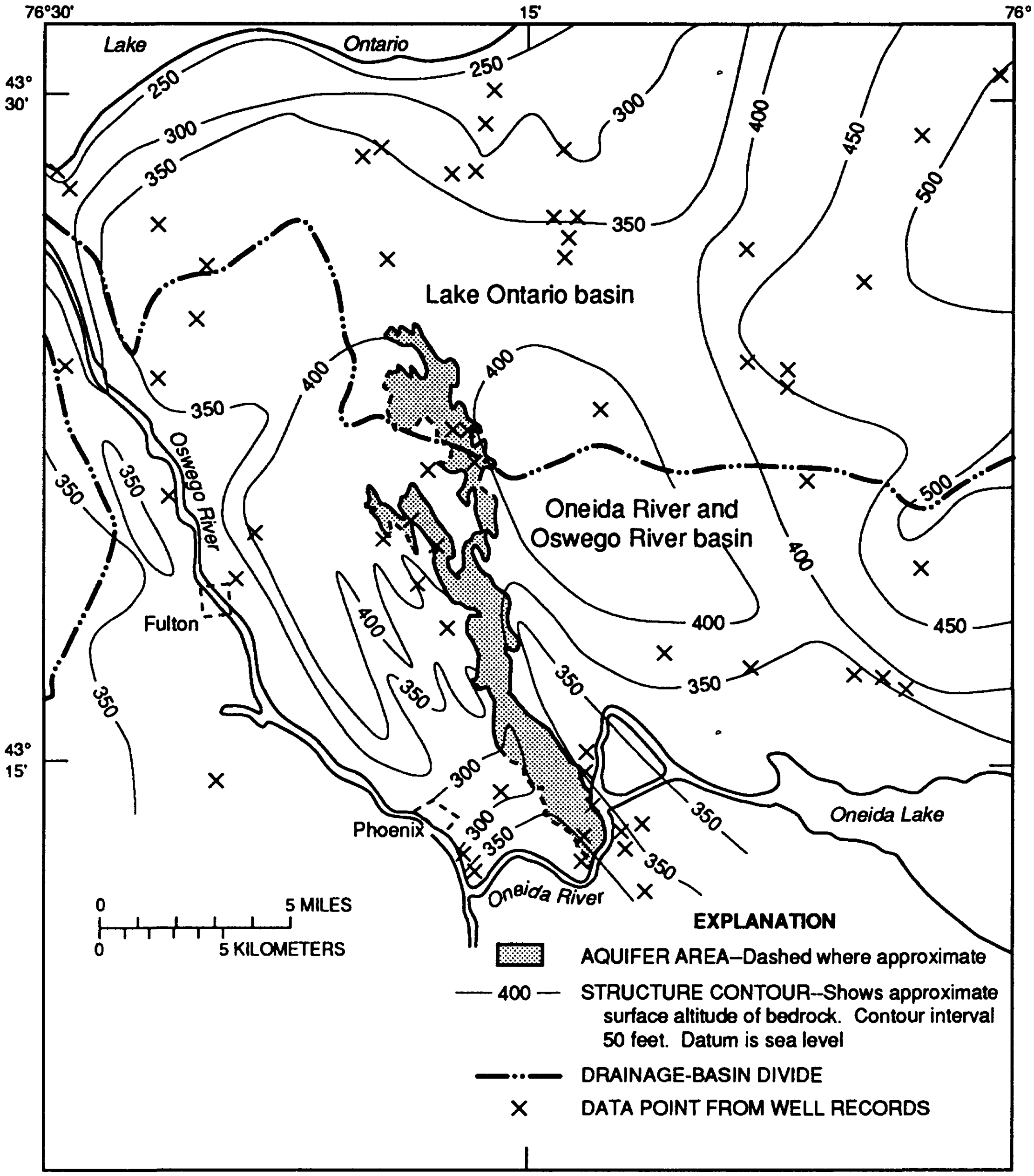
Seismic-refraction surveys were conducted at eight sites to supplement test-drilling data. These surveys provided information on depth to the water table and to bedrock. Location of seismic refraction surveys are shown on plate 1.

Because the aquifer is relatively thin (less than 80 ft in most places), the striking of a sledge hammer on a metal plate at land surface was an adequate energy source. A series of 12 geophones were spread in 120- to 240-ft arrays on the ground, and arrival times of compressional sound waves generated by the impact were recorded and plotted as a function of source-to-geophone distances. A three-layer parallel-boundary formula (Dobrin, 1976, p. 299) was used to calculate depth to water and to the till/bedrock interface:

$$z_1 = \frac{t_2}{2} \frac{V_2V_1}{\sqrt{(V_2)^2-(V_1)^2}}$$

$$z_2 = \frac{1}{2}\, t_3 \, \frac{2z_1\sqrt{(V_3)^2-(V_1)^2}}{V_3V_1} \, \frac{V_3V_2}{\sqrt{(V_3)^2-(V_2)^2}}$$

and $z_3 = z_1 + z_2$,



Base from U.S. Geological Survey, 1960, 1:250,000

Figure 2.--Bedrock-surface altitude in the western part of Oswego County. (Location is shown in fig. 1.)

where z_1 = depth to layer 2, (thickness of layer 1) (L),
z_2 = depth from bottom of layer 1 to top of layer 3, (thickness of layer 2) (L),
z_3 = depth from land surface to top of layer 3 (L),
t_2 = intercept time for layer 2 (t),
t_3 = intercept time for layer 3 (t),
V_1 = velocity of sound in layer 1 (L/t),
V_2 = velocity of sound in layer 2 (L/t), and
V_3 = velocity of sound in layer 3 (L/t).

Water-Level Measurements

Water levels were measured monthly in the nine wells installed by the USGS from May 1987 through May 1988 to measure the annual water-table fluctuation in different parts of the aquifer.

Ground-Water Sampling

Ground-water samples were collected for laboratory analysis from 25 wells that tap the Sand Ridge aquifer—9 from test wells drilled during the study and 16 from selected municipal, community, and private wells. Three of the community and municipal wells were sampled approximately every 6 weeks over a 1-year period. Results of water-quality analyses indicate (1) the natural water quality of the aquifer, (2) areas that may be affected by contamination, and (3) temporal and areal differences in water quality within the aquifer.

The USGS test wells were sampled by pumping with a peristaltic pump. A minimum of three well volumes of water were removed from the test well before samples were collected to ensure that the samples were representative of aquifer water. Private, domestic, and municipal wells were sampled at convenient taps after water had been allowed to run for several minutes to ensure that fresh water from the aquifer had flowed into the well.

Ground-water samples were analyzed for specific conductance, pH, and concentrations of common ions, nutrients, alkalinity, and hardness. In addition, water from the three wells sampled about every 6 weeks were analyzed for trace elements. These constituents are indicators of general ground-water quality. Results of the chemical analyses are presented in table 4 (at end of the report).

Acknowledgments

Appreciation is given to James Best of Best Well Drilling, Henry Bickom of Bickom Well Drilling[1], and William Yorton of Kincaid Well Drilling for providing well data.

GEOLOGY

The study area is underlain by unconsolidated glacial deposits and sedimentary bedrock. Rock outcrops are uncommon because the glacial deposits mantle the bedrock nearly everywhere.

Bedrock

The Sand Ridge aquifer is underlain by Upper Ordovician- and Silurian-age sedimentary rocks that dip south-southwestward at approximately 50 ft/mi. The northern part of the study area is underlain by the Medina Group of Silurian age and Queenston Formation of Ordovician age, which consist of mostly red shale and sandstone, and most of the southern part is underlain by the Clinton Group, which consists of shale, dolostone, and some thin beds of limestone (fig. 3). The southernmost tip of the aquifer, from the Oneida River to about 1,000 ft north of it, may be underlain by the Lockport Dolomite. Most of the aquifer occupies a 40- to 100-ft-deep bedrock valley (pl. 2) that was a topographical control for deposition of the glacial deposits that formed much of the aquifer. Eskers, which form much of the aquifer, typically follow low areas such as valleys (Shreve, 1985).

Surficial Material

The Sand Ridge aquifer consists of glaciofluvial sediments (eskers, subglacial outwash, and kames) and glaciolacustrine (deltaic and beach) sediments (pl. 3).

Glacial Chronology

The last major expansion of ice to cover the study area, the Valley Heads glacier, was about

[1] Use of firm names is for identification purposes and does not imply endorsement by the U.S. Geological Survey.

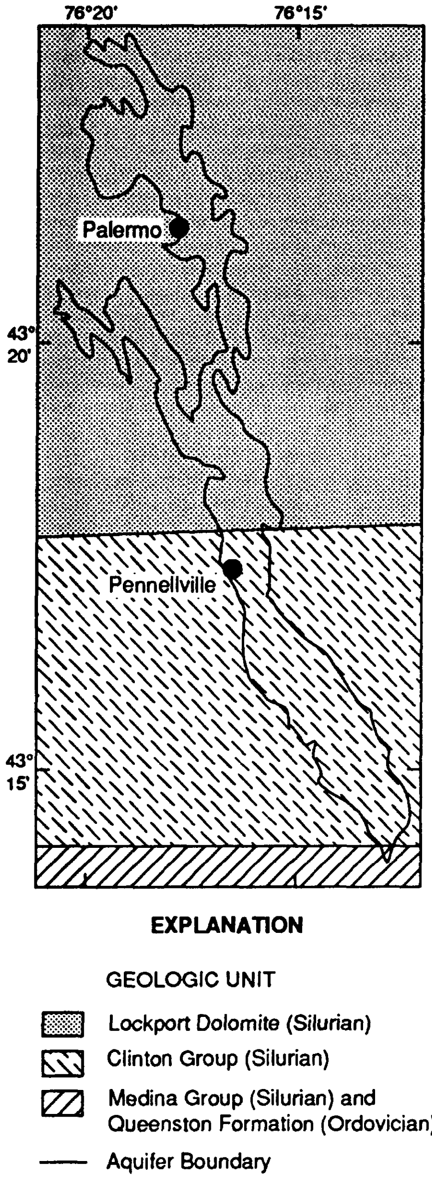


Figure 3.--Bedrock geology of the Sand Ridge aquifer area. (Location is shown in fig. 1.)

13,000 years before present (Fullerton, 1980). Recession of the ice margin across the study area occurred between the time of maximum advance of Valley Heads ice (about 13,000 years before present) and the draining of proglacial Lake Iroquois, about 12,000 years before present (Fullerton, 1980). The study area was covered by Lake Iroquois, which inundated much of the Erie-Ontario plain when the last ice receded north into the Lake Ontario basin. The materials that form the Sand Ridge aquifer were deposited 10,400 to 13,000 years before present during the deglaciation of the area.

Glaciofluvial deposits

During the early stages of deglaciation, when the ice was relatively thick, large volumes of meltwater flowed southward from the Lake Ontario basin to somewhere in the Syracuse area or beyond through ice-walled tunnels, generally at the bottom of the ice (fig. 4A). Sand and gravel was deposited in these meltwater tunnels and in preglacial valleys beneath and in depressions on the surface of the ice. When the ice melted, the fluvial sediments that had been deposited within the tunnels remained in the form of eskers, with either a sinuous dendritic pattern of narrow, multiple ridges, or broad-crested ridges ranging from 15 to 50 ft in height (fig. 5). Where subglacial meltwaters deposited sand and gravel in larger openings beneath the ice, such as preglacial valleys, subglacial outwash deposits formed.

The forms and types of sediment that form eskers depend on the kinds of material that ice overrode, the ice-tunnel gradient, and the freeze-thaw conditions within the ice (Shreve, 1985). For example, sharp-crested eskers that consist of poorly bedded sand, gravel, and boulders formed in steeply descending tunnels where heating of the ice by flowing water caused relatively rapid melting of basal ice. Multiple-crested eskers formed in gently descending tunnels, where the lower velocity of meltwater caused less melting of the basal ice. Broad-crested eskers consisting of well-sorted medium to coarse sand formed in ascending tunnels, where velocity of meltwater flow was slowest, and, because little or no heat was generated by water flowing against the ice, either no melting of basal ice occurred, or the meltwater froze onto the walls of the tunnel. The central and northern parts of the aquifer contain sharp- and multiple-crested eskers, whereas the southern part contains broad-crested eskers and some sharp- and multiple-crested eskers.

The northwest-southeast direction of modern stream beds in the area has resulted from the topographic control exerted by similarly oriented drumlins. Glacial meltwater that flowed in tunnels within the ice followed a preglacial stream valley and interdrumlin lowlands (pl. 2) and deposited sand and gravel that partly or wholly buried the valley (fig. 5 and pl. 2) and some of the interdrumlin areas. Modern stream channels have formed outside the valley-fill areas.

Eskers, too, follow the preglacial stream valley and interdrumlin areas. Eskers in the interdrumlin areas are common in the northern part of the Sand Ridge aquifer, where they are typically 10 to 40 ft thick and, in some places, are discontinuous and(or)

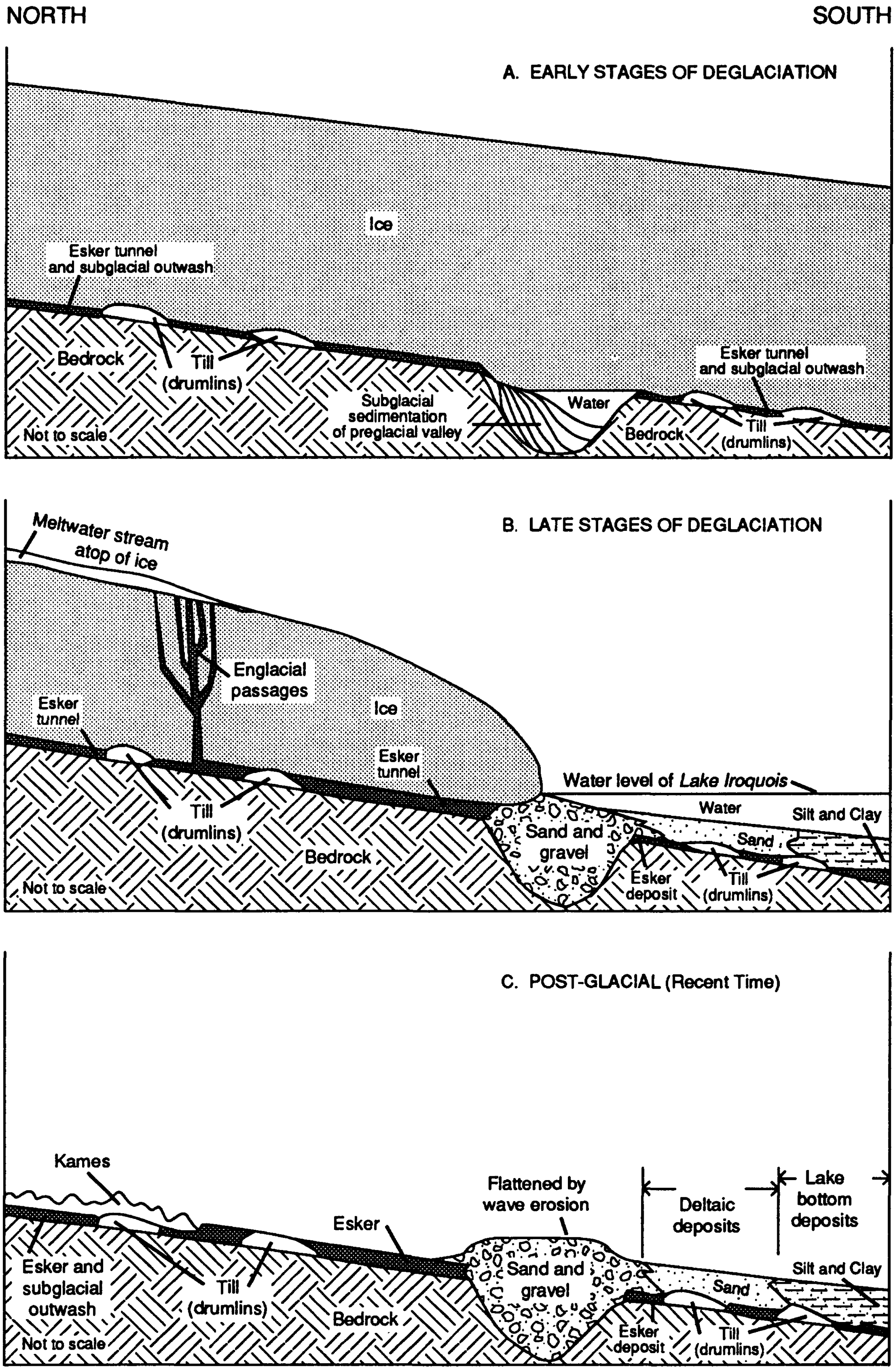


Figure 4.--Modes of deposition of glacial deposits that form the Sand Ridge aquifer.

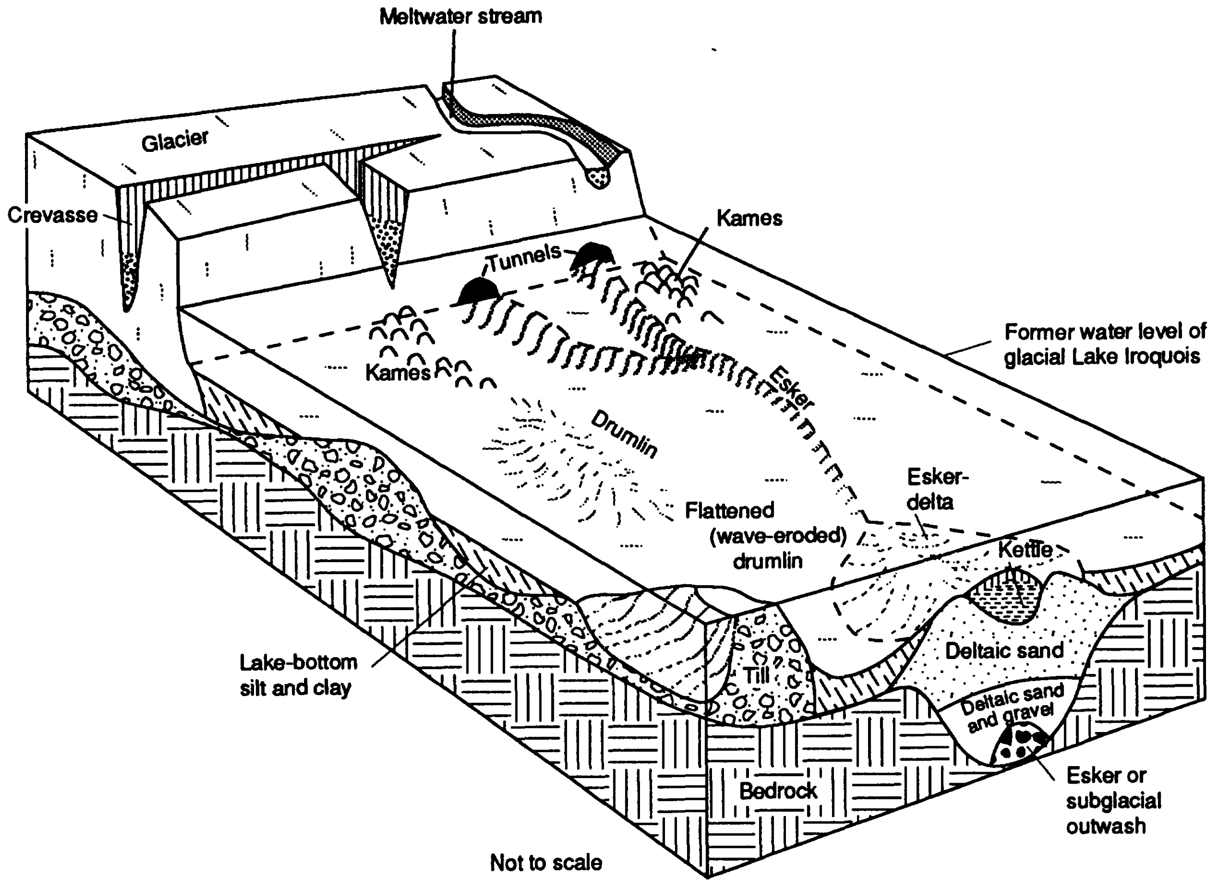


Figure 5.--Origin of typical glacial features in the Sand Ridge aquifer area.

buried beneath lacustrine deposits. Parts of these eskers have braided, bifurcated patterns that connect to a main-trunk esker in the preglacial bedrock valley. Only those eskers that are connected to the main-trunk esker system in the preglacial bedrock valley are considered to be part of the Sand Ridge aquifer.

Sand and gravel that was deposited by meltwater on top of the ice subsequently formed irregular hummocks called kames as the ice melted. Kames are present as irregular patches throughout the aquifer (pl. 3) and range in thickness from 10 to 100 ft. Kames in the aquifer contain a mixture of silty fine sand to coarse cobble gravel, but sand is the major component. In some areas, the surface of the aquifer is pitted with "kettles"—roughly circular depressions that range from a few feet to several thousand feet across and 5 to 50 ft deep. Kettles formed where ice blocks became separated from the retreating glacier and were subsequently surrounded and buried by sediment. When these blocks melted, the sediment cover collapsed, leaving depressions. Kettles that intersect the water table and are partly filled with water are called kettle lakes, of which Pleasant Lake (fig. 1) is an example.

Glaciolacustrine Deposits

During deglaciation of the study area, the retreating ice formed a barrier that ponded meltwater and northward-draining streams in the Ontario lowlands. A temporary glacial lake (Lake Iroquois) formed in front of the ice and inundated the lowlands below an elevation of 435 to 450 ft (fig. 5). Evidence of the lake in the study area consists of (1) deltas graded to lake level; (2) lake-bottom sediments on the flanks of eskers and in interdrumlin areas; (3) eskers, kames, deltas, and drumlins that have flattened tops caused by erosion by wave action; and (4) beaches that were deposited along the periphery of the lake (fig. 5).

An esker-delta in the southern part of the study area (fig. 6) formed where a glacial stream deposited a delta that prograded into Lake Iroquois. The coarse-grained sediments (gravel, pebbly sand, and medium to coarse sand) were deposited near the mouth of the esker's tunnel, whereas the fine-grained sediments (fine sand, silt, and clay) settled farther out in the lake (figs. 4B, 4C). Fine-grained lake bottom sediments that consist of silt and clay particles, settled in deep water (which was mostly in the southern part of the aquifer) and, in some places, on the flanks and on top of submerged eskers and kames. Wherever relatively impermeable silt and clay flanks or overlies the eskers and kames, it forms the upper and lateral boundaries of the aquifer, and till or bedrock forms the lower boundary (fig. 7).

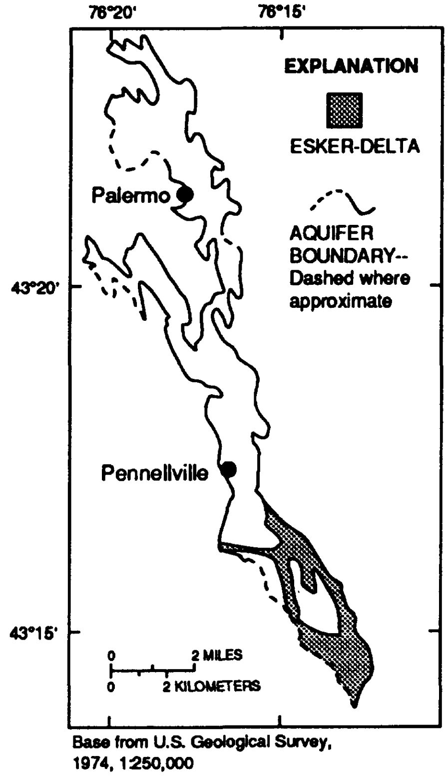


Figure 6.--Location of esker-delta in southern part of aquifer.

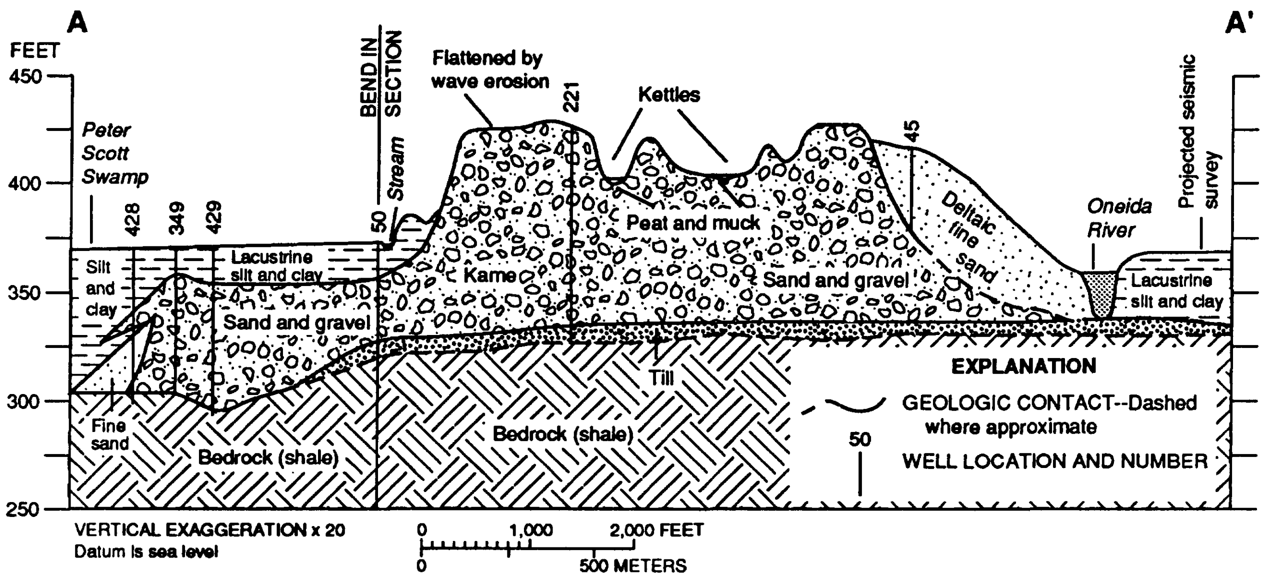


Figure 7.--Geologic section A-A' showing typical stratigraphy of the Sand Ridge aquifer. (Location of section shown on pl. 1.)

HYDROLOGY

The principal water-bearing zones of the Sand Ridge aquifer lie within the glaciofluvial deposits (eskers, subglacial outwash, and kames) and the glaciolacustrine deposits (deltas and beaches). The underlying till and bedrock, which are relatively impermeable, form the bottom boundary of the aquifer. Lacustrine silt and clay and some scattered drumlins, which all have low permeability, form the lateral boundaries of the aquifer. Lacustrine silt and clay overlies and confines the aquifer along parts of the aquifer margin (fig. 7).

Permeability of Deposits

The sediments that form the aquifer range widely in permeability. The most permeable of these are glaciofluvial deposits of esker material, subglacial outwash, and glaciolacustrine beach deposits consisting of sand and gravel. The grain-size difference between material that forms the sharp, multicrested eskers and the material that forms the broad-crested eskers produce large differences in permeability from one part of the aquifer to another. Sharp-crested eskers, which consist of coarse sand and gravel, have higher permeability than broad-crested eskers, which consist mostly of sand.

Kames are moderately permeable because they typically consist of poorly sorted sediments that range in grain size from silt to coarse gravel. Those in the study area consist mostly of sand. Deltaic deposits, which grade from pebbly sand near the mouth of the meltwater tunnel to silt and clay farther from it, generally are moderately to poorly permeable (figs. 5, 6). Only the sand component of deltaic deposits is included as part of the aquifer because silt and clay generally do not yield usable amounts of water to domestic wells. The lateral boundary of the aquifer in areas of deltaic deposits is indistinct because the grain size of the sediments is gradational. In other parts of the aquifer, the boundary between permeable material (sand and gravel) and adjacent sediments (till, silt, and clay) is more distinct.

Reported laboratory measurements of vertical hydraulic conductivity of four core samples collected at various depths during drilling of well 349 (public supply well for the Village of Phoenix) ranged from 186 to 496 ft/d and averaged 281 ft/d (Harnish and Lookup Associates, 1972). Vertical hydraulic conductivity was determined with a permeameter that measures the rate of flow of water through a known area of sediment sample under constant-head conditions (Johnson Division Co., 1972). The hydraulic conductivity of glaciofluvial deposits changes with the direction of measurement because the clay and platy rock particles within the deposit are generally oriented horizontally. Freeze and Cherry (1979) reported that horizontal hydraulic conductivity of core samples analyzed in the laboratory was generally 2 to 10 times greater than vertical hydraulic conductivity. Therefore, the average horizontal hydraulic conductivity of the four core samples would probably range from 482 to 2,810 ft/d (2 to 10 times greater than the average vertical hydraulic conductivity of 281 ft/d). Because the saturated thickness of the aquifer at well 349 is about 60 ft, the transmissivity (horizontal hydraulic conductivity multiplied by saturated thickness) at this site is estimated to be between 28,900 to 169,000 ft^2/d.

The northern part of the aquifer is generally unconfined, whereas the southern part may be unconfined, confined, or semiconfined by fine sand, silt, or clay, depending on location. High areas in the southern part of the aquifer are unconfined, but low-lying areas, which are generally along the aquifer margins from south of Pleasant Lake to the Oneida River (pl. 1), are overlain by silt, fine sand, or clay that semiconfine or confine the aquifer. Fine sand is considered a semiconfining unit in this report because it has low to moderate permeability that can permit significant leakage of water to the underlying aquifer. Silt and clay forms a confining unit because it does not transmit water readily.

Recharge

The aquifer is recharged solely by infiltration of precipitation that falls directly onto its surface. Wherever sand and gravel deposits are at land surface, surface runoff is minimal because most rain and snowmelt that is not lost through evapotranspiration readily infiltrates to the water table. Since the aquifer is generally the high area of the surrounding land, runoff from adjacent uplands results in little or no significant recharge to the aquifer.

Hydrographs of water levels in the aquifer indicate that most recharge occurs during periods of precipitation and snowmelt from late fall through spring. (See hydrograph for well 10, pl. 1.) Water levels in the aquifer typically are highest in March, when rain and snowmelt provide large amounts of recharge. (Several inches of water may accumulate in the winter snowpack.) Little recharge occurs during summer because most rainfall evaporates or is intercepted by vegetation and is then transpired to the atmosphere.

Nearly all rain and snowmelt infiltrate where sand and gravel is at land surface, but only 25 to 50 percent of this water reaches the water table as recharge; the remaining 75 to 50 percent is lost through evapotranspiration (Kantrowitz, 1970, p. 67; MacNish and Randall, 1982, p. 32). Estimated recharge to the Sand Ridge aquifer is calculated to range from 10.5 to 21 in/yr or 0.5 to 1.0 million gallons per day per square mile, from the average annual precipitation of 42 in. at the Brewerton Lock 23 precipitation station (fig. 1). Total recharge to the entire aquifer (15.9 mi^2) ranges from 7.9 to 15.9 Mgal/d.

Discharge

Ground water moves from areas of high hydraulic head to areas of low hydraulic head, and the rate of flow is controlled by the hydraulic gradient and transmissivity of the aquifer. Under nonpumping conditions, ground water moves from the central part of the Sand Ridge aquifer to the edges of the aquifer, where it either discharges to surface-water bodies such as wetlands, Oneida River, springs, and small streams, or leaves the aquifer as subsurface flow into adjacent geologic deposits.

In most parts of the Sand Ridge aquifer, the potentiometric surface roughly parallels the land surface. The contours of the highest water levels roughly follow the northwest-southeast-trending center or top of the aquifer (pl. 1). Ground water generally flows to the east and west from the top or middle of this ridge to the margins of the aquifer and to adjacent wetlands (pl. 1 and fig. 8)

Approximately half of the aquifer's 50-mi perimeter borders wetlands. Other significant discharge areas are the Oneida River along the southern margin of the aquifer, several small streams that originate on the aquifer, a well field in the southern part of the aquifer near the intersection of Kline Road and County Route 12, springs along the edges of the aquifer, and evapotranspiration. Most of those streams on and adjacent to the aquifer increase in flow along their courses over the aquifer as a result of ground-water discharge, which indicates that streams are ground-water-discharge areas and contribute no recharge to the aquifer.

Ground water is also discharged from the aquifer by the pumping of two municipal wells for the Village of Phoenix in the western part of the aquifer (fig. 8 and pl. 1). One well, no. 349, is 1,700 ft west of the intersection of Kline Road and County Route 12; the other, well 50, is about 400 ft north of the same intersection and 275 ft east of Kline Road (pl. 1). The two wells pump about 225,000 gallons per day (82,125,000 gallons per year) and supply water to about 3,000 people living in the village and in several outlying areas (table 1). Water pumped by the municipal wells is discharged or removed from the aquifer and is transported to the village through pipes; the water pumped from the aquifer by private wells is returned through septic and other waste systems.

An aquifer test during April 14-22, 1972, in which municipal well 349 at the eastern edge of Peter Scott swamp was pumped at an average rate of 1,300 gal/min, indicated hydraulic connection with the other municipal well (well 50) on Kline Road (Peter Struthers, private consultant, written commun., 1972). During the 8-day pumping period, the water level at well 50 declined 6 ft. During pumping conditions, the cone of depression extended below Peter Scott swamp to the west, which suggests that the pumping of well 349 induces infiltration from the swamp.

Water-Level Fluctuations

The annual fluctuation of ground-water levels measured in nine wells in the aquifer from May 1987 through May 1988 ranged from 1.5 to 4.5 ft (pl. 1). The range of fluctuation measured during this period may be less than normal because precipitation was abnormally low during March and April 1989, the time of year in which large amounts of recharge normally occur and raise the water table to peak levels. Ground-water levels rise when the rate of recharge exceeds the rate of discharge, which usually occurs during and shortly after precipitation and snowmelt in late fall, winter, and early spring, when plants are dormant and the evaporation rate is low. Ground-water levels generally decline during late spring, summer, and early fall, when the rate of discharge exceeds the rate of recharge. During the growing season, local recharge could be nearly zero for as long as 6 months, and ground-water levels during this period decline steadily unless an exceptionally large storm causes them to rise briefly.

Ground-Water Yield and Availability

Some farms and homes obtain water from till, lake deposits, or bedrock. Most wells that tap the till and lake deposits are dug wells that are less than 25 ft deep and about 3 ft in diameter. These wells generally yield less than 0.5 gal/min, but their large diameter provides sufficient water storage for intermittent, short-term withdrawals at rates that exceed the well yields. Drilled wells could probably obtain 20 to 50 gal/min at many locations by penetrating 300 ft or more of bedrock, although some deep wells yield very little water. Well yields from the Medina Group and Queenston Formation were reported to range from 1 to 28 gal/min and averaged 3 gal/min, whereas well yields from the Clinton Group were slightly higher and ranged from 1 to 125 gal/min and averaged 10 gal/min (Kantrowitz, 1970).

Yields of wells that tap the Sand Ridge aquifer are much larger than those of wells that tap till, lake-bottom sediments, or bedrock. Well 349, in the southwestern part of the study area, has a 20-in.-diameter casing, a screen that extends from 40 to 64 ft, and the capability to produce 1.3 Mgal/d (900 gal/min) with a drawdown of 36 ft (Peter Struthers, private consultant, written commun., 1972). Well

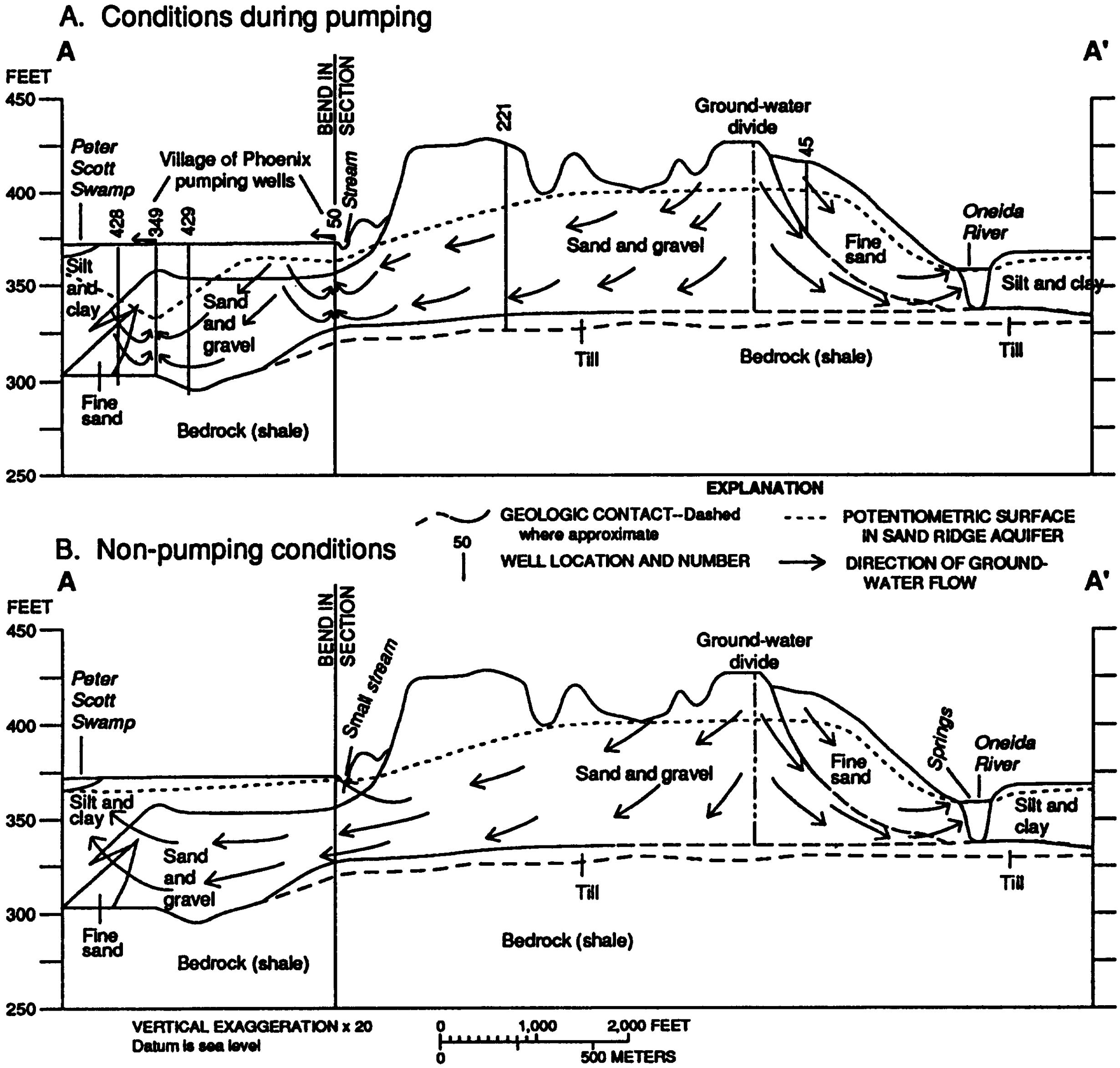


Figure 8.--Geohydrologic section A-A' through the southern part of the Sand Ridge aquifer showing potentiometric surface, direction of ground-water flow, and discharge areas: A. During pumping conditions, some water is induced from Peter Scott swamp to pumped well 349. B. During nonpumping conditions, ground water discharges to Peter Scott swamp.

349 (locally known as Village of Phoenix Well 3) was constructed in 1972 to a depth of 64 ft. Well 50, also in the southwestern part of the study area, has a 12-in.-diameter casing and a screen that extends from 29 to 44 ft, and can produce about 0.7 Mgal/d (400 gal/min) with a drawdown of 5.5 ft (Peter Struthers, private consultant, written commun., 1972). Well 50 (locally known as Village of Phoenix Well 2) was constructed in 1949 to a depth of 44 ft. The specific capacity of wells 349 and 50 were estimated by Struthers in 1972 to be 25 and 73 gal/min per foot of drawdown, respectively. Estimated pumpage from the aquifer by public and private wells is listed in table 1.

A program of extensive test-hole drilling and geophysical investigations were conducted by a private consultant (Peter Struthers, private consultant, written commun., 1972) in an effort to locate areas where large yields could be obtained at each site. Once the most productive zones of the aquifer had been located at each site, the screen length and slot size were chosen to optimize the yield of each well. Where efforts to locate the most productive zones of the aquifer have not been made, smaller yields can generally be expected.

Most domestic and farm wells that tap the Sand Ridge aquifer are constructed of 6-in.-inside-diameter casings and are not screened, but finished open-ended. These wells are designed to meet only small demands of several hundred gallons per day. Yields reported by drillers for 52 domestic and farm wells completed in the Sand Ridge aquifer indicate that well yields range from 5 to 50 gal/min and average 15 gal/min. Domestic wells finished in sand with thin sand and gravel zones can be expected to have yields in the lower end of the yield range (5 to 15 gal/min), whereas wells finished in coarse sand and gravel can be expected to have yields of 15 to 50 gal/min. The major limiting factor to the potential yield of domestic wells drilled into the Sand Ridge aquifer is the absence of a well screen.

Larger quantities of water (several hundred gallons per minute) can be obtained from properly developed large-diameter screened wells. Such wells are much more costly to install, however, than

Table 1.--Suppliers, population served, and average pumpage from the Sand Ridge aquifer.

[Locations of communities are shown on plate 1.]

Suppliers	Population served	Average pumpage (gallons per day)
Municipal community water systems: Village of Phoenix and several outlying areas	3,000[a]	225,000[a]
Other Community Systems (trailer parks):		
Northridge Acres	100[b]	10,000[d]
Sandridge Mobile Court	600[b]	60,000[d]
Idle Wheels	150[b]	15,000[d]
Clark Lane	230[b]	23,000[d]
Conifer	375[b]	37,500[d]
J Ann J	175[b]	17,500[d]
Private individual supplies	2,400[c]	240,000[d]
TOTAL	7,030[d]	628,000

[a] William Farley, Code and zoning enforcement officer, Town of Schroeppel, oral commun., 1989.

[b] New York State Department of Health, 1982.

[c] Approximate number of private homes over the aquifer times 3.6 (average number of persons per household).

[d] Population served times 100 gallons (estimated average water consumption per person per day).

open-ended wells. Many wells that tap the aquifer were drilled through 10 to 80 ft of sand before being finished in more productive sand and gravel zones. Some wells in the southern part of the aquifer tap a sand and gravel zone that is confined below lacustrine sandy clay and fine sand. This zone was thin, and consequently, the wells commonly extended 1 to 5 ft into underlying shale, which contributes some water to these wells (fig. 9). The thickness of the buried sand and gravel aquifer varies within short distances (fig. 9), as illustrated by the logs of several closely spaced wells drilled for both the Village of Phoenix (pl. 1) and for a housing development at Ironwood Drive (see inset, pl. 1; sections B-B' and C-C'). Note that geologic sections B-B' and C-C' are parallel sections only 200 ft apart (fig. 9).

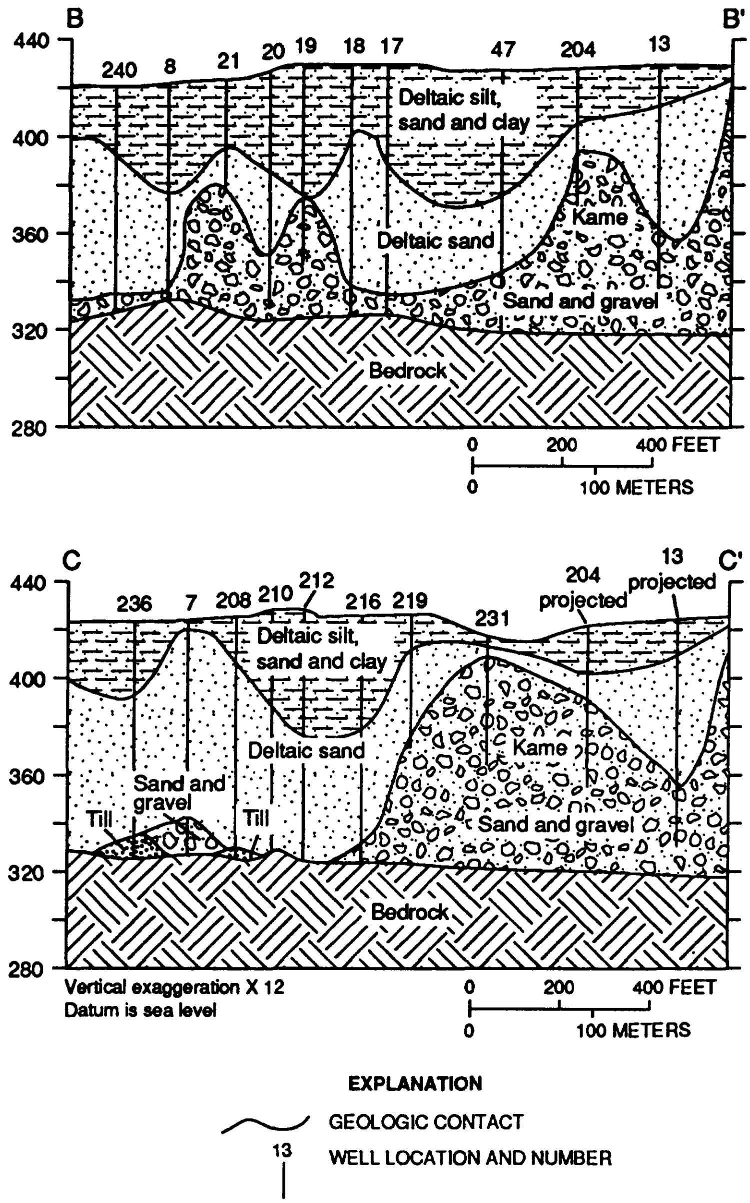


Figure 9.--Geologic sections B-B' and C-C' showing highly variable thickness of buried sand and gravel zones at Ironwood Drive in the southern part of the aquifer. (Line of section shown in inset map on pl. 1.)

WATER QUALITY

Water samples were collected during August 1987 from 25 selected wells completed in the Sand Ridge aquifer (locations are shown on pl. 1; results are given in table 4, at end of report). The wells are scattered throughout the aquifer and range in depth from 12 to 97 ft. Three of the wells (50, 53, and 100) were sampled eight times from May 1987 through March 1988 to discern temporal changes or local differences in the water quality. Twenty of the wells are completed in the unconfined part of the aquifer; the other five are completed in the confined part. Only one of the three wells sampled routinely (well 100) is finished in the confined part of the aquifer. Eighteen of the wells are in the south-central part of the aquifer and are underlain by shale and dolostone of the Clinton Group; the remaining seven are in the northern part of the aquifer and are underlain by red shale and by sandstone of the Queenston Formation and Medina Group. The Sand Ridge aquifer consists of unconsolidated sediments derived primarily from these shales, sandstones, and dolostones.

Chemical and Physical Characteristics

Chemical analyses of ground-water samples (table 2) indicate that the quality of water in the Sand Ridge aquifer generally meets New York State drinking-water standards. Concentrations of most constituents were similar to those found in the late

Table 2.--Minimum, maximum, and median concentrations of dissolved constituents and properties of ground water from selected wells in the Sand Ridge aquifer, 1981.

[Analyses by U.S. Geological Survey Central Laboratory, Denver, Colo. ft = feet; mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm - microsiemens per centimeter at 25 degrees Celsius; < = less than. Dashes indicate no applicable New York State drinking-water standard for that constituent.]

Property or constituent	Number of samples	Value or concentration			New York State drinking-water standard
		minimum	maximum	median	
Well depth (ft)	24	12	97	55.5	--
Specific Conductance (µS/cm)	45	201	783	324	--
Alkalinity (mg/L) as $CaCO_3$	45	71	218	134	--
pH	45	7.6	8.4	8.0	--
Nitrite plus nitrate (NO_2+NO_3) (mg/L)	39	<.01	3.7	1.0	10
Hardness (mg/L) as $CaCO_3$	43	54	280	160	--
Calcium (mg/L)	43	14	81	38	--
Magnesium (mg/L)	43	4.6	32	15	--
Sodium (mg/L)	43	1.5	58	6.7	--
Potassium (mg/L)	43	<.1	14	1.1	--
Chloride (mg/L)	43	1.3	130	6.7	250
Sulfate (mg/L)	43	2.5	33	16	250
Fluoride (mg/L)	43	<.1	.4	.1	1.5
Silica (mg/L)	43	6.3	13	8.4	--
Arsenic (µg/L)	3	<1	1	1	50
Barium (µg/L)	3	190	440	250	1,000
Cadmium (µg/L)	3	<1	<1	<1	10
Copper (µg/L)	3	8	10	9	1,000
Iron (µg/L)	45	3	770	14	300
Lead (µg/L)	3	<5	<5	<5	50
Manganese (µg/L)	45	<1	1,100	31	300
Strontium (µg/L)	3	77	150	120	--
Zinc (µg/L)	3	17	260	53	5,000
Lithium (µg/L)	3	<4	<4	<4	--
Selenium (µg/L)	3	<1	<1	<1	10
Mercury (µg/L)	3	<.1	.9	.2	--

1960's during a study of the eastern Oswego River basin by Kantrowitz (1970), which includes the Sand Ridge aquifer.

Specific Conductance

Specific conductance is a measure of the capacity of water to conduct an electrical current. It is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids concentration in water. Typically, the dissolved solids concentration, in milligrams per liter (mg/L), is about 65 percent of the specific conductance, in microsiemens per centimeter at 25° C (µS/cm). This relation is not constant, however, and can range from as low as 55 percent to as high as 80 percent. Specific conductance of water samples ranged from 201 to 783 µS/cm, with a median of 324 µS/cm (table 2).

pH

pH is a measure of hydrogen-ion activity in water and is inversely proportional to the acidity. The pH scale ranges from 0 to 14, and each unit increase or decrease represents a 10-fold change in hydrogen-ion concentration. A pH less than 7.0 is said to be acidic, and a pH greater than 7.0 is said to be basic. The primary influence on pH in most ground water is the interaction of the soil and rock molecules with gaseous and dissolved carbon dioxide, bicarbonate, and carbonate ions. The pH of ground water in the study area ranged from 7.6 to 8.4 (slightly basic), with a median of 8.0

Hardness

Hardness of water is a physical-chemical characteristic that is primarily attributable to the presence of calcium and magnesium and is expressed as equivalent calcium carbonate ($CaCO_3$). Hardness of ground water in the Sand Ridge aquifer ranged from 54 to 280 mg/L as $CaCO_3$ (soft to very hard), with a median concentration of 160 mg/L (hard). Classification of hardness is as follows (Hem, 1985):

Hardness range (mg/L of $CaCO_3$)	Description
0 - 60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

Hardness in water used for ordinary domestic purposes does not become a problem until it exceeds a concentration of 100 mg/L (Hem, 1985, p. 159). Concentrations greater than 100 mg/L can decrease the effectiveness of soap because certain cations, primarily calcium and magnesium, react with soap to form insoluble compounds. These cations also leave a precipitate when the water is heated. Elevated concentrations of hardness generally are present in areas where water is in contact with limestone, dolostone, or unconsolidated sediments derived from these rocks.

Alkalinity

Alkalinity is a measure of the concentrations of carbonate (CO_3^{--}), bicarbonate (HCO_3^-), and hydroxide (OH^-), which determine the capacity of a solution to neutralize acid. The median concentration of alkalinity in ground water in the study area is 134 mg/L. Water from three wells (10, 238, and 350) with depths less than 30 ft had alkalinity concentrations of 180, 71, and 163 mg/L, respectively, indicating that the soils have a capacity to neutralize acid precipitation. Precipitation in the study area is moderately acidic, with a pH of 4.2 to 4.4 (Peters and Bonelli, 1982).

Chloride and Sodium

Potential sources of chloride and sodium in ground water include road-deicing salt, septic-tank effluents, dissolution of sodium-bearing minerals within the aquifer, and mineralized ground water in bedrock that may discharge into sand and gravel aquifers. Elevated concentrations of chloride are generally found in ground water near major roads that are heavily salted. None of the Sand Ridge aquifer wells sampled had concentrations of chloride that exceeded the New York State drinking-water standard (250 mg/L). The median concentrations of chloride and sodium were both 6.7 mg/L; the maximum concentrations of chloride and sodium were 130 mg/L and 58 mg/L, respectively. Both ions were detected at well 350 in the northern part of the aquifer. Well 350 is a shallow dug well that possibly is affected by either road salt or septic-tank effluent.

Nitrate

The major sources of nitrogen to ground water are processes and activities on or near land surface, such as (1) land application of organic and inorganic fertilizers, (2) leakage of septic-tank effluent, (3) decomposition of organic material in the soil to ammonia and then to nitrate by nitrifying bacteria, and (4) introduction of atmospheric nitrogen to the soil by nitrogen-fixing plants and bacteria. Nitrite plus nitrate (as N) concentrations ranged from less than 0.01 mg/L (below detection limit) to 3.7 mg/L, with a median of 1.0 mg/L, all well below the New York State drinking-water standard of 10 mg/L for nitrate. Wells (45, 53, and 238) with concentrations of nitrite plus nitrate (as N) greater than 3.0 mg/L were in agricultural or unsewered, high-density residential areas.

Trace Elements

Median concentrations of iron and manganese in water from the Sand Ridge aquifer were 14 µg/L and 31 µg/L, respectively (table 2). Dissolved iron and manganese concentrations exceeded the New York State drinking-water standards in water from nine of the wells sampled; maximum concentrations were 770 µg/L for iron and 1,100 µg/L for manganese. The highest concentration of iron (770 mg/L) was at the Village of Phoenix municipal well 349, near Peter Scott swamp. Elevated iron concentrations in association with hydrogen sulfide generally indicate reducing (anaerobic) conditions in the soil or aquifer. Because swampy areas generally foster reducing conditions, shallow ground water beneath swamps tends to contain higher-than-normal amounts of dissolved iron. Accordingly, pumping from wells near swampy areas can induce recharge from the swamp and produce water that is high in dissolved iron. An aquifer test conducted by a private consultant (Peter Struthers, private consultant, written commun., 1972) showed how water is induced from the wetland to the municipal pumped well. New York State drinking-water standards specify a maximum concentration of 300 µg/L for either iron or manganese or a total of 300 µg/L if both are present. Although high concentrations of iron and manganese do not present a health hazard, they do have a detrimental effect on taste, odor, and color of the water. Iron in excessive amounts forms red oxyhydroxide precipitates that stain laundry and plumbing fixtures and support the growth of iron bacteria in water-distribution systems. When exposed to air, water that contains high concentrations of iron and manganese becomes turbid as the iron and manganese ions become oxidized and form colloidal precipitates.

Concentrations of other trace elements did not exceed New York State drinking-water standards. Concentrations of arsenic, cadmium, mercury, and selenium were at or below laboratory detection limits in many samples. Minimum, maximum, mean, and median values for all measured constituents are presented in table 2 along with New York State drinking-water standards.

Environmental Influences

The major influences on water quality in an aquifer are the chemical composition of precipitation, the composition of the underlying bedrock, the composition and solubility of the sand and gravel deposits, residence time of water in the aquifer, and the local effects of human's activities. A statistical comparison of ground-water samples in the Sand Ridge aquifer, by rock unit and depth, was done to identify patterns or significant differences in chemical concentrations within the aquifer. All comparisons were made by use of box plots with notches—a statistical test that compares significant differences between medians of distributions (McGill and others, 1978). The notches represent an approximate 95-percent confidence interval about the median. If the notches of one distribution do not overlap those of another distribution, the differences between the two distributions are considered to be significant at the 95-percent confidence level.

The Sand Ridge aquifer consists of unconsolidated glacial deposits that originated mostly from the shale and sandstone that underlies the study area. Wells were grouped first according to underlying bedrock unit (eight are underlain by the Queenston formation in the northern part of the aquifer, and 17 are underlain by the Clinton Group in the southern part) to identify any water-quality differences due to bedrock composition. Box plots of all chemical constituents in water samples indicated no significant differences in median concentrations at the 95-percent confidence level between the two units. Wells were then grouped by depth—those greater than 50 ft (11 wells) and those less than 50 ft (14 wells)—to identify any differences in water quality that might be due to proximity to the land surface or bedrock. Again, the grouping showed no significant differences at the 95-percent level in median concentrations of any of the chemical constituents. Finally, wells were grouped according to depth and bedrock unit, and, again, no significant differences in median concentrations were observed.

The effects of human activities on water quality in the Sand Ridge aquifer are reflected primarily in the unconfined part of the aquifer. Because the water here is generally close to land surface and because most of the aquifer is unconfined, precipitation can readily infiltrate to the saturated zone and carry with it any contaminants that originate at land surface. The confined part of the aquifer is protected, to some degree, from direct surface contamination by a relatively impermeable layer of sediment that overlies the sand and gravel.

The predominant land use in the Sand Ridge aquifer study area is forest, which occupies about 49 percent of the aquifer area. Agricultural and farmland constitutes 31 percent of the land; water and wetlands, 13 percent; residential, 6 percent; and gravel pits, 1 percent. Four of the wells sampled had elevated nitrite plus nitrate (as N) concentrations ranging from 2 to 3.7 mg/L, and three of these wells also had relatively high concentrations of chloride (22.0 to 37 mg/L) and sodium (11.0 to 27 mg/L). Two other wells for which no nitrate analysis was available also had relatively high concentrations of sodium and chloride. The well with the highest concentration of sodium (58 mg/L) and chloride (130 mg/L) was a shallow (12-ft-deep) dug well in an unconfined zone in the aquifer. The elevated concentrations of nitrate, sodium, and chloride in these wells may reflect their location in agricultural areas and near major roads, where agricultural fertilizer and road salt are possible sources of these constituents.

Temporal and Areal Differences

Three wells were sampled at approximately 6-week intervals for 1 year to discern temporal changes in water quality within the Sand Ridge aquifer. Two of the wells (well 50, which supplies water to the Village of Phoenix, and well 53, which supplies water to a mobil home park) are in the southern part of the study area—well 50 on the western side and well 53 on the eastern side (pl. 1). The third well (well 100, which supplies water to a housing development), is in the central part of the study area. Well 50 is 45 ft deep and taps the confined part of the aquifer. The mobile-home well field contains well 53, about 50 ft deep and three additional wells, one 70 ft deep, one 110 ft deep, and one 138 ft deep. The 138-ft well is finished in shale; the two shallower wells tap the unconfined part of the aquifer. The 110-ft well may be finished in both the unconfined part of the aquifer and bedrock. Water samples from this site were collected from the distribution system and not the individual wells; therefore, no determination of which well was in use at the time of sample collection could be made. The owner of the mobile home park stated that the primary sources of supply to the park are the two deep wells. Individual water samples could have been representative of water from one well or a combination of all four. Well 100 (which serves the housing development) is 80 ft deep and may be screened in the semiconfined or unconfined part of the aquifer and is underlain by sandstone. Each of the wells was sampled eight times during the year. One sample from well 50 was rejected because constituent concentrations were less than half the mean of the seven other samples from the same well; the sample might have been collected before the well was completely purged of a chemical that is routinely injected to prevent rust.

Time plots of 12 individual constituent concentrations at the three wells (fig. 10) do not indicate any seasonal pattern. The cyclic variation of most of the constituents from the mobile-home park (well 53) probably represents differences among the three wells at that site. Well 100 (in the housing cluster) had the most consistent concentrations over the sampling period, with very little variation in concentrations of alkalinity, hardness, magnesium, calcium, sodium, potassium, chloride, iron, and manganese, and only moderate variation in pH and concentrations of sulfate (fig. 10).

Comparison of median concentrations (table 3, p. 22) of constituents of samples from the three wells by use of box plots showed that water from well 50 (Village of Phoenix well) had significantly (95-percent confidence level) higher concentrations of alkalinity, hardness, calcium, iron, and manganese than did water from the other two wells and significantly higher specific conductance than water from well 100 (housing cluster). Water from well 100, in turn, had significantly lower median pH, concentrations of nitrite and nitrate (as N), specific conductance, and chloride, than the other two wells; a significantly lower median potassium concentration than well 50; and significantly lower median concentrations of sulfate and silica than well 53. Well 53 had the highest median concentration of nitrite and nitrate (as N). Minimum, maximum, and median values for the three wells are presented in table 3.

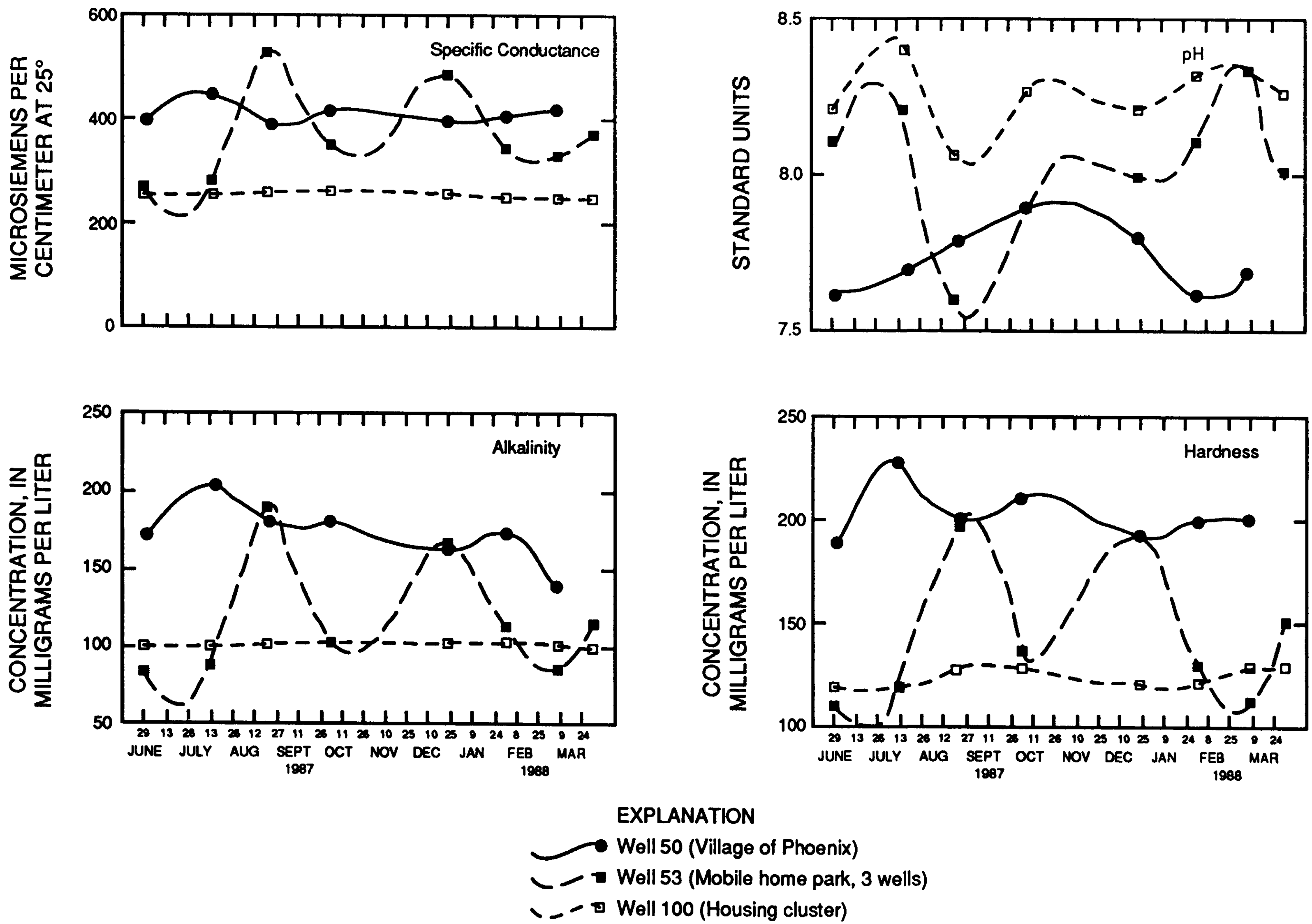


Figure 10.--Concentrations of chemical constituents of water from three wells sampled every 6 weeks from June 1987 through April 1988 in the Sand Ridge aquifer. (Locations are shown on pl. 1.)

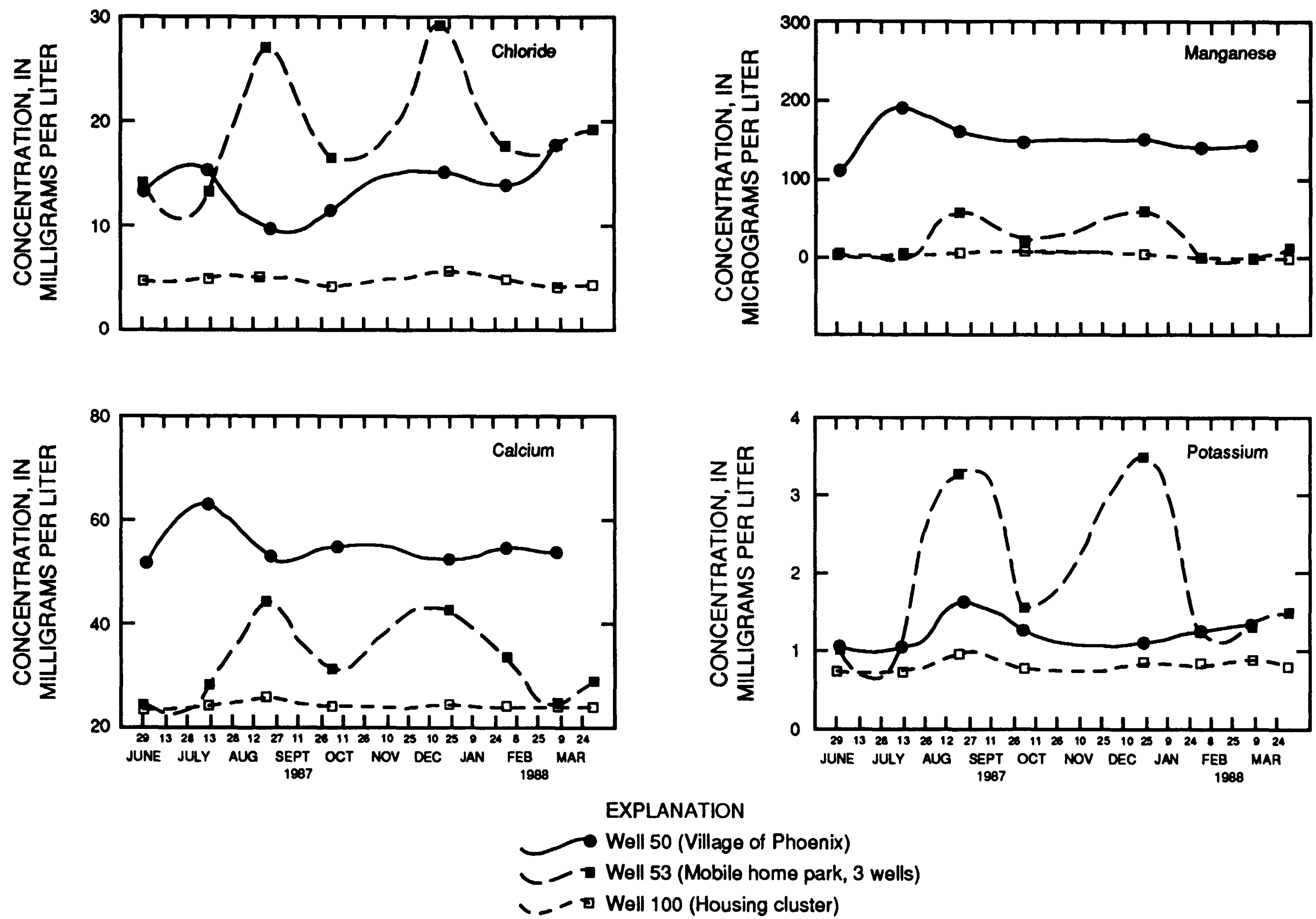


Figure 10.--(continued) Concentrations of chemical constituents of water from three wells sampled every 6 weeks from June 1987 through April 1988 in the Sand Ridge aquifer. (Locations are shown on pl. 1.)

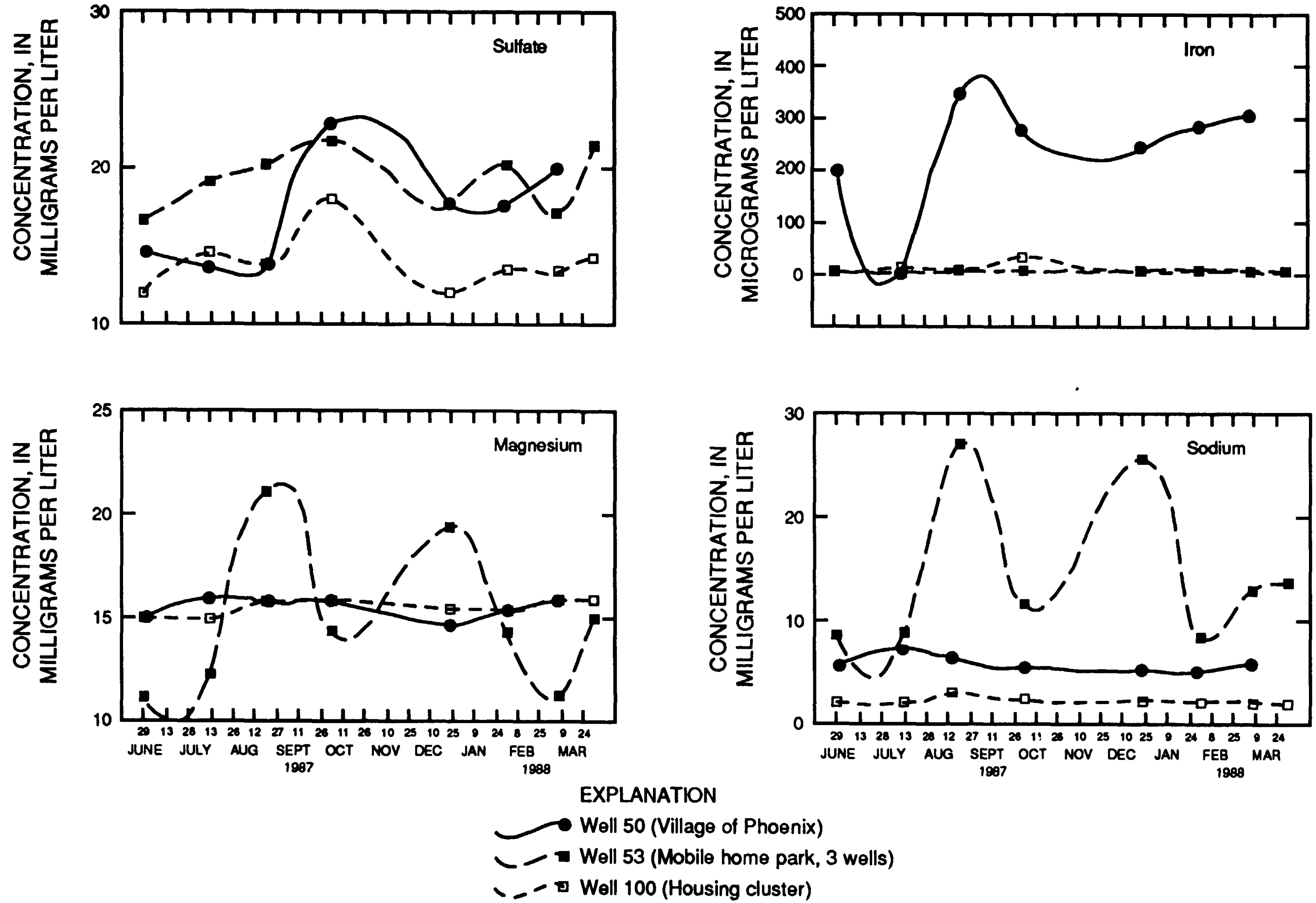


Figure 10.--(continued) Concentrations of chemical constituents of water from three wells sampled every 6 weeks from June 1987 through April 1988 in the Sand Ridge aquifer. (Locations are shown on pl. 1.)

Table 3.--Minimum, maximum, and median values and concentrations of selected constituents in water samples collected from three routinely sampled wells in the Sand Ridge aquifer.

[Well locations shown in pl. 1. Dashes indicate no New York State drinking-water standard for that constituent. mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens per centimeter at 25 degrees Celsius; < = less than.]

Property or constituent	Number of samples	Value or concentration			New York State drinking-water standard
		minimum	maximum	median	
		Well 50			
Specific Conductance (µS/cm)	7	388	457	407	--
Alkalinity as $CaCO_3$	7	137	209	177	--
pH	7	7.6	7.9	7.7	--
Nitrite plus nitrate as N	7	.1	1.0	.1	10
Hardness as $CaCO_3$	7	190	230	200	--
Calcium, dissolved (mg/L)	7	52	65	55	--
Magnesium, dissolved (mg/L)	7	14	16	16	--
Sodium, dissolved (mg/L)	7	5.2	7.9	6	--
Potassium, dissolved (mg/L)	7	1.1	1.6	1.3	--
Chloride, dissolved (mg/L)	7	9.5	17	13	250
Sulfate, dissolved (mg/L)	7	14	22	17	250
Fluoride, dissolved (mg/L)	7	.1	.2	.1	1.5
Silica, dissolved (mg/L)	7	7.7	8.8	8	--
Iron, dissolved (µg/L)	7	11	350	280	300
Manganese, dissolved (µg/L)	7	110	190	140	300
		Well 53*			
Specific Conductance (µS/cm)	8	273	526	331	--
Alkalinity as $CaCO_3$	8	82	195	110	--
pH	8	7.6	8.3	8.0	--
Nitrite plus nitrate as N	8	2.3	3.7	2.8	10
Hardness as $CaCO_3$	8	110	200	135	--
Calcium, dissolved (mg/L)	8	25	45	31	--
Magnesium, dissolved (mg/L)	8	11	21	13	--
Sodium, dissolved (mg/L)	8	8.4	27	13	--
Potassium, dissolved (mg/L)	8	1	3.5	1.4	--
Chloride, dissolved (mg/L)	8	12	29	17	250
Sulfate, dissolved (mg/L)	8	16	22	19	250
Fluoride, dissolved (mg/L)	8	.1	.1	.1	1.5
Silica, dissolved (mg/L)	8	8.4	11	9.2	--
Iron, dissolved (µg/L)	8	4	13	6	300
Manganese, dissolved (µg/L)	8	1.0	62.0	12.0	300

Table 3.--Minimum, maximum, and median values and concentrations of selected constituents in water samples collected from three routinely sampled wells in the Sand Ridge aquifer--(continued).

[Well locations shown in pl. 1. Dashes indicate no New York State drinking-water standard for that constituent. mg/L = milligrams per liter; µg/L = micrograms per liter; µS/cm = microsiemens per centimeter at 25 degrees Celsius; < = less than.]

Property or constituent	Number of samples	Value or concentration minimum	maximum	median	New York State drinking-water standard
		Well 100			
Specific Conductance (µS/cm)	8	249	261	252	--
Alkalinity as $CaCO_3$	8	102	105	102	--
pH	8	8.1	8.4	8.2	--
Nitrite plus nitrate as N	8	1.5	1.6	1.6	10
Hardness as $CaCO_3$	8	120	130	125	--
Calcium, dissolved (mg/L)	8	23	26	24	--
Magnesium, dissolved (mg/L)	8	15	16	16	--
Sodium, dissolved (mg/L)	8	1.8	3.1	2.0	--
Potassium, dissolved (mg/L)	8	.7	1	.8	--
Chloride, dissolved (mg/L)	8	4.3	6.4	5.0	250
Sulfate, dissolved (mg/L)	8	12	18	14	250
Fluoride, dissolved (mg/L)	8	.1	.2	.1	1.5
Silica, dissolved (mg/L)	8	7.4	8	7.8	--
Iron, dissolved (µg/L)	8	3	45	6.5	300
Manganese, dissolved (µg/L)					

* Analytical results may reflect the ground-water chemistry of any one of a cluster of four wells or a composit of all four.

SUMMARY

This report describes the geologic framework, hydrologic characteristics, and water quality of the Sand Ridge aquifer and forms a foundation for the development of ground-water-protection strategies by local and state agencies and for future studies of the local ground-water-supply potential.

The Sand Ridge aquifer is a 53-mi-long, 15.9-mi^2 ridge that consists of glaciofluvial sediments (eskers, subglacial outwash, and kames) and glaciolacustrine (deltaic and beach) sediments that were deposited during deglaciation of the area 12,000 to 13,000 years ago. The esker delta deposit forms most of the aquifer and is one of the largest of such deposits in New York.

The northern part of the aquifer is generally unconfined, and the southern part is unconfined, confined, or semiconfined. Laboratory measurements of vertical hydraulic conductivity of four core samples collected from a test well ranged from 186 to 496 ft/d and averaged 281 ft/d. Horizontal hydraulic conductivity is typically 2 to 10 times greater than vertical hydraulic conductivity of core samples analyzed in the laboratory. Therefore, the average horizontal hydraulic conductivity of the four core samples would probably range from 482 to 2,810 ft/d.

Recharge, which is derived solely from precipitation that falls directly on the aquifer, ranges from 7.9 to 15.9 Mgal/d. Wetlands are the principal discharge areas of the aquifer; other significant discharge areas are the Oneida River to the south, streams that have headwaters originating on the aquifer, the Village of Phoenix well field (which pumps about 55.6 Mgal annually), springs along the edge of the aquifer, and evapotranspiration. The aquifer supplies water to about 7,000 people. Pumpage from the aquifer is estimated to be about 0.63 Mgal/d.

The aquifer is capable of yielding water at a rate of several hundred gallons per minute to large-diameter (greater than 6-inch-inside-diameter) screened wells that are properly developed. The two municipal wells for the Village of Phoenix can pump water at rates of 900 and 400 gal/min. Estimated transmissivity at these well sites ranges from 29,000 to 169,000 ft^2/d. Drillers' reported yields from 52 domestic and farm wells that have open-end 6-inch-diameter casings ranged from 5 to 50 gal/min and average 15 gal/min.

Chemical analyses of ground-water samples indicate that the water quality in the Sand Ridge aquifer generally meets New York State Health Department drinking-water standards, although iron concentrations in nine wells exceeded these standards. A statistical comparison of water quality of wells grouped according to bedrock composition, by depth, and by bedrock and depth combined, indicated that no constituent median concentrations differed significantly areally within the study area.

A comparison of median concentrations of selected constituents from three well sites sampled eight times over a 1-year period reveals some significant differences in concentrations of constituents, but time plots of constituent concentrations at those wells did not reveal any discernible seasonal fluctuations. Some constituent concentrations in water from well site 53 exhibited a cyclic pattern, probably attributable to the fact that the water comes from three wells of possibly differing water chemistry.

REFERENCES

Chute, N. E., 1979, Glacial Lake Iroquois in central New York: Northeastern Geology, v. 1, p. 69-105.

Dobrin, M. B., 1976, Introduction to geophysical prospecting (3rd ed.): New York, McGraw-Hill, 630 p.

Flint, R. F., 1971, Glacial and quaternary geology: New York, John Wiley, 892 p.

Freeze, A. R., and Cherry, J. A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice Hall, Inc., 604 p.

Fullerton, D. S., 1980, Preliminary correlation of post-Erie interstadial events (16,000-10,000 radiocarbon years before present), central and eastern Great Lakes Region, and Hudson, Champlain, and St. Lawrence lowlands, United States and Canada: U.S. Geological Survey Professional Paper 1089, 52 p.

Harnish and Lookup Associates, 1972, Waterworks facilities report, Village of Phoenix, Oswego County, New York: Newark, N.Y., Harnish and Lookup Associates, 6 chap., 85 p.

Hem, J. D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Johnson Division Co., 1972, Ground water and wells: St. Paul, Minn., Johnson Division, Universal Oil Products, 440 p.

Kantrowitz, I. H., 1970, Ground-water resources in the eastern Oswego River basin, New York: New York State Water Resources Commission Basin Planning Report ORB-2, 129 p.

MacNish, R. D., and Randall, A. D., 1982, Stratified-drift aquifers in the Susquehanna River basin, New York: New York State Department of Environmental Conservation Bulletin 75, 68 p.

McGill, R., Tukey, J. W., and Larson, W. A., 1978, Variations of box plots: American Statistician, v. 32, p. 12-16.

Miller, T. S., 1980, Surficial geology of the Pennellville Quadrangle, Oswego County, New York: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-411, 1 sheet, scale 1:24,000.

Muller, E. H., 1980, Surficial geology of part of Brewerton Quadrangle, Oswego County, New York: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-402, 1 sheet, scale 1:24,000.

Muller, E. H., and Miller, T. S., 1980, Surficial geology of Central Square Quadrangle, Oswego County, New York: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-2039, 1 sheet, scale 1:24,000.

National Oceanic and Atmospheric Administration, 1986, Climatological data—annual summary, New York, 1986: National Oceanic and Atmospheric Administration, v. 98, no. 13, 18 p.

New York State Department of Health, 1964, Drinking-water standards: Part 72, subchapter H, chapter II, title 10(Health) of the Official Compilation of Codes, Rules, and Regulations of the State of New York.

_____ 1982, New York State atlas of community water-system sources: Albany, New York State Department of Health, 79 p.

Peters, N. E., and Bonelli, J. E., 1982, Chemical composition of bulk precipitation in the north-central and northeastern United States, December 1980 through February 1981: U.S. Geological Survey Circular 874, 63 p.

Rickard, L. V., and Fisher, D. W., 1970, Geologic map of New York, Finger Lakes sheet: New York State Museum and Science Service, Map and Chart Series 15, 1 sheet, scale 1:250,000.

Shreve, R. L., 1985, Esker characteristics in terms of glacier physics, Katahdin esker system, Maine: Geological Society of America Bulletin, v. 96, p. 639-646.

TABLES 4 AND 5

Table 4.--Chemical analyses of water from

[Well locations are shown in pl. 1. µS/cm =
dashes indicate no data; < = less than;

Well number	Aquifer type[1]	Underlying bedrock unit[2]	Principal aquifer[3]	Sample date yr mo d	Well depth (ft)	Specific conductance (µS/cm)	Alkalinity (as $CaCO_3$)	pH (units)	Dissolved concentration, in					
									Nitrite plus nitrate (as N)	Hardness (as $CaCO_3$)	Calcium	Magnesium	Sodium	Potassium
3	U	Clnn	S&G	87 08 11	47	301	136	7.8	< 0.10	160	41	13	4.0	1.6
10	U	Qnsn	S&G	87 08 11	22	576	180	7.8	2.00	280	81	19	11.0	2.8
36	U	Clnn	S&G	87 08 11	95	201	84	8.3	--	--	--	--	--	--
45	U	Clnn	S&G	87 08 11	43	548	134	7.7	3.70	220	62	17	21.0	1.0
50	C	Clnn	S&G	87 05 29	45	407	175	7.6	<.10	190	52	15	5.4	1.1
50	C	Clnn	S&G	87 07 14	45	457	209	7.7	<.10	230	65	16	7.9	1.1
50	C	Clnn	S&G	87 08 11	45	396	183	7.8	<.10	200	55	16	6.9	1.6
50	C	Clnn	S&G	87 09 29	45	423	177	7.9	<.10	210	57	16	6.0	1.3
50	C	Clnn	S&G	87 12 01	45	388	164	7.8	.38	190	53	14	5.2	1.1
50	C	Clnn	S&G	88 01 12	45	399	177	7.6	1.00	200	56	15	5.3	1.3
50	C	Clnn	S&G	88 02 24	45	413	137	7.7	.13	200	55	16	6.7	1.4
* 53	U	Qnsn	S&G	87 05 29	100	273	86	8.1	2.30	110	25	11	8.4	
53	U	Qnsn	S&G	87 07 14	100	283	92	8.2	2.50	120	28	12	8.7	1.1
53	U	Qnsn	S&G	87 08 11	100	526	195	7.6	3.20	200	45	21	27.0	3.3
53	U	Qnsn	S&G	87 09 29	100	346	101	7.9	2.70	140	31	14	12.0	1.6
53	U	Qnsn	S&G	87 12 01	100	468	170	8.0	3.20	190	43	19	26.0	3.5
53	U	Qnsn	S&G	88 01 12	100	316	118	8.1	2.60	130	31	13	9.6	1.3
53	U	Qnsn	S&G	88 02 24	100	282	82	8.3	3.70	110	25	11	13.0	1.3
53	U	Qnsn	S&G	88 03 30	100	353	121	8.0	2.80	150	35	15	14.0	1.5
100	U	Qnsn	S&G	87 05 29	80	256	102	8.2	1.60	120	23	15	1.8	.7
100	U	Qnsn	S&G	87 07 14	80	249	102	8.4	1.60	120	24	15	2.0	.7
100	U	Qnsn	S&G	87 08 11	80	251	102	8.1	1.60	130	26	16	3.1	1.0
100	U	Qnsn	S&G	87 09 29	80	261	102	8.3	1.60	130	24	16	2.0	.7
100	U	Qnsn	S&G	87 12 01	80	256	102	8.2	1.60	120	24	15	1.9	.8
100	U	Qnsn	S&G	88 01 12	80	251	105	8.3	1.50	120	24	15	1.9	.8
100	U	Qnsn	S&G	88 02 24	80	254	104	8.3	1.50	130	24	16	1.9	.9
100	U	Qnsn	S&G	88 03 30	80	251	102	8.2	1.50	130	24	16	2.1	.7
108	U	Qnsn	S&G	87 08 11	58	306	87	8.3	--	130	24	16	9.6	.7
172	U	Qnsn	S&G	87 08 11	60	317	162	8.0	<.10	170	48	11	1.7	1.2
209	C	Clnn	S&G	87 08 11	32	303	101	7.9	<.10	110	24	11	4.8	<.1
215	U	Clnn	S&G	87 08 11	89	274	157	8.0	<.10	160	38	16	7.0	1.2
217	C	Clnn	S&G	87 08 11	69	281	103	7.6	<.10	120	28	13	6.8	1.5
221	U	Clnn	S&G	87 08 11	64	362	185	7.8	<.10	180	48	15	3.1	1.0
228	U	Clnn	S&G	87 08 11	56	386	192	7.8	<.10	200	57	13	1.6	.7
231	U	Clnn	S&G	87 08 11	50	238	104	8.4	--	--	--	--	--	--
233	U	Clnn	S&G	87 08 11	38	324	165	7.9	<.10	170	47	12	1.5	.7
238	U	Clnn	S&G	87 08 11	30	216	71	8.2	3.40	92	24	7	1.5	3.9
349	C	Clnn	S&G	87 08 11	64	416	187	7.8	<.10	190	52	15	8.1	1.7
350	U	Qnsn	S&G	87 08 22	12	783	163	7.8	--	260	65	23	58.0	1.2
351	U	Qnsn	S&G	87 08 11	40	280	108	8.2	--	140	36	11	3.8	1.0
352	U	Clnn	S&G	87 08 11	90	443	102	8.1	--	150	32	17	20.0	14
353	U	Clnn	S&G	87 08 11	75	354	183	7.9	<.10	180	51	12	2.5	.6
354	U	Clnn	S&G	87 08 11	97	341	179	8.0	<.10	--	--	--	--	--
355	U	Clnn	S&G	87 08 11	50	487	218	7.7	.12	250	53	28	7.4	1.6
356	C	Clnn	Clnn	87 08 11	55	366	217	7.7	<.10	250	47	32	9.6	6.6

[1] u = unconfined
c = confined.
[2] Clnn = Shale, dolostone, and limestone of the Clinton Group; Qnsn = red sandstone of the Medina Group and Queenston Formation;
[3] S&G = sand and gravel.
* Analytical results may reflect the ground-water chemistry of any one of a cluster of four wells or a composit of all four.

selected wells in the Sand Ridge aquifer.
micrograms per centimeter at 25 degrees Celsius;
yr = year, mo = month; d = day; ft = feet.]

milligrams per liter				**Dissolved concentration, in micrograms per liter**												
Chloride	Sulfate	Fluoride	Silica	Arsenic	Barium	Boron	Cadmium	Copper	Iron	Lead	Manganese	Strontium	Zinc	Lithium	Selenium	Mercury
2.1	21	.2	8.3	--	--	--	--	--	10	--	1,100	--	--	--	--	--
22	19	.1	9.2	--	--	--	--	--	9	--	220	--	--	--	--	--
--	16	.1	7.8	--	--	--	--	--	6	--	2	--	--	--	--	--
37	17	.1	8.9	--	--	--	--	--	11	--	2	--	--	--	--	--
13	15	< .1	7.8	--	--	--	--	--	200	--	110	--	--	--	--	--
14	14	< .1	8.4	--	--	--	--	--	11	--	190	--	--	--	--	--
9.5	14	.1	8.8	< 1	440	10	< 1	10	350	< 5	160	120	53	< 4	< 1	0.2
11	22	.1	8.5	--	--	--	--	--	280	--	140	--	--	--	--	--
14	17	.1	7.7	--	--	--	--	--	260	--	140	--	--	--	--	--
13	17	.2	7.8	--	--	--	--	--	310	--	130	--	--	--	--	--
17	20	.2	8.0	--	--	--	--	--	340	--	130	--	--	--	--	--
14	16	< .1	8.6	--	--	--	--	--	8	--	5	--	--	--	--	--
12	19	8.7	--	--	--	--	--	--	4	--	9	--	--	--	--	--
26	20	.1	11.0	1	250	100	< 1	8	6	< 5	62	150	260	< 4	< 1	0.9
15	21	.1	9.3	--	--	--	--	--	13	--	17	--	--	--	--	--
29	17	.1	11.0	--	--	--	--	--	4	--	58	--	--	--	--	--
17	20	.1	9.0	--	--	--	--	--	< 10	--	< 10	--	--	--	--	--
17	17	.1	8.4	--	--	--	--	--	4	--	1	--	--	--	--	--
19	22	.1	9.9	--	--	--	--	--	5	--	13	--	--	--	--	--
5	12	< .1	7.4	--	--	--	--	--	< 3	--	3	--	--	--	--	--
5.4	15	< .1	7.6	--	--	--	--	--	20	--	< 1	--	--	--	--	--
5.4	14	.1	8.0	< 1	190	10	< 1	9	11	< 5	4	77	17	< 4	< 1	< 0.1
4.3	18	.1	7.8	--	--	--	--	--	45	--	1	--	--	--	--	--
6.4	12	.1	7.8	--	--	--	--	--	< 3	--	< 1	--	--	--	--	--
6.1	14	.2	7.6	--	--	--	--	--	< 10	--	< 10	--	--	--	--	--
5.4	14	.1	7.9	--	--	--	--	--	< 3	--	< 1	--	--	--	--	--
5.3	15	.2	8.0	--	--	--	--	--	< 3	--	< 1	--	--	--	--	--
28	18	.1	8.6	--	--	--	--	--	7	--	3	--	--	--	--	--
2.2	5.6	< .1	9.1	--	--	--	--	--	80	--	600	--	--	--	--	--
4.0	15	.1	11.0	--	--	--	--	--	44	--	300	--	--	--	--	--
1.8	15	.2	13.0	--	--	--	--	--	490	--	40	--	--	--	--	--
8.3	29	.1	6.7	--	--	--	--	--	180	--	90	--	--	--	--	--
3.7	9.4	.1	7.6	--	--	--	--	--	320	--	440	--	--	--	--	--
3.4	11	.1	8.9	--	--	--	--	--	14	--	150	--	--	--	--	--
--	16	.1	6.3	--	--	--	--	--	19	--	< 1	--	--	--	--	--
2.1	6.2	.1	8.5	--	--	--	--	--	590	--	330	--	--	--	--	--
5.4	15	.1	8.2	--	--	--	--	--	14	--	240	--	--	--	--	--
14	11	.1	8.4	--	--	--	--	--	770	--	740	--	--	--	--	--
130	19	.1	8.3	--	--	--	--	--	85	--	2	--	--	--	--	--
4	10	.1	9.6	--	--	--	--	--	48	--	42	--	--	--	--	--
34	33	.1	6.9	--	--	--	--	--	6	--	8	--	--	--	--	--
3.3	8.1	.1	8.4	--	--	--	--	--	56	--	58	--	--	--	--	--
--	2.5	.4	7.8	--	--	--	--	--	90	--	9	--	--	--	--	--
6.7	30	.2	11.0	--	--	--	--	--	13	--	31	--	--	--	--	--
6.2	20	.3	11.0	--	--	--	--	--	620	--	12	--	--	--	--	--

Table 5.--Records of wells and test holes in the study area.

[Dashes indicate no data. Locations shown on pl. 1. Altitudes are in feet above sea level. In. = inch; ft = feet; gal/min = gallons per minute.]

Well or test hole number[1]	Latitude ° ' "	Longitude ° ' "	Owner[2]	Date drilled (mo d yr)	Casing diameter (in.)	Test-hole or well depth (ft)	Depth to bedrock (ft)	Aquifer type[3]	Altitude of land surface (ft)	Water level Feet	Water level Date	Reported yield (gal/min)	Remarks[3] (* = chemical analysis available)
3	431303	0761253	USGS	5-21-87	2	47	51	Sand	399	15.3	6-18-87	--	* Fine sand 0-38, medium sand 38-48, till 48-51, bedrock at 51 ft.
5	431331	0761306	Weimer	3-24-86	6	91	89	Sand & Clnn	421	26	3-24-86	6	Sand 0-89, shale 89-91 ft.
7	431332	0761307	Grammes	2-14-86	6	96	96	S&G	420	28	2-14-86	15	Sand 0-80, S&G 80-96, bedrock at 96 ft.
8	431333	0761309	Cree	2-3-86	6	94	89	S&G & Clnn	422	29	2-3-86	12	S&G 0-45, sand 45-86, S&G 86-89, shale 89-94 ft.
10	431903	0761632	USGS	6-3-87	2	22	--	S&G	409	6.7	6-18-87	--	* S&G 0-2, sand 2-4, S&G 4-26, red till 26-39 ft.
11	431713	0761545	USGS	6-5-87	2	92	--	S&G	431	27	6-5-87	--	Test boring. Fine to medium sand 0-18, silty sand 18-23, silt 23-45, silty sand 45-65, sand 65-78, pebbly sand 78-89, S&G 89-92 ft.
12	432000	0761629	USGS	6-3-87	--	67	67	--	407	5	6-3-87	--	Test boring. Fill 0-5, clay 5-33, fine sand 33-58, silt 58-62, red till 62-67, red sandstone at 67 ft.
13	431346	0761305	Noce	8-26-85	6	94	--	S&G	426	30	8-26-85	30	Sandy clay 0-15, sand 15-72, S&G 72-94 ft.
16	431340	0761306	McKenzie	4-1-86	6	105	105	S&G & Clnn	427	32	4-1-86	20	Sand and clay 0-70, fine sand 70-103, gravel and fractured shale 103-105 ft.
17	431339	0761307	Vestigo	10-04-85	6	105	102	S&G & Clnn	427	32	10-04-85	8	Sand 0-8, clay 8-17, sand and clay 17-48, fine sand 48-93, S&G 93-102, bedrock 102-105 ft.
18	431338	0761307	Mazur	8-30-85	6	102	101	S&G & Clnn	428	36	8-30-85	20	Sandy clay 0-24, fine sand 24-94, S&G 94-101, bedrock 101-102 ft.
19	431336	0761307	Leroy	12-19-85	6	82	--	S&G	428	32	12-19-85	10	Sandy clay 0-55, S&G 55-82 ft.
20	431335	0761307	Augustine	12-17-85	6	98	--	S&G	424	31	12-17-85	10	Sandy clay 0-7, clay 7-21, sandy clay 21-40, fine sand 40-70, fine S&G 70-96, S&G 96-98 ft.
21	431334	0761308	Martens	11-13-85	6	46	--	S&G	422	30	11-13-85	8	Sand 0-7, clay 7-15, sandy clay 15-28, fine sand 28-44, S&G 44-46 ft.
22	431337	0761258	Wesley	3-26-86	6	52	--	S&G	417	32	3-26-86	20	Sand and clay 0-38, S&G 38-52 ft.

[1] County sequential number assigned by the U.S. Geological Survey

[2] USGS = U.S. Geological Survey.

[3] Clnn = Shale, dolostone, and limestone of the Clinton Group; Qnsn = red sandstone of the Medina Group and Queenston Formation; S&G = sand and gravel.

Table 5.--Records of wells in the study area--continued.

[Dashes indicate no data. Locations shown on pl. 1. Altitudes are in feet above sea level. In. = inch; ft = feet; gal/min = gallons per minute.]

Well or test hole number[1]	Latitude ° ' "	Longitude ° ' "	Owner[2]	Date drilled (mo d yr)	Casing diameter (in.)	Test-hole or well depth (ft)	Depth to bedrock (ft)	Aquifer type[3]	Altitude of land surface (ft)	Water level Feet	Water level Date	Reported yield (gal/min)	Remarks[3] (* = chemical analysis available)
28	431230	0761325	Restuccio	7-5-82	6	43	25	Clnn	375	15	7-5-82	12	Sand and clay 0-25, shale 25-43 ft.
29	431231	0761327	Young	4-9-84	6	57	40	Clnn	372	10	4-9-84	20+	Clay 0-12, clay and sand 12-36, clay,sand and gravel 36-40, shale 40-57 ft.
36	431345	0761322	Baker	7-1-86	6	95	--	S&G	420	18	7-1-86	5	*Clay 0-15, sand 15-90, S&G 90-95 ft.
37	431346	0761319	Dahlin	7-7-86	6	101	100	S&G	420	25	7-7-86	15	Till 0-15, clay 15-25, sand 25-90, S&G 90-100, bedrock 100-101 ft.
42	431345	0761312	Kastin	9-2-86	6	104	--	S&G	430	32	9-9-86	5	Cobbly soil(till?) 0-15, clay 15-28, sand 28-98, S&G 98-104 ft.
43	431345	0761311	Law	9-5-86	6	106	--	S&G	430	32	9-5-86	10	Till 0-18, clay and sand 18-35, sand 35-102, S&G 102-106 ft.
44	431344	0761309	Quigy	7-9-86	6	104	--	S&G	428	31	7-9-86	15	Till(?) 0-15, clay 15-60, clay and sand 60-90, S&G 90-104 ft.
45	431432	0761310	Burns	8-7-79	6	43	--	Sand	425	16	8-7-79	10	* Sand 0-43, gravel at 43 ft.
46	431434	0761437	Village of Phoenix	1931	240	25	--	S&G	370	11.9	6-28-62	500	Dug well; yield in 1972 was reported as 20 gal/min.
47	431342	0761307	Korez	4-7-86	6	110	104	S&G & Clnn	422	34	4-7-86	20	Sandy clay 0-45, fine sand 45-80, sand 80-102, S&G 102-104, fractured rock 104-110 ft.
48	431342	0761309	Corn	6-27-86	6	106	--	S&G	420	10	6-27-86	10	Gravel and wood 0-10, clay 10-20, sand 20-100, S&G 100-106 ft.
49	431437	0761416	Village of Phoenix	6-21-67	--	62	60	--	378	--	--	--	Test hole. Clay 0-56, till 56-60, shale 60-62 ft.
50	431445	0761416	Village of Phoenix	9-16-48	24	45	--	S&G	375	9.3	9-16-48	400	*Municipal well. S&G 0-2, muck 2-4, sandy clay 4-15, S&G 15-46, clay 46-47 ft.
52	431511	0761319	Herr	9-27-84	6	35	34	S&G & Clnn	398	2	9-27-84	5	Clay 0-10, sand 10-31, S&G 31-34, shale 34-35 ft.
53	431522	0761348	Sandridge Mobile Court	--	6	50	--	S&G	430	--	--	--	*Three other wells at this site, 70, 110, and 138 ft. The 138-ft-deep well is reported to be finished in shale.

[1] County sequential number assigned by the U.S. Geological Survey

[2] USGS = U.S. Geological Survey.

[3] Clnn = Shale, dolostone, and limestone of the Clinton Group; Qnsn = red sandstone of the Medina Group and Queenston Formation; S&G = sand and gravel.

Table 5.--Records of wells in the study area--continued.

[Dashes indicate no data. Locations shown on pl. 1. Altitudes are in feet above sea level. In. = inch; ft = feet; gal/min = gallons per minute.]

Well or test hole number[1]	Latitude ° ' "	Longitude ° ' "	Owner[2]	Date drilled (mo d yr)	Casing diameter (in.)	Test-hole or well depth (ft)	Depth to bedrock (ft)	Aquifer type[3]	Altitude of land surface (ft)	Water level Feet	Water level Date	Reported yield (gal/min)	Remarks[3] (* = chemical analysis available)
54	431523	0761319	Becker	8-21-85	6	31	18	S&G & Clnn	394	5	8-21-85	5	S&G 0-18, shale 18-31 ft.
56	431343	0761320	Boorhis	9-16-86	6	85	--	S&G	430	23	9-16-86	20	Sand 0-8, clay 8-30, sand and clay 30-45, sand 45-83, S&G 83-85 ft.
57	431344	0761319	Horzempa	9-12-86	6	95	--	S&G	430	23	9-12-86	10	Sand 0-10, sand and clay 10-40, sand 40-70, sand 70-74, S&G 74-78, sand 78-90, S&G 90-95 ft.
58	431340	0761309	Rybak	8-15-86	6	105	104	S&G	430	28	8-15-86	6	Dirty gravel 0-20, clay 20-35, sand 35-100, S&G 100-104, bedrock 104-105 ft.
60	431539	0761559	Muldering	6-27-83	6	78	--	Sand	375	30	6-27-83	10	Till 0-30, S&G 30-60, S&G and clay 60-65, S&G 65-70, sand 70-78 ft.
61	431542	0761555	Henler	7-12-83	6	115	82	S&G & Clnn	380	20	7-12-83	--	Clay 0-20, S&G and clay 20-77, gravel 77-82, bedrock 82-115 ft.
63	431543	0761559	Jezerski	7-1-83	6	62	57	Clnn	385	5	7-1-83	5	Clay and gravel 0-10, S&G 10-35, clay and S&G 35-55, 55-57 ?, bedrock 57-62 ft.
67	431340	0761310	Ironwood Estates	8-12-86	6	97	--	S&G	430	28	8-12-86	15	Dirty gravel (till?) 0-15, sand 15-20, clay 20-36, sand 36-85, S&G 85-97 ft.
69	431340	0761307	Ironwood Estates	9-9-86	6	96	--	S&G	430	34	9-9-86	5	Sand 0-18, sand and clay 18-30, fine sand 42 88, S&G 88-96 ft.
70	431551	0761239	Raulli	4-29-85	6	23	23	S&G & Clnn	372	4	4-29-85	10	Clay 0-20, S&G 20-23, shale at 23 ft.
71	431556	0761428	Mercer	5-2-80	6	112	96	Clnn	425	20	5-2-80	20+	Sand 0-96, bedrock 96-112 ft.
72	431603	0761340	Gibson	1981	6	53	50	Clnn	392	3	1981	10	Clay 0-20, S&G 20-32, S&G with clay 32-40, till 40-50, bedrock 50-53 ft.
76	431616	0761632	Balcon	1981	6	48	41	Clnn	391	4	1981	6+	Clay 0-41, bedrock 41-48 ft.
80	431642	0761755	Phinney	1950	6	116	54	Clnn	400	19	7-28-60	5	--
81	431643	0761506	--	1987	6	86	80	Clnn	445	--	--	--	Sand 0-56, till 56-80, bedrock 80-86 ft.
83	431648	0761539	Mann	8-21-80	6	89	85	Clnn	395	10	8-21-80	5	Bedrock at 85 ft.
85	431654	0761600	Godfrey	5-13-81	6	50	45	Clnn	400	10	5-13-81	8	Clay and cemented S&G 0-45, bedrock 45-50 ft.
88	431714	0761731	Reynolds	1952	6	90	90	S&G	400	22.2	7-28-60	20	--
91	431721	0761632	Hunkins	12-20-79	6	120	54	Clnn	430	28	12-20-79	4	Silt and clay 0-54, bedrock 54-120 ft.
93	431724	0761533	Hildenbrand	12-6-79	6	76	85	Sand	420	30	12-6-79	5	Sand and silt 0-77 ft.

[1] County sequential number assigned by the U.S. Geological Survey

[2] USGS = U.S. Geological Survey.

[3] Clnn = Shale, dolostone, and limestone of the Clinton Group; Qnsn = red sandstone of the Medina Group and Queenston Formation; S&G = sand and gravel.

Table 5.--Records of wells in the study area--continued.

[Dashes indicate no data. Locations shown on pl. 1. Altitudes are in feet above sea level. In. = inch; ft = feet; gal/min = gallons per minute.]

Well or test hole number[1]	Latitude ° ' "	Longitude ° ' "	Owner[2]	Date drilled (mo d yr)	Casing diameter (in.)	Test-hole or well depth (ft)	Depth to bedrock (ft)	Aquifer type[3]	Altitude of land surface (ft)	Water level Feet	Water level Date	Reported yield (gal/min)	Remarks[3] (* = chemical analysis available)
95	431727	0761747	Stuart	4-12-81	6	93	73	Clnn	390	25	4-12-81	40	S&G 0-10, till 10-73, shale 73-93 ft.
96	431734	0761531	Haney	7-16-83	6	85	--	S&G	425	30	7-16-83	25	Sand 0-50, fine sand 50-83, S&G 83-85 ft.
99	431739	0761529	Kellogg	10-6-82	6	80	67	Clnn	445	--	--	30	Till 0-67, bedrock 67-80 ft.
100	431744	0761547	Conifer mobile homes	8-15-84	6	80	--	S&G	435	18	8-15-84	50	*Small community water supply. Fine to medium sand 0-50, clay 50-56, sand 56-63, till 63-66, coarse gravel 66-80 ft.
101	431751	0761556	Gristwood	7-21-83	6	133	74	Qnsn	415	30	7-21-83	3	Till 0-10, clay and S&G, 10-74, sandstone and shale 74-133 ft.
102	431754	0761622	Gristwood	12-1-80	6	101	72	Qnsn	455	23	12-1-80	2	S&G 0-72, bedrock 72-101 ft.
104	431805	0761325	Poisssant	9-28-77	6	67	35	Qnsn	410	4	9-28-77	3	Clay 0-18, S&G 18-35, siltstone and shale 35-67 ft.
105	431807	0761422	Jordan	5-7-86	6	24	--	S&G	445	5	5-7-86	5	Clay or till 0-4, S&G 4-24 ft.
106	431815	0761726	Kastler	1957	6	64	60	Qnsn	450	13.2	7-28-60	--	--
107	431821	0761443	Wood	4-19-84	6	88	56	Qnsn	437	10	4-19-84	4	S&G 0-56, bedrock 56-77 ft.
108	431828	0761508	Pyzdoraski	6-3-82	6	58	--	S&G	425	5	6-2-82	10+	*Sand 0-55, S&G 55-58 ft.
110	431830	0761507	Pyzdoraski	7-12-82	6	86	--	S&G	425	20	7-12-82	10-15	Sand 0-85, gravel 85-86 ft.
112	431837	0761740	Rauhala	1941	6	86	60	Qnsn	450	27.3	7-28-60	--	--
113	431840	0761520	Craner	1947	6	91	--	Clnn	440	--	--	--	--
115	431847	0761435	Derby	5-4-82	6	68.3	--	S&G	428	6	5-4-82	10	Clay 0-10, till 10-45, S&G 45-68.3 ft.
117	431915	0761715	Doss	1956	6	41	--	S&G	460	5	1956	15	--
118	431927	0761605	Beck	--	6	80	--	S&G	420	16.8	8-15-87	--	--
120	431931	0761732	Slivinski	4-6-81	6	87	50	Qnsn	470	20	4-6-81	5	Till 0-50, sandstone 50-87 ft.
121	431933	0761748	Alpeter	9-17-79	6	63	--	S&G	440	10	9-17-79	5	S&G 0-63 ft.
123	431940	0761809	Dubois	1957	6	120	80	Qnsn	460	30	1957	--	--
126	431943	0761755	Hill	4-13-84	6	105	66	Qnsn	450	20	4-13-84	3	Till 0-66, sandstone 66-105 ft.
127	432006	0761547	Baer	5-13-83	6	125	98	Qnsn	461	40	5-13-83	4	S&G 0-48, clay with S&G and silt (till?) 48-52, S&G with silt 52-98, bedrock 98-125 ft.
128	432009	0761710	Whipple	1957	6	68	--	S&G	460	--	--	15	--
129	432009	0761725	McGinley	1920	6	75	30	Qnsn	470	31.5	7-27-60	--	--
133	432010	0761742	McGinley	1959	6	43	--	Qnsn	470	29.6	7-28-60	--	--

[1] County sequential number assigned by the U.S. Geological Survey

[2] USGS = U.S. Geological Survey.

[3] Clnn = Shale, dolostone, and limestone of the Clinton Group; Qnsn = red sandstone of the Medina Group and Queenston Formation; S&G = sand and gravel.

*U.S. GOVERNMENT PRINTING OFFICE: 1993-711-679