HYDROGEOLOGY AND GROUND-WATER QUALITY OF LANNON-SUSSEX AREA,

NORTHEASTERN WAUKESHA COUNTY, WISCONSIN

by R. D. Cotter

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4213

Prepared in cooperation with the

UNIVERSITY OF WISCONSIN-EXTENSION,

GEOLOGICAL AND NATURAL HISTORY SURVEY

and the WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Madison, Wisconsin

1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION TABLE

For the use of readers who prefer the International System of Units (SI), the conversion factors for the terms used in this report are listed below.

Multiply inch-pound unit	By	To obtain SI unit
inch (in.)	25.4	millimeter (mm)
inches per hour (in/h)	2.540	centimeter per hour (cm/h)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	4,047	square meter (m^2)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

The term "sea level" used in this report refers to the National Geodetic Datum of 1929 (NGVD of 1929). The NGVD of 1929 is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level.

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ABSTRACT

The Silurian dolomite aquifer in the Lannon-Sussex area of southeastern Wisconsin is overlain by glacial deposits, but is within 8 feet of the land surface over 15 percent of the study area. The proximity of the dolomite aquifer to land surface makes it susceptible to contamination from man's activities. Water from the aquifer was analyzed and several characteristics were monitored in a 30-square-mile area of Waukesha County.

The water is hard, commonly having a hardness of more than 350 milligrams per liter as $CaCO_3$, and high in iron, commonly containing more than 0.3 milligrams per liter. However, nutrient concentrations are not high; nitrogen, <8 milligrams per liter; phosphorous, none detected; and potassium, <4 milligrams per liter. The chloride content of the water averages more than 50 milligrams per liter indicating contamination probably from septic systems. The water quality varies over time. High concentrations of chloride and, occasionally, of bacteria correlate with periods of ground-water recharge over a period of 17 months. Chloride concentrations were highest in water from wells where housing density is high.

An attempt was made to relate water-quality changes with depth to beds of cherty dolomite that are identified in geologic logs; it was postulated that these zones might be confining beds. Although the beds appear to extend over the area, no evidence was found that they are confining beds, other than reports of a few artesian wells. Water quality, indicated by chloride content, showed no significant relation to well-bottom altitude, casing-bottom altitude, or well depth.

INTRODUCTION

Background

Much of the population in northeastern Waukesha County depends on individual water wells finished in the Silurian dolomite aquifer. Only the village of Sussex has municipal sewer and water service. Water movement in the Silurian dolomite is mostly through interconnected joints and solution channels. Water can move rapidly through this aquifer and there is often little attenuation of any contained pollutants. Where overlying glacial deposits are thin, the deposits offer little capacity for adsorbing or retarding pollutants. The increased use of septic-tank systems in the study area may affect the water quality within the Silurian dolomite aquifer because thin glacial drift places the point of entry of septic-tank effluent closer to the jointed Silurian bedrock.

This study is a cooperative project of the University of Wisconsin-Extension, Geological and Natural History Survey, the Wisconsin Department of Natural Resources, and the U.S. Geological Survey.

Purpose and Scope

The purpose of this report is to describe the ground-water quality in an area of shallow, fractured dolomite bedrock that contains individual wells and septic systems. It describes the geology and ground-water quality of the Lannon-Sussex area in northeastern Waukesha County, Wisconsin.

Description of the Study Area

The study area is approximately 30 mi^2 and is located in northeastern Waukesha County. It is bounded on the east by the Fox River and on the north by the Waukesha-Washington County line. The west and south boundary connects two stream segments and a series of topographic highs. The area includes the village of Sussex, the village of Lannon, several areas of dense housing, and rural area (fig. 1).

A subarea of about 5 mi^2 was studied in detail to better define the degree of contamination of water in the Silurian dolomite aquifer and to study changes in water quality with season. The chosen area includes the village of Lannon, where ground-water contamination had been reported. It also includes a housing development northwest of Lannon, some rural development, and several quarries. Most areas of dense housing are northwest of Lannon and have lot sizes of 1 to 2 acres. Lots are typically less than 1 acre within Lannon.

Method of Study

Ground-water samples and well-log, water-level, auger-hole, and drillers' report data were collected and analyzed to describe the hydrogeology and ground-water quality of the study area. Records of 344 wells were used in the study (fig. 1). Of these wells, 276 were visited and 181 were sampled for water quality.

Records of 126 wells within the subarea were collected and used to prepare maps to define the subarea hydrology (fig. 1). Nine of these wells were monitored monthly for water level, specific conductance, and chloride concentration.

Acknowledgments

Thanks are extended to the hundreds of well owners who allowed measurements and sampling of their wells. The cooperation of municipal and county personnel, well drillers, and many others who provided assistance and information is greatly appreciated. Special acknowledgment is made of the Wisconsin Department of Natural Resources for supplying well records.

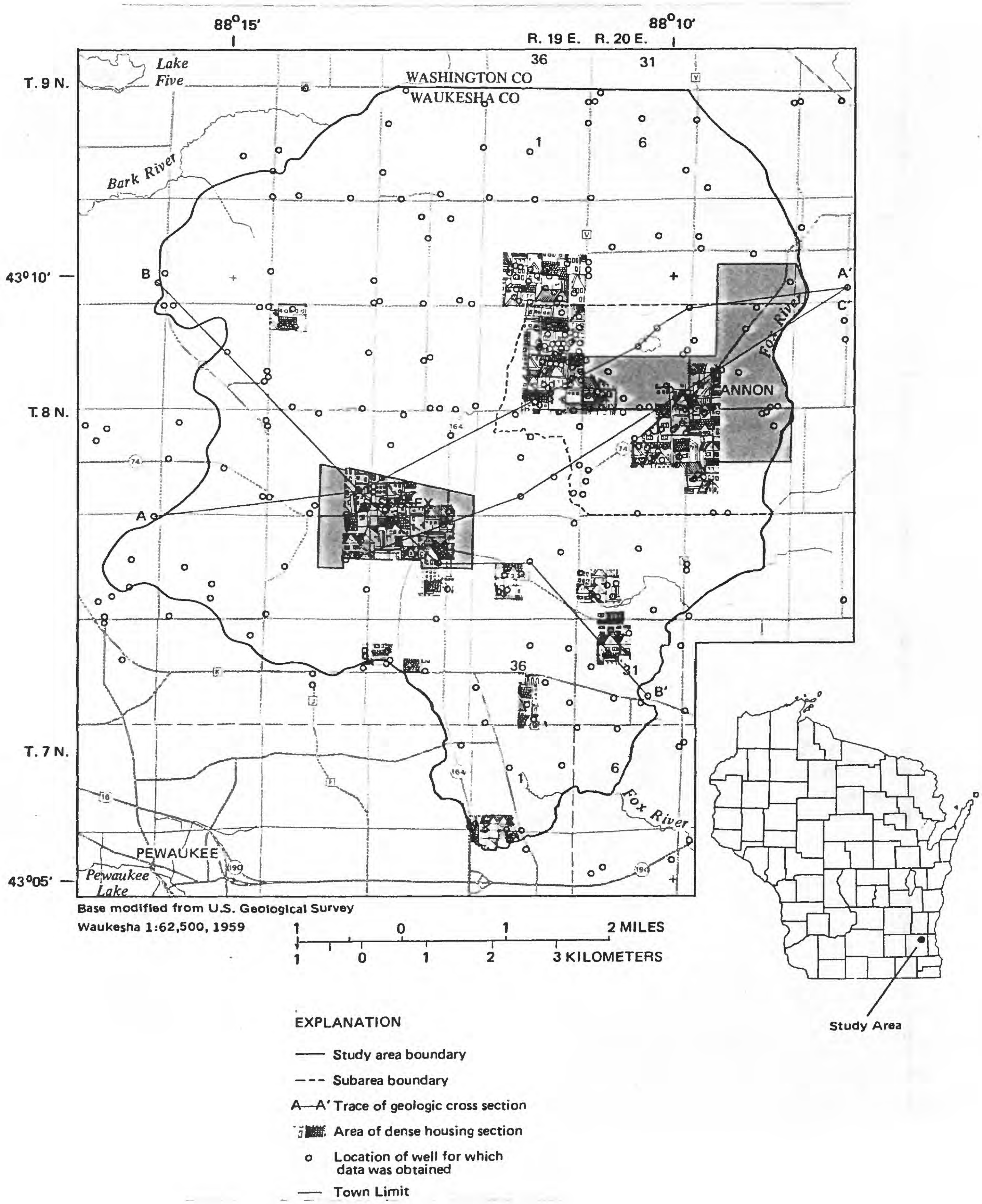


Figure 1. Location of study area and subarea

HYDROGEOLOGY

The principal sources of ground water in northeastern Waukesha County are the sand-and-gravel aquifer, the Silurian dolomite aquifer, and the sandstone aquifer. Aquifers are permeable, water-yielding rock units. This report describes the sand-and-gravel aquifer and the Silurian dolomite aquifer. Their characteristics are shown in table 1. The sandstone aquifer is not considered here because it is effectively sealed off from the upper aquifers by the Ordovician Maquoketa Shale.

Sand-and-Gravel Aquifer

This aquifer consists of sand and gravel deposits in the glacial drift. Unconsolidated glacial deposits overlie most of the study area, although they are very thin in a large part of the area. The type and extent of the glacial deposits is shown in figure 2, and their thickness is shown by the depth to bedrock map (fig. 3).

These deposits are generally thickest in the northwestern and southwestern parts of the study area and exceed 100 ft in places. Bedrock is less than 8 ft below land surface and is exposed locally in a band stretching from southeast of Sussex to northeast of Lannon. Nearly one-half of the subarea is underlain by bedrock within 8 ft of the land surface.

Most of the unconsolidated materials in the study area consist of unsorted glacial till containing clay-size to boulder-size material. This unconsolidated material was deposited in end moraines and ground moraines. Small surficial deposits of outwash and glacio-lacustrine sediments are present in the northwestern and southeastern parts of the study area.

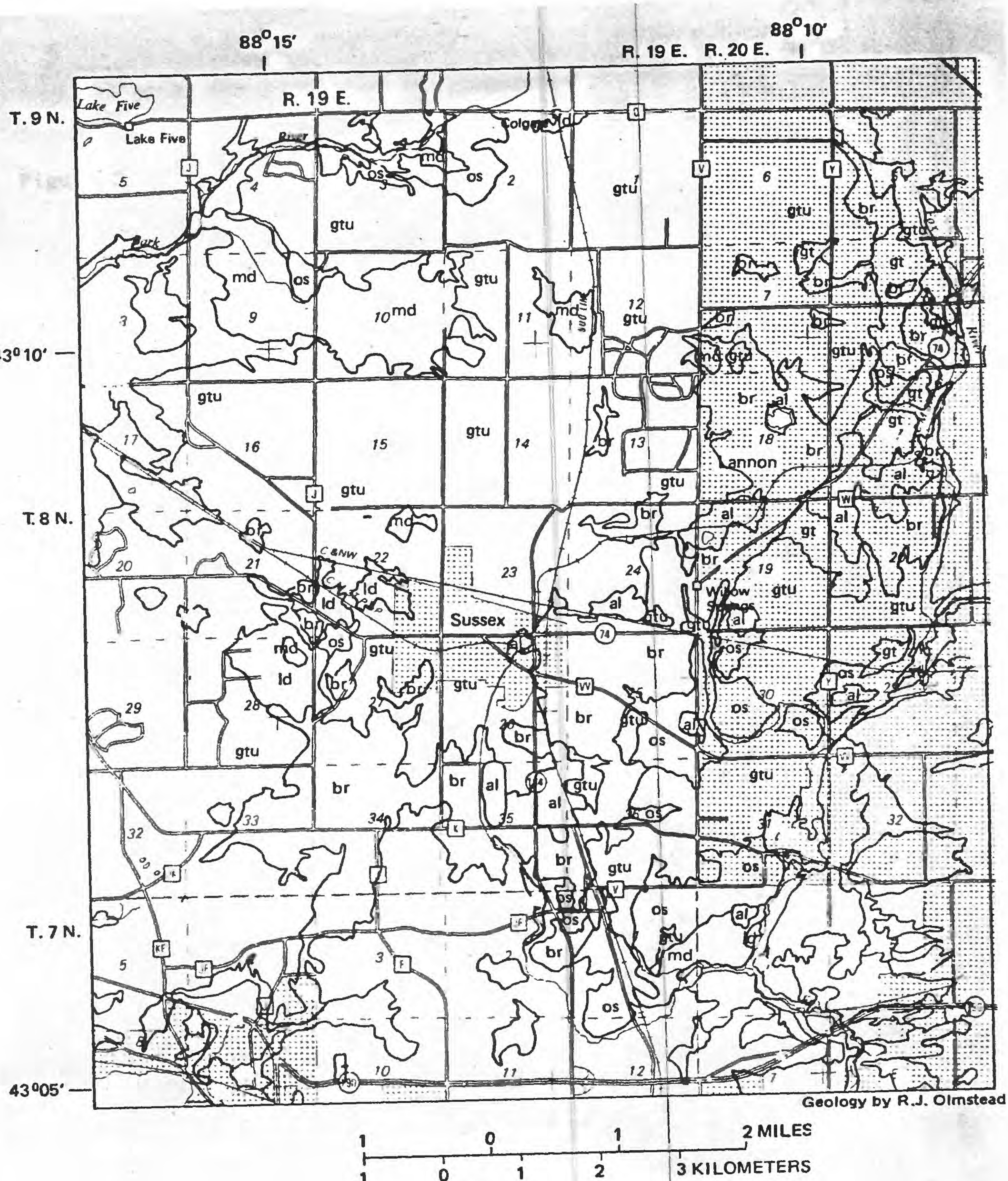
End moraines are ridge-like features that trend north to south through the study area. They have rolling to hummocky surfaces. Ground moraines have low relief with gently undulating surfaces. The soils formed on the till are typically silt and clay loams with moderately low permeabilities that usually range between 0.20 and 2.0 in/h (fig. 4). The thickness of these deposits is variable but is generally less than 100 ft thick in the study area.

Outwash and glacio-lacustrine deposits are composed mainly of stratified silt, sand, and gravel. They are deposited in glacial stream valleys and flood plains, in glacial lake beds, and as fan or deltaic deposits beyond the ice front. The topography of these areas is generally flat. Glacio-lacustrine sediments also contain large amounts of organic material. They are usually poorly drained and the water table is within a few feet of the land surface. Outwash deposits are normally well-drained. Permeability of the soils formed in these materials ranges from 0.20 to 20.0 in/h in the glacial lacustrine deposits and is commonly >20 in/h in outwash deposits (fig. 4). This makes the permeability of soils developed in outwash about 20 times greater than that in soils developed on the next most permeable deposit.

The sand-and-gravel aquifer yields as much as 2,000 gal/min to wells in Waukesha County. Fifteen gallons per minute, enough for a domestic supply, is available from this aquifer almost everywhere within the county where it has adequate thickness. Much of the aquifer is unsaturated and thin in the study area.

Table 1.--Characteristics of the sand-and-gravel and Silurian dolomite aquifers

Aquifer	Approximate thickness (feet)	Rock characteristics	Factors controlling permeability
Sand-and-gravel	0-200	Sand and gravel layers and lenses within the glacial and alluvial deposits. Includes well-sorted sand, silty sand and gravel, and "clean" sand and gravel.	Permeability is from interconnected intergranular pore space. Well-sorted gravels are extremely permeable.
Silurian dolomite	150-300	Thick to thin-bedded, fine- to coarse-grained dolomite. Upper part more massive; lower part more thinly bedded. Contains pyrite in bottom 140 to 180 ft and glauconite in bottom few feet.	An extensive system of joints and fractures, commonly enlarged by solution, account for the permeability of this otherwise dense rock. The amount and location of fractures is highly variable, but fracturing seems most abundant near the top.

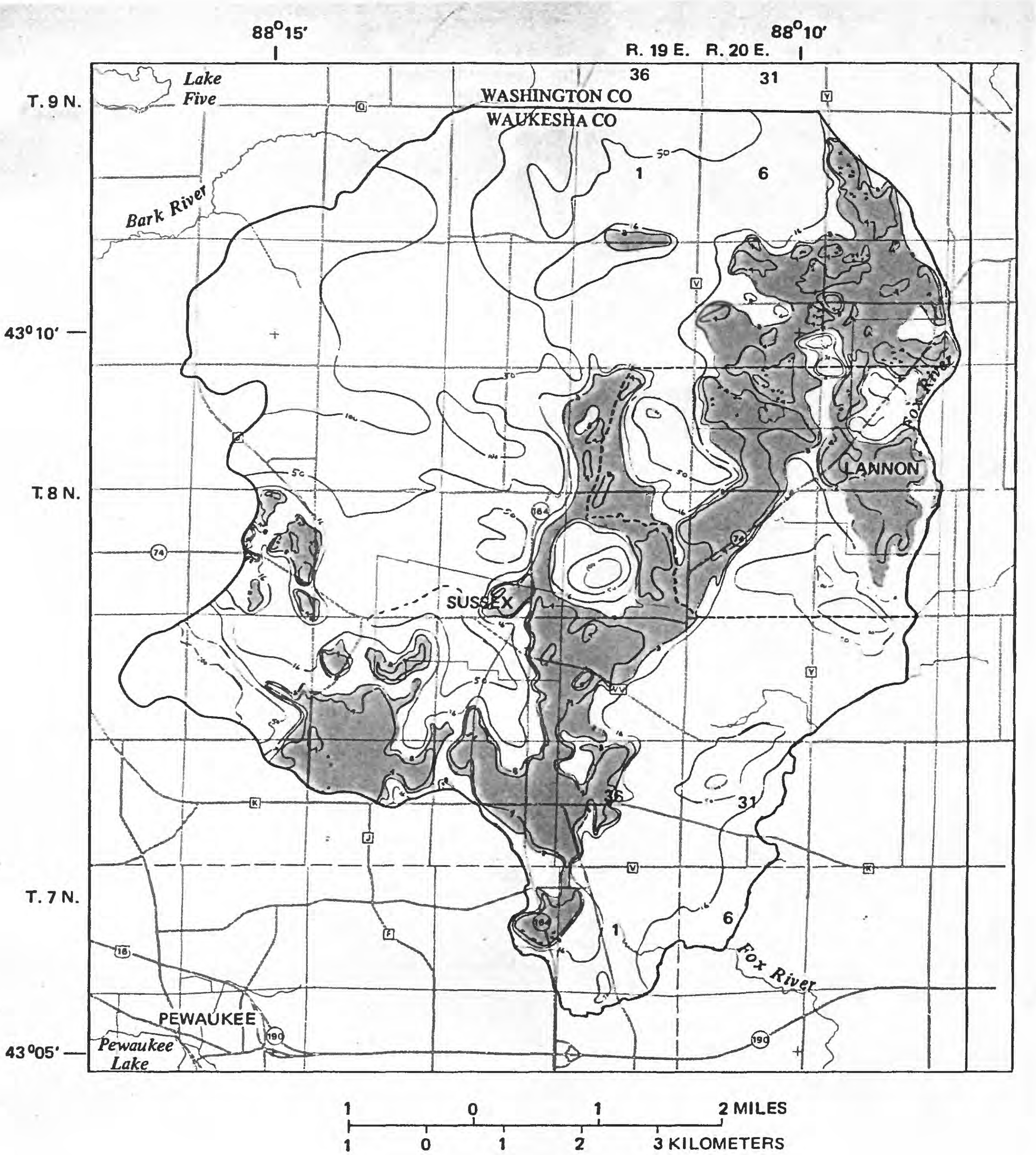


EXPLANATION

Surficial Material

- gtu — Glacial Till (Unstratified and unsorted clay, silt, sand, gravel & boulders)
- gt — Glacial Till, clayey
- os — Outwash and ice-contact stratified sand, gravel & boulders
- av — Alluvium
- al — Altered land
- md — Marsh (organic deposits)
- ld — Lake deposits (clay, silt and sand)
- br — Bedrock, or bedrock beneath thin glacial drift cover
- —— Study area boundary
- - - - Subarea boundary

Figure 2. Glacial Geology



EXPLANATION

Line of equal depth to bedrock
Interval variable. Dashed where approximately located.
Based on soils maps and well data.

Study area boundary

Subarea boundary

× Bedrock outcrop

Area in which bedrock is within 8 feet of landsurface.

Figure 3. Depth of bedrock

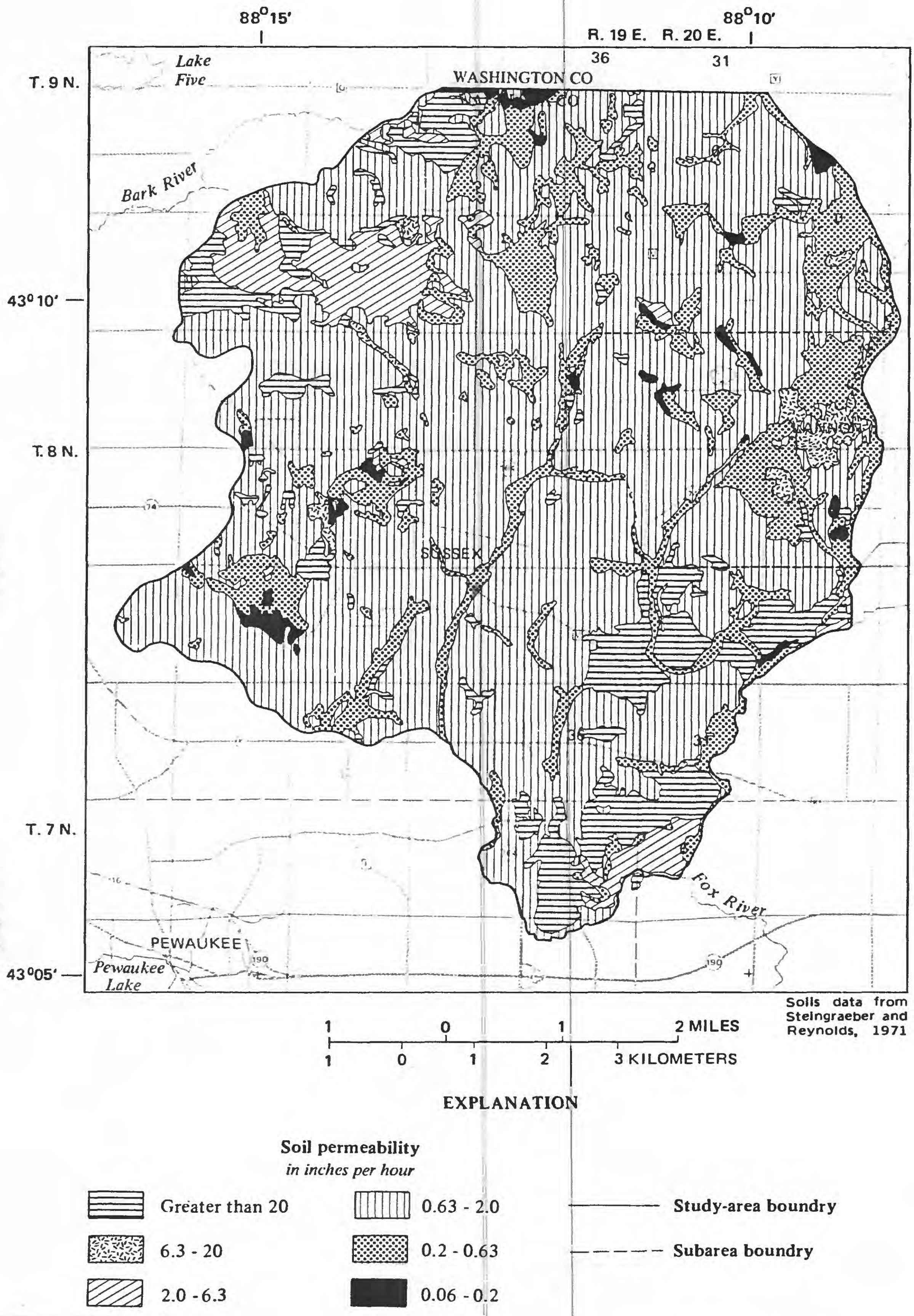


Figure 4. Permiability of soils

Silurian Dolomite Aquifer

The Silurian dolomite aquifer includes the entire Silurian dolomite section. The dolomite is the uppermost bedrock unit throughout the study area; its thickness ranges from less than 150 ft along the western margin of the study area to greater than 300 ft near Menomonee Falls. The beds dip eastward at 25 ft/mi (approximately).

The shape of the bedrock surface is shown in figure 5. It is similar to the surface topography. It slopes to the southeast and to the west from a northeast-to-southwest trending bedrock ridge in the center of the study area. A bedrock valley extends northwest from this ridge. The bedrock surface altitude ranges from more than 960 ft above mean sea level in the southwest part of the study area to less than 800 ft in the northwest.

The bedrock is a thin-to-massive bedded, buff to very dark gray, fine-grained to coarsely crystalline, dense to porous and vuggy, variably fractured dolomite with interspersed fossiliferous and cherty layers. It is partially exposed in several quarries in the study area. Geologic logs prepared from well samples by the Wisconsin Geological and Natural History Survey (WG&NHS) indicate varying amounts of chert and pyrite in the dolomite. Small amounts of glauconite are also present locally in the bottom few feet of the dolomite.

Outcrops of Silurian dolomite are common, especially in a band about 2 mi wide that extends from northeast of Lannon to south of Sussex. Much of this area is covered by drift that is only a few feet thick. In fact, in 15 percent of the study area the dolomite bedrock is less than 8 ft below land surface (fig. 3). Where exposed, the bedrock surface commonly has near-vertical jointing. However, there seems to be no preferred azimuth orientation of these joints. In Door County, where this dolomite was studied, joints tend to be small and discontinuous and to diminish in size and number with depth (Sherrill, 1978, p. 12). Joints may also be enlarged by dissolution. Bedding-plane joints are deeper in the Silurian dolomite, are more continuous, and yield larger amounts of water than the near-vertical surface joints. In Waukesha County, joints are significant localized sources of water in the upper layers of the Silurian dolomite (Gonthier, 1975).

Well yields as high as 500 gal/min are obtained from this aquifer in Waukesha County (Gonthier, 1975, p. 18). In areas of shallow bedrock, such as in the study area, most domestic wells obtain water from the dolomite.

Production Zones

Horizontal (or bedding-plane) zones of differing permeability occur in the Silurian dolomite. In Door County, several water-bearing zones were delineated in this aquifer (Sherrill, 1978, p. 12-13). The presence of such zones in the study area is indicated by artesian heads that are found in some wells finished in the aquifer. Drillers report that some wells flowed in excess of 40 gal/min at the time of drilling; this indicates horizontal confining zones within the dolomite.

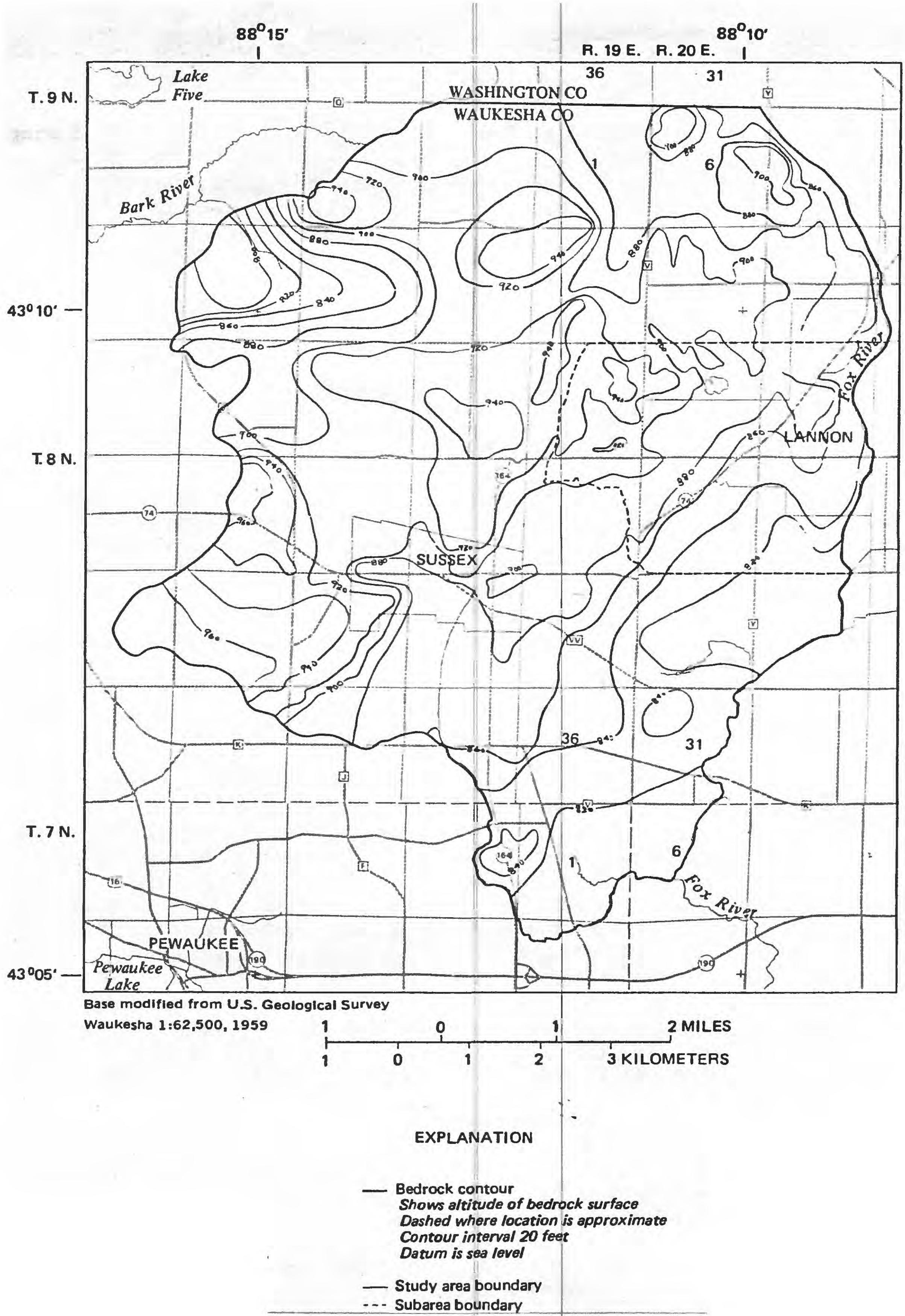


Figure 5. Bedrock topography

Differences in permeability of zones are probably related to the lithology of the bedrock. Sherrill (1978, p. 13) found that areally extensive water-bearing zones are located at lithologic changes. Sample logs of the WG&NHS described zones of cherty dolomite within the Silurian dolomite in the study area. An attempt was made to correlate these zones between wells using sample logs. Figure 6 shows correlation lines connecting zones of cherty dolomite, described in sample logs, within the Silurian bedrock. A bottom cherty zone about 20 ft thick occurs atop the Maquoketa Shale; a second zone, 40-50 ft thick, occurs about 100 to 150 ft above the top of the shale. A third, upper zone is present in two places along the section; it was probably removed by erosion elsewhere.

It is possible that wells in the study area obtain their water from several continuous, or semicontinuous water-bearing zones that are present in conjunction with cherty dolomite--either within or adjacent to it.

Recharge and Movement

The Silurian dolomite aquifer is recharged by leakage that enters the dolomite through the overlying glacial drift. The type and thickness of unconsolidated materials overlying the bedrock affect the amount of recharge to the aquifer. Recharge to the Silurian dolomite aquifer is more rapid in areas of near-surface bedrock and in areas of renewable outwash deposits than in areas of glacial till.

Ground water in the study area moves within a water-table system and probably within several semiconfined zones. Water levels in wells open to shallow permeable glacial deposits, and to unconfined upper layers of the Silurian dolomite, represent the water table. Water levels in wells open to deeper zones in the dolomite represent the potentiometric surface of that zone, and may be above (in discharge areas) or below (in recharge areas) the water table. It is not possible to determine what surface(s) is represented by a well's water level because vertical gradients and detailed lithology in the wells are unknown and many wells are open to more than one zone. Therefore, potentiometric maps of individual zones cannot be drawn from available data.

A potentiometric map (fig. 7) was drawn using water levels for nearly all of the 350 wells for which records were obtained. Only a few water levels that differed significantly from those around them were ignored. Differences in heads from different zones are commonly only a few feet. The resultant potentiometric map is considered to be a fair representation of the water-table surface.

Flow in this system is regionally from northwest to southeast. Locally, flow is away from highs in the water table and toward streams and lakes, where ground water is discharged to surface water. Dewatering of quarries near Lannon and Sussex has created local cones of depression in the water tables.

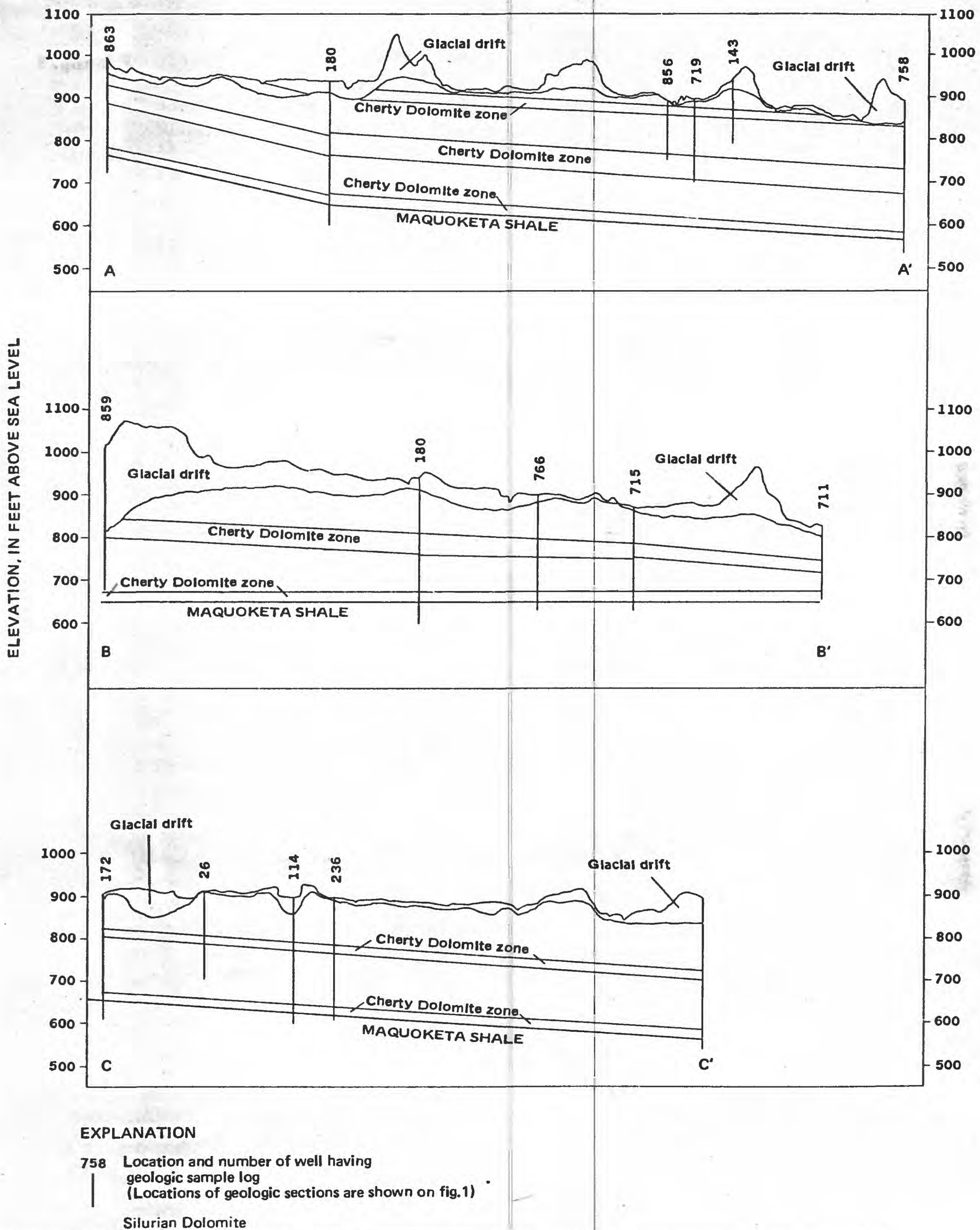
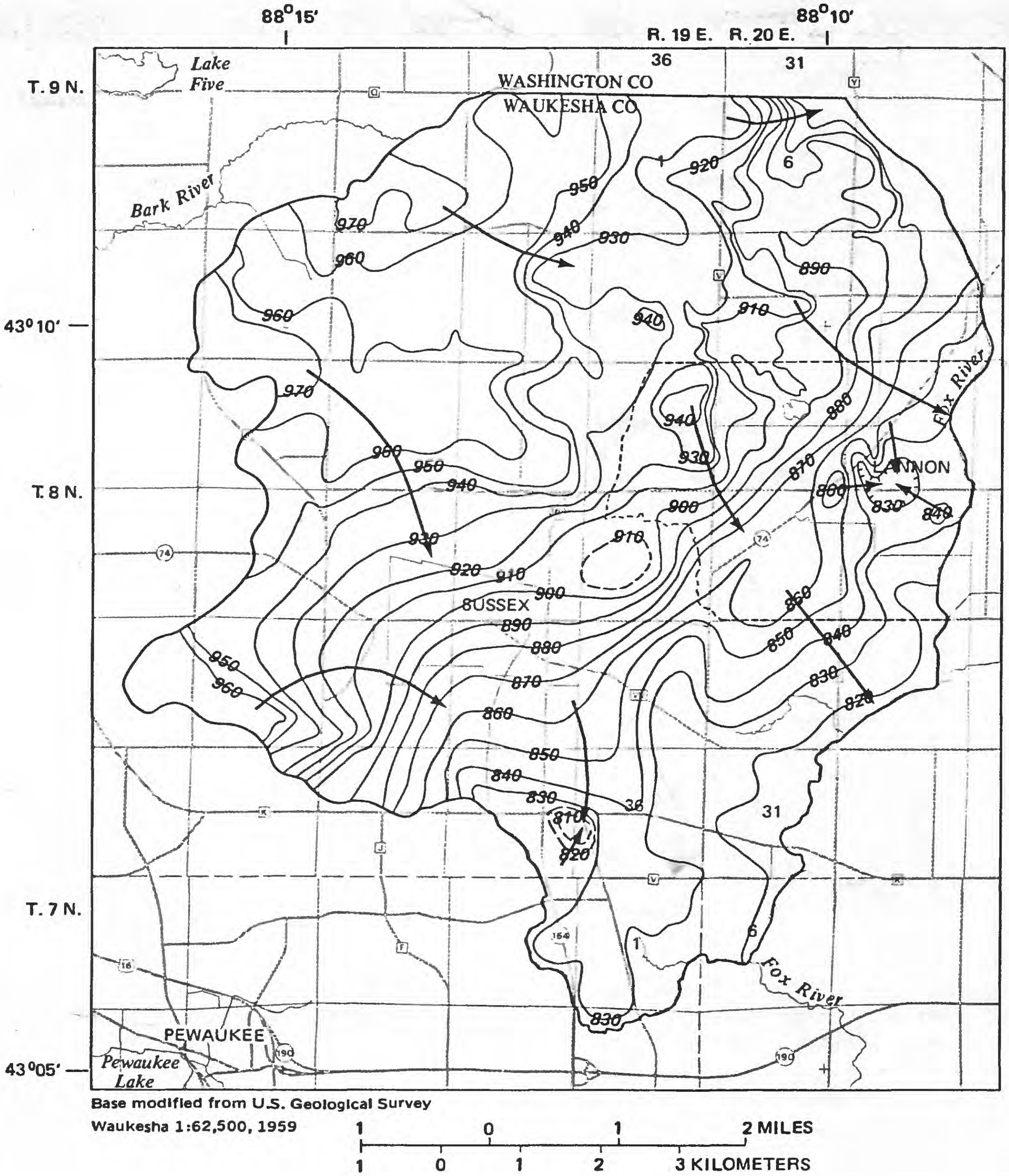


Figure 6. Geologic sections A-A', B-B', and C-C' showing cherty zones in the Silurian dolomite



EXPLANATION

—900— Water-table contour
Shows altitude of water table Dashed where approximately located. Contour interval 10 feet. Datum is sea level. Based on measured and reported waterlevels Average water levels used for monitored wells.

——— Study area boundary

– – – – Subarea boundary

———► Direction of shallow ground-water flow

Figure 7. Water table

GROUND-WATER QUALITY

Ground water in the study area is hard and commonly high in iron; this is typical for southern Wisconsin. However, iron concentrations in water from five wells in the Lannon area exceeded 1 mg/L. The average for Waukesha County is less than 0.6 mg/L. The hardness is due to the calcium and magnesium dissolved from the dolomite in the soil, glacial deposits, and bedrock. The iron is also dissolved from these materials. The concentrations of some minor dissolved constituents in the ground water (chloride in particular) appear to be influenced by land use.

Water from five wells was analyzed for all the common inorganic constituents to determine overall water quality. Specific conductance and chloride were measured at 181 wells in the study area to obtain an indication of water quality areally and with depth; 85 of these wells were in the subarea. In order to look into nitrogen content and its source, 74 samples were taken from 57 wells and analyzed for four of the nitrogen species. Nine wells were sampled monthly between March 1977 and July 1979 for chloride, specific conductance, total coliform, fecal coliform, and pH to study variation of water quality with time.

The general inorganic water quality can be seen from table 2. Analyses of samples from five wells (locations on figure 8) can be compared with County and Statewide averages. As stated earlier, calcium and magnesium concentrations are high. The high calcium (78-140 mg/L) and magnesium (37-70 mg/L) concentrations result in high hardness and high total solids. The values for these constituents are above County or Statewide averages for this aquifer. Ground water from this aquifer is hard. Iron concentrations in water from the five wells greatly exceed County and State averages (table 2). Strontium concentrations are high in wells Wk-856 (1.4 mg/L) and Wk-932 (3.8 mg/L). Sodium and chloride concentrations are equal to or less than County and Statewide averages for water from three of the wells, but concentrations are somewhat high in well Wk-1050 (30 and 75 mg/L) and even higher in well Wk-1052 (68 and 190 mg/L). These concentrations suggest contamination, probably from a local source. Mean concentrations from a larger sampling of wells shows higher concentations. (See text on Chloride.) High concentrations of nutrients (nitrogen species, potassium, and phosphorous) are commonly considered to be evidence of pollution from waste disposal sites, septic systems, agricultural fertilizers, and livestock waste. The nutrient concentrations from the five wells are not high.

Table 2.--Chemical analyses of ground water from the Silurian dolomite aquifer in the Lannon area, Waukesha County, and statewide

[Results in milligrams per liter except iron and manganese (ug/L), pH (standard units), temperature (°C), and specific conductance (umhos)]

	Well number					Waukesha County 1/		Entire aquifer in Wisconsin 1/	
	856	932	1044	1050	1052	Mean value	No. of wells	Mean value	No. of wells
Well location	T. 8 N., R. 20 E., sec. 18	T. 8 N., R. 20 E., sec. 20	T. 8 N., R. 20 E., sec. 19	T. 8 N., R. 20 E., sec. 17	T. 8 N., R. 19 E., sec. 12				
Date sampled	April 22, 1981	April 22, 1981	April 22, 1981	April 22, 1981	April 22, 1981				
Water temperature	12	10.5	10.0	13.0	10.0				
Calcium, dissolved	78	140	140	87	100	91	41	82	317
Magnesium, dissolved	37	51	70	43	50	40	41	38	317
Potassium, dissolved	2.5	3.1	2.2	2.3	1.5	2.7	27	2	187
Sodium, dissolved	5.3	14	18	30	68	21	41	18	295
Strontium, dissolved	1.4	3.8	.13	.14	.38	---	---	---	---
Alkalinity, total $CaCO_3$	310	270	250	340	300	284	41	262	303
Chloride, dissolved	20	27	45	75	190	32	42	17	359
Fluoride, dissolved	.3	.3	.0	.1	.2	.5	41	.5	315
Sulfate, dissolved	39	300	370	46	75	104	42	101	359
NO_2 as N	.00	.00	.00	.00	.00	---	---	---	---
NO_3 as N	.12	.02	.02	.02	.02	1.0	42	1.0	296
NH_4 as N	.08	.07	.04	.03	.18	---	---	---	---
Organic N as N	.05	.08	.10	.09	.23	---	---	---	---
Phosphorus, dissolved	.00	.00	.00	.00	.00	---	---	---	---
Iron, dissolved	1,200	5,300	1,900	3,200	1,500	555	45	662	360
Manganese, dissolved	30	20	120	90	20	43	15	45	335
Silica, dissolved	8.8	8.1	8.2	30	17	---	---	---	---
Hardness	350	560	640	390	460	388	44	356	363
Hardness, noncarbonate	39	290	390	54	160	---	---	---	---
Solids, residue on evaporation at 180°C	395	764	887	534	733	494	42	459	348
pH, field	7.2	7.2	7.2	7.2	---				

1/ From Kammerer, 1981.

Chloride

Chloride was measured in water from 101 Silurian dolomite wells throughout the study area that were cased less than 10 ft into bedrock. It was also measured in a group of 80 Silurian dolomite wells that were cased more than 25 ft into bedrock. Of these 181 wells, 85 were in the subarea. A comparison of chloride concentration with casing penetration follows:

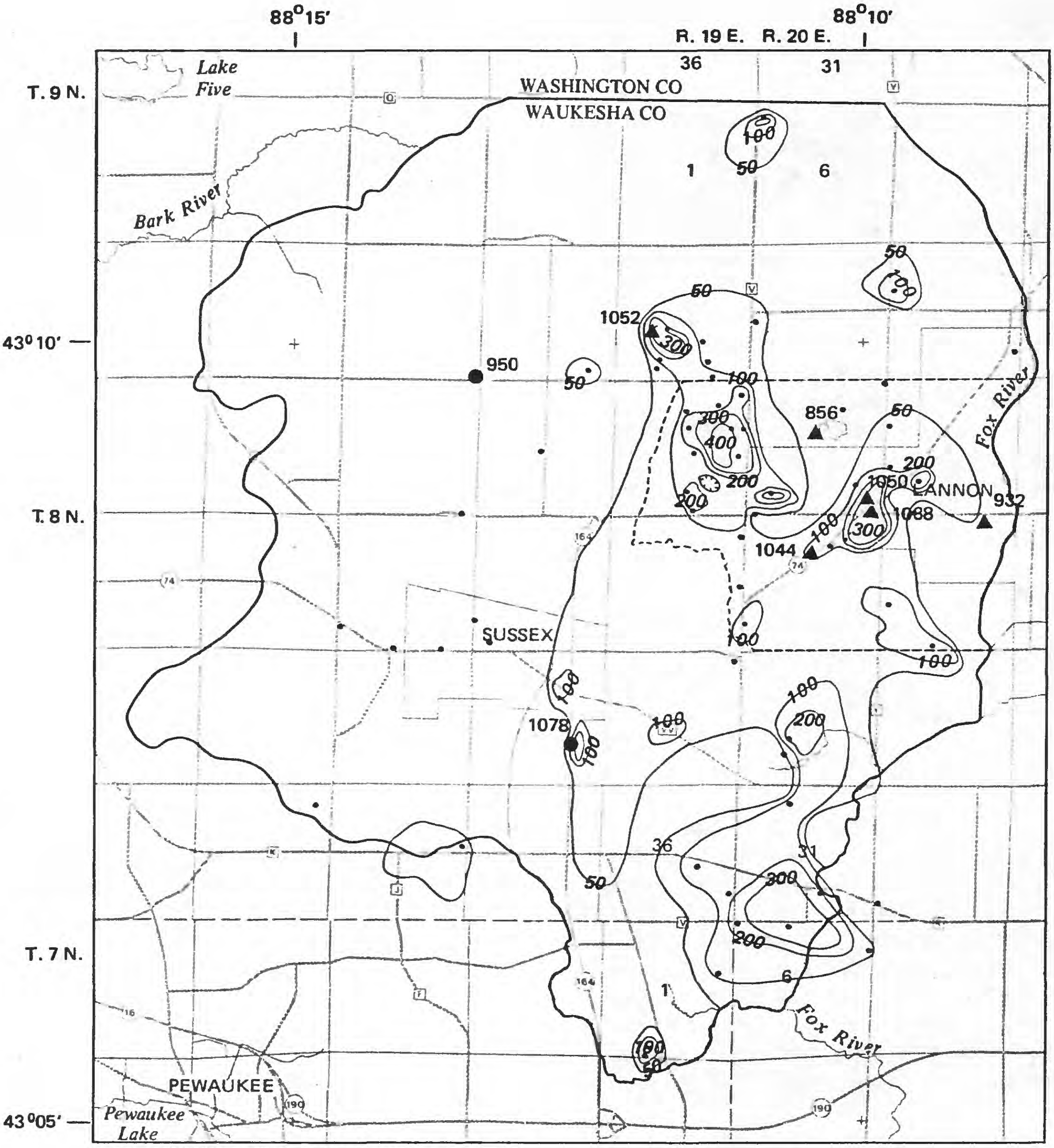
	Entire study area			Subarea only		
	Chloride (mg/L)			Chloride (mg/L)		
	No. of wells	Range	Mean	No. of wells	Range	Mean
Wells with <10 ft casing into rock	101	5-435	95	41	21-435	177
Wells with >25 ft casing into rock	80	3-320	58	44	12-320	80

Although the mean concentration of chloride is considerably greater in wells that have only a few feet of casing into bedrock, the differences are not statistically significant. Chloride concentrations from the two groups of wells (those with 755 ft of casing and those with <10 ft) in the table were transformed (using log +1) to obtain a normal distribution and tested to determine the probability that they were from different sources. At the 95 percent confidence level there was no significant difference between the means of the two data sets. Two random samples from a single data set would be as different as these (the chloride concentrations) 31 percent of the time.

These mean concentrations compare to a mean concentration, Statewide, for the Silurian dolomite aquifer, of 17 mg/L from a sampling of 359 wells (table 2).

Plots of chloride concentration as a function of well bottom altitude, well depth, casing bottom altitude, and land surface altitude also showed no definitive interrelationship that might be expected if higher concentrations were related to stratigraphic zones.

The areal distribution of concentrations of chloride in Silurian dolomite water in March and April 1977 is shown in figure 8. The areas of high concentration of chloride show litte or no relationship to depth to bedrock (fig. 3), and coincide with areas of high soil permeability (fig. 4) only in the extreme southeast. Areas of high chloride concentration do correspond fairly well to areas with the highest housing density; this can be seen by comparing figure 8 with figure 1.



Base modified from U.S. Geological Survey
Waukesha 1:62,500, 1959

1 0 1 2 MILES

1 0 1 2 3 KILOMETERS

EXPLANATION

—*200*— **Line of chloride concentration in ground water from wells in Silurian dolomite aquifer**
Contour interval 100 milligrams per liter, with supplemental 50 milligram per liter contour.

———— Study area boundary

– – – – Subarea boundary

• **Well sampled for chloride**

● **Well monitored for changes in water quality (see fig. 10)**

▲ **Well sampled for chemical analysis (see table 2)**

1052 **Well number**

Figure 8. Chloride concentrations in ground water March-April 1977

The areal distribution of chloride in the subarea during May 1978 is shown in figure 9. The pattern is very similar to that determined in March and April 1977 (fig. 8), and, again, the areas of highest concentrations correspond to areas of high population density. The high population density in the subarea also corresponds with higher chloride concentrations in the subarea, as shown in the preceding table.

The high chloride concentration in ground water in the area seems to indicate contamination. Overall, the average concentrations are 3 to 6 times the Statewide average for this aquifer (table 2). The high concentrations in areas of high housing density indicate that the chloride may be entering the ground-water system through septic tanks from water-softening regeneration brine and domestic waste or from contamination by road salt. Because chloride is generally conservative, it is affected only by dilution.

Nitrogen

Seventy-four samples of water from 57 wells in the Silurian dolomite were analyzed for nitrogen species. Thirty-four wells were sampled in May 1977 and 40 in September 1978. Seventeen of the total of 57 wells were sampled during both years. Statistics for nitrogen species were calculated using an average value for each well. The maximum, minimum, mean, and median values are summarized in tabular form for ammonia, organic nitrogen, nitrite, and nitrate nitrogen (table 3).

If it is assumed that most nitrogen leaves the septic system as NH_4+ or as organic nitrogen (Dudley and Stevenson, 1973), the relative abundance of nitrogen species should indicate relative distance from a contaminant source (or time of travel of the contaminant) in a series from least oxidized (organic nitrogen and ammonia) to most oxidized (nitrite and nitrate). In the study area, most of the nitrogen has been oxidized to nitrate. This is postulated to be due largely to water movement through significant thickness of unsaturated materials that allow oxidation to occur and in part to the ability of the clay soils to adsorb NH_4+. The highest oxidation state, nitrate, is conservative and travels readily in ground water.

Even though nitrate nitrogen was present in the highest concentration of the nitrogen species, very few of the samples showed significant concentrations of NO_3-N, and none exceeded the State-established limit of 10 mg/L. The highest concentrations of nitrate were found in water from shallow wells that have casings that do not penetrate bedrock significantly.

Table 3.--Summary of concentrations of nitrogen species in water from the Silurian dolomite aquifer in the study area

(Composite samples by site)

Constituent	Number of samples	Concentration in milligrams/liter as N			
		Minimum	Maximum	Mean 1/	Median
Organic nitrogen	61	<0.01	0.87	0.21	0.18
Ammonia nitrogen	61	< .01	.29	.04	.02
Nitrite, total	61	< .01	.13	.006	<.01
Nitrate, total	77	< .01	7.6	.96	.05

1/ <.01 used as 0.00 in calculating mean.

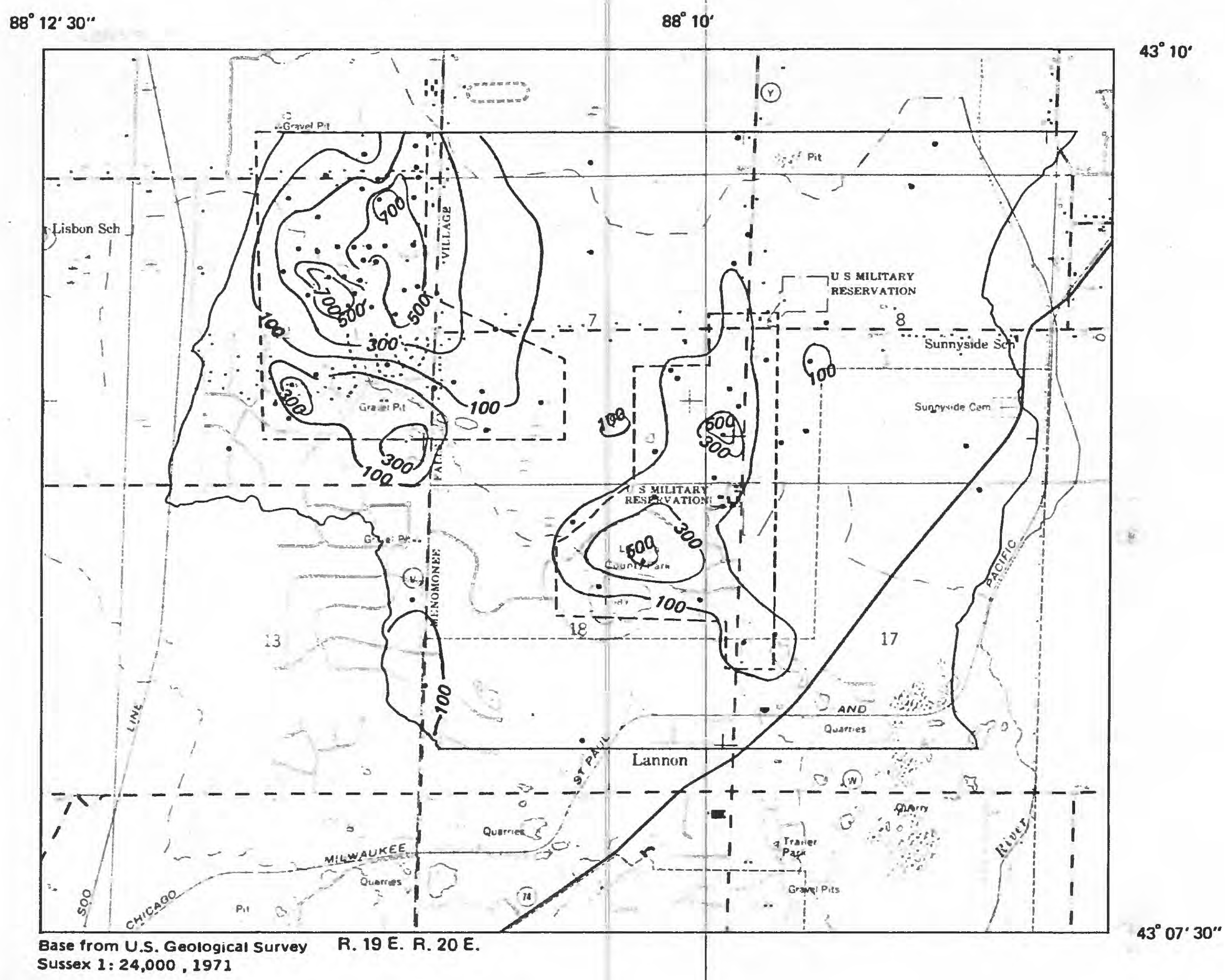
Variation with Time

Nine wells were sampled monthly between March 1977 and July 1979 to study variation of water quality with time (fig. 8). Graphs of variation in chloride, specific conductance, total coliform, fecal coliform, pH, precipitation, average daily air temperature, and water level in the wells were compared. Two examples are shown in figure 10: plots for wells Wk-950 and Wk-1069.

During the monitoring period, there was a period of high recharge in the summer and fall of 1977 in response to heavy precipitation from June through October. The highest ground-water levels were in July 1977. There was also recharge in the summer-fall of 1978 and the spring of 1979.

These periods of high ground-water recharge correlate generally with highs in total coliform and specific conductance, and lows in pH (fig. 10). The pH range for all wells was 6.9 to 7.9. Maximum chloride concentrations were less than 50 mg/L in three of the wells, 50-100 mg/L in two, and 150 to 500 mg/L in four wells. Specific conductance maximums were between 750 and 2,500 umhos.

Bacteria counts in water samples indicated little contamination. Total coliform was detected on occasion in all wells. In general, the counts were high in the period May through September. Fecal coliform bacteria colonies were not identified in water from six of the nine wells. Water from two of the wells contained only one colony in one sample each. In well Wk-1078, fecal coliform was a large part of the total coliform. This well has only 19 ft of casing which increases the liklihood of contamination; it is the only well that has less than 40 ft of casing. However, except for well Wk-1078, coliform detected in well water was largely total coliform for which several sources exist, many of which are not related to fecal contamination.



0 1 2 MILES
0 1 2 3 KILOMETERS

EXPLANATION

— *100* — Line of equal chloride concentration, in milligrams per liter. *Contour interval 200 milligrams per liter.*

——— Subarea boundary

[ ] Area of dense housing

• Well sampled for chloride

Figure 9. Chloride concentrations in ground water May 1978

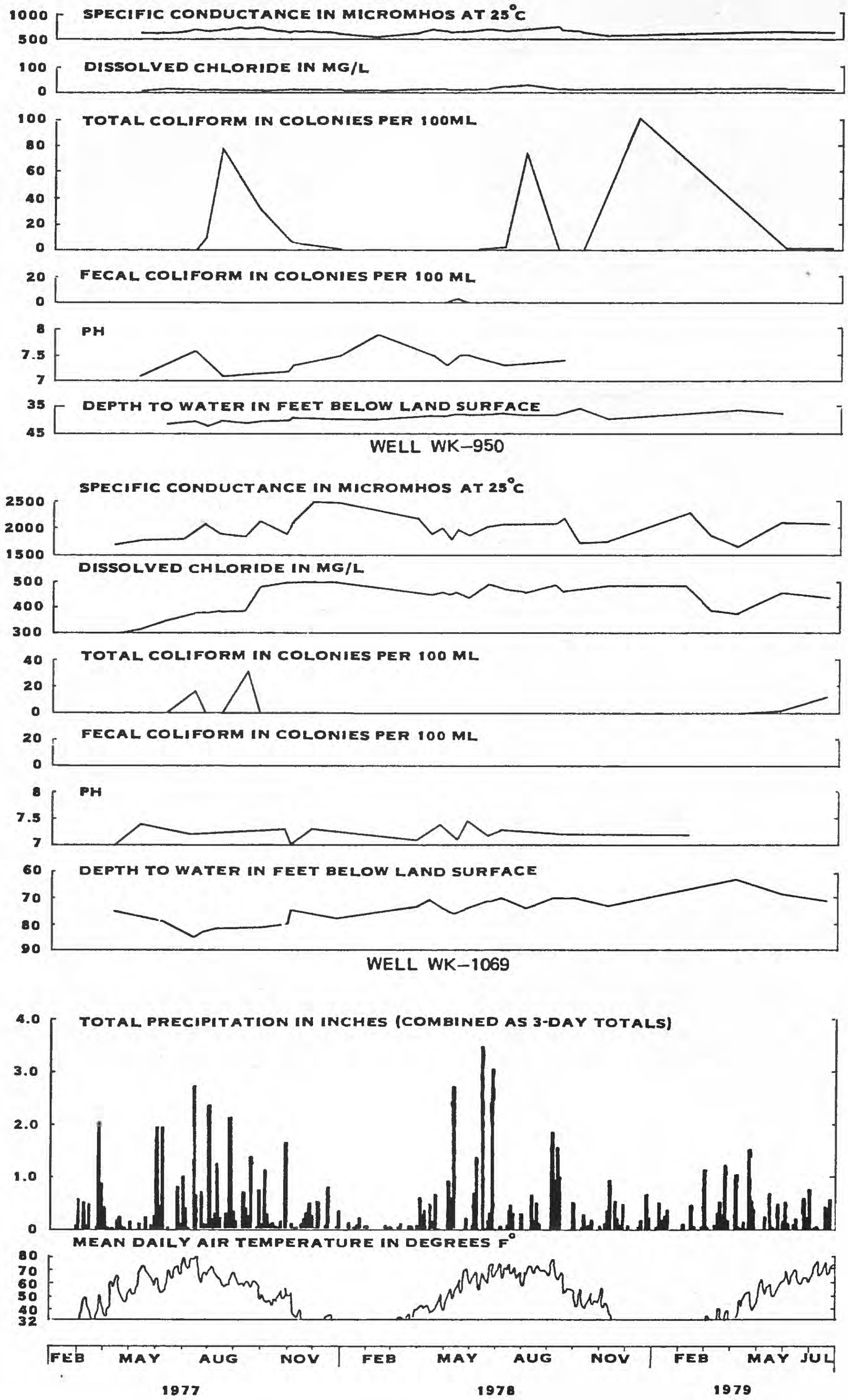


Figure 10. Precipitation, air temperature, ground-water levels, and ground-water quality for wells Wk-950 and Wk-1069

In general, the inorganic water quality, indicated by specific conductance and chloride concentrations, does not vary greatly with time. Although values do fluctuate, they tend to remain in the same range year round. Concentrations vary more between wells than with time. Chloride concentrations are above the aquifer average in all of the nine wells, indicating possible contamination. Bacterial contamination (where it occurs) appears to be sporadic and is probably induced by high recharge. Periods of high fecal coliform bacteria counts in well Wk-1078 correspond to periods of heavy rainfall in April, May, August, and September 1978.

SUMMARY AND CONCLUSIONS

Natural ground-water quality in the Silurian dolomite aquifer in Wisconsin is characterized by high hardness and iron. Ground-water quality in the Lannon-Sussex area has apparently been affected by land use. Although nutrient concentrations (nitrogen, phosphorus, and potassium) are not high, high chloride concentrations appear to reflect contamination from septic systems.

Although ground-water quality varies slightly with time, the areal variation is greater than the time variation. High concentrations of chloride (three to six times the Statewide average) and occasionally of bacteria correspond to periods of ground-water recharge. Chloride concentrations in water from wells that have than 25 ft of casing penetrating bedrock were compared with concentrations from wells that penetrate more than 25 ft into rock. No statistically significant differences were found. Chloride concentrations were found to be higher in wells in the subarea where housing density is high.

An attempt was made to relate water-quality changes with depth to beds of cherty dolomite identified in geologic logs; it was postulated that these zones might be confining beds. Although the beds appear to extend over the area, insufficient hydraulic and chemical data were available to relate to this scanty geologic evidence. Water quality, as indicated by chloride content, showed no significant relation to well bottom altitude, casing bottom altitude, or well depth.

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