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VERIFICATION OF THE POTENTIAL YIELD OF THE SHALLOW DOLOMITE AQUIFER IN DUPAGE COUNTY, ILLINOIS

by Robert T. Sasman, Richard J. Schicht, Curtis R. Benson, and R. Scott Ludwigs

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CONTENTS

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INTRODUCTION

Scope of Study

Because of its responsibility for allocating the Lake Michigan water which Illinois is permitted to divert from the Great Lakes Basin, the Illinois Division of Water Resources must consider alternative sources of water available to the Chicago metropolitan region. In early 1979, the Division contracted with the Illinois State Water Survey to study the shallow dolomite aquifer, an important alternative source, to verify its potential yield. The plan of the investigation was to analyze the effects of continually increasing pumpage, and identify areas of existing and potential problems and areas where additional pumpage can be developed.

In the summer of 1979, as part of this study, a detailed data collection program in the shallow dolomite was conducted over a 700-square-mile area as shown in figure 1. The area centered on DuPage County but also included parts of west and northwest Cook County, east Kane County, northeast Kendall County, and north Will County. It was bounded on the west by the Fox River and on the east and southeast by the Des Plaines River. Data obtained included pumpage from major water users and more than 1200 water level measurements. In addition, 295 water samples were collected for subsequent analysis. Water quality information will be discussed in a subsequent report.

The data collected have provided a base of analysis for the following purposes:

- To compare the 1979 piezometric surface map with an earlier piezometric map to show the effect of increased withdrawals on water levels.
- To delineate areas of over-utilization and areas showing little effect of existing pumpage.
- To compare the piezometric surface with the dolomite bedrock surface in order to identify areas where dewatering of the dolomite has taken place.
- To prepare a water budget taking into account pumpage, the potential yield, and the dewatering of both the dolomite aquifer and the overlying sand and gravel.

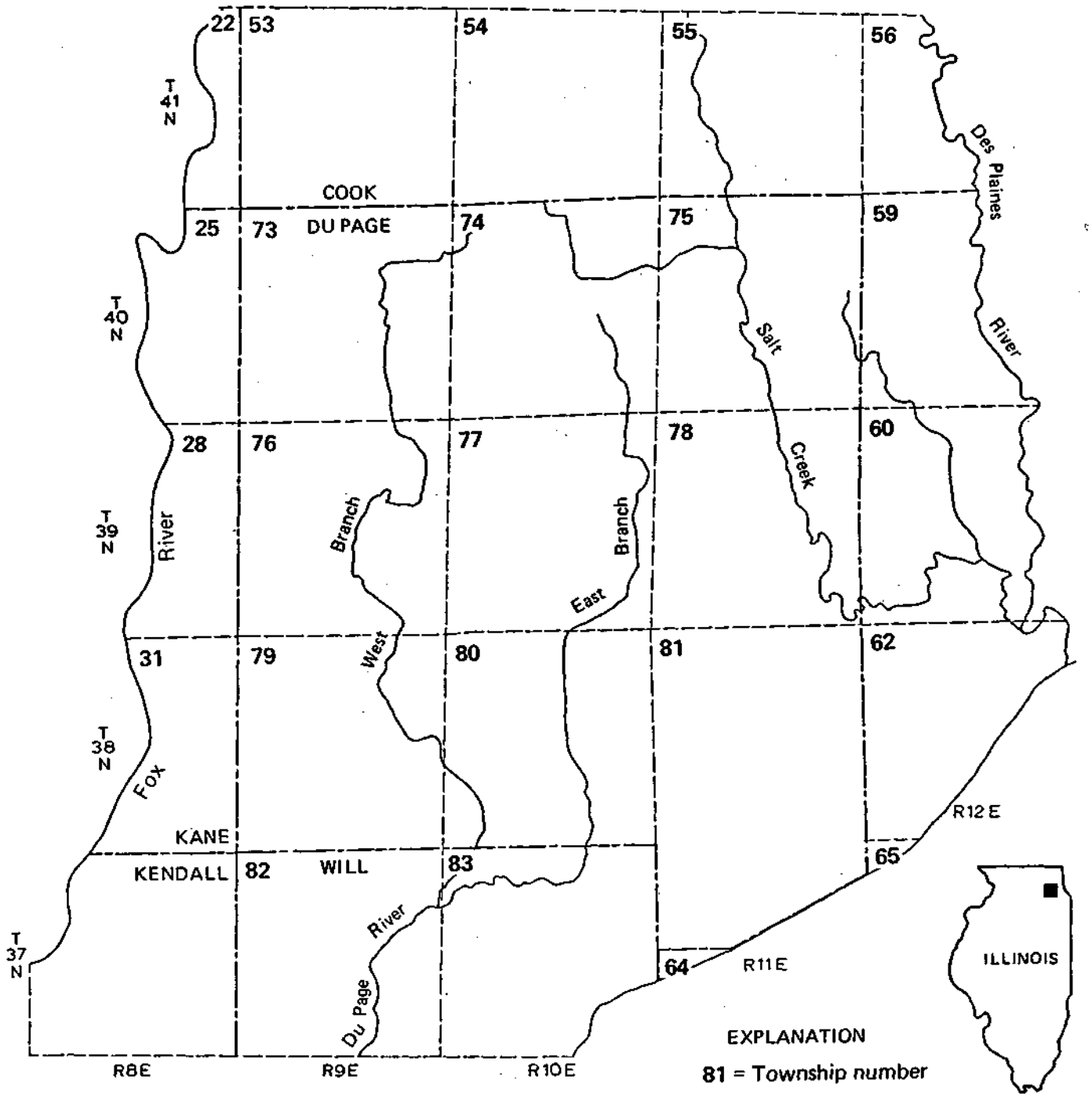

Figure 1. Township numbering system and location of study area

Zeizel et al. (1962) provided the first detailed report on the ground water resources of DuPage County. A study by Sasman (1974) included a 1966 piezometric surface map as well as pumpage and other data concerning the dolomite aquifer in DuPage County. The map and other data in Sasman's report were compared with data obtained during the present study in order to analyze the changes that occurred during the 13-year interval.

Prickett et al. (1964) presented an analysis of the shallow dolomite aquifer in the LaGrange area. This study also helped provide some comparison with present conditions. The data obtained in this and other sections outside of DuPage County provided important basic information for these areas and insured that all regions affected by pumpage within DuPage County would be included in the investigation. Rivers on the east and west sides of the area helped to assure reasonable hydrologic boundaries.

Acknowledgements

Special recognition needs to be given to the numerous individuals and organizations who provided access to their wells during the field work part of this project. Water levels were measured in more than 850 private, domestic wells, and water samples were collected from more than 100 of these wells. Water levels and water samples were collected from shallow dolomite wells in every municipality that has shallow wells in the area.

Most of the water levels and samples from domestic wells were obtained by Don Arnold, Tim Larson, Ralph Laukant, and Rebeccah Prastein, four area college students who were hired for the project. With no prior experience and only a brief orientation period, they performed an outstanding job, and the project could not have been completed in the allotted time span without their ready participation.

Special appreciation is also given to representatives of the Cook County and DuPage County Forest Preserve Districts, DuPage County Public Works Department, Argonne National Laboratory, and Fermi National Laboratory for assisting with water level measuring and sampling of numerous wells on their properties.

Jeanette Prastein reviewed most of the students' measurement calculations, tabulated much of the pumpage data, and typed the original report. The Survey's graphic arts staff, under the guidance of John W. Brother, Jr., prepared all the final figures, J. Loreena Ivens edited the final manuscript, and Alice Wallner prepared the camera copy.

GEOLOGY AND HYDROLOGY

For a detailed discussion of the geology and hydrology of the aquifers in northeastern Illinois, the reader is referred to Suter et al. (1959) and

Zeizel et al. (1962). The following section is based largely upon those two reports.

Unconsolidated deposits, mainly glacial drift ranging in thickness from a foot or less to slightly more than 200 feet, overlie,the bedrock in the area. Groundwater in the drift is obtained from sands and gravels that occur as surface deposits or more commonly as deposits underlying or interbedded with glacial till. Moderate to large supplies of groundwater are primarily encountered in sand and gravel at the base of the drift, directly above bedrock.

Deeply buried sand and gravel deposits, some associated with buried bedrock valleys, are present in northwestern Cook, northern DuPage, and northeastern Kane Counties. Areas less than 50 feet thick, with poor possibilities for water-bearing sand and gravel, occur primarily in the southern and eastern part of the study area.

Groundwater in sand and gravel aquifers commonly occurs under leaky artesian conditions. Recharge to sand and gravel aquifers is derived mostly by vertical leakage of water from surface deposits through glacial drift deposits overlying the aquifers. Surface deposits are recharged locally from precipitation. Glacial drift aquifers in large areas of northeastern Illinois are in hydraulic connection with underlying shallow bedrock aquifers.

The bedrock immediately beneath the glacial drift consists almost entirely of dolomite rocks of Silurian age. Small areas of the bedrock surface in northern DuPage, eastern Kane, and northeastern Kendall Counties consist of rocks of the Maquoketa Formation.

Rocks of Silurian age are the Alexandrian Series overlain by the Niagaran Series. The thickness of the Silurian dolomite in the western part of the area ranges from less than 50 to 100 feet. It thickens to the east and southeast and is more than 300 feet thick in parts of west-central Cook County. Where valleys occur in the bedrock, the Silurian rocks are thin or missing. In many areas, especially where these rocks are more than 100 feet thick, Silurian dolomite wells yield several hundred gallons per minute.

Groundwater in the shallow dolomite aquifers occurs in joints, fissures, and solution cavities. The water-bearing openings are irregularly distributed both vertically and horizontally, and the yields of shallow dolomite wells vary greatly from place to place. Available geohydrologic data suggest that on a regional basis, the shallow dolomite aquifers are permeated by numerous fractures and crevices which extend for considerable distances and are interconnected. The shallow dolomite aquifers receive recharge from overlying glacial deposits, or directly from precipitation where they are not covered by the drift. The upper part of the aquifer is usually the most productive.

The Maquoketa Formation consisting of shale and dolomite rocks of Ordovician age underlies the Silurian rocks. Yields are usually very limited, although in some areas the dolomite contributes moderate quantities of water to wells penetrating both Silurian and Maquoketa rocks. The relatively impermeable shales of the Maquoketa Formation act as a partial barrier to the downward movement of groundwater from the Silurian dolomite aquifer into the deeper Cambrian-Ordovician aquifer. The thickness of the Maquoketa Formation ranges from less than 100 feet in the western part of the area to more than 200 feet in much of northern and eastern DuPage County and in Cook County.

The Cambrian-Ordovician and Mt. Simon Aquifers lie beneath the Maquoketa Formation and have been described in detail in many State Water Survey and Geological Survey reports including Suter et al. (1959).

SHALLOW AQUIFER PUMPAGE

Shallow aquifer pumpage for public and major non-public supplies in the study area increased from 32.1 million gallons per day (mgd) in 1966 to 61.7 mgd in 1978, an increase of about 92 percent. Ninety-three percent of the 1978 shallow aquifer pumpage was from the dolomite bedrock. Table 1 shows the combined dolomite and sand and gravel pumpage for the study area for the period 1966-1978.

Table 1. Shallow Aquifer Public and Major Non-public Pumpage (mgd) in the Study area, 1966-1978

County	*1966*	*1967*	*1968*	*1969*	*1970*	*1971*	*1972*
Cook	6.90	7.54	8.38	8.67	9.48	10.71	11.73
DuPage	24.00	24.86	27.74	28.74	31.62	34.14	35.12
Kane	.93	.94	1.03	1.02	1.08	1.30	1.47
Kendall	.01	.02	.01	.03	.03	.05	.06
Will	.28	.31	.51	.54	.52	1.09	1.57
Total	32.12	33.67	37.67	39.00	42.73	47.29	49.95

County	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*
Cook	11.79	11.79	12.36	11.80	11.52'	10.78
DuPage	38.39	36.24	19.64	42.95	44.39	45.79
Kane	1.54	1.42	1.44	1.36	1.34	1.30
Kendall	.06	.07	.09	.09	.05	.07
Will	2.13	2.39	3.66	3.55	3.71	3.75
Total	53.91	51.91	57.19	59.75	61.01	61.69

During this same period, pumpage in DuPage County increased from 24 to 45.8 mgd, an increase of about 91 percent. Ninety-five percent of the 1978 shallow aquifer pumpage in DuPage County, or 43.5 mgd, was from the dolomite. Schicht et al. (1976) calculated the potential yield of these shallow aquifers in DuPage County to be approximately 44.4 mgd.

Bensenville is the only municipality within the study area that has always obtained all of its water from deep wells. Nine public water supplies in DuPage County (Addison, Glendale Heights, Glen Ellyn, Hinsdale, Lisle, Warrenville, Wheaton, Winfield, and Woodridge), three in Cook County (Burr Ridge, Indian Head Park, and LaGrange Highlands), and one in Will County (Bolingbrook) have always obtained all of their water from shallow wells. Downers Grove and Itasca have obtained all of their water from shallow wells for more than 40 years. Batavia and Geneva, on the edge of the area in Kane County, obtain all of their water from deep wells. All of the other municipalities in the area obtain water from both shallow and deep wells in widely ranging proportions. Figure 2 shows the general location of most of the municipalities in the area pumping significant volumes of water from the shallow aquifers.

PIEZOMETRIC SURFACE, 1979

In order to determine areas affected by groundwater withdrawals and directions of groundwater movement in the Silurian dolomite aquifer, a piezometric surface map was prepared from nonpumping water levels measured in wells during the summer of 1979 (figure 3). The map represents the elevation to which water will rise in a well completed in the Silurian dolomite aquifer. In a few instances, wells are open to basal sand and gravel deposits above the dolomite bedrock. The basal sand and gravel is in direct contact with the dolomite, and the two formations act as one hydrologic unit. The direction of groundwater movement is at right angles to the elevation contour lines.

As shown on this map, groundwater in the entire area moves in all directions from high elevations toward streams, well fields, and quarry dewatering areas.

Before significant groundwater development, the groundwater levels were generally above surface water levels in rivers and streams, and groundwater discharged into these surface waters throughout the region. A significant part of streamflow was derived from groundwater.

Groundwater withdrawals in numerous areas have lowered water levels considerably below stream level, resulting in reduction in streamflow. In some areas surface water probably percolates through the stream bed and eventually into the dolomite aquifer. In 1979 groundwater levels were above water levels of the surface waterways in only a few areas, including along some reaches of the Fox, DuPage, and Des Plaines Rivers and Salt Creek.

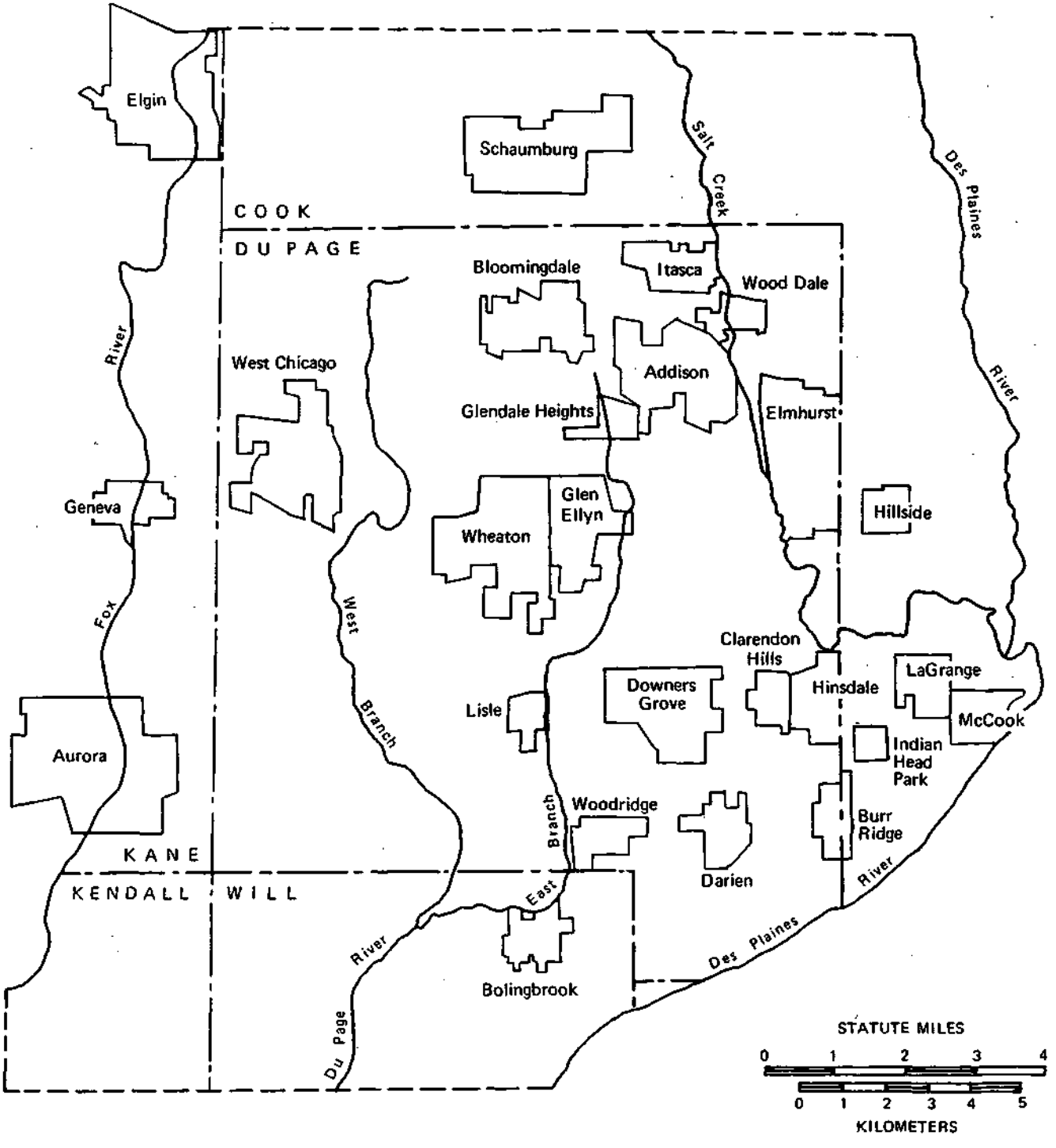

Figure 2. Locations of selected municipalities

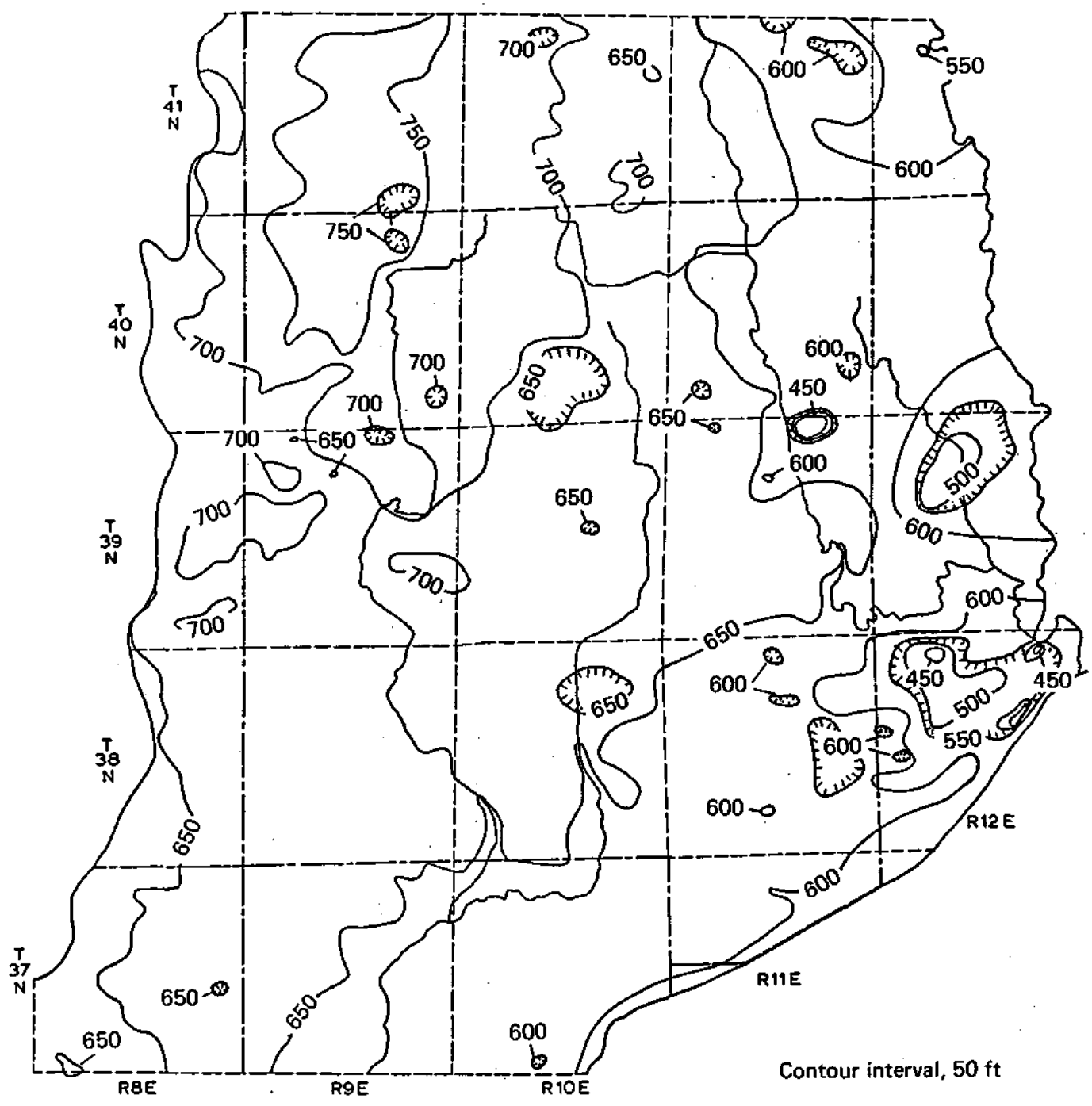

Figure 3. Piezometric surface of the shallow dolomite aquifer during the summer of 1979

Heavy, concentrated groundwater withdrawals have produced cones of depression in many parts of the area. Most dramatic are cones of depression at and adjacent to rock quarries at McCook-Lyons, Township 62; Elmhurst, Township 78; and Hillside, Township 60. Pumpage for dewatering at these quarries has been continuous for more than 80 years.

Other major cones of depression are attributable to pumpage from wells, primarily for public water supplies. In addition to the effects of quarry dewatering at McCook-Lyons and Elmhurst, heavy well pumpage in these areas has also contributed greatly to low piezometric surface elevations. Other significant cones of depression are evident around the communities of Itasca, Wood Dale, Addison, West Chicago, and Glendale Heights. Pumpage has caused major distortion of contours on the potentiometric surface in a large area of southeast DuPage County. Numerous smaller cones of depression and distorted contours occur throughout the area as a result of heavy local or regional pumpage.

The average slope of the piezometric surface rnages from a low of about 10 feet per mile in areas little affected by pumpage to more than 25 feet per mile near and within major cones of depression.

An analysis of the piezometric surface for 1979 indicated that about 68 percent of the study area was influenced by groundwater withdrawals from the Silurian dolomite aquifer. Figure 4 shows approximate boundaries of areas influenced by pumpage and the volume of pumpage from major wells and well fields within identified areas. Within DuPage County about 80 percent of the area was influenced by groundwater withdrawals.

CHANGES IN WATER LEVELS, 1966-1979

Comparison of the piezometric surface map for 1966 (figure 5) and 1979 (figure 3) for DuPage County and part of western Cook County gives an indication of the water level change during the 13-year period. Areas of change in water levels are shown in figure 6. More than 98 square miles, or 30 percent of DuPage County, experienced a decline of more than 10 feet. Smaller but major portions of the county, totaling about 8.5 square miles, had declines of more than 30 feet. In a few areas, declines of more than 50 feet were recorded.

The most dramatic area of water level decline in DuPage County is in the Glendale Heights area in the north central part of the county. More than 3 square miles have had a decline of over 30 feet. Other large areas of significant decline are in the Carol Stream-Bloomingdale-Roselle area, the Itasca-Wood Dale-Addison area, the Wheaton-Glen Ellyn area, and in the Hinsdale-Clarendon Hills-Westmont-Willow Brook-Darien-Burr Ridge area. Numerous other pumping centers throughout the county have experienced noticeable declines during the past 13 years.

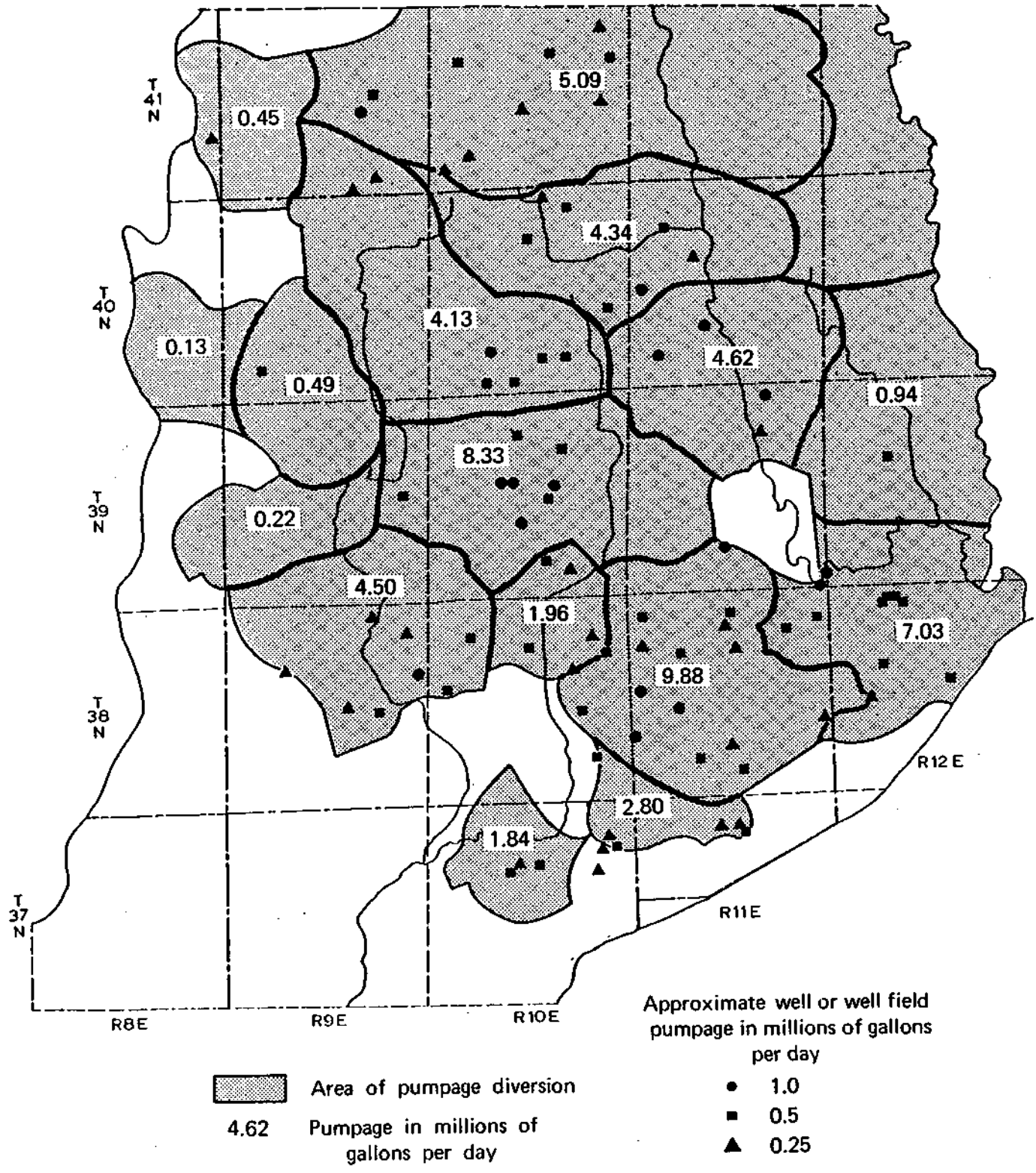

Figure 4. Areas influenced by groundwater withdrawals in 1979

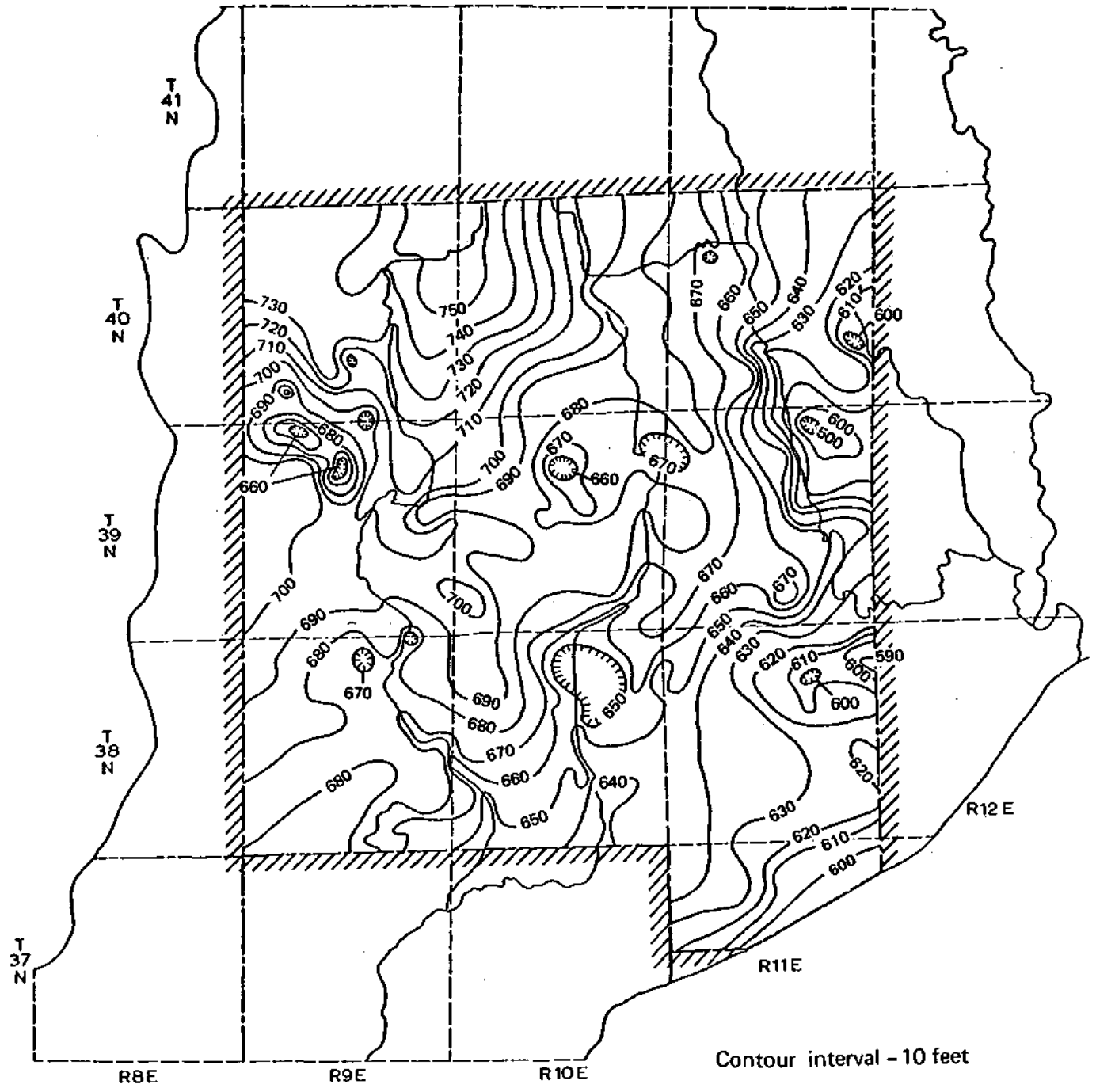

Figure 5. Piezometria surface of the shallow dolomite aquifer in DuPage County, 1966

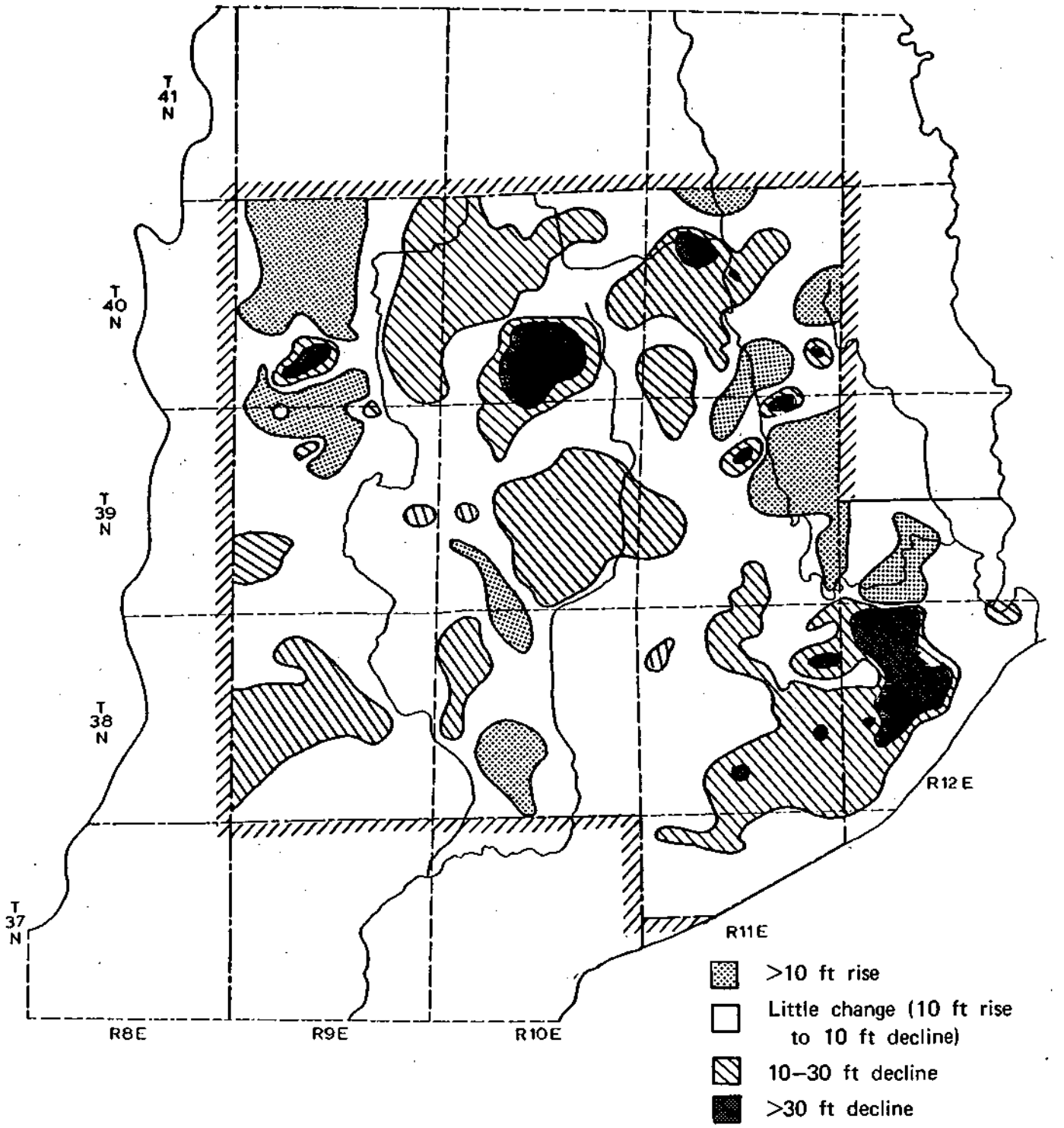

Figure 6. Change in piezometrio surface in DuPage County and part of Cook County, 1966-1979

Over the 98 square miles of DuPage County where water levels have declined 10 feet or more, the average decline during the past 13 years has been approximately 1.5 feet per year. Over the entire area of DuPage County, water levels have declined an average of about 0.5 feet per year.

An area of approximately 13 square miles in western Cook County also had a water level decline of more than 10 feet. In much of this area (6.3 square miles), the decline was more than 30 feet.

Water level declines in Cook County are primarily due to water withdrawals at the quarries and for public supplies at LaGrange, LaGrange Highlands, and Indian Head Park. Numerous additional well supplies for public, industrial, and commercial systems have contributed to the large area of decline. During the past 13 years, water levels in this part of Cook County have declined at a rate of approximately 2.3 feet per year.

Comparison of the two piezometric maps indicates several areas where water levels have risen more than 10 feet since 1966. Particularly in the vicinity of West Chicago and Elmhurst-Oak Brook, rises in water levels reflect decreased withdrawals from dolomite wells. In some areas, indicated rises in water levels may be due to more detailed data collected in 1979 or to variations in precipitation.

In addition to a comparison of the piezometric maps of 1966 and 1979, water level measurements in specific wells furnish an indication of fluctuations over a period of time. Water level fluctuations in shallow dolomite and sand and gravel wells are influenced by a number of factors, including frequency and duration of the pump operation cycle, pumping rate of the well being measured, influence from other wells in the area, hydrologic and geologic characteristics of the rock formation, and short- and long-term variations in weather conditions.

Figures 7, 8, and 9 present water level hydrographs of several wells for periods of 7 to 20 years. Water levels in 6 of these wells are measured monthly or recorded on continuous recording instruments. They show considerable variation, ranging from slight rises or essentially no change in a few wells to a decline of more than 100 feet in a well near LaGrange (figure 8). Five of the selected wells show average declines ranging from 1.2 to 8.5 feet per year for the period 1966-1979. Four others show average declines of 0.1 to 0.9 feet per year. Four wells show no significant change of water level during recent years.

WATER LEVEL-BEDROCK SURFACE RELATIONSHIP

Past experience indicates that a great potential exists for a significant decline in well yields when the water level lowers below the top of the dolomite. Previous analysis of well production tests by Zeizel et al. (1962) indicates a higher yield per foot of formation in the upper part of the dolomite bedrock. There is evidence that at least 12 communities in

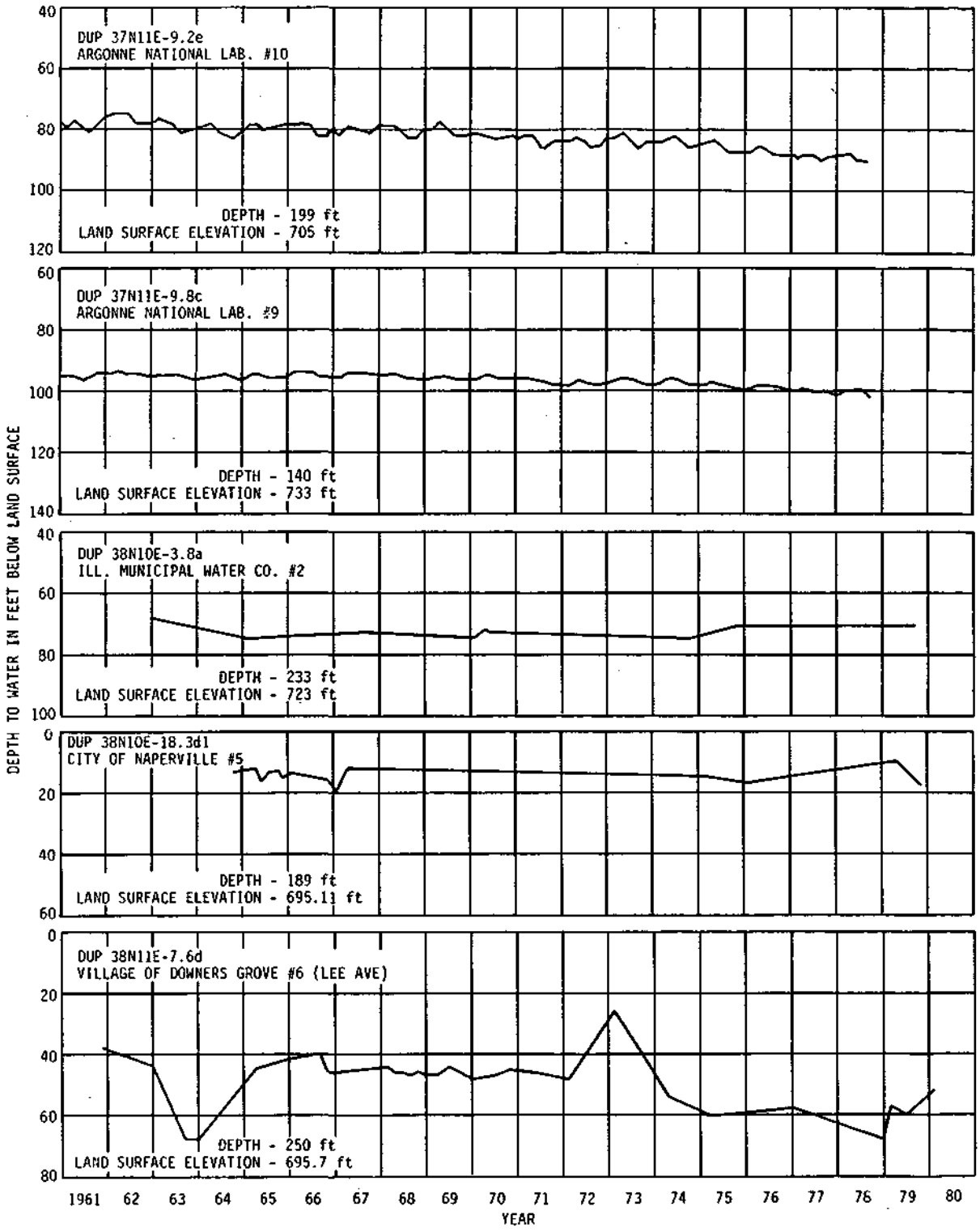

Figure 7. Hydrographs of water levels in selected wells

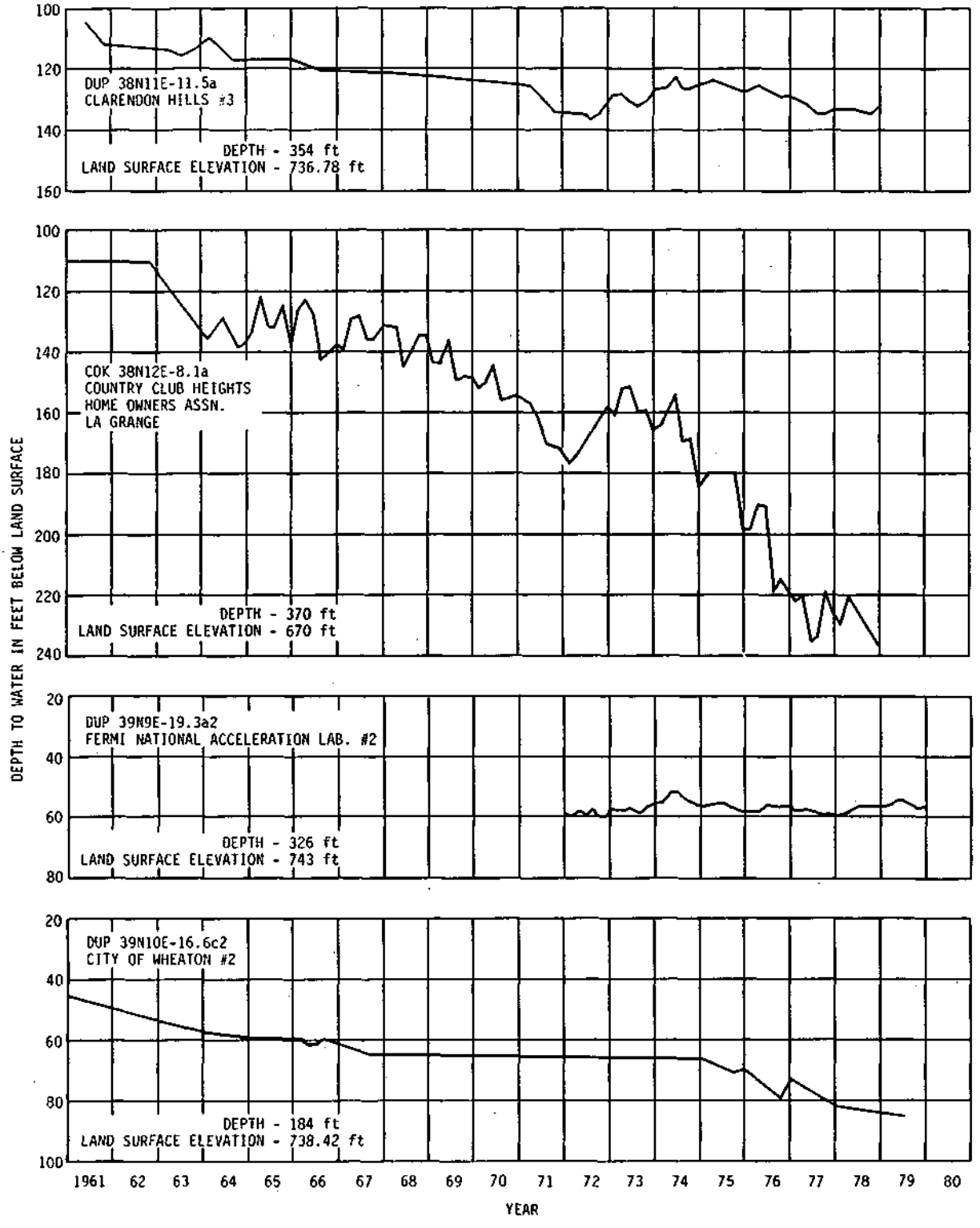

Figure 8. Hydrographs of water levels in selected wells

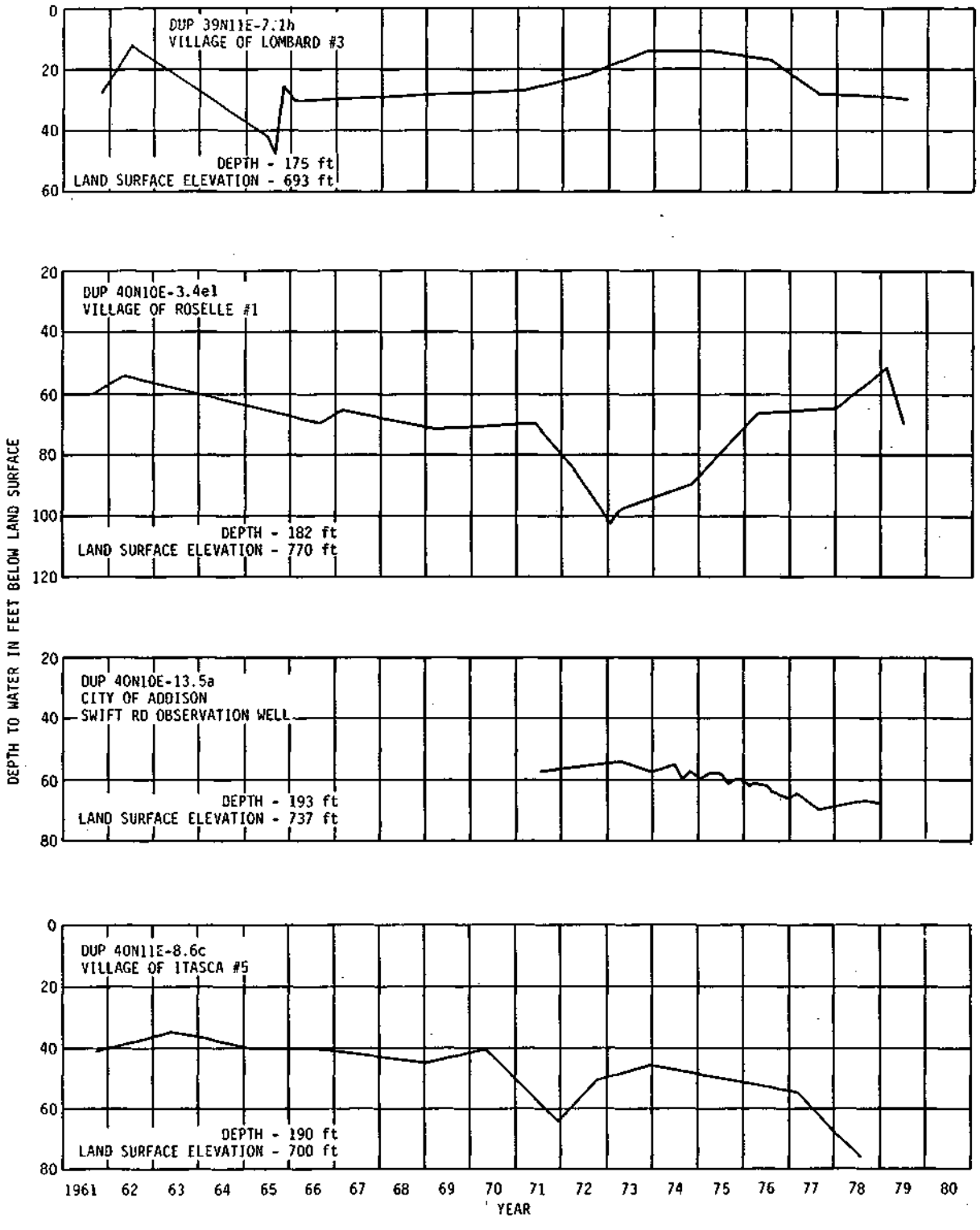

Figure 9. Hydrographs of water levels in selected wells

the metropolitan area have observed intermittent or continuous loss of capacity as a result of partial bedrock dewatering. Nearly all of the communities are in the west suburban area, and most are in DuPage County. A list of the communities is given in table 2.

To determine areas where the dolomite has been dewatered, piezometric surface maps were compared with the map of the bedrock surface (figure 10). The 1979 water level-bedrock surface relationship map is shown in figure 11. The water level has lowered below the top of the rock over more than 77 square miles, or 11 percent of the entire area. Water levels are more than 50 feet below the bedrock surface over more than 14 square miles and more than 100 feet below the bedrock surface over 6 square miles. An average thickness of nearly 39 feet of rock has been dewatered over the 77 square miles.

The largest areas and thickest sections of dewatered rock are associated with the quarry operations in the east and southeast parts of the region. Heavy well pumpage, primarily for public supplies, has greatly expanded the area in the southeast. This one area covers more than 25 square miles.

Other significant areas of dewatered rock, due primarily to pumpage for public supplies, are in the north central and south central areas of DuPage County. A few areas are associated with high bedrock surface elevations.

By 1979, water levels in DuPage County were below the bedrock surface over more than 28 square miles. This is approximately 8.6 percent of the county area. The average thickness of dewatered rock is about 27 feet.

Table 2. Communities That Have Experienced Loss of Dolomite Well Capacity

Communities	*Township*
Addison	75
Clarendon Hills	81
Downers Grove	81
Glen Ellyn	77
Hinsdale	81
Itasca	75
Lisle	80
Oak Brook	78
Schaumburg	54
Villa Park	78
West Chicago	76
Wood Dale	75

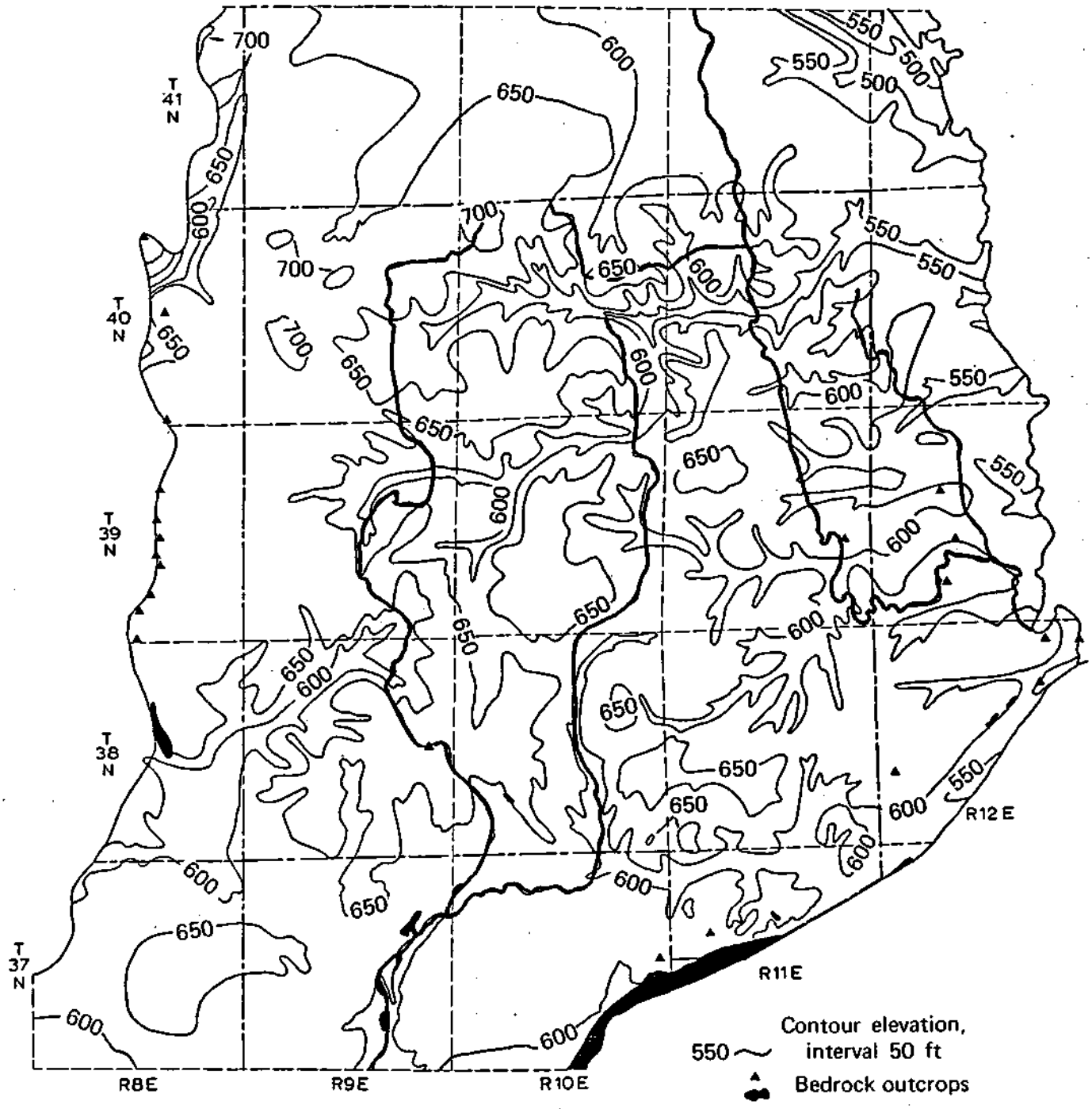

Figure 10. Bedrock surface (after Zeizel et al., 1962)

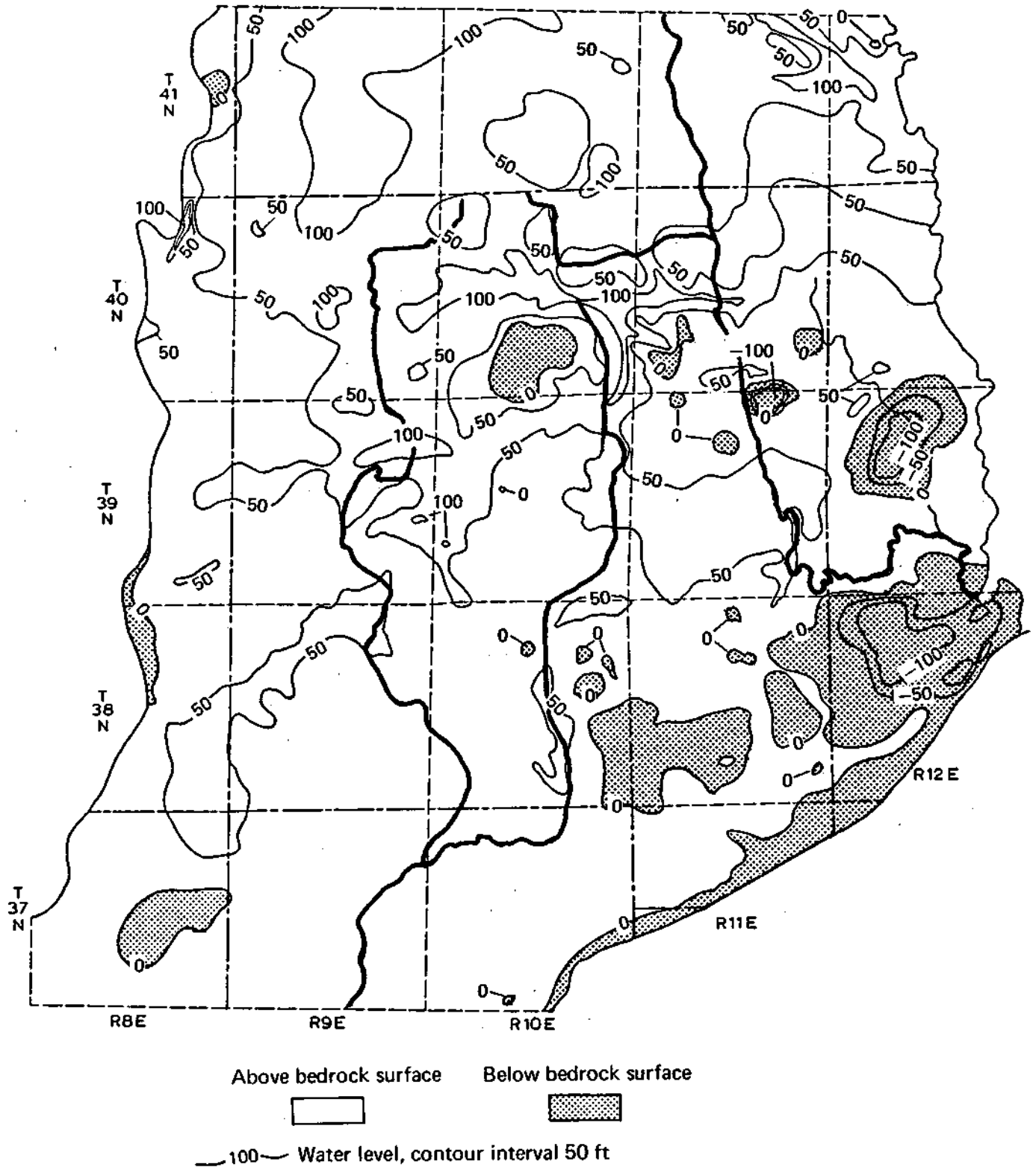

Figure 11. Water level-bedrock surface relationship in 1979

A 1966 water level-bedrock surface relationship map was also prepared (figure 12). Comparing the 1966 and 1979 map areas (figures 11 and 12) of DuPage County permits a calculation of the volume of rock dewatered during the 13-year period. This area increased from approximately 19 to 28.5 square miles, or nearly 50 percent. The average thickness of this 9.5 square miles of dewatered rock was 27.6 feet.

WATER LEVEL-BASAL SAND AND GRAVEL RELATIONSHIP

Yields of dolomite wells have generally been higher in areas where the overlying glacial drift contains moderate to thick deposits of sand and gravel in close proximity to the bedrock surface. Thus it is reasonable to expect an even greater loss of well capacity where dewatering of sand and gravel has taken place over dewatered bedrock.

In order to identify these areas, a review was made of all the well construction logs in those areas of dewatered rock. Of particular interest were those logs that showed 10 or more feet of sand and gravel immediately above the bedrock. Additional data from the files of the State Geological Survey were also reviewed. These data were then correlated with the 1966 and 1979 water level-bedrock surface relationship maps.

It is estimated that of the 28.5 square miles in DuPage County where dewatering had occurred by 1979, approximately 10 square miles or 35 percent of the area contained basal sand and gravel at least 15 feet thick. The average thickness was approximately 30 feet. About 40 percent of this area, or 4 square miles, was dewatered during the period 1966-1979. Since the water level was below the bedrock surface over this entire area, it can be assumed the entire thickness of sand and gravel has been dewatered.

WATER BUDGET

In order to verify previous analyses of the potential yield of the shallow groundwater aquifers, a groundwater budget for DuPage County was prepared by balancing withdrawals with potential yield plus the volume of material dewatered multiplied by the specific yield.

Groundwater withdrawals from the shallow aquifers in DuPage County averaged 36.7 mgd during the past 13 years; 34.3 mgd was from the dolomite and 2.4 mgd was from sand and gravel.

The potential yield is defined as the maximum amount of groundwater that can be developed from a reasonable number of wells and well fields without creating critical water levels or exceeding recharge. A previous study by Schicht et al. (1976) gave the potential yield of DuPage County as 44.4 mgd.

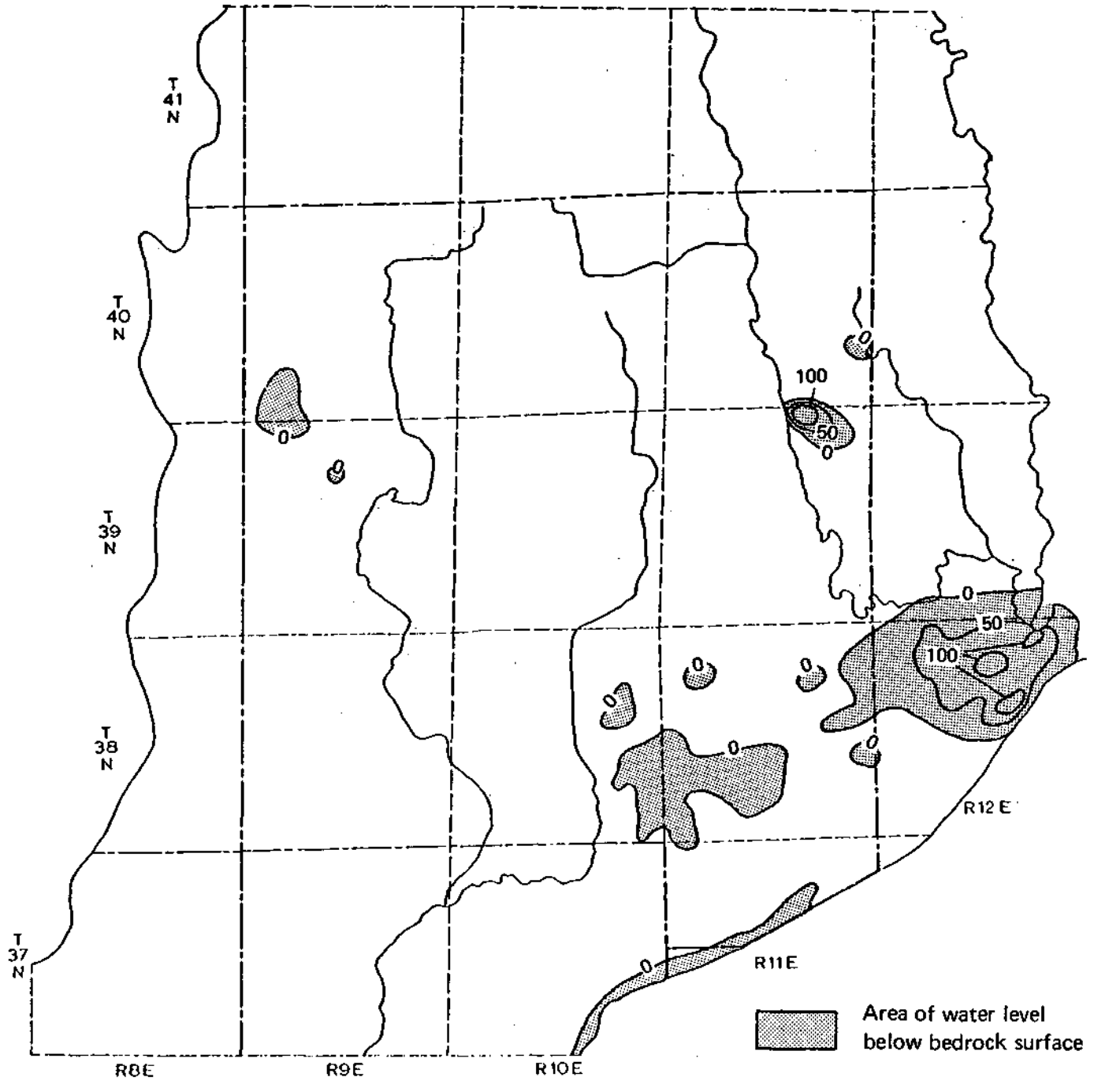

Figure 12, Water level-bedrock surface relationship in 1966

The volume of rock dewatered during the 13-year period is 7.3×10^9 cu ft (9.5 square miles x 27.6 ft). At least an additional 3.3×10^9 cu ft (4.0 square miles x 30 ft) of sand and gravel has been dewatered.

Todd (1959) defines specific yield as the percentage of the volume of water which can be drained by gravity to its own volume. According to Todd (1959) and based on the experience of the authors, 20 percent for the sand and gravel is reasonable. Less information on the specific yield of dolomite is available. The equation given below was solved to determine the specific yield of the dolomite bedrock.

$$Q = R \times a + \frac{V_d \times 7.48 \times Y_{gd}}{t} + \frac{V_s \times 7.48 \times Y_{gs}}{t}$$

where

Q = average withdrawals, 1966-1979 = 36.7 mgd

R = potential yield = 39.4 mgd*

a = percent of potential yield diverted into cones of depression, 90 percent

V_d = change in volume of dewatered rock = 7.3×10^9 cu ft

V_s = change in volume of dewatered sand and gravel = 3.3×10^9 cu ft

Y_{gd} = specific yield for the dewatered rock = unknown

Y_{gs} = specific yield = 0.2 for sand and gravel

7.48 = gal/cu ft

t = 13 years, 1966-1979 x 365 days per year

*Reduced by 5 mgd which is estimated to be the recharge to surficial sand and gravels. The average withdrawals (Q) include sand and gravel pumpage which is from wells finished in basal sand and gravel.

The specific yield of the dolomite bedrock was computed to be 0.017. This would appear to be a reasonable value when compared with the value given by Prickett et al. (1964) of 0.03 for the Chicago Heights area.

Pumpage over most of DuPage County is in excess of the potential yield. In order to balance the demand with the available supply, approximately 5.9 billion gallons has been withdrawn from storage within the dolomite and sand and gravel aquifers. This is equivalent to an average pumpage of 1.2 mgd during the past 13 years.

SUMMARY AND CONCLUSIONS

Groundwater withdrawals from the shallow dolomite aquifer in the west suburban area of the Chicago metropolitan region have had a severe impact on water levels and on the long-range capability of wells and well fields to continue to meet demands for increasing volumes of water by municipalities, industries, and individuals.

Shallow aquifer pumpage in the study area increased 92 percent during the period 1966-1978 and was 61.7 mgd in 1978; 57.3 mgd was from the dolomite, and 4.4 mgd was from sand and gravel. Pumpage in DuPage County increased 91 percent during the same period. The 1978 pumpage of 45.8 mgd was 103 percent of the potential yield.

As a result of the continual increase in pumpage and pumpage above the potential yield throughout much of the area, water levels have lowered considerably, and major sections of the aquifer system have been at least partially dewatered. Well yields in several municipalities have declined as the result of the effects of heavy pumpage. Large volumes of rock and sand and gravel have been dewatered as water is withdrawn from storage within the aquifer to make up the deficit between water demand and the potential yield.

In DuPage County, water levels in the shallow dolomite declined more than 10 feet over an area of 98.4 square miles during the period 1966-1979. This includes nearly 30 percent of the entire county. The average decline over the 98.4 square miles was approximately 1.5 feet per year. Water levels declined more than 30 feet over 8.5 square miles.

The decline in water levels has resulted in water levels being lowered below the bedrock surface over approximately 9.5 square miles of DuPage County since 1966. An average of 27.6 feet of rock has been dewatered over this area. In addition to the dewatered rock, approximately 4 square miles of sand and gravel above the dewatered bedrock has been dewatered an average of about 30 feet.

A volume of 7.3 billion cubic feet of dolomite and 3.3 billion cubic feet of sand and gravel has been dewatered in DuPage County during the period 1966-1979. Approximately 5.9 billion gallons of water has been withdrawn from the shallow aquifer system in excess of that available from natural recharge. This is equivalent to average pumpage of 1.2 mgd.

Schicht et al. (1976) predicted that the groundwater demand in DuPage County would be 97.2 mgd by the year 2000. If pumpage was in the same ratio as in 1978, shallow aquifer pumpage would be approximately 63 mgd. This would be approximately 18 mgd more than the potential yield of these aquifers. Withdrawal of 18 mgd from storage within the aquifers would result in extremely severe dewatering over extensive areas. Major decreases in yields would be experienced in nearly all wells and well fields throughout the county.

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