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Ground-Water Levels and Pumpage in the East St, Louis Area, Illinois, 1978-1980

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ILLINOIS STATE WATER SURVEY

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GROUND-WATER LEVELS AND PUMPAGE IN THE EAST ST. LOUIS AREA, ILLINOIS, 1978-1980

by Mark A. Collins and Susan S. Richards

ABSTRACT

Ground-water levels and pumpage in the East St. Louis area from 1978 through 1980 are considered in this report. Large quantities of ground water chiefly for industrial and municipal use are withdrawn from wells penetrating a sand and gravel aquifer along the valley lowlands of the Mississippi River.

Ground-water pumpage decreased from 65.7 million gallons per day (mgd) in 1978 to 58.6 mgd in 1980. Of the total 1980 pumpage 74.4 percent was industrial; 17.6 percent was for public water supplies; 6.5 percent was for domestic use; and 1.5 percent was for irrigation. Pumpage in the East St. Louis area is concentrated in four major pumping centers: the Alton, Wood River, Granite City, and National City areas. Pumpage in the Monsanto area, once considered a major pumping center, has sufficiently decreased so that it is now a minor pumping center.

Ground-water levels in the Alton and Wood River areas generally declined near the Mississippi River and increased inland due to shifts in the distribution of pumpage and low river stage. In the Granite City area, ground-water levels generally rose with decreased pumpage. Conversely, increased pumpage in the National City area caused ground-water levels to decline. Ground-water levels in the Monsanto area continued to recover with reduced pumpage.

INTRODUCTION

The East St. Louis area (figure 1) is one of the most heavily populated and industrialized areas in Illinois. The ground-water resources of a sand and gravel aquifer underlying the area have been developed extensively. It is estimated that during 1980 an average of 58.6 mgd was withdrawn chiefly from industrial and municipal wells.

In 1965 the State Water Survey issued Report of Investigation 51 (Schicht, 1965), which described in detail the ground-water resources of the East St. Louis area. The report was the culmination of a period of intensive data collection initiated in 1941 after alarming water level recessions were observed by local industries. Previous reports which summarized water levels and pumpage and aided in the preparation of Report of Investigation 51 had been published in 1953 (Bruin and Smith) and 1962 (Schicht and Jones). The ground-water geology of the area had been described previously by the State Geological Survey (Bergstrom and Walker, 1956).

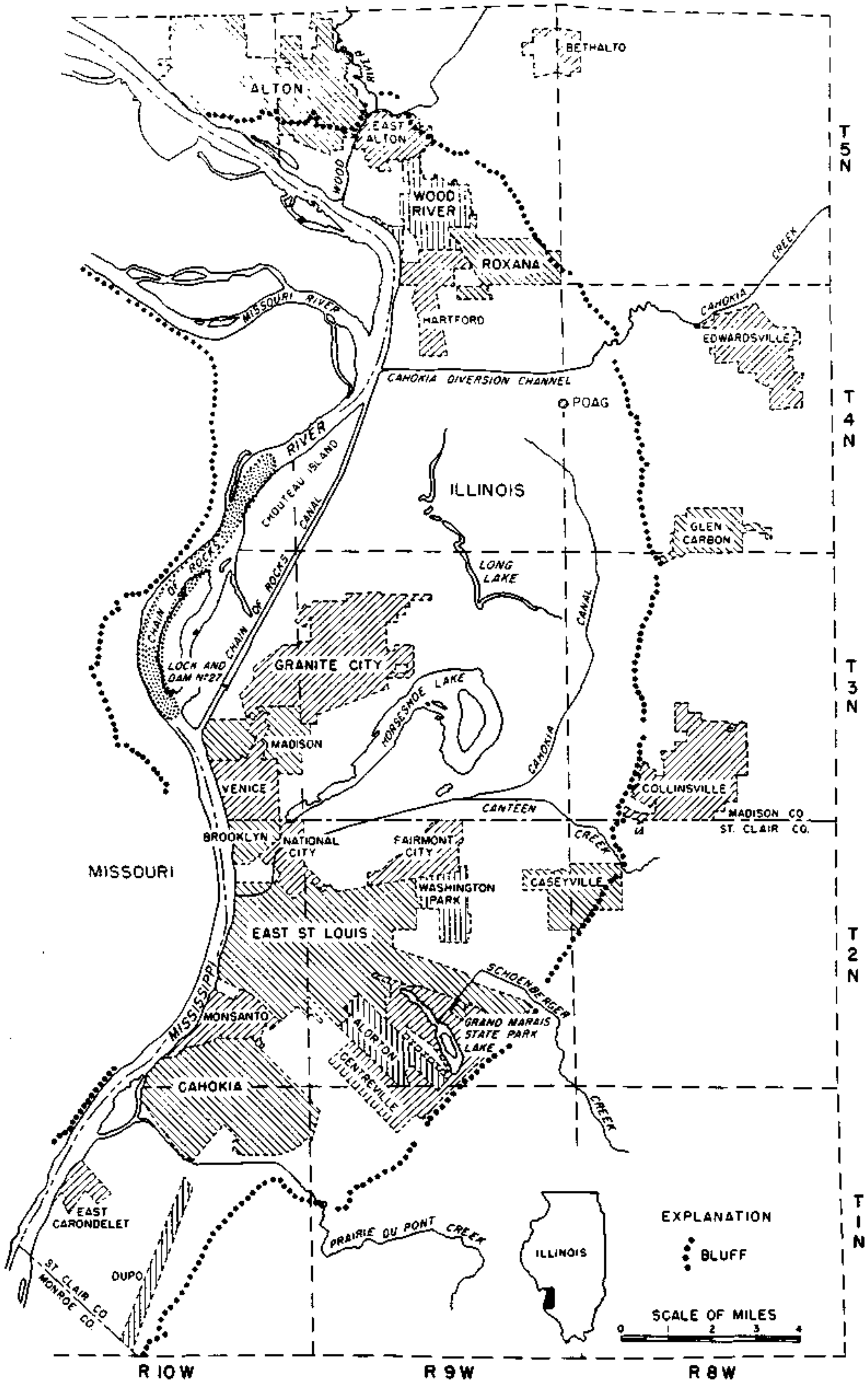

Figure 1. East St. Louis area

Studies described in Report of Investigation 51 indicated that in 1962 the practical sustained yield of the sand and gravel aquifer exceeded withdrawals. However, extrapolation of past ground-water use indicated that pumpage would exceed the practical sustained yield in the Monsanto area within a few years. It was estimated that the practical sustained yield of the other major pumping centers probably would not be reached until after 1980, and that with the development of additional pumping centers the potential yield of the sand and gravel would exceed 188 mgd.

To validate the predictions of Report of Investigation 51 and delineate problem areas, data collection has continued for the entire area. Previous summaries of pumpage and water levels were published in 1968 (Reitz), 1972 (Baker) and 1979 (Emmons). This report summarizes water level and pumpage data collected from 1978 through 1980.

Acknowledgments

This report was prepared under the direction of James P. Gibb and Ellis W. Sanderson, former Head and Acting Head, respectively, of the Ground-Water Section of the Illinois State Water Survey. The authors gratefully acknowledge the assistance of Adrian P. Visocky and Joseph D. Ritchey during preparation of technical portions of this report. James R. Kirk supplied water use data and information regarding data collection methods; Michael D. Broten supplied computer-generated well hydrographs; John W. Brother, Jr., prepared the remaining illustrations; Pamela Lovett did the typing; and Gail Taylor did the final editing.

GEOLOGY AND HYDROLOGY

Large supplies of ground water, chiefly for industrial development, are withdrawn from permeable sand and gravel in unconsolidated valley fill in the East St. Louis area. According to Bergstrom and Walker (1956), the valley fill is composed of recent alluvium and glacial valley-train material and is underlain by Mississippian and Pennsylvanian rocks consisting of limestone and dolomite with subordinate amounts of sandstone and shale. Because of the low permeability of the bedrock formations and poor water quality with depth, the bedrock does not constitute an important aquifer in the area. The valley fill ranges in thickness from a featheredge near the bluff boundaries and along the Chain of Rocks reach of the Mississippi River to more than 170 feet near the city of Wood River, averaging 120 feet across the entire area. The thickness of the valley fill is generally greatest and exceeds the average in places near the center of a buried bedrock valley that bisects the area, as shown in figure 2. The valley fill becomes progressively coarser with depth. The coarsest deposits most favorable for development are commonly encountered near bedrock and often average between 30 and 40 feet in thickness.

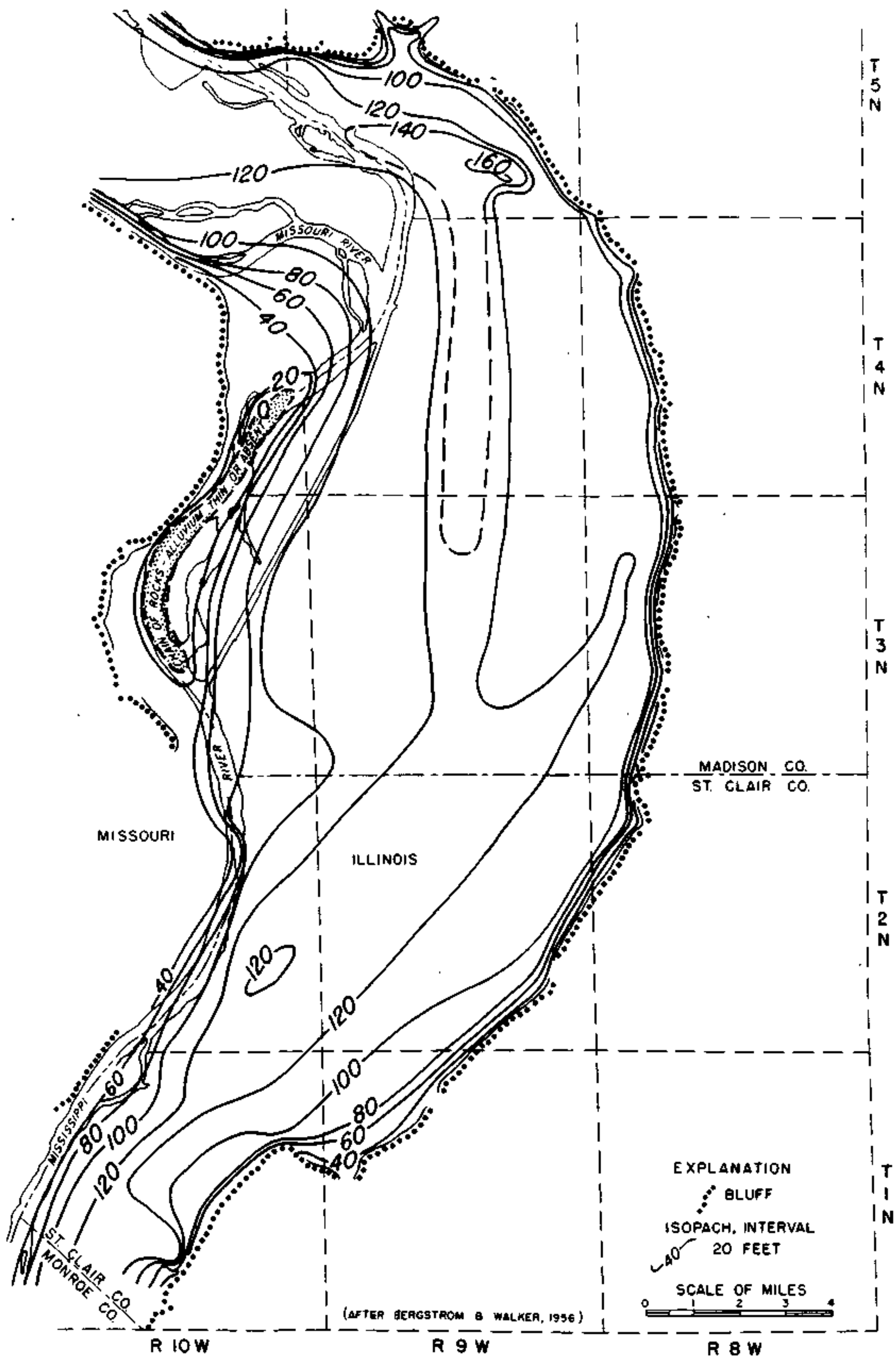

Figure 2. Thickness of valley fill deposits

Ground water in the valley fill occurs under leaky artesian and water-table conditions. Because ground water occurs more commonly under leaky artesian conditions, the level to which water rises in wells is hereafter called the piezometric surface.

Recharge within the area is from precipitation, induced infiltration of surface water from the Mississippi River and lesser water bodies in the area, and subsurface flow from the bluffs bordering the area. A fraction of the annual precipitation seeps downward through surface materials and into the valley fill material. Recharge by induced infiltration occurs at places where pumpage from wells has lowered the elevation of the piezometric surface below the level of a surface water body.

PUMPAGE FROM WELLS

The first significant withdrawal of ground water in the East St. Louis area started in the late 1890s. Prior to 1900 ground water was used primarily for domestic and farm supplies; since 1900 pumpage has been mostly for industrial use. Estimated pumpage from wells increased from 2.1 mgd in 1900 to 111.0 mgd in 1956, as shown in figure 3, and

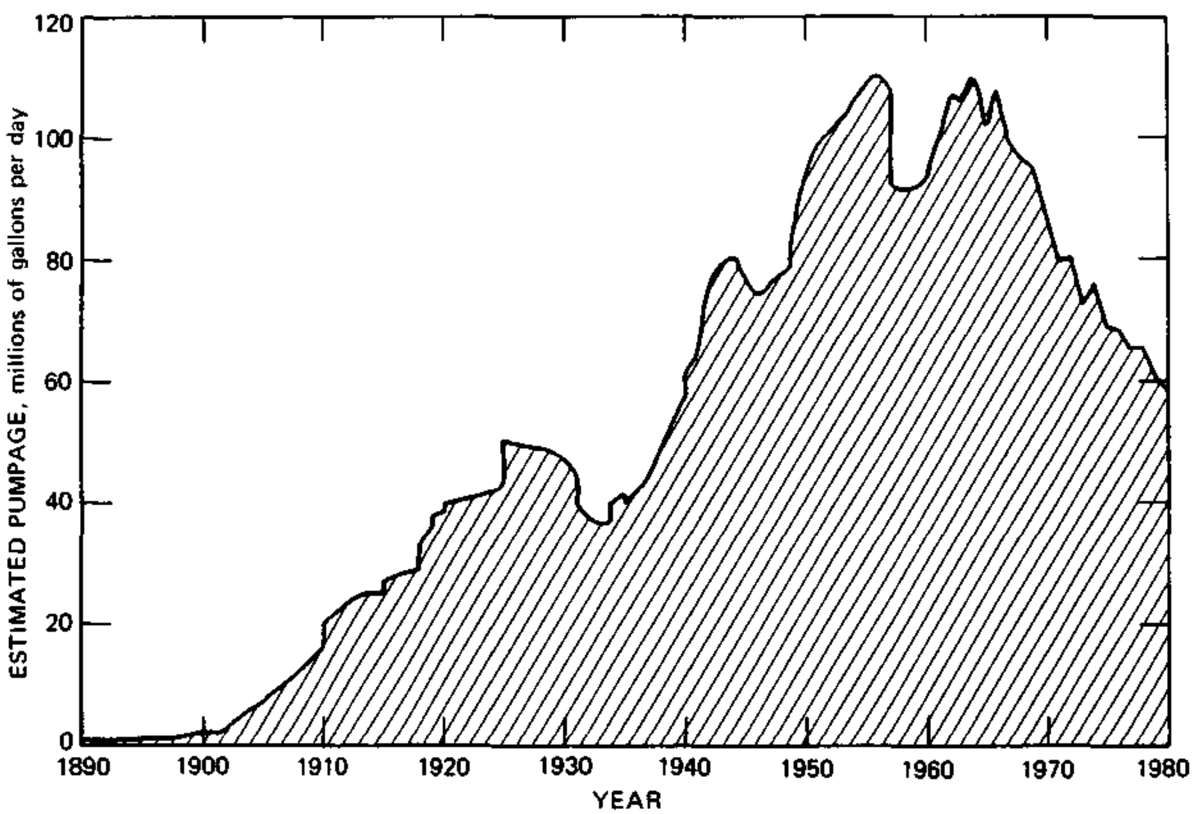

Figure 3. Estimated pumpage, 1890-1980

then declined sharply to 92.0 mgd in 1958. By 1964 pumpage had again increased to 110.0 mgd, but it has declined steadily from 1966 to the present. This decrease, primarily in industrial use, has been attributed to unacceptable water quality and the high cost of wastewater disposal (Planning and Management Consultants, Ltd., 1982).

Pumpage data are classified in this report according to four categories: 1) **public,** including municipal and institutional; 2) **industrial;** 3) **domestic,** including rural farm nonirrigation and rural nonfarm; and 4) **irrigation,** including farms, golf courses, and cemeteries. Most water-supply systems furnish water for several types of uses. A public supply commonly includes water used for drinking and other domestic uses, manufacturing processes, and lawn sprinkling. Industrial supplies may also be used in part for drinking and other domestic uses. No attempt has been made to determine the final use of water within the public and domestic categories; for example, any water pumped by a municipality is called a public supply, regardless of the use of the water. However, the final use of water within the industrial category has been determined in part, and any water pumped by an industry and furnished to a municipality is included in the public supply category.

Pumpage, 1978 through 1980

Pumpage declined from 65.7 mgd in 1978 to 58.6 mgd in 1980. Estimated pumpage for the period 1971 to 1980 is shown in figure 4. Distribution of 1980 pumpage was as follows: public supply systems accounted for 17.6 percent or 10.3 mgd, industrial pumpage was 74.4 percent or 43.6 mgd, domestic pumpage was 6.5 percent or 3.8 mgd, and irrigation pumpage was 1.5 percent or 0.9 mgd.

Public Supplies. Municipal and institutional uses are included in public supplies. The estimated pumpage for public water supply systems has remained approximately constant, with public supply withdrawals totaling 10.0 mgd in 1978, 11.0 mgd in 1979, and 10.3 mgd in 1980.

Pumpage of public water supplies reflects seasonal variations to some extent. Municipal pumpage is generally 25 to 30 percent higher during the summer months than during the winter months. Institutional pumpage is primarily for air conditioning and therefore is also affected by seasonal changes in temperature.

Industrial Supplies. The major industries in the East St. Louis area using ground water are oil refineries, chemical plants, ore refining plants, meat packing plants, and steel plants. Most of the industrial plants do not meter their pumpage, and pumpage estimates are therefore based on the number of hours the pump operated, the pump capacity, and in some cases on production data. Industrial pumpage generally is more uniform throughout the year than public pumpage unless large air conditioning installations are used, the industry is seasonal, or a change in operation occurs as a result of strikes or vacation shutdowns. Indus-

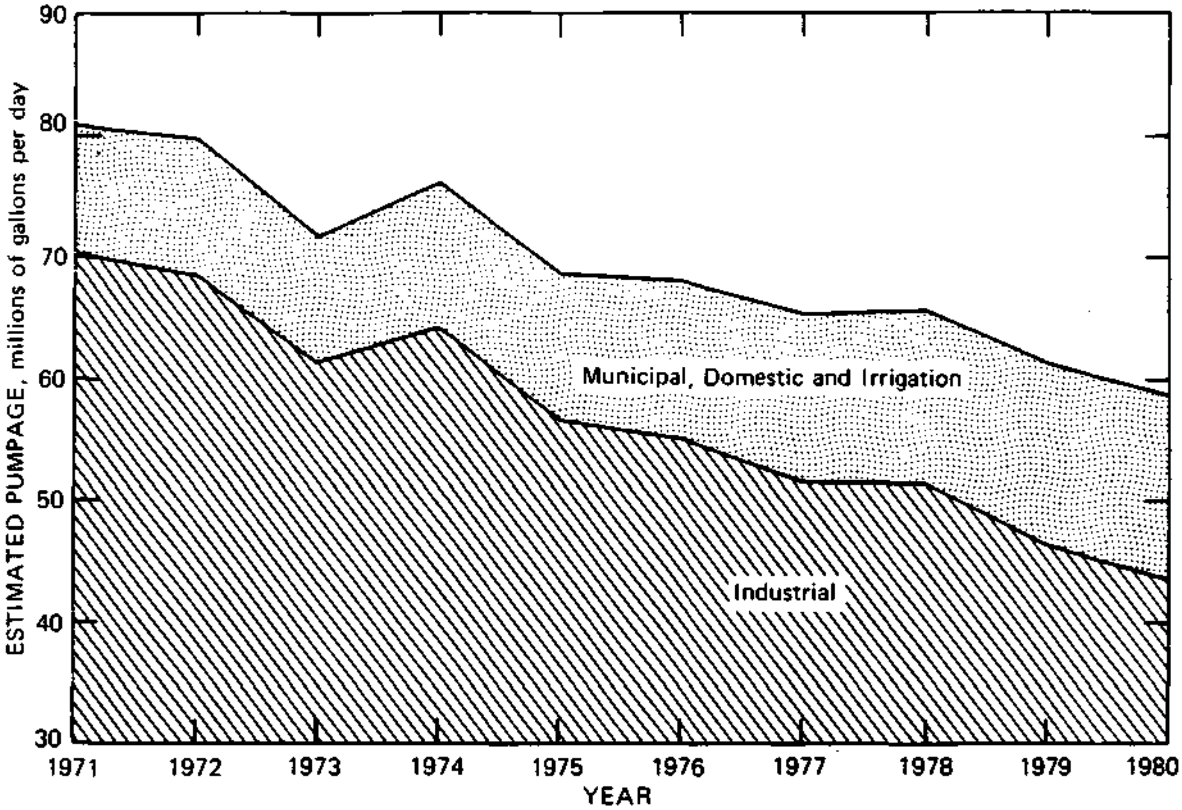

Figure 4. Estimated pumpage, 1971-1980, subdivided by use

trial pumpage decreased from 51.4 mgd in 1978 to 43.6 mgd in 1980 (figure 4). This reduction was due to a combination of water conservation measures, industrial production cutbacks, and the conversion from ground water to river water as a source by several industries.

Domestic Supplies. Emmons (1979) estimated domestic pumpage, including rural farm nonirrigation and rural nonfarm use. This estimate was made by considering rural population as reported by the U.S. Bureau of the Census and per capita use of 50 gallons per day (gpd). Average domestic pumpage for the period 1971 to 1978 was estimated to be 2.4 mgd. More recent data (Kirk et al., 1982) indicate per capita use for the East St. Louis area to be approximately 80 gpd. On the basis of this figure, average domestic use for the period 1978 to 1980 is estimated to be 3.8 mgd.

Irrigation Supplies. Irrigation pumpage is seasonal and can vary considerably from year to year. The amount of irrigation pumpage should generally reflect precipitation patterns and the number of acres irrigated. Irrigation pumpage estimates in the East St. Louis area were based on interview data concerning the estimated hours of operation and well discharge rates, number of acres irrigated, equivalent depths of water applied, and number of applications made.

In 1978, irrigation pumpage was estimated to be 164 million gallons, or 450,000 gallons per day (figure 5). This figure represents a decrease of 390,000 gallons per day from 1977. This decrease is explained by shortages of precipitation in the early months of the growing season in 1977 and by alternating above- and below-average amounts of precipitation during the 1978 growing season. A prolonged precipitation shortage occurred in 1977; the shortages in 1978 were more numerous but were not as long or severe.

In 1979, irrigation pumpage rose to 248 million gallons, or 679,000 gallons per day. This increase is attributed to below-average precipitation in May and June of that year. Above-average precipitation occurred in April, July, and August of that year, tempering irrigation demands.

In 1980, irrigation pumpage increased to 333 million gallons, or 911,000 gallons per day. This increase in irrigation use resulted from above-average temperatures and below-average precipitation from April through July, and near normal conditions in August and September.

In 1977, there were 40 irrigation well owners, who reported 32 active wells. In 1980, only 23 wells were reported used. Because of

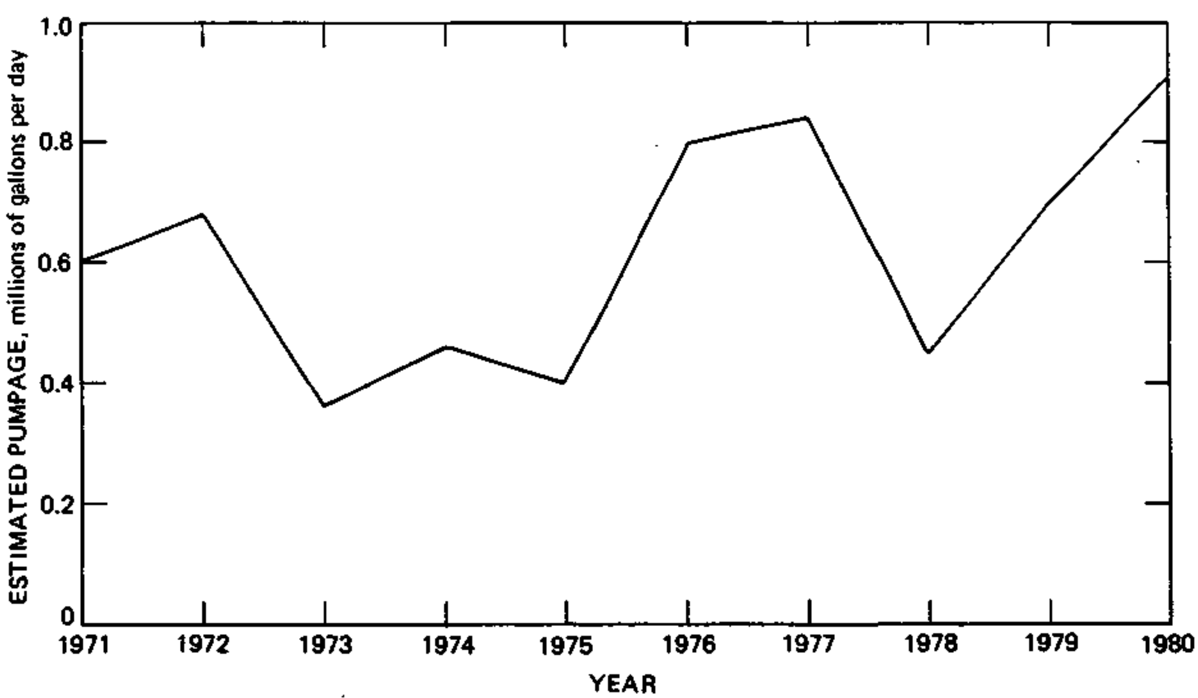

Figure 5. *Estimated irrigation pumpage, 1971-1980* seasonal variations and different methods of data collection, trends in irrigation pumpage are inconclusive; however, more rigorous data collection procedures are not justified due to the small amount of irrigation pumpage in comparison with other uses.

Distribution of Pumpage

Pumpage in the East St. Louis area i3 now concentrated in four major pumping centers and six minor pumping centers. The major pumping centers are at Alton, Wood River, National City, and Granite City. Minor pumping centers are at Poag, Glen Carbon, Troy, Caseyville, Fairmont City, and Monsanto.

Distribution of the 1980 pumpage and locations of pumping centers are shown in figure 6. Prior to 1953, pumpage from wells was concentrated mainly in areas 1 or more miles from the Mississippi River. During and after 1953. pumpage from wells located a few hundred feet or less from the Mississippi River increased greatly. Table 1 lists the distribution of pumpage from wells near the river (less than a mile) from 1971 through 1980. Figure 7 shows the distribution and location of pumpage from wells near the Mississippi River in 1980.

Estimated pumpage in the major pumping centers and Monsanto is shown in figure 8. Pumpage in the Monsanto area decreased significantly from 1975 to 1980 because of conversion by industries to the Mississippi River as a source of water. The greatest use of ground water in the Monsanto area is for metal processing. Since 1978, pumpage has been sufficiently low that Monsanto is now considered a minor pumping center.

Ground-water withdrawals in the Alton area are primarily from wells owned by five industries. The greatest use of water is for boxboard manufacturing. During the 1970s, water use by the boxboard industry declined rather steadily, while other uses remained essentially constant. Thus total estimated pumpage declined from a peak of 14.6 mgd in 1972 to 6.0 mgd in 1980.

The Wood River area constitutes the largest pumping center in the American Bottoms. Pumpage in 1980 totaled 27.3 mgd; 46.9 percent of this total, or 12.8 mgd, was derived from wells near the Mississippi River. From 1975 through 1980, pumpage in the Wood River pumping center was rather constant, fluctuating between 27.2 mgd in 1978 and 25.3 mgd in 1975, a total variation of less than 10 percent. Pumpage in the Wood River area supplies oil refineries and municipalities.

Pumpage in the Granite City area fluctuated erratically throughout the 1970s. Estimated pumpage decreased from 9.3 mgd in 1978 to 7.7 mgd in 1979 and 4.6 mgd in 1980. These decreases reflect reduction in ground-water use by steel production industries, the primary users in this area.

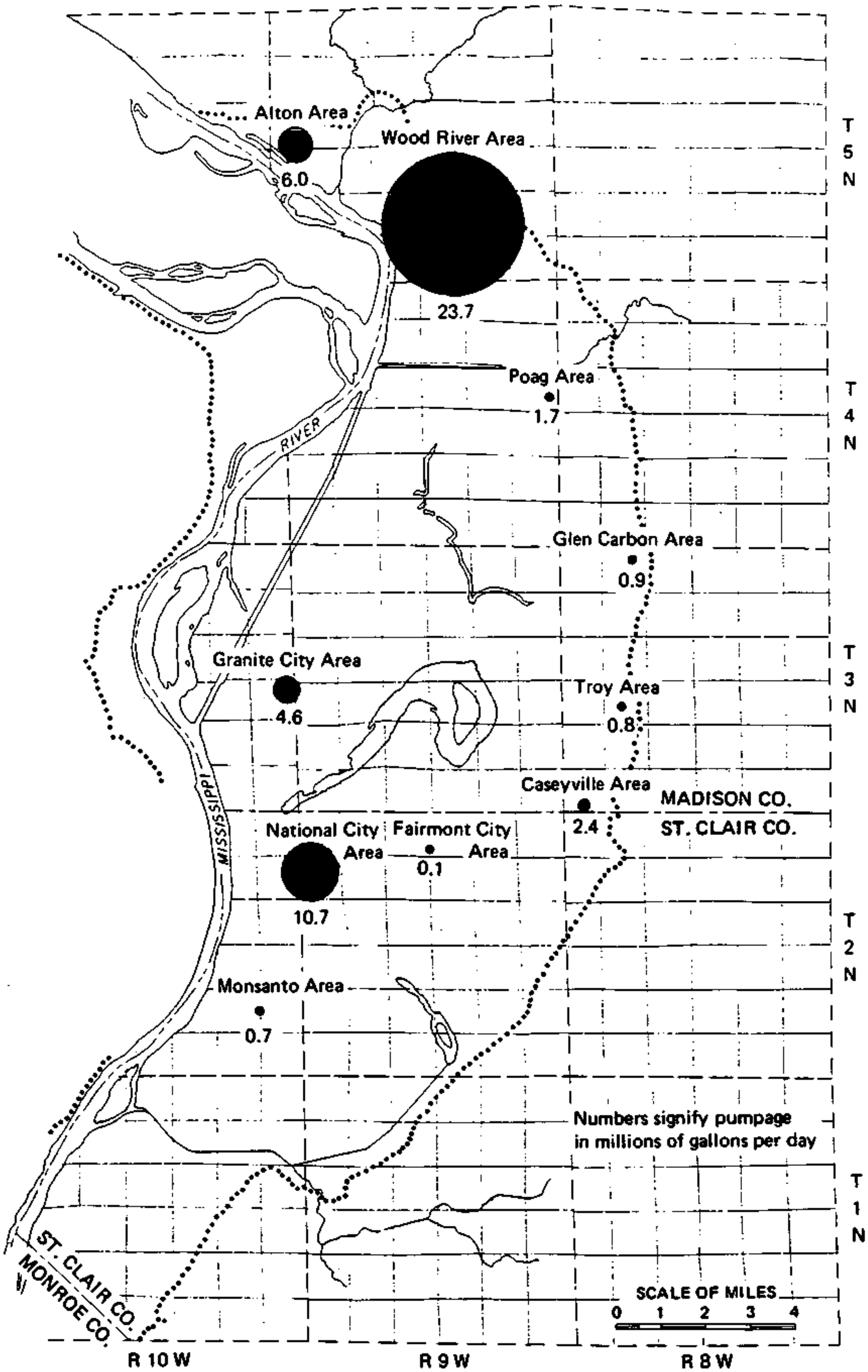

Figure 6. Distribution of estimated pumpage, 1980

Table 1. Distribution of Pumpage from Wells near Mississippi River
(Pumpage in millions of gallons per day)

	Alton	Wood River	Monsanto
1971			
All wells	14.2	29.0	12.1
Wells near river	8.1	13.1	5.7
1972			
All wells	14.6	27.1	9.8
Wells near river	11.1	11.8	5.0
1973			
All wells	12.9	26.2	9.5
Wells near river	10.0	11.7	5.0
1974			
All wells	12.4	28.2	10.2
Wells near river	9.9	11.4	4.3
1975			
All wells	9.7	25.3	11.3
Wells near river	7.9	10.8	4.5
1976			
All wells	8.8	25.7	6.9
Wells near river	7.1	9.6	4.0
1977			
All wells	7.3	27.1	4.1
Wells near river	5.9	13.3	2.8
1978			
All wells	9.5	27.2	1.2
Wells near river	9.2	14.3	0
1979			
All wells	6.4	25.6	1.0
Wells near river	6.4	12.2	0
1980			
All wells	6.0	27.3	0.7
Wells near river	6.0	12.8	0

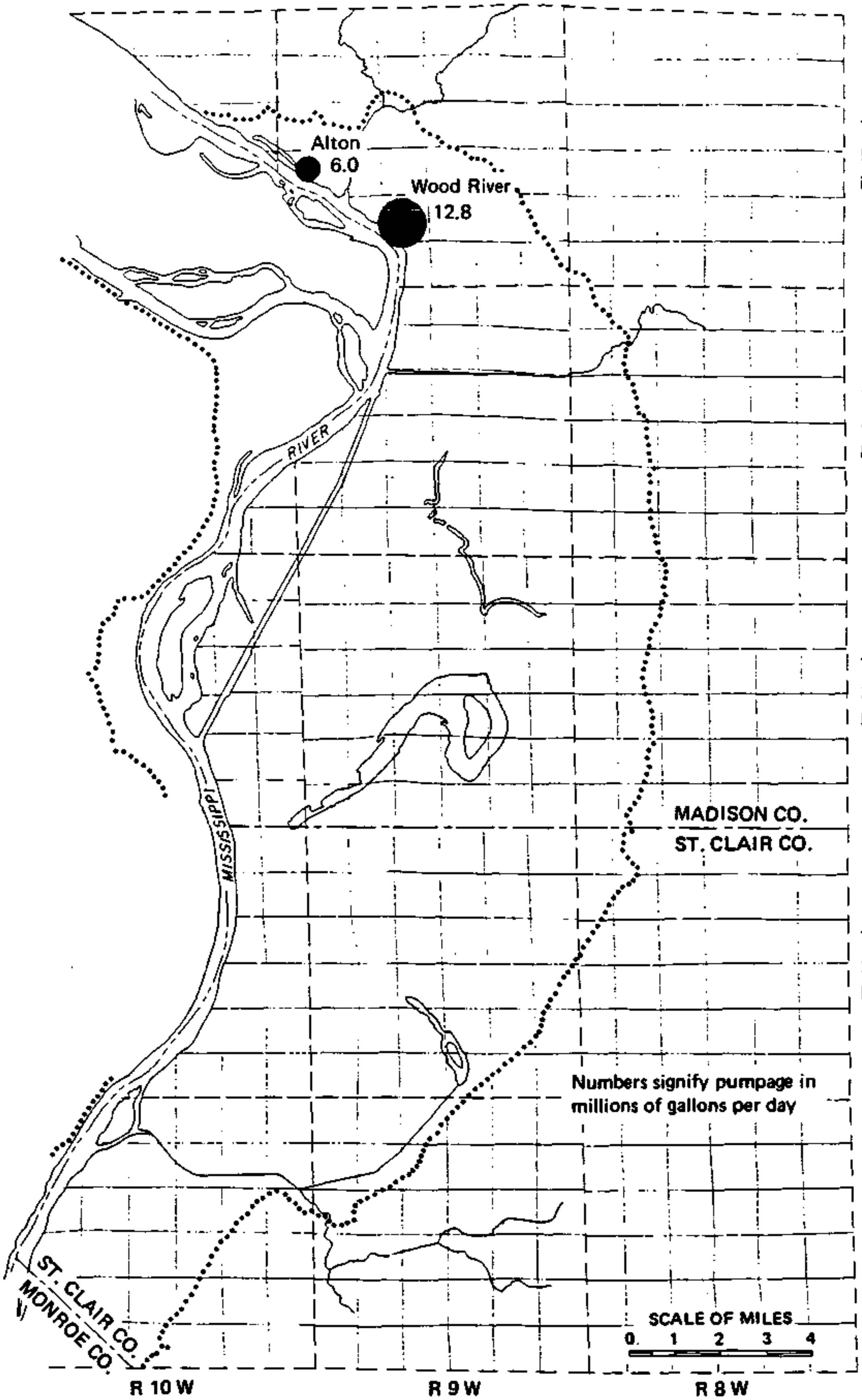

Figure 7. Distribution of estimated pumpage near the Mississippi River, 1980

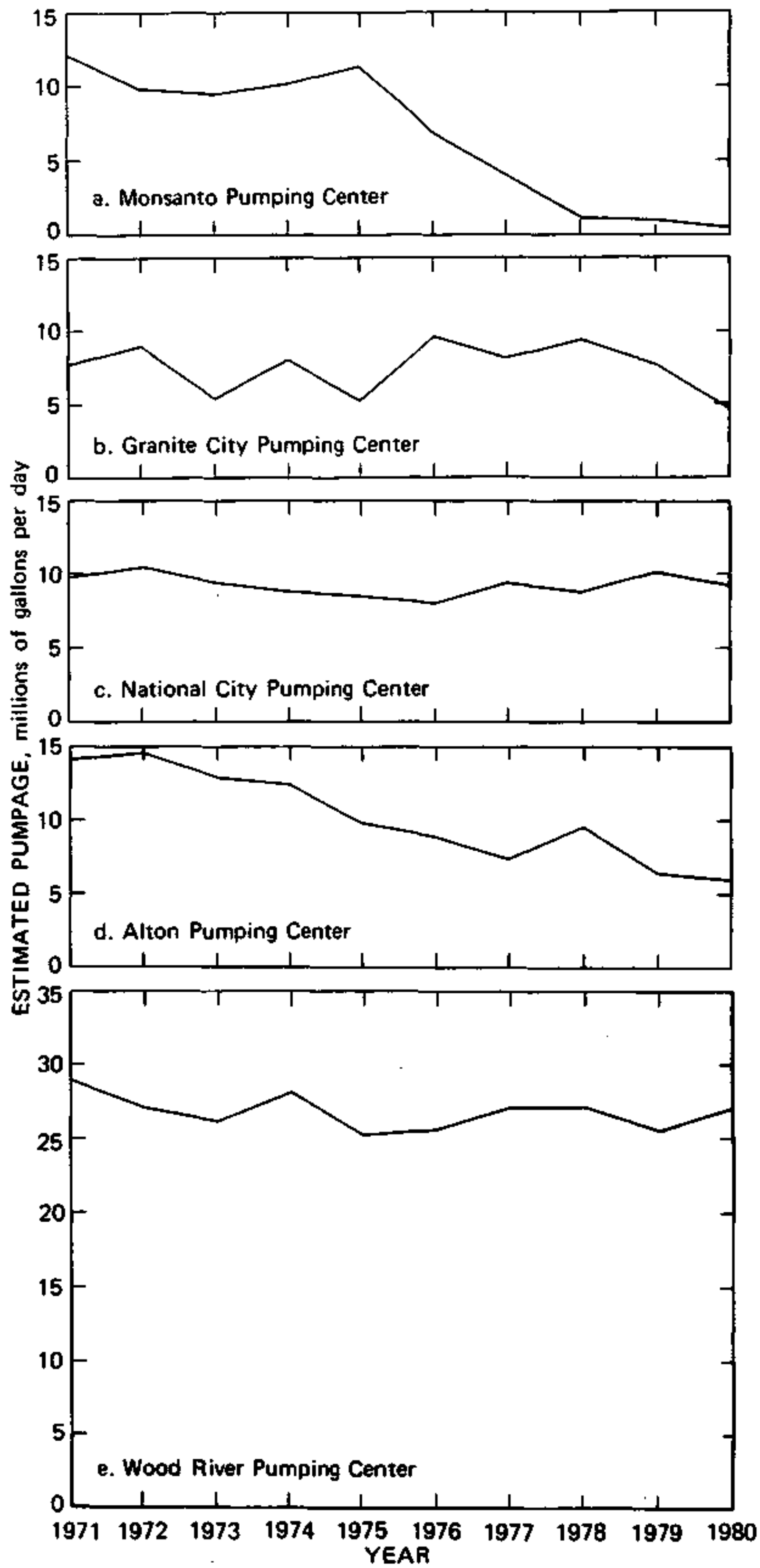

Figure 8. Estimated pumpage, major pimping centers and Monsanto

Ground-water withdrawals in the National City area are used for meat packing plants and dewatering sites near interstate highways. Pumpage decreased from a peak of 10.5 mgd in 1972 to 8.1 mgd in 1976, and then increased to 9.4 mgd in 1980. This rise is attributed to the increased pumpage at the interstate highway dewatering sites necessary to offset reductions in pumpage in the Monsanto and Granite City areas.

Combined ground-water pumpage from the minor pumping centers, excluding Monsanto, is shown in figure 9. Pumpage in Fairmont City is used for industrial supply; all other pumping areas primarily supply municipalities. Total pumpage from these minor pumping centers remained essentially constant throughout the 1970s.

WATER LEVELS IN WELLS

Water levels in wells in the American Bottoms have been measured periodically for more than 40 years by the State Water Survey and other concerned public and private parties. The locations of SWS observation wells active from 1971 through 1980 are shown in figure 10.

Water levels in wells generally recede in late spring, summer, and early fall when the combination of discharge from the ground-water reservoir by evapotranspiration and ground-water discharge to streams and pumpage exceeds recharge from precipitation and infiltration induced from surface water bodies. Ground-water levels generally begin to recover in early winter when conditions are favorable for recharge from precipitation. The recovery of ground-water levels is especially pronounced during the early spring months when precipitation recharge exceeds evapotranspiration and discharge to streams, resulting in most of the annual recharge to the aquifer.

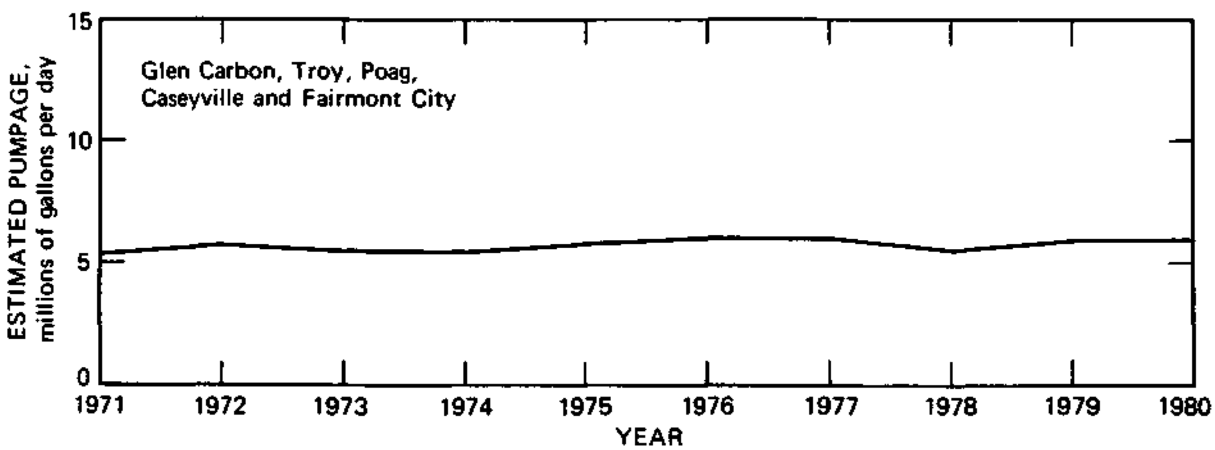

Figure 9. Estimated pumpage, minor pumping centers excluding Monsanto

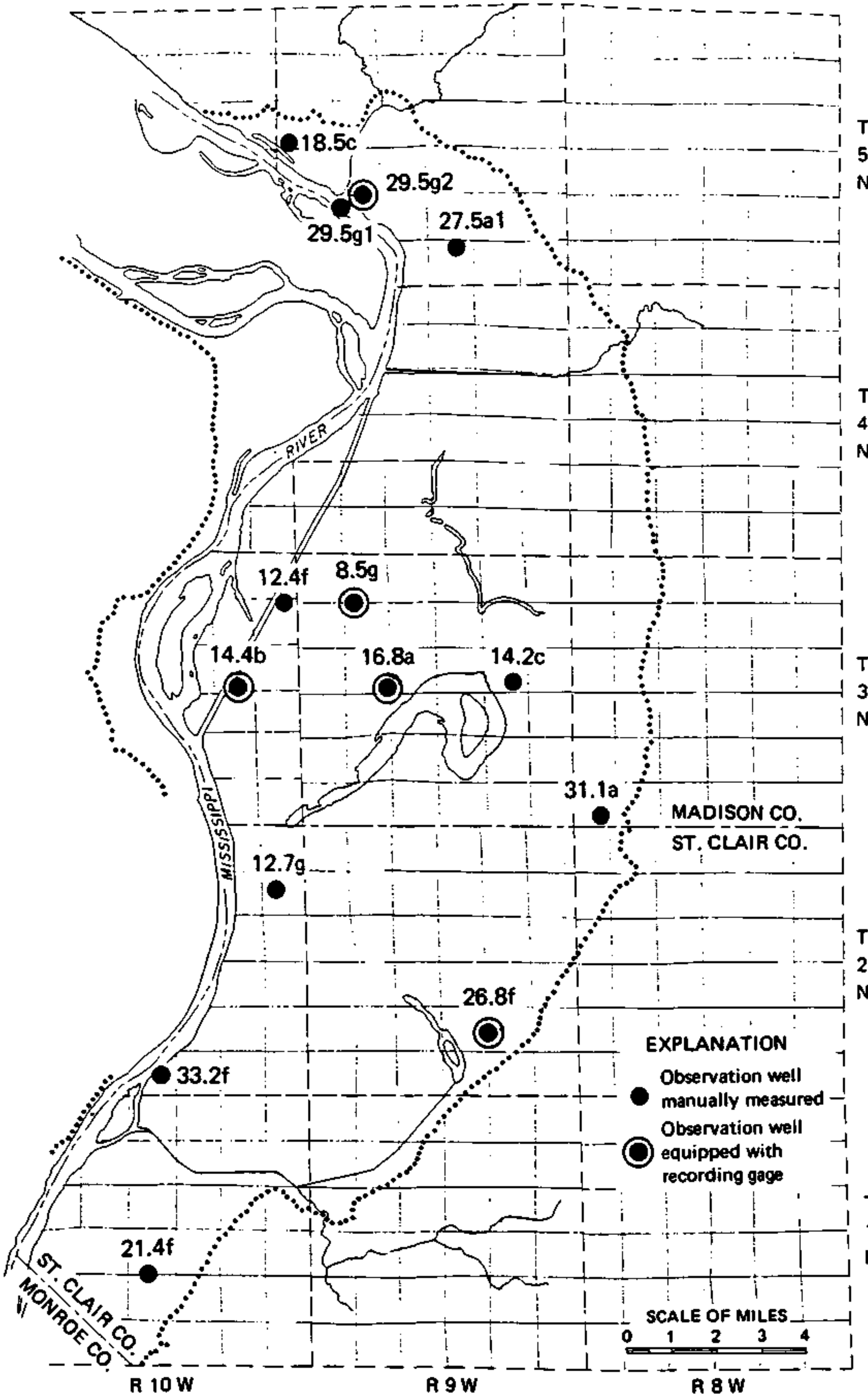

Figure 10. Locations of SWS observation wells

The water level measured in a well at a particular time will reflect not only seasonal variation, but also factors such as recent climatic conditions, nearby pumpage, and the water levels of nearby surface water bodies. Figure 11 shows the average monthly high and low water levels' and the record high and low water levels observed during the period of record for four wells in the American Bottoms. From these graphs, it can be seen that ground-water levels are usually highest during April to June, and are lowest in September, October, and November. The influence of nearby hydrologic features can also be seen.

Well MAD3N9W-l6.8a is located in an urban setting near Horseshoe Lake in the center of the area. Horseshoe Lake can be considered to have a nearly constant water surface elevation, which limits fluctuations of the surrounding ground-water levels. Furthermore, the presence of urban structures (e.g., buildings and paved surfaces) limits the area through which vertical recharge can occur. As a result of these factors, the annual fluctuation at Well MAD3N9W-l6.8a is about 1 foot.

In contrast, Well STC2N9W-26.8f2 is located near the bluff in the southern part of the area and is not greatly affected by pumpage or surface water influence. The annual fluctuation at Well STC2N9W-26.8f2 is about 2 ft. Well MAD5N9W-29.4f, located near the Mississippi River at Alton, is influenced by river stage fluctuations and pumpage. Well MAD3N10W-14.4b is located in the west-central part of the area near Chain of Rocks Canal. Well MAD3N10W-l4.4b is annually more stable than Well MAD5N9W-29.4f because water levels are more constant in Chain of Rocks Canal than in the Mississippi River, and because of a greater pumpage influence at Well MAD5N9W-29.4f.

Since 1900, ground-water levels have changed appreciably in the five major pumping centers. According to Schicht and Jones (1962), the greatest water level declines for the period from 1900 to November 1961 occurred in the five major pumping centers: 50 ft in the Monsanto area, 40 ft in the Wood River area, 20 ft in the Alton area, 15 ft in the National City area, and 10 ft in the Granite City area. Part of the declines, 2 to 12 ft, were attributed to the construction of levees and drainage ditches.

Reitz (1968) and Baker (1972) described the changes in ground-water levels from 1962 through 1971. Ground-water levels generally continued to decline through 1964, but began to rise about 1965 as the effects of decreased pumpage and above-average precipitation and river stages became noticeable.

Ground-water levels generally continued to increase from 1972 to 1977 (Emmons, 1979). Decreases in pumpage caused ground-water levels to rise 2 ft in the Monsanto and Wood River areas and 5 feet in National City. Little change was observed in the Alton and Granite City pumping centers. In Alton, a change of observation wells to a site nearer the center of pumpage obscured the rise in ground-water levels resulting from

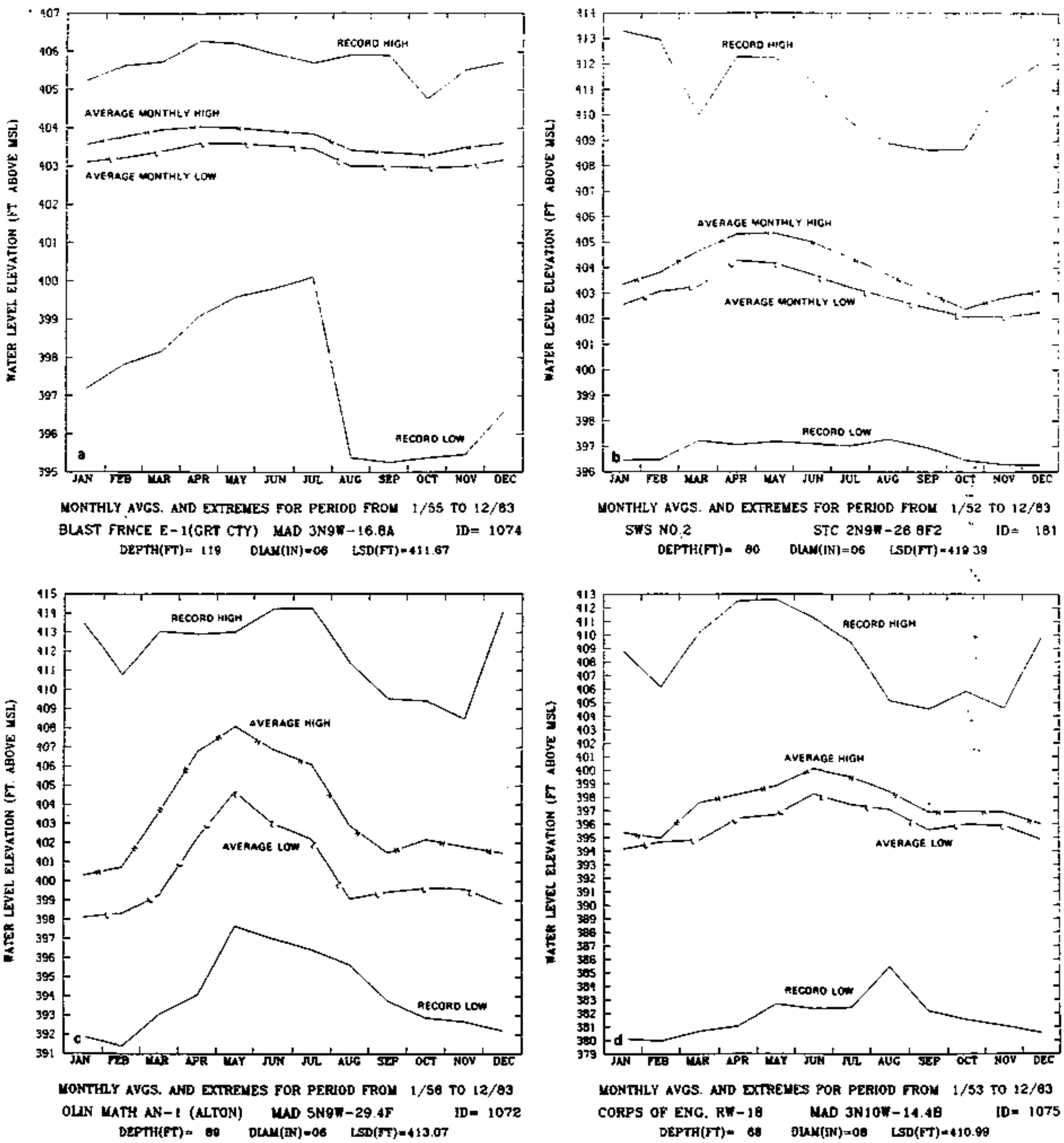

Figure 11. Average and record monthly high and low water levels

a decrease in pumpage. Erratic pumpage in the Granite City area produced small observed changes in ground-water levels.

Figure 12 shows the mean monthly Mississippi River stages from 1971 through 1980, and figure 13 shows the observed annual precipitation for the same period at Edwardsville (which lies near the crest of the bluff slightly north of the center of the area). Hydrographs of selected wells are shown in figure 14. Single line hydrographs represent water levels for wells where the water level is measured monthly. Hydrographs with two lines represent water levels for wells equipped with continuous recorders; the lines represent the observed monthly high and low ground-water levels.

From 1978 through 1980, ground-water levels in Well MAD5N9W-29.4f (fig. 14a) generally reflect Mississippi River stages. The hydrograph of well MAD3N10W-l4.4b (fig. 14b) also reflects river stage but, as noted above, is a subdued replica of hydrographs of both river stage and Well MAD5N9W-29.4f because of water level control in Chain of Rocks Canal. Flood events in 1978 and 1979 caused corresponding peaks in both ground-water hydrographs. In 1980, river stages were generally below normal, while the ground-water levels fluctuated between average annual highs and lows (figures 11c and 11d). This apparent discrepancy in 1980 is interpreted as the residual effect of two years (1978-1979) of generally high river stage.

Well MAD5N9W-27.5a1 (fig. 14c) is located near the geographical center of the Wood River pumping center. In this area, total pumpage remained essentially constant for the period 1971 to 1980. The distribution of pumpage, however, shifted toward the Mississippi River. As a result ground-water levels increased inland, as seen in the hydrograph of

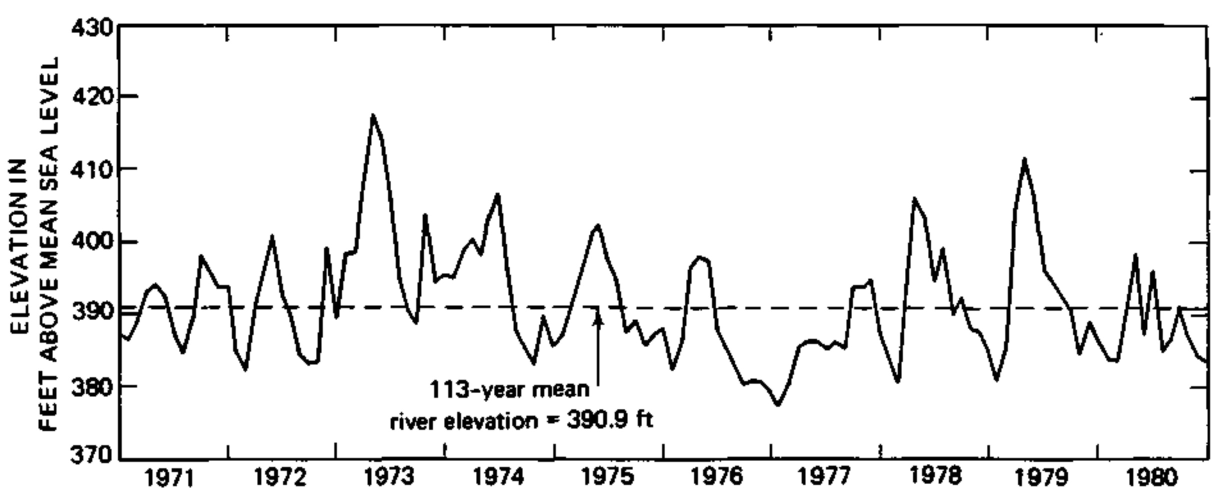

Figure 12. Mean monthly river stages, St. Louis gaging station, 1971-1980

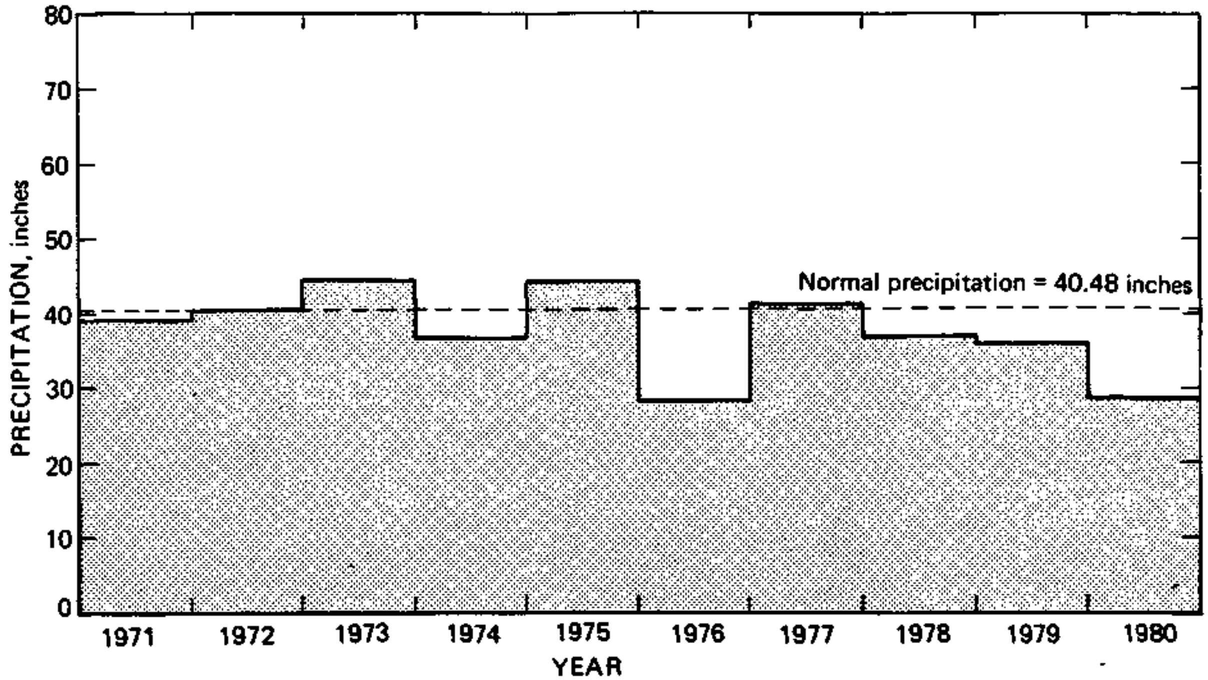

Figure 13. Annual precipitation at Edwardsville, 1971-1980

Well MAD5N9W-27.5a1. The water level increase at this well was more than 1 foot from 1978 to 1980.

The composite hydrograph of Wells STC2N10W-12.7g (fig. 14d) also shows the effects of pumpage. These wells are located in the National City pumping center, about four miles from the river. The hydrograph of these wells indicates that at this location ground-water level elevations are consistently below river stage (figure 12). This condition is created by pumpage. The relatively large annual fluctuations are the result of pumpage and the variable effect of pumpage-induced recharge from the Mississippi River. There are no apparent trends toward increasing or decreasing ground-water level elevations, indicating fairly constant pumpage and a balance between pumpage and the various forms of recharge.

Well MAD3N9W-16.8a (fig. 14e) lies north of Horseshoe Lake. As noted above, Horseshoe Lake has a stabilizing influence on ground-water levels in this area. Well MAD3N9W-16.8a is also affected by pumpage from the Granite City pumping center, but is far enough distant from the center of pumpage that the effect is small. From 1978 to 1980, Granite City pumpage decreased by nearly 5 mgd. However, because of the distance between the pumping center and the observation of Horseshoe Lake, an increase of less than 1 foot in ground-water levels has resulted.

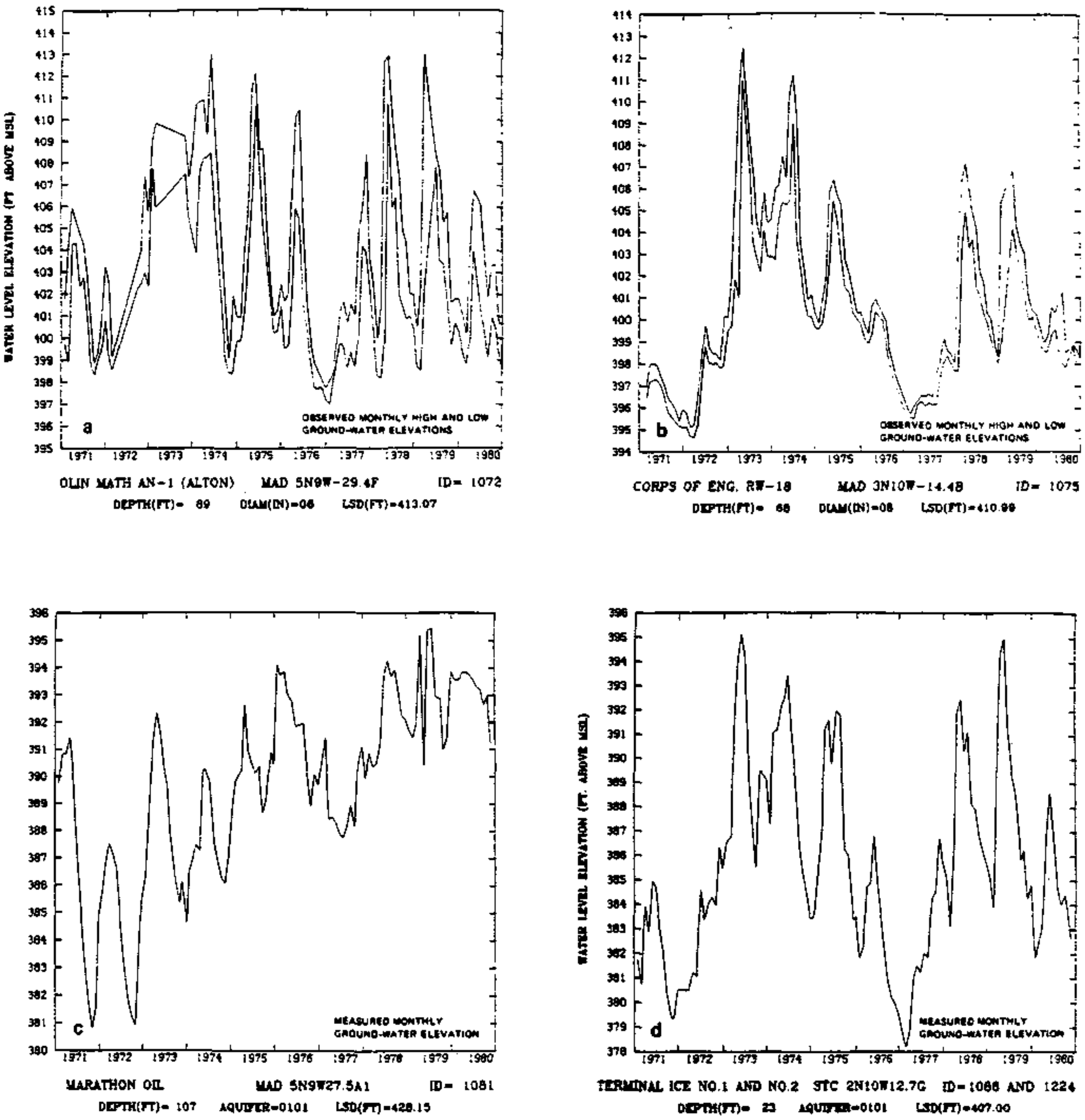

Figure 14. Hydrographs of selected wells, 1971-1980

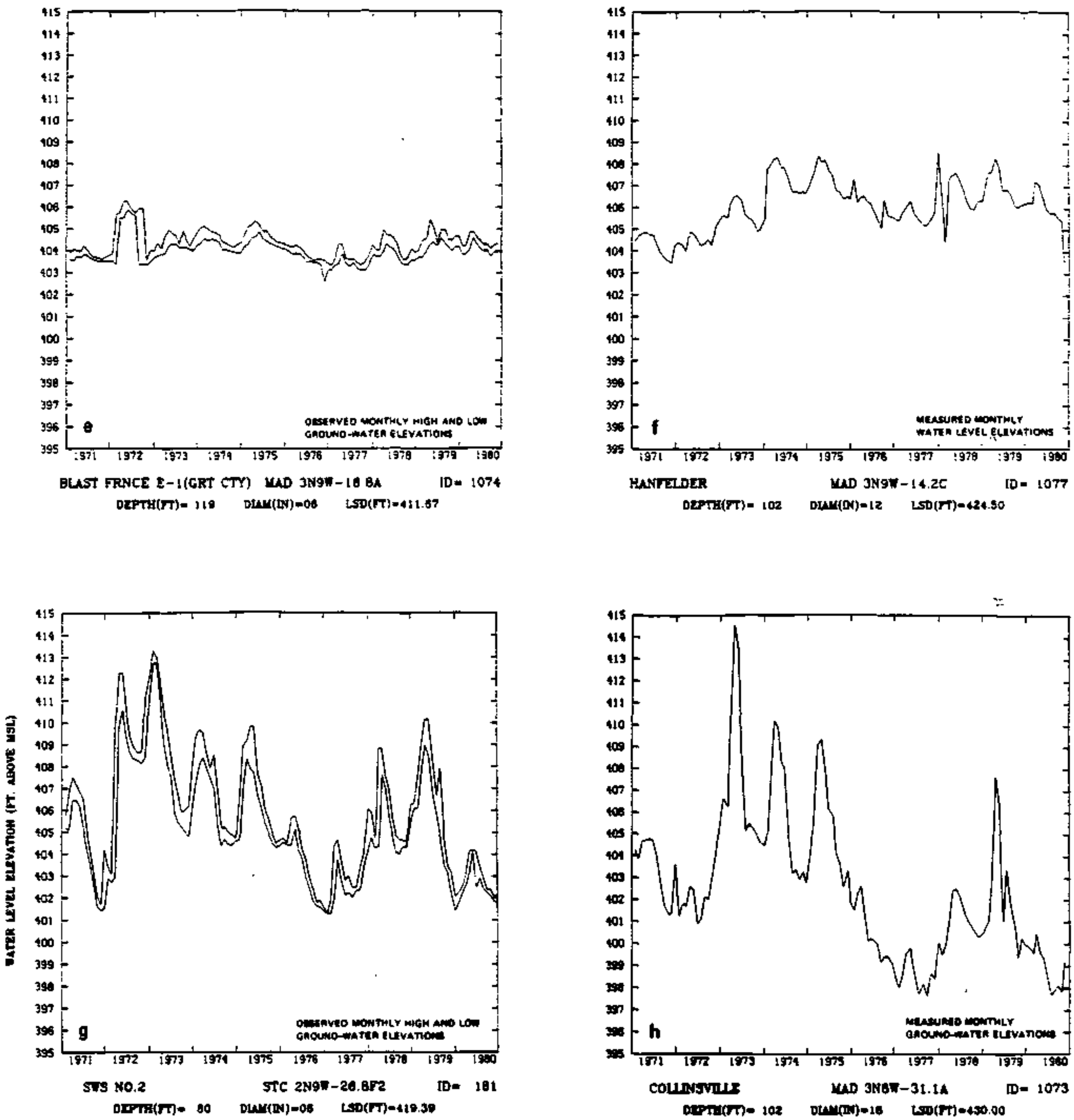

Figure 14. Concluded

Well MAD3N9W-14.2C (fig. 14f), which lies near the northeast end of Horseshoe Lake, also shows the stabilizing influence of the lake. The annual fluctuation of water levels in this well appears to be less than 3 feet. This is more variation than in Well MAD3N9W-16.8a, and is explained by the difference in land use surrounding these wells. Well MAD3N9W-16.8a is in a relatively urban, developed area, while the predominant land use near Well MAD3N9W-14.2c is agricultural, permitting a greater response due to infiltrated precipitation. For the period from 1978 to 1980, no changes in ground-water levels were noted at Well MAD3N9W-14.2c, other than those attributable to precipitation patterns.

Ground-water levels in Well STC2N9W-26.8f2 (fig. 14g) vary according to precipitation and ground-water inflow from the uplands which lie immediately to the east of the well. During 1978 and 1979, ground-water levels responded to spring recharge and then declined with slightly below average annual precipitation. Precipitation rates significantly below average in 1980 left ground-water levels near their lowest point in the 1971-1980 decade.

Well MAD3N8W-31.1a (fig. 14h) lies north of Well STC2N9W-26.8f2 in a similar geologic setting; however, it is affected by pumpage from the Caseyville pumping center. As a result, water level elevations in Well MAD3N8W-31.1a were generally 2 to 4 feet lower than those in Well STC2N9W-26.8f2 for the period from 1978 to 1980. A long-term decreasing trend in water levels is attributable to an increase in pumpage; this trend appears to have stabilized (with pumpage) from 1978 to 1980.

PIEZOMETRIC SURFACE

Ground-water level measurements were made in 253 wells in November and December 1980 when ground-water levels were near minimum annual stages. Water level data for the Mississippi River and the measured wells are provided in table 2 and the appendix, respectively. A piezometric surface map for November 1980 (figure 15) was prepared from the water level data.

Emmons (1979) compared the features of the November 1977 (figure 16) and November 1971 (figure 17) piezometric surface maps, and found that changes could be noted in all the major pumping centers. In the Alton area, a large decrease in pumpage by one industry caused the cone of depression to move slightly to the southwest. The Wood River area had a well-defined center of pumpage in 1971. An expansion of the pumpage center occurred by 1977, because a major industry changed the location of its ground-water source. In the Granite City area a decrease in ground-water withdrawal by one industry caused the center of pumpage to decrease in size. In the National City area the cone of depression enlarged because of increased pumpage. In the Monsanto area, a conversion in water supply from ground water to surface water caused one of the two cones of depression, evident in 1971, to disappear.

Table 2. Mississippi River Stages

Gage description	Mississippi River mile number	Water Surface Elevations (feet) 11/30/71	11/15/77	11/12/80
Lock and Dam No. 26 Alton, IL (lower)	202.7	403.6	408.3	418.9
Hartford, IL	196.8	402.9	407.6	399.3
Chain of Rocks, M0	190.4	398.4	399.9	398.6
St. Louis, MO	179.6	388.4	396.3	383.4
Engineer Depot, MO	176.8	387.1	394.9	382.7

Between 1977 and 1980, these trends continued. At Alton, the cone of depression remained near the Mississippi River and ground-water levels seemed to be recovering near the bluff. At Wood River, the center of .-pumpage also shifted toward the Mississippi, and spread along the river in response to changes in the distribution of pumpage. The cones of depression at Granite City and Monsanto were no longer evident. This is due to continued reduced levels of pumping. At National City, the increase in pumpage at the highway dewatering sites is causing a decline of ground-water levels and expansion of the cone of depression in this area.

The general pattern of ground-water flow throughout the 1970s was slow movement toward the cones of depression or the Mississippi River and other streams. Historically, pumpage established hydraulic gradients from the Mississippi River toward all major pumping centers; this was not true in 1980. The combination of reduced pumpage at Monsanto and low river stage in November 1980 created a ground-water divide between the National City and Monsanto pumping centers and the Mississippi River. Other major pumping centers were still inducing infiltration of river water into the ground-water system.

Emmons (1979) discussed the slope of the piezometric surface in 1971 and 1977 for areas near and remote from pumping centers. The average slope of the piezometric surface away from the cones of depression was 5 feet per mile in 1971, 4 feet per mile in 1977, and 3 feet per mile in 1980. In the Wood River cone of depression, gradients averaged 15 feet per mile in 1971 and 1977, but reduced to 10 feet per mile in 1980. In the Alton area, the average slope of the piezometric surface was 15 feet per mile in 1971, 10 feet per mile in 1977, and 20 feet per mile in 1980. Gradients averaged 10 feet per mile in National City in 1971, 1977, and 1980. In the Granite City area, the gradient of the cone of depression

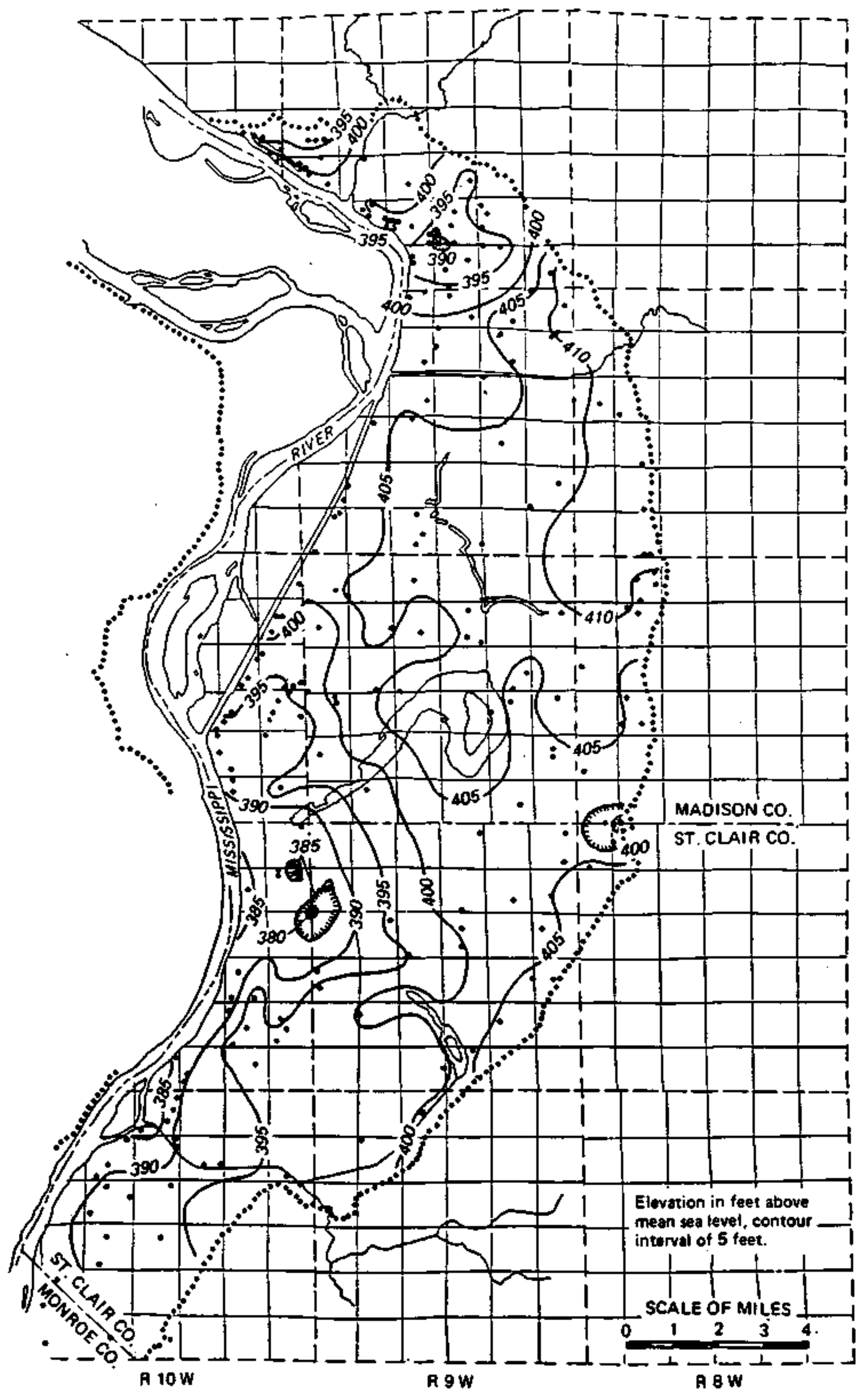

Figure 15. Approximate elevation of piezometria surface, November 1980

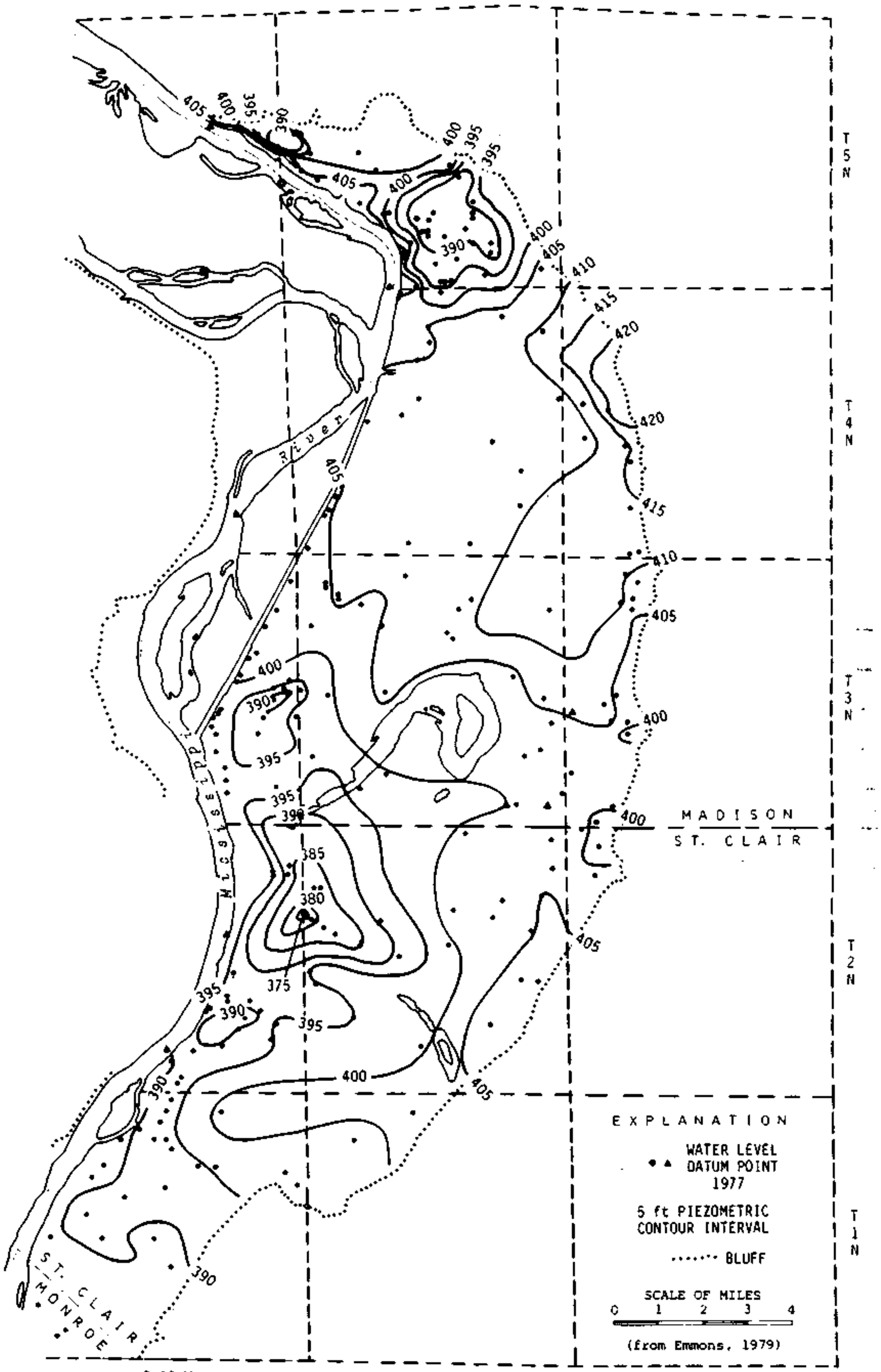

Figure 16. Approximate elevation of piezometric surface, November 1977

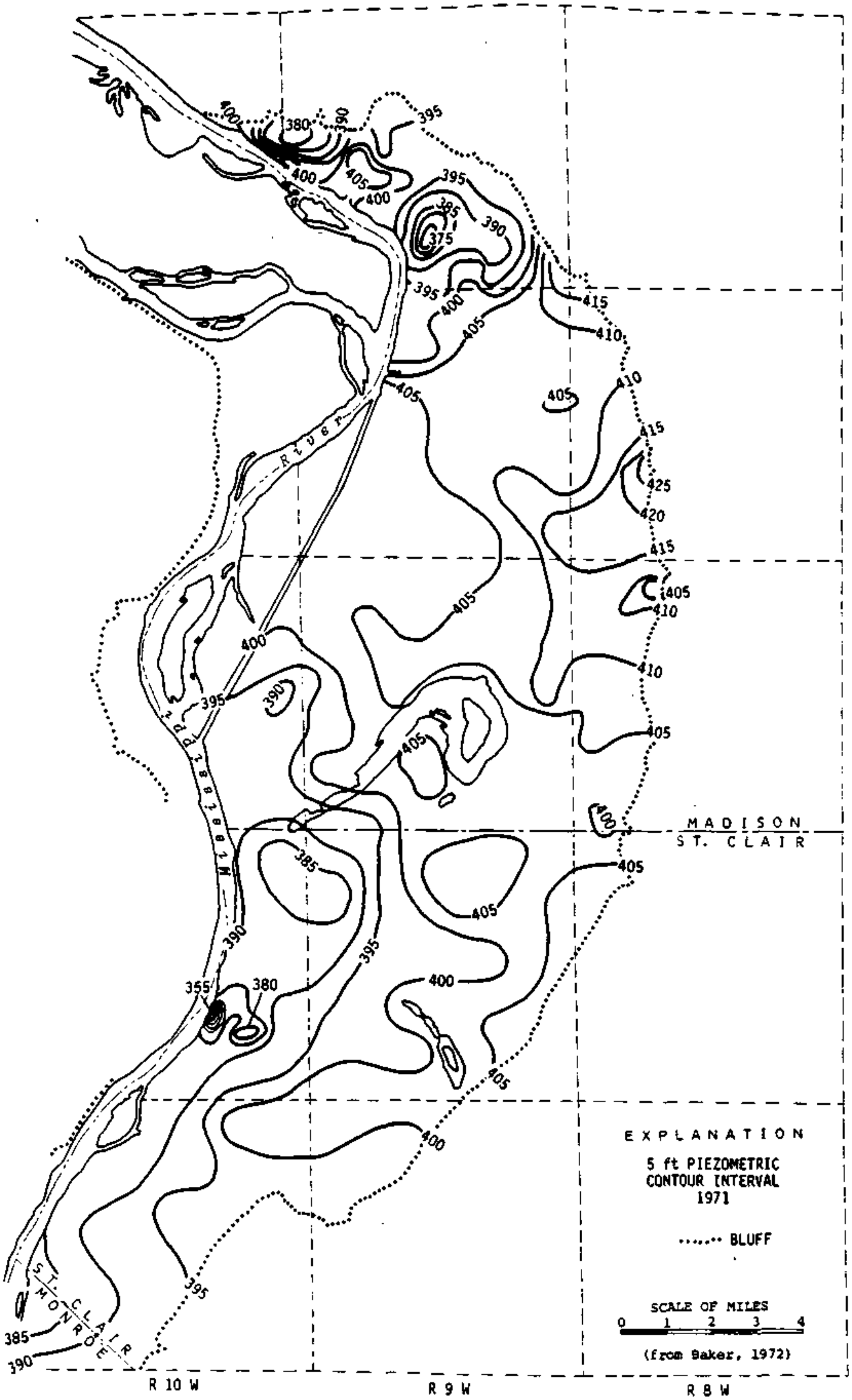

Figure 17. Approximate elevation of piezometrio surface, November 1971

averaged 10 feet per mile in 1971 and 1977, but decreased to 5 feet per mile in 1980.

Changes in Ground-Water Levels

Ground-water level changes were computed from a comparison of piezometric surface maps for November 1977 and November 1980, and a map illustrating estimated changes in water levels was prepared (figure 18). A similar map for the period from 1971 to 1977 (Emmons, 1979) is included for comparison (figure 19). Dramatic changes in water levels occurred in the Monsanto, Wood River, and Alton pumping centers during the period from 1971 to 1977. Emmons (1979) attributed these changes to shifts in distribution or reduction of pumpage.

The map of estimated ground-water level changes for the period from 1977-1980 outside pumping centers shows little change. Near pumping centers, trends established between 1971 and 1977 continued. Decreases in water levels in areas near the Mississippi River were generally due to low river stage. In the Wood River area, however, decreases in water level elevations of more than 5 feet were caused by pumpage. Ground-water levels increased in inland portions of the Alton and Wood River areas. These rises are due to the shift of pumping distribution toward the river in these areas. In the Granite City area, ground-water levels were generally rising with decreased pumpage. A local area of ground-water level decline near the Granite City pumping center is assumed to be due to a slight shift in the distribution of pumpage by an industrial user. Increased pumpage in the National City area expanded the area of declining ground-water levels near the river. Ground-water levels continued to recover in the Monsanto area with reduced pumpage.

Areas of Diversion

Areas of diversion of pumping centers in November 1977 and November 1980 are shown in figure 20. The boundaries of areas of diversion represent approximate locations of ground-water divides. The intersection of two or more ground-water divides represents a stagnation point, or a point of zero velocity. In figure 20, however, this interpretation should not be applied. In this figure, intersections are drawn merely for convenience; they represent, at best, regions of low velocity and extreme complexity in flow patterns.

Within the boundaries of an area of diversion of a pumping center, ground water will flow toward that pumping center. Change in the size of an area of diversion reflects a change in pumpage or geohydrologic boundaries. Diversion areas for major pumping centers and Caseyville are listed in table 3. The most significant change in an area of diversion occurred at Monsanto, where there was a decrease of 10.2 square miles due to the reduction in pumpage in this area. Small reductions in the area of diversion were observed at Wood River and National City. At Wood

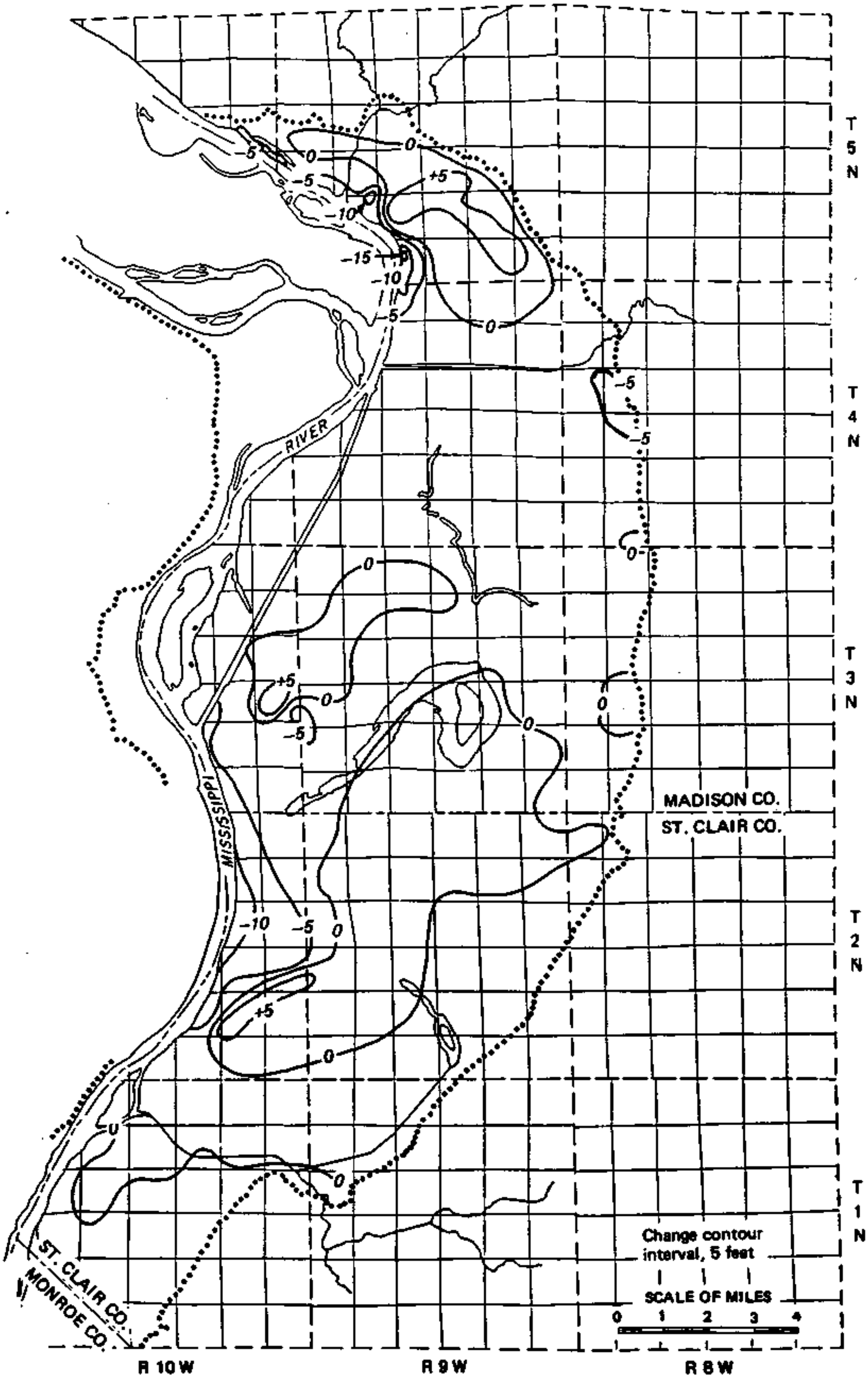

Figure 18. Changes in piezometric surface from November 1977 to November 1980

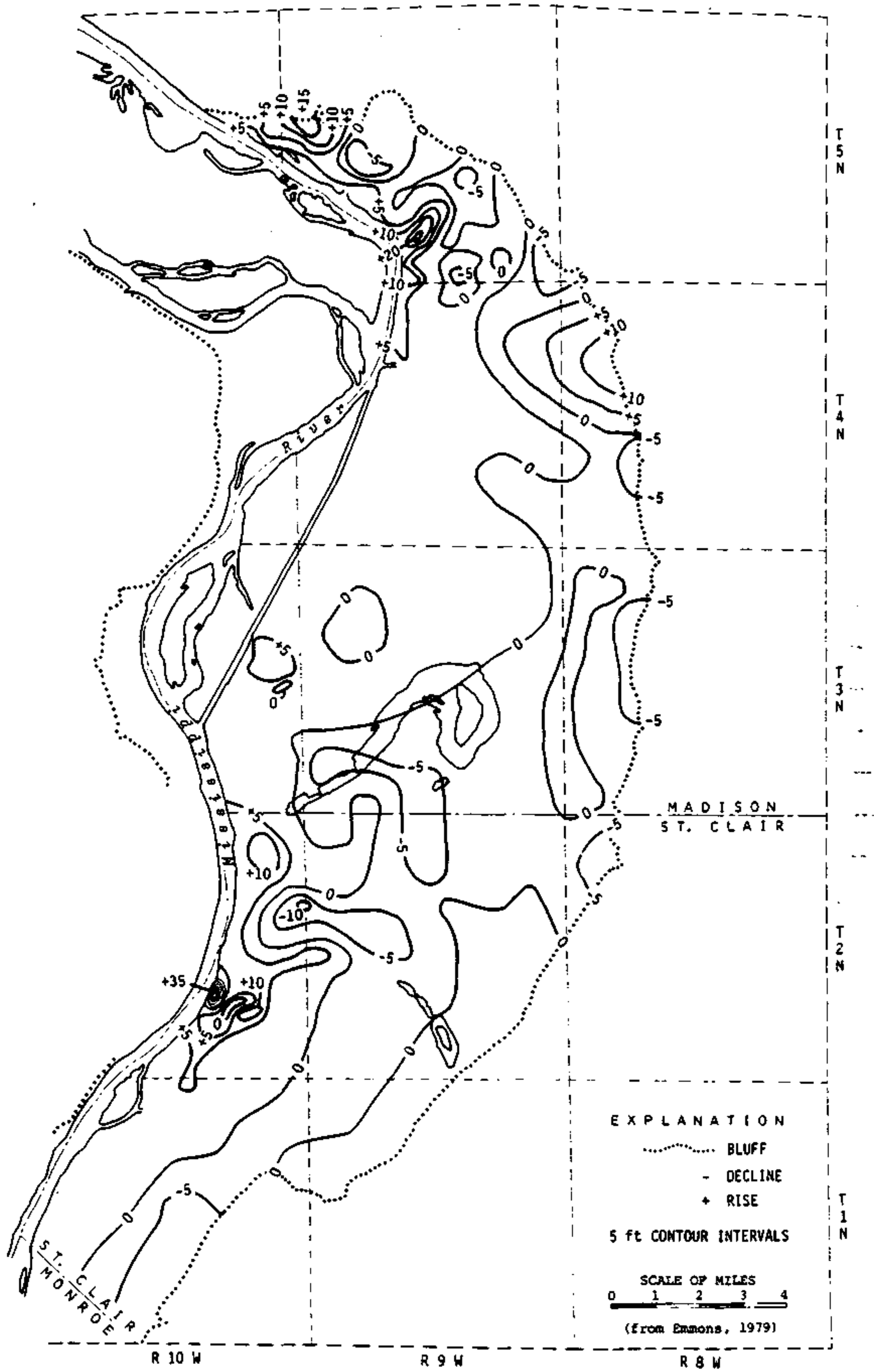

Figure 19. Changes in piezometric surface from November 1971 to November 1977

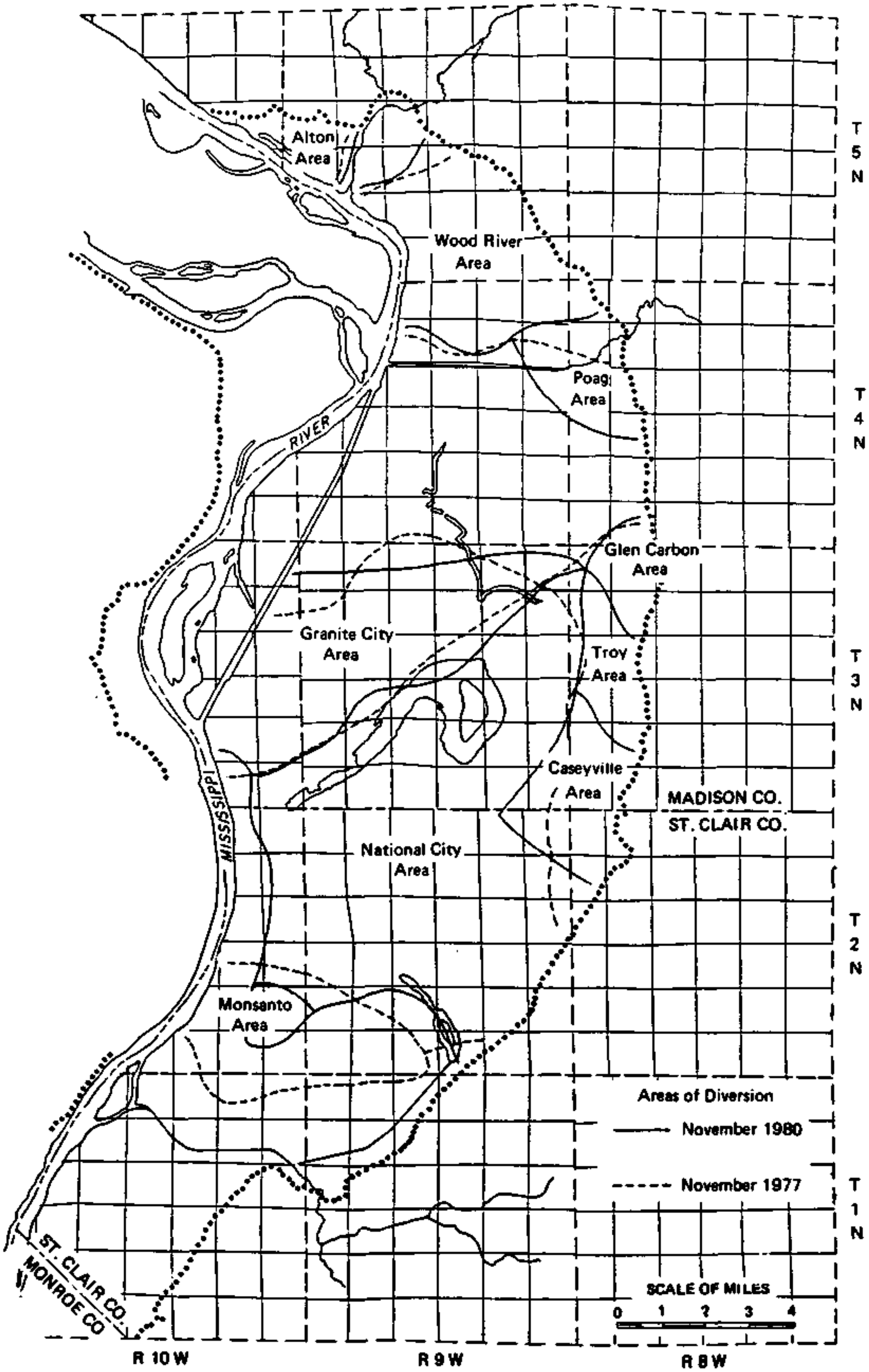

Figure 20. Approximate areas of diversion for November 1977 and November 1980

Table 3. Areas of Diversion

Pumping Center	Diversion Area (square miles) 1971	1977	1980
Alton	3.3	2.4	2.9
Wood River	23.7	16.3	15.7
Granite City	15.7	18.8	20.9
National City	25.9	55.0	51.5
Monsanto	17.3	11.7	1.5
Poag	-	-	4.6
Caseyville	6.0*	14.3*	7.4
Troy	-	-	3.8
Glen Carbon	-	-	2.9

*Represents Caseyville, Troy, and Glen Carbon

River the reduction (0.6 sq. mi.) is attributed to the shift in pumpage distribution toward the Mississippi River. The decrease of 3.5 square miles at National City can be attributed to the presence of the ground-water divide between the river and the pumping center. Other changes are considered to be insignificant.

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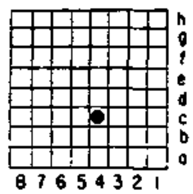
APPENDIX

The well-numbering system used in this report is based on the location of the well, and uses the township, range, and section for identification. The well number consists of five parts: county abbreviation, township, range, section, and coordinate within the section. Sections are divided into rows of 1/8-mile squares. Each 1/8-mile square contains 10 acres and corresponds to a quarter of a quarter of a quarter section. A normal section of 1 square mile contains 8 rows of 1/8-mile squares; an odd-sized section contains more or fewer rows. Rows are numbered from east to west and lettered from south to north as shown in the diagram.



St. Clair **County**

T2N, R10W

sec. **23**

The number of the well shown above is STC 2N10W-23.4c. Where there is more than one well in a 10-acre square they are identified by arabic numbers after the lower case letter in the well number. Any number assigned to the well by the owner is shown in parentheses after the location well number. The abbreviations for counties discussed in this report are:

Madison	MAD	Monroe	MON	St. Clair	STC

There are parts of the East St. Louis area where section lines have not been surveyed. For convenience in locating observation wells, normal-section lines were assumed to exist in areas not surveyed.

Water Level Data for Wells

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 5N10W-				
13.1a		402.58	399.89	-2.69
13.1b			397.72	
13.2a	396.73		399.06	
13.4c1	384.07			
13.4c3		393.63	392.03	-1.60
13.4c7			390.78	
13.5c	398.64	405.84	400.06	-5.78
13.6d	399.69		400.81	
24.1h	397.04	408.29	399.00	-9.29
MAD 5N9W-				
18.3c		388.68	393.51	+4.83
18.4b	364.10			
18.5C1			393.30	
18.5C2			394.02	
18.5c			397.30	
18.6c		387.38	390.30	+2.92
19.3c	400.49	406.89	401.02	-5.87
19.4h	386.50	395.19	396.33	+1.14
19.6e	399.82	405.32	402.86	-2.46
19.7f	399.26	405.06	400.12	-4.94
19.8g	398.81	405.05	399.59	-5.46
20.2e		398.60		
20.4h1			402.0	
20.4h2	408.0		404.0	
20.4h3		398.16	399.0	+0.84
20.5a	402.04		A	
20.8g2	398.73			
21.5c	404.48	404.11	404.88	+0.77
22.2c2		388.86	A	
22.2c3		389.80	A	
22.2c6		381.22	391.46	+10.22
22.2c7		391.87	392.13	+0.26
22.2c8	396.85		392.38	
22.2c9	396.85		391.52	
22.2c10			392.60	
22.4e		401.66	A	
26.7f			396.12	
26.8d		387.31	393.84	+6.53
26.8d			396.21	
26.8e		388.39	A	
26.8g1		394.03	398.61	+4.58
26.8g2	394.11		397.25	

Water Level Data (Continued)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 5N9W-(Cont'd)				
27.1b1	388.52		A	
27.1b4		388.80	A	
27.5a1	384.69	389.44	390.42	+0.98
27.5a2		389.88	391.23	+1.35
27.7a			387.43	
27.7e		386.03	388.95	+2.92
27.7e2		391.70	395.14	+3.44
27.7e3		391.86	394.61	+2.75
27.8a1			387.91	
27.8a2	371.23	387.77		
27.8b1	370.12	387.14	390.06	+2.92
27.8b2			399.08	
27.8b3		388.60	383.58	-5.02
27.8c			384.46	
27.8d1	376.34		A	
27.8d2		390.96		
28.1a1			390.27	
28.1a2	374.57			
28.1b1	376.96	389.20	386.94	-2.26
28.1b2			394.06	
28.2d	384.64	387.86	A	
28.4c	395.85		397.01	
28.7e1		394.60	398.75	+4.15
27.7e2		389.61		
27.8a2	371.23	387.77		
27.8a1	370.12	387.77		
27.8b2		388.60		
27.8d2		390.96		
28.8e			394.84	
28.8e1			393.45	
28.8e2			395.14	
28.8e5		400.64		
29.1e	399.00		397.68	
29.3h1	398.5			
29.3h2	397.50		398.91	
29.3h3	398.50		399.44	
29.4f			399.58	
29.4g	400.50	407.27	404.22	-3.05
29.5g	403.18		403.57	
29.5g			399.14	
33.5e1	390.44	400.44	393.0	-7.44
33.5e2	391.90	400.89		
33.5f		409.50	394.0	-15.50
34.3e1		392.38		
34.3e2			393.71	

Water Level Data (Continued)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 5N9W-(Cont'd)				
34.4a	408.00	394.71		
34.5a1		393.62		
34.6a1	382.49	407.76	395.37	-12.39
34.6a2	390.00	393.59	395.50	+1.91
34.6b	401.00			
34.7d1	391.00	394.54	394.79	+0.25
34.7d2		393.74		
35.5f	388.0	384.94		
35.5h	384.00	388.38	390.0	+1.62
35.6b	394.0	396.0	396.0	0.00
35.8h1	388.50	390.17	392.84	+2.67
35.8h3			393.08	
36.4c	415.10	408.73	409.77	+1.04
MAD 4N9W-				
1.2e			410.26	
1.7h	403.44	404.09	404.50	+0.41
2.3b	408.33	407.0	409.31	+2.31
3.2b			402.00	
3.6f	396.30	397.79	398.21	+0.42
4.2g3		405.80	396.07	-9.73
4.2g4	396.70		396.31	
4.2g5		407.05	403.14	-3.91
4.2f	399.62	400.05	397.99	-2.06
4.5f		406.42	396.19	-10.23
9.2b		405.30	400.87	-4.43
10.8e	399.83	402.70	402.30	-0.40
10.8h	401.44	405.18	402.82	-2.36
11.3b1			404.83	
11.3b2			405.30	
11.3b3			405.13	
11.5g			406.40	
12.4h		411.04	410.45	-0.59
12.4g	406.89		408.21	
13.1d5	400.16	409.50	407.49	-2.01
13.1d7		409.15	407.17	-1.98
14.8h			401.76	
16.2C1	404.55	407.03		
16.2C2		404.13	400.16	-3.97
20.3g	403.00	406.82	401.90	-4.92
21.5h		411.59	410.73	-0.86
23.5d	407.57	407.87	406.07	-1.80
23.5f		402.85		
23.8e		404.22		
24.3c		404.37		

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 4N9W-(Cont'd)				
25.4e	408.70	409.06	407.76	-1.30
25.8a	419.43	409.90	408.16	-1.74
29.8d	401.68	404.93	400.99	-3.94
30.1b	401.77	404.75	400.93	-3.82
31.2h	401.46	404.61	400.91	-3.70
31.3g	400.97	403.56	399.08	-4.48
31.6a	401.42	403.97	400.78	-3.19
33.2d			406.93	
33.4b			407.80	
34.1b	404.32	407.87	406.60	-1.27
MAD 4N8W-				
17.8b1	412.00			
17.8b2	414.00	420.54	412.60	-7.94
18.4c		412.10	411.20	-0.90
19.4e	408.64	407.87		
20.4a	425.0	417.90	413.70	-4.20
20.5d		412.95		
29.4a		414.39	412.35	-2.04
32.3a		412.64	412.83	+0.19
32.4a		411.76	413.03	+1.27
MAD 3N10W-				
1.1c	401.30	403.39	400.92	-2.47
12.4f	400.04	403.05	400.77	-2.28
12.6c	399.41	402.05	400.62	-1.43 .
13.1b3	391.74			
13.1b4			395.88	
13.2b		395.41		
13.3a	386.88	395.37	398.42	+3.05
13.4a			393.94	
13.5a		394.52	A	
13.8g	396.12		399.63	
13.8g1		409.43	409.55	+0.12
14.1f	396.12	399.09	399.53	+0.44
14.3c	395.48	403.25	398.84	-4.41
14.4b	395.31	399.85	398.34	-1.51
22.1a	390.51	398.85	392.02	-6.83
22.1c	390.35	398.17		
23.6c	393.10	396.62	395.80	-0.82
23.7c	391.34	398.34	392.90	-5.44
24.1c1		399.37	391.60	-7.77
24.3h2		389.11	397.40	+8.29
24.5f	389.58	385.16	393.50	+8.34
24.6d	393.85	391.60	397.44	+5.84
24.7c	391.65	390.02	395.05	+5.03

Water Level Data (Continued)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 3N10W-(Cont'd)				
25.8h	392.15	391.89	390.27	-1.62
26.6b	392.57	396.34	393.88	-2.46
26.7d	391.82			
26.8e	391.98	397.02	393.53	-3.49
26.8h		398.92	392.72	-6.20
35.6f	393.15	396.63	390.47	-6.16
35.6h	392.87	396.31	392.50	-3.81
36.5g2		398.17	397.49	-0.68
MAD 3N9W-				
3.1a	406.35	407.76	405.29	-2.47
4.5e		406.44	406.66	+0.22
6.1b	404.26	403.84	405.22	+1.38
6.3c	402.62	403.47	401.77	-1.70
7.6d	401.73	402.23	398.55	-3.68
8.1d		405.80	405.47	-0.33
9.4c			400.38	
9.4e	403.99		A	
9.5h		404.10		
10.2a			405.82	
10.4b		406.17	405.25	-0.92
10.4g1		410.60		
10.4g2		406.40	406.47	+0.07
10.6c	407.47	409.60		
12.3g	410.84	414.60	409.72	-4.88
14.2c	405.44	404.18	402.01	-2.17
14.4a	406.57	404.33	404.55	+0.22
17.3a		404.95	404.90	-0.05
18.8a1		394.10	DRY	
18.8a2			399.00	
19.3g1		399.37	400.30	+0.93
19.3h	399.18	398.92	400.46	+1.54
23.5f		402.85	402.48	-0.37
23.8e		404.43	406.43	+2.00
24.3c		404.37		
24.4g	409.98	409.65	409.32	-0.33
25.5e			402.44	
25.5f	403.40	403.36	403.45	+0.09
25.8e	404.27	404.50		
29.1a		398.82	A	
30.6e	400.47	402.47	398.19	-4.28
32.3b	394.89			
32.6g	397.83	397.45	398.11	+0.66
35.3d		401.95	403.50	+1.59
36.1f	401.75	402.57		

Water Level Data (Continued)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
MAD 3N8W-				
5.2d	403.20	409.04	409.41	+0.37
5.2f2	412.09			
5.2f3	413.94		409.97	
5.4a1	408.81	406.07		
5.4a3			406.26	
5.5e		410.25	409.63	-0.62
5.6d2	411.91			
8.4g	406.82	405.35	404.90	-0.45
8.5g			402.33	
8.6h	409.30	410.78	410.88	+0.10
18.7e	408.77	408.13	407.99	-0.14
19.1f		407.54		
20.5a1	404.44	398.66	401.02	+2.36
20.5a2			399.98	
20.5a3			402.23	
20.5c		402.00	403.50	+1.50
20.7h		403.12	404.02	+0.90
20.8c	406.28	405.24	405.54	+0.30
30.7b	403.61	402.64	402.57	-0.07
31.1a			394.21	
31.2a	399.62	396.40	395.86	-0.54
32.8d		400.36	400.22	-0.14
STC 2N10W-				
1.2h		386.44	385.64	-0.80
1.3a1		385.79	383.36	-2.43
11.4e	390.11		382.70	
12.3g	381.51	390.29	387.45	-2.84
12.3h			384.20	
12.6g2		394.19	390.64	-3.55
12.6h1		395.81		
12.6h2			387.00	
23.3a3	398.31	402.40	399.32	
23.6f	385.98	394.19	386.80	-7.39
23.7a	383.75	392.07	388.70	-3.37
23.7b	383.51	394.24		
25.5d	392.33	395.83	396.24	+0.41
25.6e	391.05		392.64	
25.7b		394.66	395.79	+1.13
26.1g1	390.10	392.28	A	
26.4f		386.56	A	
26.5d2		392.46		
26.5d3		392.55	397.68	+5.13
26.8a3	388.51	390.54	397.88	+7.34
26.8g			388.73	

Water Level Data (Continued)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
STC 2N10W-(Cont'd)				
27.2h1	361.25	395.49	A	
33.1f	386.07	388.64	388.58	-0.06
34.5h	385.46	392.16	388.45	-3.71
34.7c	387.28	391.92	389.34	-2.58
34.8b	387.63	391.20	390.02	-1.18
35.3e	391.93		396.40	
STC 2N9W-				
1.3b		400.96	403.43	+2.47
1.3g		404.78	401.86	-2.92
3.2g	404.02	402.78	403.93	+1.15
7.5e1	382.73	383.26	383.85	+0.59
7.5e2	380.70		384.10	
7.6e1	381.00	383.77		
7.6e3			386.52	
10.5a	406.52	406.54	406.0	-0.54
11.4c	400.24	399.74	401.57	+1.83
12.5d	405.35	405.12	404.73	-0.39
13.7f	403.51	404.60	403.27	-1.33
14.6h		400.96	A	
15.5c	398.72	397.85	396.52	-1.33
15.5f			403.52	
16.7a		392.72	395.12	+2.40
17.2g	397.57	391.45	395.54	+4.09
19.7d	393.32	391.46	396.25	+4.79
19.8f1	389.06	395.00	390.06	-4.94
19.8f2			391.30	
23.1e		408.18	406.70	-1.49
24.6e	406.42	408.02	406.10	-1.92
26.7e		407.23	405.55	-1.68
28.3a	397.84	399.73	A	
29.8f	398.41	398.84	400.65	+1.81
33.1e			395.53	
34.4h	403.26	405.40	404.68	-0.72
STC 2N8W-				
6.1e		398.67	399.27	+0.60
6.5a			409.80	
6.5h		403.09	A	
7.2h3	396.12	401.70	A	
STC 1N10W-				
2.8e	399.49	404.84	A	
4.1g	389.12	391.80	388.41	-3.39
4.2e	388.72	391.58	388.48	-3.10

Water Level Data (Concluded)

Well number	Water-level elevation (feet above msl) Nov 1971	Nov 1977	Nov 1980	Water-level change (feet) Nov 1977 to Nov 1980
STC 1N10W-(Cont'd)				
4.3c	388.68	391.44	385.78	-5.66
4.7b	387.08	390.25	381.34	-8.91
8.2h	386.41	388.82	387.68	-1.14
8.5c	386.47	388.65	389.22	+0.57
8.7a	386.20	388.70	388.02	-0.68
9.1f	391.99	393.14	390.41	-2.73
9.2h	391.34	393.01	391.47	-1.54
9.4h	389.41	391.22		
10.1c	396.21	395.64	394.47	-1.17
10.4c	394.14	394.00	394.67	+0.67
12.5b	392.44	396.76	396.02	-0.74
13.3h	398.14	396.73	398.01	+1.28
16.2g	396.58	394.62	394.05	-0.57
17.1e	390.95	391.98	392.35	+0.37
17.5g			390.20	
17.8b	393.67	396.25	393.74	-2.51
19.6f	385.57	387.09		
20.5f		391.11	394.15	+3.04
20.6a			392.08	
21.1a	391.97	389.20		
21.4f	393.97	388.73	391.19	+2.46
30.6h	384.11	386.95	386.38	-0.57
STC 1N9W-				
4.5e	400.83	401.20	400.86	-0.34
8.8h	397.78	398.67	398.44	-0.23
MON 1N10W-				
30.8b	384.82	386.58	382.62	-3.96
31.4d	392.10	DRY		
31.7c		387.40	388.32	+0.92
32.5d		386.68	388.42	+1.74