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SUMMARY OF MONTHLY WATER-LEVEL DATA FOR THE SUPERCONDUCTING SUPER COLLIDER STUDY AREA IN ILLINOIS

by Adrian P. Visocky

Prepared for the
Illinois Department of Energy and Natural Resources

Champaign, Illinois
April 1990

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ABSTRACT

Monthly water-level measurements were made at 26 individual piezometers and nine nested piezometers finished in the Maquoketa, Galena, Platteville, and Ancell Groups in the Superconducting Super Collider (SSC) study area in northeastern Illinois. West-to-east flow gradients in individual units vary from 7.3 feet/mile to 23.6 feet/mile, while vertical head gradients of from 0.29 foot/foot to 2.75 feet/foot have been observed. The implications of these vertical gradients to estimates of recharge are discussed.

INTRODUCTION

In 1988, the Illinois State Water Survey published in its Circular 170 (Visocky and Schulmeister, 1988) a compilation of results of fieldwork conducted for the SSC siting study. The report included a description of the hydrogeology of the study area; a description and analysis of the potentiometric surfaces of the Prairie, Upper Bedrock, and Midwest Bedrock Aquigroups; an analysis of monthly water-level data collected from the SSC piezometric network; a report of an aquifer test conducted in wells finished in the Ancell Group; a water quality summary for the various bedrock units pertinent to the SSC study; and an assessment of current and projected ground-water pumpage in the study area. The data described in Circular 170 were for the period December 1984 through July 1987.

After the publication of Circular 170, water-level measurements continued in the piezometers through the spring of 1989. Most of these installations were abandoned and plugged by July 1, 1989, and only seven remain for future monitoring and research. This report is intended to update the monthly water-level data presented in Circular 170 and, in some instances, to revise the interpretations of those earlier data in light of the additional information.

Acknowledgments

This project was funded by the Illinois Department of Energy and Natural Resources. The author wishes to acknowledge the following individuals for their contributions.

The updating of information was conducted under the general supervision of Ellis W. Sanderson, Head of the Ground-Water Section at the State Water Survey, who also made a technical review of the report. Personnel from the Water Survey's Northern Field Office, under the direction of its head, William H. Baker, collected the monthly water-

level data and maintained the security and integrity of the piezometer installations. Word processing was done by Pamela Lovett. The graphs were plotted on the computer by the author and prepared for publication by John W. Brother, Jr.; and Gail Taylor edited the report.

DESCRIPTION OF SSC AREA AND PIEZOMETER NETWORK

Geology

The geology of the SSC study area has been described in Circular 170 (Visocky and Schulmeister, 1988) and in greater detail by Willman et al. (1975) and Kempton et al. (1985, 1987a, 1987b). The following brief description has been excerpted from the section on hydrogeology in Circular 170, which in turn was taken largely from the other reports listed above.

Glacial Drift

Glacially derived sediments of Quaternary age overlie an erosional topography on Paleozoic dolomites and shale. The drift thickness varies from 0 to greater than 400 feet, filling bedrock valleys in some places and supporting glacial landforms in others.

Bedrock

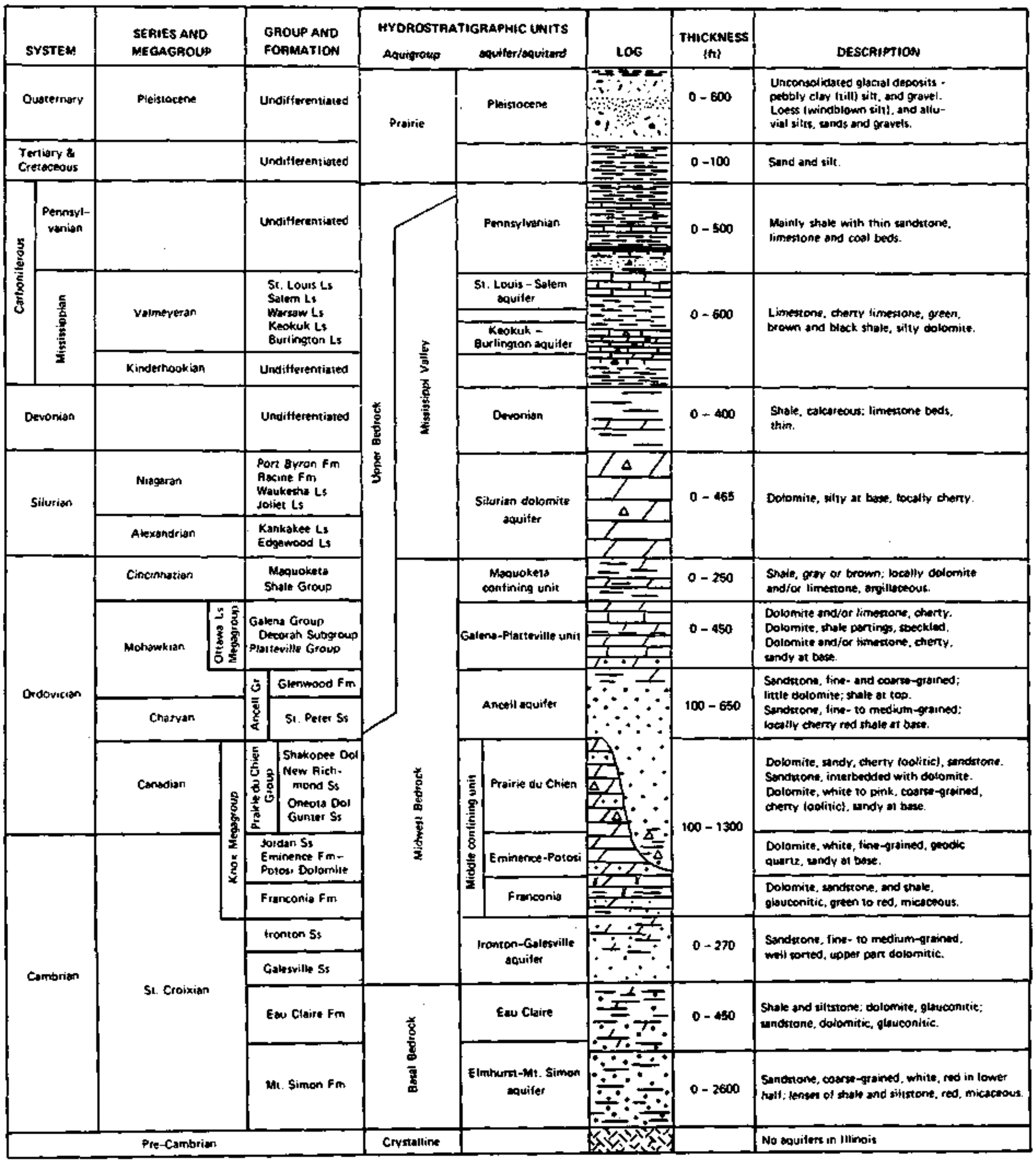
Bedrock above the Pre-Cambrian basement consists of Cambrian, Ordovician, and Silurian sedimentary strata, with a combined thickness of approximately 4,000 feet (figure 1). The rock units dip approximately 0.1 to 0.2 degree to the southeast, with the Ordovician Galena Group exposed at the bedrock surface in De Kalb and northwestern Kendall Counties. In western Kane County these dolomite units are overlain by interbedded shale and dolomite of the Ordovician Maquoketa Group, which in turn are overlain by dolomite formations of the Silurian System in eastern Kane and Du Page Counties.

Of particular interest to this report are the rocks of the Ordovician System, consisting of the Maquoketa (youngest), Galena, Platteville, Ancell, and Prairie du Chien (oldest) Groups.

Hydrology

The nomenclature and hydrologic division of the rock units used in this report are based on those suggested by Visocky et al. (1985) and are presented in figure 1. This terminology divides the hydrogeologic units into aquigroups, which in turn are subdivided into aquifers and confining units.

The uppermost aquigroup in the study area is the Prairie Aquigroup, composed of glacial drift and alluvium, whose lithologic variability supports local and intermediate flow systems. Recharge to these flow systems is primarily from local precipitation. Significant



SYSTEM	SERIES AND MEGAGROUP	GROUP AND FORMATION	HYDROSTRATIGRAPHIC UNITS Aquigroup	HYDROSTRATIGRAPHIC UNITS aquifer/aquitard	LOG	THICKNESS (ft)	DESCRIPTION
Quaternary	Pleistocene	Undifferentiated	Prairie	Pleistocene		0 - 600	Unconsolidated glacial deposits - pebbly clay (till) silt, and gravel. Loess (windblown silt), and alluvial silts, sands and gravels.
Tertiary & Cretaceous		Undifferentiated				0 -100	Sand and silt.
Carboniferous Pennsylvanian		Undifferentiated	Upper Bedrock Mississippi Valley	Pennsylvanian		0 - 500	Mainly shale with thin sandstone, limestone and coal beds.
Mississippian	Valmeyeran	St. Louis Ls Salem Ls Warsaw Ls Keokuk Ls Burlington Ls		St. Louis - Salem aquifer Keokuk - Burlington aquifer		0 - 600	Limestone, cherty limestone, green, brown and black shale, silty dolomite.
	Kinderhookian	Undifferentiated					
Devonian		Undifferentiated		Devonian		0 - 400	Shale, calcareous; limestone beds, thin.
Silurian	Niagaran	Port Byron Fm Racine Fm Waukesha Ls Joliet Ls		Silurian dolomite aquifer		0 - 465	Dolomite, silty at base, locally cherty.
	Alexandrian	Kankakee Ls Edgewood Ls					
Ordovician	Cincinnatian	Maquoketa Shale Group	Midwest Bedrock	Maquoketa confining unit		0 - 250	Shale, gray or brown; locally dolomite and/or limestone, argillaceous.
	Mohawkian Ottawa Ls Megagroup	Galena Group Decorah Subgroup Platteville Group		Galena-Platteville unit		0 - 450	Dolomite and/or limestone, cherty. Dolomite, shale partings, speckled. Dolomite and/or limestone, cherty, sandy at base.
		Ancell Gr Glenwood Fm		Ancell aquifer		100 - 650	Sandstone, fine- and coarse-grained; little dolomite; shale at top. Sandstone, fine- to medium-grained; locally cherty red shale at base.
	Chazyan	St. Peter Ss					
	Canadian Knox Megagroup	Prairie du Chien Group Shakopee Dol New Richmond Ss Oneota Dol Gunter Ss		Middle confining unit Prairie du Chien		100 - 1300	Dolomite, sandy, cherty (oolitic), sandstone. Sandstone, interbedded with dolomite. Dolomite, white to pink, coarse-grained, cherty (oolitic), sandy at base.
Cambrian	St. Croixian Knox Megagroup	Jordan Ss Eminence Fm–Potosi Dolomite		Eminence-Potosi			Dolomite, white, fine-grained, geodic quartz, sandy at base.
		Franconia Fm		Franconia			Dolomite, sandstone, and shale, glauconitic, green to red, micaceous.
		Ironton Ss		Ironton-Galesville aquifer		0 - 270	Sandstone, fine- to medium-grained, well sorted, upper part dolomitic.
		Galesville Ss					
		Eau Claire Fm	Basal Bedrock	Eau Claire		0 - 450	Shale and siltstone; dolomite, glauconitic; sandstone, dolomitic, glauconitic.
		Mt. Simon Fm		Elmhurst-Mt. Simon aquifer		0 - 2600	Sandstone, coarse-grained, white, red in lower half; lenses of shale and siltstone, red, micaceous.
Pre-Cambrian			Crystalline				No aquifers in Illinois

Note: The rock-stratigraphic and hydrostratigraphic-unit classifications follow the usage of the Illinois State Geological Survey.

Figure 1. Stratigraphy and hydrostratigraphy of the rocks in the study area (From Visocky et *al., 1985)*

sand and gravel deposits, often at the base of the drift, provide moderate-sized to large ground-water supplies to communities in the area, especially in the eastern part of Kane County. In areas where basal sands and gravels exist, there is often a hydraulic connection between the Prairie Aquigroup and an underlying water-bearing unit referred to as the **Upper Bedrock Aquigroup.**

In the upper portion of the bedrock, the hydrologic system is not affected by variations in bedrock surface lithology. Because the geologic strata are dipping to the east, the Silurian, the Maquoketa, and (in the western part of the study area) the Galena carbonates make up the uppermost bedrock in the study area. Extended periods of weathering and the release of overburden pressures at this exposed surface produced a fractured, relatively permeable zone, which extends laterally across geologic boundaries and varies with depth, depending on the nature and extent of fractures and incipient joints.

The depth of this weathered zone has been defined in Circular 170 as 50 feet, based on fracture frequency noted in pressure tests on the SSC wells. The network of interconnected fractures delineates the Upper Bedrock Aquigroup. This aquigroup is extensively developed for water supplies in the eastern part of the study area where Silurian dolomites constitute the bedrock surface. Recharge to the Upper Bedrock Aquigroup is from the overlying Prairie Aquigroup, whose variability in thickness and lithology creates local and intermediate flow systems within the Upper Bedrock Aquigroup.

In the eastern part of the study area, the Upper Bedrock Aquigroup also includes that portion of the Silurian dolomite existing below a depth of 50 feet. Visocky et al. (1985) refer to the Silurian, where it is unconfined by Devonian strata, as the Upper Bedrock Aquigroup.

The **Midwest Bedrock Aquigroup** is defined as including that portion of the bedrock that is not within the Upper Bedrock Aquigroup but is above the Eau Claire confining units of the Basal Bedrock Aquigroup (see figure 1). The hydrology of the Midwest Bedrock Aquigroup varies internally as a function of its different lithologic units. This report deals chiefly with two of these units, the Maquoketa and Galena-Platteville Units.

The **Basal Bedrock Aquigroup** includes the productive Elmhurst-Mt. Simon aquifer, with shales of the Eau Claire Formation acting as a confining unit. The Elmhurst-Mt. Simon rests on Pre-Cambrian crystalline rock, which has little hydrologic significance in the study area.

Piezometer Network

Test holes were drilled under the direction of the State Geological Survey for the purpose of providing hydrologic and geologic information about the site. During the fall of 1984, nine test holes were drilled, and seven (F-l, F-2, F-3, F-5, F-6, F-7, and F-9) were completed as "piezometers" (see discussion below), with 1-inch PVC casing installed and the bottom 5 feet slotted. During the spring of 1985, an additional eight boreholes were drilled and completed as piezometers (F-10 through F-17). In these wells the bottom 20 feet of casings were slotted. Since at that time the target elevation of the proposed SSC tunnel was 400 feet (MSL), all but one of the piezometers were finished at an approximate elevation of 400 feet (F-13 was finished in the Maquoketa Group at an elevation of 713 feet). During the summer of 1986, piezometers S-18 through S-22 were constructed, and that fall, numbers S-23, S-24, S-26, S-27, S-28, and S-30 were added. These 11 piezometers were constructed by using 1½-inch PVC casing with 10 feet of screen at the bottom. The bottom-hole elevations of these piezometers ranged from 274 to 349 feet, because modifications of the proposed tunnel design called for new target elevations.

The final series of observation wells for the SSC study was completed in early 1987 with the construction of three 8-inch-diameter experimental boreholes near Kaneland (SSC-1), Fermilab (SSC-2), and Big Rock (SSC-3). An aquifer test conducted at the Kaneland test well is described in Circular 170. Each well was completed with three nested piezometers installed within the borehole and was grouted so that the piezometers were open to three zones separated vertically by about 100 feet. These nested piezometers are numbered as follows: Kaneland--SSC-1-1, -2, and -3 (K-l, K-2, and K-3, for short); Fermilab--SSC-2-1, -2, and -3 (L-l, L-2, and L-3); and Big Rock--SSC-3-l, -2, and -3 (B-l, B-2, and B-3).

Table 1 summarizes the locations and construction features of the piezometers and indicates the geologic units in which the piezometers are set. The well-numbering system used in this report is described below. The geographical distribution of the piezometers is shown in figure 2.

Hydrologic data were obtained by the Water Survey through monthly measurements of water levels in these wells. It is recognized that a strict definition of the term "piezometer" refers to a well open to a discrete point. This term, however, has been extended to the SSC wells, because the open interval of each well is small compared to the thickness of the geologic unit penetrated. In this report the terms "piezometer" and "wells" are used interchangeably, since within the vertical scale of the geologic units, the distinction is not important. The geologic information resulting from the drilling is presented in detail by Curry et al. (1988), Graese et al. (1988), Kempton et al. (1987a,b), and Vaiden et al. (1988).

Through a pressure-testing technique known as packer testing, horizontal hydraulic conductivities were measured by the State Geological Survey along 20-foot intervals in each of the boreholes. Selected packer test results are presented here in a discussion of their implications to recharge estimates. Detailed results of those tests are discussed in the sources listed above.

Table 1. Locations and Construction Features of SSC Piezometers

Piezometer	Location	Measuring pt. elev. (MSL)	Piez. depth (ft)	Piez. elev. (ft) MSL	Diameter (in.)	Screen or slot length (ft)«	Geologic unit	Remarks
F-1	DUP39N9E-20.4b	739.5	347	392.5	1.0	5	Haquoketa	
F-2	DUP40N9E-17.1d	785.5	382	403.5	1.0	5	Galena	
F-3	KNE40N8E-2.6b	702.2	311	391.2	1.0	5	Galena	Plugged
F-5	DEK39N5E-1.8b	865.6	465	400.6	1.0	5	Platteville	Plugged
F-6	KEN37N8E-23.3f	711.9	305	406.9	1.0	5	Haquoketa	
F-7	KNE39N6E-20.1h	796.3	394	402.3	1.0	5	Galena	
F-9	DEK41N5E-10.1a	916.9	490	426.9	1.0	5	Platteville	Plugged
F-10	KNE38N8E-25.4f	706.4	338	368.4	1.0	20	Galena	
F-11	DEK38N5E-14.5C	731.3	350	381.3	1.0	20	Platteville	
F-12	KNE40N6E-10.5b	872.0	466	406.0	1.0	20	Platteville	
F-13	KNE40N6E-10.5b	870.0	157	713.0	1.0	20	Haquoketa	
F-14	DEK40N4E-16.1b	870.8	478	392.8	1.0	20	Platteville	
F-15	KNE4lN8E-30.8d	848.0	455	393.0	1.0	20	Galena	Plugged
F-16	KEN37N7E-3.6a	659.5	262	397.5	1.0	20	Galena	
F-17	DEK38N5E-27.5h	743.3	349	394.3	1.0	20	Platteville	Plugged
S-18	KEN37N8E-9.4a	656.0	355	301.0	1.5	10	Galena	
S-19	KEN37N7E-16.1H	646.0	297	349.0	1.5	10	Galena	
S-20	KEN37N8E-2.1f	717.0	416	301.0	1.5	10	Galena	
S-21	KEN37N8E-7.1h	648.0	304	344.0	1.5	10	Galena	
S-22	KNE38N6E-26.6d	663.0	371	292.0	1.5	10	Galena	
S-23	KNE39N6E-34.1f	754.0	474	280.0	1.5	10	Platteville	
S-24	KNE40N7E-22.6d	903.0	605	298.0	1.5	10	Platteville	
S-26	KNE39N6E-14.8c	815.0	503	312.0	1.5	10	Platteville	
S-27	KNE40N8E-20.2b	739.0	465	274.0	1.5	10	Platteville	
S-28	DUP38N9E-5.7a	731.0	435	296.0	1.5	10	Galena	
S-30	KNE40N6E-36.1C	883.0	545	338.0	1.5	10	Platteville	
Kanel and Nested Piezometers:								
SSC-1-1 <K-1)	KNE39N6E-3.4d	841.0	421	420.0	1.5	10	Galena	
SSC-1-2 (K-2)	KNE39N6E-3.4d	841.0	521	320.0	2.0	10	Platteville	
SSC-1-3 (K-3)	KNE39N6E-3.4d	841.0	640	201.0	1.5	10	Ancell	
Fermi lab Nested Piezometers;								
SSC-2-1 (L-1)	DUP39N9E-32.8f	753.0	317	436.0	1.5	10	Maquoketa	
SSC-2-2 (L-2)	0UP39N9E-32.8f	753.0	417	336.0	2.0	10	Galena	
SSC-2-3 (L-3)	DUP39N9E-32.8f	753.0	571	182.0	1.5	10	Platteville	
Big Rock Nested Piezometers;								
SSC-3-1 (B-1)	KNE38N6E-23.2H	688.0	277	411.0	1.5	10	Galena	
SSC-3-2 (B-2)	KNE38N6E-23.2h	688.0	377	311.0	2.0	10	Galena	
SSC-3-3 (B-3)	KNE38N6E-23.2H	688.0	477	211.0	1.5	10	Platteville	

*Numbers F-1 through F-17 were installed with slotted pipe, rather than screen.

Note: Revised from Circular 170 (Visocky end Schulmeister, 1988)

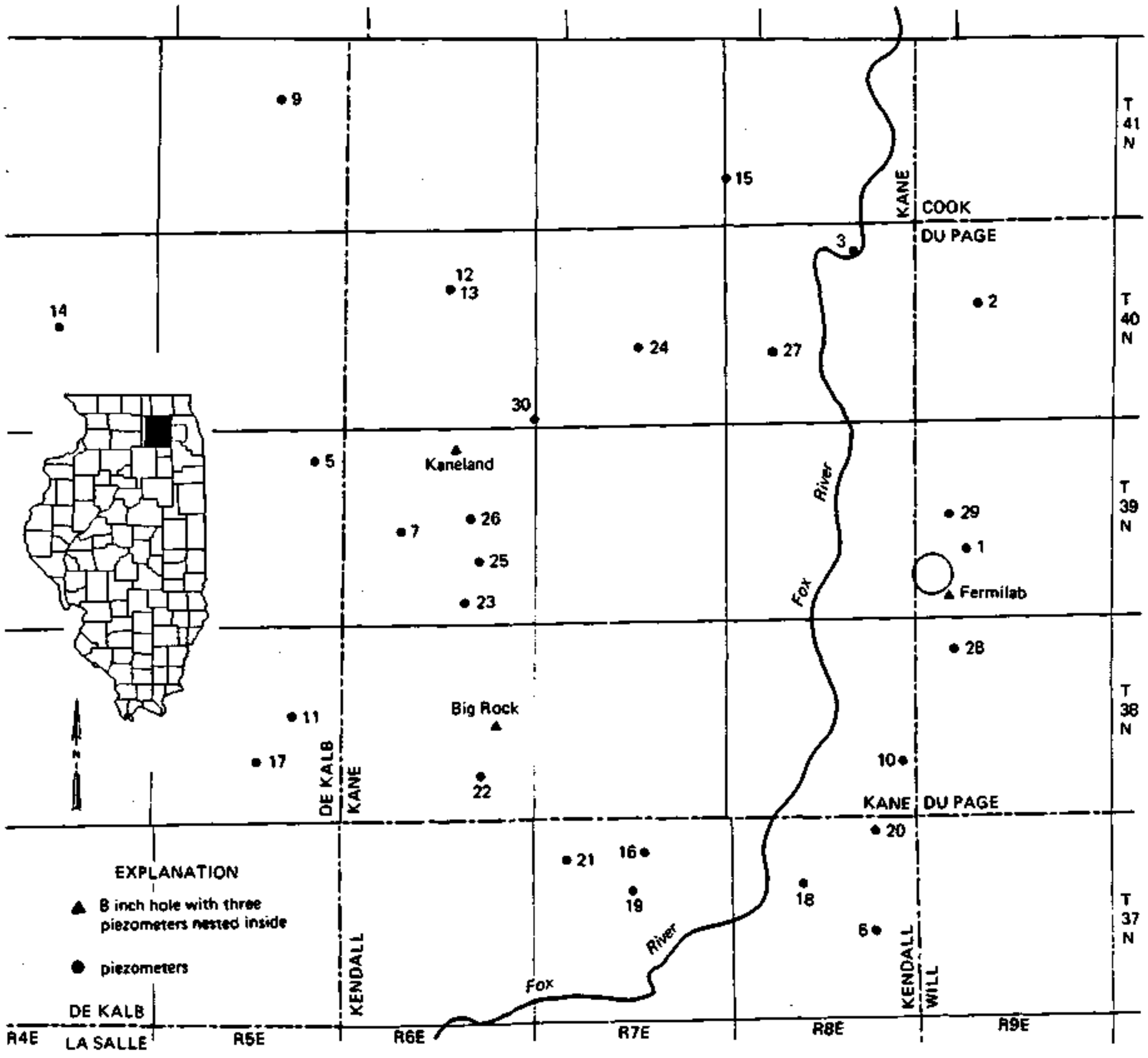
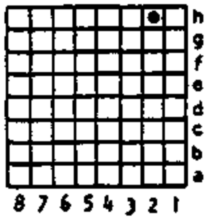


Figure 2. Locations of piezometers

Well-Numbering System

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 coordinates 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 one square mile contains eight 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 below.

The number of the well shown in
Sec. 25 at the right is as follows:
KNE 38N8E-25.2h



In this report, three-letter codes are used for the following counties:

De Kalb	DEK	Kane	KNE
Du Page	DUP	Kendall	KEN

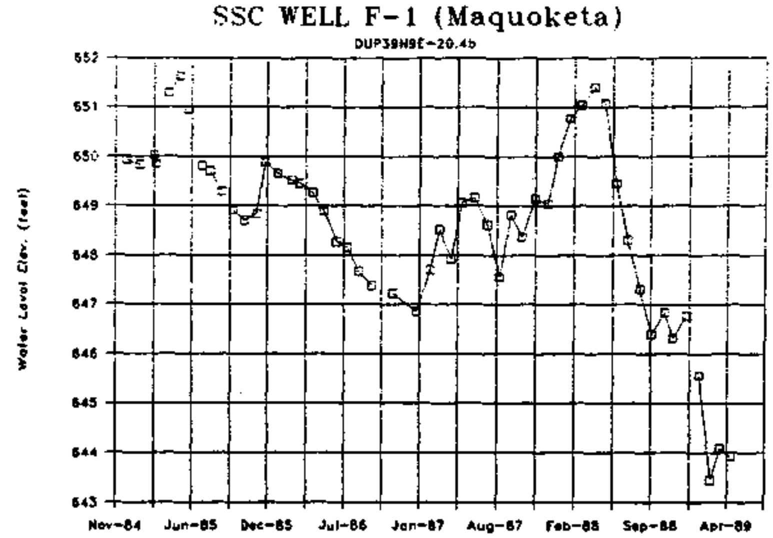
MONTHLY WATER-LEVEL DATA

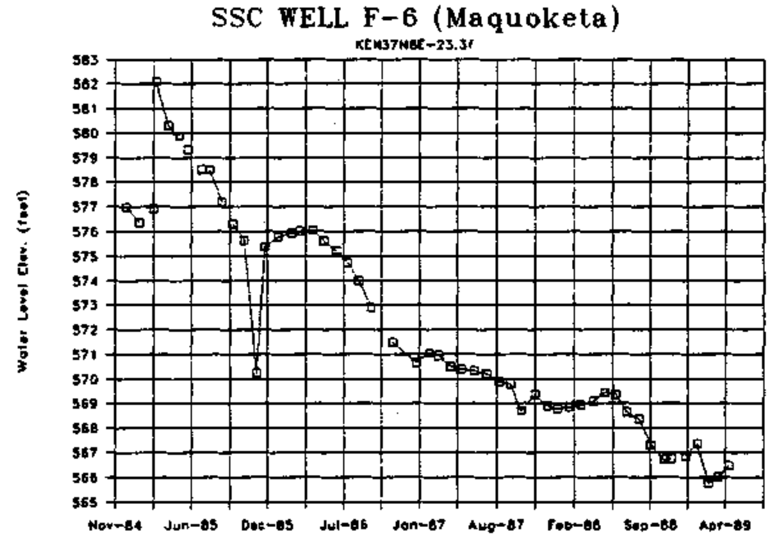
The first series of piezometers for the SSC study (F-l through F-3, F-5 through F-7, and F-9) was completed in the fall of 1984. Monthly water-level measurements were then made at these sites and at subsequently installed piezometers. By the fall of 1986, 26 piezometers had been completed. Five of the piezometers (F-3, F-5, F-9, F-15, and F-17) were eventually abandoned after various periods of monitoring, because they were remote from the redesigned SSC tunnel configuration. In addition to the individual piezometers, nine nested piezometers at three sites were also measured beginning in February 1987.

The individual piezometers are grouped for discussion purposes according to the geologic formation in which they are screened. The nested piezometers are treated separately, since they are open to various formations at one site. A complete tabulation of monthly water levels up to May 1989 is presented in the appendix.

Maquoketa Levels

Figure 3 shows water-level hydrographs for piezometers F-l, F-6, and F-13, which were completed in the Maquoketa Group. The cyclic patterns observed through July 1987 (Circular 170) continued through April 1989. Fluctuations correlate fairly well with precipitation data from Aurora and De Kalb, shown in figures 4 and 5, respectively.





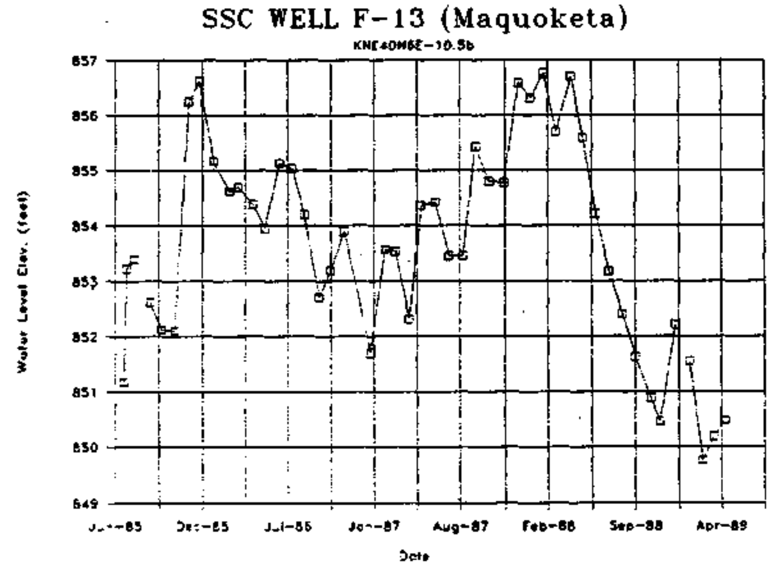
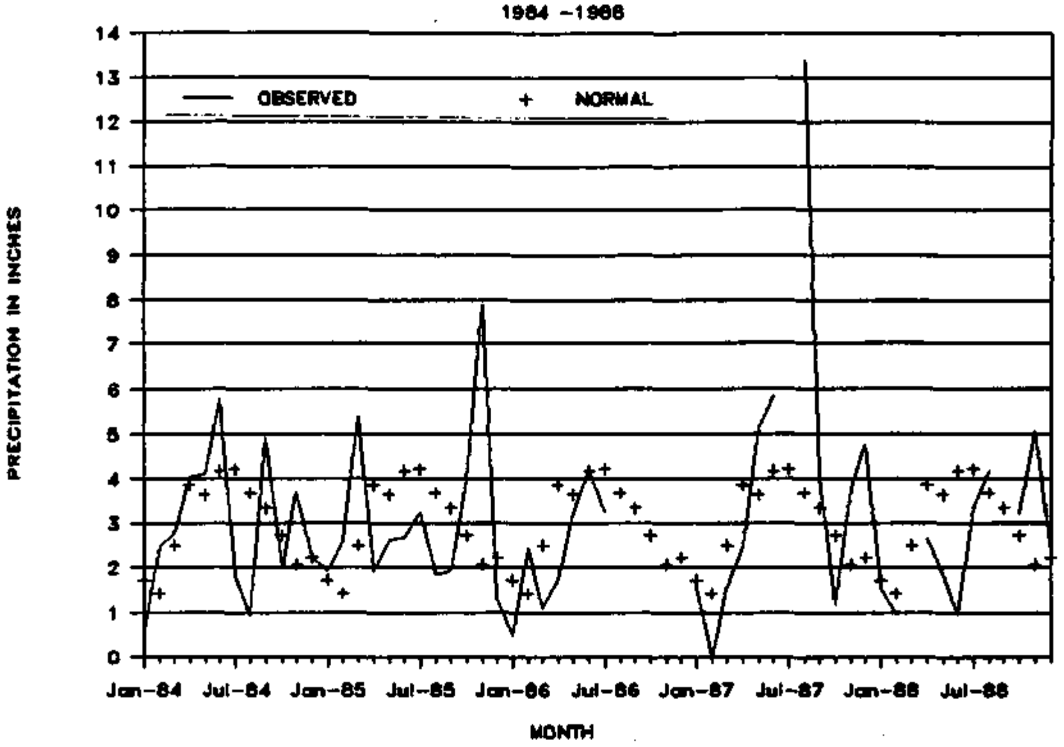


Figure 3. Hydrographs for Maquoketa piezometers F-1, F-6, and F-13

PRECIPITATION AT AURORA



DEPARTURE FROM NORMAL PRECIPITATION

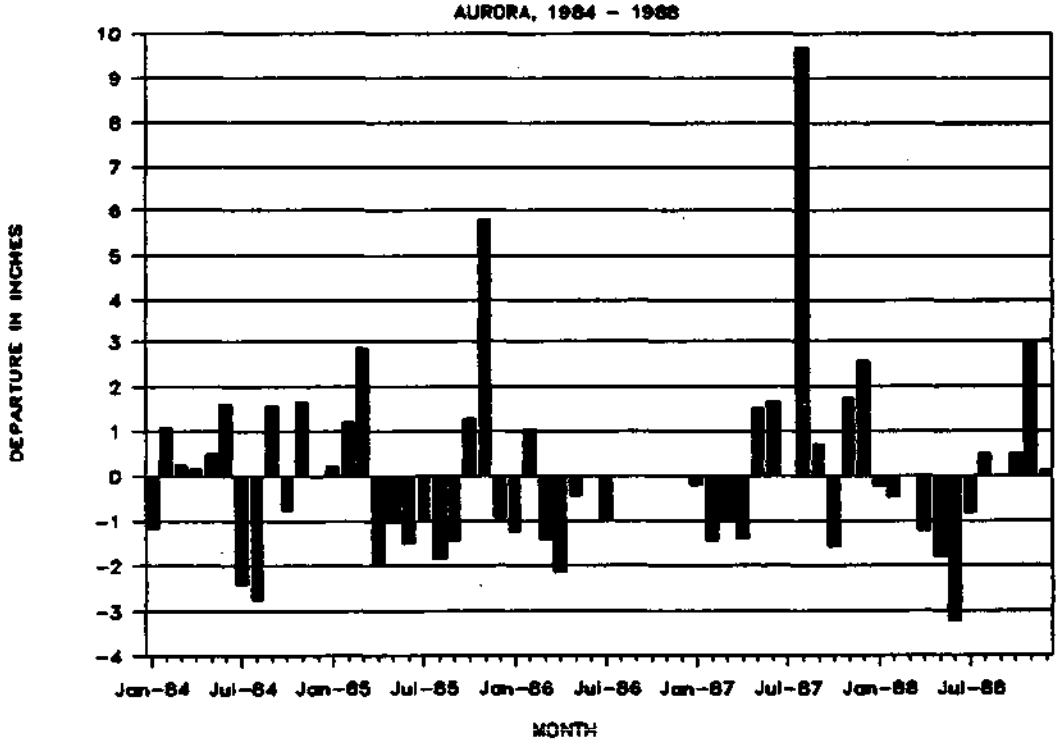
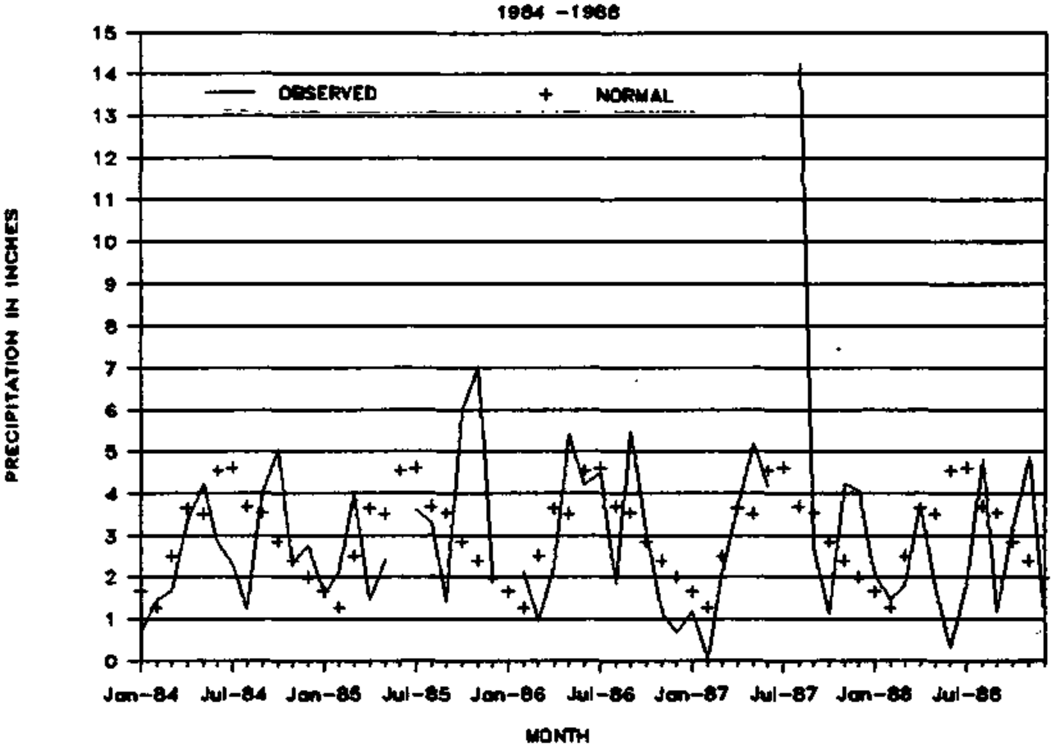


Figure 4. Precipitation data for Aurora, 1984-1988

PRECIPITATION AT DEKALB



DEPARTURE FROM NORMAL PRECIPITATION

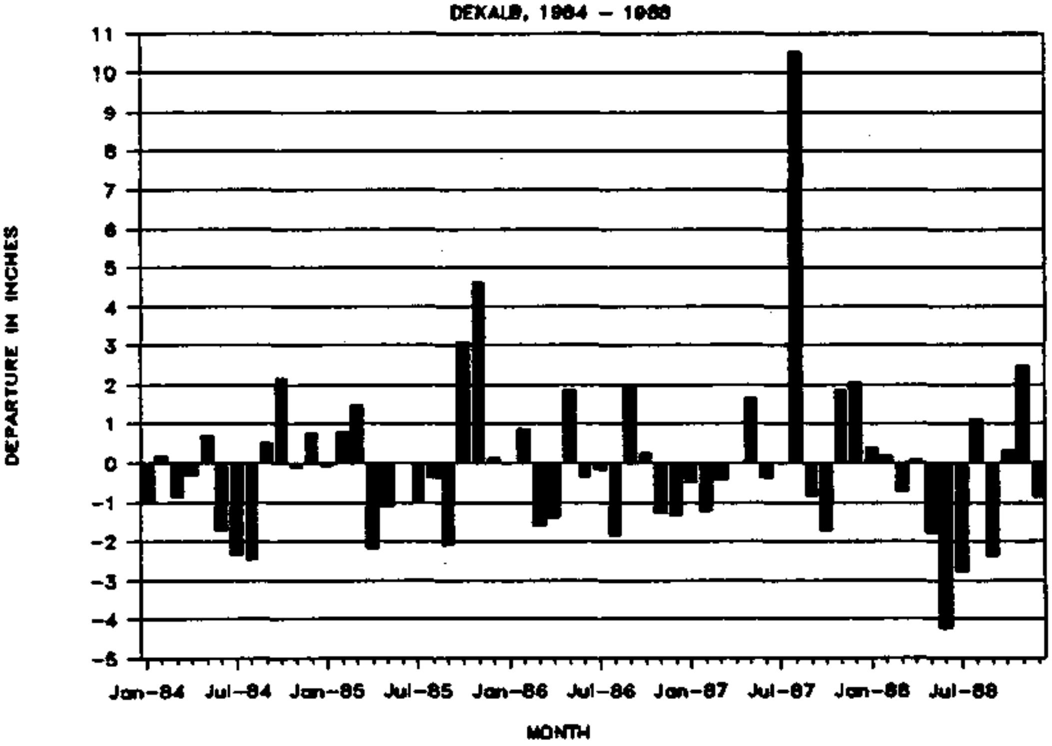


Figure 5. Precipitation data for De Kalb, 1984-1988

Seasonal declines and recoveries are most notable in F-l and F-13. At F-6, the cyclic nature is more subdued and is superposed on a downward trend that began in the spring of 1985. Water levels declined about 15 feet in that well between 1985 and 1989. The reason for this decline in water levels is unknown, but it is probably not attributable to deep pumpages in the area, in view of the fact that a nearby piezometer, S-20, finished in the Galena Group, did not exhibit a corresponding decline.

Figure 6 is a combined plot of all three hydrographs, showing that the relative stability of water levels at the three sites noted in Circular 170 has continued. Water levels at F-13 have averaged about 853 feet in elevation above mean sea level (MSL), about 205 feet above those at F-l and about 285 feet above those presently observed at F-6. These levels and the relative locations of the three piezometers suggest that the average southeasterly flow gradient in the Maquoketa Group is about 12 feet per mile. This gradient was incorrectly reported as 17 feet per mile in Circular 170.

Figure 7 shows the combined hydrographs for F-12 and F-13. Piezometer F-12 is located at the same site as F-13, near Virgil in Section 10, T40N, R6E, but is completed in the Platteville Group, 307 feet deeper than F-13. Water levels in the Maquoketa Group at the site have continued to average about 260 feet higher than those in the Platteville. The vertical gradient, calculated from the head difference and bottom-hole elevations of the wells, is about 0.84 foot per foot, essentially the same as reported in Circular 170.

Galena Levels

Piezometers F-2, F-3, F-7, F-10, F-15, and F-16 were installed in 1984-1985 and finished in the Galena Group. In 1986, additional Galena piezometers were constructed at sites S-18 through S-22 and S-28. Water-level monitoring at F-3, F-10, and F-15 was discontinued in the summer of 1986, as described in Circular 170. Hydrographs for F-10 and F-15 were presented in that report. Water levels at S-18 and S-28 fell below the bottoms of these wells soon after they were constructed.

Figure 8 shows hydrographs for the remaining Galena piezometers: F-2, F-7, F-16, and S-19 through S-22. Water-level measurements at S-22 were discontinued after September 1988 because of site inaccessibility. Water levels at F-2 were apparently perched initially, then slowly declined to near 440 feet in elevation by the summer of 1986. Since that time they have exhibited a gradual rise, punctuated by two sharp recovery events in the winter of 1987-1988. Levels rose in January 1988 by 24 feet from their December 1987 stages and rose again in March 1988 by 20 feet over the previous month. These sharp rises were verified in the field as authentic, and they call into question the integrity of the seals around the casing. All the wells are furnished with lockable caps to prevent vandalism, and these sharp rises were not duplicated elsewhere. Since March 1988, water levels at F-2 have gradually declined to their earlier, more normal stages.

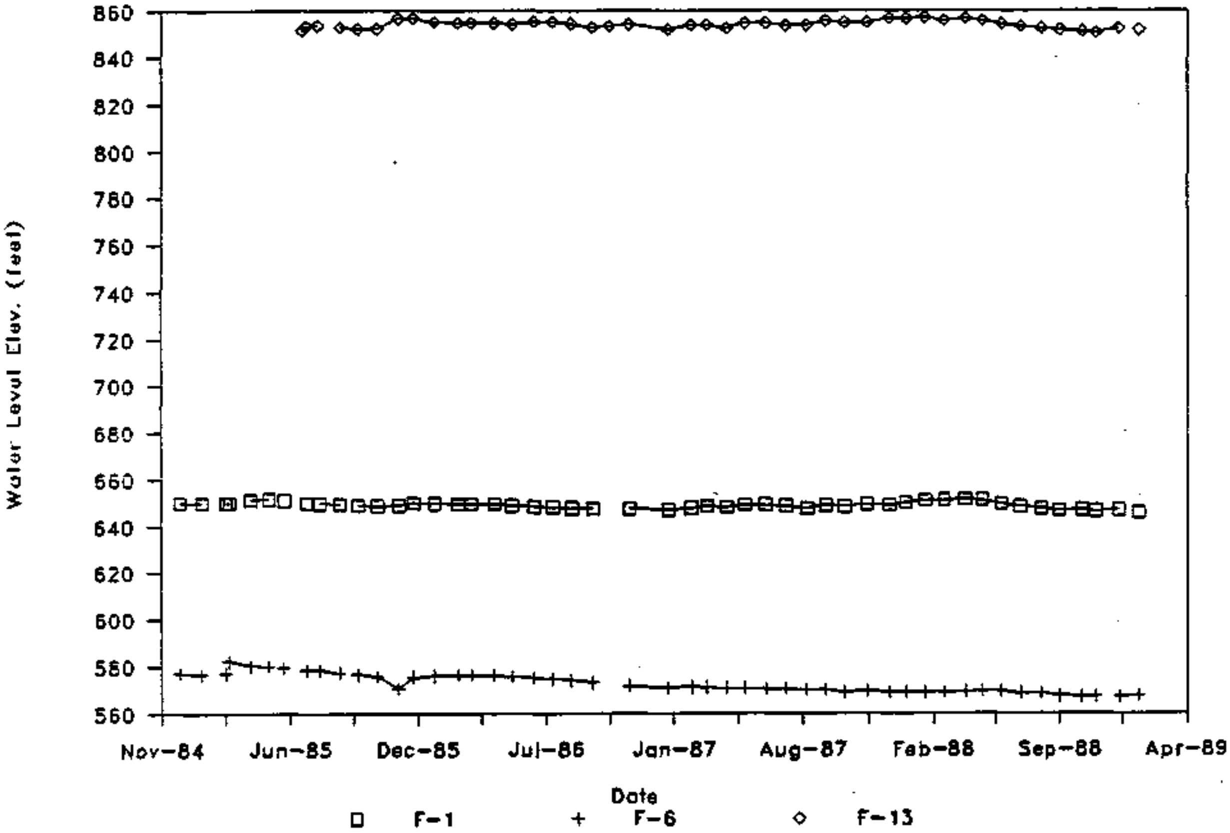


Figure 6. Comparison of hydrographs for F-1, F-6, and F-13

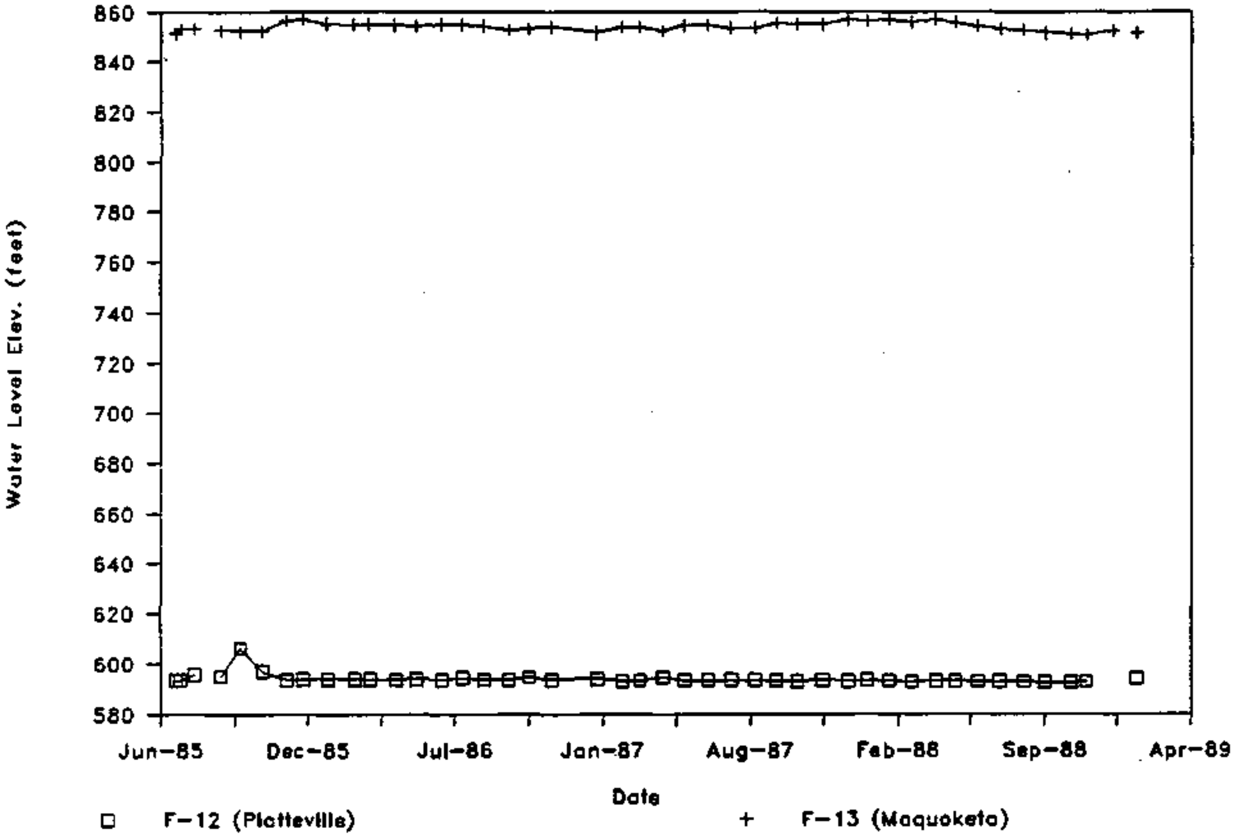
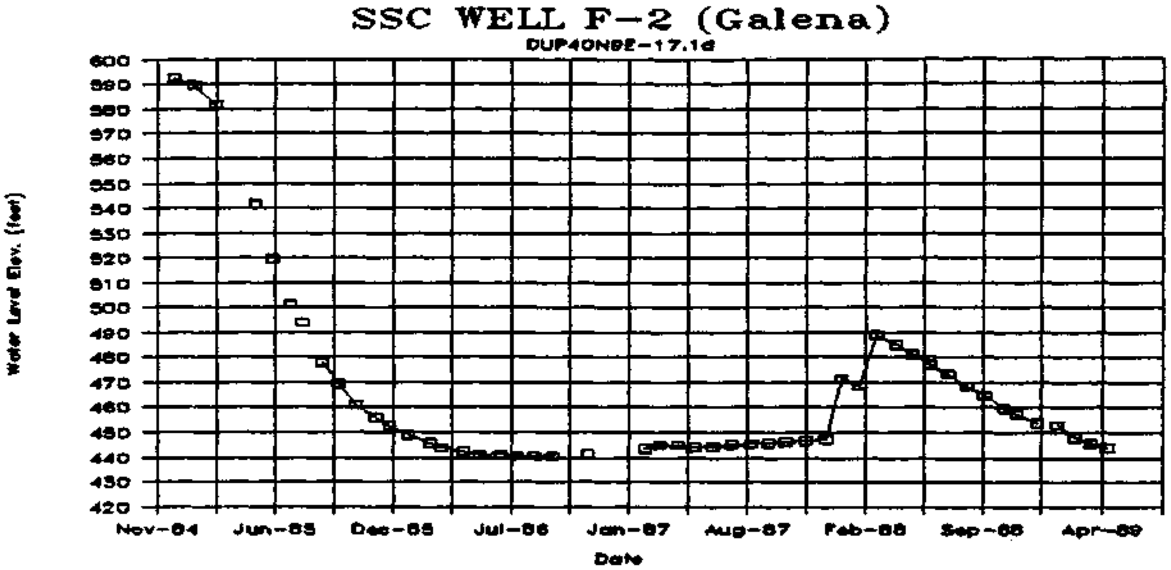
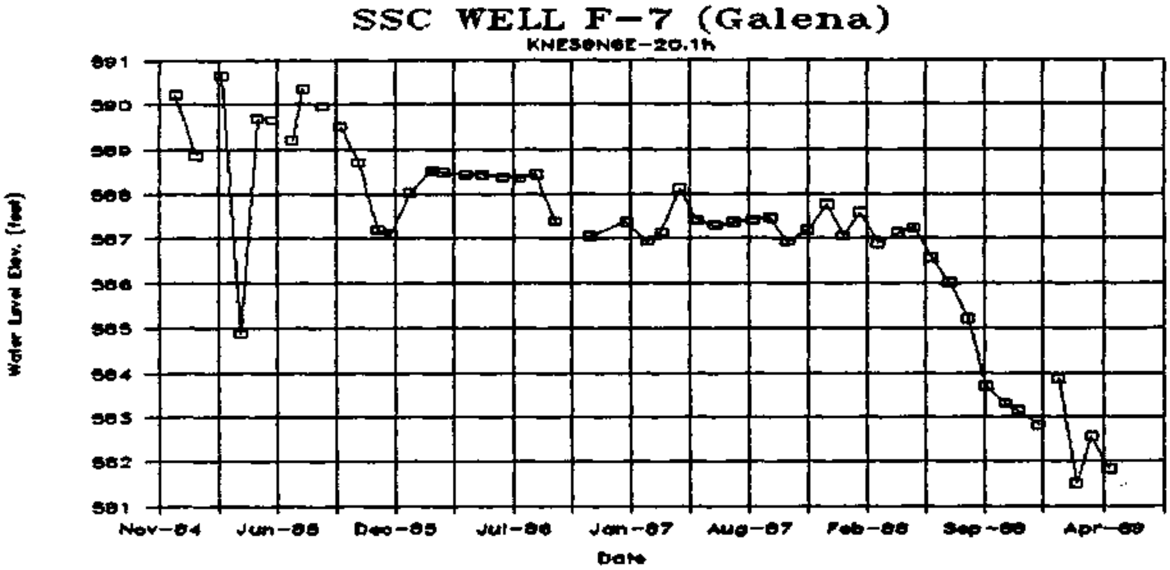


Figure 7. Comparison of Maquoketa and Platteville water levels at Virgil, Illinois





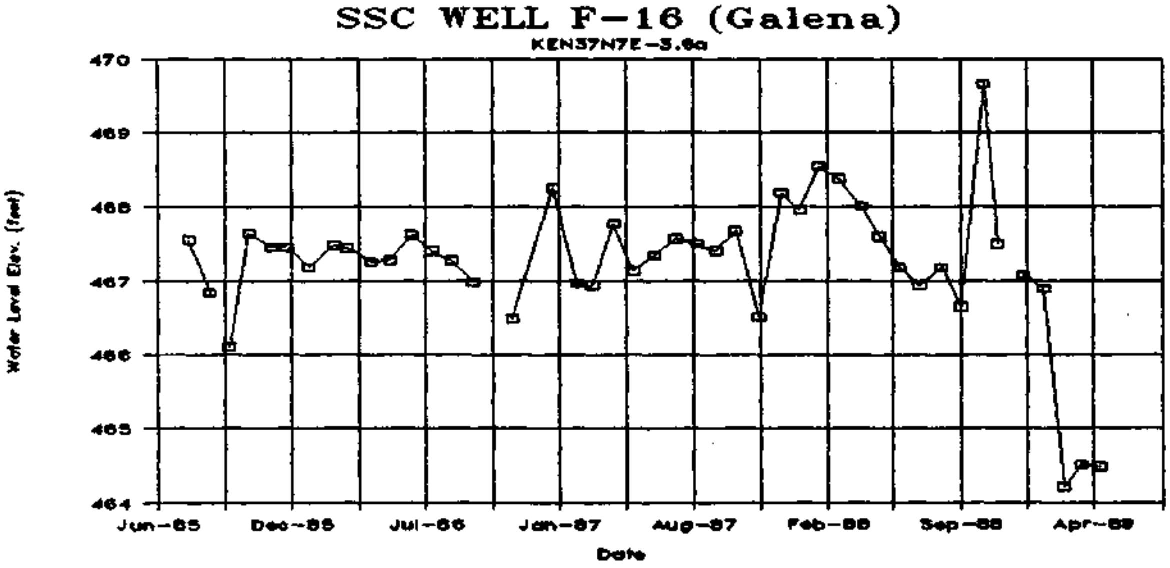
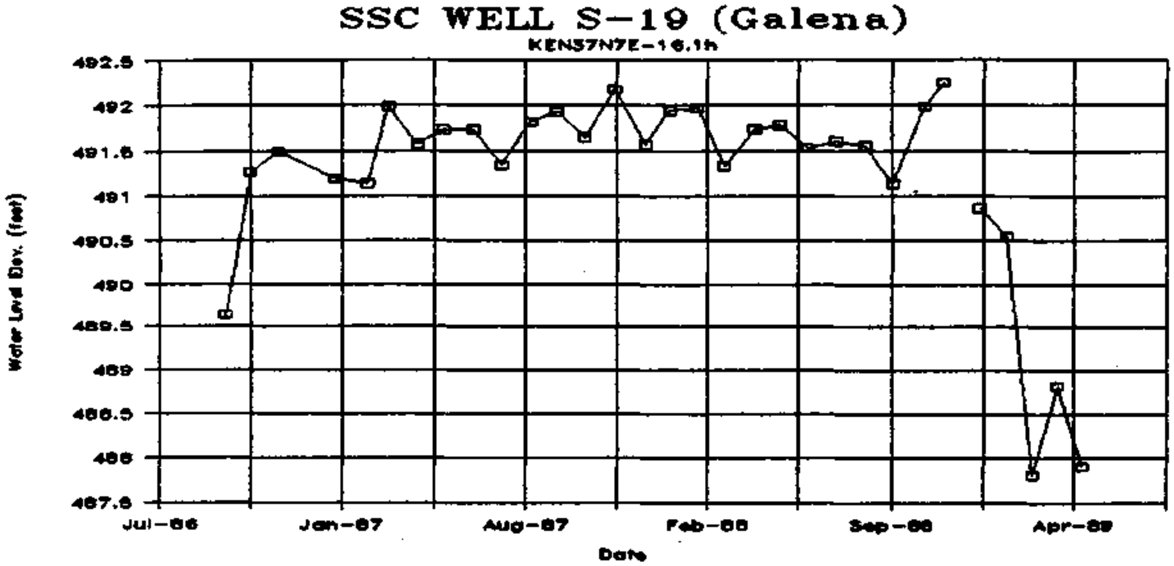


Figure *8. Hydrographs for F-2, F-7, F-16, and S-19 through S-22*



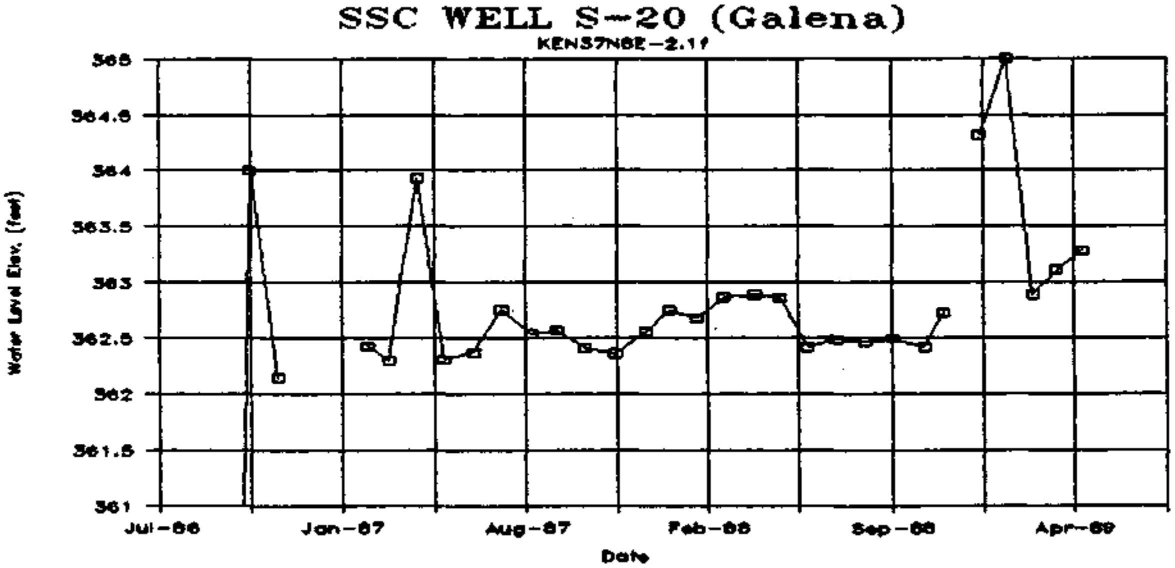
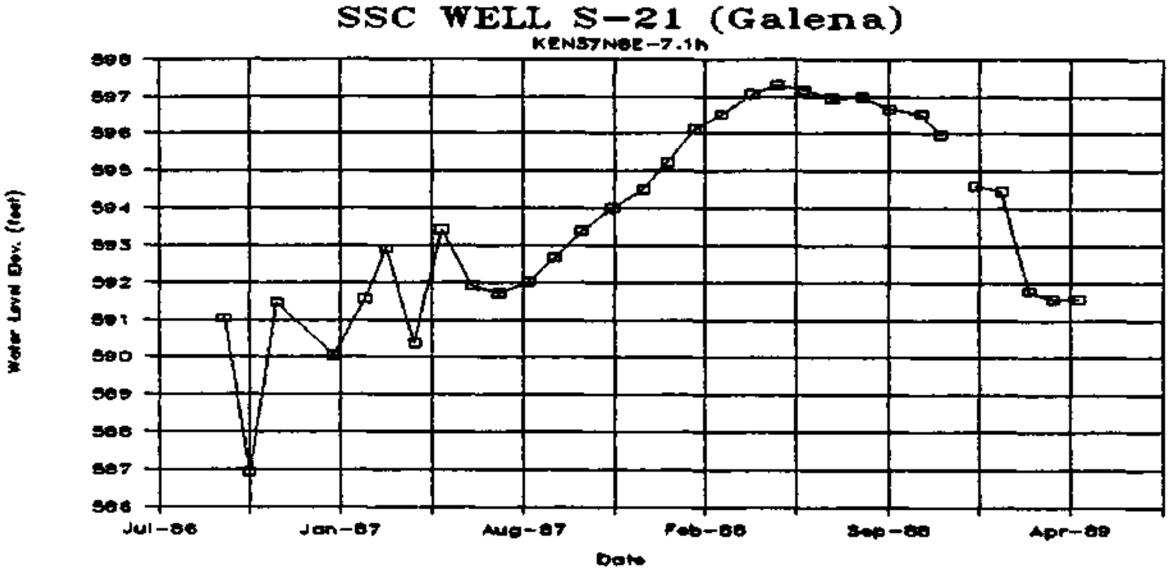


Figure 8. Continued



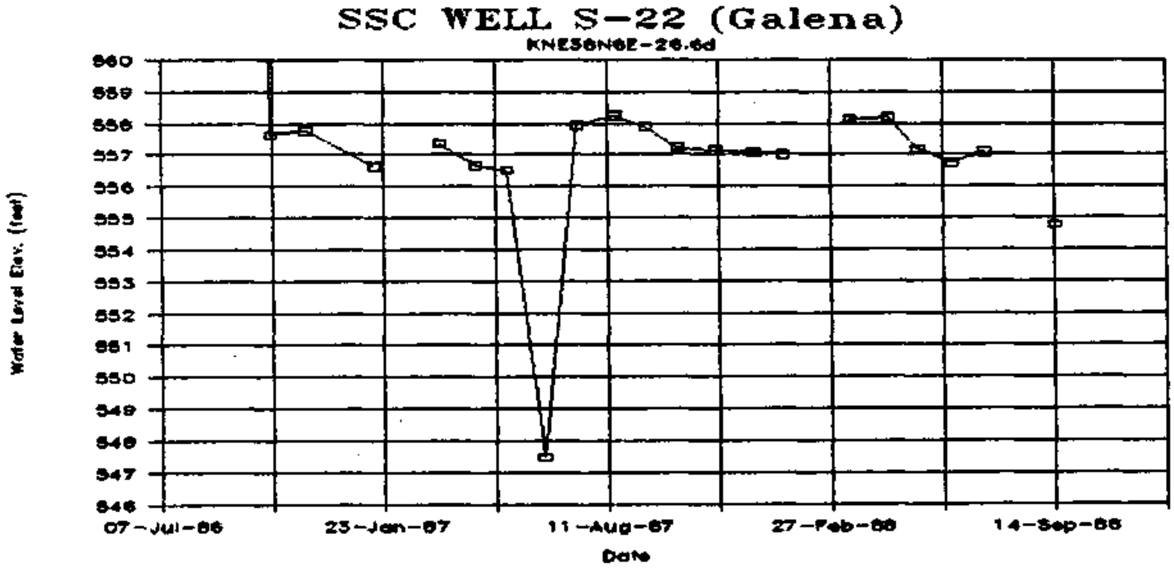


Figure 8. Concluded

Water levels at F-7 showed little change until 1988, when a sharp decline began, presumably in response to the statewide drought. At F-16, S-19, and S-22, water levels also remained quite stable; declines in levels in these wells began only in late summer 1988. At S-20, levels remained steady and actually rose slightly after the fall of 1988. It is possible that the apparent stability of levels in these piezometers was a sluggish response resulting from muddy conditions left after construction. Development of the piezometers after construction was minimal, and some of them could be at least partially plugged in their slotted or screened sections.

Water levels at S-21 exhibited a gradual recovery up through the spring of 1988 and began to decline slightly in the summer months. This decline in levels accelerated during the fall and winter. Again, this type of response could suggest initial partial clogging. The stages at this piezometer, however, are higher than any others in the vicinity. Current stages, for example, are more than 100 feet above those at S-19 and 128 feet above those at F-16, both of which are downgradient from S-21 but within about two miles proximity. Strangely, levels at S-21 are also about 35 feet higher than at S-22 and even about 10 feet higher than levels at both F-7 and B-l (the top Galena piezometer in the nested wells near Big Rock), even though these three wells are all upgradient from S-21. A plot of the hydrographs for S-21, F-7, and B-l, however, shows that these three water levels are in good agreement, or at least were in good agreement in spring 1989 (figure 9), and suggests that they are more representative of regional Galena water levels than are those at F-16, S-19, and S-22, as speculated above.

A combined plot of hydrographs for piezometers F-2, F-7, S-20, S-21, B-l, and L-2 (figure 10) shows that large head differences exist in a general west-to-east direction, but flow gradients vary from place to place. For example, water levels at F-7 stand 245 feet above those at the Galena piezometer (L-2) at Fermilab, and the head difference between S-21 and S-20 is currently 228 feet. The flow gradients for these two sets of piezometers, however, are 14.4 feet per mile and 23.6 feet per mile, respectively. Gradients from F-7 to F-2 and F-7 to S-20 are 7.3 feet per mile and 12.8 feet per mile, respectively. The latter gradient has held rather consistently throughout the period of record and agrees with the southeasterly gradient reported in Circular 170.

Platteville Levels

The periods of record for the 11 piezometers finished in the Platteville Group are divided into two groups, excluding the nested piezometers. F-5, F-9, F-ll, F-12, F-14, and F-17 were drilled in 1984 and 1985, while S-23, S-24, S-26, S-27, and S-30 were drilled in 1986 and were located close to the proposed SSC ring corridor (figure 2). F-5, F-9, and F-17 were plugged in August 1986, and the hydrographs for their period of record were presented in Circular 170.

Figure 11 shows the hydrographs for F-ll, F-12, and F-14. While the hydrograph for F-12 is relatively stable and does not exhibit clear seasonal cycles, those for F-ll and F-14 do exhibit such cycles. The

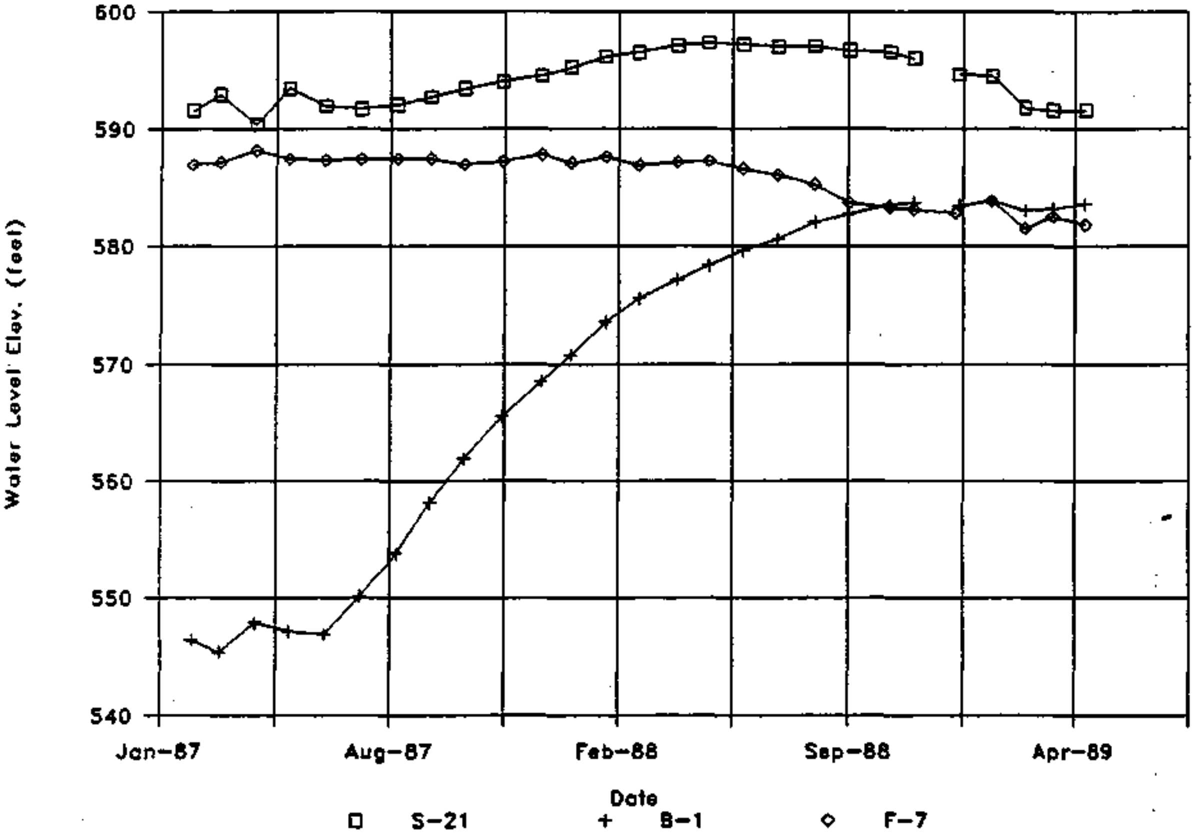


Figure 9. *Comparison of hydrographs for S-21, F-7, and B-1*

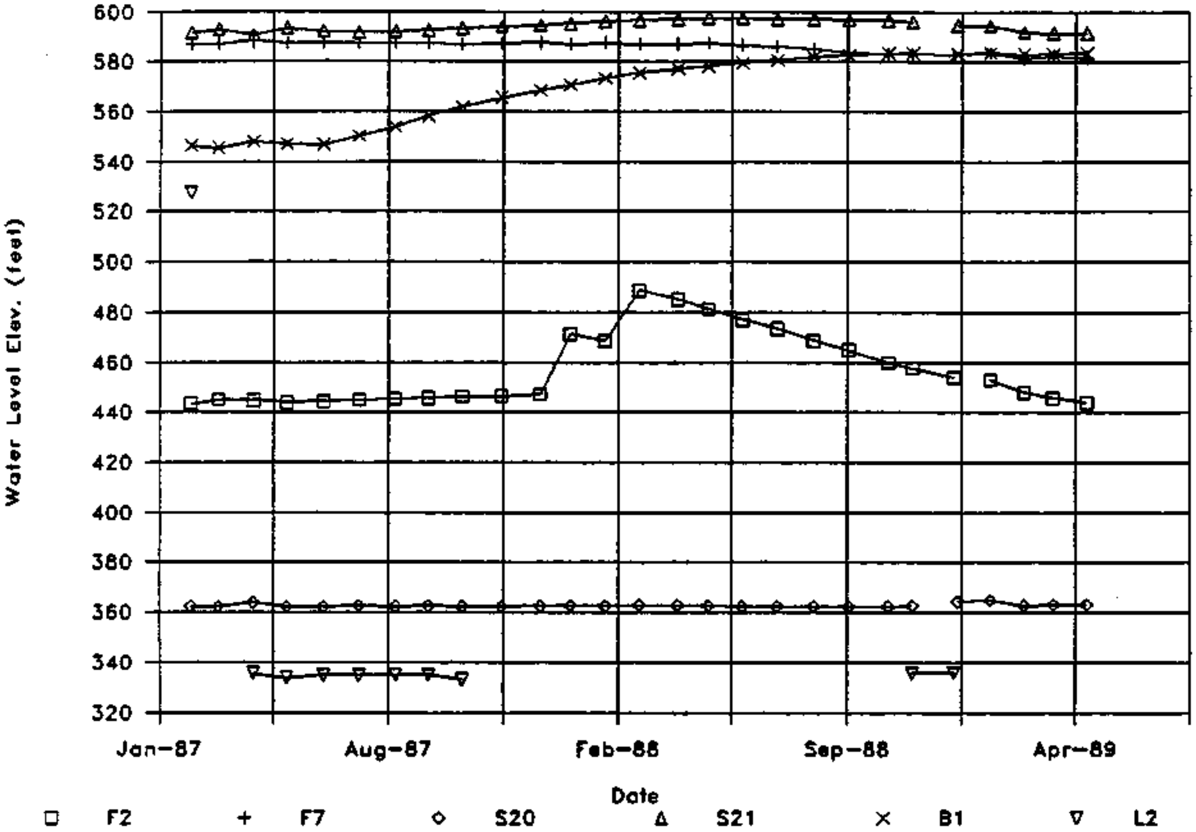
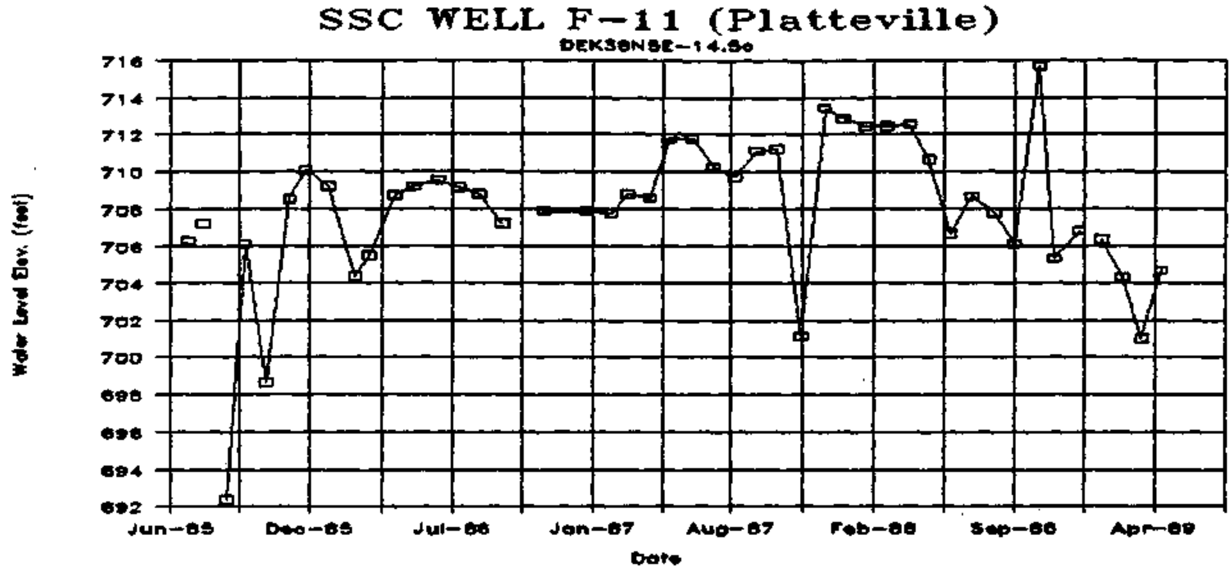
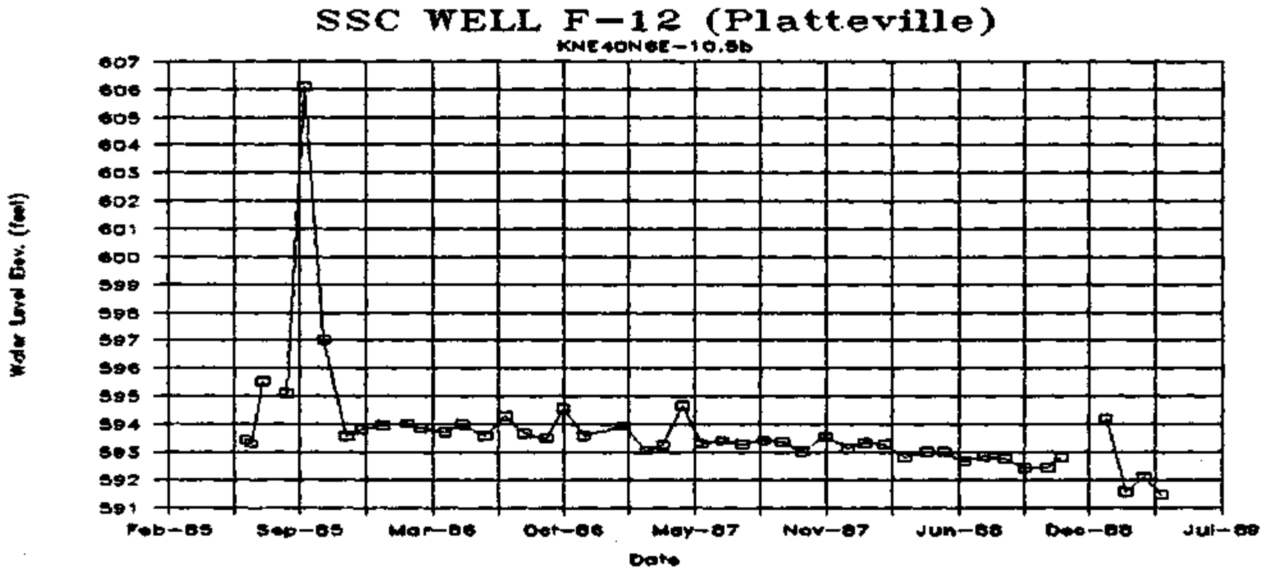


Figure 10. Comparison of hydrographs for six Galena wells (F-2, F-7, S-20, S-21, B-1, and L-2)





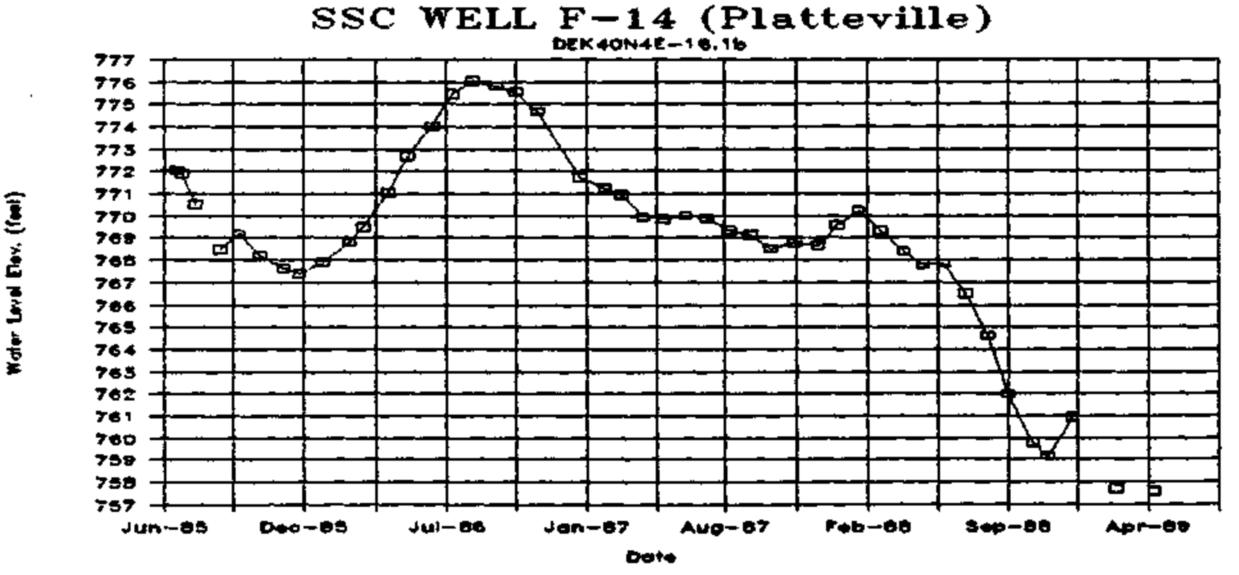


Figure 11. Hydrographs for F-11, F-12, and F-14

cyclic nature of the hydrographs is especially pronounced at F-14, and that hydrograph also seems to suggest a lag of one or two months in water-level response to precipitation at De Kalb (figure 5). In Circular 170 it was suggested that the more pronounced nature of seasonal cycles at F-14 occurs because the Maquoketa Group at the site is thin and recharge occurs more readily.

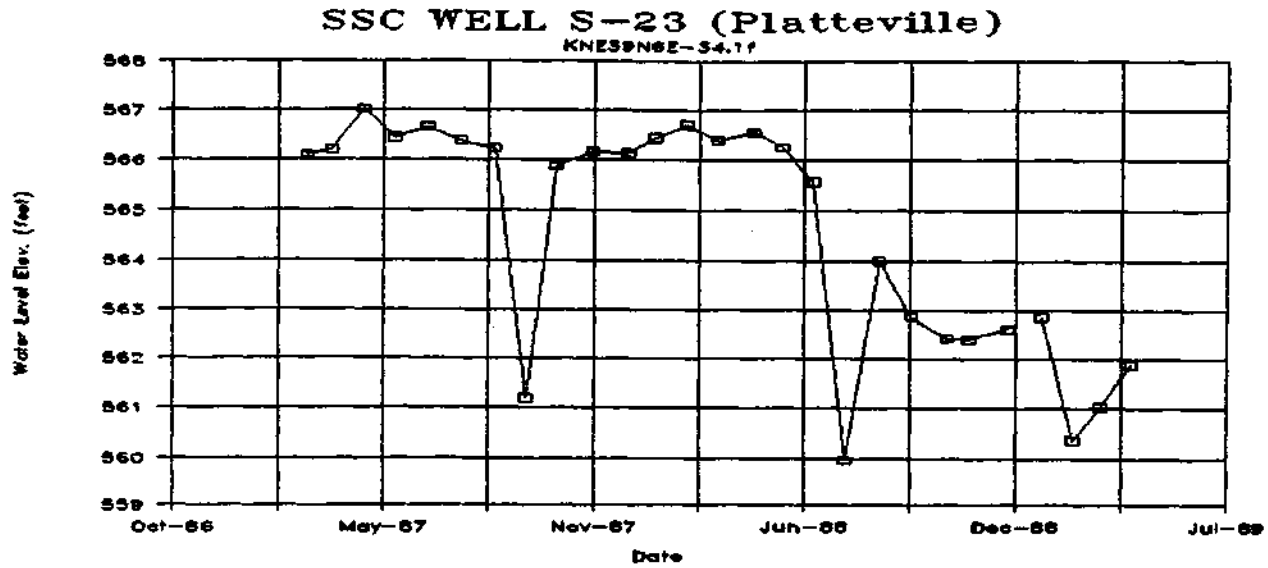
Figure 12 shows the hydrographs for piezometers S-23, S-24, S-26, S-27, and S-30, which were located around the western and northern arcs of the ring corridor, and L-3, the nested piezometer at Fermilab, finished in the Platteville Group. Water levels in most of these piezometers fluctuated only slightly over their periods of record and generally declined during the dry period that began in 1988. Water levels in L-3, on the other hand, have continued to decline since its completion. It is likely that this decline mirrors in a subdued manner the continuing decline of water levels in the underlying Ancell and deeper units resulting from heavy ground-water pumpage to the east. The intermittent large deviations from trends observed at S-23, S-24, and S-30 are believed to be spurious, representing measurement errors in all probability (this is also suggested as the cause for a similar large rise in levels at F-12 in September 1985).

Figure 13 shows the hydrographs, along a west-to-east profile, for F-14, F-12, S-24, and L-3. The profile illustrates the strong head gradient within the Platteville in an easterly direction. Water levels at F-14 stand at about 757 feet MSL, about 166 feet higher than levels at F-12, about 271 feet above those at S-24, and 468 feet higher than at L-3. The overall flow gradient from F-14 to L-3 is 16.5 feet/mile, while the gradient between the segments F-14 to F-12, F-12 to S-24, and S-24 to L-3 is 13.7 feet/mile, 17.6 feet/mile, and 16.3 feet/mile, respectively. The overall gradient from west to east agrees with the potentiometric surface for May 1987, presented in Circular 170.

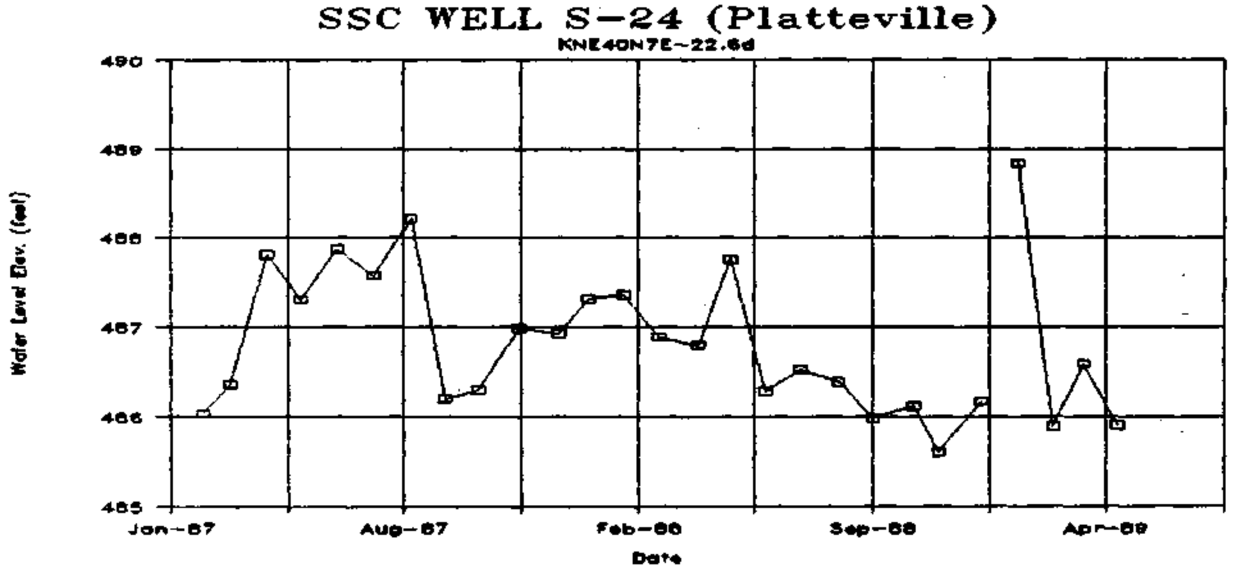
Nested Piezometers

In early 1987, three sets of nested piezometers were constructed near Kaneland (SSC-1), Fermilab (SSC-2), and Big Rock (SSC-3), as summarized in table 1. Each nest of piezometers was constructed by installing 1½- to 2-inch-diameter casing and screen inside an 8-inch borehole and grouting so that the piezometers were open to three zones separated vertically by about 100 feet. The bottom-hole elevations of the piezometers were approximately 400 feet, 300 feet, and 200 feet. At the Kaneland well, three major units were monitored: the Galena, Platteville, and Ancell Groups. At Fermilab, the units open to the piezometers were the Maquoketa, Galena, and Platteville Groups. At Big Rock, the upper two piezometers were set opposite the Galena, and the lower one opposite the Platteville. In Circular 170, the middle piezometer, SSC-3-2 (B-2, for short), was incorrectly reported as being open to the Platteville Group.

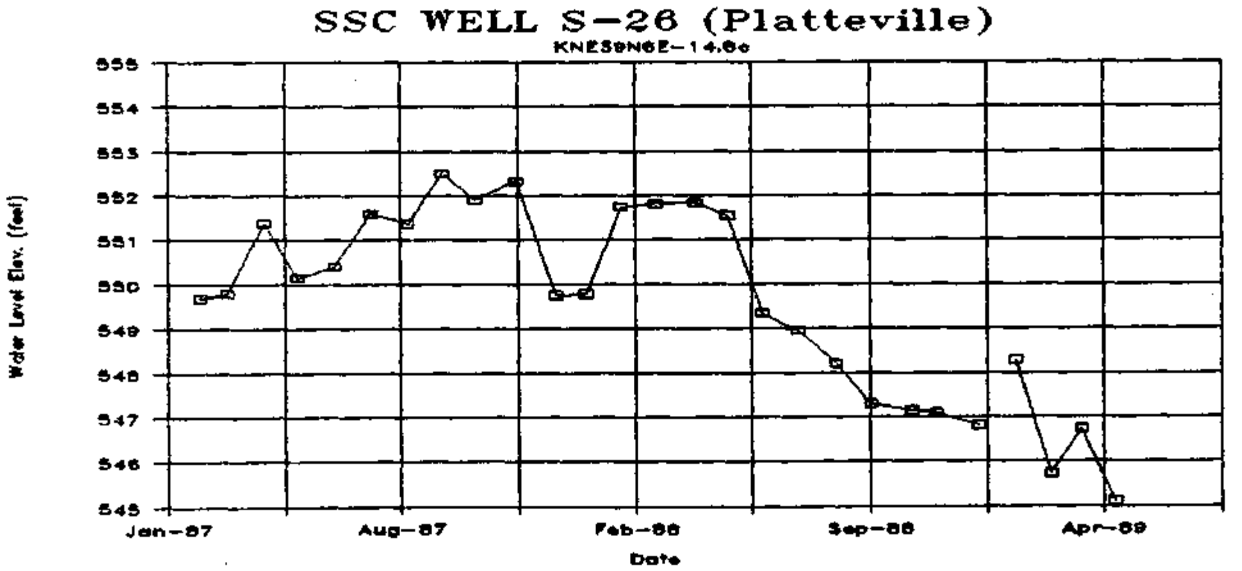
As described in Circular 170, the hydrographs of the Kaneland piezometers, SSC-1-1, -2, and -3 (K-l through K-3, for short), are virtually identical, even though the bottom-hole elevations of these


SSC WELL S-23 (Platteville)

KNE39N6E-34.1f

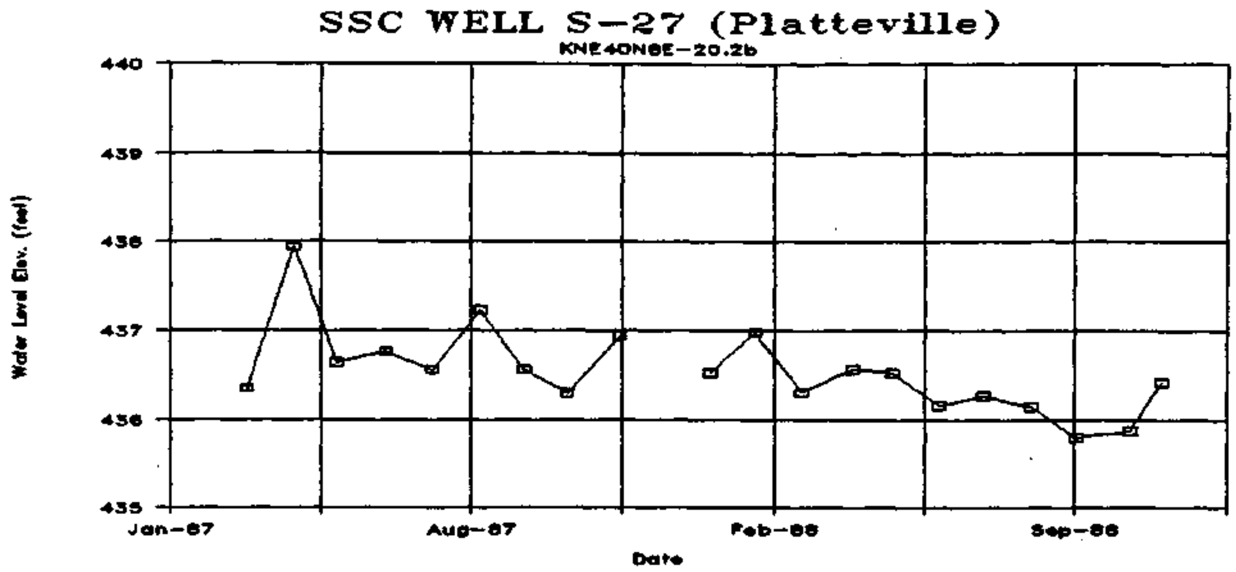

SSC WELL S-24 (Platteville)

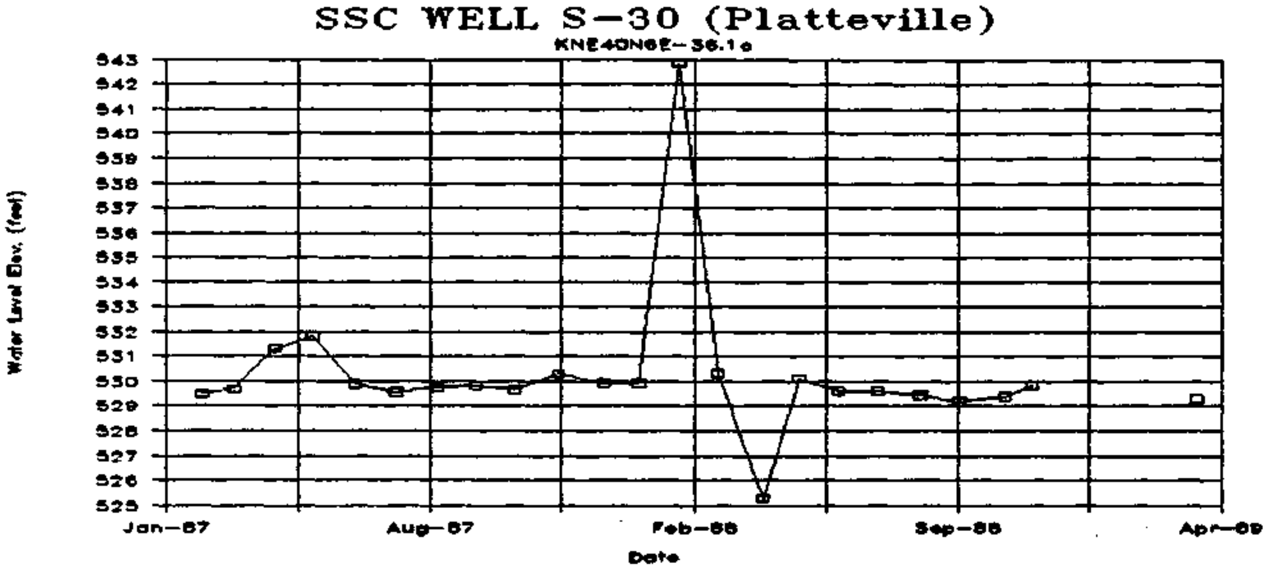
KNE40N7E-22.6d


SSC WELL S-26 (Platteville)

KNE39N6E-14.6c

Figure 12. *Hydrographs for S-23, S-24, S-26, S-27, S-30, and L-3*





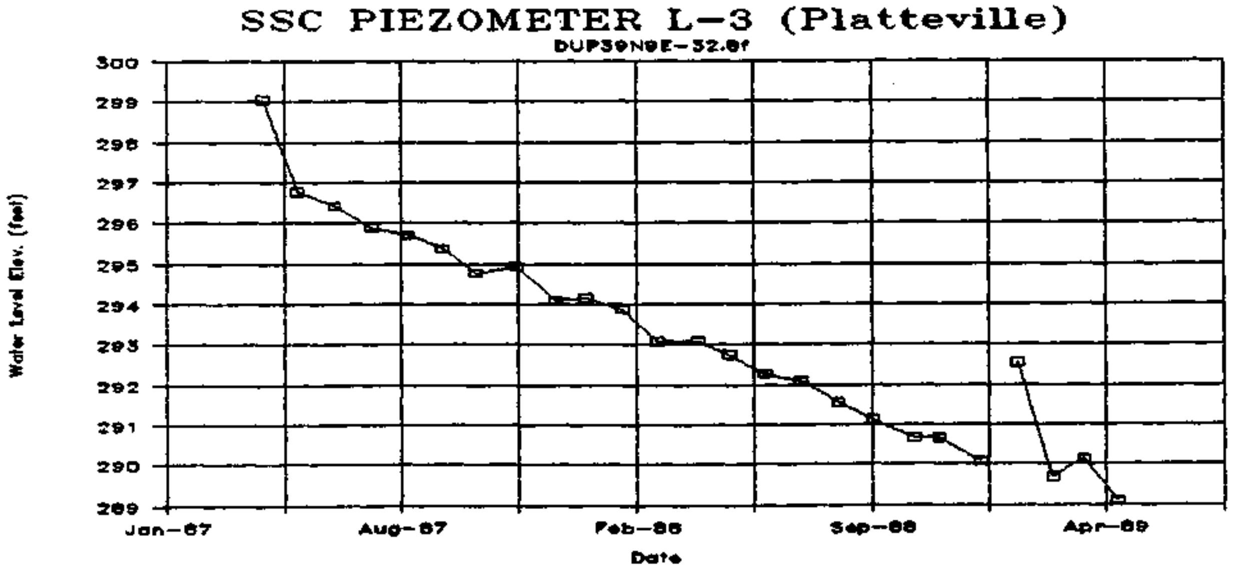


Figure 12. Concluded

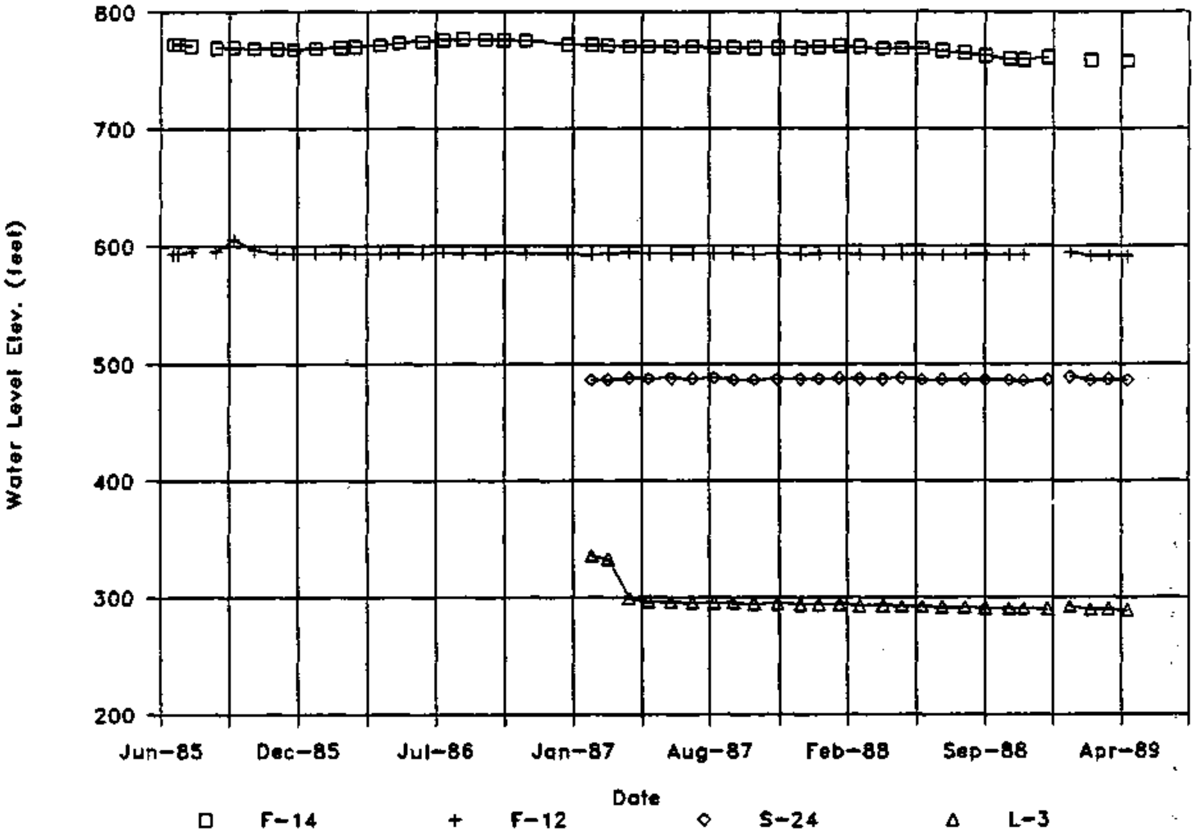


Figure 13. Comparison of hydrographs for four Platteville wells (F-14, F-12, S-24, and L-3)

piezometers are separated by about 100 feet. The extremely close correspondence among water levels over their periods of record implies that vertical communication exists between the screened portions of the piezometers. There is a fair correlation between these water levels and those at B-3, F-14, and S-26, all of which are Platteville piezometers. An aquifer test conducted at the site and described in Circular 170, however, indicated that water levels in the Ancell Group were only about 14 feet lower than levels in the Platteville, suggesting that the levels in all three piezometers could also be reflecting Ancell stages. Since it is impossible to identify which aquifer is represented by the hydrographs at Kaneland, they are not included in this report.

Figure 14 shows hydrographs for the Fermilab nested piezometers, SSC-2-1, -2, and -3 (L-l through L-3, for short). Water levels in the middle (Galena) piezometer, L-2, were below the bottom of the screen from November 1987 through October 1988, and again from January to April 1989. Water levels in the Maquoketa piezometer, L-l, gradually declined from over 670 feet MSL in the summer of 1987 to just below 610 feet MSL, about 275 feet above recent stages in the Galena piezometer, L-2, and 320 feet above those in L-3, the Platteville piezometer. The high levels in L-l are about 35 feet below stages at F-l, the Maquoketa piezometer located about two miles to the north (incorrectly reported in Circular 170 as three miles north), and about 40 feet above stages at F-6, the Maquoketa piezometer about 10 miles to the south-southwest. The hydrographs in figure 14 suggest that a vertical head gradient of about 2.75 feet/foot exists between the Maquoketa and Galena Groups at Fermilab -- down from the 3.35 feet/foot reported in Circular 170. A vertical gradient of 0.29 foot/foot existed between the Galena and Platteville Groups before water levels fell below the bottom of the middle piezometer. This compares closely with the 0.26 foot/foot noted in Circular 170.

At Big Rock (figure 15), water levels in the upper piezometer, SSC-3-1 (B-l, for short), gradually recovered about 35 feet from their initial stages following completion in early 1987, and eventually stood at about 583 feet MSL, about 52 feet above water levels in both lower piezometers, B-2 and B-3. The resulting vertical head gradient between the upper part of the Galena and the Platteville at Big Rock is 0.52 foot/foot, which is nearly four times the gradient observed in 1987 and reported in Circular 170. Apparently, the screen in B-l was clogged initially but gradually cleared, allowing water levels to assume their current stages. It is not clear why there is such a close correspondence (generally between 0.5 foot and 1 foot) between water levels in B-2 and B-3, however. It is possible that the seal between these screens is not watertight and that, as a result, the water levels in B-2 are merely reflecting stages in the Platteville. Another possibility is that the vugginess observed by Vaiden et al. (1988) in down-hole videocamera inspection of SSC-3 allows significant vertical hydraulic continuity to exist between the strata opposite B-2 and B-3.

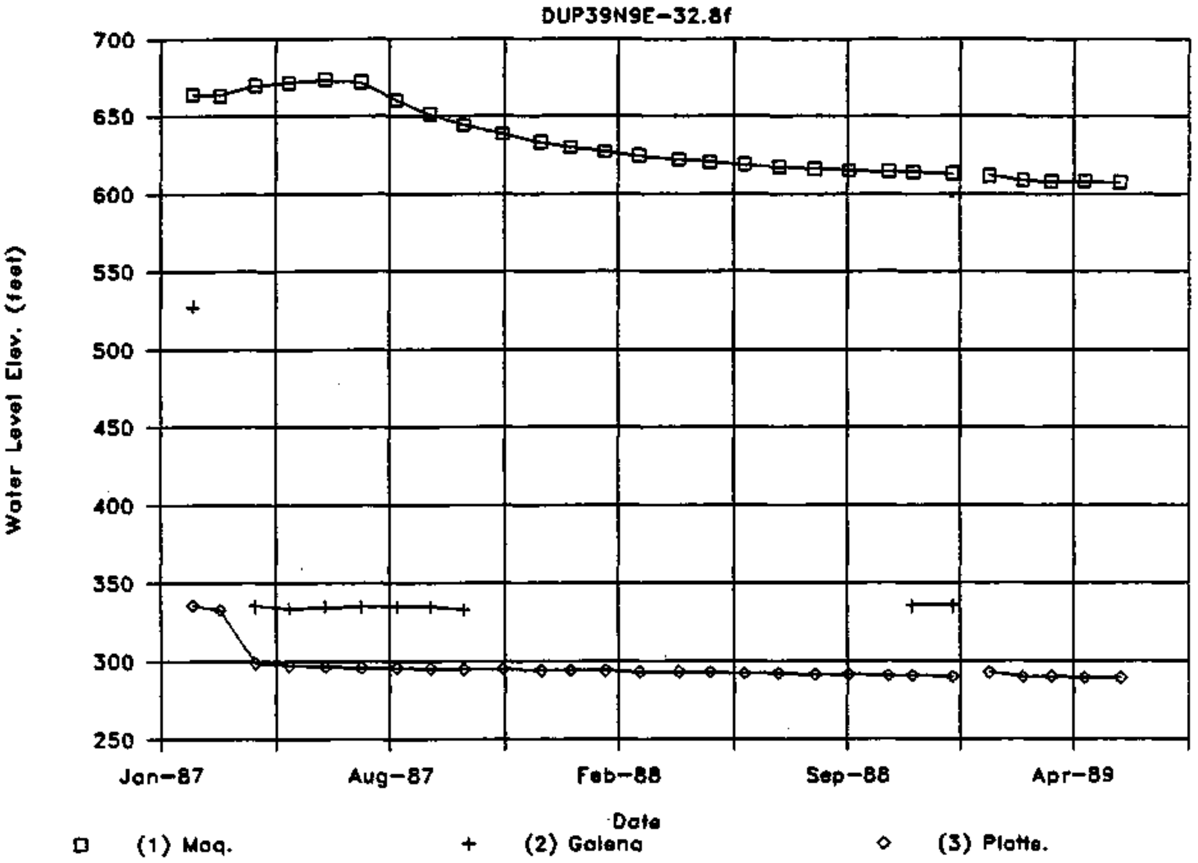


Figure 14. Comparison of hydrographs for nested piezometers at Fermilab (SSC-2-1, -2, and -3, or L-1, L-2, and L-3)

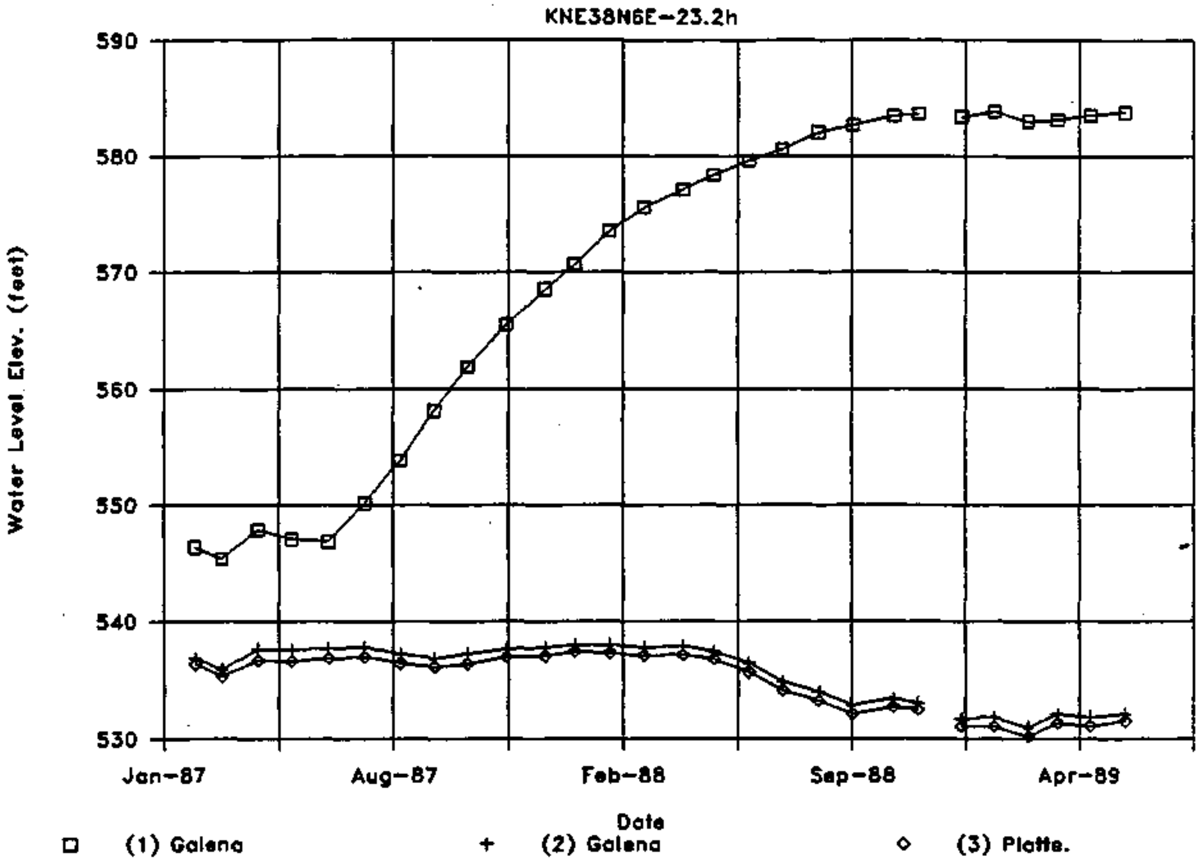


Figure 15. Comparison of hydrographs for nested piezometers at Big Rock (SSC-3-1, -2, and -3, or B-1, B-2, and B-3)

Implications of Vertical Gradients for Estimating Ground-Water Recharge

Walton (1960) used a flow net analysis of the potentiometric surface of the Midwest Bedrock Aquigroup in the Chicago area to estimate the amount of vertical leakage that was occurring through the Maquoketa Unit as a result of the vertical head gradients induced by pumpage. Using 1958 data, he determined the recharge rate to be about 2,100 gallons per day per square mile (gpd/sq mi) and the vertical hydraulic conductivity of the Maquoketa Unit to be 5 x 10^{-5} gallons per day per square foot (gpd/sq ft). Later computer model studies by Prickett and Lonnquist (1971) and Visocky (1982) corroborated these estimates.

Borehole pressure tests, employing packers over selected intervals, were used by the State Geological Survey during the SSC study to estimate horizontal hydraulic conductivities for various bedrock units (Graese et al., 1988). Values for the Maquoketa and Galena-Platteville Groups generally ranged from 0.02 to 200 gpd/sq ft and from 0.02 to 20 gpd/sq ft, respectively, although some values less than 0.02 gpd/sq ft were also reported in both units.

Estimates of recharge through confining units can be made by applying Darcy's law and values of vertical gradient and vertical hydraulic conductivity from field or laboratory data. Vertical hydraulic conductivity data are not readily available, however, and attempts are often made to use horizontal conductivities instead, even though anisotropies of from 3:1 to 10:1 (horizontal:vertical conductivity) are often observed in laboratory analyses of cores (Freeze and Cherry, 1979). Estimates of recharge were attempted, nonetheless, using vertical gradients observed in the SSC piezometers (reported above) and the horizontal hydraulic conductivities reported by Graese et al. (1988). The vertical conductivity was assumed to be 0.02 gpd/sq ft, and the vertical gradients were those observed at Big Rock, Fermilab, and Virgil. The results are summarized below in table 2.

Table 2. Estimates of Recharge from SSC Field Parameters

Site	Units	Vertical gradient	Vertical recharge (gpd/sq mi)
Big Rock	Gal/Platt	0.525	700
Fermilab	Maq/Gal	2.75	3,800
	Gal/Platt	0.29	400
Virgil	Maq/Platt	0.84	1,200

It can be seen from table 2 that the results of these recharge calculations are from 2 to 3 orders of magnitude higher than the rate estimated by Walton. When the above vertical gradients are used, however, with Walton's value of vertical hydraulic conductivity (5 X 10^{-5}) to calculate recharge, the values range from 400 to 3,800 gpd/sq mi and average 1,500 gpd/sq mi (table 2). These results are in much closer agreement with both Walton's calculations and the computer studies cited above. Apparently, on a regional scale at least, vertical movement of water through the Maquoketa, Galena, and Platteville units is controlled by much lower hydraulic conductivities than those horizontal-direction values observed in borehole packer tests.

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Appendix. Monthly Water-Level Data
(Distance to water in feet)

		SSC-F1	SSC-F2	SSC-F3	SSC-F5	SSC-F6	SSC-F7	SSC-F9	SSC-F10	SSC-F11	SSC-F12	SSC-F13	SSC-F14	SSC-F15	SSC-F16	SSC-F17	SSC-S18	SSC-S19
	Depth:	342.00	377.00	312.00	462.00	300.00	389.00	490.00	337.70	350.00	436.00	157.00	478.00	455.00	264.50	349.00	355.20	388.60
Date	Elev.:	739.50	785.54	702.22	865.57	711.93	796.29	916.86	706.39	731.33	871.97	870.00	870.76	847.96	659.49	743.33	656.00	646.00
12-Dec-84		89.57	192.97	308.70	139.83	134.95	206.07	77.83										
15-Jan-85		89.67	195.65	310.70	175.48	135.57	207.43	243.17										
21-Feb-85			203.65															
22-Feb-85		89.47				135.00												
27-Feb-85		89.66																
28-Feb-85					174.43	129.83	205.63	243.04										
01-Apr-85		88.21		310.70	174.72	131.63	211.42	244.04										
30-Apr-85		87.88	243.69	310.70	175.01	132.04	206.60	244.02										
10-May-85				>312						36.15								
24-May-85		88.55		>312	175.17	132.59	206.62	243.89	285.75	33.40								
29-May-85			265.96	>312														
21-Jun-85				>312							278.54	18.82	98.71					
28-Jun-85		89.69	283.96	>312		133.41	207.09	246.44	294.08	25.01	278.66	16.77	98.85	385.49				
16-Jul-85				>312	175.00		205.93	241.64			276.43	16.61	100.23					
18-Jul-85		89.80	291.53	>312		133.43			301.95	24.09				385.44	191.93			
19-Aug-85		90.21		>312	175.31	134.72	206.33		307.57						192.65			
21-Aug-85			307.30	>312				243.30		39.01	276.85	17.38	102.26					
17-Sep-85		90.58	316.16	>312	175.73	135.60	206.78	240.03	312.33	25.23	265.88	17.87	101.58	386.58	193.37	23.01		
17-Oct-85		90.79	324.52	>312	175.33	136.28	207.58	240.55	316.97	32.64	274.94	17.90	102.55	385.62	191.85	23.40		
19-Nov-85		90.66	329.54	>312	176.83	141.70	209.08	242.00	319.30	22.83	278.38	13.75	103.10	385.31	192.03	17.63		
12-Dec-85		89.62	332.67	>312	176.02	136.55	209.17	241.55	320.55	21.25	278.15	13.38	103.35	384.86	192.03	16.30		
14-Jan-86		89.85	336.65	>312	175.40	136.15	208.25	240.00	321.70	22.10	278.00	14.83	102.85	384.81	192.30	18.75		
20-Feb-86		89.98	339.78	>312	175.05	136.80	207.76	240.27	322.70	26.96	277.93	15.38	101.95	384.51	192.01	19.63		
12-Mar-86		90.04	341.72	>312	175.13	135.92	207.81			25.83	278.10	15.31	101.26	384.68	192.05	19.82		
17-Apr-86		90.23	343.17	310.58	175.76	135.87	207.86	240.48	326.12	22.61	278.24	15.62	99.70	384.88	192.23	19.92		
15-May-86		90.61	344.45	>312	175.69	136.32	207.85	239.87	327.49	22.12	277.96	16.05	98.08	384.41	192.21	20.38		
18-Jun-86		91.22	344.30	>312	175.88	136.71	207.91	240.14	329.25	21.77	278.41	14.87	96.73	385.18	191.86	19.28		
17-Jul-86		91.34	345.02	>312	175.88	137.20	207.94	240.98	328.27	22.15	277.66	14.97	95.32	384.81	192.08	18.64		
15-Aug-86		91.83	345.00	Plugged	Plugged	137.96	207.84	Plugged	331.70	22.55	278.30	15.80	94.73	Plugged	192.20	Plugged		
17-Sep-86		92.11	344.88	*	*	139.01	208.90	*	333.16	24.09	278.47	17.30	94.94	*	192.50	*	>355	156.37
14-Oct-86				*	*			*			277.38	16.81	95.23	*		*	>355	154.74
14-Nov-86		92.27	344.00	*	*	140.45	209.24	*	335.10	23.43	278.40	16.10	96.08	*	193.00	*	352.15	154.51
15-Jan-87		92.63		*	*	141.26	208.91	*	Dry	23.44	278.03	18.30	99.05	*	191.24	*	Dry	154.81
19-Feb-87		91.80	342.00	*	*	140.87	209.35	*	Dry	23.53	278.90	16.43	99.50	*	192.52	*	Dry	154.86
15-Mar-87		90.98	340.55	*	*	140.97	209.14	*	Dry	22.52	278.74	16.46	99.80	*	192.55	*	Dry	154.01
15-Apr-87		91.57	340.71	*	*	141.43	208.17	*	Dry	22.70	277.29	17.69	100.79	*	191.71	*	Dry	154.43
14-May-87		90.43	341.59	*	*	141.53	208.87	*	Dry	19.53	278.65	15.64	100.89	*	192.35	*	Dry	154.26
15-Jun-87		90.33	341.08	*	*	141.59	208.99	*	Dry	19.53	278.57	15.57	100.75	*	192.14	*	Dry	154.26
16-Jul-87		90.87	340.50	*	*	141.72	208.91	*	Dry	21.05	278.67	16.55	100.86	*	191.92	*	Dry	154.66
17-Aug-87		91.95	340.02	*	*	142.05	208.87	*	Dry	21.58	278.56	16.54	101.45	*	191.98	*	Dry	154.18
15-Sep-87		90.68	339.62	*	*	142.13	208.83	*	Dry	20.28	278.60	14.57	101.63	*	192.08	*	Dry	154.07
14-Oct-87		91.13	339.18	*	*	143.24	209.35	*	Dry	20.08	278.97	15.20	102.24	*	191.81	*	Dry	154.35
17-Nov-87		90.36	338.89	*	*	142.56	209.09	*	Dry	30.19	278.42	15.22	101.98	*	192.97	*	Dry	153.82
21-Dec-87		90.46	330.29	*	*	143.02	208.52	*	Dry	17.89	278.84	13.42	102.08	*	191.30	*	Dry	154.43
16-Jan-88		89.50	314.20	*	*	143.14	209.23	*	Dry	18.46	278.62	13.69	101.19	*	191.52	*	Dry	154.05
15-Feb-88		88.73	316.87	*	*	143.09	208.71	*	Dry	18.83	278.70	13.24	100.53	*	190.94	*	Dry	154.03
16-Mar-88		88.46	296.78	*	*	143.00	209.40	*	Dry	18.88	279.15	14.30	101.44	*	191.11	*	Dry	154.67
19-Apr-88		88.10	300.30	*	*	142.84	209.15	*	Dry	18.75	278.96	13.30	102.36	*	191.48	*	Dry	154.26
16-May-88		88.43	304.09	*	*	142.48	209.05	*	Dry	20.67	278.96	14.41	102.92	*	191.88	*	Dry	154.22
15-Jun-88		90.05	308.43	*	*	142.55	209.72	*	Dry	24.70	279.30	15.78	102.91	*	192.30	*	Dry	154.47
15-Jul-88		91.19	312.08	*	*	143.28	210.26	*	Dry	22.62	279.11	16.83	104.24	*	192.55	*	Dry	154.40
16-Aug-88		92.19	316.88	*	*	143.55	211.07	*	Dry	23.52	279.22	17.60	106.14	*	192.30	*	Dry	154.44
15-Sep-88		93.10	320.62	*	*	144.62	212.60	*	Dry	25.21	279.55	18.37	108.78	*	192.83	*	Dry	154.86
20-Oct-88		92.66	325.65	*	*	145.21	212.98	*	Dry	15.61	279.54	19.11	110.97	*	189.82	*	Dry	154.02
10-Nov-88		93.18	327.83	*	*	145.18	213.15	*	Dry	26.01	279.16	19.54	111.59	*	191.99	*	Dry	153.75
16-Dec-88		92.73	331.56	*	*		213.47	*	Dry	24.51		17.79	109.84	*		*	Dry	
19-Dec-88						145.06									192.41			155.13
17-Jan-89		93.93	332.50	*	*	144.56	212.43	*	Dry	24.97	277.75	18.45		*	192.59	*	Dry	155.44
16-Feb-89		96.05	337.53	*	*	146.16	214.79	*	Dry	27.02	280.42	20.24	113.05	*	195.28	*	Dry	158.19
14-Mar-89		95.41	339.75	*	*	145.93	213.74	*	Dry	30.29	279.86	19.81		*	194.98	*	Dry	157.18
11-Apr-89		95.58	341.55	*	*	145.45	214.46	*	Dry	26.66	280.49	19.51	113.17	*	195.01	*	Dry	158.09
12-May-89		95.76	343.45	*	*	145.02	214.30	*	Dry	25.31	280.35	19.88	112.80	*	195.28	*	Dry	157.84

Appendix. Concluded

		SSC-S20	SSC-S21	SSC-S22	SSC-S23	SSC-S24	SSC-S26	SSC-S27	SSC-S28	SSC-S30	SSC-K1	SSC-K2	SSC-K3	SSC-L1	SSC-L2	SSC-L3	SSC-B1	SSC-B2	SSC-B3
	Depth:	416.20	303.50	371.00	474.00	605.00	502.00	465.00	435.00	545.00	421.00	521.00	640.00	317.00	417.00	571.00	277.00	377.00	477.00
Date	Elev.:	717.00	648.00	663.00	754.00	903.00	815.00	739.00	731.00	883.00	841.00	841.00	841.00	753.00	753.00	753.00	688.00	688.00	688.00
12-Dec-84																			
15-Jan-85																			
21-Feb-85																			
22-Feb-85																			
27-Feb-85																			
28-Feb-85																			
01-Apr-85																			
30-Apr-85																			
10-May-85																			
24-May-85																			
29-May-85																			
21-Jun-85																			
28-Jun-85																			
16-Jul-85																			
18-Jul-85																			
19-Aug-85																			
21-Aug-85																			
17-Sep-85																			
17-Oct-85																			
19-Nov-85																			
12-Dec-85																			
14-Jan-86																			
20-Feb-86																			
12-Mar-86																			
17-Apr-86																			
15-May-86																			
18-Jun-86																			
17-Jul-86																			
15-Aug-86																			
17-Sep-86		364.80	56.96	14.81															
14-Oct-86		353.00	61.07	105.37															
14-Nov-86		354.85	56.53	105.22															
15-Jan-87			57.95	106.37							292.39	292.20	292.28						
19-Feb-87		354.57	56.43		187.90	416.96	265.30	303.11	427.45	353.51	292.55	292.67	292.54	88.82	225.43	417.08	141.63	151.14	151.65
15-Mar-87		354.70	55.08	105.63	187.81	416.64	265.20	302.65	Dry	353.29	293.46	293.67	293.35	89.40		419.73	142.63	152.10	152.70
15-Apr-87		353.07	57.62	106.33	186.98	415.19	263.61	301.06	Dry	351.68	291.15	291.33	291.35	83.16	417.40	453.95	140.10	150.36	151.33
14-May-87		354.69	54.56	106.47	187.56	415.69	264.84	302.36	Dry	351.17	291.79	291.92	291.87	81.68	419.10	456.23	140.90	150.37	151.40
15-Jun-87		354.63	56.09	115.52	187.34	415.13	264.60	302.23	Dry	353.11	291.41	291.37	291.27	79.53	418.21	456.57	141.11	150.30	151.12
16-Jul-87		354.24	56.28	105.06	187.62	415.42	263.40	302.44	Dry	353.42	291.74	291.68	291.76	81.18	418.15	457.11	137.85	150.22	151.04
17-Aug-87		354.46	55.97	104.76	187.77	414.78	263.62	301.77	Dry	353.24	291.87	291.69	291.89	92.68	417.88	457.30	134.18	150.75	151.56
15-Sep-87		354.43	55.33	105.09	192.80	416.80	262.50	302.44	Dry	353.10	292.14	292.31	292.23	101.71	417.86	457.63	129.88	151.12	151.85
14-Oct-87		354.59	54.61	105.75	188.12	416.70	263.09	302.70	Dry	353.33	292.81	292.79	292.85	108.64	420.00	458.23	126.12	150.72	151.64
17-Nov-87		354.64	54.00	105.85	187.83	416.01	262.68	302.06	Dry	352.70	292.41	292.03	292.15	114.53	Dry	458.06	122.48	150.36	151.05
21-Dec-87		354.44	53.50	105.91	187.86	416.07	265.24	-	Dry	353.05	291.83	291.94	291.82	119.72	Dry	458.91	119.47	150.22	150.98
16-Jan-88		354.25	52.78	105.98	187.57	415.68	265.21	302.48	Dry	353.07	291.62	291.73	291.67	122.67	Dry	458.83	117.27	149.95	150.55
15-Feb-88		354.32	51.86		187.30	415.64	263.25	302.02	Dry	340.14	291.49	291.51	291.59	125.88	Dry	459.12	114.40	149.94	150.68
16-Mar-88		354.13	51.49	104.87	187.61	416.11	263.19	302.69	Dry	352.67	291.82	291.95	291.90	128.36	Dry	459.92	112.41	150.23	150.92
19-Apr-88		354.11	50.93	104.80	187.44	416.20	263.16	302.43	Dry	357.73	291.69	291.76	291.66	130.82	Dry	459.91	110.87	150.07	150.84
16-May-88		354.14	50.68	105.83	187.74	415.24	263.45	302.48	Dry	352.87	291.73	291.80	291.73	132.53	Dry	460.24	109.64	150.58	151.27
15-Jun-88		354.58	50.83	106.25	188.43	416.72	265.65	302.84	Dry	353.37	292.07	292.25	292.16	134.11	Dry	460.73	108.39	151.55	152.34
15-Jul-88		354.51	51.05	105.90	194.05	416.47	266.04	302.73	Dry	353.39	294.01	294.03	293.97	135.71	Dry	460.91	107.42	153.18	153.90
16-Aug-88		354.53	51.01	-	190.00	416.61	266.80	302.85	Dry	353.54	294.78	294.65	294.57	136.91	Dry	461.45	105.97	154.03	154.76
15-Sep-88		354.50	51.34	108.22	191.11	417.01	267.71	303.19	Dry	353.81	295.18	295.10	295.16	138.10	Dry	461.86	105.31	155.14	155.96
20-Oct-88		354.58	51.46		191.57	416.88	267.84	303.12	Dry	353.60	295.78	295.87	295.87	138.42	Dry	462.33	104.55	154.64	155.33
10-Nov-88		354.27	52.01		191.59	417.39	267.90	302.58	Dry	353.18	294.68	294.71	294.59	139.07	417.25	462.33	104.33	154.92	155.57
16-Dec-88					191.38	416.83	268.18							139.99	417.19	462.93			
19-Dec-88		352.68	53.38														104.60	156.34	156.96
17-Jan-89		352.00	53.52		191.13	414.16	266.72		Dry					141.21	Dry	460.45	104.18	156.20	156.98
16-Feb-89		354.11	56.21		193.64	417.10	269.25		Dry		296.88	296.98	296.96	144.26	Dry	463.31	104.98	157.04	157.83
14-Mar-89		353.89	56.44		192.96	416.41	268.27		Dry	353.71				145.01	Dry	462.86	104.83	155.94	156.67
11-Apr-89		353.72	56.43		192.10	417.09	269.89		Dry					145.02	Dry	463.89	104.43	156.18	156.95
12-May-89		354.22	56.34		189.85	416.91	268.79	304.23	Dry					145.66	Dry	464.01	104.19	155.99	156.54