INTERACTION OF GROUND WATER WITH THE ROCK RIVER NEAR BYRON, ILLINOIS

by Charles Avery

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square foot (ft^2)	0.09290	square meter
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
gallon per minute (gal/min)	0.06308	liter per second
gallon per minute (gal/min)	227,100	milliliter per hour

Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter expresses the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8\ (°C) + 32$$

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

Interaction of Ground Water with the Rock River near Byron, Illinois

by Charles Avery

Abstract

Ground-water discharge to the Rock River in the study area, estimated by three independent methods, ranged from 16,300 to 30,900 cubic feet per day; the low value, determined by the use of the modified Darcy equation, is an estimate only of ground-water discharge from the southern side of the Rock River. The vertical distribution of trichloroethene (TCE) in ground water was determined at a test hole along the estimated centerline of the contaminant plume and as close to the river as property access would allow. The maximum concentrations of TCE of 3 micrograms per liter were found at depths of 59 and 64 feet. The contaminant was dispersed across a vertical interval of about 75 feet at depths of 19 to 94 feet. All of the TCE in ground water discharges to the Rock River because no TCE was detected below a depth of 109 feet, and increasing vertical head gradients with depth indicate ground-water flow from a depth of 119 feet is to the river. The maximum possible discharge of TCE is estimated to be about 1.7 grams per day. A finite-difference numerical model was used to simulate ground-water flow along a vertical section through the ground-water system from the Byron Superfund site to the Rock River. Results of the ground-water flow simulation indicate that, if underflow in the St. Peter aquifer occurs beneath the Rock River, it would be water that was present at depth in the flow system at the Byron Superfund site rather than contaminated water that had recharged the system in the vicinity of the Byron Superfund site.

INTRODUCTION

Water samples collected in 1985 from residential wells along the southern side of the Rock River in a housing area called Rock River Terrace were analyzed for volatile organic compounds (VOC's) (Douglas Yeskis, U.S. Environmental Protection Agency, written commun., 1990). The concentration of trichloroethene (TCE) in water from some of these wells was high enough to cause the U.S. Environmental Protection Agency (USEPA) and the Illinois Environmental Protection Agency to initiate action to replace the water supply with an alternative source. Since then, the USEPA has expressed concern about the concentration of TCE discharging to the Rock River and whether some VOC's are being transported beneath the river.

In October 1989, the U.S. Geological Survey (USGS), in cooperation with the USEPA, began a study of ground-water flow and contaminant movement from the Byron Superfund site near Byron, Ill., to the Rock River. The study area is in Ogle County in north-central Illinois, about 4 mi southwest of the town of Byron and about 15 mi southwest of Rockford (fig. 1). The Byron Superfund site is about 1.5 mi southeast of the Rock River (fig. 2).

The study was done to determine the probable loading rates of organic contaminants to the Rock River from the plume of ground-water contamination emanating from the Byron Superfund site. The possibility that some of the contaminated ground water does not discharge immediately to the Rock River downgradient of the site but flows beneath the Rock River as part of a regional flow path also was evaluated.

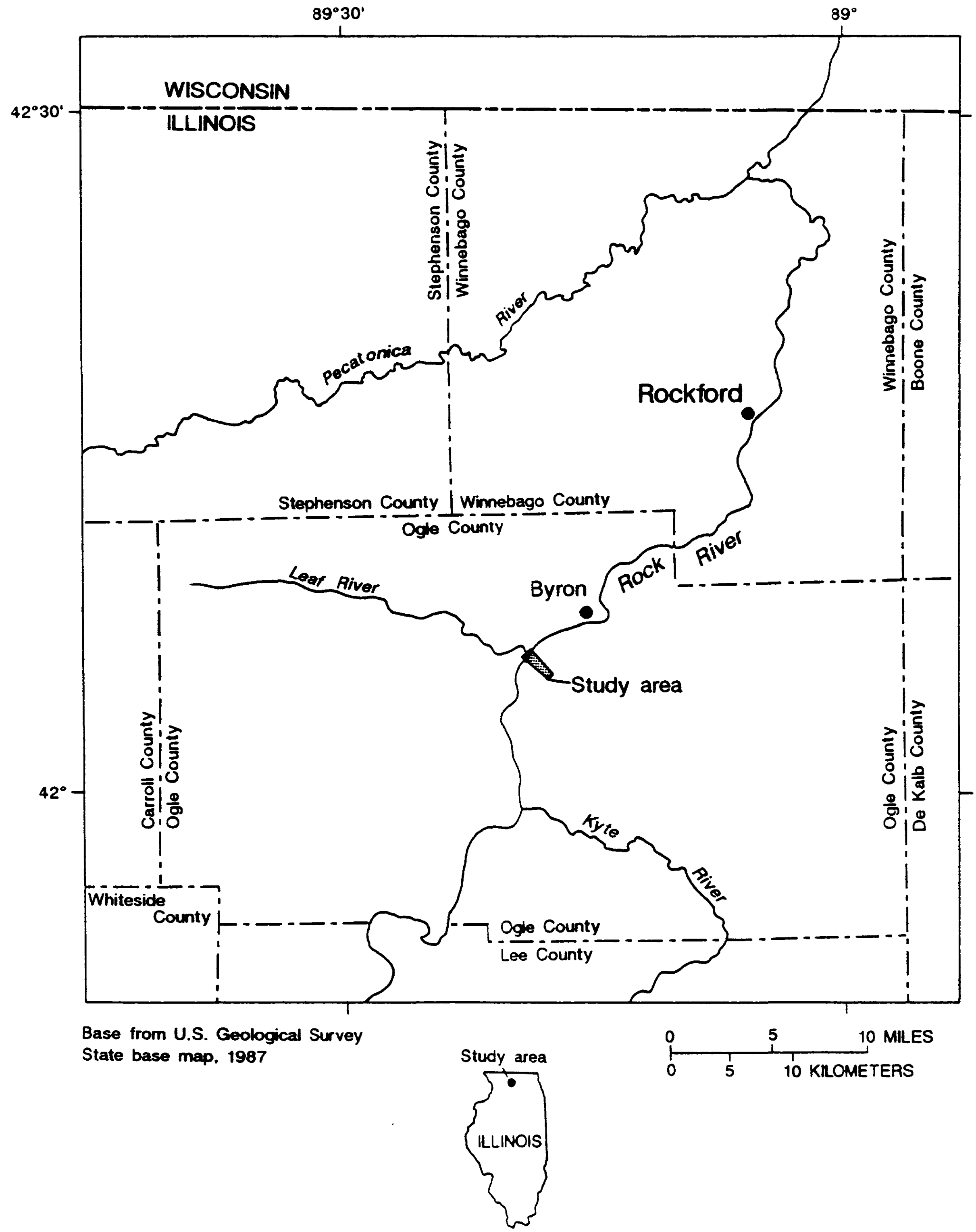


Figure 1. Location of study area.

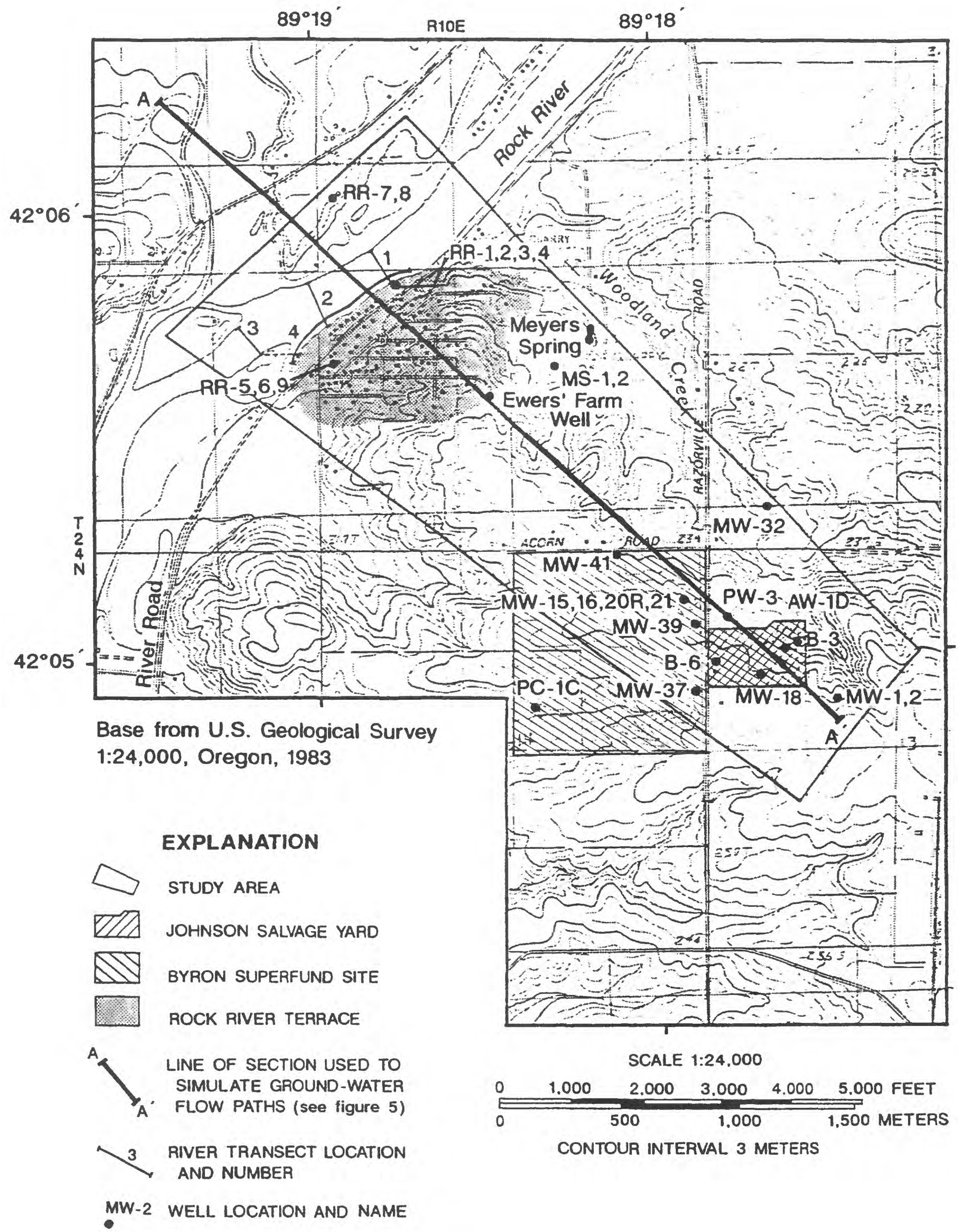


Figure 2. Location of data-collection sites at the Byron Superfund site near Byron, Ill.

Purpose and Scope

This report describes the results of the study of the interaction between the ground-water system and the Rock River in the vicinity of the Byron Superfund site near Byron, Ill., and gives estimates of the loading of contaminants originating from the Superfund site to the Rock River. The study concentrated on the ground-water flow and contaminant movement in the St. Peter Sandstone and in the unconsolidated sediments along the Rock River. The report discusses the methods used to collect detailed data regarding ground-water levels, ground-water discharge to the Rock River, and ground-water chemistry as related to the contaminant loading of the Rock River and the potential for underflow beneath the river. The work was done between October 1989 and October 1991.

Nearly all data collection was limited to a narrow area upgradient from the ¾-mi reach of the Rock River bordered by Rock River Terrace (fig. 3). Water levels were measured in 16 observation wells open to the St. Peter or alluvial aquifers. Estimates of horizontal hydraulic conductivity of the St. Peter and alluvial aquifers were determined from slug tests completed at several observation wells. A packer test at five different intervals was completed in one well, known as the Ewers' Farm well, open to about 100 ft of the St. Peter Sandstone. This test was done to determine the vertical head and contaminant distributions in the St. Peter aquifer.

Water samples for chemical analysis were collected periodically from all observation wells open to the St. Peter aquifer, from four wells open to the Galena-Platteville aquifer, from eight wells open to the alluvial aquifer at the Rock River, from a spring discharging from the Galena-Platteville aquifer, and from the ground-water-collection devices installed in the river. Concentrations of VOC's were determined by laboratories participating in the USEPA Contract Laboratory Program (CLP) for each sample, when possible. The USEPA CLP laboratories analyzed for cyanide in a few samples. The amount of water obtained from the seepage meters, one of the three types of ground-water-sampling methods used at the river, was not always sufficient for analysis.

Superfund-Site History

Cattle and fish kills during the 1970's on land now encompassed by the Superfund site initiated investigations of soil and water contamination caused by the uncontrolled disposal of chemical wastes. The site was placed on the USEPA Superfund's National Priorities List in 1982 (Douglas Yeskis and others, written commun., 1990).

VOC contamination was discovered in water from domestic wells in housing areas between the Superfund site and the Rock River in 1986. A Record of Decision for the Superfund site in 1989 dictated that the municipal water supply from the city of Byron would be used to supply uncontaminated water to residents in the area (Douglas Yeskis and others, written commun., 1990).

Methods of Investigation

Ground-water discharge to the river was determined by three independent methods: (1) the collection of actual ground-water discharge to the river by seepage meters, (2) the use of an estimation technique incorporating the modified Darcian equation to determine ground-water flow to the river, and (3) the use of a numerical model to represent a vertical section through the ground-water-flow system from the site to the river and to simulate ground-water discharge to the river along that section.

Sampling methods for obtaining representative ground-water samples for water-chemistry analyses from beneath the river included the passive collection of ground-water discharge by seepage meters, induced withdrawal of ground water from well points, and bottom river-water sampling. Seepage meters were installed about every 100 ft along the sampling lines transecting the river (fig. 2). Ground-water samples were collected about 100 ft above Woodland Creek to serve as control samples. During the fall of 1989, seepage meters were installed at all locations on all three sampling lines transecting the river, and all three sampling methods were used at the sampling sites along the second sampling line. During the spring and summer of 1990, well-point and river sampling were done only at sites along the second sampling line transecting the river and along the fourth sampling line, which was parallel to the south-side river bank. All of the samples were analyzed for VOC's and cyanide when enough water was collected. The water from the well-point and bottom river-water sampling, as well as the samples from all the observation wells, were collected by pumping with a low-discharge (less than 1 gal/min), positive-displacement,

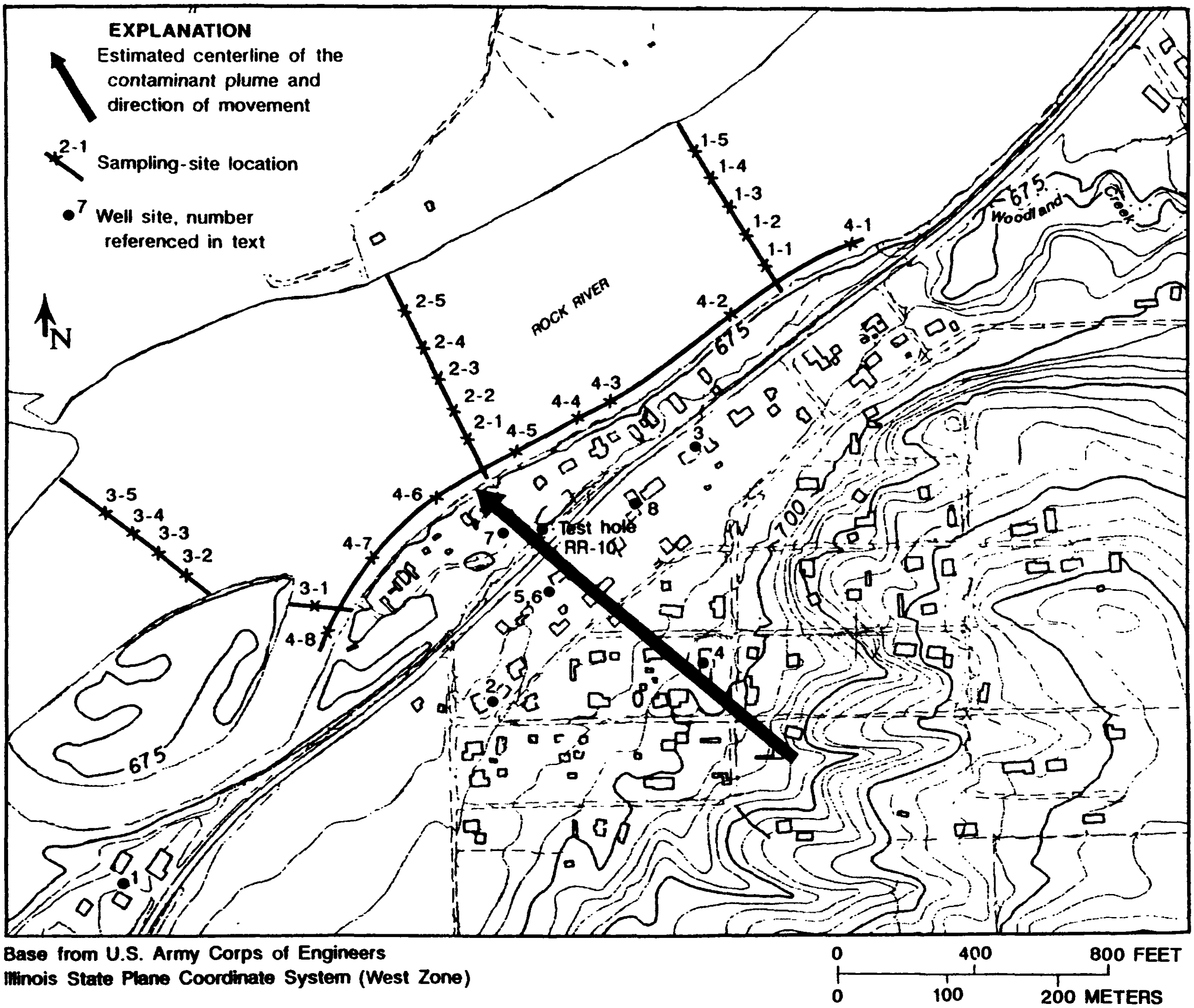


Figure 3. Location of data-collection sites in Rock River Terrace and along transects in the Rock River, and the estimated centerline of the contaminant plume and direction of movement.

submersible pump. The well points were driven into the river bottom such that the 1-ft-long screens at the bottom of the casing were entirely buried in the alluvium. The bottom river-water sampling was done by pumping river water at the river-alluvium interface. The design and use of seepage meters is described by Lee (1977); the sampling area of each seepage meter was 2.7 ft^2.

Slug tests were done in selected observation wells that were open to the St. Peter and alluvial aquifers. The data were collected by electronic data-logger and analyzed by the methods of Bouwer and Rice (1976) and Bouwer (1989). The slug tests were done to ensure that the observation wells were open to the aquifer and to provide data on the hydraulic properties of the aquifers in addition to those reported by Kay and others (1989, table 7).

Water levels in all of the observation wells open to the St. Peter or alluvial aquifers were measured once during each of the field periods. These data provided information on the potentiometric surface and hydraulic gradient in the St. Peter aquifer, the vertical hydraulic-head distribution in the alluvial aquifer at the river, and the seasonal changes in water levels in these aquifers.

Additional ground-water sampling and the drilling of a test hole were done in October 1991 to locate a monitoring well along the estimated centerline of the contaminant plume. Ground-water sampling and analysis for VOC's in selected wells in the Rock River Terrace area were done to estimate the lateral distribution of contamination. A test hole was augered and the ground water sampled for VOC's and analyzed by a portable gas chromatograph to estimate the vertical distribution of contamination.

Acknowledgments

The author extends his appreciation to Douglas Yeskis, USEPA, for his support and active participation during this project, and to Linda Ewers, who allowed access to her irrigation well for the extensive packer testing of the St. Peter aquifer.

GEOHYDROLOGIC SETTING

The hydrogeologic conditions in the area were described in previous investigations (Piskin, 1976; Gilkeson and others, 1977; Kay and others, 1989; Douglas Yeskis, U.S. Environmental Protection Agency, written commun., 1987) made as part of the Remedial Investigation studies at the Byron Superfund site. Most of the previous studies dealt with the contamination in the Galena-Platteville aquifer in the immediate vicinity of the Superfund site.

During previous investigations, it was determined that a potential for downward ground-water flow exists from the Galena-Platteville aquifer through the Glenwood Formation (Kay and others, 1989, p. 8-14) to the St. Peter aquifer. Also, VOC contamination in the St. Peter aquifer below the Byron Superfund site and in the alluvial aquifer downgradient from the Superfund site at the Rock River was documented. No data were collected at the site below the upper part of the St. Peter Sandstone; previous reports on the Superfund site do not describe the hydrogeology below the St. Peter Sandstone.

Geology

The stratigraphic nomenclature used in this report (fig. 4) is that of the Illinois State Geological Survey (Willman and others, 1975) and does not always coincide with the usage of the USGS. The aquifer nomenclature used in this report is as follows: The St. Peter aquifer is the saturated part of the St. Peter Sandstone of Ordovician age, the Galena-Platteville aquifer is the saturated part of the Galena and Platteville Groups of Ordovician age, and the alluvial aquifer is the saturated part of the alluvium of Quaternary age along the Rock River. The Glenwood Formation is a confining unit between the Galena-Platteville and St. Peter aquifers. The rock units in this area are described by Kay and others (1989, p. 8-14).

Hydrology

The hydrology of the area between the Superfund site and the river is complex because of the presence of fractures and solution openings in the rocks of the Galena and Platteville Groups, truncation of the Galena and Platteville Groups at the river bluffs, and the contrasting hydraulic properties of the geologic units. Some flow in the St. Peter aquifer may not discharge to the Rock River because of the large thickness of the St. Peter Sandstone at the Rock River

System	Group	Formation	Member	Lithology	Thickness, in feet	Aquifer
QUATERNARY				Alluvium, silty at top, grading downward to sand with occasional gravel	0-120+	Alluvial aquifer
				Loess, windblown silt, leached	0-15	
				Sand and silt, windblown, leached	0-15	
				Outwash, sand and gravel	0-180	
				Till, brown silty clay to clayey silt with few boulders, stiff	0-26	
				Silt, brown to gray, calcareous, stiff	0-10	
				Till, brown silty sand with few boulders, very stiff to hard	0-25	
ORDOVICIAN	GALENA	DUNLEITH		Dolomite, buff, finely crystalline, thin to medium bedded with white and gray chert nodules, green shale partings in lower portion	0-100	Galena-Platteville aquifer
		GUTTEN-BERG		Dolomite, buff, red speckled with red shale partings	0-6	
	PLATTEVILLE	QUIMBYS MILL		Dolomite, buff and gray, occasional white chert nodules	0-13	
		NA-CHUSA		Dolomite, buff and gray, occasional white chert nodules	0-23	
		GRAND DETOUR		Dolomite, mottled buff and dark gray, finely crystalline, medium to massive bedded, thin gray and reddish-brown shale partings	0-46	
		MIFFLIN		Dolomite, buff to gray, finely crystalline, medium to massive bedded, thin gray shale partings	0-26	
		PECA-TONICA		Dolomite, mottled white and dark gray, occasional finely crystalline, medium to massive bedded, thin gray shale partings	0-31	
		GLENWOOD	HARMONY HILL	Shale, green, gray, and brown, thinly laminated	0-5	
			DAYSVILLE	Shale, brown and gray, sandy dolomite, greenish-gray, fine-grained dolomitic sandstone, greenish-gray	0-32	
		ST. PETER SANDSTONE		Sandstone, white, fine-grained, quartzose, friable	420?	St. Peter aquifer

Figure 4. Stratigraphic description and aquifer nomenclature (modified from Kay and others, 1989, fig. 5).

and the presence of a regional flow system in the St. Peter aquifer.

Recharge

The Galena-Platteville aquifer is recharged primarily by infiltration of precipitation through the glacial till on the upland areas, but most of the infiltration probably is restricted to areas where the glacial till is very thin. Several erosional cuts in the river bluffs probably act as localized areas of recharge to the Galena-Platteville aquifer during runoff. The St. Peter aquifer is recharged by vertical leakage through the Glenwood Formation and by infiltration of precipitation on outcrop and subcrop areas south of the Superfund site.

Recharge of the alluvial aquifer along the Rock River occurs by ground-water discharge from the Galena-Platteville and St. Peter aquifers where these formations subcrop beneath the alluvium. Ground-water flow also may discharge from the Galena-Platteville aquifer to thin alluvium along the lower reaches of the smaller ephemeral channels cut into the river bluffs and then discharge to the alluvial aquifer by underflow.

Ground-Water Flow

Ground-water flow in the local flow systems between the Byron Superfund site and the river is toward the north and northwest. Ground-water levels (table 1) in the observation wells indicate that ground water in the Galena-Platteville aquifer flows toward the Rock River, Woodland Creek, and an unnamed ephemeral stream on the western side of the study area. Ground-water flow in the St. Peter aquifer is toward the Rock River.

Much of the ground-water flow in the Galena-Platteville aquifer probably occurs through interconnected fractures and solution openings. Flow of ground water through fractured rock may not follow the shortest path from high to low water level but may find the path of least resistance.

Hydraulic Properties

A few aquifer and slug tests have been conducted on test wells in the area. Data from an aquifer test reported by Kay and others (1989, p. 41-47) were used to determine values of horizontal hydraulic conductivity for two observation wells open to the St. Peter aquifer. Values of horizontal hydraulic conductivity determined from slug tests on six other wells open to the St. Peter aquifer performed during this study generally were greater than those values reported by Kay and others (1989); the results are as follows:

Well	Horizontal hydraulic conductivity, in feet per day
MS-2	5.7
MW-2	2.6
MW-20R	8.6
MW-21	5.2
MW-37	5.1
MW-39	2.0

Slug tests also were performed on four observation wells in the alluvial aquifer along the river, but a horizontal-hydraulic-conductivity value was determined for only one well. The data for the other three wells could not be analyzed correctly by available analytical methods because the aquifer transmissivity was very high. The results are as follows:

Well	Horizontal hydraulic conductivity, in feet per day
RR-1	damped oscillatory response, not interpretable
RR-2	damped oscillatory response, not interpretable
RR-5	2.1
RR-6	water levels responded too quickly to analyze

Discharge

Discharge from the local ground-water-flow systems is to the alluvium and, ultimately, to the Rock River. The Galena and Platteville Groups thin to zero in the bluffs above the river (Kay and others, 1989, fig. 7). Most of the ground water in the Galena-Platteville aquifer flows downward into the St. Peter and alluvial aquifers behind the bluffs along the Rock River valley, as indicated by the general absence of springs (except for Meyers Spring, which discharges about 100 gal/min) along the basal contact of the Platteville Group in the bluffs.

Much of the ground water in the shallow ground-water-flow systems of the area eventually discharges to the Rock River because the river is entrenched as much as 150 ft below the adjacent

Table 1. Well-completion and water-level data for selected wells in the vicinity of the Byron Superfund site near Byron, Ill.
[ft, feet; --, no water-level measurement. The altitude of the Rock River at Woodland Creek was 671.18 ft on April 30, 1990, and 673.51 ft on August 20, 1990; it was not measured on November 9, 1989. The August 20, 1990, river-level measurement was made during the recession from a high river stage caused by runoff from a major rainstorm that had occurred during the previous 2 days]

					November 9, 1989		April 30, 1990		August 20, 1990	
Well number or name	Depth of well (ft)	Top of open interval (ft)	Bottom of open interval (ft)	Contributing aquifer[1]	Depth to water (ft)	Water-level altitude (feet above sea level)	Depth to water (ft)	Water-level altitude (feet above sea level)	Depth to water (ft)	Water-level altitude (feet above sea level)
AW-1D	161.0	155.87	160.87	365GLPV	--	--	--	--	--	--
B-3	50	36	50	365GLPV	--	--	--	--	44.5	772.5
B-6	97.9	83.7	97.9	365GLPV	--	--	--	--	87.75	759.87
Ewers' Farm Well[2]	230	42	230	365STPR	--	--	--	--	--	--
MS-1	47	36	47	365GLPV	--	--	--	--	--	--
MS-2	82	71	82	365STPR	51.49	676.31	50.05	677.75	49.15	678.65
MW-1	70.83	13	70.83	365GLPV	--	--	--	--	44.25	815.99
MW-2	230	225	230	365STPR	175.77	684.60	174.56	685.81	173.95	686.42
MW-15	86	75	86	365GLPV	--	--	--	--	62.15	758.66
MW-16	120	109	120	365GLPV	--	--	--	--	62.25	758.57
MW-18	237	226	237	365STPR	144.35	706.34	141.7	709.0	140.8	709.9
MW-20R	190.66	180.66	190.66	365STPR	139.55	681.17	138.04	682.68	137.62	683.10
MW-21	233.88	223.88	233.88	365STPR	139.56	681.21	138.42	682.35	137.63	683.14
MW-32	45.97	18.53	45.97	365GLPV	--	--	--	--	--	--
MW-37	202	192	202	365STPR	159.09	682.43	157.89	683.63	157.26	684.26
MW-39	185	175	185	365STPR	152.73	681.61	151.42	682.92	150.80	683.54
MW-41	120	110	120	365GLPV	--	--	--	--	56.25	758.37
PC-1C	113.1	103.1	113.1	365STPR	--	--	--	--	--	--
PW-3	90	9	90	365GLPV	--	--	--	--	--	--
RR-1	53	42	53	110QRNR	6.05	670.56	5.29	671.32	3.60	673.01
RR-2	25	14	25	110QRNR	6.13	670.55	--	--	3.71	672.97
RR-3	15.3	5.27	15.3	110QRNR	6.47	670.52	5.77	671.22	3.85	673.14
RR-4	89	84	89	110QRNR	6.11	670.55	5.34	671.32	3.74	672.92
RR-5	39.17	34.17	39.17	110QRNR	17.88	670.54	17.03	671.39	15.96	672.46
RR-6	25.37	15.37	25.37	110QRNR	17.82	670.53	16.23	672.12	15.94	672.41
RR-7	44	33.87	43.87	110QRNR	37.73	671.02	36.63	672.12	35.40	673.35
RR-8	100	95	100	110QRNR	33.08	676.05	36.99	672.14	36.71	672.42
RR-9	57	52	57	110QRNR	--	--	--	--	14.21	674.19
RR-10	113	108	113	110QRNR	--	--	--	--	--	

[1]110QRNR, alluvial aquifer; 365GLPV, Galena-Platteville aquifer; 365STPR, St. Peter aquifer.

[2]The Ewers' farm well was isolated at five different depths (December 4-6, 1989) by using a downhole packer assembly; the packed intervals and water levels are as follows:

	Depth below ground, in feet	Depth to water, in feet
Packed interval 1	200-209	107.03
Packed interval 2	180-189	107.84
Packed interval 3	160-169	107.87
Packed interval 4	140-149	107.87
Packed interval 5	120-129	107.97

upland areas. On the basis of a difference between water levels measured at a staff gage located at the confluence of Woodland Creek with the Rock River, which is about 250 ft upstream from the RR-1 well cluster (fig. 2), and those measured in adjacent observation wells, the potential for ground-water discharge to the river exists in this reach of the river. Water samples collected in the seepage meters indicate that ground water does discharge to the river. The elevation of the Rock River at the time of the ground-water-level measurements (November 9, 1989) was 670.46 ft above sea level. During the three sampling periods the water levels in all of the observation wells open to the alluvial aquifer at the river were higher than the river level (table 1).

The effect of the Rock River on the regional flow system of the St. Peter aquifer in the vicinity of the study area may be slight if the alluvium along the river contains a significant thickness of silt and clay at depth, limiting ground-water discharge. If an upward gradient does not exist in the St. Peter aquifer on the north side of the river, then ground water may flow beneath the river from the south to the north. Vertical ground-water gradients in the St. Peter aquifer were not measured on the north side of the river. If a confining layer is present at depth in the alluvium or a downward ground-water gradient exists, discharge from the St. Peter aquifer to the river may be less than the maximum possible discharge and contaminants in the St. Peter aquifer potentially could be transported beyond the river by underflow. Although test holes in the alluvium have not penetrated large thicknesses of silt and clay, they have not penetrated the entire thickness of the alluvium.

Water Chemistry

The organic chemistry of the ground water in the vicinity of the Byron Superfund site and in the vicinity of the Rock River (tables 2-4) has been determined. Ground water was sampled from observation wells in the vicinity of the Byron Superfund site and along the Rock River in the Rock River Terrace subdivision and from temporary sampling sites on the river. Three rounds of sampling were done in order to observe seasonal changes in water quality.

The organic chemicals present in the ground water in the vicinity of the Byron Superfund site and their concentrations differ from those near the river. Concentrations of TCE are less than about 10 µg/L, and the concentrations of other chlorinated hydrocarbons generally are less than 2 µg/L, in the vicinity of the river. Chloroform was detected in a few of the ground-water samples obtained at wells RR-2 and RR-3 and from the ground-water-collection devices in the river. The presence of the chloroform in the two shallowest monitoring wells in the well RR-1 cluster, the absence of the chloroform in upgradient monitoring wells, and the known association of chloroform with septic systems indicate that the source of chloroform may be the Rock River Terrace subdivision.

INTERACTION OF GROUND WATER WITH THE ROCK RIVER

The rate of ground-water discharge to a river changes if the hydraulic-head difference between the river level and the water level in the underlying aquifer changes. Transient hydraulic-head differences develop when the natural rise and fall of the river and ground-water levels upgradient from the river in the aquifer do not occur simultaneously. Though ground-water levels immediately adjacent to the river generally reflect river-level changes, the regional ground-water hydraulic gradient to the river is less steep because upgradient ground-water levels do not reflect river-level changes. The transient nature of the ground-water hydraulic gradient and its relation to the river level cause transient variations in ground-water discharge to the river. At Rock River Terrace, the rise of ground-water levels in early spring lags behind the rise of stage in the Rock River. During late spring and early summer, the decline in ground-water levels lags behind the decline in river level. The ground-water hydraulic gradient decreases from a maximum in late spring and early summer to a minimum in fall and winter as the ground-water levels rise and fall seasonally. The ground-water discharge and the potential load of contaminants are greatest during the period of greatest ground-water hydraulic gradient. Concentrations of contaminants in the ground water beneath the river increase during fall and winter because of the reduction in ground-water discharge resulting from a decrease in the ground-water hydraulic gradient.

Table 2. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., November and December 1989

[Analyzed by U.S. Environmental Protection Agency contract laboratories. TCE, Trichloroethene; PCE, Tetrachloroethene; 1,1,1-TCEA, 1,1,1-Trichloroethane; 1,1-DCEE, 1,1-Dichloroethene; 1,2-DCEE, 1,2-Dichloroethene; 1,2-DCEA, 1,2-Dichloroethane; <, less than; N.A., not analyzed; J, the constituent was detected in the sample but the concentration was below the reporting level; 90/96, concentrations in duplicate samples. The field and trip blank samples analyzed for quality assurance/quality control did not contain any detectable organic constituents]

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		TCE	PCE	1,1,1-TCEA	1,1-DCEE	1,2-DCEE
AW-1D	11-17-89	<5	<5	<5	<5	<5
B-3	11-08-89	1,200/1,200	90/96	<50/<50	71/76	830/860
Ewers' pack 1	12-05-89	<5	<5	<5	<5	<5
Ewers' pack 2	12-06-89	<5	<5	<5	<5	<5
Ewers' pack 3	12-06-89	<5	<5	<5	<5	<5
Ewers' pack 4	12-06-89	<5	<5	<5	<5	<5
Meyers Spring	11-16-89	52	<5	<5	<5	2J
MS-1	11-16-89	<5	<5	<5	<5	<5
MS-2	11-16-89	13	<5	<5	<5	<5
MW-2	11-16-89	<5	<5	<5	<5	<5
MW-15	11-15-89	340	4J	12	<5	6
MW-18	11-14-89	95	10	6	<5	12
MW-20R	11-15-89	230/260	4J/3J	9/9	<5/<5	11/10
MW-21	11-15-89	<5	<5	<5	<5	<5
MW-32	12-05-89	<5	<5	<5	<5	<5
MW-37	11-17-89	<5	<5	<5	<5	<5
MW-39	11-17-89	11/10	<5/<5	<5/<5	<5/<5	<5/<5
PW-3	12-07-89	190/200	5/5	10/10	<5/<5	11/10
RR-1	11-01-89	<5	<5	<5	<5	<5
RR-2	11-02-89	1J	<5	<5	<5	<5
RR-3	11-01-89	<5	<5	<5	<5	<5
RR-4	11-01-89	<5/<5	<5/<5	<5/<5	<5/<5	<5/<5
RR-5	11-02-89	7	<5	<5	<5	<5
RR-6	11-02-89	3J	<5	<5	<5	<5
RR-7	11-07-89	<5	<5	<5	<5	<5
RR-8	11-07-89	<5	<5	<5	<5	<5
Seepage meter 1-1	11-08-89	<5	<5	<5	<5	<5
Seepage meter 1-2	11-08-89	<5	<5	<5	<5	<5
Seepage meter 1-3	11-08-89	<5	<5	<5	<5	<5
Seepage meter 1-4	11-08-89	<5	<5	<5	<5	<5
Seepage meter 1-5	11-08-89	2J	<5	<5	<5	<5
Seepage meter 2-1	11-07-89	<5	<5	<5	<5	<5
Well point 2-1	11-08-89	<5	<5	<5	<5	<5
River sample 2-1	11-08-89	<5	<5	<5	<5	<5
Seepage meter 2-2	11-08-89	<5	<5	<5	<5	<5
Well point 2-2	11-08-89	<5	<5	<5	<5	<5
River sample 2-2	11-08-89	<5/<5	<5/<5	<5/<5	<5/<5	<5/<5
Seepage meter 2-3	11-08-89	<5	<5	<5	<5	<5
Well point 2-3	11-14-89	<5	<5	<5	<5	<5
River sample 2-3	11-14-89	<5	<5	<5	<5	<5
Seepage meter 2-4	11-07-89	<5	<5	<5	<5	<5
Well point 2-4	11-14-89	<5	<5	<5	<5	<5
River sample 2-4	11-14-89	<5	<5	<5	<5	<5
Seepage meter 2-5	11-07-89	<5	<5	<5	<5	<5
Well point 2-5	11-14-89	<5	<5	<5	<5	<5
River sample 2-5	11-14-89	<5	<5	<5	<5	<5
Seepage meter 3-1	11-08-89	<5	<5	<5	<5	<5
Seepage meter 3-2	11-08-89	<5	<5	<5	<5	<5
Seepage meter 3-3	11-08-89	<5	<5	<5	<5	<5
Seepage meter 3-4	11-08-89	<5	<5	<5	<5	<5
Seepage meter 3-5	11-08-89	<5	<5	<5	<5	<5
Well point background	11-08-89	<5	<5	<5	<5	<5
River sample background	11-08-89	<5	<5	<5	<5	<5

Table 2. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., November and December 1989–Continued

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		1,2-DCEA	Chloroform	Toluene	Methylene chloride	Cyanide
AW-1D	11-17-89	<5	<5	<5	<5	<10
B-3	11-08-89	<50/<50	<50/<50	<50/<50	<50/<50	99.4/102
Ewers' pack 1	12-05-89	<5	<5	<5	<5	<10
Ewers' pack 2	12-06-89	<5	<5	5	<5	<10
Ewers' pack 3	12-06-89	<5	<5	<5	<5	<10
Ewers' pack 4	12-06-89	<5	<5	<5	<5	<10
Meyers Spring	11-16-89	<5	<5	<5	<5	18.7
MS-1	11-16-89	<5	<5	<5	<5	<10
MS-2	11-16-89	<5	<5	<5	<5	<10
MW-2	11-16-89	<5	<5	<5	<5	<10
MW-15	11-15-89	2J	<5	<5	<5	<10
MW-18	11-14-89	<5	<5	<5	<5	<10
MW-20R	11-15-89	4J/4J	<5/<5	<5/<5	<5/<5	<10/<10
MW-21	11-15-89	<5	<5	<5	<5	<10
MW-32	12-05-89	<5	<5	<5	<5	<10
MW-37	11-17-89	<5	<5	<5	<5	<10
MW-39	11-17-89	<5/<5	<5/<5	<5/<5	<5/<5	<10/<10
PW-3	12-07-89	<5/<5	<5/<5	<5/<5	<5/<5	<10/<10
RR-1	11-01-89	<5	<5	<5	4J	<10
RR-2	11-02-89	<5	15	<5	2J	<10
RR-3	11-01-89	<5	<5	<5	2J	<10/<10
RR-4	11-01-89	<5/<5	<5/<5	<5/<5	<5/<5	<10
RR-5	11-02-89	<5	<5	<5	<5	<10
RR-6	11-02-89	<5	<5	<5	<5	<10
RR-7	11-07-89	<5	<5	<5	<5	<10
RR-8	11-07-89	<5	<5	<5	<5	<10
Seepage meter 1-1	11-08-89	<5	<5	<5	<5	N.A.
Seepage meter 1-2	11-08-89	<5	<5	<5	<5	<10
Seepage meter 1-3	11-08-89	<5	<5	<5	<5	<10
Seepage meter 1-4	11-08-89	<5	<5	<5	<5	<10
Seepage meter 1-5	11-08-89	<5	<5	<5	<5	<10
Seepage meter 2-1	11-07-89	<5	<5	<5	<5	<10
Well point 2-1	11-08-89	<5	<5	<5	<5	<10
River sample 2-1	11-08-89	<5	<5	<5	<5	<10
Seepage meter 2-2	11-08-89	<5	<5	<5	<5	<10
Well point 2-2	11-08-89	<5	<5	<5	<5	<10/<10
River sample 2-2	11-08-89	<5/<5	<5/<5	<5/<5	<5/<5	<10
Seepage meter 2-3	11-08-89	<5	<5	<5	<5	<10
Well point 2-3	11-14-89	<5	<5	<5	<5	<10
River sample 2-3	11-14-89	<5	<5	<5	<5	<10
Seepage meter 2-4	11-07-89	<5	<5	<5	<5	<10
Well point 2-4	11-14-89	<5	<5	<5	<5	<10/<10
River sample 2-4	11-14-89	<5	<5	<5	<5	<10
Seepage meter 2-5	11-07-89	<5	<5	<5	<5	<10
Well point 2-5	11-14-89	<5	<5	<5	<5	<10
River sample 2-5	11-14-89	<5	<5	<5	<5	<10
Seepage meter 3-1	11-08-89	<5	<5	<5	<5	<10
Seepage meter 3-2	11-08-89	<5	<5	<5	<5	N.A.
Seepage meter 3-3	11-08-89	<5	<5	<5	<5	<10
Seepage meter 3-4	11-08-89	<5	<5	<5	<5	<10
Seepage meter 3-5	11-08-89	<5	<5	<5	<5	N.A.
Well point background	11-08-89	<5	<5	<5	<5	<10
River sample background	11-08-89	<5	<5	<5	<5	<10

[1]The sampling lines used for the seepage-meter, well-point, and river samples are located as shown in figure 2 and each location along the sampling line is numbered 1 through 5, starting from the southern side. The background samples were obtained about 100 feet upstream from the confluence of Woodland Creek with the Rock River. Ewers' pack 1, 2, 3, 4 refer to the packed interval 1, 2, 3, or 4 from which a water sample was pumped (table 1). Packed interval 5 blew out before a water sample was collected.

Table 3. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., April and May 1990

[Analyzed by U.S. Environmental Protection Agency contract laboratories. TCE, Trichloroethene; PCE, Tetrachloroethene; 1,1,1-TCEA, 1,1,1-Trichloroethane; 1,1-DCEE, 1,1-Dichloroethene; 1,2-DCEE, 1,2-Dichloroethene; <, less than; N.A., not analyzed; J, the concentration of the constituent is below contracted detectable limits; 34/33, values of duplicate samples. One or more trip of field blank samples taken for quality assurance/quality control had detectable concentrations of methylene chloride, acetone, 2-hexanone, chloroform, xylene, or 1,2-dichloropropane]

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		TCE	PCE	1,1,1-TCEA	1,1-DCEE	1,2-DCEE
B-3	04-30-90	2,100	170	<100	84J	790
B-6	05-01-90	750	<25	12J	<25	<25
Meyers Spring	04-30-90	34/33	<5/<5	<5/<5	<5/<5	2J/<5
MS-2	05-01-90	11	<5	<5	<5	3J
MW-2	04-30-90	<5	<5	<5	<5	<5
MW-20R	04-30-90	210	4J	7J	<10	11
MW-21	05-01-90	<5	<5	<5	<5	<5
MW-37	05-01-90	<5	<5	<5	<5	<5
MW-39	05-02-90	16/15	<5/<5	<5/<5	<5/<5	<5/<5
PC-1C	05-02-90	<5	<5	<5	<5	<5
RR-1	05-10-90	.8J	<2	<2	<2	<2
RR-2	05-15-90	.9J/.9J	<2/<2	<2/<2	<2/<2	<2/<2
RR-3	05-10-90	<2	<2	<2	<2	<2
RR-4	05-10-90	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2
RR-5	05-10-90	8	<2	<2	<2	1J
RR-6	05-11-90	5	<2	<2	<2	.9J
RR-7	05-14-90	<2	<2	<2	<2	<2
RR-8	05-14-90	<2	<2	<2	<2	<2
Well point 1-5	05-18-90	<2	<2	<2	<2	<2
River sample 1-5	05-18-90	<2	<2	<2	<2	<2
Well point 2-1	05-20-90	<.35/<.35	<.36/<.36	<.45/<.45	<.72/<.72	<.55/<.55
River sample 2-1	05-20-90	<.35	<.36	<.45	<.72	<.55
Well point 2-2	05-20-90	<.35	<.36	<.45	<.72	<.55
River sample 2-2	05-20-90	<.35	<.36	<.45	<.72	<.55
Well point 2-3	05-20-90	<.35	<.36	<.45	<.72	<.55
River sample 2-3	05-20-90	<.35	<.36	<.45	<.72	<.55
Well point 2-4	05-20-90	<.35	<.36	<.45	<.72	<.55
River sample 2-4	05-20-90	<.35	<.36	<.45	<.72	<.55
Well point 2-5	05-20-90	<.35	<.36	<.45	<.72	<.55
River sample 2-5	05-20-90	<.35	<.36	<.45	<.72	<.55
Well point 4-1	05-14-90	<2	<2	<2	<2	<2
Well point 4-2	05-16-90	<2	<2	<2	<2	<2
Well point 4-3	05-15-90	<2	<2	<2	<2	<2
Well point 4-4	05-14-90	<2	<2	<2	<2	<2
Well point 4-5	05-16-90	<2	<2	<2	<2	<2
Well point 4-6	05-14-90	.5J	<2	<2	<2	<2
Well point 4-7	05-17-90	<2/<2	<2/<2	<2/<2	<2/<2	<2/<2
Well point 4-8	05-16-90	well point did not recharge sufficiently to obtain water sample				
Well point background	05-18-90	<2	<2	<2	<2	<2
River sample background	05-18-90	<2	<2	<2	<2	<2

Table 3. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., April and May 1990–Continued

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		4-Methyl-2-Pentanone	Chloroform	2-Hexanone	Methylene chloride	Cyanide
B-3	04-30-90	<200	<100	<200	61J	908
B-6	05-01-90	<50	<25	<50	<50	23/24
Meyers Spring	04-30-90	<5/<5	<5/<5	<5/<5	<5/<5	19.5/N.A.
MS-2	05-01-90	<10	<5	<10	<5	N.A.
MW-2	04-30-90	<10	<5	<10	<5	N.A.
MW-20R	04-30-90	<20	<10	<20	<10	2.5
MW-21	05-01-90	3J	<5	4J	<5	N.A.
MW-37	05-01-90	<10	<5	<10	3J	N.A.
MW-39	05-02-90	3J/<10	<5/<5	<10/<10	2J/<5	N.A.
PC-1C	05-02-90	<10	<5	<10	7	N.A.
RR-1	05-10-90	<2	<2	<5	<1	N.A.
RR-2	05-15-90	<2/<2	8/8	<5/<5	<1/<1	N.A.
RR-3	05-10-90	<2	14	<5	<1	N.A.
RR-4	05-10-90	<2/<2	<2/<2	<5/<5	<1/<1	N.A.
RR-5	05-10-90	<2	<2	<5	<1	N.A.
RR-6	05-11-90	<2	<2	<5	<1	N.A.
RR-7	05-14-90	<2	<2	<5	<1	N.A.
RR-8	05-14-90	<2	<2	<5	<1	N.A.
Well point 1-5	05-18-90	<2	<2	<5	<1	N.A.
River sample 1-5	05-18-90	<2	<2	<5	<1	N.A.
Well point 2-1	05-20-90	<.98/<.98	<.31/<.31	<1.34/<1.34	<.98/<.98	N.A./N.A.
River sample 2-1	05-20-90	<.98	<.31	<1.34	<.98	N.A.
Well point 2-2	05-20-90	<.98	<.31	<1.34	<.98	N.A.
River sample 2-2	05-20-90	<.98	<.31	<1.34	<.98	N.A.
Well point 2-3	05-20-90	<.98	<.31	<1.34	<.98	N.A.
River sample 2-3	05-20-90	<.98	<.31	<1.34	<.98	N.A.
Well point 2-4	05-20-90	<.98	<.31	<1.34	<.98	N.A.
River sample 2-4	05-20-90	<.98	<.31	<1.34	<.98	N.A.
Well point 2-5	05-20-90	<.98	<.31	<1.34	<.98	N.A.
River sample 2-5	05-20-90	<.98	<.31	<1.34	<.98	N.A.
Well point 4-1	05-14-90	<2	<2	<5	<1	N.A.
Well point 4-2	05-16-90	<2	<2	<5	<1	N.A.
Well point 4-3	05-15-90	<2	<2	<5	<1	N.A.
Well point 4-4	05-14-90	<2	<2	<5	<1	N.A.
Well point 4-5	05-16-90	<2	<2	<5	<1	N.A.
Well point 4-6	05-14-90	<2	<2	<5	<1	N.A.
Well point 4-7	05-17-90	<2/<2	<2/<2	<5/<5	<1/<1	N.A.
Well point 4-8	05-16-90	well point did not recharge sufficiently to obtain water sample				
Well point background	05-18-90	<2	<2	<5	<1	NA
River sample background	05-18-90	<2	<2	<5	<1	NA

[1]The sampling lines used for the seepage-meter, well-point, and river samples are located as shown in figure 2. Line 4 was located parallel to the south river bank and the individual sites were spaced at preselected intervals in about 4 feet of water during the spring and summer sampling rounds.

Table 4. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., August and September 1990

[Analyzed by U.S. Environmental Protection Agency contract laboratories. TCE, Trichloroethene; PCE, Tetrachloroethene; 1,1,1-TCEA, 1,1,1-Trichloroethane; 1,1-DCEE, 1,1-Dichloroethene; 1,2-DCEE, 1,2-Dichloroethene; 1,2-DCEA, 1,2-Dichloroethane; <,less than; --, no additional organic compounds; J, the constituent was detected in the sample but the concentration was below the reporting level; 10/10, values of duplicate samples. One or more trip or field blank samples taken for quality assurance/quality control had detectable concentrations of methylene chloride, chloroform, toluene, acetone, 4-Methyl-2-Pentanone, 1,1,1-TCEA, or xylene]

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		TCE	PCE	1,1,1-TCEA	1,1-DCEE	1,2-DCEE
B-3	08-23-90	310	28	<5	29	200
Meyers Spring	08-29-90	34	<.36	1	<.72	1
Meyers Spring	09-20-90	40	1	2	<5	<5
MS-2	08-23-90	12	<5	<5	<5	<5
MW-1	08-21-90	<5	<5	<5	<5	<5
MW-2	08-21-90	<5	<5	<5	<5	<5
MW-15	08-22-90	210	3J	<5	4J	5
MW-16	08-22-90	200	3J	<5	4J	9
MW-20R	08-21-90	220	3J	<5	5J	10
MW-21	08-21-90	<5	<5	<5	<5	<5
MW-37	08-22-90	<5	<5	<5	<5	<5
MW-41	08-23-90	230/260	3J/4J	<5/<5	5/6	8/9
RR-1	09-17-90	<.7	<.6	<.7	<.8	<.8
RR-2	09-17-90	1/.9	<.6/<.6	<.7/<.7	<.8/<.8	<.8/<.8
RR-3	09-17-90	<.7	<.6	<.7	<.8	<.8
RR-4	09-17-90	<.7	<.6	<.7	<.8	<.8
RR-5	08-28-90	8	<.36	<.45	<.72	<.55
RR-5	09-20-90	6/6	<5/<5	<5/<5	<5/<5	<5/<5
RR-6	08-28-90	5/5	<.36/<.36	<.45/<.45	<.72/<.72	<.55/<.55
RR-7	08-27-90	<.35	<.36	<.45	<.72	<.55
RR-8	08-27-90	<.35	<.36	<.45	<.72	<.55
RR-9	08-28-90	11	<.36	<.45	<.72	1
Well point 2-1	09-19-90	<.7	<.6	<.7	<.8	<.8
River sample 2-1	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 2-2	09-19-90	<.7	<.6	<.7	<.8	<.8
River sample 2-2	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 2-3	09-19-90	<.7	<.6	<.7	<.8	<.8
River sample 2-3	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 2-4	09-20-90	<.7	<.6	<.7	<.8	<.8
River sample 2-4	09-20-90	<.7	<.6	<.7	<.8	<.8
Well point 2-5	09-20-90	<.7	<.6	<.7	<.8	<.8
River sample 2-5	09-20-90	<.7	<.6	<.7	<.8	<.8
Well point 4-1	09-18-90	<.7	<.6	<.7	<.8	<.8
River sample 4-1	09-18-90	<.7	<.6	<.7	<.8	<.8
Well point 4-2	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 4-3	09-19-90	<.7	<.6	<.7	<.8	<.8
River sample 4-3	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 4-4	09-19-90	<.7	<.6	<.7	<.8	<.8
Well point 4-5	09-18-90	1	<.6	<.7	<.8	<.8
River sample 4-5	09-18-90	<.7	<.6	<.7	<.8	<.8
Well point 4-6	08-29-90	<.35	<.36	<.45	<.72	<.55
Well point 4-6	09-18-90	.8	<.6	<.7	<.8	<.8
River sample 4-6	09-18-90	.8	<.6	<.7	<.8	<.8
Seepage meter 4-6	08-29-90	<.7	<.6	<.7	<.8	<.8
Well point 4-6U	09-18-90	<.7	<.6	<.7	<.8	<.8
Well point 4-6D	09-18-90	<.7	<.6	<.7	<.8	<.8
Seepage meter 4-6D	09-20-90	<.7	<.6	<.7	<.8	<.8
Well point 4-6F	09-20-90	.8/1	<.6/<.6	<.7/<.7	<.8/<.8	<.8/<.8
River sample 4-6F	09-20-90	<.7	<.6	<.7	<.8	<.8
Well point 4-6N	08-29-90	<.35	<.36	<.45	<.72	<.55
Well point 4-6N	09-18-90	<.7/<.7	<.6/<.6	<.7/<.7	<.8/<.8	<.8/<.8
Well point 4-7	09-18-90	<.7	<.6	<.7	<.8	<.8
Well point 4-8	09-18-90	<.7	<.6	<.7	<.8	<.8
River sample 4-8	09-18-90	<.7	<.6	<.7	<.8	<.8
Well point background	09-20-90	<.7	<.6	<.7	<.8	<.8
River sample background	09-20-90	<.7	<.6	<.7	<.8	<.8

Table 4. Concentrations of volatile organic compounds and cyanide in ground water in the vicinity of the Byron Superfund site near Byron, Ill., August and September 1990—Continued

Well or site name or number[1]	Sampling date	Concentration, in micrograms per liter				
		1,2-DCEA	Chloroform	Toluene	Methylene-chloride	Other compounds
B-3	08-23-90	<5	<5	<5	<9	([2,3])
Meyers Spring	08-29-90	<.37	<.31	.4J	<.98	([4])
Meyers Spring	09-20-90	<5	<5	.4J	<5	([4])
MS-2	08-23-90	<5	<5	3J	9	--
MW-1	08-21-90	<5	<5	<5	17	--
MW-2	08-21-90	<5	<5	<5	<5	--
MW-15	08-22-90	<5	<5	<5	8	--
MW-16	08-22-90	<5	<5	<5	9	--
MW-20R	08-21-90	2J	<5	<5	16	--
MW-21	08-21-90	<5	<5	<5	<5	--
MW-37	08-22-90	<5	<5	2J	11	--
MW-41	08-23-90	<5/<5	<5/<5	<5/2J	12/11	--/--
RR-1	09-17-90	<.4	<.6	<.8	<1	([5])
RR-2	09-17-90	<.4/<.4	7/7	<.8/<.8	<1/<1	--/--
RR-3	09-17-90	<.4	5	<.8	<1	([4])
RR-4	09-17-90	<.4	<.6	<.8	<3	([6])
RR-5	08-28-90	<.37	<.31	<.65	<.98	--
RR-5	09-20-90	<5/<5	<5/<5	<5/<5	<5/<5	([4])/--
RR-6	08-28-90	<.37/<.37	<.31/<.31	<.65/<.65	<.98/<.98	--/--
RR-7	08-27-90	<.37	<.31	<.65	<.98	--
RR-8	08-27-90	<.37	<.31	<.65	<.98	--
RR-9	08-28-90	<.37	<.31	<.65	<.98	--
Well point 2-1	09-19-90	<.4	<.6	<.8	2	--
River sample 2-1	09-19-90	<.4	<.6	<.8	<1	--
Well point 2-2	09-19-90	<.4	<.6	<.8	<1	--
River sample 2-2	09-19-90	<.4	<.6	<.8	2	--
Well point 2-3	09-19-90	<.4	<.6	<.8	<1	--
River sample 2-3	09-19-90	<.4	<.6	<.8	<1	--
Well point 2-4	09-20-90	<.4	<.6	<.8	<1	--
River sample 2-4	09-20-90	<.4	<.6	<.8	<1	--
Well point 2-5	09-20-90	<.4	<.6	<.8	<1	([7])
River sample 2-5	09-20-90	<.4	<.6	<.8	<1	([8])
Well point 4-1	09-18-90	<.4	<.6	<.8	1J	--
River sample 4-1	09-18-90	<.4	<.6	<.8	<1	--
Well point 4-2	09-19-90	<.4	<.6	<.8	<1	--
Well point 4-3	09-19-90	<.4	<.6	<.8	<1	--
River sample 4-3	09-19-90	<.4	<.6	.6J	<1	([9])
Well point 4-4	09-19-90	<.4	<.6	<.8	2	--
Well point 4-5	09-18-90	<.4	<.6	<.8	1J	--
River sample 4-5	09-18-90	<.4	<.6	<.8	<1	--
Well point 4-6	08-29-90	<.37	<.31	<.65	<.98	--
Well point 4-6	09-18-90	<.4	<.6	<.8	<1	--
River sample 4-6	09-18-90	<.4	<.6	<.8	<1	--
Seepage meter 4-6	08-29-90	<.4	<.6	<.8	<1	--
Well point 4-6U	09-18-90	<.4	<.6	<.8	<1	--
Well point 4-6D	09-18-90	<.4	<.6	<.8	<1	--
Seepage meter 4-6D	09-20-90	<.4	<.6	<.8	<1	([10])
Well point 4-6F	09-20-90	<.4/<.4	<.6/<.6	<.8/<.8	<1/<1	--/([8])
River sample 4-6F	09-20-90	<.4	<.6	<.8	<1	--
Well point 4-6N	08-29-90	<.37	<.31	<.65	<.98	--
Well point 4-6N	09-18-90	<.4/<.4	<.6/<.6	<.8/<.8	<1/<1	--/--
Well point 4-7	09-18-90	<.4	<.6	<.8	<1	--
Well point 4-8	09-18-90	<.4	<.6	<.8	<1	--
River sample 4-8	09-18-90	<.4	<.6	<.8	<1	--
Well point background	09-20-90	<.4	<.6	<.8	<1	--
River sample background	09-20-90	<.4	<.6	<.8	<1	--

[1]Several additional sampling sites were established around site 4-6 during the summer sampling period; they are not shown in figure 2 because of their proximity to site 4-6. Site 4-6N is located at river bank opposite site 4-6; site 4-6F is located about 25 feet from site 4-6 in the opposite direction from shore; site 4-6U is located about 50 feet upriver and in about the same depth of water; and site 4-6D is located about 55 feet downriver and in about the same depth of water.

[2]120 µg/L Vinyl chloride. [3]4J µg/L Benzene. [4]2 µg/L 4-Methyl-2-Pentanone. [5]3 µg/L 4-Methyl-2-Pentanone. [6]2 µg/L Chloromethane. [7]11 µg/L Acetone. [8]10 µg/L Acetone. [9]1 µg/L 4-Methyl-2-Pentanone. [10]13 µg/L Acetone.

Ground-Water Discharge to the Rock River

The total ground-water discharge to the Rock River in the ¾-mi reach was estimated by three independent methods–seepage-meter measurements, application of the modified Darcy equation, and numerical ground-water-flow modeling. The values of ground-water discharge to the Rock River estimated by these methods range from 16,300 to 30,900 ft^3/d; the low value, determined by the modified Darcy equation, was only that discharge from the southern side of the Rock River.

Actual ground-water discharge to the river was measured in fall of 1989 by means of seepage meters placed on the river bottom along three transects (fig. 2). The range of seepage collected at the meters was from 2.2 to 421 mL/h (milliliters per hour). Excluding the anomalously large values from two meters that were affected greatly by leakage of river water into the meters, the average seepage rate was about 40 mL/h, or 960 mL/d (milliliters per day). This value, extrapolated to the ¾-mi reach of the river, results in a total estimated ground-water discharge to the river of 30,900 ft^3/d. This discharge value includes ground water that flows toward both sides of the river to discharge along this reach.

The second method of estimating ground-water discharge to the river was used to determine only discharge from the southern side of the river; the method incorporates the assumption that all ground-water flow through the entire thickness of the St. Peter aquifer from the southern side of the river discharges to the river. This discharge can be estimated by the modified Darcy formula,

$$Q = KIA, \tag{1}$$

where

Q is ground-water discharge;

K is horizontal hydraulic conductivity of the St. Peter aquifer [5.7 ft/d (feet per day)];

I is horizontal hydraulic gradient of the flow system in the St. Peter aquifer at the river [0.0017 ft/ft (foot per foot)]; and

A is cross-sectional area of the St. Peter aquifer (1.68×10^6 ft^2).

By use of this formula, the ground-water discharge to the river from the St. Peter aquifer south of the river was estimated to be 16,300 ft^3/d. The horizontal hydraulic conductivity was calculated from data from well MS-2, the well nearest the river open to the St. Peter aquifer. The horizontal hydraulic gradient was the change in water level from MW-2 to the river, a distance of about 8,200 ft. The cross-sectional area of the St. Peter aquifer was determined from the estimated thickness of the fully saturated St. Peter Sandstone (400 ft) and the width of the study area at the river (about 4,200 ft).

The third method of estimating ground-water discharge to the river was a preliminary simulation of ground-water flow along a vertical section (fig. 1) through the ground-water system following a flow line from the Byron Superfund site to the river with a finite-difference numerical ground-water-flow model. (Model development is discussed in the section on Underflow and Dispersal of Contaminants later in this report.) Discharge to the river was simulated in the model by an algorithm that determined the amount of water discharged from the flow system as a result of differences between water levels in the aquifer immediately underlying the river and the river stage, and the vertical hydraulic conductivity of the riverbed material. Results of the model simulation indicate that the discharge to the river in the cross-sectional unit area of the river is 4.62 ft^3/d, or an estimated 19,400 ft^3/d when extrapolated to the entire river reach. This discharge includes ground-water flow from both the northern and southern sides of the river.

Contaminant Loading to the Rock River

Ground-water contaminants at the Byron Superfund site and downgradient toward the river include VOC's and cyanide (tables 2-4). Contamination by VOC's originating from the Byron Superfund site is greatest in the Galena-Platteville aquifer. The St. Peter aquifer is contaminated with VOC's at wells MS-2, MW-18, and MW-20R. The alluvial aquifer is contaminated with VOC's at wells RR-2, RR-5, RR-6, RR-9, and RR-10 (tables 2-4). Cyanide and TCE are present at Meyers Spring. Of the VOC's determined in water samples from the vicinity of the Rock River, TCE is present most persistently and in the highest concentrations because its concentration at the Byron Superfund site is the highest of any VOC, and it is not readily biodegradable. The presence of methylene chloride in wells RR-1, RR-2, and RR-3 and of chloroform in well RR-2 appear to be isolated detections of these compounds that are unrelated to contamination from the Byron Superfund site; methylene chloride most likely was introduced into the sample at the laboratory, and chloroform can emanate from septic systems (Douglas Yeskis, oral commun., 1990).

Water samples were collected from selected wells on the basis of accessibility and areal distribution in May 1991 and analyzed for VOC's to estimate the lateral and vertical extent of the contaminant plume near the Rock River. The results of analyses for TCE, a major organic contaminant, and field-determined water-quality properties are as follows:

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mvolts, millivolts; µg/L, micrograms per liter; <, less than]

Well-site number (fig. 2)	pH (standard units)	Specific conductance (µS/cm)	Temperature (°C)	Eh (mvolts)	Trichloroethene (µg/L)
1	7.2	593	11.7	84	<2
2	7.3	601	11.2	106	<2
3	7.1	894	15.3	93	7
4	7.2	859	13.6	121	[1]11/10
5 (RR-5)	7.4	786	11.9	152	[1]6/8
6 (RR-9)	6.9	837	11.6	119	8
7	7.0	881	11.9	94	4
8	7.0	935	12.9	123	5

[1]Duplicate samples

An estimate of the lateral distribution of the contaminants was made from these data but the vertical distribution of contaminants could not be determined because depth information was lacking for most of the wells. The water-quality data did not show a conclusive lateral pattern, probably because of the variable depths at which the wells were open to the aquifer. The center of the contaminant plume was estimated to be upgradient from wells RR-5 and RR-9 and to intersect the river at an oblique angle (fig. 3) on the basis of the TCE concentrations in water from well points temporarily installed in the river and wells in Rock River Terrace.

A test hole (RR-10) (fig. 3) was augered in October 1991 along the estimated centerline of the contaminant plume and as close to the river as property access would allow, which was about 195 ft from the river. Drilling was done with a lead-screen hollow-stem auger that was advanced at 5-ft intervals. Ground water was sampled at 5-ft intervals and analyzed for VOC's by means of a portable gas chromatograph. Only TCE concentrations were quantified, although the presence of very low concentrations of other compounds was sometimes indicated by the chromatograms (Robert Brock, U.S. Geological Survey, written commun., 1991). A low-discharge pump and packer assembly was used to pack off the overlying water column about 5 ft above the lead-screen auger flight. Three well volumes of water, unless otherwise indicated, were pumped from the hollow-stem-auger string before each water sample was collected. Results of water-quality sampling are shown in table 5.

The highest concentrations of TCE in test hole RR-10 were found at depths of 59 and 64 ft. The contaminant was dispersed across a vertical interval of about 75 ft, from 19 to 94 ft below land surface.

The increasing upward hydraulic gradient with depth indicates that ground water to a depth of 119 ft flows to the river. The same vertical hydraulic gradients at depths of 64 and 89 ft indicate that ground water between those depths flows horizontally. This is possible because the only location where only vertical ground-water flow would be expected is directly under the river. All of the contaminated ground water discharges to the Rock River, as indicated by the absence of TCE below a depth of 109 ft, and increasing vertical head gradients with depth indicate that ground water to a depth of 119 ft flows to the river.

TCE is the only VOC present in measurable concentrations in ground water that is discharging to the Rock River, as determined from analyses of water samples from the observation wells along the river. The minimum detectable concentration of TCE ranged from 0.35 to 5 µg/L, depending on which USEPA CLP laboratory analyzed the sample. The concentrations of TCE detected in the samples of ground-water discharge to the river never exceeded 2 µg/L. The maximum possible discharge of TCE to the river reach during the period of study can be determined by multiplying the estimated ground-water-discharge rate to the area of the river reach (30,900 ft^3/d, as interpolated from measurements made with the seepage meters) by 2 µg/L. The maximum discharge of TCE is estimated to be about 1.7 g/d (grams per day). This is a maximum possible value because the TCE concentration in the ground-water discharge at the river did not exceed 2 µg/L during any of the sampling periods and was of much less concentration along most of the river during all of the sampling periods.

Table 5. Field water quality, trichloroethene concentrations, and vertical hydraulic gradient at well RR-10, October 1991

[LSD, land-surface datum; ft, feet; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mvolts, millivolts; µg/L, micrograms per liter; ND, not detected; <, less than; 1 WV, number of well volumes withdrawn before sampling; --, not determined]

Depth to sample below LSD (ft)	pH (standard units)	Specific conductance (µS/cm)	Temperature (°C)	Eh (mvolts)	Trichloroethene concentration (µg/L)	Vertical hydraulic gradient[1]
14	7.1	1,276	13.9	28	ND	-0.010
19	7.1	1,248	13.1	-8	1	--
24	7.2	1,121	12.4	28	1	--
29	--	1,010	12.1	40	1	--
34	--	--	--	--	1	--
39	--	--	--	--	2	--
44	7.1	823	12.0	46	2	--
49	7.1	823	12.2	28	1	--
54 (2 WV)	--	--	--	--	2	--
54 (4 WV)	--	--	--	--	2	--
54 (6 WV)	7.2	864	11.6	-5	1	--
59 (1 WV)	--	--	--	--	2	--
59 (4 WV)	--	--	--	--	3	--
59 (6 WV)	7.2	884	11.8	33	2	--
64	--	--	--	--	3	--
64 (6 WV)	7.1	853	11.5	-2	3	+.045
69	7.1	852	11.1	40	1	--
74	7.1	796	11.1	55	<1	--
79	7.1	749	11.2	32	<1	--
84	7.1	728	11.2	5	<1	--
89	7.2	734	11.3	4	<1	+.045
94	7.2	700	11.7	46	<1	--
99			did not sample			
104			could not pump enough water			
109	7.0	602	12.0	27	ND	--
114			did not sample			
119 (1 WV)	--	--	--	--	ND	+.095

[1](-) value means water level in well below river level; (+) value means water level in well above river level.

Underflow and Dispersal of Contaminants

Even though water levels in wells open to the alluvial aquifer along the river indicate that ground water is discharging to the river, some ground water in the St. Peter aquifer may be passing beneath the Rock River as part of a regional flow system. No wells open to the St. Peter aquifer are available to verify this possibility. If some water in the St. Peter aquifer is bypassing the Rock River by underflow, contaminants that are being transported in the St. Peter aquifer would then be carried along the regional flow path. If underflow occurs, (1) containment of the contamination would be unlikely, and (2) the contaminants could affect other ground-water supplies drawn from the St. Peter aquifer in this regional flow path.

The hypothesis that ground water flows beneath the Rock River was examined by modeling the ground-water-flow system. A finite-difference numerical model (McDonald and Harbaugh, 1988) was used to simulate ground-water flow along a vertical section through the flow system that extends along the ground-water-flow path from a point about 0.5 mi southeast of and upgradient from the Byron Superfund site downgradient to a point about 1 mi on the other side of the river. The numerical model was constructed to help conceptualize the distribution of hydraulic properties and the directions of ground-water flow in the aquifer system. A rough calibration to several known ground-water levels was done. Reasonable vertical head distributions across the Glenwood Formation, across the confining unit between the Galena-Platteville and St. Peter aquifers, and at the river in the alluvial aquifer were obtained. Model-simulated water levels were within 10 ft of measured water levels at observation wells in the St. Peter and alluvial aquifers.

The lack of some data forced assumptions to be made in the model about boundary conditions and the distribution of hydraulic properties. The assumed no-flow boundary at the base of the model probably is not realistic because the depths of the alluvium and St. Peter Sandstone below the river are unknown, as are the steady-state ground-water fluxes along the lateral boundaries at each end of the model. A vertical distribution of estimated constant-head values was used at each lateral boundary. The distribution and values of horizontal and vertical hydraulic conductivities used in the model simulation were changed slightly to calibrate to the measured water levels. The resultant ground-water-flux distribution at the lateral boundaries resulted in deep, near-vertical flow paths in the St. Peter aquifer, as determined with the particle-tracking routine of the computer model (Pollock, 1989). The horizontal and vertical water-level distribution in the model is very sensitive to changes in the hydraulic properties of the Glenwood Formation, about which very little is known. The measured 50-ft hydraulic-head loss with depth in the Galena-Platteville aquifer (Douglas Yeskis, oral commun., 1990) could not be simulated by the model. The hydraulic-head distribution in the St. Peter aquifer on the northern side of the river is unknown.

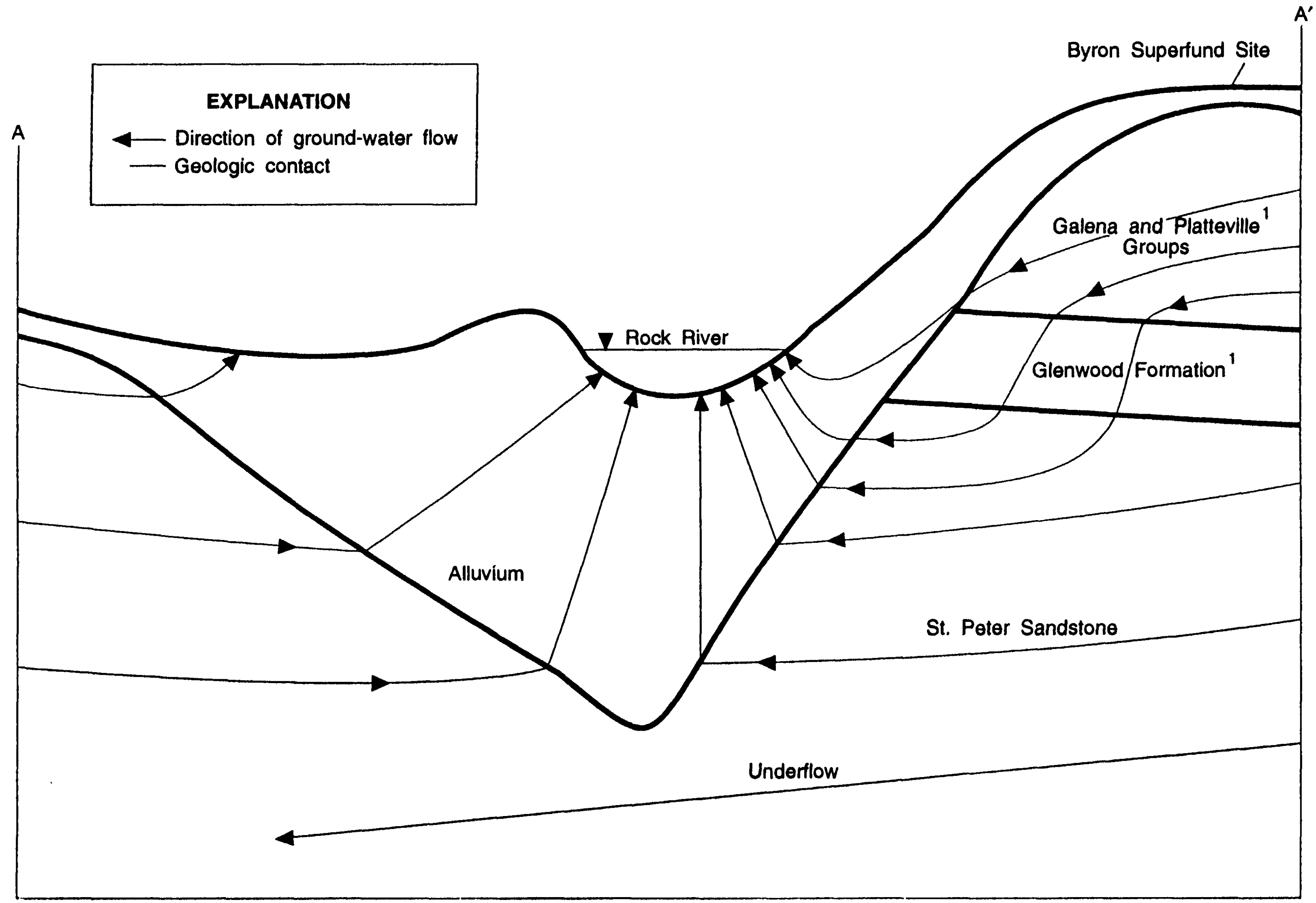
When a decreasing hydraulic-head distribution and a discharge-flux boundary in the St. Peter aquifer on the northern side of the river were placed in the model in an attempt to simulate underflow beneath the Rock River, a small amount of underflow did occur. The water, however, entered the flow system along the lateral boundary upgradient from the Byron Superfund site more than 150 ft below the top of the St. Peter aquifer. Results of model simulation indicate that the underflow would be ground water that already was present at depth in the flow system at the Byron Superfund site rather than contaminated water that had recharged the ground-water-flow system in the vicinity of the Byron Superfund site (fig. 5).

SUMMARY

This report describes the results of the study of the interaction between the ground-water system and the Rock River in the vicinity of the Byron Superfund site near Byron, Ill., and gives estimates of the loading of contaminants originating from the Byron Superfund site to the Rock River. The report discusses the methods used to collect detailed data regarding ground-water levels, ground-water discharge to the Rock River, and ground-water chemistry as related to the contaminant loading of the Rock River. The work was done during October 1989–October 1991. The hydrology of the area between the Byron Superfund site and the Rock River is complex because of the presence of fractures and solution openings in the dolomite of the Galena and Platteville Groups, the truncation of the Galena and Platteville Groups at the river bluffs, and the contrasting hydraulic properties of the Galena and Platteville Groups, the St. Peter Sandstone, the Glenwood Formation, and the alluvial deposits.

The values of ground-water discharge to the Rock River estimated by three independent methods–seepage meters, the modified Darcy equation, and numerical ground-water-flow modeling–ranged from 16,300 to 30,900 ft^3/d; the low value, calculated by use of the modified Darcy equation, is an estimate only of ground-water discharge from the southern side of the Rock River. An estimate of the lateral distribution of the contaminants was made from selected water-quality data, but the vertical distribution of contaminants could not be determined because data on depths of most of the wells were unavailable. A test hole (RR-10) was augered in October 1991 to determine the vertical distribution of contaminants along the estimated centerline of the contaminant plume about 195 ft from the river. The highest concentrations of trichloroethene (TCE) (3 µg/L) in test hole RR-10 were found at depths of 59 and 64 ft. The contaminant was dispersed across a vertical interval of about 75 ft at depths of 19 to 94 ft below land surface. All of the contaminated ground water is discharging to the Rock River, as indicated by the absence of TCE below a depth of 109 ft and increasing vertical head gradients with depth that indicates ground water to a depth of 119 ft flows to the river. The maximum possible discharge of TCE to the river reach during the period of study is estimated to be about 1.7 g/d.

A finite-difference numerical model was used to simulate ground-water flow along a vertical section through the ground-water system from the Byron Superfund site to the Rock River. Model simulation indicates that any underflow in the St. Peter aquifer



[1] Unit represents usage of the Illinois State Geological Survey

Not to scale

Figure 5. Generalized hydrogeologic section showing model-simulated ground-water flow paths between the Byron Superfund site and the Rock River, and hypothetical ground-water flow beneath the Rock River. (See fig. 1 for location of line of section.)

beneath the Rock River would be ground water that already was present at depth in the flow system at the Byron Superfund site rather than contaminated water that had recharged the ground-water-flow system in the vicinity of the Byron Superfund site.

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