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# Areal Studies Aid Protection of Ground-Water Quality in Illinois, Indiana, and Wisconsin

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In 1991, the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, initiated studies designed to characterize the ground-water quality and hydrogeology in northern Illinois, and southern and eastern Wisconsin (with a focus on the north-central Illinois cities of Belvidere and Rockford, and the Calumet region of northeastern Illinois and northwestern Indiana). These areas are considered especially susceptible to ground-water contamination because of the high density of industrial and waste-disposal sites and the shallow depth to the unconsolidated sand and gravel aquifers and the fractured, carbonate bedrock aquifers that underlie the areas. The data and conceptual models of ground-water flow and contaminant distribution and movement developed as part of the studies have allowed Federal, State, and local agencies to better manage, protect, and restore the water supplies of the areas.

Water-quality, hydrologic, geologic, and geophysical data collected as part of these areal studies indicate that industrial contaminants are present locally in the aquifers underlying the areas. Most of the contaminants, particularly those at concentrations that exceeded regulatory water-quality levels, were detected in the sand and gravel aquifers near industrial or waste-disposal sites. In water from water-supply wells, the contaminants that were present generally were at concentrations below regulatory levels. The organic compounds detected most frequently at concentrations near or above regulatory levels varied by area. Trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane (volatile

chlorinated compounds) were most prevalent in north-central Illinois; benzene (a petroleum-related compound) was most prevalent in the Calumet region. Differences in the type of organic compounds that were detected in each area likely reflect differences in the types of industrial sites that predominate in the areas. Nickel and aluminum were the trace metals detected most frequently at

concentrations above regulatory levels in both areas. Contaminants in the shallow sand and gravel aquifers and carbonate aquifers appear to have moved with ground water discharging to local lakes, streams, and wetlands. Ground-water flow and possibly contaminant movement is concentrated in the weathered surface zones and in deeper fractures of the carbonate aquifers underlying both areas.

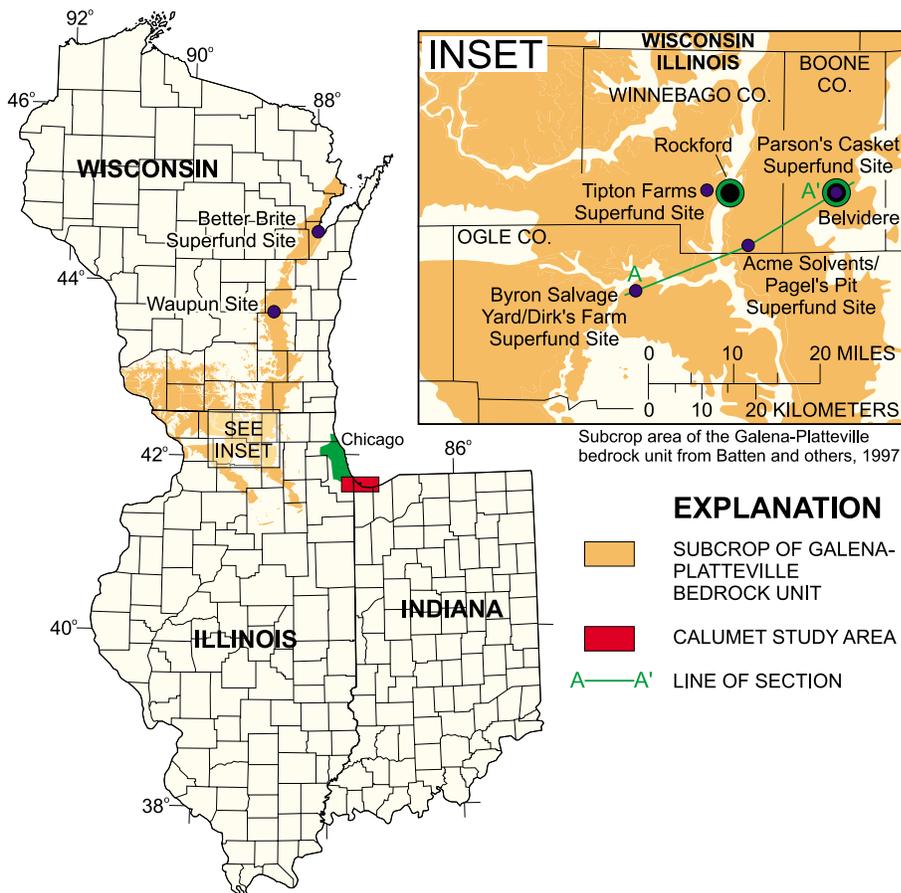


Figure 1. Subcrop of Galena-Platteville bedrock unit, line of section A-A', and study areas in Illinois, Indiana, and Wisconsin.

## INTRODUCTION

In industrialized areas, hazardous-waste-disposal sites commonly are located a short distance from each other (less than 1 mile). Ground-water contamination that may be associated with the sites can result in coalescing contaminant plumes that extend for long distances from the sites (in some cases more than 2 miles). Thorough understanding of the hydraulic, geologic, and chemical properties of the aquifer(s) that affect local and regional ground-water flow and contaminant movement enables determination of the extent of ground-water contamination derived from each site. Areal characterizations of aquifers, especially characterizations based on the analysis of extensive field data, provide the conceptual foundation necessary for investigators beginning site-specific studies at waste-disposal sites to effectively and efficiently assess the local hydrogeologic conditions. Areal characterizations also are necessary in areas where contaminants have been detected in public water-supply wells that are remote from known sources of contamination.

In 1986, the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA), Region V, Office of Superfund, began studies of the water quality and hydrogeology of specific hazardous-waste sites in Illinois. A need was recognized for an areal characterization of the water quality and the relation of water quality to the hydrogeology to resolve ground-water-contamination issues associated with the cleanup of many of the hazardous-waste sites and to protect public-water supplies. Therefore, the USGS and the USEPA initiated ground-water-quality studies in two areas in Illinois that extended into the neighboring States of Wisconsin and Indiana. These studies, begun in 1991, were designed to characterize the ground-water quality and its relation to the prevailing hydrogeology in areas that ranged in size from part of a municipality to parts of two States. The areas included (1) northern Illinois and southern and eastern Wisconsin and (2) the Calumet region of northeastern Illinois and northwestern Indiana (near Chicago) (fig. 1). The study in

northern Illinois and southern and eastern Wisconsin focused on north-central Illinois, including the cities of Belvidere and Rockford. Conceptual models of ground-water flow and contaminant distribution and movement that were developed as part of the studies will allow Federal, State, and local agencies to better manage, protect, and restore the quality of the areas' water supplies. This report summarizes selected results of the completed and ongoing areal studies conducted by the USGS and the USEPA during 1991–98.

## WATER QUALITY AND HYDROGEOLOGY OF NORTHERN ILLINOIS AND SOUTHERN AND EASTERN WISCONSIN

Aquifers in the glacial drift (sand and gravel) of Quaternary age (less than about 75,000 years old) (fig. 2) and the carbonate deposits (dolomite and limestone) of the Platteville and Galena Groups of Ordovician age (about 450 million years old) are a major water-supply source in northern Illinois and southern Wisconsin. The glacial drift and Galena-Platteville aquifers are considered highly susceptible to contamination because the aquifers are near the land surface (each typically at a depth of less than 50 feet (ft)) and the deposits that compose and overlie the aquifers have relatively high hydraulic conductivity (at least 1 foot per day) (Keefer, 1995). Winnebago County, in the approximate center of the area of study (fig. 1), is considered to have the greatest potential for ground-water contamination of any county in Illinois (Bhagwat and Berg, 1991). Contaminants typically associated with industrial wastes have been detected in many water-supply wells open to the shallow aquifers of the region, particularly near the cities of Belvidere and Rockford (fig. 1). The study of water quality in northern Illinois and southern and eastern Wisconsin consists of (1) a general characterization of the hydrogeology of the entire Galena-Platteville aquifer and (2) a focused characterization of the water quality and hydrogeology of the glacial drift and Galena-Platteville aquifers in Belvidere and Rockford.

SYSTEM	ROCK STRATIGRAPHY	AQUIFER OR CONFINING UNIT
QUATERNARY	Undesignated	Glacial drift aquifer (northern Illinois, southern Wisconsin)
		Calumet aquifer (northeastern Illinois, northwestern Indiana)
DEVONIAN	Atrium Shale	Confining unit
	Traverse Formation	Silurian-Devonian aquifer
	Detroit River Formation	
SILURIAN	Racine Dolomite (northeastern Illinois)	Silurian-Devonian aquifer
	Wabash Formation (northwestern Indiana)	
ORDOVICIAN	Maquoketa Shale Group	Confining unit
	Galena Group	Galena-Platteville aquifer
	Platteville Group	
	Glenwood Formation	Confining unit
	St. Peter Sandstone	St. Peter Sandstone aquifer
CAMBRIAN	Eminence Formation	Confining unit
	Potosi Dolomite	
	Franconia Formation	
	Ironton Sandstone	Ironton-Galesville aquifer
	Galesville Sandstone	
	Eau Claire Formation	Confining unit
	Elmhurst Sandstone Member	Elmhurst-Mt. Simon aquifer
	Mt. Simon Sandstone	

**Figure 2.** Generalized stratigraphy and hydrogeologic units in northern Illinois, southern Wisconsin, northeastern Illinois, and northwestern Indiana (modified from Woller and Sanderson, 1974, fig. 1, and Nicholas and others, 1987, fig. 3.1-1).

### Galena-Platteville Aquifer

The carbonate bedrock that composes the Galena-Platteville aquifer is present at the land surface, or directly underlies thin soil or glacial deposits, across most of northern Illinois and southern and eastern Wisconsin (fig. 1). In this subcrop area along the axis of the structural Wisconsin Arch, the Galena-Platteville deposits are predominately dolomite (Willman and Kolata, 1978). The carbonate bedrock has been fractured to varying degrees by structural forces and partly dissolved by ground water. The fractures include near-vertical joints to near-horizontal partings developed along bedding planes. The resulting increase in the vertical and horizontal

hydraulic conductivity of the aquifer allows rapid distribution of contaminants that may enter the aquifer through the overlying glacial deposits. Protection of the water quality of the Galena-Platteville aquifer is of great importance in the area because the aquifer is the source of water for thousands of residential wells and hundreds of industrial and municipal supply wells.

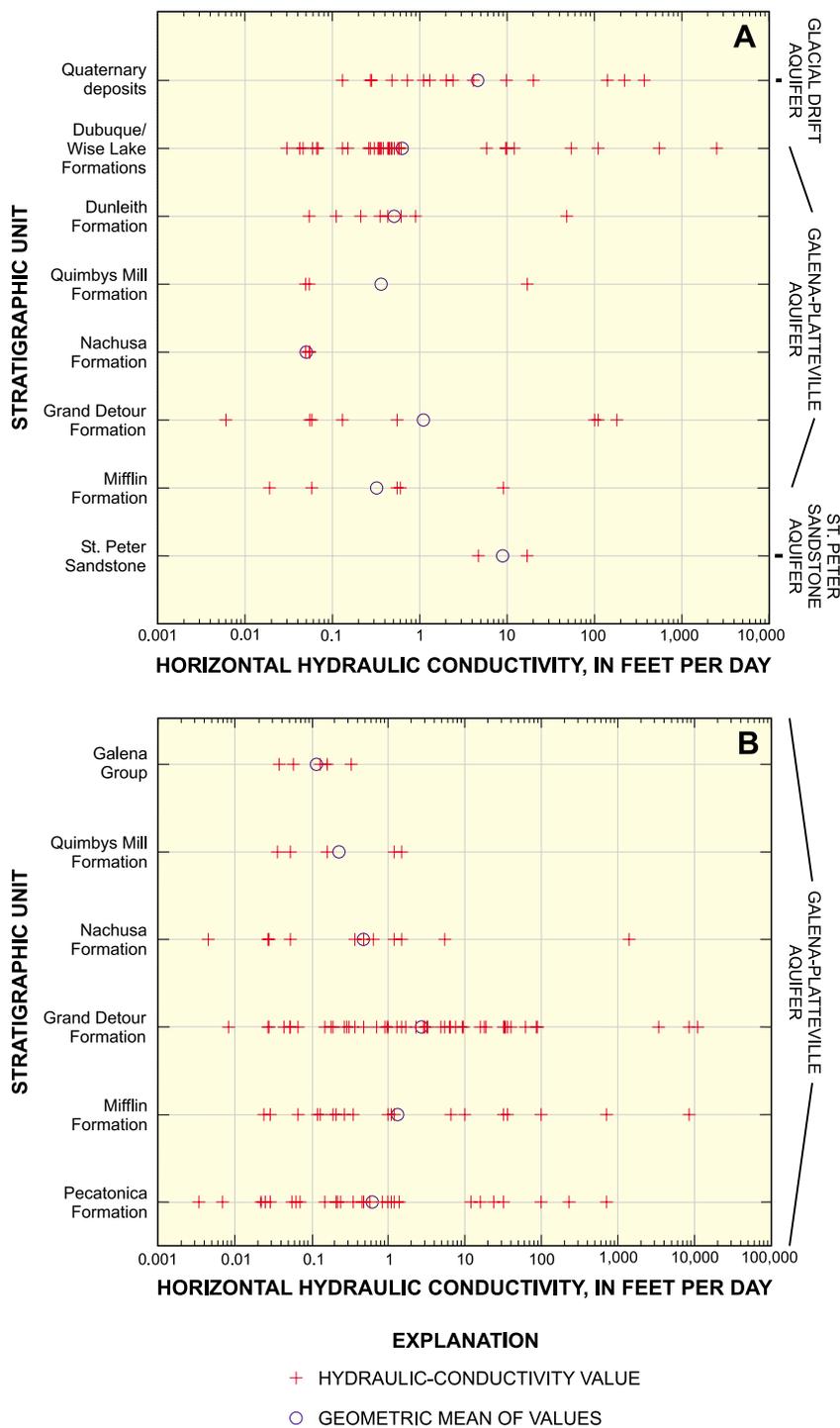
Effective characterization of the geology and hydrology of the Galena-Platteville aquifer and their relation to contaminant movement is difficult because of the heterogeneous (nonuniform) nature of the fractures. Unfortunately, the detailed data necessary for thorough characterization can be difficult and expensive to obtain. Because of the difficulty and expense of data collection, detailed assessments have not been done routinely. The data that have been collected commonly are not readily available to the public. Many of the sites are under investigation for regulatory reasons, and the data are not published.

In order to overcome the obstacles described above, the USGS has developed three general products to assist current and future investigators seeking to characterize the hydrogeology and contaminant movement in the Galena-Platteville aquifer. These products include (1) a bibliography of selected references on the hydrogeologic and chemical properties of the Galena-Platteville bedrock unit, (2) a series of maps detailing the geometry of the unit, and (3) a compilation of various types of hydrogeologic data. References in the bibliography are arranged by their application to counties in Illinois and Wisconsin and include assigned key words referencing the content to geophysical, hydraulic, and physical properties; lithology; inorganic and organic geochemistry; and water use. The maps include a planimetric map of the subcrop area of the Galena-Platteville bedrock unit and contour maps of the depth to the bedrock surface, the topography of the bedrock surface, and the thickness of the bedrock unit. The hydrogeologic data, which are available from the USGS upon request, include extensive lithologic, hydrologic, geophysical, and water-quality data collected at sites

investigated by the USGS and USEPA. The data were obtained, in part, from evaluation of rock cores, geophysical logging and water-quality sampling of test boreholes and monitoring wells and single- and multiple-well aquifer tests. The distribution of horizontal hydraulic

conductivity within the stratigraphic units that compose the Galena-Platteville aquifer at two sites in Illinois is shown in figure 3.

Preliminary analysis of the hydrogeologic and water-quality data available from the Galena-Platteville aquifer in



north-central Illinois indicates that (1) elevated concentrations of contaminants are not routinely associated with intervals of elevated hydraulic conductivity except at the Byron Salvage Yard near Byron, Ill. (fig. 1), where fracture-related hydraulic conductivities are among the highest in the area; (2) solution zones with appreciable hydraulic conductivity may coincide with stratigraphic transitions and, thus, can be areally continuous; (3) hydraulic properties of individual stratigraphic units, including hydraulic conductivity and porosity, generally vary across the area; (4) the variability of the properties associated with a particular stratigraphic unit is site dependent; (5) throughout the area, ground-water flow is primarily through fractures in the aquifer and contributions of flow through pores in the dolomite matrix varies locally; (6) vertical gradients in the aquifer generally are downward; and (7) flow between the Galena-Platteville aquifer and the underlying St. Peter Sandstone aquifer likely increases east of Rockford (figs. 1 and 4). The Harmony Hill Shale

Member of the Glenwood Formation that directly underlies the Galena-Platteville aquifer thins in the eastern part of the area and seems to be increasingly coarse grained, thus, reducing its capacity to restrict flow and possibly the movement of contaminants between the two aquifers. Most municipal water-supply wells in the area are open, in part, to the St. Peter Sandstone aquifer, with many of the wells open to the Galena-Platteville aquifer and the St. Peter Sandstone aquifer.

Preliminary analysis of the hydrogeologic and water-quality data available from the Galena-Platteville aquifer in Wisconsin indicate that the hydraulic characteristics of the aquifer vary substantially between the southern part and the northeastern part of the area (fig. 1). The hydraulic conductivity of the southern part of the aquifer is greater than that of the northeastern part; consequently, more water wells have been completed in the southern part of the aquifer.

## Belvidere, Illinois

Belvidere (fig. 1), a city of about 18,000 in Boone County, has had a mixed agricultural- and industrial-based economy since the late 1800's. Hazardous wastes have been disposed of at numerous industrial facilities and three solid-waste landfills in the area. Currently, one closed industrial facility and two of the three closed landfills are USEPA Superfund sites (on the National Priorities List of hazardous-waste sites in greatest need of remediation). Volatile organic compounds (VOC's), semivolatile organic compounds (SVOC's), and trace metals have been detected in the glacial drift aquifer, the Galena-Platteville aquifer, and the deeper bedrock aquifers (including the Cambrian-Ordovician aquifer) supplying water to the municipal and private supply wells in and around Belvidere. VOC's include petroleum-related compounds and chlorinated solvents used, in part, for degreasing and dry-cleaning. SVOC's commonly are used in disinfectants, insecticides, deodorants, and plasticizers or are by-products

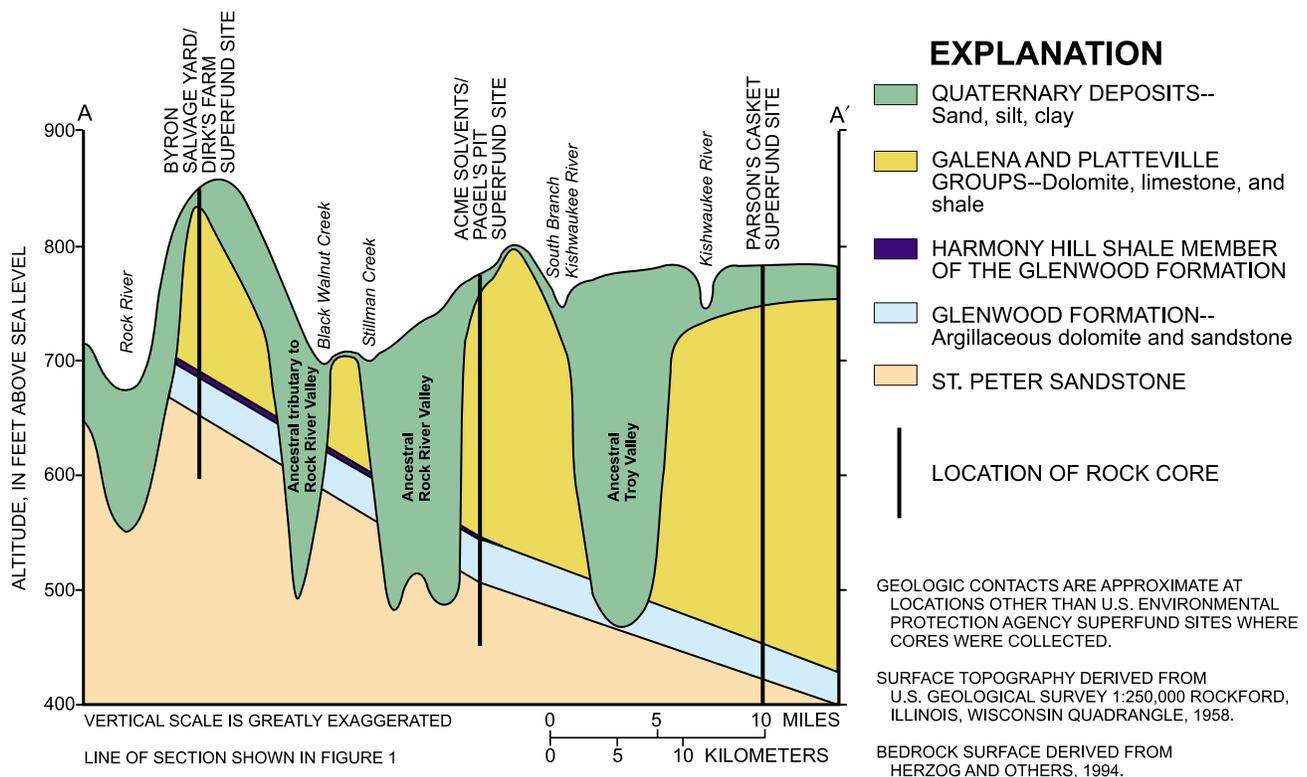


Figure 4. Generalized geologic section A-A' of glacial drift and bedrock units in north-central Illinois.

of coal tar and petroleum processing. During 1989–96, pumping of two municipal water-supply wells was discontinued because concentrations of VOC's in the water consistently were above Maximum Contaminant Levels (MCL's—concentration limits established by the USEPA for the protection of public-water supplies). Private wells near a closed industrial facility also were abandoned, apparently because of high concentrations of trace metals in water samples (Illinois Environmental Protection Agency, 1987).

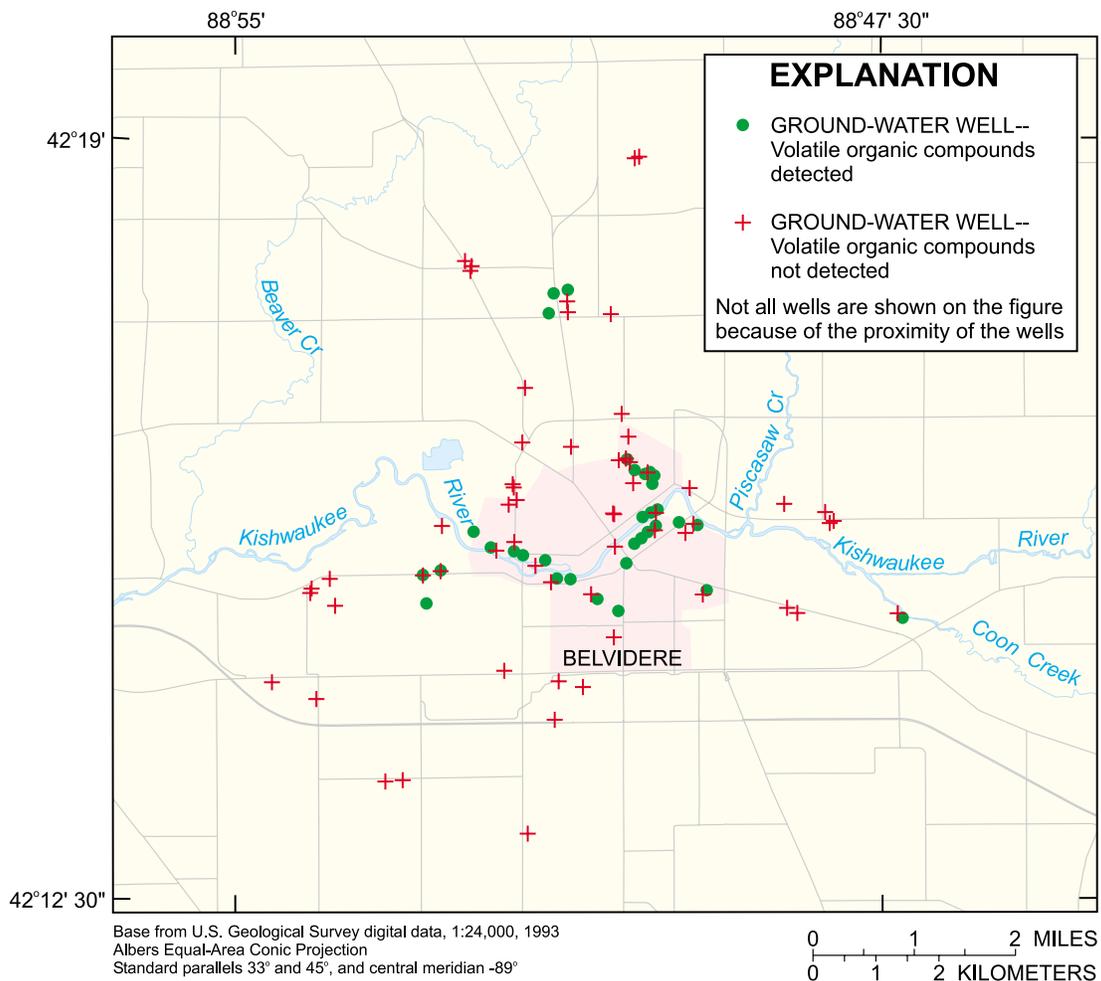
In 1992, the USGS began a study of the water quality and hydrogeology of the shallow aquifers that underlie 80 square miles (mi<sup>2</sup>) in and near Belvidere (fig. 5). The objectives of the study are to provide the data and conceptual framework necessary to (1) determine the present distribution of contaminants in the area's aquifers,

the pathways of migration, and the factors affecting distribution and (2) provide assistance in developing strategies for remediation of ground-water contamination and protection of the area's ground-water supplies. Emphasis is placed on understanding the effect of Superfund and other hazardous-waste sites on the ground-water quality of the area and identifying the source and migration pathways of contaminants detected in water pumped by the municipal wells.

Initially, available data were compiled for 725 wells to provide a preliminary understanding of the water quality and hydrogeology of this study area. The data were inadequate for satisfying the specific objectives of the study. Most of the water-quality data were from one aquifer, the glacial drift aquifer, and were collected over a period of 27 years (1976–93). Few hydrogeologic data were

available from the bedrock aquifers. As part of the effort to collect appropriately distributed water-quality and hydrogeologic data, a series of synoptic (snapshot) studies were undertaken. During one week in July 1993, water-quality data were collected from 97 wells and water levels were measured at 152 wells and 8 surface-water sites. During similar periods in 1994–96, additional water-quality data were collected from about 30 wells. Rock cores were collected, and geophysical logging and aquifer testing were performed at selected boreholes and wells open to the glacial drift and bedrock aquifers.

All water samples were analyzed for VOC's, and selected samples were analyzed for trace metals, SVOC's, or other constituents. VOC's were detected in samples from 50 of the wells included in the study (fig. 5). No VOC's were



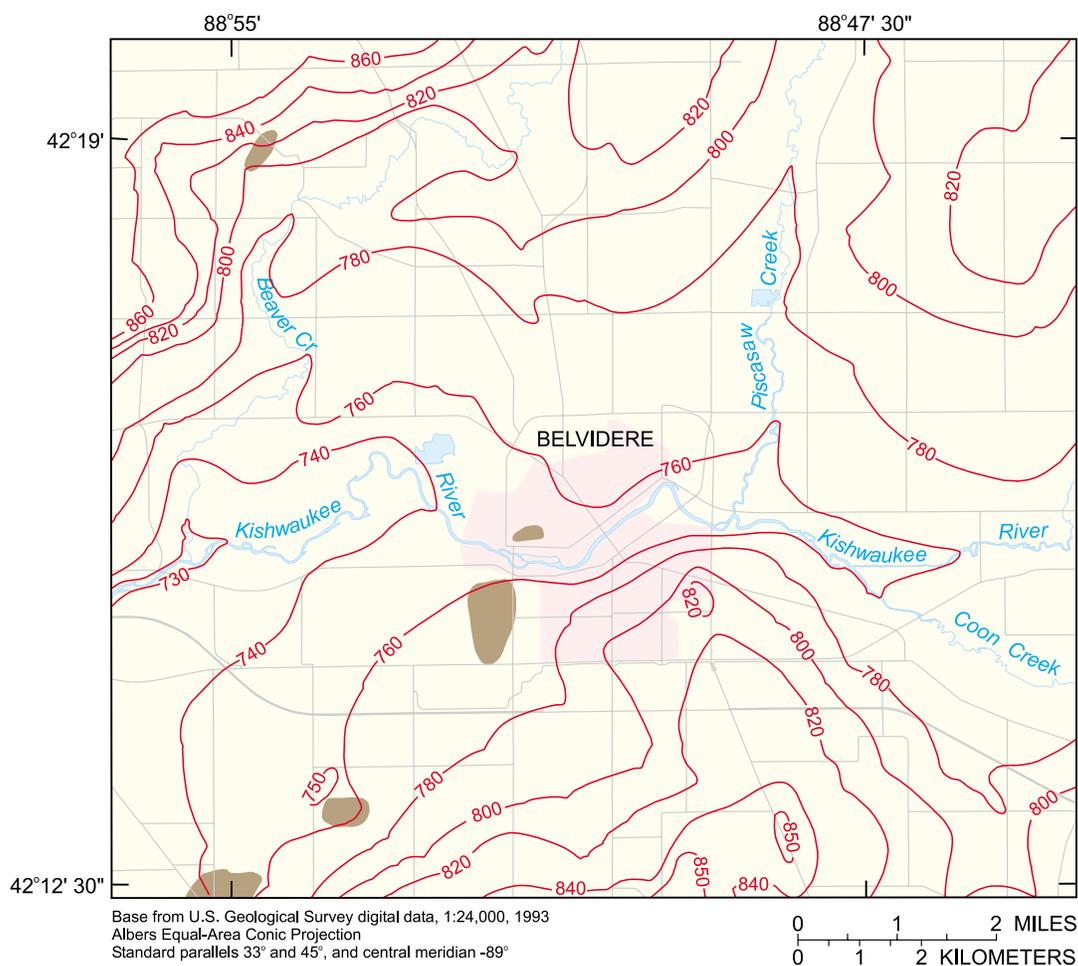
**Figure 5.** Wells in which volatile organic compounds were detected in the vicinity of Belvidere, Ill., July 1993 (modified from Mills and others, 1999, fig. 12a).

detected in samples from the six municipal wells in use during the study. At least one VOC was detected at a concentration above the MCL in about 20 percent of the sampled wells. Concentrations were above MCL's for trichloroethene (TCE), perchloroethene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,2-dichloroethene (total) (1,2-DCE), and benzene. Although 1,2-DCE was the VOC detected at the highest concentration (470 micrograms per liter (mg/L)), TCE and PCE were the most frequently detected VOC's and were present at the highest concentrations in samples from most wells. Nickel,

detected in one sample, was the only other constituent with a concentration above an MCL.

The glacial drift aquifer is composed of sand-and-gravel deposits that are up to 260 ft thick within the axis of the ancestral Troy Valley (fig. 4). The deposits are from 0 to 90 ft thick along the eastern edge of the valley, near Belvidere. Depths to water are about 50 ft or less in wells open to the glacial drift aquifer and 90 ft or less in wells open to the Galena-Platteville aquifer. Generally, the altitude of water levels in the aquifers are similar, ranging from about 900 to 750 ft above sea level across the

area. The potentiometric surfaces (an imaginary surface representing the static head of ground water and defined by the level to which water will rise in a tightly cased well) in the glacial drift aquifer (fig. 6) and the Galena-Platteville aquifer are subdued representations of the land surface. Horizontal ground-water flow in both aquifers is primarily towards the Kishwaukee River and its principal tributaries. The vertical component of ground-water flow is downward in most of the area, especially in the urbanized part affected by pumping of the Belvidere municipal wells and in the upland part remote from the principal



### EXPLANATION

- APPROXIMATE AREA WHERE GLACIAL DRIFT IS UNSATURATED
- 800 POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased wells. Contour interval 20 feet except where indicated. Datum is sea level

**Figure 6.** Potentiometric levels in the glacial drift aquifer in the vicinity of Belvidere, Ill., July 1993 (modified from Mills and others, 1999, plate 1).

surface-water drainages. Upward flow generally is restricted to near-stream areas where ground water is discharging to the streams.

Generally, the concentrations of VOC's were higher and the number of VOC's detected were greater in water samples from the glacial drift aquifer than in samples from the Galena-Platteville aquifer and deeper bedrock aquifers. The elevated concentrations and spatial distribution of VOC's detected in samples from the glacial drift aquifer usually allowed identification of a nearby source area. Except in the immediate vicinity of a known hazardous-waste site, identification of source areas was difficult for VOC's detected in the bedrock aquifers. VOC's detected in water samples from the bedrock aquifers typically were at low concentrations (less than 5 µg/L). VOC's typically were detected within 1,000 ft of the Kishwaukee River (fig. 5), where most of the industrial and waste-disposal sites in the area are located. The principal pathways of ground-water flow and contaminant movement appear to be (1) flow through the glacial drift aquifer with discharge to the nearby Kishwaukee River and (2) flow through the weathered surficial zone and fractures in the Galena-Platteville aquifer. Within the immediate vicinity of Belvidere, most discharge from the Galena-Platteville aquifer is to the municipal wells, the Troy Bedrock Valley, and the Kishwaukee River.

One bedding-plane fracture in the Galena-Platteville aquifer, at an altitude of about 520 ft above sea level, has been detected over an area representing

about 1.5 mi<sup>2</sup>. Flow through this and other fractures may contribute to the movement of contaminants into municipal-supply wells that are partly open to the Galena-Platteville aquifer. Additionally, the Harmony Hill Shale Member of the Glenwood Formation (fig. 2) is composed of clayey-silty sandstone in the immediate vicinity of Belvidere. The absence of shale in this area may enhance movement of water and contaminants between the Galena-Platteville aquifer and the St. Peter Sandstone aquifer and, thus, contribute further to the presence of VOC's in the Belvidere municipal wells. VOC's have been detected intermittently at the two monitoring wells in Belvidere open to the St. Peter Sandstone aquifer.

### Rockford, Illinois

Rockford (fig. 1), the second largest city in Illinois with a population in the metropolitan area of about 140,000, has been a manufacturing center for more than a century. Past methods for the disposal of contaminant wastes produced by these manufacturing activities have allowed the movement of contaminants to ground water. Ground-water contamination has been particularly widespread in the southeastern part of the city (fig. 7), where concentrations of VOC's above MCL's have resulted in dozens of residential wells and at least one municipal well removed from service. As part of a group of Federal, State, and private investigators, the USGS conducted a study of the water quality and hydrogeology of the Galena-

Platteville aquifer underlying southeast Rockford. The study, which supplemented previous studies of the glacial drift aquifer, was necessary to (1) establish the extent of contamination in the Galena-Platteville aquifer, (2) provide an indication if contaminants in the aquifer had the potential to migrate into underlying aquifers used by the city for water supply, and (3) guide additional investigations in this area.

VOC's, primarily 1,1,1-TCA and other chlorinated solvents, were detected in discretely sampled (packed) depth intervals over most or all of the thickness of the Galena-Platteville aquifer in each of the three boreholes drilled for the study. Total concentrations of VOC's exceeded 2,000 µg/L in more than 40 percent of the sample intervals (fig. 8). VOC's also were detected in an area of the aquifer where these compounds were thought to be absent, indicating that the vertical and horizontal extents of contamination were greater than previously had been identified.

Water levels in one borehole (BH3) (fig. 7) were compared to pumping schedules in the nearest municipal water-supply well to determine the potential for contaminant movement from the Galena-Platteville aquifer into the underlying aquifer utilized for municipal water supply. The municipal well, open to the St. Peter Sandstone aquifer and to deeper units of the Cambrian-Ordovician aquifer (fig. 2), was about 0.5 mi from borehole BH3 (fig. 7). Fluctuations in water levels could not be correlated consistently to pumping schedules. The

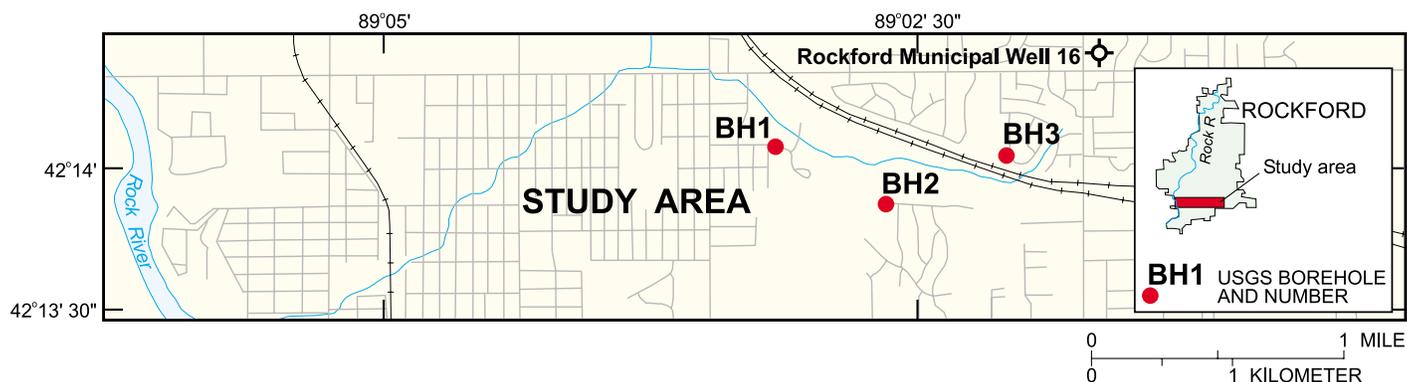


Figure 7. Locations of the study area, test boreholes, and selected municipal well in Rockford, Ill. (modified from Kay and others, 1994, fig.1).

apparent absence of pumping stresses in the Galena-Platteville aquifer, as determined at the borehole, indicated that VOC's near the base of the Galena-Platteville aquifer were not likely to move into the underlying aquifer in response to the current municipal-well-pumping activity.

Results of geophysical logging and water-level measurements in the boreholes indicate that the vertical component of ground-water flow in the Galena-Platteville aquifer in the vicinity of the boreholes is downward (fig. 8). The measured flow rates, up to 8.0 gallons per minute, are high for

an aquifer that is not being stressed by nearby pumping. Such rates indicate large changes in potentiometric head (water levels) with depth in the aquifer, believed to result from limited vertical interconnection between permeable fractures. Most ground-water flow in the study area appears to be horizontal, through variably oriented fractures in the weathered surficial zone of the Galena-Platteville aquifer and selected near-horizontal fractures. Flow through the weathered surficial zone of the aquifer is distributed across the entire area. There is no evidence that ground water flows across the entire area in the deeper fractures; however, flow through a

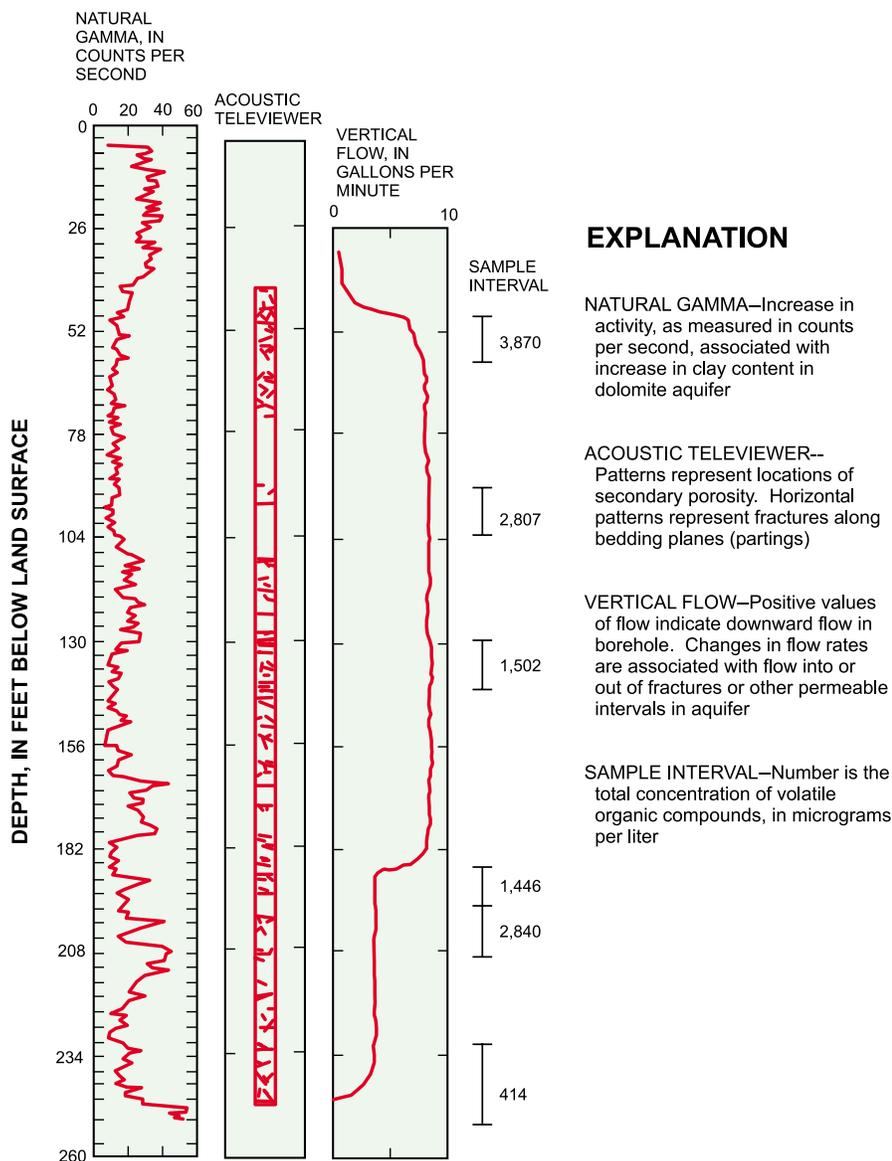
fracture at about 540 ft above sea level may occur across a large part of the area.

## WATER QUALITY AND HYDROGEOLOGY OF NORTHEASTERN ILLINOIS AND NORTHWESTERN INDIANA

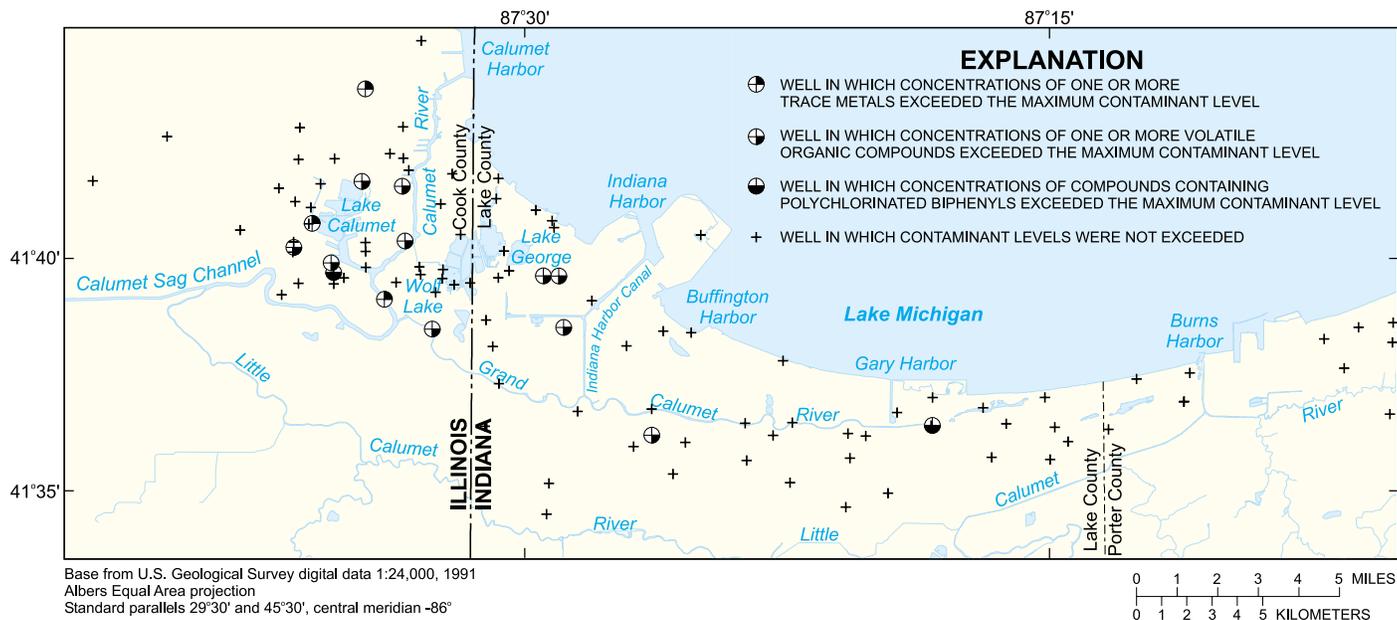
The Calumet region of northeastern Illinois and northwestern Indiana, on the southern shore of Lake Michigan near Chicago, is one of the most intensively industrialized areas in the United States (figs. 1 and 9). Industry in this 240-mi<sup>2</sup> area includes steel mills, petroleum-processing facilities, and chemical-production plants, as well as waste-incineration facilities and landfills. Many of the industrial facilities that once operated in this area have ceased operations. Thus, there is potential for industrial and commercial redevelopment.

Previous site-specific studies have documented extensive contamination of shallow ground water and surface water in the area as the result of industrial and waste-disposal activities. Water-quality concerns primarily relate to the protection of the rivers, lakes, and wetlands in the area, as well as to redevelopment. Drinking-water supply wells that withdraw water from the shallow glacial drift and carbonate aquifers generally are in less industrialized areas or are open to deeper parts of the aquifers that are unaffected by contamination. Many of the lakes and streams in the area are important habitat for fish and for migrating and nesting birds. In addition, Lake Michigan is the source of drinking water for millions of people. Redevelopment of this area requires that the ground-water contamination associated with specific facilities be characterized to assess the environmental liability of an abandoned industrial property and the feasibility of its redevelopment.

The USGS has completed studies to better define the sources and extent of ground-water and surface-water contamination in the Calumet region and the factors that may account for the distribution of contaminants. Information gained from these studies will provide assistance in the design of remediation strategies and will be important in the redevelopment of the region.



**Figure 8.** Geophysical data and total concentrations of volatile organic compounds in the packed intervals of borehole BH2 in Rockford, Ill., fall 1992 (modified from Kay and others, 1994, fig. 7).



**Figure 9.** Wells in which Maximum Contaminant Levels were exceeded in the Calumet region, Illinois, and Indiana, June 1993 (modified from Duwelius and others, 1996, fig. 12).

In 1992, the USGS completed a syn-optic evaluation of surface-water and ground-water levels and the location and thickness of light-nonaqueous-phase liquids (LNAPL's) in the subsurface of the Calumet region. Most LNAPL's are petroleum-related compounds that are less dense than water and, thus, float on the ground-water surface (water table). Hydrogeologic properties of the unconsolidated surficial and shallow carbonate deposits in the area and three-dimensional rates and directions of ground-water flow were determined as part of the study. The surficial deposits in the region are silt, clay, sand, gravel, and fill; the carbonate deposits are primarily dolomite of Silurian and Devonian age (about 350 to 400 million years old) (fig. 2).

LNAPL's were detected only near some of the refineries, gas stations, industrial facilities, and waste-disposal facilities. Shallow ground-water flow in the eastern three-fourths of the area is through lake derived sand deposits and waste fill that compose the Calumet aquifer (fig. 2). Deep ground-water flow is through carbonate deposits of the Silurian-Devonian aquifer, primarily within the weathered surface and fractures concentrated in the upper third of the aquifer (Lloyd and Lyke, 1995). The Calumet and Silurian-Devonian aquifers

are separated by a confining unit primarily composed of silt and clay, which is present at land surface in the western part of the area. The water table generally is a subdued representation of the land surface but is affected by recharge from landfill leachate, ponded water, and discharge to sewers and dewatering centers. Shallow, horizontally moving ground water naturally discharges to surface-water bodies, including Lake Michigan, in most of the area. Vertical gradients of ground-water flow generally are downward from the Calumet aquifer into the underlying confining unit and the Silurian-Devonian aquifer. Ground-water flow in the Silurian-Devonian aquifer primarily is toward a dewatering center near the confluence of the Little Calumet and Grand Calumet Rivers (fig. 9); flow is toward other pumping centers in the region, as well.

In 1993, water samples were collected from wells open to the Calumet aquifer, the confining units, and the Silurian-Devonian aquifer throughout the area. The samples were analyzed for a wide variety of inorganic and organic constituents, including major ions, trace metals, VOC's, SVOC's, and pesticides.

Major-ion chemistry indicated that water from the Silurian-Devonian aquifer generally is a sodium-bicarbonate type,

which can be distinguished from water in the Calumet aquifer and the confining unit. Some samples from the Calumet aquifer and the confining unit were a sodium-chloride-type water. Distinguishing water types can be useful in understanding the extent of water movement between aquifers and, thus, aid in development of strategies to protect aquifers utilized for water supply. The sodium-chloride-type water in the Calumet aquifer possibly represents the effect of deicing salts that have washed from roadways into the shallow ground water. The most frequently detected VOC's in ground water generally were petroleum-related compounds; concentrations of one compound, benzene, were above the MCL in 11 of the 128 samples. Barium, arsenic, mercury, lead, and aluminum were the most frequently detected trace metals; concentrations of nickel and aluminum were most frequently above MCL's or other regulatory levels. The highest concentrations of VOC's and trace metals were detected in water samples from wells in or near industrial or waste-disposal areas (fig. 9). Low concentrations of trace metals and pesticides were detected in samples from five wells in residential areas. VOC's, as well as many other waste-related constituents, were detected in samples from the Calumet aquifer, the confining

unit, and the waste-fill materials, typically in waste-disposal and industrial areas and along some roadways.

Since 1872, waste materials have been used to infill surface-water bodies to accommodate industrial and urban expansion in the Calumet region. Fill materials include slag, dredging spoil, industrial wastes, construction debris, and natural material. Mapping by the USGS of the location, thickness, volume, type, and date of deposition for the fill material indicates that currently (1996) about  $2.1 \times 10^{10}$  cubic feet of fill material covers about 60 mi<sup>2</sup> of this region (fig. 10). Fill deposits are concentrated along Lake Michigan; the Calumet, Little Calumet, and Grand Calumet Rivers; and the Calumet Sag Channel. Sampling results of the synoptic evaluation of water quality and other investigations indicate that increased concentrations of VOC's, SVOC's, pesticides, cyanide, metals, or major ions in ground water are associated with industrial wastes, municipal solid wastes, and perhaps dredging spoil. Increased concentrations of major ions in ground water may be associated with construction debris, ash and cinder, and natural fill.

## SUMMARY AND CONCLUSIONS

Northern Illinois and the Calumet region of northeastern Illinois and northwestern Indiana (near Chicago) are considered especially susceptible to ground-water contamination because of the high density of hazardous-waste sites and the shallow depth to the underlying sand and gravel aquifers and fractured carbonate aquifers. A need was recognized for an areal characterization of the water quality and the relation of water quality to the hydrogeology to resolve ground-water-contamination issues associated with the cleanup of many of the hazardous-waste sites and to protect public-water supplies. The U.S. Geological Survey and U.S. Environmental Protection Agency initiated ground-water-quality studies of the areas in 1991. The studies of the shallow aquifers underlying northern Illinois (including the cities of Belvidere and Rockford), southern and eastern Wisconsin, and the Calumet region provided insight into the extent of ground-water contamination and the properties of the aquifers that affect the distribution of the industrial contaminants. Data collected as part of the studies indicate the distribution of contaminants in the aquifers is not widespread; contaminants at concentrations exceeding regulatory levels were detected most frequently near industrial or hazardous-waste sites. Contaminants

in water pumped from water-supply wells generally were at concentrations below regulatory levels. VOC's were the most frequently detected contaminants in each of the areas studied. Most contaminants were detected in water from the sand and gravel aquifers at or near land surface; contaminants in these aquifers primarily discharge to nearby lakes and streams. Contaminants also were detected in water from the carbonate aquifers that underlie the sand and gravel aquifers; concentrations in the carbonate aquifers generally were lower than concentrations in the overlying sand and gravel aquifers. Movement of contaminants in the carbonate aquifers is primarily through the weathered surficial zone and deep fractures. The fractures commonly intercept water-supply wells that are cased only into the top few feet of the carbonate aquifers; near-horizontal fractures developed along bedding planes may allow widespread distribution of contaminants in the aquifers. Data and conceptual models of ground-water flow and contaminant distribution and movement developed as part of the studies have been used in investigations of specific hazardous-waste sites and by Federal, State, and local agencies to better manage, protect, and restore the quality of the areas' water supplies.

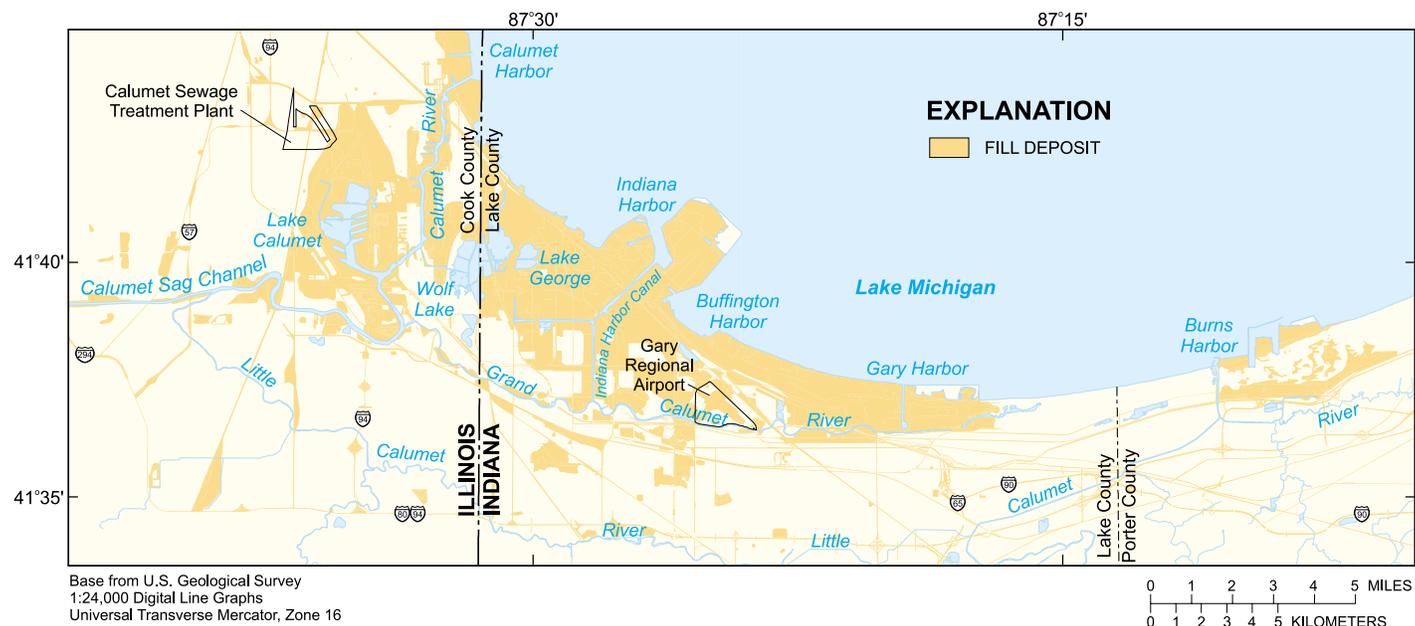


Figure 10. Location of fill deposits in the Calumet region, Illinois, and Indiana (modified from Kay and others, 1997b, plate 1).

## Northern Illinois, Southern and Eastern Wisconsin

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If you are interested in additional information about the studies described in this report, other collaborative studies by the USGS and USEPA, or other studies, products, or services of the USGS, please contact:

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