

U.S. Department of the Interior
U.S. Geological Survey

Geology, Hydrology, and Water Quality in the Vicinity of a Brownfield Redevelopment Site in Canton, Illinois

By Robert T. Kay, David B. Cornue, and James R. Ursic

Open-File Report 01-307

In cooperation with the
U.S. Environmental Protection Agency

DeKalb, Illinois
2002

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

Use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement of the U.S. Government.

For additional information write to:

District Chief
U.S. Geological Survey
221 N. Broadway Avenue
Urbana, IL 61801

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

Abstract	1
Introduction	1
Purpose and Scope	4
Study Methods	5
Acknowledgments.....	10
Geology	10
Hydrology	16
Water Quality	19
Field Parameters.....	20
Organic Compounds.....	20
Metals, Major Cations, and Cyanide.....	27
Summary and Conclusions.....	31
References Cited	32

FIGURES

1. Map showing location of Canton, Illinois, and the study area.....	2
2. Map showing location of the study area, potential sources of contamination, monitoring wells, physical test boreholes, and line of geologic section A-A' in the vicinity of the Canton Brownfield site, Canton, Illinois.....	3
3. Diagram showing stratigraphy, lithology, and hydrology of unconsolidated deposits at boring USGS-SB1 in the vicinity of the Canton Brownfield site, Canton, Illinois	11
4. Diagram showing geologic section A-A' in the vicinity of the Canton Brownfield site, Canton, Illinois.....	12
5-9. Maps showing:	
5. Thickness of sand deposit in the vicinity of the Canton Brownfield site, Canton, Illinois	14
6. Altitude of top of sand deposit in the vicinity of the Canton Brownfield site, Canton, Illinois	15
7. Thickness of upper semiconfining unit in the vicinity of the Canton Brownfield site, Canton, Illinois	17
8. Potentiometric surface of the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 19, 2000.....	18
9. Specific conductance, pH, and concentrations of barium, calcium, magnesium, and potassium in the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000.....	22
10. Graphs showing correlation of selected chemical constituents in the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000.....	30

TABLES

1. Well, lithologic, and hydraulic information in the vicinity of the Canton Brownfield site, Canton, Illinois 6

2. Water levels measured in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000 7

3. Results of geotechnical testing of geologic samples in the vicinity of the Canton Brownfield site, Canton, Illinois..... 9

4. Horizontal-hydraulic-conductivity values determined from slug tests done in wells in the vicinity of the Canton Brownfield site, Canton, Illinois..... 19

5. Horizontal hydraulic gradients and ground-water velocity along selected lines of flow in the vicinity of the Canton Brownfield site, Canton, Illinois, August 19, 2000 20

6. Field parameters measured in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000 21

7. Concentrations of volatile organic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000..... 23

8. Concentrations of semivolatile organic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000 24

9. Concentrations of pesticide and polychlorinated biphenyl compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000..... 25

10. Concentrations of inorganic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000..... 28

CONVERSION FACTORS AND VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
Area		
acre	4,047	square meter
Volume		
gallon (gal)	3.7685	liter
Flow rate		
gallon per minute (gal/min)	3.7685	liter per minute
foot per day (ft/d)	0.3048	meter per day
foot per year (ft/yr)	0.3048	meter per year
Hydraulic conductivity*		
foot per day (ft/d)	0.3048	meter per day
Hydraulic gradient		
foot per foot (ft/ft)	0.3048	meter per meter
Pressure		
pound per square inch (lb/in ²)	6.895	kilopascal

***Hydraulic conductivity:** Foot per day is the mathematically reduced term of cubic foot per day times foot per square foot of aquifer cross-sectional area.

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

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.

Altitude, as used in this report, refers to distance above or below sea level.

Abbreviated water-quality units used in this report: Chemical concentration is given in metric units. Chemical concentration is given in micrograms per liter (µg/L). Micrograms per liter is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter (mg/L).

Abbreviations

µS/cm	microsiemens per centimeter
µg/Kg	micrograms per kilogram
mg/L	milligrams per liter
µg/L	micrograms per liter
mv	millivolts
µm	micrometers

Geology, Hydrology, and Water Quality in the Vicinity of a Brownfield Redevelopment Site in Canton, Illinois

By Robert T. Kay¹, David B. Cornue², and James R. Ursic³

Abstract

The U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency and Environmental Operations, Inc., assisted in the characterization of the geology, hydrology, and water quality at a Brownfield redevelopment site in Canton, Illinois. The investigation was designed to determine if metals and organic compounds historically used in industrial operations at the site resulted in a threat to the water resources in the area. The hydraulic units of concern in the study area are the upper semiconfining unit, the sand aquifer, and the lower semiconfining unit. The upper semiconfining unit ranges from about 1 to 19 feet in thickness and is composed of silt-and-clay deposits with a geometric mean vertical hydraulic conductivity of 7.1×10^{-3} feet per day. The sand aquifer is composed of a 1 to 5.5 foot thick sand deposit and is considered the primary pathway for ground-water flow and contaminant migration from beneath the study area. The geometric mean of the horizontal hydraulic conductivity of the sand aquifer was calculated to be 1.8 feet per day. The direction of flow in the sand aquifer is to the east, south, and west, away from a ground-water ridge that underlies the center of the site. Ground-water velocity through the sand aquifer ranges from 7.3×10^{-2} to 2.7×10^{-1} feet per day. The lower semiconfining unit is composed of sandy silt-and-clay deposits with a

geometric mean vertical hydraulic conductivity of 1.1×10^{-3} feet per day.

Volatile organic compounds were detected in ground water beneath the study area. Pesticide compounds were detected in ground water in the western part of the study area. Partial or complete degradation of some of the volatile organic and pesticide compounds is occurring in the soils and ground water beneath the study area. Concentrations of most of the metals and major cations in the ground water show some variation within the study area and may be affected by the presence of a source area, pH, geochemical environment, precipitation-dissolution reactions, and ion-exchange reactions. Antimony, thallium, and 1,1-dichloroethane were detected in water samples from one well each at concentrations above their respective U.S. Environmental Protection Agency maximum contaminant levels.

INTRODUCTION

The Canton Brownfield redevelopment site, located near the center of the city of Canton in Fulton County, Illinois (figs. 1, 2), was used for the manufacture of farming implements from 1840 through 1983. From 1984 through 1994, the Canton Brownfield site (hereafter referred to as the site) was used for manufacturing of metal parts, tire recycling, and sand blasting operations. In 1997, a fire destroyed most of the buildings on the northeastern part of the site. The site currently (2001) is unused and is the target of the city of Canton's redevelopment efforts under its 1998 Brownfield Assessment Demonstration Pilot grant award from the U.S. Environmental Protection Agency (USEPA).

¹ U.S. Geological Survey, DeKalb, Illinois

² Environmental Operations, Inc., St. Louis, Missouri

³ U.S. Environmental Protection Agency, Chicago, Illinois

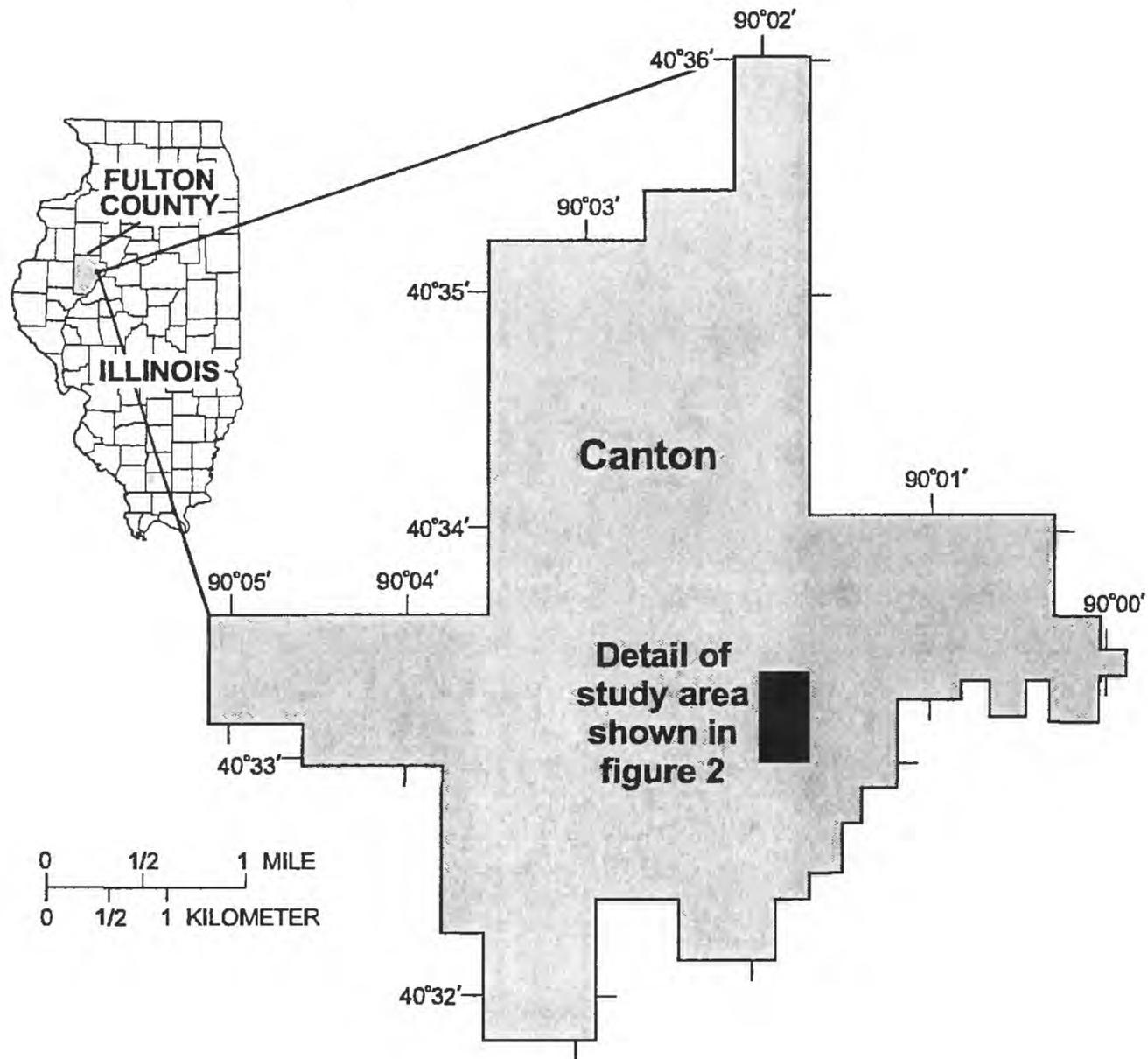


Figure 1. Location of Canton, Illinois, and the study area.

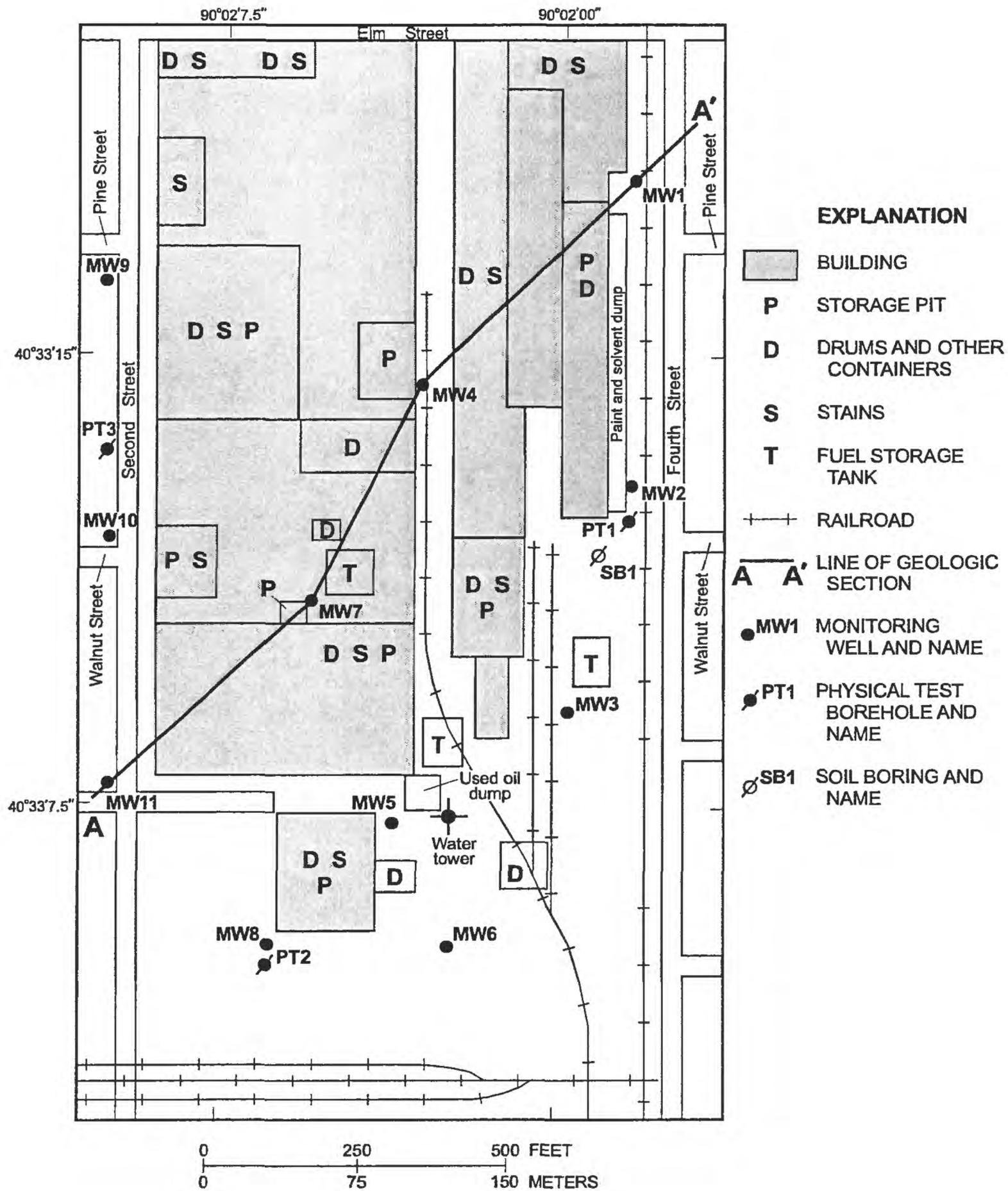


Figure 2. Location of the study area, potential sources of contamination, monitoring wells, physical test boreholes, and line of geologic section A-A' in the vicinity of the Canton Brownfield site, Canton, Illinois.

The site, as defined in this report, is about 33 acres in size and is bounded by Second Street to the west, Elm Street to the north, Fourth Street to the east, and unidentified railroad tracks to the south (fig. 2). The area of concern for this study (hereafter referred to as the study area) is bounded by the railroad tracks to the south, wells MW9-11 to the west, Elm Street to the north, and Fourth Street to the east.

Numerous pits, vats, and tanks used for the storage of fuel oil, paints, solvents, corrosives, and other liquids were or are present in and around the buildings on the site (Environmental Operations, Inc., 2000) (fig. 2). Hundreds of 1-, 5-, and 55-gal containers, many of which had leaked, were present in the buildings and near the water tower in the southern part of the site. An underground pipeline used to transport solvents is present near the center of the site. Surface paint stains were present in parts of the buildings and paint and solvent wastes reportedly were disposed of along railroad tracks in the eastern part of the site and near the water tower in the southern part of the site.

Soil samples collected from 59 soil borings located throughout the site contained detectable concentrations of volatile organic compounds (VOC's), including benzene (maximum concentration 2,500 $\mu\text{g}/\text{Kg}$), ethylbenzene (maximum concentration 400,000 $\mu\text{g}/\text{Kg}$), toluene (maximum concentration 1,500,000 $\mu\text{g}/\text{Kg}$), xylenes (maximum concentration 2,000,000 $\mu\text{g}/\text{Kg}$), cyclohexane (maximum concentration 22,000 $\mu\text{g}/\text{Kg}$), methylcyclohexane (maximum concentration 340,000 $\mu\text{g}/\text{Kg}$), isopropylbenzene (maximum concentration 46,000 $\mu\text{g}/\text{Kg}$), and chlorinated solvents (maximum concentration 10,000 $\mu\text{g}/\text{Kg}$ of tetrachloroethene) (Thomas Pachowicz, Ecology and Environment, Inc., written commun., 2000). These compounds are not produced in nature and their presence is due to an anthropogenic source.

VOC's in soils tended to be located in two areas beneath the site. The first area is approximately defined by Second Street to the west, the water tower to the south and east, and a line projecting from the approximate mid-point between Walnut and Pine Streets to the north (fig. 2). The second area is approximately located between the buildings from Elm Street to the projection of Pine Street. The samples with

the highest concentration of all but one of the VOC's (benzene) were taken from borings done in the vicinity of the used oil dump, the underground solvent line (PCE) and the former oil house.

Soil samples collected from the 59 soil borings also contained detectable concentrations of semi-volatile organic compounds (SVOC's), including naphthalene (maximum concentration 5,500 $\mu\text{g}/\text{Kg}$) and 2-methylnaphthalene (maximum concentration 17,000 $\mu\text{g}/\text{Kg}$) (Thomas Pachowicz, Ecology and Environment, Inc., written commun., 2000). Samples from 28 of the soil borings, focused mainly in the western part of the site, contained detectable concentrations of the polychlorinated biphenol arochlor-1254 and pesticide compounds including beta-benzenehexachloride, heptachlor, aldrin, heptachlor epoxide, endosulfan, dieldrin, alpha chlordane and gamma chlordane. These compounds also are not produced in nature and their presence in soils indicates an anthropogenic source.

Based on the history of industrial and waste-disposal operations at the site, and the presence of high concentrations of anthropogenic compounds in soils in the study area, it was anticipated that contaminated ground water might have been present at the site (Environmental Operations, Inc., 2000). Contamination in ground water, if present, has the potential to affect human health and the environment and to impair site redevelopment.

The U.S. Geological Survey (USGS) and Environmental Operations, Inc. (EOI), in cooperation with the USEPA, conducted a study of the geology, hydrology, and water quality in the vicinity of the site from August 2000 through April 2001. This study was done to determine if ground water in the vicinity of the site contained contaminants at sufficiently high concentrations to potentially affect human health and the environment, or redevelopment of the site.

Purpose and Scope

This report describes the results of an investigation of the hydrogeology and water quality in the vicinity of the Canton Brownfield site. The results of geophysical logging, two series of water-level measurements, slug testing, and water-quality sampling

from 11 monitoring wells installed in the study area for this investigation are presented. In addition, this report presents the results of geotechnical, mineralogic, and stratigraphic analysis of lithologic sampling from soil borings in the study area. The report describes the geology, stratigraphy, and hydrology in the study area, identifies the directions and estimates the rate of ground-water flow, describes ground-water quality, and identifies potential factors that affect hydrology and water quality in the unconsolidated deposits underlying the study area.

Study Methods

The investigation comprised drilling, installation, and development of 11 monitoring wells (table 1, fig. 2) followed by measurement of water levels, slug testing, water-quality sampling, and geophysical logging in each of the wells. Lithologic samples used for analysis of the geotechnical properties of the geologic deposits were collected at borings PT1, PT2, and PT3 (fig. 2). These field activities were performed in accordance with the work plan (Environmental Operations, Inc., 2000), which was approved by the USEPA, Region V. Lithologic samples used to determine the stratigraphy of the geologic deposits were collected at soil boring SB1 (fig. 2).

The boreholes for the monitoring wells were drilled using a 8.25 in. outside diameter hollow stem auger to a depth of 25 to 35 ft below land surface. Continuous undisturbed core samples were obtained for lithologic description by advancing a 3.5 in. inside diameter continuous split-spoon sampler with the augers. Wells were drilled to intercept a sand layer identified at about 24 ft beneath the study area (Savage, 1921) that is the primary pathway for horizontal ground-water flow beneath the study area (the sand aquifer).

Monitoring wells were constructed of flush-threaded, 2 in. diameter schedule 40 polyvinyl chloride (PVC) screen and riser pipe. Screens were slotted, with a 0.010-in. opening, varied in length from 5 to 10 ft, and typically were placed about 3 in. above the bottom of the borehole. A granular sand pack was placed in the annular space from the bottom of the borehole typically to about 1.5 ft above the top of the screen. About 1 ft of filter sand was placed over the sand pack. The length of the sand pack is the interval to which the well is open to

the geologic deposit (the open interval in table 1).

About 2 ft of bentonite pellets or chips were placed above the filter sand; then granular bentonite was used to fill the borehole annulus to about 1.5 ft below ground surface. Filter sand was placed above the bentonite to a depth of about 0.75 ft, where a flush mount protective casing encased in concrete was installed. Waterproof locking caps were used to seal the top of the casing at each well.

Well development was performed using a 1.7 in. hand pump designed to agitate the water column in the well. A minimum of five well volumes was removed from each well during development. Well development was done from 5 to 15 days after well construction and from 2 to 4 days prior to well sampling.

Water levels were measured in all of the monitoring wells on August 15 and 19, 2000 (table 2). Water levels were measured in select monitoring wells on August 16-18, 2000. Water levels in any given well varied by less than 1.2 ft and typically varied by less than 0.50 ft during this period. Because of the similarity of the water levels, only the water-level data collected on August 19 will be discussed. Water levels were measured by use of an electric water-level indicator incremented to 0.01 ft. Ground-water levels were measured relative to the top of the 2 in. diameter PVC riser pipe in each of the wells. Ground-water level altitudes were calculated by subtracting the depth to water from the surveyed altitude of the top of the PVC riser pipe. Measurements to detect a light nonaqueous phase liquid in well MW7 were made by use of an oil-water interface probe incremented to 0.01 ft. The areal location of the wells, the altitude of the top of the riser pipe, and the altitude of the land surface were measured by registered land surveyors.

Horizontal hydraulic conductivities of the sand aquifer were calculated from data collected during slug testing in monitoring wells MW1-MW11. Slug tests involved instantaneous lowering of the water level in the well by removal of a water-filled bailer from the well and measurement of water-level rise (recovery) with time using a calibrated 0-10 lb/in² pressure transducer connected to a data logger. Water-level measurements were collected on a logarithmic time scale. A total of three slug tests were done in each well. A series of water-level measurements were made prior to the start of each test to ensure that ground-water levels had stabilized.

Table 1. Well, lithologic, and hydraulic information in the vicinity of the Canton Brownfield site, Canton, Illinois

[>, greater than]

Well name	Latitude/Longitude	Altitude, top of inner casing (feet above sea level)	Land-surface altitude (feet above sea level)	Depth of open interval (feet below land surface)	Depth to bottom of fill deposit at well (feet)	Depth to bottom of upper clay layer at well (feet)	Depth to bottom of sand deposit at well (feet)	Depth to bottom of lower clay layer at well (feet)	Thickness of upper semi-confining unit at well (feet)
MW1	40°33'18.5"/90°01'43.5"	660.21	660.4	17-30	10.	26.5	28.	>30	19
MW2	40°33'12.5"/90°01'44"	657.50	657.7	20-33	2.	23.	24.5	>34	14
MW3	40°33'09.5"/90°01'45"	658.30	658.6	16-25	2.5	21.5	23.	>25	11
MW4	40°33'16.5"/90°01'49"	658.55	658.8	23-30	5.	27.	29.	>31	19
MW5	40°33'08"/90°01'49"	657.22	657.6	10-25	5.	19.5	23.	>25	12
MW6	40°33'05.5"/90°01'47.5"	658.27	658.6	21-30	3.	23.	27.	>30	15
MW7	40°33'11"/90°01'53"	660.58	660.9	17-30	2.	21.	26.5	>30	5
MW8	40°33'06"/90°01'51.5"	657.10	657.5	11-25	0.5	19.	24.	>25	9
MW9	40°33'17"/90°01'56"	658.93	659.1	12-25	2.	18.	19.	>25	9
MW10	40°33'12.5"/90°01'56"	657.50	657.7	13-30	2.	24.	28.	>30	12
MW11	40°33'08.5"/90°01'56"	655.35	655.6	16-25	2.5	19.5	23.	>25	1

Slug-test data were analyzed based on the technique of Bouwer and Rice (1976). This technique was developed for use in unconfined aquifers with wells that fully or partially penetrate the aquifer. The following conditions are assumed in the application of the Bouwer and Rice technique.

1. Drawdown of the water table in the vicinity of the well is negligible.
2. Flow above the water table can be ignored.
3. Head losses as the water enters the well are negligible.
4. The hydraulic unit tested is homogeneous and isotropic.

These conditions appear to have been met or approximated in the wells tested during this study.

When analyzing the slug-test data, it was assumed that the thickness of the sand aquifer and the length of the well through which water enters the aquifer are equal to the saturated thickness of the sand layer at the well. The borehole diameter was assumed to be equal to the nominal outside diameter of the borehole. For well MW11, where the water table intercepted the well screen, calculation of the radius of the well casing was done in accordance with the recommendations of Bouwer and Rice (1976). For those wells where the water level prior to the start of the test was above the top of the screen, the radius of the casing was assumed to equal the nominal value of 1 in.

Water-quality data were collected using the micro-purge technique (Barcelona and others, 1994; Shanklin and others, 1995). This technique involves use of a peristaltic pump with replaceable Teflon tubing placed at the depth of the sand aquifer in the well and pumping at a rate designed to induce minimal drawdown in the well, typically less than 0.25 gal/min. New tubing was used for each well. Field parameters (temperature, pH, dissolved oxygen concentration, oxidation-reduction potential, turbidity, and specific conductance) of the water were measured during purging by use of a calibrated Hydrolab in-line flow-through cell. Water-quality samples were collected after monitoring established that the field parameters were changing by less than 10 percent for every quarter well volume or after three well volumes were purged if the parameters did not stabilize. The sample turbidity typically was less than 10 nephelometric turbidity units.

Water samples were placed in pre-preserved bottles, immediately stored on ice in a cooler, and delivered to the lab for analysis within 36 hours of collection. Samples were analyzed for volatile organic compounds using USEPA method 8260, metals and major cations using USEPA method 6010, semivolatile organic compounds using USEPA method 8270, cyanide using USEPA method 9012, and pesticide and polychlorinated biphenyl compounds using USEPA method 8021. As specified in the approved Quality Assurance Project Plan (Environmental Operations Inc., 2000), the appropriate pump blank, trip blank, matrix spike-matrix spike duplicate, and duplicate samples were collected for quality assurance and quality control. Proper chain-of-custody was maintained for all samples. Review of the quality-assurance and quality-control data indicate the sampling results are acceptable. Sampling results attributed to field or laboratory contamination are not discussed in this report. Estimated concentrations less than the quantitation limit, denoted by a J data qualifier, are assumed to be true values for the purposes of this report.

Concentrations of every field parameter, major cation, and metal detected in water samples from five or more wells were plotted against each other and a linear regression analysis of the plots was done. Correlation coefficient (R^2) values were obtained for each of the plots using analytical methods provided in the Microsoft Excel spread sheet package. An acceptable linear correlation was considered to be present between two constituents if the R^2 value for the plot exceeded 0.60. All correlations with an R^2 value greater than 0.60 are considered to be related and are discussed in the report. Correlations with an R^2 value less than 0.60 are not considered to be related and typically are not discussed in the report.

A total of nine lithologic samples from borings PT1, PT2, and PT3 were collected in Shelby tubes for analysis of vertical hydraulic conductivity, particle-size analysis, and moisture content (Janet Jacobi, Shively Geotechnical, Inc., written commun., 2000) (table 3). Vertical hydraulic conductivity was measured in accordance with the American Society for Testing Material (ASTM) method D5084 (American Society of Testing Materials, 2000). Particle-size analysis was done in accordance with ASTM method D422 (American Society of Testing Materials, 1998).

Table 3. Results of geotechnical testing of geologic samples in the vicinity of the Canton Brownfield site, Canton, Illinois

[Bold denotes saturated samples; UCL, upper clay layer; LCL, lower clay layer; USU, upper semiconfining unit; LSU, lower semiconfining unit; --, not applicable]

Boring name	Sample depth (feet)	Moisture content (percent)	Vertical hydraulic conductivity (feet per day)	Geology	Hydraulic unit
PT1	9-11.5	25.0	2.2×10^{-2}	UCL	USU
PT1	16-18.5	23.5	7.4×10^{-4}	UCL	USU
PT1	30-32.5	12.7	1.3×10^{-3}	LCL	LSU
PT2	10-12.5	26.7	7.9×10^{-2}	UCL	USU
PT2	15-17.5	21.6	1.0×10^{-1}	UCL	USU
PT2	25-27.5	14.7	9.6×10^{-4}	LCL	LSU
PT3	5-7.5	26.0	1.3×10^{-3}	UCL	USU
PT3	13-15.5	22.6	2.4×10^{-3}	UCL	USU
PT3	23-25.5	14.8	9.4×10^{-4}	LCL	LSU
Geometric mean value for USU	--	--	8.6×10^{-3}	--	--
Geometric mean value for LSU	--	--	1.1×10^{-3}	--	--

Natural-gamma, inphase, and quadphase electrical conductivity logs were run in each of the monitoring wells in March 2001. Natural-gamma logs measure the amount of gamma radiation emitted by the deposits near the well, which typically is a function of the clay content of the deposits. Inphase and quadphase conductivity logs measure the decay of an electrical signal emitted from the logging device. Decay of the signal is related to the electric properties of the rock and fluid surrounding the well, which can be affected by the presence of ground-water contamination and non-aqueous phase liquids. The only substantial variations in the response of the geophysical logs with depth were attributed to the effects of well construction. Because the geophysical logs did not identify variations in water quality or geology at the site, they are not discussed in this report.

Lithologic samples were collected in 1.5 in. diameter Shelby tubes at boring SB1 by use of a Geoprobe sampler. Sample collection began at a depth of about 1 ft, immediately below the concrete in this location, and ended at 37 ft, where the deposit was too hard for the probe to penetrate (refusal). Refusal commonly is associated with encountering bedrock, and it is assumed that boring SB1 sampled the entire thickness of the unconsolidated materials at that location. Lithologic samples from boring SB1 were sent to Myrna Killey of the Illinois State Geological Survey (ISGS) (written commun., 2001) for lithologic description and analysis of clay and carbonate mineralogy. Also, Ms. Killey completed a detailed assessment of the stratigraphy of the Quaternary deposits.

Acknowledgments

The authors thank the following people for their assistance with the investigation: Clark Wilson of the city of Canton, Myrna Killey of the ISGS, and Michael Gifford and Stavros Emmanuel of the USEPA.

GEOLOGY

The Pennsylvanian-aged Carbondale Formation is the uppermost bedrock deposit beneath the study area (Willman and others, 1967). Lithologic logs from well MW2 and an abandoned water-supply well located on the northwest part of the site (Savage, 1921) indicate that the top of the Carbondale Formation is composed of shale and is present at a depth of about 34 to 40 ft beneath the study area. The stratigraphic nomenclature used in this report is that of the ISGS (Willman and others, 1967; Willman and Frye, 1970; Lineback and others, 1979) and does not necessarily follow the usage of the USGS.

The bedrock beneath the site is unconformably overlain by Quaternary-aged sand, silt, and clay (figs. 3, 4). Detailed assessment of the stratigraphy of the Quaternary deposits indicate that the Quaternary deposits beneath the study area are the Radnor Till Member of the Glasford Formation, the Berry Clay Member of the Glasford Formation, the Roxana Silt, and the Peoria Silt.

The Radnor Till Member of the Glasford Formation is presumed to be the lowermost Quaternary deposit beneath the study area. The Radnor Till is a heterogeneous deposit composed primarily of a silt-and-clay till (diamicton) with interbedded silts and sands (fig. 3). The Radnor Till is present between about 621 and 641 feet above sea level (asl) at SB1. The Radnor Till in west-central Illinois is characterized by a high percentage of illite (typically about 77 percent) followed by chlorite and kaolinite (about 15 percent) and expandable clays (about 8 percent) in the particles less than 2 μm in size and a predominance of dolomite (about 19 percent) over calcite (about 5 percent) in particles less than 74 μm in size (Lineback and others, 1979). These percentages are representative of the Radnor Till below about 21 ft in the study area. However, the gleyed deposits in the upper part of the Radnor Till beneath the study area have as much as 90 percent expandable clay minerals in the 17-20.7 ft interval, decreasing to about 6 percent in the 20.9-24 ft interval (Myrna Killey, Illinois State Geological Survey, written commun., 2001). Gleyed deposits above 21 ft also have been leached of calcite and dolomite particles less than 74 μm in size.

SYSTEM	STAGE	FORMATION	MEMBER	HYDRAULIC UNIT	DEPTH (feet below land surface)	DESCRIPTION
QUATERNARY	Holocene			Unsaturated	0-2	Fill: gravelly sandy silt, black and coaly.
	Wisconsinan	Peoria Silt			2-13	Gleyed silty clay, clay, and clayey silt; olive, gray, and light brownish gray; mottled with light olive brown and brownish yellow; manganese oxide nodules and spots; noncalcareous.
				Roxana Silt	13-15.4	Gleyed clayey silt; very dark brown, very dark grayish brown, and dark gray; some finely disseminated organics; becomes more clayey downward; noncalcareous. Abrupt oblique contact with underlying deposit.
	Sangamonian		Berry Clay	Upper semiconfining unit	15.4-17	Silty clay; dark grayish brown and olive brown; noncalcareous. Interval 16.0-16.4 feet is clayey silt to clay, black; noncalcareous.
	Illinoian	Glasford	Radnor Till		17-20.7	Gleyed sandy silty clay diamicton; gray; tough, dense; between 18.0 and 18.4 feet more heavily oxidized; dark yellowish brown with thin reddish brown streaks along healed joints/rootlet traces; noncalcareous.
					20.7-20.9	Pebbly sand; dark grayish brown heavily mottled with light olive brown; oxidized; noncalcareous.
					20.9-24	Gleyed sandy silt (20.9-23.1 feet). Coarsening downward sequence beginning with gray clayey silt from 23.1-23.3 feet; gray sandy silt, granules, small pebbles from 23.3-24.0 feet.
					24-25.8	Silty sand and gravel from 24.0-25.8 feet, gray. Noncalcareous to 24.2 feet, slightly calcareous becoming rapidly calcareous below. Abrupt contact with underlying deposit.
					Sand aquifer	24-25.8
				Lower semiconfining unit	25.8-28	Gleyed silty clay diamicton, gray to dark gray; tough, dense; contains pockets of grayish brown silt; rapidly calcareous.
					28-29.1	Very fine well-sorted sand from 28.0 to 28.2 feet, gray to olive gray; from 28.2-29.1 feet silt and some very fine sand, gray; all calcareous.
					29.1-30.9	Clayey silty diamicton, dark gray to gray, with horizontal breakage planes present between 29.9 and 30.9 feet; calcareous.
					30.9-31.6	Dominantly fine sand with some medium-coarse sand and granules to 31.5 feet, gray to dark gray; poor to medium sorting; calcareous. From 31.5 - 31.6 feet silt, gray; calcareous.
					31.6-35.4	Silty to clayey silt diamicton, olive gray to dark grayish brown and dark gray; rapidly calcareous.
				35.4-36	Silt to clayey silt, dark grayish brown; finely bedded to laminated; noncalcareous to slightly calcareous downward.	
				36-37	Pebbly silty clay diamicton, dark gray; tendency to horizontal breakage in top 0.1 foot; calcareous. Woody sliver about 1 centimeter long at 37.4 feet.	

Figure 3. Stratigraphy, lithology, and hydrology of unconsolidated deposits at boring USGS-SB1 in the vicinity of the Canton Brownfield site, Canton, Illinois (lithologic and stratigraphic description by Myrna Killey, Illinois State Geological Survey).

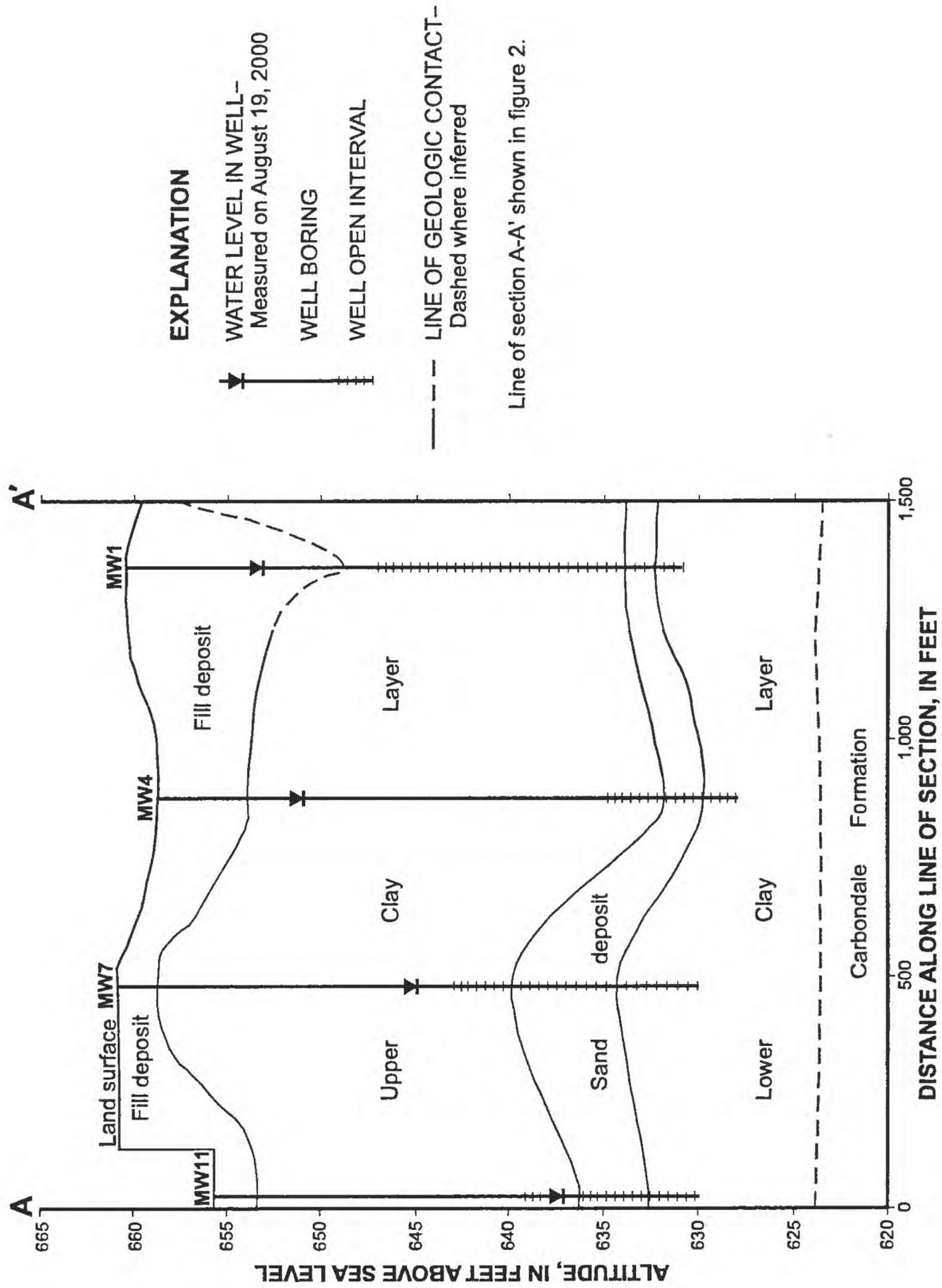


Figure 4. Geologic section A-A' in the vicinity of the Canton Brownfield site, Canton, Illinois.

The Berry Clay Member of the Glasford Formation is composed of silty clay that is present between about 641 and 642.6 fasl at SB1. The Berry Clay is an accretion-gley part of the Sangamon Geosol, which is a widespread weathering zone between Illinoian-Stage tills and Wisconsinan-Stage loess deposits. The Berry Clay in west-central Illinois is characterized by an absence of carbonate minerals in particles less than 74 μm in size, and a variable percentage of illite (about 9 to 50 percent) and expandable clay minerals (about 28 to 83 percent), with a generally consistent percentage of chlorite and kaolinite (about 8 to 22 percent) in the particles less than 2 μm in size (Lineback and others, 1979). The Berry Clay at boring SB1 contains 88 percent expandable clay minerals, 9 percent illite, 3 percent chlorite and kaolinite, and has been leached of calcite and dolomite particles less than 74 μm in size (Myrna Killey, Illinois State Geological Survey, written commun., 2001).

The Roxana Silt is the oldest Wisconsinan Stage deposit beneath the study area and is present between about 642.6 and 645 fasl at SB-1. The Roxana Silt is a loess deposit characterized in west-central Illinois by variable percentages of illite (19 to 37 percent); expandable clays (34 to 80 percent); and chlorite and kaolinite (8 to 32 percent); with small amounts of dolomite (typically absent but locally as much as 13 percent), and little or no calcite (Lineback and others, 1979). At boring SB1, the Roxana Silt is composed of about 76 percent expandable clay minerals, about 16 percent illite, and about 8 percent chlorite and kaolinite (Myrna Killey, Illinois State Geological Survey, written commun., 2001). The Roxana Silt has been leached of calcite and dolomite particles less than 74 μm in size at boring SB1.

The Peoria Silt is the youngest geologic deposit beneath the study area and is present between about 645 and 656 fasl. The Peoria Silt is a loess deposit characterized in west-central Illinois by variable percentages of illite (16 to 63 percent); expandable clays (11 to 72 percent); chlorite and kaolinite (9 to 37 percent); and dolomite (typically about 25 percent but absent in some areas), and little or no calcite (Lineback and others, 1979). At boring SB1, the Peoria Silt is composed of about 86 percent expandable clay minerals, about 10 percent illite, and about 4 percent chlorite and kaolinite (Myrna Killey, Illinois State

Geological Survey, written commun., 2001). The Peoria Silt has been leached of calcite and dolomite particles less than 74 μm in size at boring SB1.

For simplification, the geologic deposits beneath the study area are divided into four units, the lower clay layer, the sand deposit, the upper clay layer, and the fill deposit (fig. 4). The lower clay layer is composed of the predominately silt and clay till deposits of the Radnor Till Member of the Glasford Formation, which are present from the bedrock surface to the bottom of the silty sand-and-gravel deposit located at a depth of 25.8 ft at SB-1 (fig. 3). The lower clay layer is about 10 to 16 ft thick beneath the study area (Savage, 1921) (fig. 4). Geotechnical analysis of three samples collected from the lower clay layer indicates that between 55 and 75 percent of this deposit is composed of grains that are in the silt or clay size fraction. The porosity (which is equal to the moisture content of a sample collected below the water table) of this deposit is about 14 percent (table 3).

The sand deposit overlies the lower clay layer (figs. 3, 4). The sand deposit is about 1 to 5.5 ft thick beneath the study area and is thickest in the southwestern part of the study area near wells MW7 and MW8 (fig. 5). The depth of the top of the sand deposit varies from about 18 to 27 ft (table 1) and tends to be largest in the northeastern part of the study area and smallest in the southwestern part of the study area. The altitude of the top of the sand deposit is less than 635 fasl in the vicinity of wells MW1, MW2, MW4, and MW10 in the northern part of the study area and increases to an altitude of more than 639 fasl to the south and northwest (fig. 6).

The silt-and-clay deposits of the upper part of the Radnor Till, the Berry Clay, the Roxana Silt, and the Peoria Silt that overlie the sand deposit compose the upper clay layer (fig. 4). The thickness of the upper clay layer ranges from about 14 to 22 ft in the study area (table 1) and shows no consistent variations with location. Geotechnical analyses of six samples taken from the upper clay layer indicates that about 70 to 99 percent of this deposit is composed of grains that are in the silt or clay size fraction. The moisture content (porosity) of this deposit is between about 21 and 26 percent (table 3). The moisture content of the upper clay layer and the lower clay layer decrease with depth (table 3), presumably resulting from increased compaction of the unconsolidated deposits.

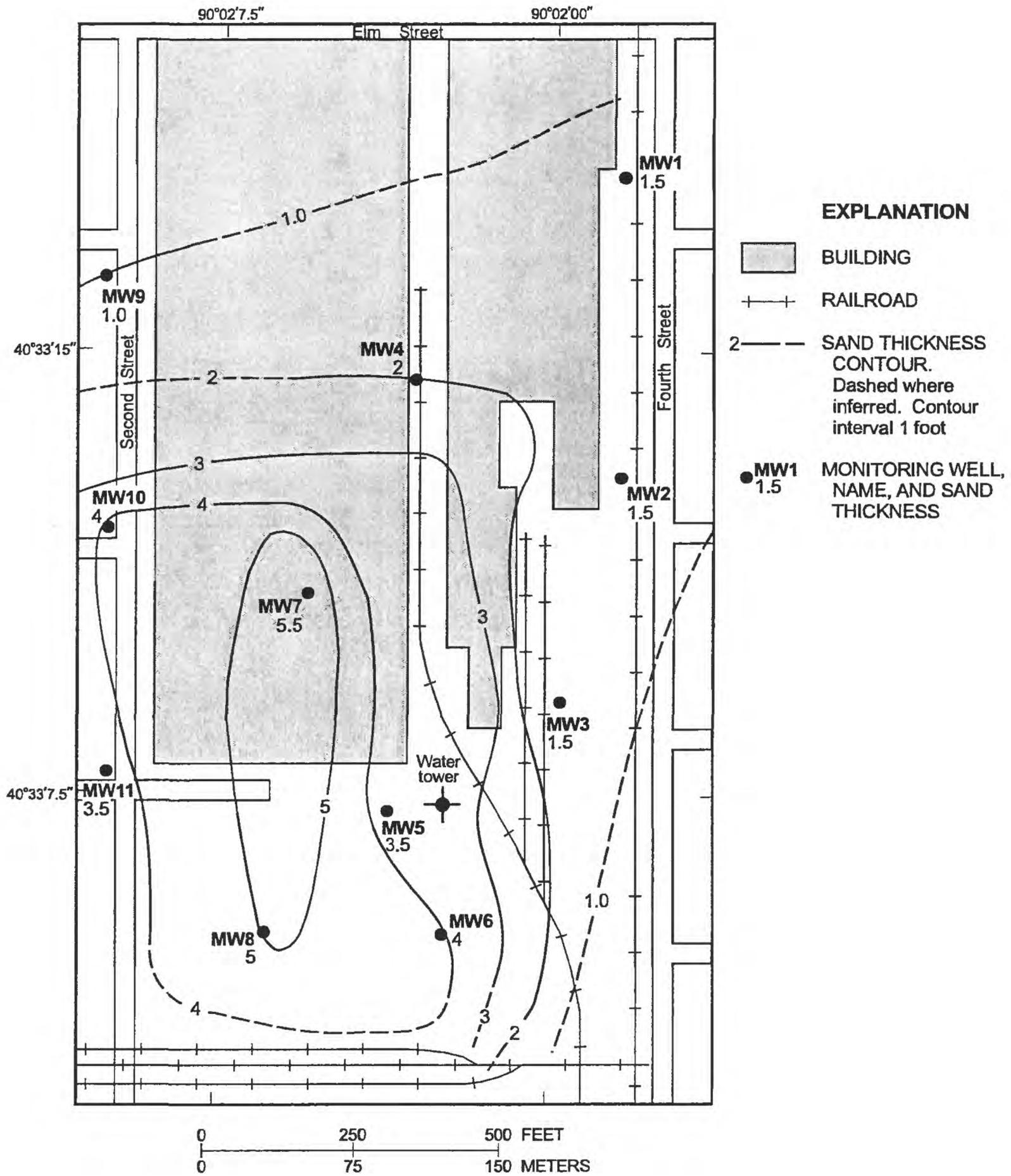


Figure 5. Thickness of sand deposit in the vicinity of the Canton Brownfield site, Canton, Illinois.

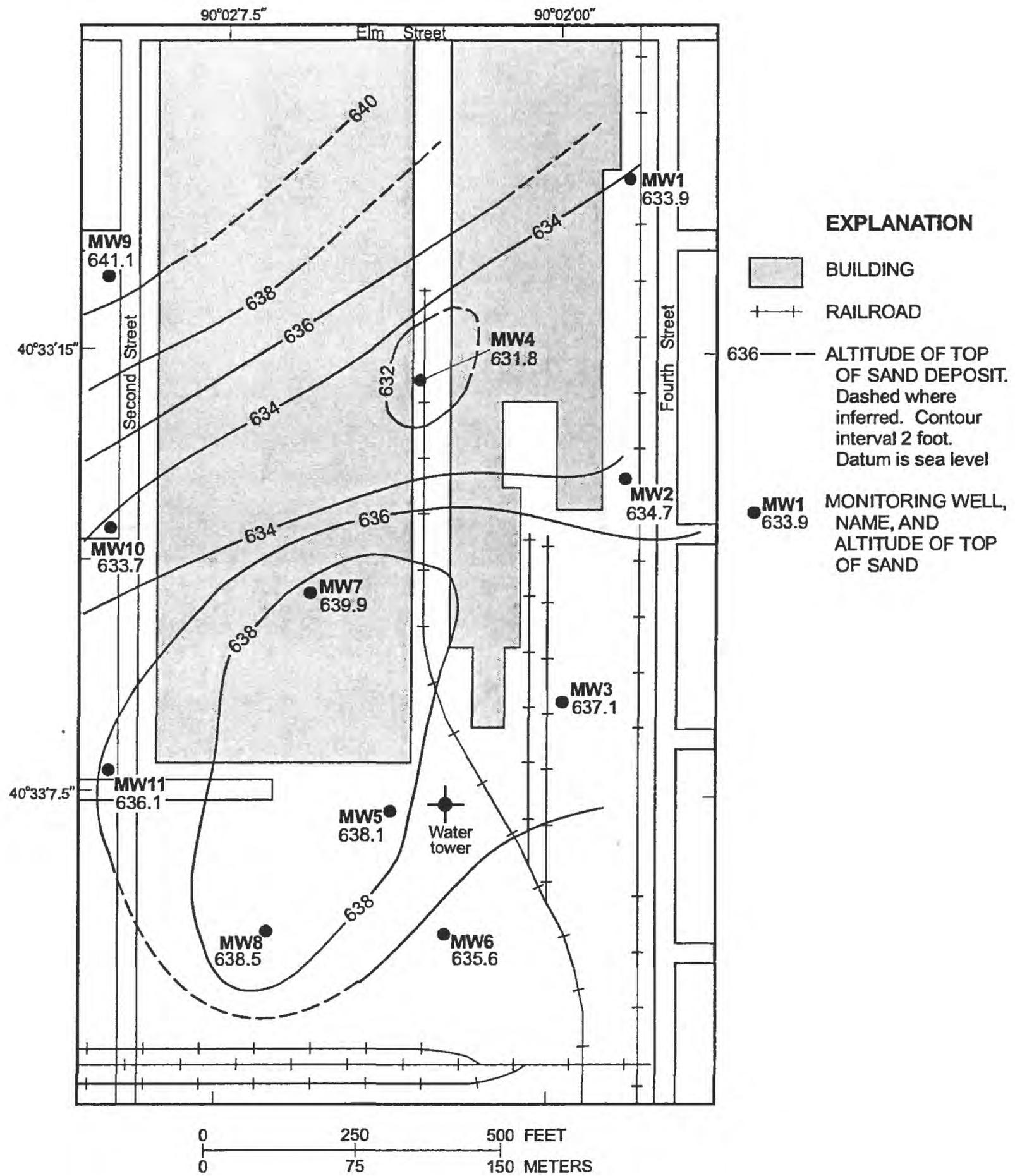


Figure 6. Altitude of top of sand deposit in the vicinity of the Canton Brownfield site, Canton, Illinois.

Fill material serves as the foundation for most of the buildings on the site and was measured to be up to 14 ft thick beneath the buildings (Thomas Packowicz, Ecology and Environment, Inc., written commun., 2000). As much as 10 ft of fill material underlies the northeast corner of the site at well MW1. About 5 ft of fill is present near the center of the site at wells MW4 and MW5 (table 1). Between 1 and 3 ft of fill are present around the periphery of the site at wells MW2, MW3, MW6, and MW8; and offsite at wells MW9, MW10, and MW11. Most of the fill offsite and around the periphery of the site is associated with foundation for roads and parking lots. Fill materials typically are natural materials (silt, clay, gravel), concrete, asphalt, and brick. Slag and cinders also were identified in the fill (Thomas Packowicz, Ecology and Environment, Inc., written commun., 2000).

HYDROLOGY

The hydraulic units of concern to this investigation are the upper semiconfining unit, composed of the saturated part of the fill and upper clay layer; the sand aquifer, composed of the sand deposit; and the lower semiconfining unit, composed of the lower clay layer. It is assumed that the thickness of the upper semiconfining unit is approximated by the distance between the top of the sand aquifer and the potentiometric surface of the aquifer. The investigation focused on characterizing the sand aquifer, which is likely to be the primary pathway for horizontal movement of water and contaminants in the study area.

Lithologic and water-level data indicate that the thickness of the upper semiconfining unit ranges from about 1 ft at well MW11 to about 19 ft at wells MW1 and MW4 (table 1, fig. 7). The thickness of the upper semiconfining unit shows an overall decrease from east to west that is attributed to variation in the altitude of the top of the sand deposit and the water-table altitude beneath the study area. Geotechnical testing of six samples from the upper semiconfining unit indicates the vertical hydraulic conductivity of this unit ranges from 7.4×10^{-4} to 1.0×10^{-1} ft/d with a geometric mean of 8.6×10^{-3} ft/d (table 3).

Water-level altitudes in the monitoring wells exceed 650 fasl in the northern and central parts of the study area at wells MW1, MW4, MW5, and MW6 (table 2) (fig. 8). Water levels decrease to the southeast

in wells MW2 and MW3 to between 648 and 649 fasl, whereas water levels decrease to the southwest at well MW11 to less than 638 fasl. Water levels could not be correlated with depth to the top of the sand aquifer, thickness of the sand aquifer, horizontal-hydraulic-conductivity value, or the depth of the well. The water level in a well penetrated by more than one hydraulic unit is a composite of the water levels and permeability of each of the units the well is open to. Because the sand aquifer is the most permeable unit monitored by each of these wells, the water level in each of the wells is assumed to approximate the potentiometric surface of the sand aquifer. If water levels in the wells approximate the potentiometric surface of the sand aquifer, flow in the sand aquifer is from the ground-water ridge near the center of the study area generally to the southeast and southwest (fig. 8).

Calculated values for the mean horizontal hydraulic conductivity obtained from analysis of the slug tests done in wells MW1-MW11 ranged from 0.23 to 79 ft/d (table 4). It is assumed that these values approximate the horizontal hydraulic conductivity of the sand aquifer at each of the wells. The geometric mean horizontal hydraulic conductivity of all of the slug tests was calculated to be 2.7 ft/d. Horizontal-hydraulic-conductivity values displayed no clear correlation with the thickness of the sand aquifer (fig. 5) or the water-level altitude at the well (table 2), but showed some variation with location. The geometric mean of the horizontal-hydraulic-conductivity values in the sand aquifer was less than 0.80 ft/d in the east-central and south-central parts of the study area at wells MW2, MW7, and MW8; increased to the north and west from about 3.0 ft/d at wells MW1, MW4, and MW11 to more than 10 ft/d in the northwestern part of the study area at wells MW9 and MW10; and increased to about 1 to 13 ft/d in the southeastern part of the study area at wells MW3, MW5, and MW6.

Horizontal hydraulic gradients at the water table were calculated by dividing the change in the altitude of the water table along two points parallel to the direction of flow by the horizontal distance between the two points (fig. 8). The horizontal hydraulic gradient was calculated along approximate lines of flow between the 652 fasl contour and the 642 fasl contour (line of flow A-A' on fig. 8), between the 652 fasl contour and well MW2 (flow line B-B'), between wells MW5 and MW11 (flow line C-C') and between the center of the ground-water ridge and well MW3 (flow line D-D').

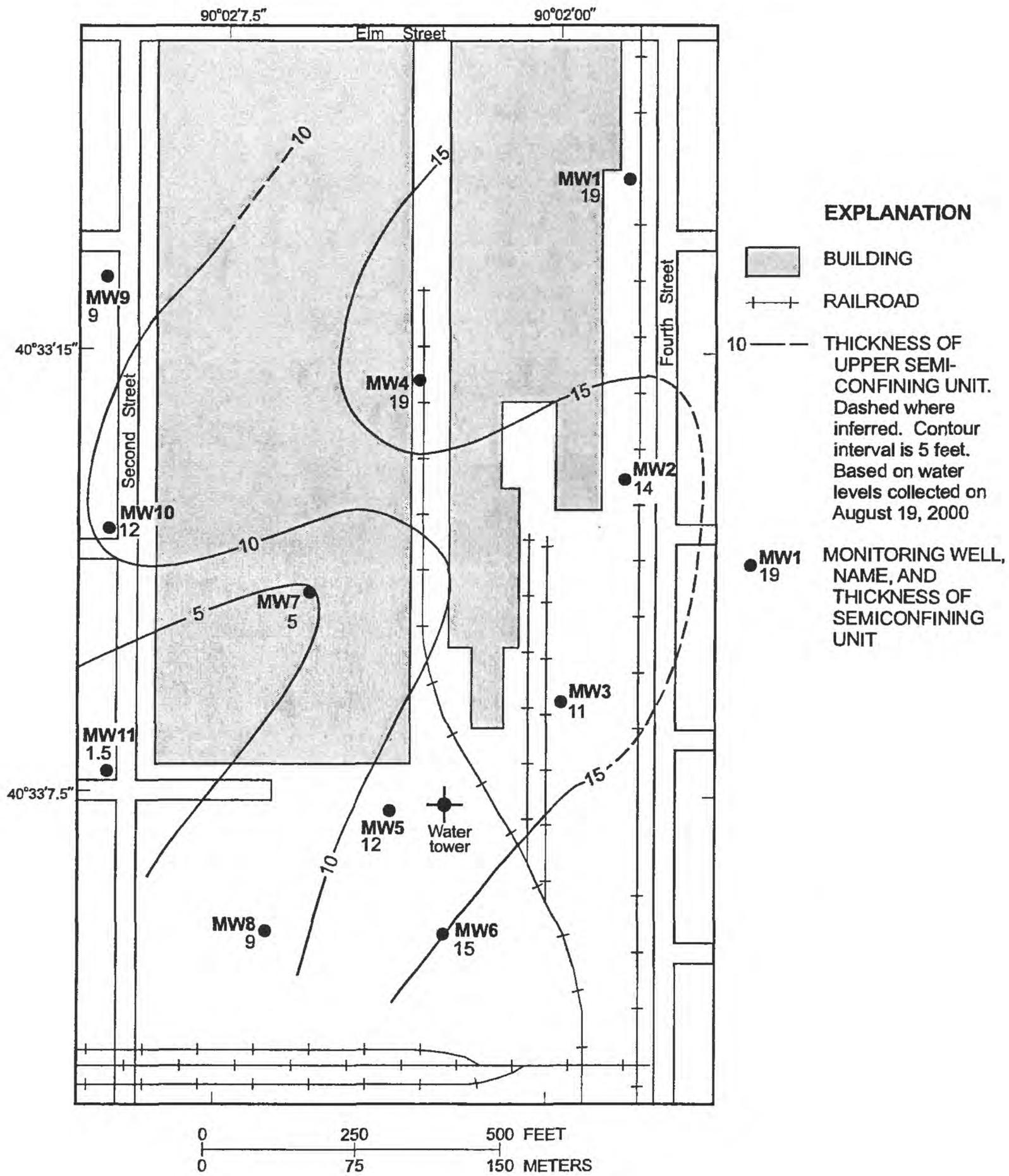


Figure 7. Thickness of upper semiconfining in the vicinity of the Canton Brownfield site, Canton, Illinois.

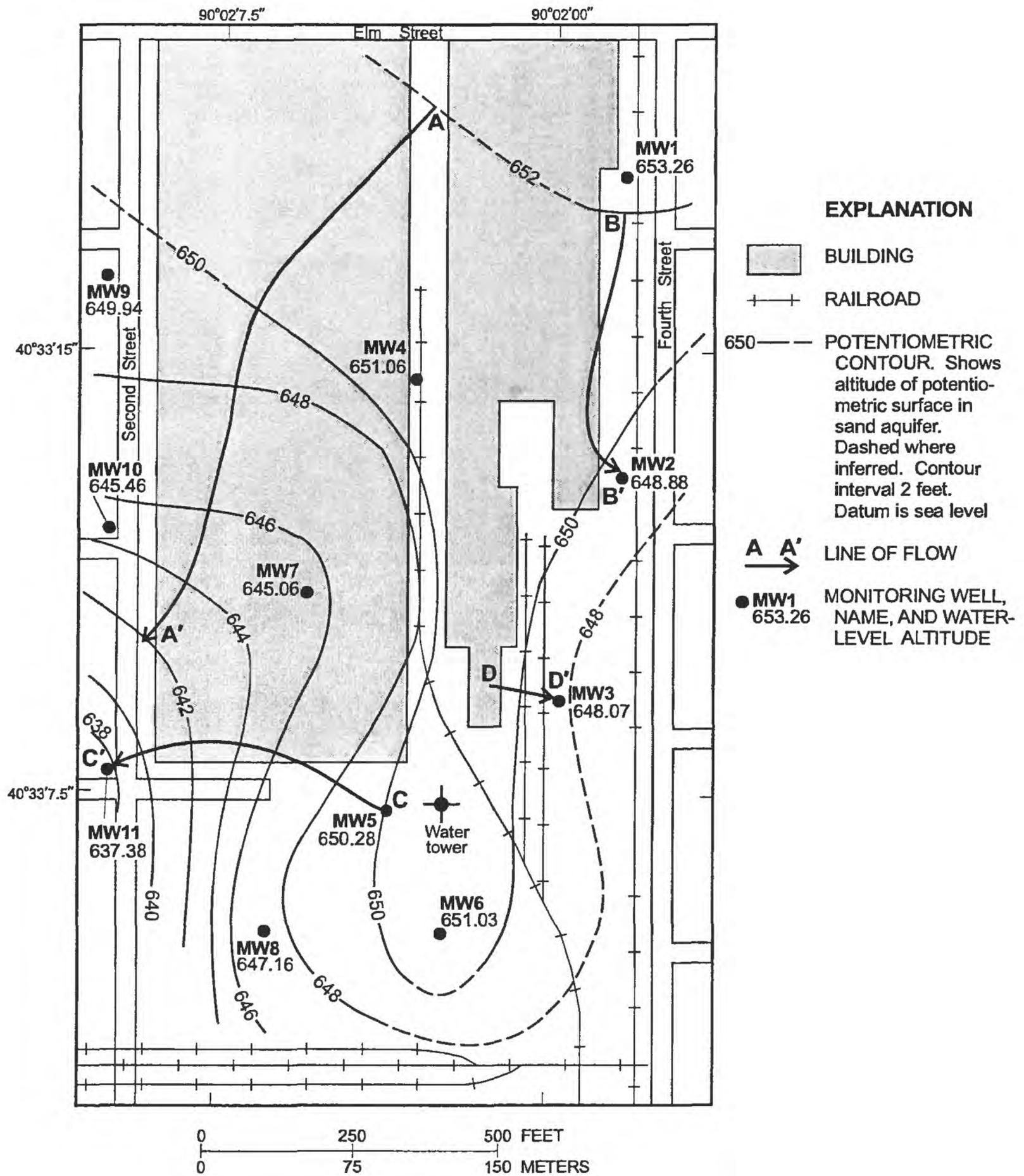


Figure 8. Potentiometric surface of the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 19, 2000.

Table 4. Horizontal-hydraulic-conductivity values determined from slug tests done in wells in the vicinity of the Canton Brownfield site, Canton, Illinois

Well name	Horizontal hydraulic conductivity (feet per day)			
	Test 1	Test 2	Test 3	Mean value of tests in well
MW1	3.1	3.2	3.2	3.2
MW2	.19	.26	.26	.23
MW3	1.6	1.5	1.5	1.5
MW4	2.7	2.6	2.7	2.7
MW5	12.	14.	14.	13.
MW6	1.0	1.0	1.0	1.0
MW7	.76	.79	.73	.76
MW8	.56	.57	.58	.57
MW9	79.	80.	78.	79.
MW10	11.	10.	14.	12.
MW11	3.3	3.7	3.8	3.6
	Geometric mean value of all tests	2.7		

These flow lines represent the probable range of horizontal hydraulic gradients in the study area. The calculated horizontal hydraulic gradient along four of the approximate lines of flow in the sand aquifer ranged from 6.9×10^{-3} to 2.5×10^{-2} ft/ft (table 5).

The velocity (v) of ground water in an aquifer is equal to

$$v = (K/n) I, \quad (1)$$

where

K is the horizontal hydraulic conductivity, in feet per day;

n is the effective porosity of the aquifer, in percent; and

I is the horizontal hydraulic gradient, in foot per foot.

K is assumed to be equal to the geometric mean value for the sand aquifer of 2.7 ft/d. The values for I are those calculated along the lines of section. The value of n for the sand aquifer is assumed to be about 17 percent. Using these values and solving equation 1, the ground-

water velocity in the sand aquifer in the study area was calculated to range from 1.10×10^{-1} to 3.97×10^{-1} ft/d (table 5) or from about 40 to 145 ft/yr.

The sand aquifer is underlain by the lower semi-confining unit. The vertical hydraulic conductivity of three samples from the lower semiconfining unit ranged from 9.4×10^{-4} to 1.3×10^{-3} ft/d (table 3) with a geometric mean of 1.1×10^{-3} ft/d. This value is within an order of magnitude of the geometric mean of the vertical hydraulic conductivity of the upper semiconfining unit.

WATER QUALITY

Water-quality data collected from the monitoring wells in the study area fall into three general categories: field parameters; organic compounds; and inorganic constituents including metals, major cations, and cyanide. It is assumed that water quality of the samples is representative primarily of the water quality in the sand aquifer.

Table 5. Horizontal hydraulic gradients and ground-water velocity along selected lines of flow in the vicinity of the Canton Brownfield site, Canton, Illinois, August 19, 2000

Line of flow (see fig. 8)	Water level at point 1 (feet above sea level)	Water level at point 2 (feet above sea level)	Length of flow line (feet)	Horizontal hydraulic gradient (foot per foot)	Horizontal hydraulic conductivity (feet per day)	Ground-water velocity (feet per day)
A-A'	652.00	642.00	1,025	0.010	2.7	0.155
B-B'	652.00	648.88	450	.0069	2.7	0.110
C-C'	650.28	637.38	510	.025	2.7	0.397
D-D'	650.00	648.07	120	.016	2.7	0.254

Field Parameters

The measured temperature of the ground water in the wells ranged from 15.9 to 18.5 °C (table 6). Ground-water temperatures showed no variations that could be clearly related to geographic location or location along flow pathways in the study area.

Specific conductance is a measure of the capability of a solution to conduct an electrical current and often is correlated with the total concentration of dissolved constituents. Specific conductance of the ground water ranged from 550 to 8,202 $\mu\text{S}/\text{cm}$ (table 6). Specific-conductance values at wells MW1, MW3, MW5, MW7, and MW9 near the center of the study area were less than 1,100 $\mu\text{S}/\text{cm}$, whereas specific-conductance values in the remainder of the study area were greater than 1,450 $\mu\text{S}/\text{cm}$ (fig. 9).

The pH is the negative log of the concentration of hydrogen ions in the water. pH values of ground-water samples ranged from 6.32 to 7.45 units (table 6). pH values in the study area tended to be higher in areas of lower specific conductance, exceeding 6.65 pH units at wells MW1, MW3, MW5, MW7, and MW9, and were less than 6.60 units in the rest of the study area (fig. 9).

The oxidation-reduction potential (ORP) of water is an indicator of the relative tendency of a solution to accept or transfer electrons. The lower the ORP value, the more reducing, or electron accepting, the solution. ORP values in the ground water ranged from -86 to 205 mv (table 6). ORP values tended to be less than 70 mv near the center of the study area at wells

MW2, MW4, MW6, MW7, MW8, and MW10, and greater than 100 mv along the edges of the study area at wells MW1, MW3, MW5, MW9, and MW11.

The concentration of dissolved oxygen in the ground water ranged from 0.23 to 4.13 mg/L (table 6). Concentrations of dissolved oxygen exceeded 1.0 mg/L in the eastern part of the study area at wells MW1, MW2, MW3, and MW5, and were less than 0.60 mg/L in the remainder of the study area.

Although a linear correlation was not observed, comparison of the values of the field parameters indicate that pH values in the ground water tended to decrease with increasing specific conductance. Water from all wells with a pH value greater than 6.60 had specific conductance values of less than 1,100 $\mu\text{S}/\text{cm}$, whereas water from all wells with a pH value less than 6.60 had a specific conductance value of greater than 1,450 $\mu\text{S}/\text{cm}$ (table 6). No other relation between field parameters was clearly indicated. Field parameters did not show a correlation with horizontal-hydraulic-conductivity values.

Organic Compounds

VOC's were detected in samples collected from wells MW4, MW5, MW7, and in the duplicate sample from well MW11 (table 7). With the exception of 1 $\mu\text{g}/\text{L}$ of di-n-octylphthalate, which also was detected in the rinsate blank, semivolatiles organic compounds and polychlorinated biphenyls were not detected in ground

Table 6. Field parameters measured in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000

[Bold denotes wells where anthropogenic organic compounds were detected; <, less than]

Well name	Field Parameter					
	Temperature (degrees Celsius)	Specific conductance (microsiemens per centimeter)	pH (standard units)	Oxidation-reduction potential (millivolts)	Turbidity (Nephelometric turbidity units)	Dissolved oxygen concentration (milligrams per liter)
MW1	17.4	550	7.03	150	5.0	1.25
MW2	18.4	2,615	6.32	34	6.8	1.72
MW3	17.1	565	6.69	200	3.5	4.13
MW4	15.9	2,493	6.45	64	2.9	.35
MW5	18.5	775	6.74	151	2.5	1.49
MW6	16.7	1,865	6.55	- 86	5.6	.31
MW7	16.4	890	7.45	38	18.7	.34
MW8	17.9	1,453	6.43	0	10.4	.23
MW9	17.9	1,003	7.10	106	8.1	.34
MW10	16.7	8,202	6.59	68	8.7	.23
MW11	16.6	1,998	6.35	205	.0	.58
Geometric mean concentrations of parameters in wells MW4, MW5, MW7, MW9, MW10, and MW11	17.0	1,745	6.8	90.3	4.6	0.45
Geometric mean concentrations of parameters in wells MW1, MW2, MW3, MW6, and MW8	17.5	1,171	6.60	<15.9	5.9	0.91

water in the study area (tables 8, 9). Pesticide compounds were detected in samples from wells MW7, MW9, MW10, and in the duplicate sample from well MW11 (table 9). 1,1-dichloroethene detected in the sample from well MW4 is the only organic compound detected above its USEPA Maximum Contaminant Level (MCL) for drinking water (7 µg/L) in the study area (U.S. Environmental Protection Agency, 1996).

The chlorinated aliphatic hydrocarbons tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (DCE), 1,1,1-trichloroethane (TCA), 1,1- and 1,2-dichloroethane (DCA), and

chloroethane were detected in the sample from well MW4 (table 7). With the exception of 1,1-DCE, these compounds are or were components of industrial solvents used for metal degreasing in the United States. 1,1-DCA and 1,1-DCE are common products of the breakdown of the TCA molecule in ground water by reductive dechlorination and hydrolysis, respectively (Vogel and McCarty, 1987). Chloroethane commonly is produced by reductive dechlorination of 1,1-DCA in ground water. It is possible that chloroethane is being further degraded to ethanol, then to carbon dioxide and water.

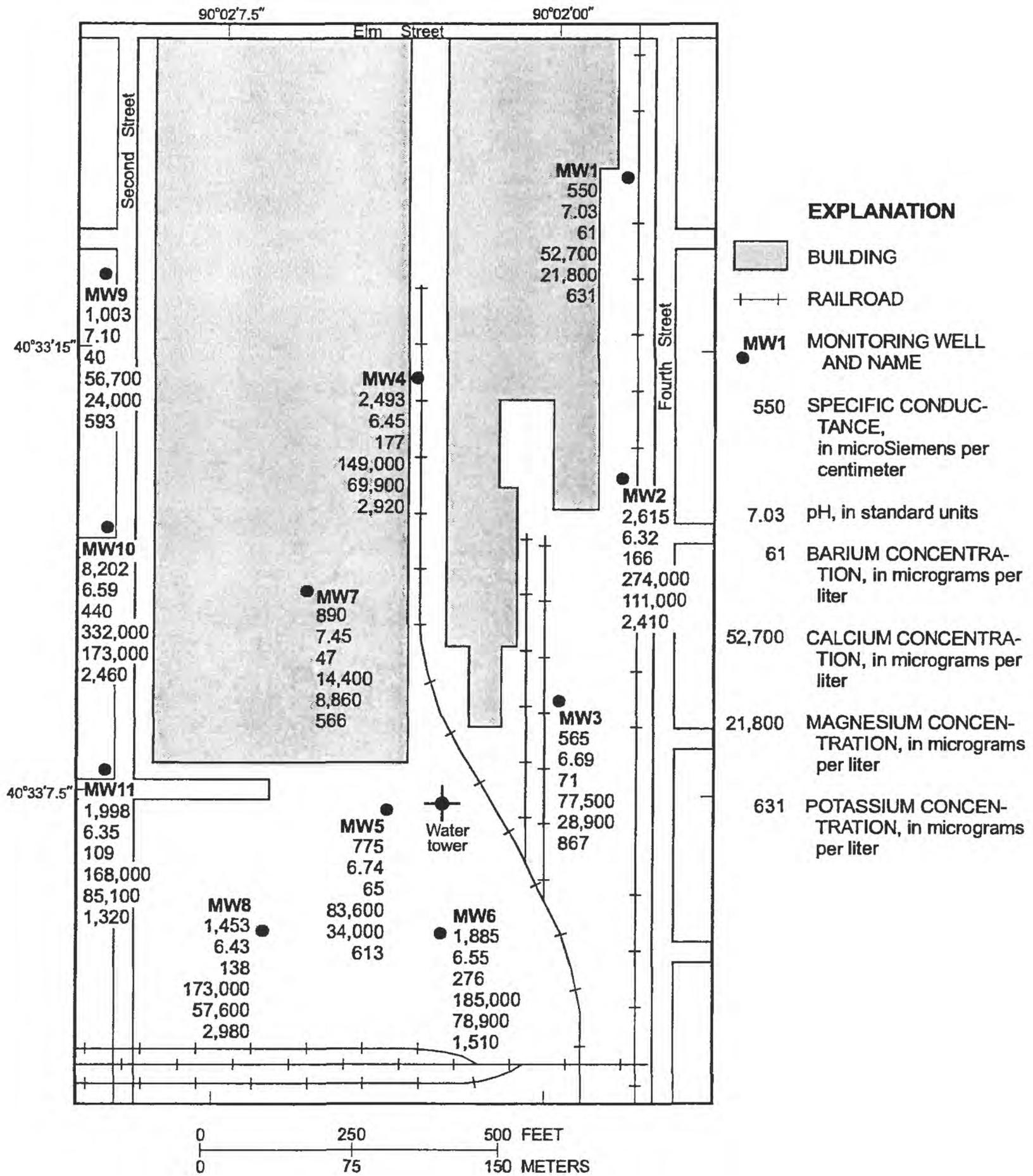


Figure 9. Specific conductance, pH, and concentrations of barium, calcium, magnesium, and potassium in the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000.

Table 7. Concentrations of volatile organic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000 (detections in bold)

[Dup., duplicate sample; µg/L, micrograms per liter; 10U, analyte not detected and detection limit; J, estimated concentration; B, compound detected in blank sample and is not considered representative of in-situ water quality]

Compound	Monitoring Well											
	MW1 (µg/L)	MW2 (µg/L)	MW3 (µg/L)	MW4 (µg/L)	MW5 (µg/L)	MW6 (µg/L)	MW7 (µg/L)	MW8 (µg/L)	MW9 (µg/L)	MW10 (µg/L)	MW11 (µg/L)	MW11 (Dup.) (µg/L)
Dichlorodifluoromethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Chloromethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Vinyl Chloride	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Bromomethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Chloroethane	10U	10U	10U	13	10U	10U	10U	10U	10U	10U	10U	10U
Trichlorofluoromethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,1-Dichloroethene	10U	10U	10U	10	10U	10U	10U	10U	10U	10U	10U	10U
1,1,2-Trichloro-1,2,2-trifluoroethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Acetone	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Carbon Disulfide	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	17
Methyl Acetate	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Methylene Chloride	10U	10U	10U	10U	10U	10U	10U	1JB	10U	10U	10U	10U
trans-1,2-Dichloroethene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Methyl tert-Butyl Ether	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,1-Dichloroethane	10U	10U	10U	58	10U	10U	10U	10U	10U	10U	10U	10U
cis-1,2-Dichloroethene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
2-Butanone	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Chloroform	10U	10U	10U	10U	19	10U	10U	10U	10U	10U	10U	10U
1,1,1-Trichloroethane	10U	10U	10U	26	10U	10U	10U	10U	10U	10U	10U	10U
Cyclohexane	10U	10U	10U	10U	10U	10U	7J	10U	10U	10U	10U	10U
Carbon Tetrachloride	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Benzene	10U	10U	10U	10U	10U	10U	3J	10U	10U	10U	10U	10U
1,2-Dichloroethane	10U	10U	10U	2J	10U	10U	10U	10U	10U	10U	10U	10U
Trichloroethene	10U	10U	10U	1J	10U	10U	10U	10U	10U	10U	10U	10U
Methylcyclohexane	10U	10U	10U	10U	10U	10U	10	10U	10U	10U	10U	10U
1,2-Dichloropropane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Bromodichloromethane	10U	10U	10U	10U	2J	10U	10U	10U	10U	10U	10U	10U
cis-1,3-Dichloropropene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
4-Methyl-2-pentanone	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Toluene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
trans-1,3-Dichloropropene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,1,2-Trichloroethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Tetrachloroethene	10U	10U	10U	3J	10U	10U	10U	10U	10U	10U	10U	10U
2-Hexanone	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Dibromochloromethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,2-Dibromoethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Chlorobenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Ethylbenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Xylenes (total)	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Styrene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Bromoform	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
Isopropylbenzene	10U	10U	10U	10U	10U	10U	1J	10U	10U	10U	10U	10U
1,1,2,2-Tetrachloroethane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,3-Dichlorobenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,4-Dichlorobenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,2-Dichlorobenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,2-Dibromo-3-chloropropane	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U
1,2,4-Trichlorobenzene	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U	10U

Table 8. Concentrations of semivolatile organic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000

[Dup., duplicate sample; µg/L, micrograms per liter; 10U, analyte not detected and detection limit; B, compound detected in blank sample]

Compound	Monitoring Well											
	MW1 (µg/L)	MW2 (µg/L)	MW3 (µg/L)	MW4 (µg/L)	MW5 (µg/L)	MW6 (µg/L)	MW7 (µg/L)	MW8 (µg/L)	MW9 (µg/L)	MW10 (µg/L)	MW11 (µg/L)	MW11 (Dup.) (µg/L)
Benzaldehyde	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Phenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
bis-(2-Chloroethyl) ether	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Chlorophenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Methylphenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,2'-oxybis(1-Chloropropane)	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Acetophenone	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Methylphenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
N-Nitroso-di-n-propylamine	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Hexachloroethane	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Nitrobenzene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Isophorone	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Nitrophenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4-Dimethylphenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
bis(2-Chloroethoxy)methane	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4-Dichlorophenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Naphthalene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Chloroaniline	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Hexachlorobutadiene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Caprolactam	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Chloro-3-methylphenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Methylnaphthalene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Hexachloro-cyclopentadiene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4,6-Trichlorophenol	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4,5-Trichlorophenol	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
1,1'-Biphenyl	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Chloronaphthalene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2-Nitroaniline	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
Dimethylphthalate	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,6-Dinitrotoluene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Acenaphthylene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
3-Nitroaniline	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
Acenaphthene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4-Dinitrophenol	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
4-Nitrophenol	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
Dibenzofuran	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
2,4-Dinitrotoluene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Diethylphthalate	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Fluorene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Chlorophenyl-phenyl ether	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Nitroaniline	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
4,6-Dinitro-2-methylphenol	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
N-Nitrosodiphenylamine	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
4-Bromophenyl-phenylether	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Hexachlorobenzene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Atrazine	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Pentachlorophenol	25U	30U	25U	25U	25U	25U	25U	28U	56U	25U	25U	25U
Phenanthrene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Anthracene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Carbazole	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Di-n-butylphthalate	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Fluoranthene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Pyrene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Butylbenzylphthalate	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
3,3'-Dichlorobenzidine	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Benzo(a)anthracene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U

Table 8. Concentrations of semivolatile organic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000—Continued

Compound	Monitoring Well											
	MW1 (µg/L)	MW2 (µg/L)	MW3 (µg/L)	MW4 (µg/L)	MW5 (µg/L)	MW6 (µg/L)	MW7 (µg/L)	MW8 (µg/L)	MW9 (µg/L)	MW10 (µg/L)	MW11 (µg/L)	MW11 (Dup.) (µg/L)
Chrysene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
bis(2-Ethylhexyl)phthalate	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Di-n-octylphthalate	10U	12U	10U	10U	10U	10U	1B	11U	22U	10U	10U	10U
Benzo(b)fluoranthene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Benzo(k)fluoranthene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Benzo(a)pyrene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Indeno(1,2,3-cd)pyrene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U
Dibenzo (a,h)anthracene	10U	12U	10U	10U	10U	10U	10U	11U	22U	10U	10U	10U

Table 9. Concentrations of pesticide and polychlorinated biphenyl compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000 (detections in bold)

[Dup., duplicate sample; µg/L, micrograms per liter; 0.050U, analyte not detected and detection limit; J, estimated concentration]

Compound	Monitoring Well											
	MW1 (µg/L)	MW-2 (µg/L)	MW-3 (µg/L)	MW4 (µg/L)	MW5 (µg/L)	MW6 (µg/L)	MW-7 (µg/L)	MW8 (µg/L)	MW9 (µg/L)	MW10 (µg/L)	MW-11 (µg/L)	MW11 (Dup.) (µg/L)
alpha-BHC	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0080 J	0.050U	0.050U
beta-BHC	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U
delta-BHC	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0020 J	0.050U	0.050U	0.0050 J	0.050U	0.050U
gamma-BHC (Lindane)	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0030 J	0.050U	0.050U
Heptachlor	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0020 J	0.050U	0.0040 J	0.050U	0.050U	0.0020 J
Aldrin	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0040 J	0.050U	0.050U
Heptachlor epoxide	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0010 J	0.050U	0.050U
Endosulfan I	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U
Dieldrin	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.0020 J	0.10U	0.10U
4,4'-DDE	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
Endrin	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
Endosulfan II	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
4,4'-DDD	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
Endosulfan sulfate	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
4,4'-DDT	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
Methoxychlor	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U
Endrin ketone	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
Endrin aldehyde	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U
alpha-Chlordane	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.0020 J	0.050U	0.050U
gamma-Chlordane	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U	0.050U
Toxaphene	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U	5.0U
Aroclor-1016	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Aroclor-1221	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U	2.0U
Aroclor-1232	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Aroclor-1242	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Aroclor-1248	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Aroclor-1254	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U
Aroclor-1260	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U	1.0U

Chloroform and bromodichloromethane were detected in the sample from well MW5 (table 7). These compounds are common by-products of chlorination of drinking water and their presence is likely the result of recharge to ground water from a leaking fire hydrant near well MW5 (Clark Wilson, city of Canton, oral commun., 2000).

Benzene, isopropylbenzene, cyclohexane, and methylcyclohexane were detected in the sample from well MW7. These compounds are all components of fuel oil and were detected in soils in the vicinity of well MW7. The presence of these compounds, combined with the detection of organic vapors and observation of a nonaqueous phase liquid on drilling equipment, in the lithologic samples obtained during drilling, and in the water purged from the well MW7 during development, indicate the potential presence of a nonaqueous phase liquid in the vicinity of well MW7. In addition, an oil sheen was described as present in many of the soil borings done in this area (Thomas Pachowicz, Ecology and Environment, Inc., written commun., 2000). A light nonaqueous phase liquid (LNAPL) was not detected in well MW7 during measurements taken immediately prior to well development and sample collection. However, the open interval of this well is below the water table and, therefore, the well is not designed to detect a LNAPL. The presence of less than 25 µg/L of total VOC's in the water from this well indicates that if a LNAPL is present at the water table in the upper semiconfining unit, natural attenuation processes are reducing the concentration of organic contaminants in the sand aquifer.

Carbon disulfide was detected in the duplicate sample from well MW11, but was not detected in the primary sample. It is unclear, therefore, if this detection represents in-situ water quality, or field or laboratory contamination. The USEPA has not established an MCL for carbon disulfide. Carbon disulfide has a variety of uses, including as an industrial solvent.

The pesticide chlordane is a mixture of compounds formerly used in the United States to protect seeds from insects and for termite control. Components of chlordane, including alpha-chlordane and heptachlor, and heptachlor epoxide, a breakdown product of heptachlor, have been detected at low concentrations in ground water from wells MW7, MW9, MW10, or MW11 (duplicate sample only) in the western part of the study area (table 9). Aldrin and

dieldrin, also pesticide compounds that formerly were used to protect seeds from insects and for termite control, were detected at low concentrations in the sample from well MW10. Dieldrin also is a breakdown product of aldrin. Alpha-, delta-, and gamma-benzenehexachloride (BHC), used for treatment of wood against boring insects, were detected at concentrations less than 0.01 µg/L in the sample from well MW10. Given the combination of pesticide compounds detected and the historical land use in and near the study area, it is possible that the pesticide compounds detected in the western part of the study area were applied to control wood-boring insects. Many of these compounds are highly persistent in the environment; however, the presence of heptachlor epoxide and perhaps dieldrin indicates that some pesticide degradation is occurring in the soils and ground water beneath the study area.

Alpha-, delta-, and gamma-BHC were not detected in 28 shallow (3-5 ft) soil samples collected at the site by Ecology and Environment, Inc. (Thomas Pachowicz, Ecology and Environment, Inc., written commun., 2000), whereas beta-BHC, which was not detected in any of the ground-water samples, was detected in three soil samples. These compounds, therefore, cannot be clearly attributed to the site and their presence may be due to another source or be an artifact of field or laboratory contamination (though field or laboratory contamination is not indicated by the quality-assurance and quality-control data). Alpha-chlordane, gamma-chlordane, heptachlor, heptachlor epoxide, aldrin, and dieldrin were detected in shallow samples collected at the site.

No clear correlation was found between the presence or concentration of organic compounds and any of the field parameters measured in the study area. Water from wells MW4, MW5, MW7, MW9, MW10, and MW11 had lower geometric mean values for temperature and dissolved oxygen concentration and higher geometric mean values for specific conductance, pH, and ORP than water from wells MW1, MW2, MW3, MW6, and MW8 (table 6). Wells MW4, MW5, MW7, MW9, MW10, and MW11 are open to those parts of the aquifer where organic compounds were detected. Organic compounds were not detected in samples from wells MW1, MW2, MW3, MW6, and MW8.

Metals, Major Cations, and Cyanide

Aluminum, barium, beryllium, calcium, copper, magnesium, manganese, nickel, potassium, sodium, and zinc were detected in all of the ground-water samples collected for this investigation (table 10). Iron was detected in the samples from wells MW2, MW3, MW6, MW7, and MW8. No other metal ion was detected in samples from more than three wells. Cyanide was not detected in any of the samples. The concentration of thallium in the sample from well MW3 and the concentration of antimony in one of the two samples from well MW6 (table 10) were the only inorganic constituents detected above their MCLs (2 and 6 $\mu\text{g/L}$, respectively) for drinking water (U.S. Environmental Protection Agency, 1996). For the purposes of this report, the major cations are calcium, magnesium, sodium and potassium and the metals are the remaining analytes listed in table 10.

Concentrations of aluminum in the ground-water samples collected for this investigation ranged from about 38 $\mu\text{g/L}$ in well MW10 to 301 $\mu\text{g/L}$ in well MW7 (table 10). Aluminum concentrations were less than 80 $\mu\text{g/L}$ in the southwestern part of the study area at wells MW5, MW8, MW10, and MW11. Aluminum concentrations in water samples from the northern and eastern parts of the study area, with the exception of the sample from well MW4, were greater than 80 $\mu\text{g/L}$.

Concentrations of barium in the ground-water samples collected for this investigation ranged from about 40 $\mu\text{g/L}$ in well MW9 to 440 $\mu\text{g/L}$ in well MW10 (table 10). Barium concentrations were less than 75 $\mu\text{g/L}$ at wells MW1, MW3, MW5, MW7, and MW9 in the northern and central parts of the study area, and were greater than 100 $\mu\text{g/L}$ in the remainder of the study area (fig. 9).

Estimated concentrations of beryllium in the ground-water samples collected for this investigation ranged from 0.31 $\mu\text{g/L}$ in well MW10 to 0.66 $\mu\text{g/L}$ in well MW7 (table 10). Estimated concentrations of beryllium were less than 0.40 $\mu\text{g/L}$ in the southwestern part of the study area at wells MW10, and MW11, and were 0.40 $\mu\text{g/L}$ or greater in the rest of the study area.

Concentrations of calcium in the ground-water samples collected for this investigation ranged from 14,400 $\mu\text{g/L}$ in well MW7 to 332,000 $\mu\text{g/L}$ in well MW10 (table 10). Calcium was the ion detected at

highest concentrations in wells MW1, MW2, MW3, MW5, MW6, MW8, and MW11. The spatial distribution of calcium concentrations in ground water beneath the study area was similar to that of barium. Calcium concentrations were less than 90,000 $\mu\text{g/L}$ at wells MW1, MW3, MW5, MW7, and MW9 in the northern and central parts of the study area and greater than 140,000 $\mu\text{g/L}$ in the remainder of the study area (fig. 9).

Concentrations of copper in the ground-water samples collected for this investigation ranged from 8.6 $\mu\text{g/L}$ in well MW5 to 17.2 $\mu\text{g/L}$ in well MW7 (table 10). Copper concentrations were less than 11 $\mu\text{g/L}$ in samples from wells MW5, MW8, MW9, MW10, and MW11 in the southwestern and western parts of the study area and were greater than 11 $\mu\text{g/L}$ in the remainder of the study area.

Concentrations of iron in the ground-water samples collected for this investigation ranged from below the detection limit of 29.5 $\mu\text{g/L}$ in six wells to about 11,000 $\mu\text{g/L}$ in well MW6 (table 10). Iron concentrations tended to be below the detection limit beneath most of the study area, but iron was detected near the eastern and southern parts of the site at wells MW2, MW3, MW6, and MW8, and in a potentially isolated area around well MW7.

Concentrations of magnesium in the ground-water samples collected for this investigation ranged from about 8,860 $\mu\text{g/L}$ in well MW7 to 173,000 $\mu\text{g/L}$ in well MW10 (table 10). The spatial distribution of magnesium concentrations beneath the study area was similar to that of barium and calcium. Magnesium concentrations were less than 40,000 $\mu\text{g/L}$ at wells MW1, MW3, MW5, MW7, and MW9 in the northern and central parts of the study area and greater than 57,000 $\mu\text{g/L}$ in the remainder of the study area (fig. 9).

Concentrations of manganese in the ground-water samples collected for this investigation ranged from about 33 $\mu\text{g/L}$ in well MW7 to about 1,800 $\mu\text{g/L}$ in well MW11 (table 10). Manganese concentrations showed no clear patterns with location in the study area.

Concentrations of nickel in the ground-water samples collected for this investigation ranged from about 1.5 $\mu\text{g/L}$ in well MW6 to 9.7 $\mu\text{g/L}$ in well MW8 (table 10). Nickel concentrations showed no clear patterns with location in the study area.

Table 10. Concentrations of inorganic compounds in water from monitoring wells in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000

[Dup., duplicate sample; µg/L, micrograms per liter; J, estimated concentration; 4.9U, analyte not detected and detection limit]

Compound	Monitoring Well												
	MW1 (µg/L)	MW2 (µg/L)	MW3 (µg/L)	MW4 (µg/L)	MW5 (µg/L)	MW6 (µg/L)	MW6 (Dup.) (µg/L)	MW7 (µg/L)	MW8 (µg/L)	MW9 (µg/L)	MW10 (µg/L)	MW11 (Dup.) (µg/L)	
ALUMINIUM	98.0J	95.8J	133	73.7J	41.1J	125	120	301	76.5J	89.6J	38.4J	43.7J	49.7J
ANTIMONY	4.9U	4.9U	4.9U	4.9U	4.9U	14.6J	4.9U	4.9U	4.9U	4.9U	4.9U	16.3J	4.9U
ARSENIC	5.6U	5.6U	5.6U	5.6U	5.6U	9.8	10.6	20.6	5.6U	5.6U	5.6U	5.6U	5.6U
BARIUM	61.0	166	70.7	177	65.2	276	277	47.2	138	40.4	440	109	107
BERYLLIUM	0.44J	0.40J	0.46J	0.42J	0.49J	0.47J	0.42J	0.66J	0.46J	0.50J	0.31J	0.38J	0.37J
CADMIUM	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U	0.50U
CALCIUM	52,700	274,000	77,500	149,000	83,600	185,000	187,000	14,400	173,000	56,700	332,000	168,000	168,000
CHROMIUM	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U	1.5U
COBALT	1.7U	3.0	1.7U	1.7U	1.7U	1.7U	1.7U	1.7U	2.0	1.7U	1.7U	3.5	3.0
COPPER	12.1	15.4	11.5	11.5	8.6	12.6	12.2	17.2	10.3	10.7	9.5	10.3	13.4
CYANIDE	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U	4.3U
IRON	29.5U	3300	85.1	29.5U	29.5U	11000	11100	642	1390	29.5U	29.5U	29.5U	29.5U
LEAD	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U	2.6U
MAGNESIUM	21,800	111,000	28,900	69,900	34,000	78,900	79,400	8,860	57,600	24,000	173,000	85,100	84,900
MANGANESE	142	214	469	1210	536	258	259	32.7	1420	351	64.0	1780	1820
MERCURY	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.10U	0.17J	0.10U	0.10U	0.10U	0.15J	0.10U
NICKEL	1.8	7.5	2.2	3.3	2.7	1.5	1.0	4.1	9.7	2.2	1.9	6.1	5.9
POTASSIUM	631	2,410	867	2,920	613	1,510	1,500	566	2,980	593	2,460	1,320	1,320
SELENIUM	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U	3.9U
SILVER	1.8U	1.8U	1.9	1.8U	1.8U	2.7	1.8U	1.8U	1.8	1.8U	1.8U	1.8U	1.8U
SODIUM	33,500J	73,400J	24,200J	227,000J	41,400J	87,200J	87,100	170,000J	40,300J	86,400J	796,000J	142,000J	147,000J
THALLIUM	7.8U	7.8U	8.1	7.8U	7.8U	7.8U	7.8U	7.8U	7.8U	7.8U	7.8U	7.8U	7.8U
VANADIUM	1.4U	1.4U	1.4U	1.4U	1.4U	1.4	1.4U	1.4U	1.4U	1.4U	1.4U	1.4U	1.4U
ZINC	9.8	13.9	10.8	10.7	8.9	10.0	9.6	25.7	10.8	12.1	8.7	15.6	18.3

Concentrations of potassium in the ground-water samples collected for this investigation ranged from 566 µg/L in well MW7 to 2,980 µg/L in well MW8. The spatial distribution of potassium concentrations beneath the study area was similar to that of barium, calcium, and magnesium. Potassium concentrations were less than 900 µg/L at wells MW1, MW3, MW5, MW7, and MW9 in the northern and central parts of the study area and greater than 1,300 µg/L in the remainder of the study area (fig. 9).

Estimated concentrations of sodium in the ground-water samples collected for this investigation ranged from 24,200 µg/L in well MW3 to 796,000 µg/L in well MW10 (table 10). Sodium was the ion detected at highest concentrations in wells MW4, MW7, MW9, and MW10 in the northwestern part of the study area. Sodium concentrations were greater than 140,000 µg/L at wells MW4, MW7, and MW11 in the west-central part of the study area. Sodium concentrations decreased to between 70,000 and 90,000 µg/L in wells MW2, MW6, and MW9 surrounding the west-central part of the study area, and decreased to less than 45,000 µg/L in the periphery of the study area at wells MW1, MW3, MW5, and MW11.

Concentrations of zinc in the ground-water samples collected for this investigation ranged from 8.7 µg/L in well MW10 to 25.7 µg/L in well MW7. Zinc concentrations showed no clear patterns with location in the study area.

Of the 19 metals and major cations detected in the ground water beneath the study area, the highest concentration of aluminum, arsenic, mercury, beryllium, copper, and zinc; and the lowest concentration of calcium, magnesium, manganese, and potassium were detected in the sample from well MW7 (table 10). The LNAPL tentatively identified in the vicinity of well MW7 appears to be affecting the concentration of these compounds by being a source of some compounds and by altering the geochemical conditions in ground water in the vicinity of well MW7, thereby affecting precipitation and dissolution of minerals in the geologic deposits.

The concentrations of calcium and magnesium in the ground-water samples from the sand aquifer show strong positive correlation, with a R^2 of 0.95 (fig. 10). Concentrations of both calcium and magnesium show a positive correlation with concentrations of barium, with an R^2 of 0.74 for barium-calcium and 0.81 for barium-

magnesium. Concentrations of both calcium and magnesium show a negative correlation with concentrations of beryllium, both having an R^2 of 0.61 (fig. 10). Barium and beryllium show a poor correlation (R^2 of 0.40), but the two wells with the lowest concentration of barium (MW7 and MW9) had the highest concentration of beryllium, and the well with the highest concentration of barium (MW10) had the lowest concentration of beryllium. Concentrations of calcium show logarithmic negative correlation with pH, having an R^2 value of 0.84 (fig. 10). The five wells with the lowest concentrations of calcium, magnesium, barium, and potassium (MW1, MW3, MW5, MW7, MW9) had pH values greater than 6.60, whereas the six wells with the highest concentration of calcium, magnesium, barium, and potassium (MW2, MW4, MW6, MW8, MW10, MW11) had pH values of less than 6.60 (fig. 9). A detailed assessment of the chemical reactions in the ground water beneath the study area is not possible without anion data. However, the available data indicate that dolomite and perhaps other carbonate minerals in the Quaternary deposits are being dissolved beneath and surrounding the study area, releasing calcium, magnesium, and perhaps barium to the ground water. The amount of dolomite dissolution is affected by the pH of the water. The increase in the concentration of these elements may have resulted in the precipitation of beryllium carbonate or hydroxide compounds or the sorption of beryllium onto aquifer solids.

Comparison of the concentrations of the metals and major cations with the field parameters indicates a positive correlation between specific conductance and concentrations of magnesium ($R^2 = 0.83$), barium ($R^2 = 0.82$), and sodium ($R^2 = 0.90$) in the sand aquifer beneath the study area. Specific conductance and calcium concentrations show a correlation coefficient of 0.55. If the data for well MW10, the well with the highest value for specific conductance, are removed from the plot only magnesium retains an R^2 value (0.82) that is greater than 0.60. Because specific conductance is affected by the concentration of ions in solution, a positive correlation between the value of specific conductance and the concentrations of the major cations is expected. The moderate to poor correlation between specific conductance and concentrations of the major cations indicates that anion concentrations also have a substantial effect on the value for specific conductance.

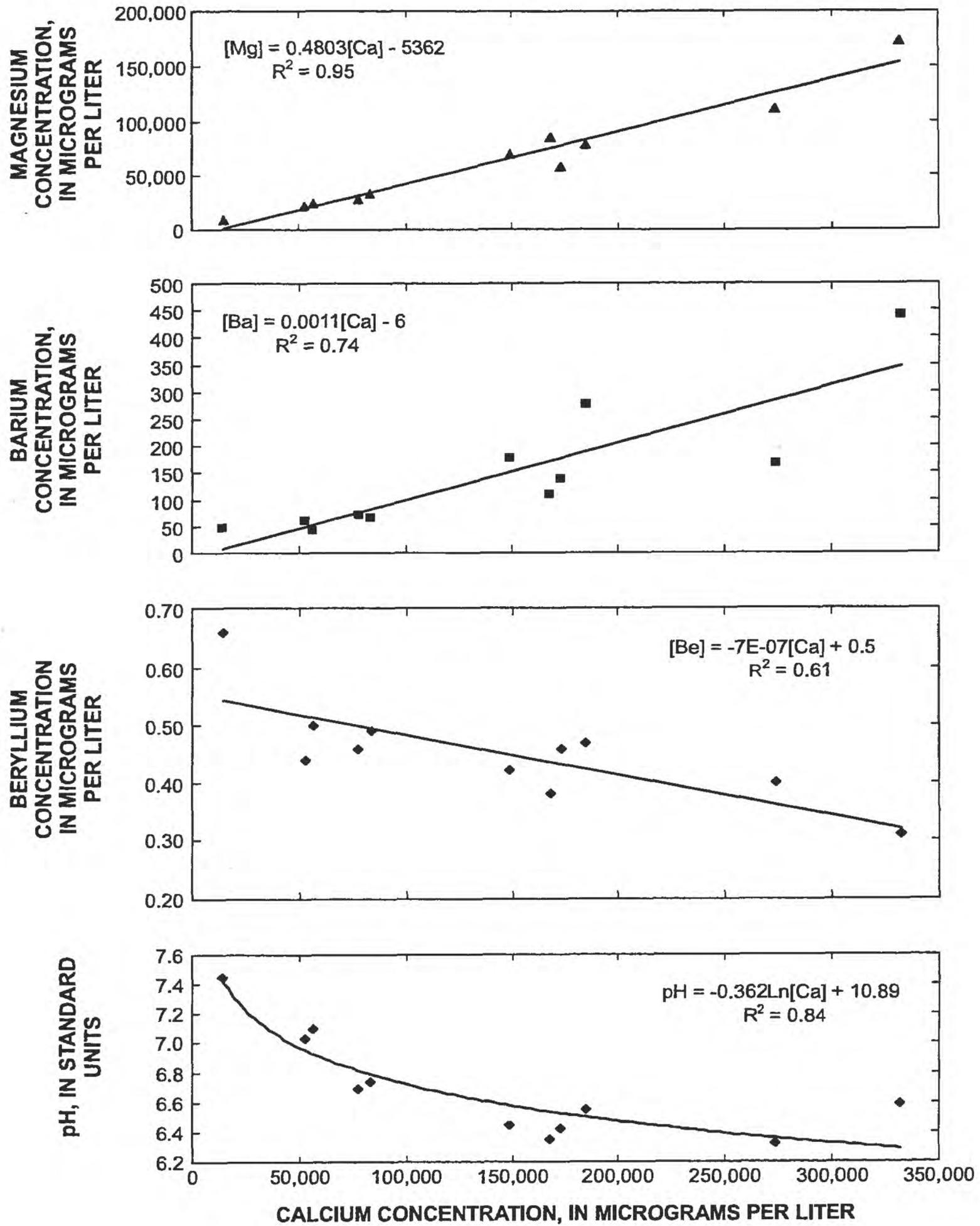


Figure 10. Correlation of selected chemical constituents in the sand aquifer in the vicinity of the Canton Brownfield site, Canton, Illinois, August 2000.

Because more than half of the wells did not contain detectable concentrations of iron, regression analysis for iron and the field parameters, metal ions, and major cations was not done. However, iron concentrations were less than the detection limit in six of the seven wells with ORP values greater than about 60 millivolts, whereas iron concentrations exceeded the detection limit in all four of the wells with an ORP value of less than about 60 millivolts. Concentrations of iron in solution appear to be affected by a more reducing geochemical environment, which favors the formation of the more soluble Fe(II) ion over Fe(III).

A linear regression analysis of the concentrations of aluminum, beryllium, and copper in the ground-water samples show a positive correlation, with an R^2 of 0.69 for both aluminum-beryllium and aluminum-copper. Concentrations of copper and beryllium are not well correlated ($R^2 = 0.29$). If the data from well MW7, the well with the highest concentration of aluminum, beryllium, and copper are removed, none of the correlation coefficients are greater than 0.40. The calculated correlation among the concentrations of aluminum, copper, and beryllium is a false correlation related to the effects of the LNAPL on geochemical properties in the ground water in the vicinity of well MW7, and not chemical processes in the sand aquifer and the upper semiconfining unit.

Concentrations of metals and major cations also were compared to the horizontal hydraulic conductivity of the sand aquifer at the wells. Although a linear correlation could not be determined, the six wells with iron concentrations below the detection limit (MW1, MW4, MW5, MW9, MW10, and MW11) all had horizontal hydraulic conductivity values greater than 2.5 ft/d, whereas all of the wells with detectable concentrations of iron (MW2, MW3, MW6, MW6, and MW8) had horizontal-hydraulic-conductivity values less than 2.0 ft/d (tables 4, 10).

The data indicate that there are two areas with differing ground-water quality beneath the study area. The first area is located near wells MW1, MW3, MW5, MW7, and MW9, and is characterized by elevated pH and comparatively low specific conductance and concentrations of calcium, magnesium, potassium, barium and perhaps beryllium. The second area constitutes the remainder of the study area and is characterized by

lower pH and comparatively high specific conductance, calcium, magnesium, potassium, and barium. The concentrations of aluminum, copper, iron, and sodium also showed some spatial variation within the study area.

Chemical processes in the ground-water system affect the concentration of metals and major cations in solution. These processes appear to be affected by a variety of factors including the pH and geochemical environment of the water, the mineralogy of the geologic deposits, the potential presence of a LNAPL, and possibly the application of road salts at the land surface. Chemical processes in the sand aquifer are likely to be affected by position within the flow pathway, as chemical processes are affected in all ground-water systems. However, there is no clear correlation between the concentration of any metal, major cation or other constituent and position within the ground-water-flow pathway beneath the study area.

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey and Environmental Operations, Inc., in cooperation with the U.S. Environmental Protection Agency, characterized the geology, hydrology, and water quality in and around the Canton Brownfield site in Canton, Illinois. This investigation was done to determine if ground water in the vicinity of the site contained contaminants at sufficiently high concentrations to potentially impact human health and the environment as well as redevelopment of the site.

There are three hydraulic units of concern in the study area, the upper semiconfining unit, the sand aquifer, and the lower semiconfining unit. The upper semiconfining unit is from about 1 to 19 ft thick and is composed of fill and clay deposits with a geometric mean vertical hydraulic conductivity of 8.6×10^{-3} ft/d. The sand aquifer is composed of the sand deposit, is about 1 to 5.5 ft thick, with a horizontal hydraulic conductivity of 0.23 to 79 ft/d. The lower semiconfining unit is composed of sandy silt-and-clay deposits with a geometric mean vertical hydraulic conductivity of 1.1×10^{-3} ft/d. The sand aquifer is the primary pathway for contaminant movement offsite and out of the study area. The overall direction of flow in the sand aquifer is to the east, south, and west, away from a ground-water ridge near the center of the study area. Ground-water

velocity through the sand aquifer was calculated to vary from about 40 to 145 ft/yr beneath the study area.

Volatile organic compounds were detected in ground water in the center of the study area. Pesticide compounds were detected in ground water in the western part of the study area. At least partial degradation of some of the volatile organic compounds and pesticides is occurring beneath the study area. Of the organic compounds detected, maximum contaminant levels were exceeded only for 1,1-dichloroethene in the sample from well MW4.

Metals and major cations were detected in water samples from the wells. Concentrations of barium, beryllium, calcium, magnesium, potassium, specific conductance, and pH all showed similar spatial patterns. Although different than the pattern for barium, beryllium, calcium, magnesium, potassium, specific conductance and pH, concentrations of many of the other metals and major cations also showed some variation with location in the study area. The concentrations of metals and major cations in the ground water appear to be affected by a combination of dissolution of dolomite minerals in the unconsolidated deposits, the presence of the light nonaqueous phase liquid, the pH, and the geochemical environment of the water. With the exception of antimony in well MW6 and thallium in well MW3, no metals were detected in water samples above the U.S. Environmental Protection Agency maximum contaminant level.

REFERENCES CITED

- American Society of Testing Materials, 1998, Standard methods for particle-size analysis of soils: p. D422-63.
- American Society of Testing Materials, 2000, Standard methods for measurement of hydraulic conductivity of saturated porous materials using a flexible wall permeameter, p. D5084-00.
- Barcelona, M.J., Wehrman, H.A., Varljen, M.D., 1994, Reproducible well-purging procedures and VOC stabilization criteria for ground-water sampling: *Ground Water*, v. 33, no. 1, p. 12-22.
- Bouwer, Herman, and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: *Water Resources Research*, v. 12, no. 3, p. 423-428.
- Environmental Operations, Inc., 2000, Phase II site investigation work plan, Brownfield redevelopment, city of Canton: Prepared for the U.S. Environmental Protection Agency, Chicago, Illinois, variously paginated.
- Lineback, J.A., Follmer, L.B., Willman, H.B., McKay, E.D., King, J.E., and Miller, N.G., 1979, Wisconsinan, Sangamonian, and Illinoian stratigraphy in central Illinois: *Illinois State Geological Survey Guidebook 13*, 139 p.
- Savage, T.E., 1921, Geology and mineral resources of the Avon and Canton quadrangle: *Illinois State Geological Survey Extract from Bulletin No. 38*, 67 p.
- Shanklin, D.E., Sidle, W.C., and Ferguson, M.E., 1995, Mirco-purge low-flow sampling of uranium-contaminated ground water at the Fernald environmental management project: *Ground Water Monitoring Review*, v. 15, no. 2, p. 168-176.
- U.S. Environmental Protection Agency, 1996, Drinking water regulations and health advisories: Office of Water Report EPA 822-B-96-002, 11 p.
- Vogel, T.M., and McCarty, P.L., 1987, Abiotic and biotic transformations of 1,1,1-trichloroethane under methanogenic conditions: *Environmental Science and Technology*, v. 21, no. 21, p. 1208-1213.
- Willman, H.B., Frye, J.C., Simon, J.A., Clegg, K.E., Swan, D.H., Atherton, E., Collinson, C., Lineback, J.A., and Buschback, T.C., 1967, Geologic map of Illinois: *Illinois State Geological Survey*, 1 p.
- Willman, H.B., and Frye, J.C., 1970, Pleistocene stratigraphy of Illinois: *Illinois State Geological Survey, Bulletin 94*, 204 p.