

**EXPANDED SITE INVESTIGATION/REMEDIAL INVESTIGATION  
RESULTS FOR THE RIVERFRONT SITE,  
NEW HAVEN, MISSOURI**

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## LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

--	incomplete or absent data
<	less than
als	above land surface
asl	above sea level
alt.	altitude
ATD	at time of drilling
bls	below land surface
B	compound detected in blank
BW	bedrock monitoring well
cis-DCE	cis-1,2-dichloroethene
Cotter	Cotter Dolomite formation
Cr	Chromium
csg	depth of casing
DGLS	Department of Geology and Land Survey
DO	dissolved oxygen
E	estimated
EM	electromagnetic survey
Eminence	Eminence Dolomite formation
ESI	Expanded Site Investigation
fig.	figure
ft	feet
Gasc	Gasconade Dolomite formation
GC	gas chromatograph
gal/min	gallons per minute
GPS	Global Positioning System
hr	hour
HRS	Hazardous Ranking System
ID	identification
in.	inch
Jeff	Jefferson City Dolomite formation
MDNR	Missouri Department of Natural Resources
MDOC	Missouri Department of Conservation
mg/kg	milligrams per kilogram

mi	mile
mL	milliliters
MW	monitoring well
N/A	not applicable
NE	not estimated
NPL	National Priorities List
NWQL	National Water Quality Laboratory
OU	Operable Unit
P	USEPA designated point
Pb	Lead
PCE	tetrachloroethene
Potosi	Potosi Dolomite formation
QAPP	Quality Assurance Project Plan
Rbdx	Roubidoux Sandstone formation
RI	Remedial Investigation
cond	specific conductance
START	Superfund Technical Assessment and Response Team
TD	total depth of well
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Potential
trans-DCE	trans-1,2-dichloroethene
TW	temporary monitoring well (alluvial well)
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
USACE	United States Army Corp of Engineers
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
VC	vinyl chloride
VOC	volatile organic compound
W	public or industrial well
WL	water level



# **EXPANDED SITE INVESTIGATION/REMEDIAL INVESTIGATION RESULTS FOR THE RIVERFRONT SITE, NEW HAVEN, MISSOURI**

## **1.0 INTRODUCTION**

New Haven, Missouri, is a small town located on the southern bank of the Missouri River, approximately 50 mi (miles) west of St. Louis, Missouri, on State Highway 100 (fig. 1). In 1986, the Missouri Department of Natural Resources (MDNR) detected the chlorinated solvent tetrachloroethene (PCE) in both of the public supply wells (W1 and W2) that served New Haven. These wells were later abandoned and two additional wells (W3 and W4) were installed. Subsequent monitoring has detected no PCE in the new wells; however, the source of the PCE contamination in wells W1 and W2 was never identified. Currently (2000), the site, referred to by the U.S. Environmental Protection Agency (USEPA) as the Riverfront Site, is proposed for the National Priorities List (NPL) and the USEPA and U.S. Geological Survey (USGS) have entered into an agreement to conduct a remedial investigation (RI) of the Riverfront Site.

During 1997, the USEPA asked the USGS to review the expanded site investigation (ESI) report for the Riverfront Site because of some outstanding questions regarding the location of a shallow ground-water divide. The USGS provided a letter summarizing their review of the ESI to the USEPA (Jeff Imes, U.S. Geological Survey, written communication, October 21, 1997). In 1998, the USEPA asked the USGS for technical assistance in obtaining additional information on ground-water flow in the New Haven area and potential directions of PCE migration. This assistance was conducted as an ESI/RI under USEPA contract DW-14-95214801-2, from April 1999 to September 2000.

## **2.0 SCOPE**

The USGS prepared a two-phased ESI/RI project proposal and work plan (Investigation of PCE contamination of municipal supply wells in the city of New Haven, Missouri, January 1999) that was approved by the USEPA on April 19, 1999. The primary objectives of this work plan were to

1. determine the altitude of the alluvial water table and shallow bedrock water table in the New Haven area,
2. determine if the Missouri River alluvial aquifer beneath the Riverfront site was contaminated by PCE, and
3. determine if substantial quantities of PCE waste are present at the old New Haven City Dump.

The scope of this initial effort was constrained by limited funds and was developed assuming that the Riverfront site (located in downtown New Haven)<sup>1</sup> was the source of the PCE contamination detected in the closed city wells. This assumption enabled the scope of the investigation to focus on the Riverfront site and exclude other potential PCE sources in the city. The Riverfront site was identified as the most probable source of the PCE contamination in city wells W1 and W2 in the ESI (Jacobs Engineering Group, Inc., 1994). This letter report summarizes the results of USGS activities during the ESI/RI. A summary of the relevant documents for the ESI/RI activities is provided in table 1.

Based on the results of the phase I investigation it was determined that additional an additional phase (Phase II) of data collection was needed to determine the distribution of PCE in the bedrock in the vicinity of city well W2 and at the old city dump. The primary objective of phase II were to:

1. provide a detailed characterization of the vertical distribution of contaminants in city well W2, and
2. determine the distribution of PCE in the bedrock in the vicinity of city well W2 and the old city dump.

This additional work was performed under the initial phase I QAPP. The scope of phase II included packer and pump tests in city well W2 and the installation of three bedrock monitoring wells (one north of city well W2, one south of city well W2, and one near the old city dump). A reconnaissance of streams in the vicinity of city well W2 also was conducted. Additional activities outside the original project scope were performed to support the removal of a contaminated water line near city well W2 and the assessment of industrial wastes discovered on a private farm southeast of New Haven.

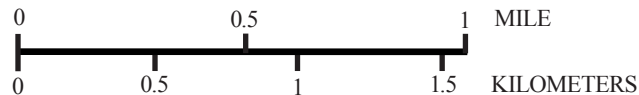
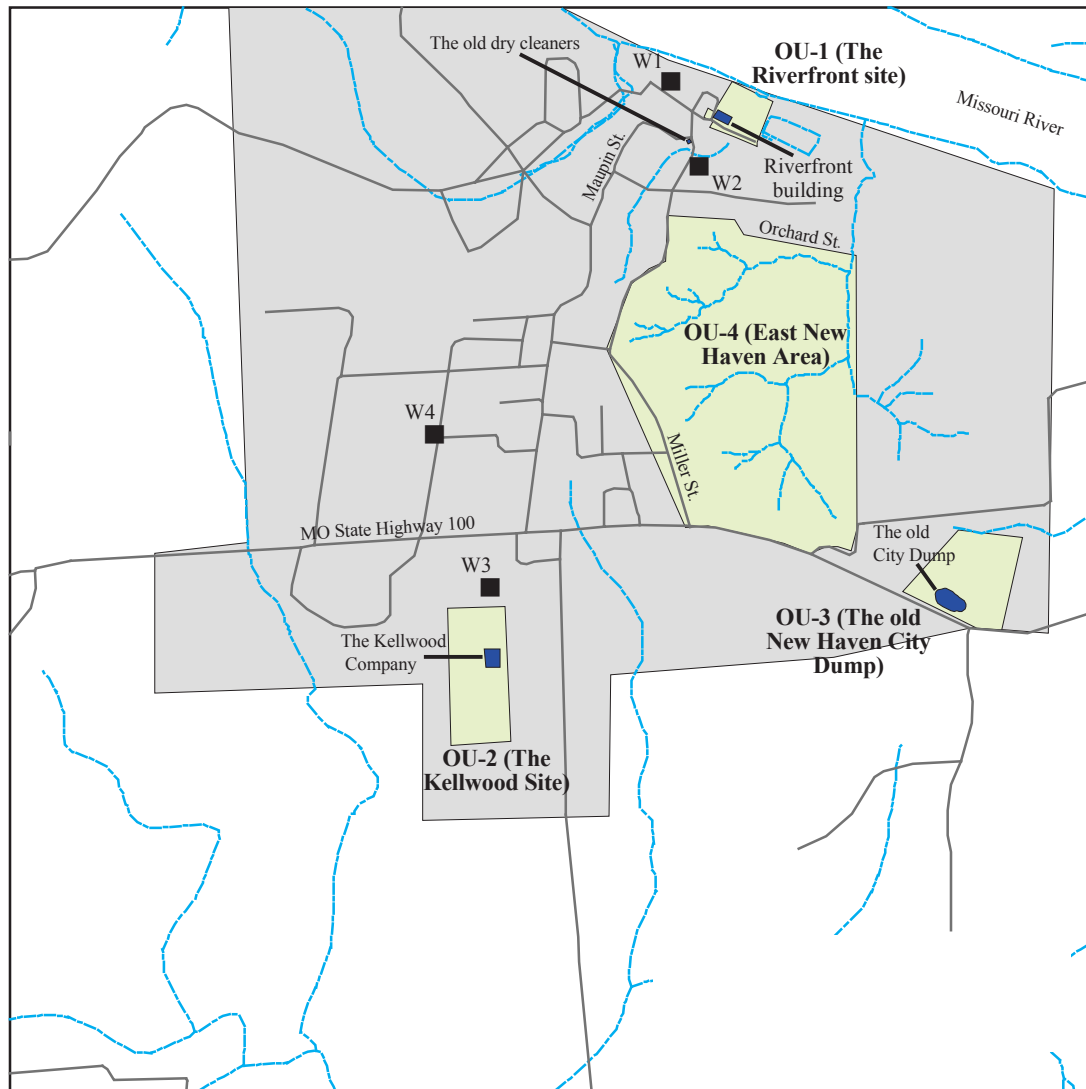
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<sup>1</sup> The entire proposed NPL site is titled "The Riverfront Site" and is designated herein as the Riverfront RI site. Within this site is the operable unit (OU), the Riverfront site located in the downtown business district. Any further reference to the Riverfront site will be to the OU.

**TABLE 1.** Summary of relevant documents and letters pertaining to the Riverfront Site ESI/RI.

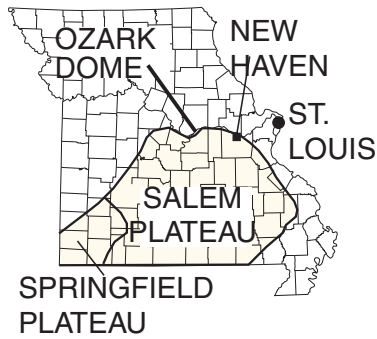
<b>Date</b>	<b>Title</b>	<b>Description</b>
October 21, 1997	Administrative letter to Ms. Shelley Brodie	USGS administrative letter report summarizing results of a technical review of the USEPA Riverfront site ESI and supporting documents.
January 1999	Investigation of PCE contamination of municipal supply wells in the city of New Haven, Missouri, January 1999	Work plan for USGS ESI/RI activities
February 23, 1999	Monitoring well installation plan, Riverfront site, New Haven, Missouri	Specifications and procedures for the installation of alluvial monitoring wells at the Riverfront site
March 1999	Quality assurance project plan for the phase I characterization of ground-water quality in the vicinity of supply well no. 2 and a reconnaissance of the old New Haven City Dump site, city of New Haven, Missouri	Quality assurance project plan (QAPP) describing USGS field activities, methods, and quality assurance checks.
November 26, 1999	Packer Tests and Monitoring Well Installation Plan, City Well No. 2 and vicinity, New Haven, Missouri	Specifications for packer testing of city well 2 and the installation and sampling of bedrock monitoring wells near city well 2 and the old New Haven City Dump. Submitted as an addendum to the March 1999 QAPP.
March 17, 2000	Administrative letter report to Ms. Shelley Brodie [Hazard Ranking System (HRS) letter]	USGS peer review document describing the geohydrology of the New Haven area and results of the ESI/RI well inventory. Report package was used by the USEPA in the HRS scoring of the New Haven site.
June 27, 2000	Letter to Ms. Shelley Brodie	Describes the USGS activities that led to the discovery of PCE in a plastic water line adjacent to the Riverfront site

The ESI/RI included a well inventory in the New Haven area to assess the ground-water flow and quality, the collection of core samples from trees growing near the downtown Riverfront site and the old New Haven City Dump, the sampling of water seeps at the old New Haven City Dump, and the installation and sampling of alluvial monitoring wells in the downtown Riverfront area. At the request of the USEPA, additional efforts performed as amendments to the original ESI/RI work plan included the evaluation of a contaminated water-supply service line and assistance during a removal action of contaminated soils near that water line, the installation and sampling of five bedrock-monitoring wells in the New Haven area, and the sampling of soils, seeps, and trees at an industrial dump site near New Haven. As a result of these investigations, the initial contaminated area of concern grew from one area to four. These four areas under investigation have become the four operable units (OUs) in the RI work plan for the proposed Riverfront NPL Site (fig. 1). These OUs are the Riverfront site (OU-1), the Kellwood site (OU-2), the old New Haven City Dump (OU-3), and the East New Haven Area (OU-4).



**EXPLANATION**

- W3 ■ CITY WELL AND NUMBER
- ∩ ROADS
- ~ STREAMS
- NEW HAVEN CITY LIMITS
- OPERABLE UNITS (OUs), NUMBERS AND NAMES ARE BOLDED



**FIGURE 1.** The location of New Haven, Missouri, and the four operable units (OUs) of the Riverfront Site.

### **3.0 PHASE I OBJECTIVE 1: BEDROCK GROUND-WATER FLOW IN THE NEW HAVEN AREA**

New Haven is underlain by bedrock units of the Ozark aquifer. The Ozark aquifer is a thick sequence of water-bearing dolostone, limestone, and sandstone formations ranging in age from Late Cambrian to Middle Devonian (Imes and Emmett, 1994). Although these formations collectively act as a regional aquifer with flow systems extending tens of miles, the water-yielding capacity of the various individual formations is variable. Geologic logs from New Haven city wells W1 and W2 and an industrial well (hereinafter referred to as the Pepsi well) indicate that the uppermost bedrock units beneath New Haven are the Ordovician age Cotter Dolomite and Jefferson City Dolomite [87 to about 395 ft (feet) thick]. Beneath the Cotter and Jefferson City Dolomites, geologic formations in the Ozark aquifer are, in order of increasing age, the Roubidoux Formation (about 115 ft thick), Gasconade Dolomite (about 310 ft thick), Eminence Dolomite (about 160 ft thick), and Potosi Dolomite (more than 170 ft thick). Based on the well depths obtained during the well inventory, most domestic wells in the New Haven area are open to the Jefferson City Dolomite and underlying Roubidoux Formation. The Roubidoux Formation probably is the most widely used formation in south-central Missouri for domestic supply (Miller and Vandike, 1997). In the New Haven area, the Roubidoux Formation contains a 30 to 50 ft thick sand zone and yields to wells are in excess of 35 to 50 gal/min (gallons per minute). High-capacity public-supply and industrial wells are drilled much deeper into the Eminence or Potosi Dolomites and have yields in the hundreds of gallons per minute. City wells W1 and W2 are cased less than 225 ft and are open to the Roubidoux Formation through the top of the Potosi Dolomite. City wells W3 and W4 are cased deeper (525 and 560 ft) through the Roubidoux Formation and are open to the Gasconade Dolomite, Eminence Dolomite, and Potosi Dolomite (well W4 only).

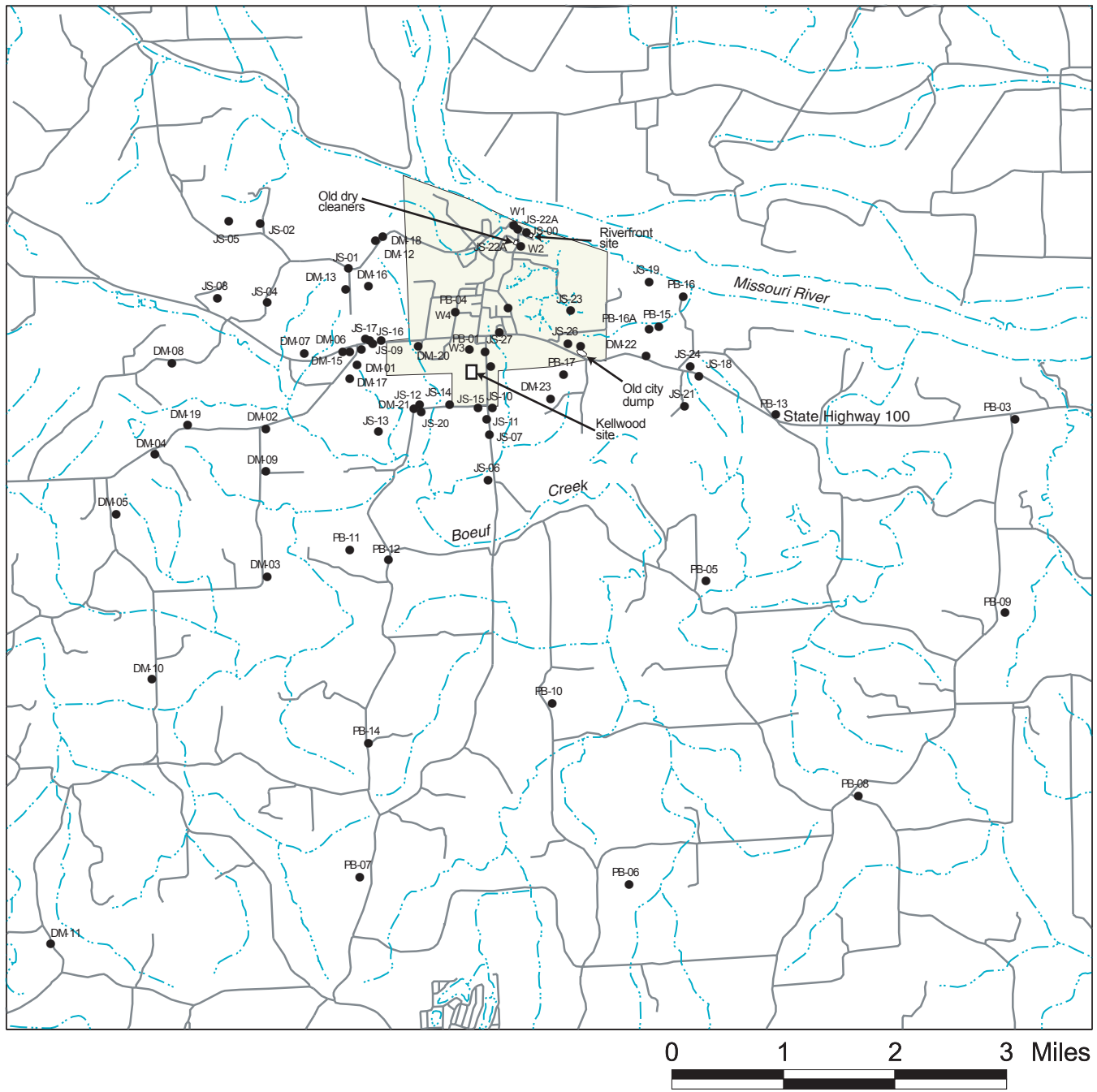
#### **3.1 Well inventory and shallow ground-water flow**

In an effort to determine the extent of the PCE contamination beneath the city of New Haven and adjacent areas, the USGS conducted a well inventory in the New Haven area. The primary objectives of this inventory were to determine if a shallow ground-water divide existed in the southern part of the city, and to develop an understanding of ground-water flow in the vicinity of four potential sources of chlorinated solvents identified by the MDNR and the USEPA (Mosby, 1988; Jacobs Engineering Group, 1994). These four potential source areas are the Riverfront site, the old dry cleaners, an industrial site in south New Haven (the Kellwood site), and the old New Haven City Dump. The results of the well

inventory were used in the Hazard Ranking System (HRS) Documentation Record for the Riverfront RI Site, New Haven, Missouri, during the proposal of the site to the NPL.

The well inventory began during February 1999 and focused on wells within 2- to 5-mi of New Haven south of the Missouri River (fig. 2). During the inventory, water-level measurements were made in selected wells and these measurements were used to construct a water-table map (fig. 3). Records at the MDNR, Division of Geology and Land Survey (DGLS) and local water-well drillers also were searched. Data collected during interviews with property owners included well depth, pump depth, drill date, general water quality and availability, and location of septic tanks or waste lagoons. Water-level measurements were obtained in 56 of the 67 inventoried domestic wells and high capacity wells (supplemental data at the end of the document). The land surface altitude of wells where water-level measurements were obtained was determined to the nearest 0.1 ft using a global positioning system (GPS) survey. With the owner's permission, water samples were collected from selected wells and screened for the presence of PCE and other volatile organic compounds (VOCs) using a portable gas chromatograph (GC). The VOCs analyzed included PCE, trichloroethene (TCE), cis-1,2-dichloroethene (cis-DCE), trans-1,2-dichloroethene (trans-DCE), vinyl chloride (VC), benzene, and toluene. If the screening indicated the presence of PCE or other VOCs, the well owner was contacted and asked for permission to collect a second sample for submittal to the USGS laboratory for confirmation. Samples were also collected from these wells as a courtesy to well owners and screened for the presence of chloride (Cl) and nitrate as nitrogen (NO<sub>3</sub>) using a portable spectrophotometer. Increased Cl and NO<sub>3</sub> concentrations may indicate affects from human or animal waste sources such as septic tanks.

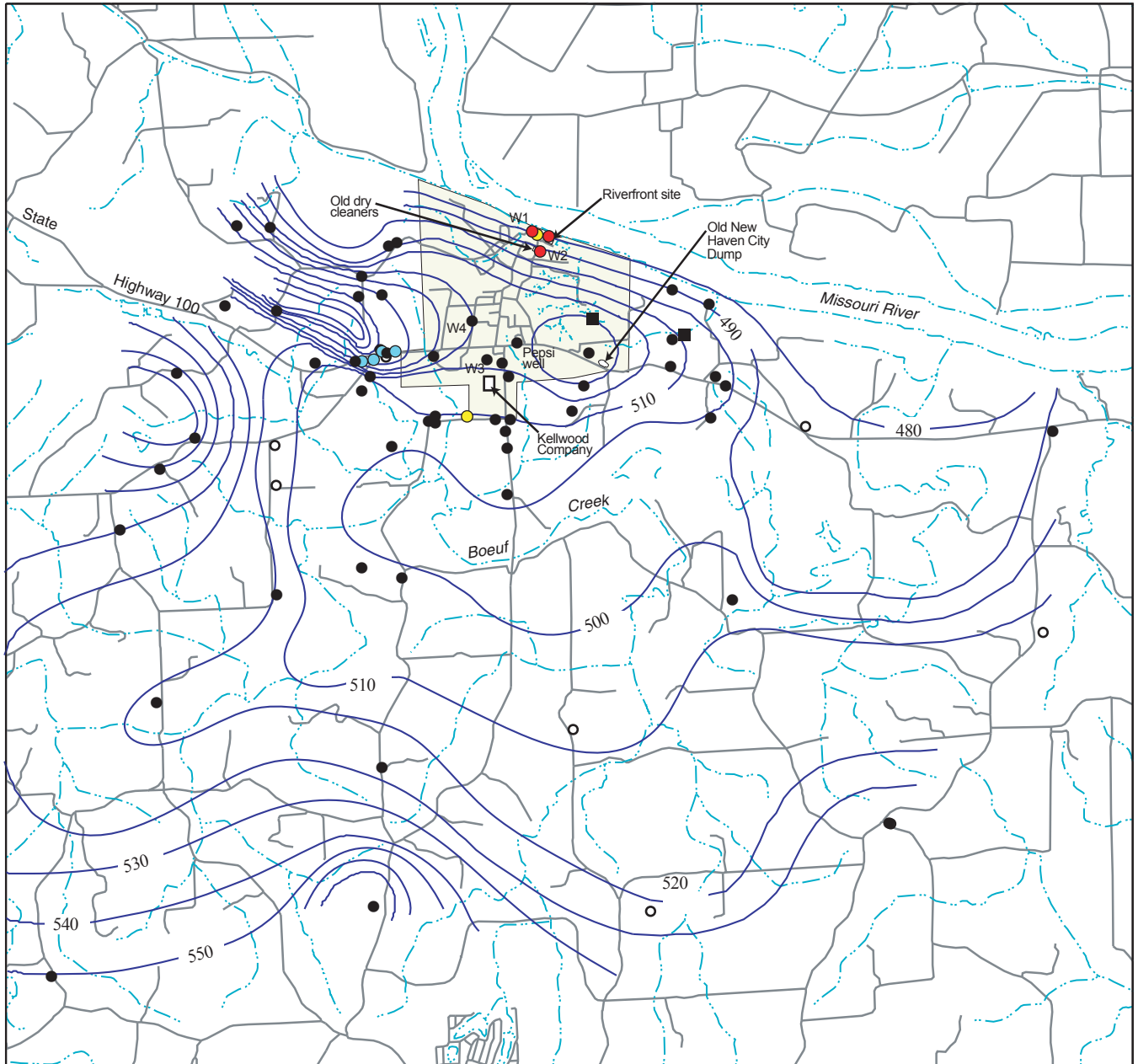
The water-table map confirms the existence of a shallow ground-water divide centered along State Highway 100 just south of the topographic divide (fig. 3). Shallow ground water flows perpendicular to contour lines of equal hydraulic head, or water-level altitude from topographic highs toward discharge areas along Boeuf Creek and the Missouri River. Shallow ground water south of this divide flows south, opposite of the regional gradient, towards Boeuf Creek. The Riverfront site, and the old dry cleaners in downtown New Haven are north of this divide and the Kellwood site is south of this divide (fig. 3). A detailed description of the water-table map and shallow and deep ground-water flow directions was provided to the USEPA as USGS peer reviewed administrative letter report dated March 11, 2000. Most of the domestic wells inventoried were less than about 400 ft deep; therefore, the water-table map reflects the altitude of the potentiometric head in the upper 400 ft of the aquifer.



**EXPLANATION**

- Well and ID number
- Spring and ID number
- Stream
- Road

**FIGURE 2.** Domestic, municipal, and industrial wells and springs inventoried in the New Haven area.



**EXPLANATION**

- |   |   |          |
|---|---|----------|
| PCE (tetrachloroethene) concentration in micrograms per liter | ● Well containing only TCE (trichloroethene) less than 5 micrograms per liter | — Stream |
| ○ NOT SAMPLED   | ■ Spring (PCE less than 0.1 ug/L)   | — Road   |
| ● LESS THAN 0.1   | — Water table contour (contour interval 10 feet)                              |          |
| ● 0.1 TO 5.0  |   |          |
| ● GREATER THAN 5.0  |   |          |

**FIGURE 3.** Altitude of the water table in the bedrock, and tetrachloroethene (PCE) and trichloroethene (TCE) concentrations in domestic, municipal, and industrial wells, and springs inventoried in the New Haven area.

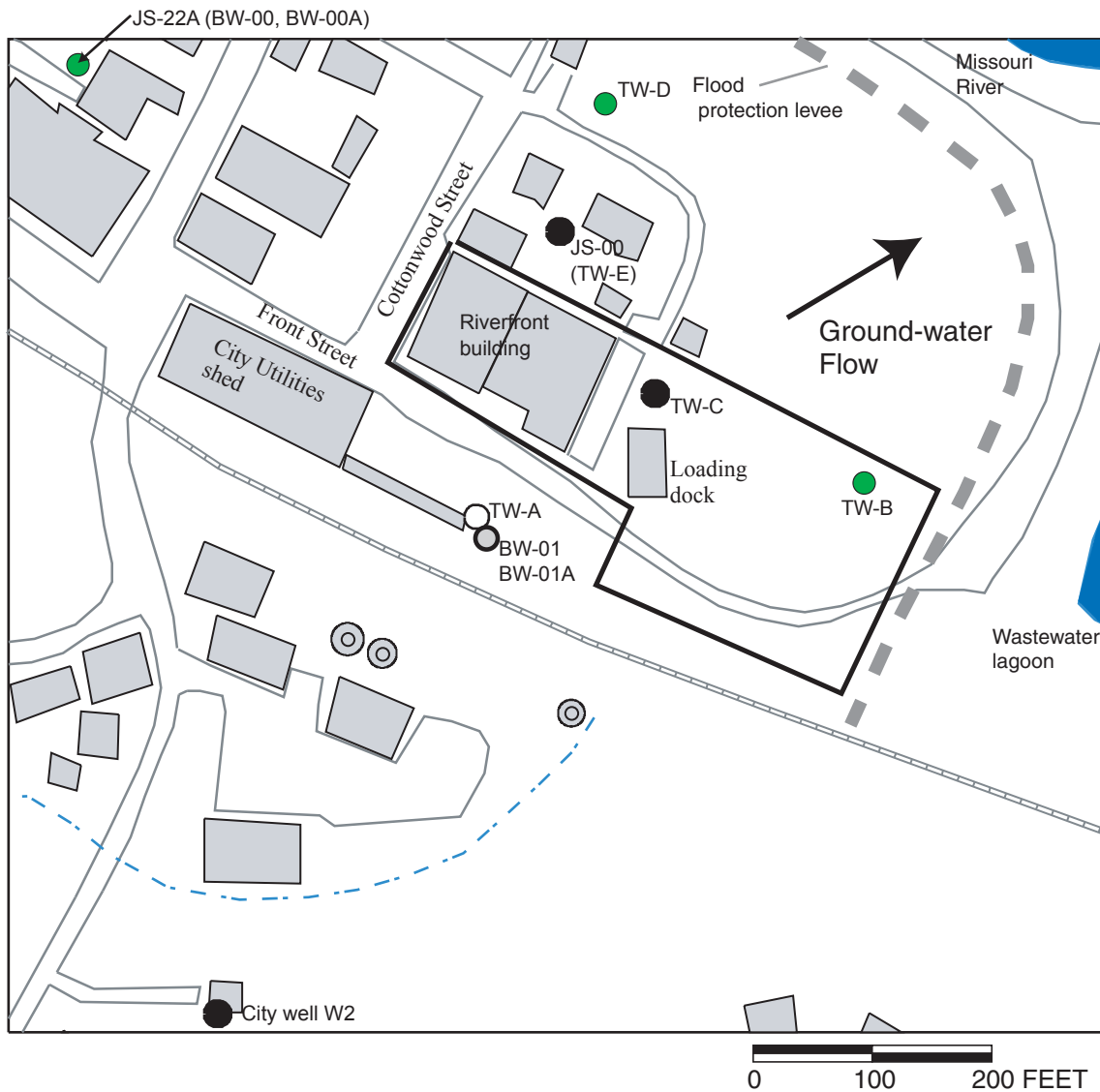


### **3.2 Distribution of volatile organic compounds in ground water in the New Haven area.**

Volatile organic compounds were detected in 8 of the 53 water samples screened by the portable GC during the well inventory. No VOCs were detected in portable GC or laboratory samples collected from city wells W3 and W4. Three wells (JS-00, JS-14, and JS-22a) contained detectable PCE concentrations ranging from 0.1 to 200 µg/L (micrograms per liter). Four wells (DM-06, DM-14, JS-03, and JS-16) contained only TCE at concentrations between 0.2 to 4.0 µg/L, and a sample from one well (JS-20) contained toluene at 1.7 µg/L. The sample from well JS-00 contained large concentrations of PCE (225 µg/L), TCE (58.2 µg/L), and cis-DCE (125 µg/L). This well is an abandoned brick-lined hand-dug well about 50 ft north of the Riverfront building (fig. 4). A laboratory split sample collected from this well confirmed the portable GC results and contained 195 µg/L PCE, 43.9 µg/L TCE, and 140 µg/L cis-DCE (table 2).

Well JS-14 is located along the southern edge of New Haven more than 1-mi south of the Riverfront site and is used for domestic supply. The screening sample from this well contained a trace quantity (0.33 µg/L) of PCE (table 2). The well owner did not want additional sampling done and the presence of PCE was qualitatively confirmed by laboratory analysis of the expired portable GC sample. Based on the water-table map, well JS-14 is downgradient of the Kellwood site (fig. 3) where the MDNR has supervised a cleanup of PCE contaminated soils (Geotechnology, Inc., 1991, 1993, 1994).

Well JS-22a (PCE of 0.1 µg/L) is an abandoned well at the old ice cream plant in downtown New Haven about 1 block west of the Riverfront site (fig. 4). No laboratory confirmation samples were collected from this well; however, during phase II of the ESI/RI (spring 2000) this well was converted into a multiple port monitoring well. The four domestic wells that contained only TCE are located to the west of New Haven along State Highway 100. Additional samples collected from wells DM-14 and JS-16 and submitted for laboratory analysis contained TCE at 1.18 and 4.62 µg/L, which confirmed the portable GC results (table 2). Because PCE was not detected in these wells, the USEPA has not made this area of TCE detections part of the NPL proposal. The well containing only toluene (JS-20) was located near the south side of New Haven.



### EXPLANATION

Concentration of PCE (tetrachloroethene) in micrograms per liter (TW indicates alluvial well, BW indicates bedrock well)

- Less than 0.1
- 0.1 to 4.99
- ◐ 5.0 to 99.9
- > 100
- ⚡ Railroad

- ▭ BUILDINGS
- ∟ ROADS
- ⚡ SITE PROPERTY BOUNDARY
- ⋯ STREAM

FIGURE 4. Features of the Riverfront site in downtown New Haven, Missouri.

**TABLE 2.** Comparison of portable gas chromatograph (GC) and laboratory analyses of volatile organic compounds (VOCs) in water samples from selected wells from the New Haven area.

[ID, identification; PCE, tetrachloroethene; TCE, trichloroethene; cis-DCE, cis-1,2-dichloroethene; <, less than; all concentrations in micrograms per liter]

Well ID	Date	Portable gas chromatograph (micrograms per liter)			Laboratory analysis (micrograms per liter)		
		PCE	TCE	cis-DCE	PCE	TCE	cis-DCE
DM-14	04-01-99	<0.1	0.75	<0.1	<0.1	1.18	<0.1
JS-14	03-24-99	0.33	<0.1	<0.1	0.11 <sup>b</sup>	<0.125	<0.125
JS-16	04-01-99	<0.1	4.0 <sup>a</sup>	<0.1	<0.1	4.62	<0.1
JS-00	02-19-99	225	58.2	125	195	43.9	140

<sup>a</sup> Portable GC indicated TCE of 2.70 µg/L in a previous sample collected on 3-25-99.

<sup>b</sup> Laboratory analysis run on headspace vial from portable GC and some VOCs may have been lost. Concentration is estimated.

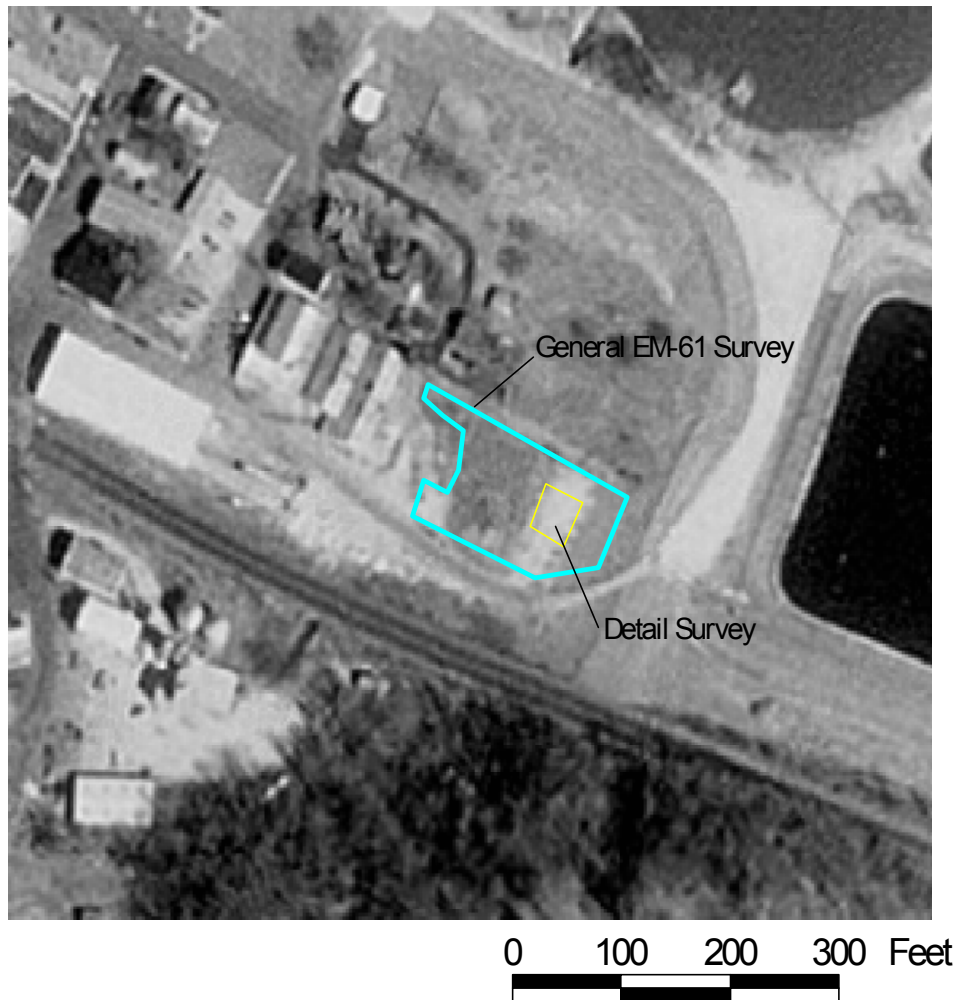
#### **4.0 PHASE I OBJECTIVE 2: DISTRIBUTION OF TETRACHLOROETHENE IN THE MISSOURI RIVER ALLUVIAL AQUIFER AT THE RIVERFRONT SITE**

The ESI indicated that shallow subsurface soil samples (less than 10 ft deep) at the Riverfront site contained PCE concentrations as large as 83 mg/kg [(milligrams per kilogram), Jacobs Engineering Group, 1994]. At the time of the ESI, no data existed on the extent of PCE contamination, if any, in the underlying alluvial aquifer. The premise of the ESI/RI work plan was that if PCE disposed at the Riverfront site contaminated city wells W1 and W2, then PCE contamination should be detected in alluvial soils, alluvial water, and in the bedrock aquifer beneath the Riverfront site. To test this hypothesis, four alluvial monitoring wells were installed in the vicinity of the Riverfront site during August 1999.

Before installing the monitoring wells, an electromagnetic survey (EM-61) was done along with the collection of soil borings and tree core samples. The EM-61 was done to detect possible buried drums in the area. The tree core samples were collected to provide preliminary data on the extent of possible PCE contamination in the subsurface and aid in selection of monitoring well locations. Highly contaminated soils were to be avoided during the monitoring well installation (to avoid the potential of carrying contamination down hole) and soil borings were conducted at each proposed monitoring well locations to determine the extent of soil contamination before well drilling began.

#### 4.1 Electromagnetic survey of the Riverfront site

The USEPA had reports that drums of industrial waste, possibly chlorinated solvents, were buried in the eastern part of the Riverfront site. To avoid encountering these potential drums during drilling, an electromagnetic survey using a hand pulled EM-61 was done. The EM-61 survey was performed in May 1999 on the east one-half of the downtown Riverfront site (fig. 5).

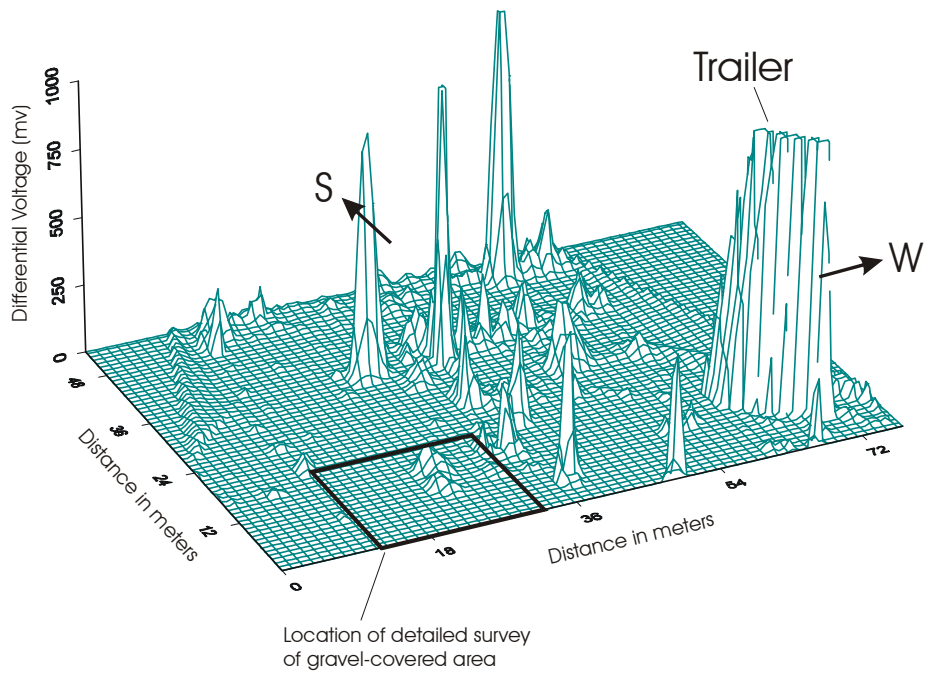


**FIGURE 5.** Approximate area covered by the May 1999, EM-61 survey at the Riverfront site (base photo is from the USGS 1986 digital orthophoto quadrangle of the New Haven, Missouri, 7-1/2 minute quadrangle map).

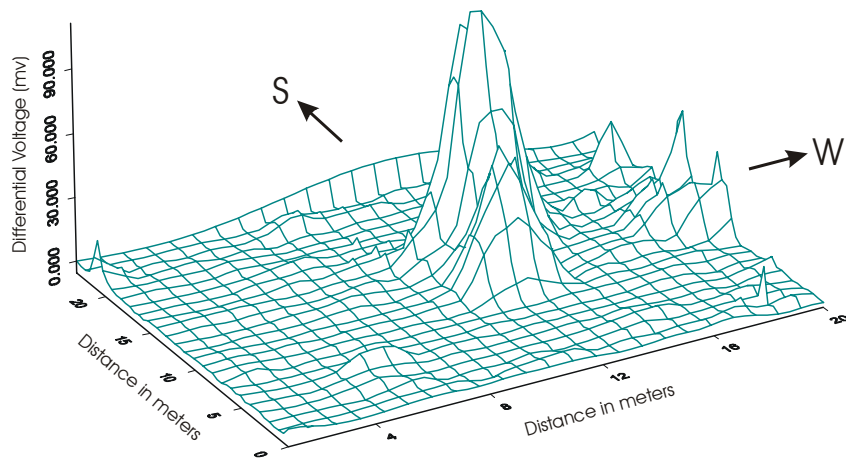
The EM-61 instrument consists of two 3-ft diameter coils about 1 ft apart fixed to a small cart that was pulled by hand across the site. The unit detects ferrous metals and indicates the presence of these as an increase in voltage on a detector with increasing size or with decreasing depth of the object. A rectangular grid was set up with a transit with the reference line being 10 ft south of the north property fence. A reference point (metal pin) was set along this line 10 ft south of the red fence post at the northeast corner of the property and 34.292 ft east along the reference line near the toe of the flood protection levee. The reference line was west and roughly parallel to the north property fence and ended about 5 ft east of the concrete slab and 10 ft south of the metal fence. Twenty-nine parallel transects were made across the site in an east-west direction beginning along the reference line just south of the north property line. The transects were spaced about 2.5 ft apart and alternated east to west then west to east. Results of the survey are shown in fig. 6.

A second detailed survey was made of a poorly vegetated gravel-covered area in the eastern one-third of the site. A total of 20 parallel north-south transects were made in this area. The eastern reference line for this survey was 39.156 ft west of the original survey reference point (that being 10 ft south of the fence and 34.292 ft east along a line 10 ft south of the fence). Results of the detail survey were similar to those of the general survey (fig. 7).

Analysis of the EM-61 data using software provided by the manufacturer (slopes of peaks, etc.) indicated numerous buried metal objects in both the general and detailed survey areas. Detailed analysis of the peaks suggests that nearly all the objects detected were near surface (less than about 2 ft deep). While performing the field survey, numerous metal objects, such as truck spring parts, bolts, cans, sheet metal, and steel rods were observed at the surface. These objects were removed when observed to avoid their interference with the EM survey. With respect to buried drums, the results are inconclusive because of the large noise caused by the shallow metal debris.



**FIGURE 6.** Perspective view (looking southwest) of the EM-61 survey area in the east part of the Riverfront site.

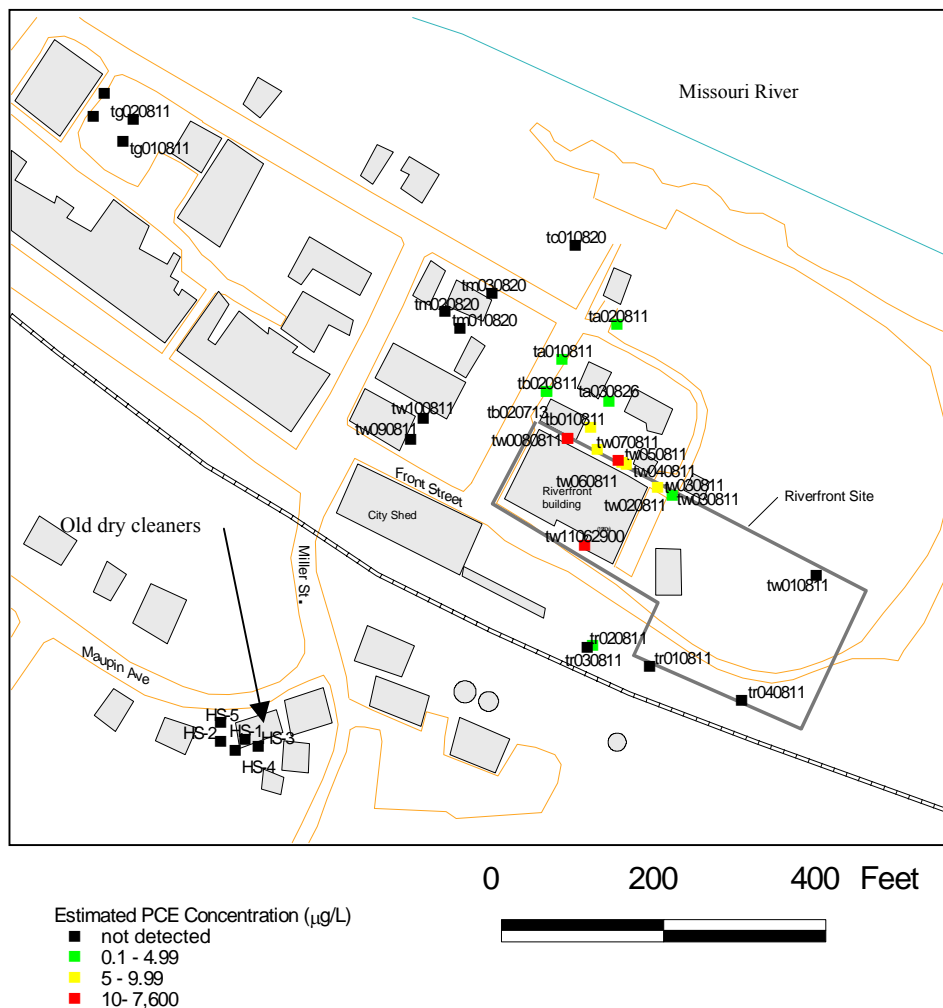


**FIGURE 7.** Perspective view (looking southwest) of the detail EM-61 survey area in the northeast part of the Riverfront site.

#### **4.2 Tree core survey in the downtown New Haven area**

The USGS has determined that trees growing above shallow ground-water plumes of chlorinated solvents can uptake these chlorinated solvents (Vroblesky, 1999). The technique is experimental, and little is known about the mechanism of transport into, through, or out of the tree. However, because of the potential for rapid delineation of PCE contamination in the subsurface and the non-invasive nature of the sampling, it was decided to conduct a tree-core survey at the Riverfront site, the old New Haven City Dump, and the old dry cleaners.

Trees with a diameter of about 3-in. or larger were selected for coring using a standard U.S. Forest Service (USFS) ¼ x 4-in. tree boring tool. If multiple species were present at a single location, preference was given to species that are known to grow rapidly and have deep root systems, such as mulberry, poplar, and cottonwood. Cores immediately were placed in 40 mL (milliliter) VOC vials and transported to the USGS laboratory in Rolla where they were held for 24 hr (hour) at room temperature. Headspace analysis was performed using the portable GC. More than 30 trees were cored in the downtown area (fig. 8).



**FIGURE 8.** Location of tree-core samples in the downtown New Haven area.

[PCE, tetrachloroethene;  $\mu\text{g/L}$ , micrograms per liter]

Core samples from trees along the north side of the Riverfront building and a single Chinese elm tree on the south side of the Riverfront building contained the largest PCE concentrations (fig. 5). The PCE concentrations are estimated because the quantity of the moisture in the tree core was not known and assumed to be 1 mL. None of the tree-core samples collected from trees west of the Riverfront site or from trees in the vicinity of the old dry cleaners contained detectable concentrations of PCE or other chlorinated solvents.



### **4.3 Soil boring at the Riverfront site**

Results of the tree-core sampling were used in selecting the locations for alluvial monitoring wells in the vicinity of the Riverfront site. Other factors considered were accessibility to the sites, assumptions about ground-water flow in the alluvium, and property owner preference. Before the installation of monitoring wells, soil borings were collected at each proposed monitoring well location to ensure that highly contaminated materials were not encountered in the subsurface. Soil borings were conducted using a trailer-mounted soil exploration drill rig. Soil core samples were obtained by pushing a 2-in. diameter slotted-steel core tube into the soil with the drill rig. If cobbles or debris were encountered, such as at proposed monitoring well location temporary monitoring well-A (TW-A), a 3-in. diameter solid stem auger was used to advance the borehole past the obstruction or the drill rig was moved several feet and boring attempted again.

Soil cores were sampled at discrete intervals and the PCE concentrations were determined via headspace using the portable GC. Soil borings were labeled according to the proposed monitoring well number (e.g. borehole B for monitoring well location TW-B) and multiple borings at a given location were designated with a numeric suffix (e.g. borehole A2). Two sets of soil borings were done. The initial soil borings were done on July 30, 1999, at proposed monitoring well locations TW-A, TW-B, and TW-C. The landowner at proposed location TW-D was not home on July 30, 1999, and no boring was done at that location. Samples collected from these borings were analyzed several days later at the USGS laboratory in Rolla, Missouri, using the headspace method and the portable GC. Except for a PCE concentration of 152  $\mu\text{g}/\text{kg}$  in a sample from borehole A (1.55 ft deep), PCE concentrations in the samples were less than 65  $\mu\text{g}/\text{kg}$  (table 3). Based on the results of the July 30, 1999 sampling, a second set of borings was done on August 10, 1999, to collect samples for laboratory analysis and to install a soil boring at proposed monitoring well location TW-D.

**TABLE 3.** Estimated tetrachloroethene (PCE) concentrations in samples from soil borings conducted in the vicinity of the Riverfront site on July 30, 1999.

[All concentrations in micrograms per kilogram; --, no data; <, less than]

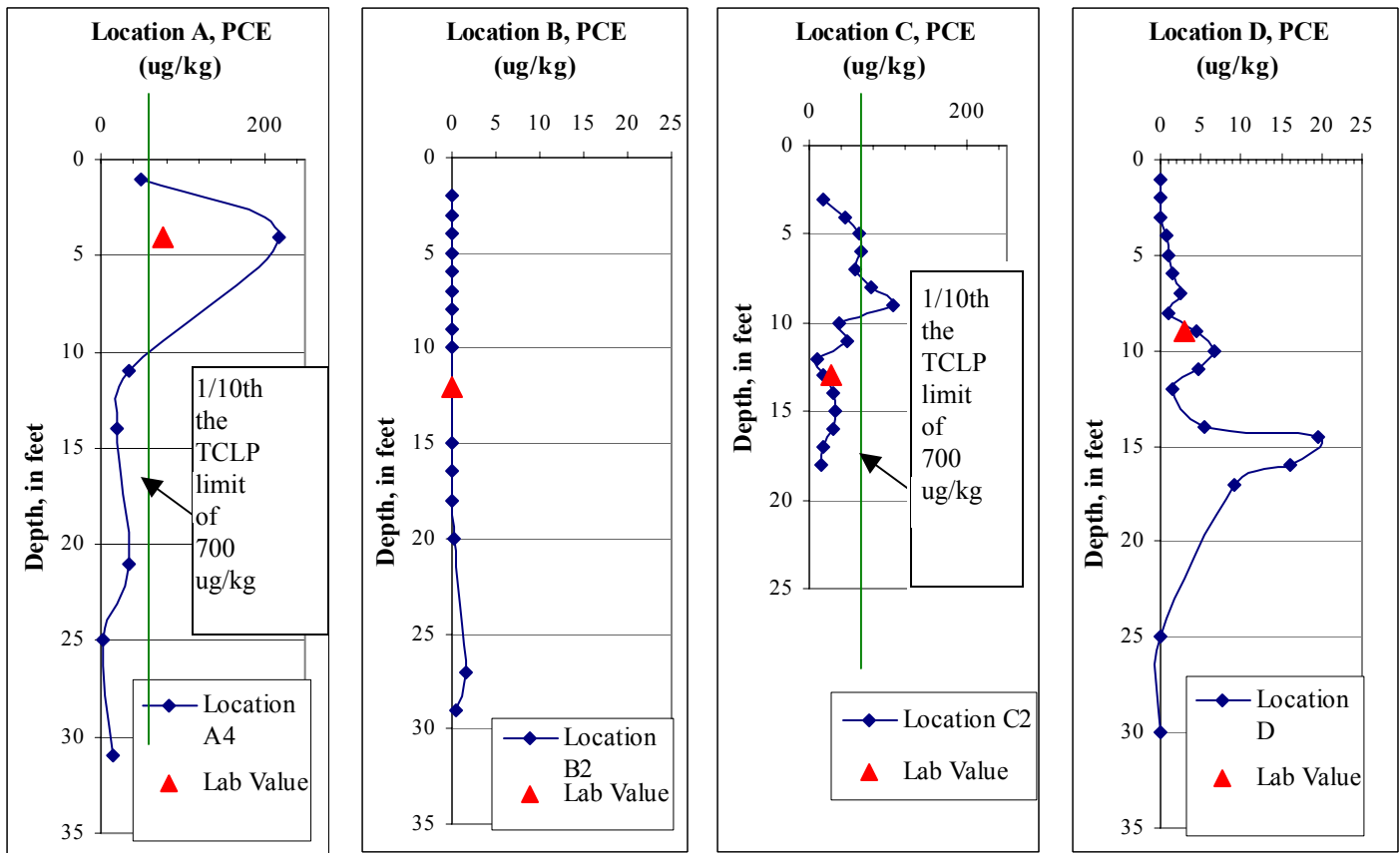
Depth (feet below land surface)	Well location TW-A			Well location TW-B	Well location TW-C
	Borehole A	Borehole A2	Borehole A3	Borehole B	Borehole C
1.5	152	--	--	--	--
2	--	--	--	<2	4
2.5	23	23	46	--	--
3	--	30	--	--	--
4	--	--	--	<2	24
4.5	--	--	60	--	--
5.3	--	--	22	--	--
6	--	--	30	<2	30
8	--	--	40	<2	26
9	--	--	64	--	--
10	--	--	--	<2	66
11	--	--	56	--	--

At location A south of the Riverfront property, refusal on a probable concrete slab was encountered and the borehole location was moved about 3 ft to the northeast (A2) where refusal also was encountered. The borehole was moved an additional 3 ft northeast (A3) and the boring was successfully completed to 11 ft deep. Soils at location TW-A were dark gray to black and had a hydrocarbon smell similar to asphalt or diesel fuel. No debris was encountered at locations TW-B or TW-C; these soils appeared to be undisturbed alluvial silts and sandy silts. Results of headspace analyses of core samples from the initial borings indicated that highly contaminated materials were not present at proposed monitoring well locations TW-A, TW-B, or TW-C.

A second round of soil borings were conducted on August 10, 1999, at all four proposed monitoring well locations. These borings were located adjacent (within 1 ft) to the initial borings done on July 30, 1999, and extended to depths up to 18 ft. Analysis of soil samples from these boreholes by the portable GC and a single laboratory sample from each borehole indicated PCE concentrations less than the 700 µg/kg limit established in the Quality Assurance Project Plan (QAPP), above which, alternate locations for the monitoring wells would have been selected. Upon approval of a final drilling plan by the U.S. Army Corp of Engineers (USACE), installation of the monitoring wells (TW-A, TW-B, TW-C, and TW-D) commenced on August 17, 1999. A summary of PCE concentrations detected samples from the August 10, 1999, soil borings and in samples collected during the installation of the monitoring wells is given in fig. 5.

The largest PCE concentrations detected in headspace samples were from location TW-A at 4 ft deep and location TW-C between 5 and 10 ft deep (fig. 9)

Generally, the upper 8 to 12 ft. of the alluvium consisted of silt and sandy silts with an increase in sand with increasing depth. A plastic clay to silt clay bed was encountered at location TW-B (11.5 to 12.5 ft.) and location TW-C (15.0 to 16.7 ft.). Sediments at location TW-D were coarser than at other locations and mostly fine-grained sand and silty-sand at depths below 6 ft grading into medium sands at depths below 14 ft. Sediments at location TW-A generally were finer-grained than at other locations and consisted mostly of clayey-silts between 0 and 10 ft, and a blue-gray plastic clay to silty-clay between 10 and 25 ft. Saturated silty-sand lenses were encountered at location TW-B at 7.5 to 8.0 ft, 9.3 to 10.0 ft, and at 10.5 to 11.0 ft deep. Saturated silty-sand lenses also were encountered at location TW-C at 11.0 to 11.5 ft and 15.9 to 17.5 ft deep. Depths to bedrock (tan dolostone) ranged from 27.5 ft at location TW-A to 34.1 ft at location TW-B.



**FIGURE 9.** Vertical distribution of tetrachloroethene (PCE) in soil borings in the vicinity of the Riverfront site, August 1999. Boring done at alluvial monitoring well locations.

[ug/kg, microgram per kilogram; mg/kg, milligram per kilogram; TCLP, Toxicity Characteristic Leaching Potential]

#### 4.4 Installation of Riverfront Alluvial Monitoring Wells

Between August 17 and August 26, 1999, four alluvial-water monitoring wells were installed in the downtown Riverfront area using a cable tool drill rig (fig. 4). These wells are TW-A, TW-B, TW-C, and TW-D. The wells were installed to the base of the alluvial aquifer (less than 35 ft deep) with 5 ft screens and filter packs designed to straddle the alluvium-bedrock contact. A fifth well (TW-E) incorporated into the alluvial monitoring well network is the abandoned hand-dug-well (JS-00) identified during the well inventory just north of the Riverfront property. The completion data and schematic illustrations for the four USGS installed wells may be viewed in table 4, and in the supplemental data at the end of the document, respectively. Drill cuttings from each well were drummed and disposed at a subtitle D landfill after

Toxicity Characteristic Leaching Potential (TCLP) characterization indicated they could not be classified as hazardous wastes.

**TABLE 4.** Completion data for USEPA monitoring wells installed in New Haven, Missouri

[asl, above sea level; bls, below land surface; --, no data; N/A, not applicable]

<b>Description</b>	<b>Well TW-A</b>	<b>Well TW-B</b>	<b>Well TW-C</b>	<b>Well TW-D</b>	<b>Well TW-E</b>
Altitude of top of casing (feet asl)	503.43	501.59	501.13	498.49	502.07
Year installed	1999	1999	1999	1999	--
Total depth (feet bls)	35.8	35.5	34.1	33.0	27.2
Geologic log available	Yes	Yes	No	Yes	Yes
Casing size (inches)	10	10	12	12	10
Depth to top of screen or open interval (feet bls)	28.7	29.1	28.0	26.0	N/A
Depth to top of bedrock (feet bls)	27.5	34.1	32.0	30.2	--
Altitude of top of bedrock surface (feet asl)	475.93	467.49	469.13	468.29	--
Upper most producing formation			Missouri River alluvium		
Bottom formation			Jefferson City Dolomite		
Static water level ATD (feet bls)	20.98	25.79	24.88	22.50	25.44
Static water altitude ATD (feet asl)	480	462	498	500	493

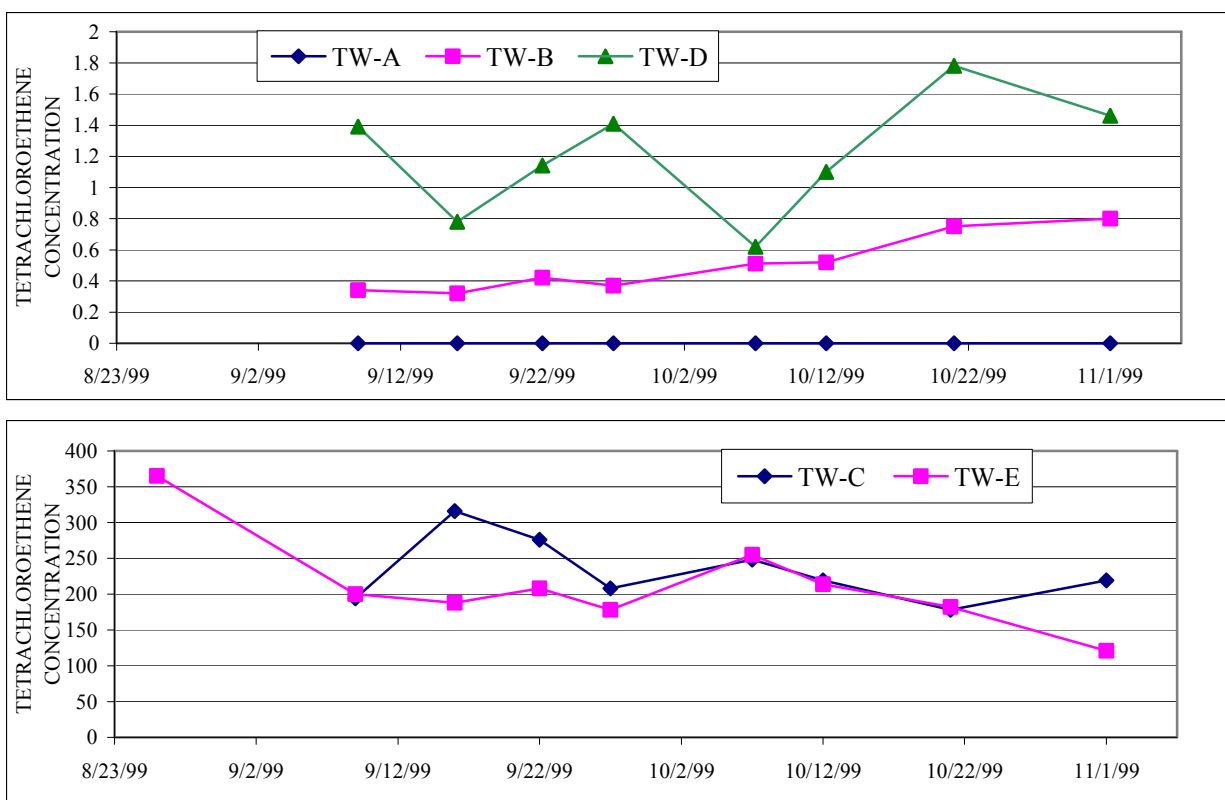
#### **4.5 Tetrachloroethene (PCE) concentrations in the Missouri River alluvium**

Beginning in September 1999, the water levels in the alluvial monitoring were measured and water samples collected weekly for eight weeks, then monthly for three months. The monitoring was done to determine the spatial and temporal variability of VOC concentrations in the alluvial aquifer. Water samples were analyzed by the portable GC (fig.10). Additional water samples were collected during week eight on November 1, 1999, and submitted for laboratory analysis to confirm the results of the portable GC.

Water-level measurements in the monitoring wells indicate that the altitude of ground water in the alluvium is highest at well TW-A and lowest in well TW-B. Water levels generally declined during the monitoring period between September 9, 1999, and January 24, 2000 (fig. 11).

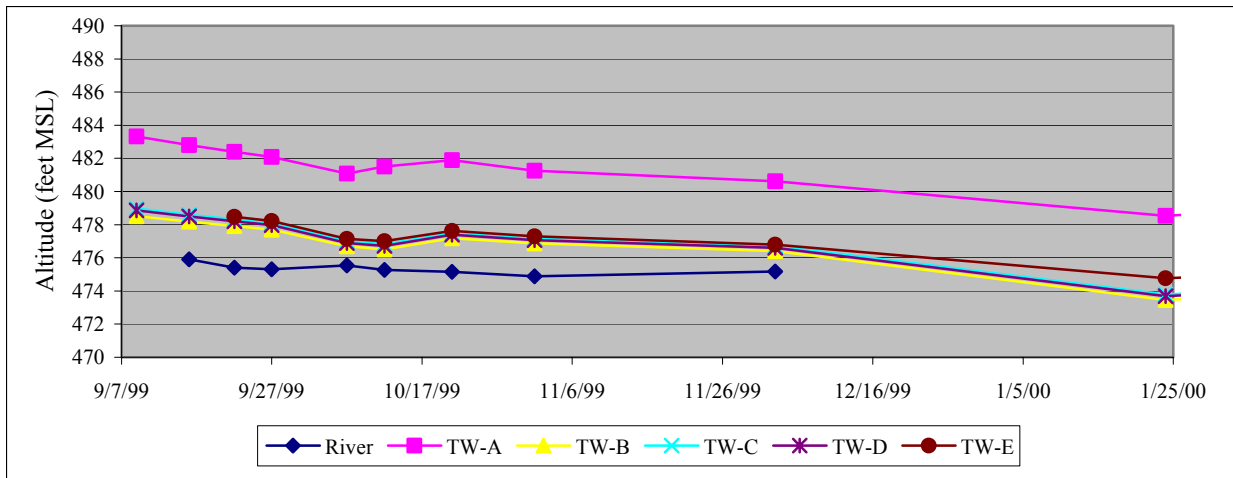
Results of the alluvial well monitoring indicate that large concentrations of PCE and other VOCs are present in the Missouri River alluvium in the vicinity of the Riverfront site. Samples from monitoring wells TW-C and the hand-dug well TW-E contained large concentrations of PCE and other VOCs (fig. 10 and table 5). Concentrations of PCE (199 and 168 µg/L), TCE (43.9 and 48.8 µg/L), and VC (0.27 and 17.1

µg/L) in the November 1, 1999, laboratory samples from monitoring wells TW-C and TW-E exceeded the Missouri Ground Water Standard of 5 µg/L for PCE and TCE and 2 µg/L for VC (table 5). Samples from monitoring wells TW-B and TW-D contained less than 2 µg/L (fig. 10 and table 5). None of the samples from monitoring well TW-A contained detectable concentrations of PCE, TCE, VC, or other VOCs. Results of the weekly sampling indicate that PCE concentrations in monitoring well TW-E tended to decrease with increasing time (and declining water level) and concentrations of PCE in monitoring well TW-D tended to increase slightly with increasing time (fig. 10).



**Figure 10.** Water levels and estimated tetrachloroethene (PCE) concentrations in alluvial monitoring wells in the vicinity of the Riverfront site, September 1999 to January 2000.

[Concentrations of tetrachloroethene (PCE) in micrograms per liter]



**FIGURE 11.** Altitude of water in the alluvial monitoring wells and in the Missouri River

**TABLE 5.** Results of laboratory analysis of water samples collected from the alluvial monitoring wells on November 1, 1999.

[<, less than; bolding indicates the compound is above the detectable limit; highlight indicates concentration is above the Missouri Ground Water Standard; E, estimated]

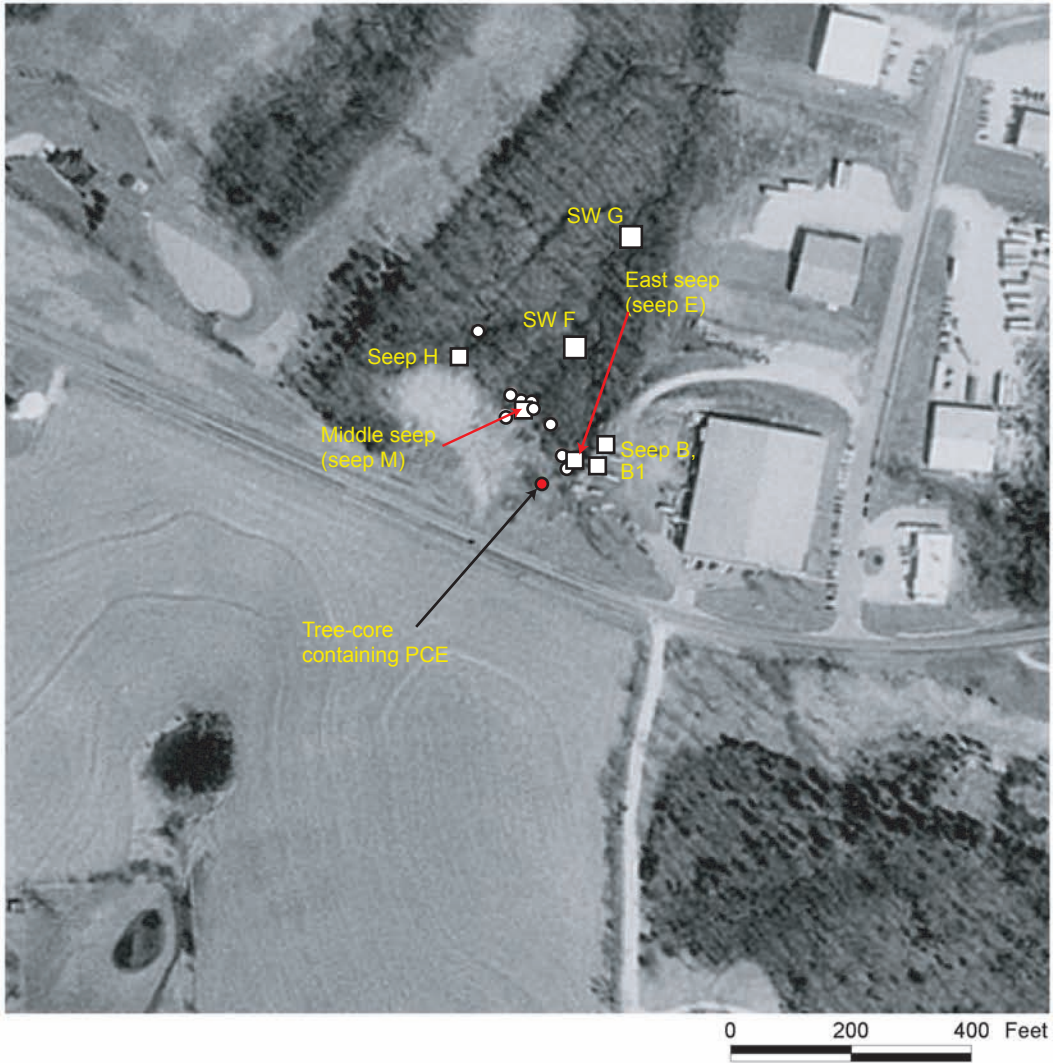
Compound name (concentration, in micrograms per liter)	Well TW-A	Well TW-B	Well TW-C	Well TW-D	Well TW-E
Vinyl chloride	<0.2	<0.2	<b>0.27</b>	<0.2	<b>17.1</b>
1,1-Dichloroethene	<0.1	<0.1	<b>0.16</b>	<0.1	<b>0.41</b>
trans-1,2-dichloroethene	<0.1	<0.1	<b>0.65</b>	<0.1	<b>21.4</b>
Methyl-t-butyl ether (MTBE)	<0.2	<b>4.39</b>	<0.4	<0.2	<0.2
cis-1,2-Dichloroethene	<0.1	<b>0.99</b>	<b>26.4</b>	<b>0.7</b>	<b>246</b>
1,1,1-Trichloroethane	<0.1	<0.1	<0.1	<0.1	<b>0.12</b>
Trichloroethene (TCE)	<0.1	<b>0.78</b>	<b>43.9</b>	<b>0.65</b>	<b>48.8</b>
Toluene	<0.1	<0.1	<b>0.16</b>	<0.1	<0.1
Tetrachloroethene (PCE)	<0.1	<b>0.82</b>	<b>199</b>	<b>1.96</b>	<b>168</b>
m & p-Xylene	<0.2	<0.2	<b>0.26</b>	<0.2	<0.2
o-Xylene	<0.1	<0.1	<b>0.09 E</b>	<0.1	<0.1

## **5.0 PHASE I OBJECTIVE 3: INITIAL CHARACTERIZATION OF THE OLD NEW HAVEN CITY DUMP**

The 1.5-acre old New Haven City Dump (hereinafter the old City Dump) was reportedly used for municipal and industrial waste disposal between the early 1950s and early 1970s. The initial characterization of the old City Dump was done to determine if substantial quantities of PCE had been disposed at that location. Work proposed during the ESI/RI included a review of historic air photographs, a site reconnaissance, seep and tree-core sampling, an EM-61 survey, and a soil-gas survey.

A reconnaissance of the old City Dump was done on February 19, 1999. The general dimensions of the old City Dump were measured and significant features such as seeps, bedrock outcrops, and old drums were noted. The surface of the old City Dump was irregular and had been used for the disposal of demolition wastes, such as curb cuts, asphalt, bricks, and brush after the old City Dump was closed to the disposal of sanitary and industrial wastes in the 1970s. Five small seeps were identified at the old City Dump (fig. 12). These seeps were scanned for VOCs using the portable GC and only one (seep M or middle seep) contained a trace concentration of PCE (0.18 µg/L). Two samples also were collected from a tributary several hundred feet north of the old City Dump, but contained no detectable PCE concentrations. The old City Dump was revisited on July 13, 1999, and tree-cores samples were collected (16 trees), as well as laboratory samples from seep M and seep E (east seep). One core sample from a cottonwood tree (nhct8) on the southeast side of the old City Dump contained PCE estimated at 0.14 µg/L. Cores from trees on the north side of the old City Dump were negative for PCE. The laboratory sample from seep M contained 0.11 µg/L PCE. No PCE was detected in the laboratory sample seep E. Based on the large amount of debris at the surface of the old City Dump and previous experience with the EM61 at the Riverfront site, it was determined that an EM-61 survey would be inconclusive and this task was abandoned. The large amount of debris at the surface precluded the installation of soil-gas samplers.



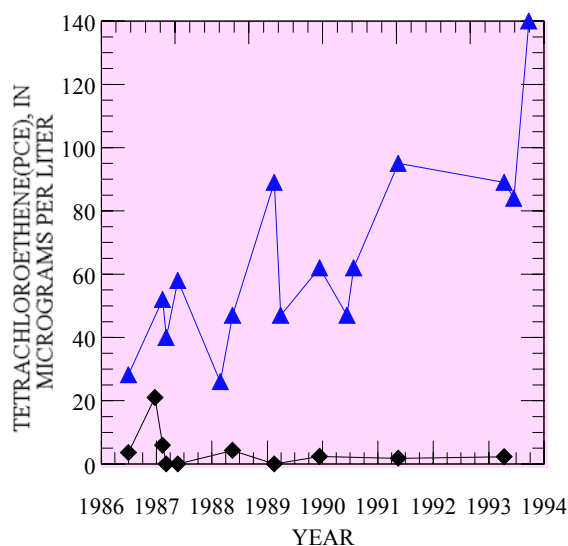


**FIGURE 12.** Location of seep and tree-core, and surface-water sampling sites at the closed New Haven City Dump.

[PCE, tetrachloroethene]

## 6.0 PHASE II OBJECTIVE 1, CHARACTERIZATION OF CITY WELL 2

There are five high production water-supply wells in the city of New Haven: city wells W1, W2, W3, W4, and an industrial well (fig. 13). The industrial well (locally referred to as the Pepsi well) was used for supply at a former soft drink bottling plant and is located in the southern part of the city. Bottling operations are no longer conducted at this facility and the well generally is on standby status and not used for drinking supply. City wells W1 and W2 were installed in 1939 and 1963 (table 6). City wells W3 and W4 were installed in 1988 and 1994. The MDNR first began monitoring for VOCs public-water supplies in Missouri in 1986. The first samples collected from wells W1 and W2 indicated the presence of PCE at 3.6 and 28.2  $\mu\text{g/L}$ . Subsequent monitoring indicated that PCE concentrations in well W2 continued to increase with time until they reached 140  $\mu\text{g/L}$  before the well was removed from service in 1993 (fig. 13). Although concentrations of PCE in well W1 generally were less than the MDNR drinking water limit of 5  $\mu\text{g/L}$ , the well was removed from service in 1989. Well W1 also had a history of bacteria contamination and the well would flow during periods of high stages of the Missouri River, suggesting a faulty casing. No PCE or other VOCs have been detected in the Pepsi well, which has been monitored occasionally since 1986 by various agencies.



**FIGURE 13.** Concentrations of tetrachloroethene (PCE) detected in the New Haven city wells W1 and W2. Data from the Missouri Department of Natural Resources.

Wells W3 and W4 are located in the south and southwestern parts of the city. Routine monitoring by the MDNR and other agencies has not detected the presence of PCE or other VOCs; however, the USEPA is concerned about possible PCE contamination at an industrial facility located about 700 ft south of city well W3. In 1987, the MDNR identified PCE contamination in soils at this facility (Singleton, 1987). Apparently, waste PCE was routinely dumped on the north side of the facility between 1972 and about 1984. Currently (2000), the MDNR is overseeing a cleanup of PCE contaminated soils at this facility. Data obtained by the USEPA indicates large concentrations of PCE (in excess of 2,000  $\mu\text{g/L}$ ) in shallow

(less than 70 ft deep) monitoring wells installed at this facility during 2000. This facility is less than 1,500 ft from domestic well JS-14 where PCE was detected at trace levels during the well inventory.

**TABLE 6.** Completion data for public and industrial supply wells in New Haven, Missouri.

[asl, above sea level; bls, below land surface; Cotter, Cotter Dolomite formation; Gasc, Gasconade Dolomite formation; Rbdx, Roubidoux Sandstone formation; Potosi, Potosi Dolomite formation; Eminence, Eminence Dolomite formation; gal/min, gallons per minute; --, no data; ATD, at time of drilling]

Description	City Well W1	City Well W2	City Well W3	City Well W4	Pepsi Well
Altitude of land surface (feet asl)	500	534	602.5	668	621
Year installed	1939	1963	1988	1994	1965
Total depth (feet bls)	992	1,075 <sup>a</sup>	885	982	1,155
Geologic log available	Yes	Yes	No	No	Yes
Casing size (inches)	10	10	12	12	8
Casing depth (feet bls)	153	210	525	560	406
Altitude of bottom of casing (feet asl)	347	324	77.5	108	215
Upper most producing formation	Cotter	Cotter	upper Gasc	upper Gasc	Rbdx
Bottom formation	Potosi	Potosi	Eminence	Eminence	Potosi
Yield (gal/min)	250	335	506	450	120
Drawdown (feet)	5	17	210	30	--
Pump capacity (gal/min)	133	213	400	450	--
Static water level ATD (feet bls)	20	72	105	168	128
Static water altitude ATD (feet above sea level)	480	462	498	500	493
Year removed from service	1989	1993	active	active	standby
Specific capacity (gallons per minute per foot of drawdown)	50	19.7	2.41	15	--

<sup>a</sup> Geophysical logging during the ESI/RI indicates that this well is actually 975 ft deep.

### 6.1 Geophysical logging of city well W2

Geophysical logs and additional packer tests were conducted in well W2 during the ESI/RI in an attempt to determine the specific interval(s) conveying PCE into the well. Geophysical logs included natural gamma, EM induction, acoustic televiwer, temperature, and specific conductance. In addition, a video log of the entire borehole was made and the vertical flow in the borehole was measured using a heat-pulse flow meter.

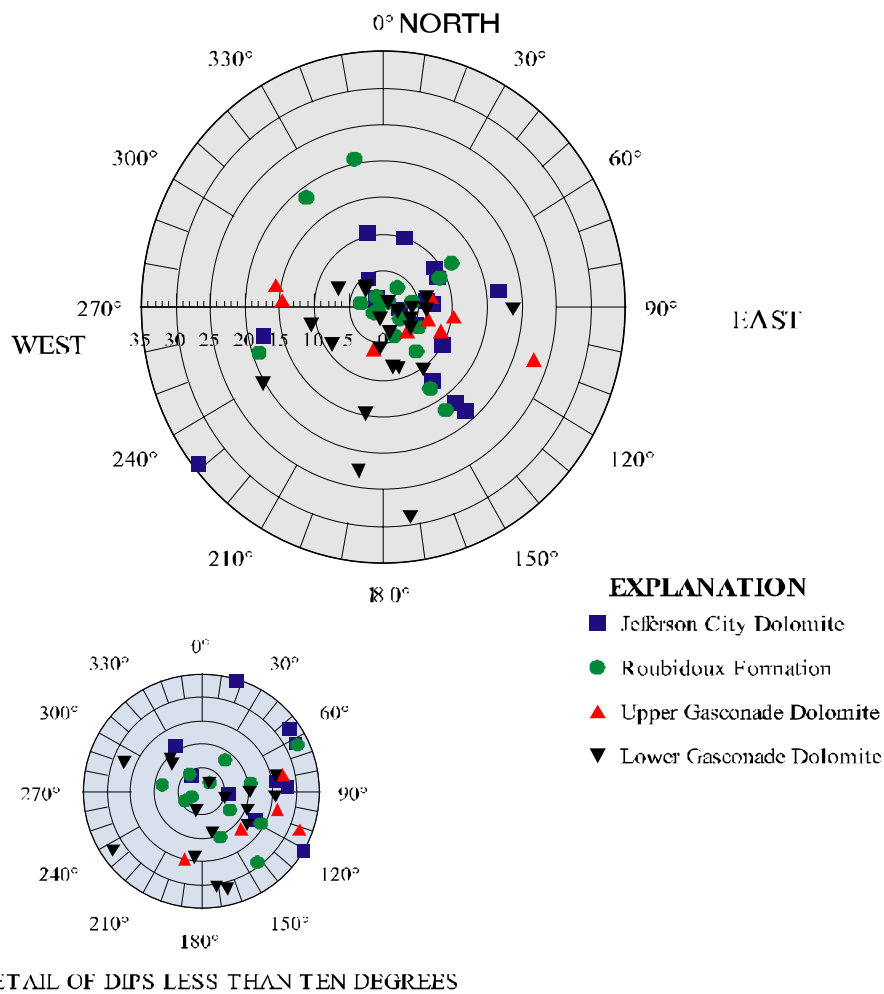
Investigations at well W2 began on December 2, 1999. The USGS contract well drilling company brushed the inside of W2 to clean the well and placed a pump in the open well 62 ft deep. The pump was started, and the color of the water was noted (dark gray to black) and photographed. Analysis of water samples from the pump outlet by the portable GC indicated PCE at concentrations between 21.5 and 34.5 µg/L. Following the cleaning of the well, a video log of the borehole was done to determine suitable

locations to set inflatable packers. Geophysical logging began on December 08, 1999 and continued non-stop through December 10, 1999. Natural gamma, temperature, specific conductance, and EM induction logs were completed to the bottom of the borehole at 875 ft. The acoustic televiewer log and borehole flow meter measurements were limited to depths of 650 ft and 431 ft, respectively, because of the length of cable on the instruments.

Results of the geophysical logging indicate an upward flow of water in the borehole of about 0.024 gal/min at 431 and 387 ft deep. The upward flow decreased to 0.017 gal/min at 365 ft and less than 0.008 gal/min at 335 ft. Vertical flow in the borehole decreased to less than the instruments resolution of 0.06 gal/min at depths above 335 ft. The decrease in upward flow occurred in the sandy part of the Roubidoux Formation and indicates that flow moving up the borehole from depths below 431 ft is moving into the Roubidoux Formation. Flow-meter tests were done again under pumping conditions of 30 gal/min (pump set at 63 ft). Results of the pumping tests indicate that, within measurement error, most of the water pumped at 30 gal/min was being produced from depths greater than 431 ft. During this test, the static water level declined less than 1 ft from 43.94 to 44.63 ft below the top of the casing.

Results of a video log made during pumping conditions on December 16, 1999, are consistent with the borehole flow-meter results, and indicate that most of the water produced while pumping at 30 gal/min was produced from a solution enlarged bedding plane at 586 ft deep. Preceding the video log, the borehole was cleaned again to remove additional debris. After cleaning, the well was pumped at 30 gal/min to remove the turbid water. A borehole video log done shortly after cleaning detected suspended particles moving up the borehole in relatively clear water above 586 ft. Below a solution enlarged bedding plane at 586 ft, the borehole became extremely turbid and little movement of suspended particles could be detected.

The acoustic televiewer log was used to measure the dip of the borehole (from vertical) and to estimate the altitude and degree of dip of fractures and bedding planes in the rocks. The televiewer is oriented to geographic north, and bedding planes or fractures intersecting the borehole are identified visually and measured via a computer program supplied by the equipment manufacturer. Dips of the bedding planes are variable with most being less than 10 degrees from the horizontal. The directions of the dips were variable with a slight tendency toward the east and southeast (fig. 14)



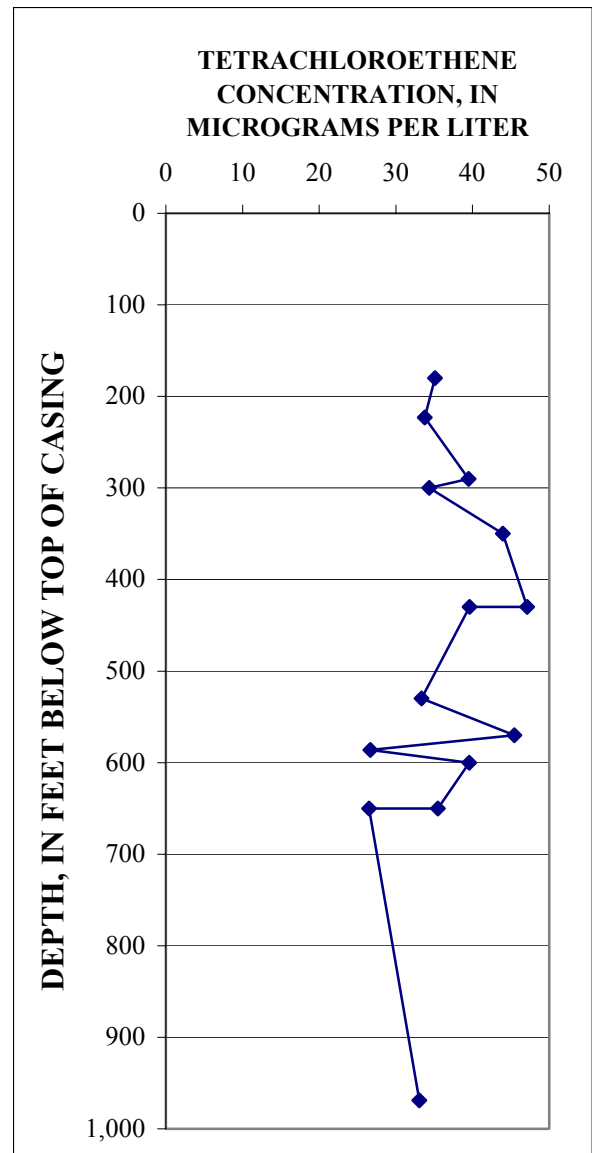
**FIGURE 14.** Measured dip and strike of bedding planes in various geologic units in city well W2. Measurements made using a downhole acoustic televiewer.

## 6.2 Distribution of tetrachloroethene in city well W2

During 1993, the city of New Haven conducted a packer test in city well W2 to determine if the casing in the well could be extended into the Gasconade Dolomite to case out the PCE contamination. The test consisted of setting an inflatable packer set at 525 ft deep and a 300-gal/min pump at 540 ft deep. The test noted an obstruction in the borehole at 648 ft deep. The well was pumped at 300 gal/min for several weeks with water samples collected and analyzed for PCE and other VOCs every few days. Concentrations of PCE in water samples collected during the test ranged between 41.5 and 45.2  $\mu\text{g/L}$  and were interpreted by the city's consultant to indicate that PCE contamination was present in the aquifer beneath the 540 ft depth. A concern regarding the packer test results was that in addition to drawing down the static water

level beneath the packer, the static water level above the packer also decreased several tens of feet suggesting that the pump also was drawing water from above the packer. Based on the results of the packer test, the city decided not to attempt to retrofit well W2 and drilled well W4.

During the ESI/RI geophysical sampling, a series of point samples were collected at various depths in well W2. Analysis of these samples indicated the presence of PCE at concentrations between 33 and 47  $\mu\text{g/L}$  throughout the entire borehole (fig. 15). Following the point samples, a series of packer tests using an inflatable packer were performed on city well W2 between May 10, 2000, and July 11, 2000 (table 7). The packer tests were done in an attempt to identify the point of entry for the PCE contamination into W2. The packer tests were done under low-flow (less than 1 to 2 gal/min) pumping conditions to minimize the potential for flow around the packer. A single packer was used and the pump was set just above the bottom of the well casing (210 ft). A summary of the packer tests is given in table 7. Packer test 1 was unique, in that a high pumping rate (30 gal/min) was used to evacuate the borehole beneath the surface casing to monitor for possible leakage around the surface casing using the downhole camera.



**FIGURE 15.** Tetrachloroethene concentrations at various depths in city well W2 under non-pumping conditions

**TABLE 7.** Summary of packer test results for city well W2. All water samples were collected from above the packer.

[all depths in feet below top of casing; gal/min, gallons per minute; PCE, tetrachloroethene; µg/L, micrograms per liter; <, less than; NE, not estimated]

Test number	Dates	Packer depth (feet)	Static water level (feet)	Final water level	Pumping rate (gal/min)	Total volume pumped (gallons)	Recovery rate (gal/min)	PCE (µg/L)
Test 1	05/10/00 -	238	213	224	Pumped dry	47	< 0.2	51.0 <sup>a</sup>
	05/11/00							45.2 <sup>b</sup>
Test 2	05/23/00 -	290	44.0	92.40	0.45	4,200	0.15	68.5 <sup>a</sup>
	05/31/00 -							72.0 <sup>b</sup>
Test 3	06/08/00	341	43.8	57.10	0.45	5,200	0.01	63.2 <sup>b</sup>
	06/12/00 -							
Test 4	06/29/00	430	44.0	46.47	1.1	31,700	NE	53.6 <sup>b</sup>
	06/29/00 -							
Test 5	07/11/00	550	43.6	43.26	1.1	17,400	NE	50.7 <sup>b</sup>

<sup>a</sup> Portable gas chromatograph analysis value.

<sup>b</sup> Laboratory analysis value.

Packer test 1 – On May 10, 2000, the inflatable packer was set at 238 ft deep in W2, and a 3-in. pump was set at 231 ft and pumped at 30 gal/min until the borehole above the packer was dry. The following afternoon the water level above the packer had recovered to 213 ft (recovery of about 0.05 gal/min) and the annulus above the packer was pumped dry again. While the annulus was dry, a downhole camera was used to inspect the bottom of the surface casing (210 ft deep) and packer for leakage. A small quantity of flow was detected from a fracture just beneath the bottom of the casing. Flow around the packer could not be verified with the camera. At the conclusion of the test, water samples were collected above the packer using a bailer and analyzed by the portable GC and the USGS laboratory. The concentration of PCE in the portable GC sample was 51 µg/L, compared to 45.2 µg/L determined by the laboratory (table 8).

Packer test 2 – On May 23, 2000, the inflatable packer was set at 290 ft deep and the 3-in. pump set at 100 ft. Pumping began and was adjusted until an equilibrium was met between the pumping rate and recharge rate (about 0.5 gal/min). A stainless-steel sampling pump with teflon hose was set at 205 ft to collect water samples during this and subsequent packer tests. On May 25, a water sample was collected from the sample pump and the purge pump rate lowered slightly to about 0.4 gal/min. The annulus above the packer was pumped for an additional 5 days. A final water sample was collected on May 30. Concentrations of PCE in samples analyzed by the portable GC were 50.4 µg/L on May 25, and increased to a maximum of 68.5 µg/L on May 30. The PCE concentration in the laboratory sample collected on May 30 was 72 µg/L (table 8).

Packer test 3 – The packer was reset at 341 ft deep on May 31, 2000. The annulus above the packer was pumped at about 0.5 gal/min for 9 days. Laboratory analysis of a water sample collected from the sample pump on June 8, 2000, detected 63.2 µg/L PCE (table 8).

Packer test 4 – On June 12, 2000, the packer was reset at 430 ft deep and the annulus above the packer pumped at 1.1 gal/min until June 29, 2000. A sample was collected using the sample pump at the conclusion of the test on June 29 and submitted for laboratory analysis. The PCE concentration in the laboratory sample was 53.6 µg/L (table 8).

Packer test 5 – The final packer test in this series began June 29, 2000. The packer was reset at 550 ft deep, and the pumping rate set at approximately 1.1 gal/min. Pumping of W2 continued until July 11, 2000, when a final water sample was collected from the sample pump. The PCE in the laboratory sample was 50.7 µg/L (table 8).

Packer test 6 – The final packer test proposed for well W2 was to be done by setting a packer at 650 ft deep and pumping from below the packer. This test was not done during the summer because of an equipment failure and is scheduled to be done during winter 2001. Results of the packer tests between 238 and 550 ft indicate that PCE concentrations were largest above 290 ft, and gradually decreased with increasing depth of the packer (table 8).

**TABLE 8.** Laboratory analyses of water samples collected during packer tests performed on New Haven city well W2.

[Intervals in depth below top of casing; ft, feet; <, less than; bolding indicates the compound is above the detectable limit; highlight indicates concentration is above the Missouri Ground Water Standard]

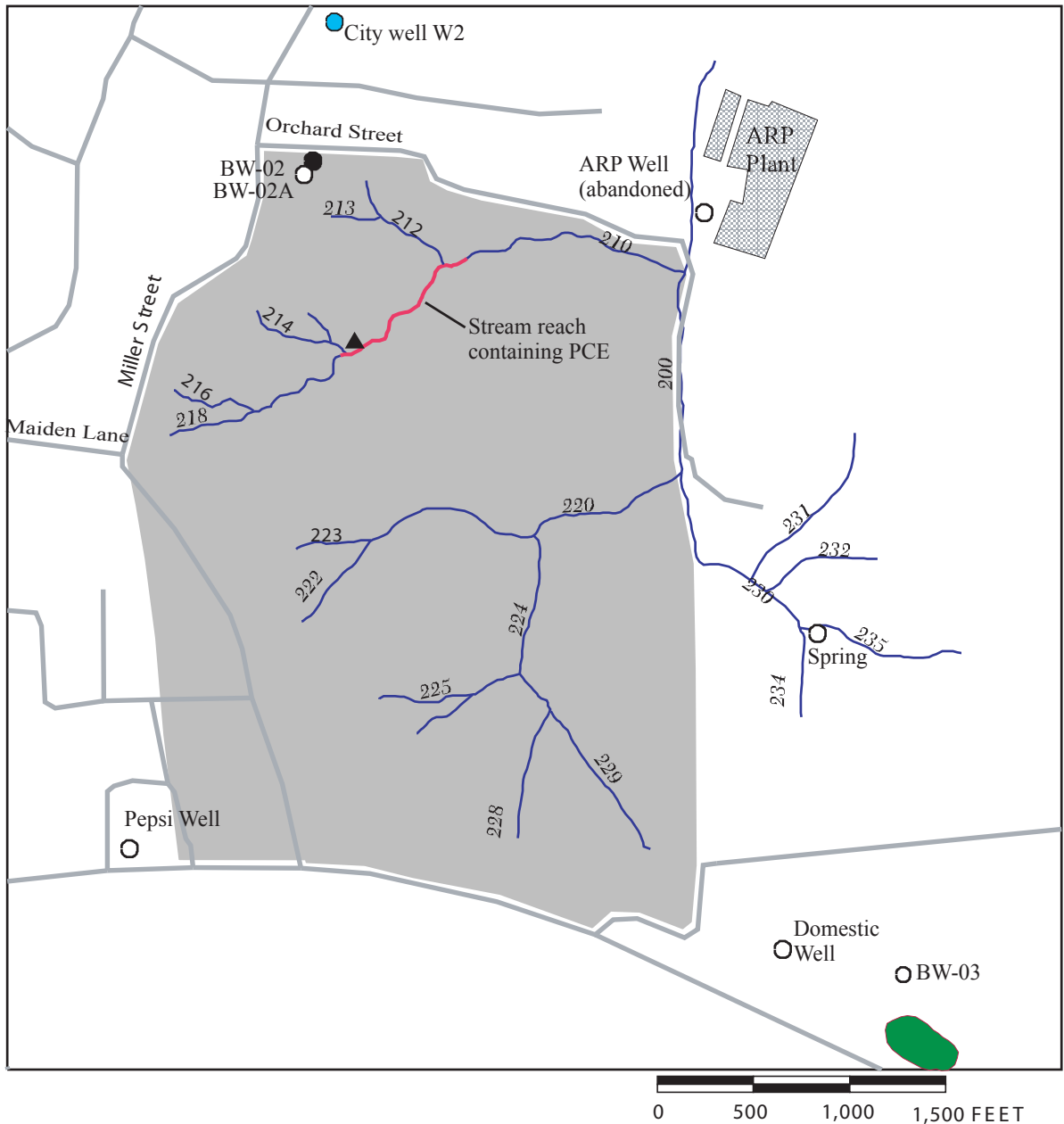
Compound name (concentration, in micrograms per liter)	No packer, Sampled 07-16-99, well open 210- 875 ft	Test 1 Sampled 05-11-00 at 210-238 ft interval	Test 2 Sampled 05-30-00 at 210-290 ft interval	Test 3 Sampled 06-08-00 at 210-341 ft interval	Test 4 Sampled 06-29-00 at 210-430 ft interval	Test 5 Sampled 07-11-00 at 210-550 ft interval
cis-1,2-Dichloroethene	16.6	<0.1	<0.1	<0.5	<0.1	<0.1
Chloroform	0.26	<0.1	<0.1	<0.5	<0.1	<0.1
Trichloroethene (TCE)	8.03	1.28	2.18	<0.5	0.19	0.21
Toluene	<0.1	2.28	<0.1	<0.5	<0.1	<0.1
Tetrachloroethene (PCE)	12.5	45.2	72	63.2	53.6	50.7
Ethylbenzene	<0.1	0.11	<0.1	<0.5	<0.1	<0.1
m & p-Xylene	<0.2	0.3	<0.2	<1	<0.2	<0.2



## **7.0 PHASE II OBJECTIVE 2, DISTRIBUTION OF TETRACHLOROETHENE IN THE BEDROCK NEAR THE RIVERFRONT SITE, CITY WELL W2, AND THE OLD CITY DUMP**

The purpose of objective 2 in the second phase of the ESI/RI proposal was to determine the lateral extent of PCE contamination in the bedrock. The second phase of the ESI/RI proposal and work plan included the installation of two bedrock monitoring wells (BW-01 and BW-02) in the vicinity of city well W2, and a single bedrock monitoring well in the vicinity of the old City Dump (BW-03). An abandoned domestic well at the old ice cream plant 1 block west of the Riverfront site (JS-00) was converted into two bedrock monitoring wells (BW-00 and BW-00A). Drilling and well installation activities were conducted between February and June 2000. Samples of drill water and drill cuttings (more than 300 samples) were collected every 5 ft to 10 ft from each well and analyzed on the portable GC. Well BW-01 was installed between the Riverfront site and city well W2 (adjacent to alluvial monitoring well TW-A) to determine if PCE was migrating from the Riverfront site to the south (fig. 16). Well BW-02 was intended to be an upgradient well and was installed to confirm the absence of PCE south of city well W2 (fig. 16). Well BW-03 was installed between the old City Dump and city well W2 to test for the presence of PCE migrating from the old City Dump toward city well W2 (fig. 17). The target zone for wells BW-01 and BW-02 was the lower part of the Roubidoux Formation (about 350 ft at location BW-01 and 450 ft at location BW-02). The target depth for BW-03 was between 200 and 300 ft.

A review of historic aerial photography indicates that the old City Dump site became active between 1945 and 1958, and was removed from service by 1986. A comparison of aerial photographs taken during 1958 and 1986 indicates that fill at the old City Dump occurred in a south to north manner in the head of a small tributary just north of Missouri State Highway 100 (fig. 17). During this period, the size of the old City Dump more than doubled.



### EXPLANATION

- |   |  |
|---|--|
| <p>PCE (TETRACHLOROETHENE) CONCENTRATION IN EXISTING WELLS AND SPRINGS SAMPLED IN MICROGRAMS PER LITERS</p> <ul style="list-style-type: none"> <li>○ LESS THAN 0.1</li> <li>● 100 TO 200</li> <li>● GREATER THAN 200</li> </ul> | <ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: green; margin-right: 5px;"></span> OLD NEW HAVEN CITY DUMP</li> <li><span style="display: inline-block; width: 15px; border-bottom: 1px solid blue; margin-right: 5px;"></span> TRIBUTARY (AND NUMBER)</li> <li><span style="display: inline-block; width: 15px; border-bottom: 1px solid gray; margin-right: 5px;"></span> ROAD</li> <li>BW-02 ● BEDROCK MONITORING WELL AND NUMBER</li> <li><span style="display: inline-block; width: 15px; height: 15px; background-color: lightgray; margin-right: 5px;"></span> EAST NEW HAVEN AREA</li> <li>▲ LABORATORY SAMPLE CONTAINING 20.7 MICROGRAMS PER LITERS OF PCE</li> </ul> |
|---|--|

**FIGURE 16.** Location of stream reach containing tetrachloroethene (PCE) and selected ground-water monitoring points in the vicinity of city well W2.



U.S. Army Corps of Engineers

1958



U.S. Geological Survey

1986

**Figure 17.** Aerial view of the closed New Haven City Dump in 1958 and 1986.

## 7.1 Installation of Bedrock Monitoring Wells

A total of seven bedrock monitoring wells were completed during the second phase of the ESI/RI (table 9). Four of the wells were drilled (BW-01, BW-02, BW-02A, and BW-03) during the ESI/RI. A fifth well (BW-01A) was completed in the annulus of well BW-01A to serve as a temporary monitoring point. Two additional wells (BW-00 and BW-00A) were installed in the abandoned ice cream plant well (JS-00). Monitoring wells BW-01 and BW-02 were drilled to 385 and 465 ft, respectively, and are open to a 30 to 50 ft thick sand zone in the Roubidoux Formation (table 9). These wells are cased with 2-1/2 in. diameter PVC riser to an altitude approximately equal to that of the casing in city well W2 (altitude about 325 ft above sea level). Monitoring well BW-01A actually is the open annulus (35 to 56.5 ft deep) of well BW-01 that was left as a temporary monitoring point for the shallow bedrock near the Riverfront site. Monitoring well BW-02A is a shallow bedrock well (open from 100 to 140 ft deep) that is nested with well BW-02 to monitor the water table (105 ft deep) at this location. Monitoring well BW-03 is located several hundred feet northwest of the old City Dump and is open from 100 to 230 ft deep. Well construction diagrams are shown in the supplemental data at the end of the document.

**TABLE 9.** Completion data for bedrock monitoring wells in New Haven, Missouri

[asl, above sea level; bls, below land surface; N/A, not applicable; Alt., altitude; Cotter, Cotter Dolomite formation; Jeff, Jefferson City Dolomite formation; Rbdx, Roubidoux Sandstone formation; ATD, at time of drilling; --, no data]

Description	BW-01	BW-01A	BW-02	BW-02A	BW-03	BW-00	BW-0A0
Altitude of land surface (feet asl)	502	502	615	615	650	500	500
Year installed	2000	2000	2000	2000	2000	1999	1999
Total depth (feet bls)	385	56.5	465	140	230	146	57
Geologic log available	Yes	Yes	Yes	Yes	Yes	No	No
Casing size (inches)	2.5	N/A	2.5	6	2.5	6	2.5
Casing depth (feet bls)	180	36	280	103	100	136	47
Alt. of bottom of casing (feet asl)	322	466	335	512	550	364	453
Alt. of bottom of well (feet asl)	117	445.5	150	475	420	354	443
Upper most producing formation	Jeff	Cotter	Jeff	Cotter	Cotter	Jeff	Jeff
Bottom formation	Rbdx	Cotter	Rbdx	Cotter	Jeff	Jeff	Jeff
Static water level ATD (bls)	24.6	--	116.9	106.33	93.0	20.71	8.87

## **7.2 Distribution of PCE in bedrock monitoring wells in the vicinity of the Riverfront site, city well W2, and the old City Dump**

During the installation of the bedrock monitoring wells, samples of drill cuttings were collected and analyzed for VOCs using the portable GC. Samples were collected every 5 ft from boreholes drilled with the cable tool (BW-01, BW-02, BW-02A, and the 325 to 465 ft interval of BW-02), and every 40 to 60 ft from air rotary boreholes (upper 325 ft of BW-02). The results of these samples were used to determine disposition of the drill cuttings and the vertical distribution of PCE in the bedrock at each well location (fig. 18). In addition, packer tests and point samples were collected in the boreholes before the well casings were installed and grouted.

Monitoring well BW-01 – Based on the water-table map (fig. 3), monitoring well BW-01 is immediately upgradient of the Riverfront site and downgradient of city well W2. The well was drilled to a depth of 385 ft with cable tool between February 1 and 25, 2000. The drill cuttings were collected every 5 ft, and analyzed using the field GC. Concentrations of PCE in drill cuttings samples generally were less than 5 µg/L, except samples from two zones between 30 to 100 ft and 250 to 280 ft below the land surface where PCE increased to a maximum of about 20 µg/L (fig. 18). The lower PCE containing zone is within the Roubidoux Formation.

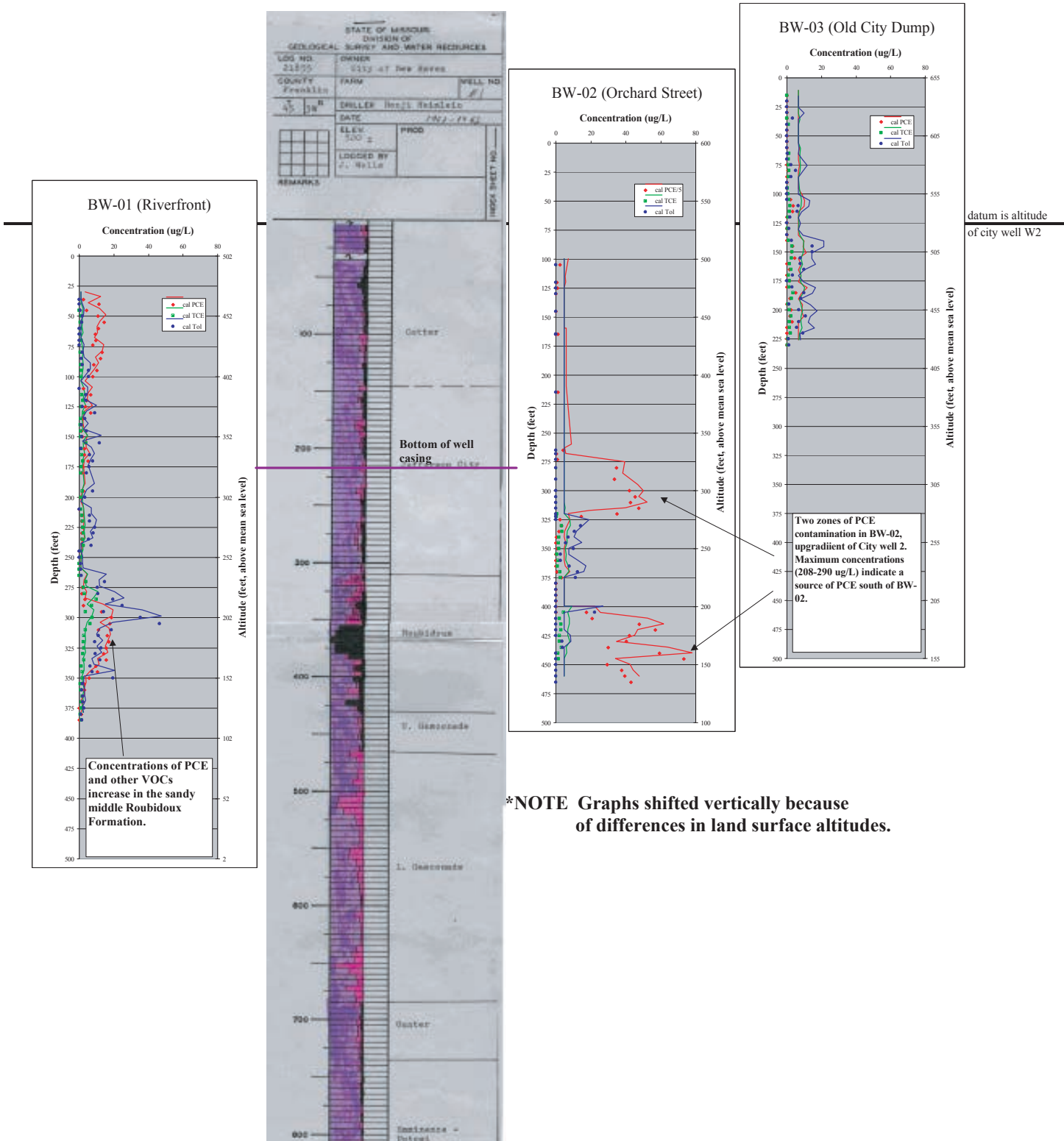
Before setting the casing in monitoring well BW-01, two point samples (295 and 380 ft deep) were collected from the borehole and two packer tests were done. The point sample at 295 ft contained 36.5 µg/L PCE whereas no PCE was detected in the point sample collected from 380 ft. For the first packer test, a bentonite packer was set at 68 ft deep, and the annulus above the packer was pumped at 0.5 gal/min for 2.2 hr using a submersible pump set at 63 ft. Five samples were collected during this packer test, and three were analyzed; one at the starting time, and then at 0.5 hr, and 1 hr intervals. Concentrations of PCE increased during the test reaching a maximum of 11.4 µg/L in the 1-hr sample. A second packer test was performed on April 6, 2000, with the packer set at 273 ft deep. During this second test, about 65 gal (gallons) of water were pumped from beneath the packer with a submersible pump before sampling. Concentrations of PCE in the sample collected from beneath the 273 ft packer were 12.0 µg/L.

Bedrock Well (BW-02) – Based on the water-table map (fig. 3), monitoring well BW-02 is upgradient from city well W2 and the Riverfront site. Because this location was expected to be free of contamination, air rotary drilling was used, and drill cuttings scanned relatively infrequently (every 40 to 60 ft) for PCE. At the beginning of the third day of drilling (borehole depth of 325 ft), PCE was detected in a water sample

collected from the well. Drilling was halted and a series of packer tests were conducted (40 ft, 105 ft, 273 ft, and 375 ft) and point samples were collected in this borehole. No PCE was detected in water samples collected from above the 40 ft packer. Laboratory analysis of a sample collected above the 105 ft packer detected PCE at 18.4 µg/L. On March 28, 2000, a packer was set at 273 ft, and the borehole above the packer was pumped at 2.5 gal/min for 1.5 hr with periodic samples collected for the portable GC. During the 1.5-hr period, PCE concentrations gradually increased from less than 0.1 to 14.4µg/L indicating that the highest levels of contamination were below the 273 ft interval. Analysis of point samples collected on March 28, 2000, indicated a dramatic increase in PCE concentrations at depths greater than 265 ft with concentrations in excess of 250 µg/L in the 305 to 325 ft interval (bottom of the borehole at the time of point sampling was 325 ft). Drilling resumed using cable tool with drill cuttings and drill water drummed for proper disposal. A final packer test was done on May 11, 2000 with a packer set to at 375 ft. The borehole beneath this packer was pumped (375 to 465 ft) and a sample collected after pumping 600 gal of water. Laboratory analysis of this sample detected PCE at 290 µg/L. Results of the packer tests, point samples, and drill cuttings samples indicate that the largest PCE concentrations in BW-02 were coming from the lower 90 ft of the borehole (fig. 18).

Bedrock Well (BW-03) – Monitoring well BW-03 was drilled using the cable tool drill rig. On the first day of drilling (March 10, 2000), the driller noted the drill cuttings foaming and an odor similar to that of latex paint. Drilling was suspended at 20 ft and samples were collected for laboratory analysis. Laboratory results were negative for PCE and other chlorinated solvents, but indicated the presence of large concentrations of ethanol (120,000 µg/L) and ethyl acetate (3,600 µg/L). These constituents were determined to be non-hazardous and a surface casing was set to a depth of 34.5 ft. Drill cuttings above 34.5 ft were drummed for disposable at a licensed subtitle D landfill. Two sandy zones, 125 to 145 and 195 to 210 ft, were encountered in this borehole. Drilling was halted at 230 ft. Analysis of drill cuttings indicated PCE concentrations less than 1 µg/L in this borehole (fig. 18).

The first round of quarterly water samples collected from the bedrock monitoring wells (July 2000) for laboratory analysis indicated that PCE is present in BW-00 (1.42 µg/L), BW-01 (5.26 µg/L), BW-01A (2.66 µg/L), and BW-02 (148 µg/L). No PCE was detected in BW-02A or BW-03 above the laboratory-reporting limit of 0.1 µg/L. The PCE concentrations in BW-02 were comparable to concentrations detected in city well W2, just before the well was removed from service. These PCE concentrations were substantially larger than those detected in the bedrock monitoring well BW-01, north of city well W2 near the Riverfront site.



**FIGURE 18.** Vertical distribution of tetrachloroethene (PCE) and other volatile organic compounds in bedrock monitoring wells

[PCE, tetrachloroethene; TCE, trichloroethene; Tol, toluene; ug/L micrograms per liter]

### **7.3 Distribution of PCE in streams near city well W2**

Because of the detection of large PCE concentrations during the installation of monitoring well BW-02 (south of city well W2), a reconnaissance of seeps, springs, and streams in the vicinity of this well was done. This area is now part of OU4 of the Riverfront Site RI. The area south of BW-02 consists mostly of overgrown pasture with thick woods along steep slopes and streams (fig. 16).

Analysis of stream samples collected during the May 04, 2000, reconnaissance indicated the presence of PCE in a small unnamed tributary (hereinafter referred to as the 210 tributary) about 800 ft south of monitoring well BW-02. Sampling of the 210 tributary at various locations and analysis by the portable GC indicates about a 500-ft reach of this tributary contains PCE concentrations between 0.5 and 30.3 µg/L. The largest concentrations were near the upper end of the tributary, and concentrations decreased steadily with increasing distance downstream. A laboratory sample collected near the upper end of the tributary contained 20.7 µg/L PCE.

## **8.0 ADDITIONAL SUPPORT ACTIVITIES**

### **8.1 Assessment of industrial waste on a private farm in the vicinity of New Haven**

On June 2, 2000, the USEPA was informed that an old dump containing industrial wastes was located on a farm near the city of New Haven. At the request of the USEPA, the USGS conducted a site visit and collected soil, water, and tree-core samples for the analysis of VOCs, semivolatile organic compounds, and selected metals. Numerous buried and partially buried decomposed drums containing solid sludge and several containing a dark colored liquid were in the process of being removed by an environmental contractor hired by the property owner. Soils in the area had a strong odor of organic solvents similar to lacquer thinner or mineral spirits. A total of eight samples (3 water, 4 soil, and 1 liquid waste from a drum) were collected and submitted for laboratory analysis on June 5 and 6, 2000. Results of the samples were negative for PCE and other chlorinated solvents but the samples contained lead (Pb) concentrations as large as 49,500 mg/kg and chromium (Cr) concentrations as large as 14,500 mg/kg, in addition to numerous volatile and semivolatile hydrocarbons, such as xylene (as large as 4,700,000 µg/kg) and naphthalene (54,000 µg/kg).



During August 2000, the USGS conducted a reconnaissance of drainages south of the old City Dump. Several drums and other debris were noted in a small tributary less than 0.5-mi south of the old City Dump. Water samples were collected from the tributary in the vicinity of these drums and screened for PCE using the portable GC. One of the samples collected immediately downstream from the drums contained PCE (maximum concentration estimated at 44 µg/L). No PCE was detected in tributary samples collected upstream from the drums. The PCE concentrations in the tributary at this location are intermittent as no PCE was detected during a second round of sampling in this area during August 2000.

## **8.2 Investigation of a water service line near the Riverfront site.**

During the installation of the bedrock monitoring well BW-01 and the alluvial monitoring well TW-A immediately south of the Riverfront site, a freeze-proof faucet (hereinafter referred to as the dog pen faucet) adjacent to these wells and the city dog pound commonly was used by the USGS as a source of rinse water for drilling tools, borehole sampling equipment, and hand washing. This faucet was supplied by a 1-1/2 in. diameter black polyethylene service line that connects to the end of a 6-in. cast-iron water main beneath Front Street near the southwest corner of the Riverfront site. A split from the polyethylene service line ran about 400 ft east to a public restroom located at the MDOC Missouri River boat access. The polyethylene service line to the dog pen faucet and the Missouri Department of Conservation (MDOC) public restroom was installed by the city of New Haven during 1995.

On May 11, 2000, the USGS used water from the dog pen faucet to rinse a submersible sample pump. The sample team had run out of organic-free blank water earlier in the day and an equipment blank was prepared by running about 20 gal of tap water from the faucet through the sample pump and hose. The equipment blank sample was analyzed for VOCs several hours later using the portable GC. The analysis detected the presence of PCE (11.2 µg/L) and TCE (0.35 µg/L). Because PCE has not been detected in previous USGS or MDNR water samples from the active city wells (W3 and W4), the sample team assumed that the PCE in the blank was caused by inadequate decontamination of the sample pump.

On May 24, 2000 the USGS collected a sample directly from the dog pen faucet to confirm that the previous detection of PCE and TCE in the equipment blank sample was, in fact, caused by inadequate decontamination. A scan of this sample using the portable GC the following day also indicated the presence of PCE and TCE; however, because of a column leak, the concentrations could not be determined. The USGS notified the USEPA of the possibility of PCE contamination at the dog pen faucet and discussed

with the City Water Department about other taps on the service line containing the dog pen faucet. The city indicated the only other tap on that same service line was the MDOC public restroom about 400 ft east of the dog pen faucet. On May 27, 2000, the USGS collected an additional water sample from the men's room sink at the MDOC public restroom east of the Riverfront site. A sample could not be collected from the dog pen faucet because the handle was locked. The sample from the men's room sink at the MDOC access contained very large concentrations of PCE (about 578 µg/L) using the portable GC.

On May 30, 31, and June 5, 2000, the USGS and personnel from the New Haven Water Department collected samples for laboratory analysis of VOCs from city wells 3 and 4, the dog pen faucet, and the men's room sink at the MDOC access (table 10). The results from these samples indicated that the samples from the MDOC restroom faucet and the dog pen faucet contained large concentrations of PCE (2,210 and 56.1 µg/L) and TCE (42.3 and 0.84 µg/L). Results of the sampling also indicate that the contamination was not present throughout the city water distribution system; samples for a fire hydrant several blocks away and city wells W3 and W4 did not contain any detectable VOCs.

**TABLE 10.** Concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) in water samples collected from the New Haven city public water supply on May 30, 31, and June 5, 2000.

[ID, identification; PCE, tetrachloroethene; TCE, trichloroethene; highlight indicates concentration is above the Missouri Ground Water Standard; bolding indicates the compound is above the detectable limit; <, less than; --, data not sent to the laboratory]

Location or well ID	Date	Portable gas chromatograph (micrograms per liter)		Laboratory analysis (micrograms per liter)	
		PCE	TCE	PCE	TCE
Dog pen faucet	5-30-2000	<b>47.3</b>	<b>0.83</b>	<b>56.1</b>	<b>0.84</b>
City well W4	5-31-2000	<0.1	<0.1	<0.1	<0.1
City well W3	5-31-2000	<0.1	<0.1	<0.1	<0.1
MDOC Men's room sink	6-5-2000	<b>2,030</b>	<b>15.0</b>	<b>2,210</b>	<b>42.3</b>
Orchard Street fire hydrant (3 blocks south of Riverfront)	5-31-2000	<0.1	<0.1	--	--

On June 14, 2000, the USGS and city of New Haven Water Department conducted a purge test of the water line supplying the MDOC public restroom. The purpose of this test was to determine if PCE concentrations decreased or increased with water use, and if PCE could be purged from the line. A valve at the west end of the polyethylene service line (at the main) is closed during the winter months to prevent the line from freezing. When the valve is closed, a weep hole opens to allow water in the unpressurized line to

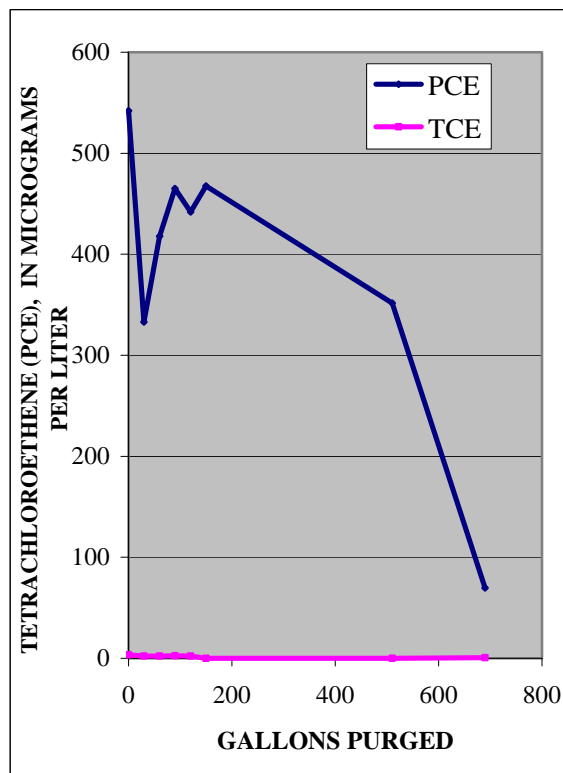
drain out into the subsurface. It was thought that contaminated water may be entering the line through this valve, and that extensive purging of the line may remove the contamination.

The volume of water in the 1-1/2 in. polyethylene service line between the MDOC restroom and the 6 in. cast iron main was estimated to be about 27.5 gal. A tap in a service bay of the MDOC restroom was opened to flush the line and was allowed to flow at about 3 gal/min for 3 hr. Water samples were collected at 0, 10, 20, 30, 40, 50, 110, 170, and 230-minute intervals, and were analyzed using the portable GC. Analytical results indicated that although PCE concentrations decreased with increasing time, they remained above the USEPA's maximum contamination limit (MCL) of 5 µg/L even after about 700 gal or 25 pipe volumes had been removed from the line (table 11, fig. 19).

**TABLE 11.** Tetrachloroethene (PCE) and trichloroethene (TCE) concentrations in water samples collected during a purge test of the public restroom water service line conducted on May 14, 2000.

[PCE, tetrachloroethene; µg/L, micrograms per liter; TCE, trichloroethene; concentrations determined using a portable gas chromatograph]

Minutes elapsed	PCE (µg/L)	TCE (µg/L)	Gallons purged
0	542	3.5	0
10	333	2.1	30
20	418	2.2	60
30	465	2.4	90
40	442	2.2	120
50	467.5	0.0	150
170	351.75	0.0	510
230	69.75	0.5	690

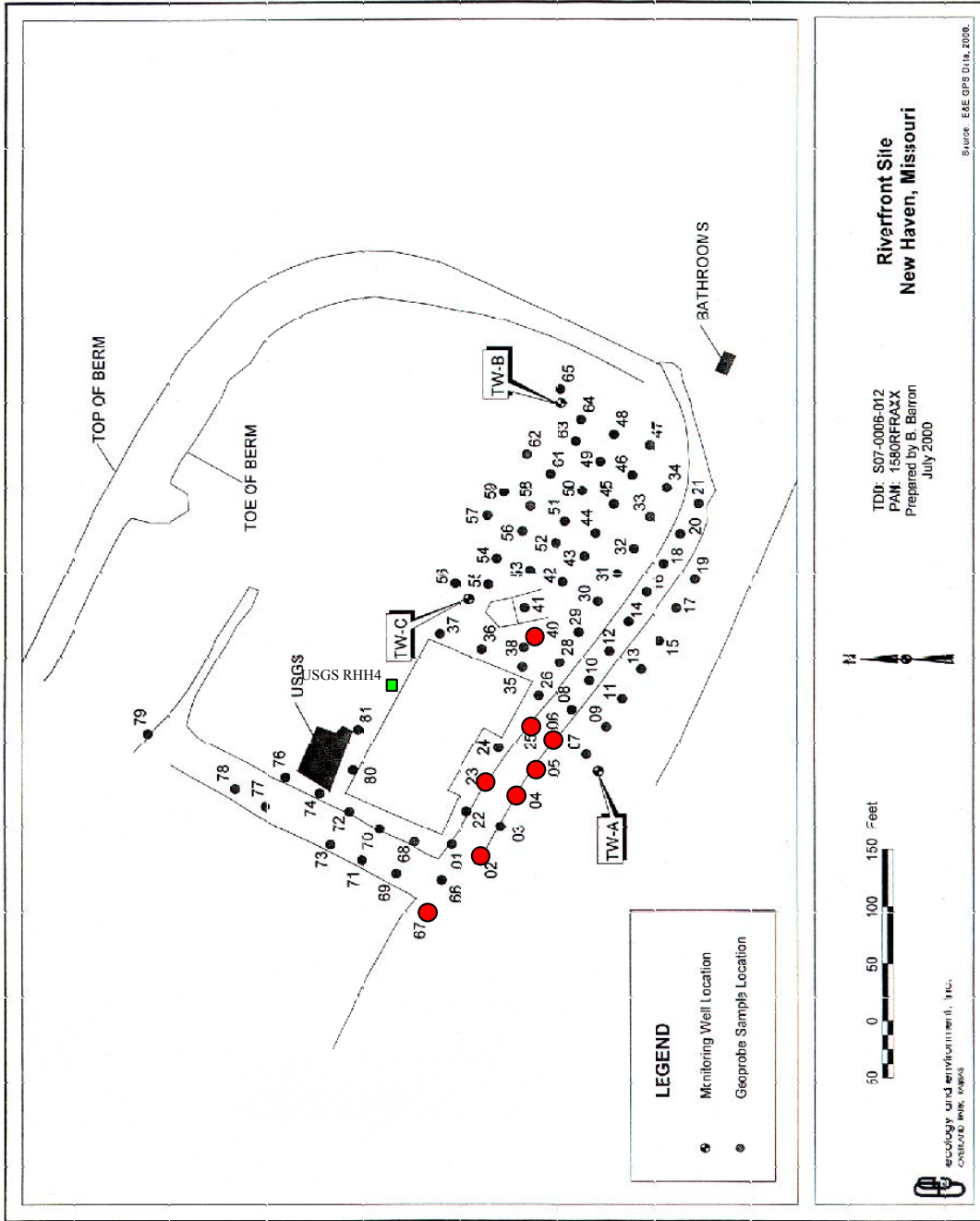


**FIGURE 19.** Plot of tetrachloroethene (PCE) and trichloroethene (TCE) concentrations in water samples collected during a purge test of the public restroom water service line, May 14, 2000.

On June 21, 2000, the USGS and city of New Haven Water Department sampled a fire hydrant at the northeast corner of the city shed. This hydrant is the first tap on the water main "up-stream" of the MDOC service line. Two samples were collected from the hydrant; one after about 30 gal had been flushed and a second after the hydrant had flowed wide-open (about 300 gal/min) for 10 minutes. A sample also was collected from the drinking water fountain in the city shed office after the fire hydrant had been purged. The service line to this fountain is the second tap "up-stream" from the MDOC service line. Analysis of the samples by the portable GC detected a trace quantity of PCE (estimated at 0.05 µg/L) in the initial sample from the fire hydrant. No PCE was detected in the second sample from the fire hydrant or the drinking water fountain in the city shed office. A prior sample collected from the drinking water fountain in the city shed office (June 1, 2000) also contained no detectable VOCs.

### **8.3 Emergency removal action of the contaminated water line and soils near the Riverfront site**

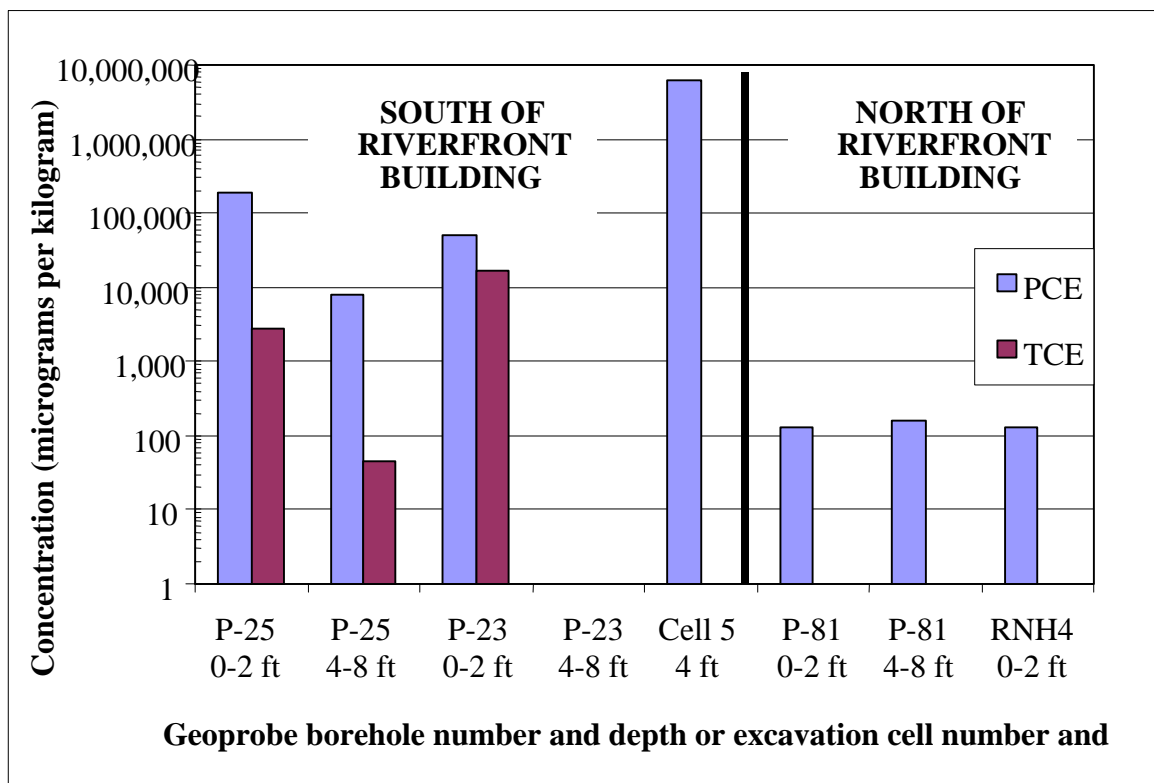
Because of the potential human exposure to PCE from faucets at the MDOC restroom and dog pen faucet, the USEPA conducted an emergency removal action to replace the contaminated polyethylene service line and remove nearby PCE contaminated soils. The USEPA conducted preliminary sampling at the Riverfront site and along the contaminated service line between July 11 and 13, 2000. An initial survey of the site and sampling was done by the USEPA's Superfund Technical Assessment and Response Team (START) Contractor. Subsurface soil samples were collected at intervals of 0 to 2, 2 to 4, and 6 to 8 ft deep at locations designated on a 40 ft rectangular grid (Kroone, 2000). The USGS was asked to provide assistance in the collection and analysis of soil samples using the portable GC. A total of 28 soil samples were analyzed by the USGS using the portable GC. Tetrachloroethene was detected in 27 of the 28 samples at concentrations ranging from 10 µg/kg to more than 1,500,000 µg/kg at location P05 (fig. 20). Splits samples from six soil samples were submitted for laboratory analysis of VOCs (fig. 21).



**Site Map**

**FIGURE 20.** Location of U.S. Environmental Protection Agency’s sample grid, and the tetrachloroethene (PCE) concentrations determined by the portable gas chromatograph in soil samples collected during the Riverfront removal action July 11, 2000, sampling. Locations containing more than 500 micrograms per kilogram PCE highlighted in red.

Between July 24 and August 04, 2000, the service line was replaced by the USEPA. On August 14, 2000, excavation of additional contaminated soil in the Riverfront area began. Because the USACE required excavation to be backfilled at the end of each workday, the USEPA asked the USGS to provide assistance with field analysis (portable GC) of soils during the excavations. Results from the portable GC were used to determine the limits of each excavation. Two of the soil samples from the excavation activities were sent to the contract laboratory; these were from Cell 5 and a USGS hand-augered borehole in the north side of the Riverfront building (RHN4). The laboratory results for these samples indicated PCE in Cell 5 (30 ft excavation centered about grid point 05 in fig. 20) at levels greater than 6 million  $\mu\text{g/L}$ , and in RHN4 at 130  $\mu\text{g/L}$  (fig. 21).



**FIGURE 21.** Tetrachloroethene (PCE) and trichloroethene (TCE) concentrations in soil samples collected during the removal action at the Riverfront site.

[P, USEPA designated point; ft, feet]

## 9.0 REFERENCES

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**SUPPLEMENTAL DATA**

**TABLE 12.** Estimated concentration of volatile organic compounds (VOCs) detected in tree core samples from the downtown Riverfront site and vicinity.

[PCE; tetrachloroethene; TCE, trichloroethene; cis-DCE, cis-1,2-dichloroethene; VC, vinyl chloride; in., inch; <, less than; E, estimated; all concentration estimated in micrograms per liter of core water; bolding indicates the compound is above the detectable limit]

Sample name	Description	Date	PCE	TCE	cis-DCE	VC	Toluene	Benzene
<b>Old dry cleaners area (Miller Street and Maupin Avenue)</b>								
df04	34-in. silver maple	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
df-1	36-in. Chinese elm	10/21/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
df1a	36-in. Chinese elm	10/21/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
df-2	30-in. silver maple	10/21/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
df-3	30-in. silver maple	10/21/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
hs01	34-in. Chinese elm	09/09/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
hs02	10-in. twin mulberry	09/09/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
hs03	20-in. hackberry	09/09/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
hs04	20-in. Chinese elm	09/09/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
hs05	22-in. Judas tree	09/09/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc1w	8-in. cottonwood N. side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
<b>Old New Haven City Dump</b>								
nhtc2w	10-in. cottonwood N. side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc3w	14-in. cottonwood N. side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc4w	4-in. red bud N. side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc5w	16-in. white oak NE side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc6w	20-in. twin cottonwood NE side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc7w	20-in. oak NE side	07/14/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
nhtc8	14-in. cottonwood SE side	07/14/99	<b>0.14</b>	<0.1	<0.1	<2	<0.1	<0.1

Sample name	Description	Date	PCE	TCE	cis-DCE	VC	Toluene	Benzene
<b>Downtown Riverfront site</b>								
t201	20-in. hackberry	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
ta01	12-in. poplar	08/11/99	<b>0.3</b>	<0.1	<0.1	<2	<0.1	<0.1
ta02	10-in. triple birch	08/11/99	<b>0.1</b>	<0.1	<0.1	<2	<0.1	<0.1
tb01	11-in. walnut	08/11/99	<b>7.1</b>	<b>0.2</b>	<0.1	<2	<0.1	<0.1
tb02	20-in. silver maple	07/14/99	<b>0.2</b>	<0.1	<0.1	<2	<0.1	<0.1
tb02	20-in. silver maple	08/11/99	<b>0.2</b>	<0.1	<0.1	<2	<0.1	<0.1
tg01	34-in. Chinese elm	08/11/99	<0.1	<0.1	<0.1	<2	<b>0.5</b>	<0.1
tg02	34-in. Chinese elm	08/11/99	<0.1	<0.1	<0.1	<2	<b>0.9</b>	<0.1
tg03	36-in. Chinese elm	08/11/99	<0.1	<0.1	<0.1	<2	1.5	3.1
tg04	34-in. silver maple	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tm01	30-in. box elder	08/20/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tm02	38-in. silver maple	08/20/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tm03	12-in. hard maple	08/20/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tn01	38-in. box elder	08/20/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tr01	7-in. hackberry	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tr02	6-in. Chinese elm	08/11/99	<b>0.1</b>	<0.1	<0.1	<2	<0.1	<0.1
tr03	4-in. triple hackberry	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tr04	4-in. hackberry	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<0.1
tw01	5-in. twin mulberry	08/11/99	<0.1	<0.1	<0.1	<2	<b>0.1</b>	<0.1
tw02	11-in. red cedar	08/11/99	<b>7.4</b>	<0.1	<0.1	<2	<b>0.5</b>	<0.1
tw03	4-in. Chinese elm	08/11/99	<b>2.0</b>	<0.1	<b>0.7</b>	<b>1.8 E</b>	<0.1	<b>0.6</b>
tw-3	4-in. Chinese elm	10/21/99	<b>1.98</b>	<0.1	<b>0.5</b>	<2	<0.1	<0.1
tw04	2-in. mulberry	08/11/99	<b>9.4</b>	<b>0.03 E</b>	<0.1	<2	<0.1	<b>0.02 E</b>
tw05	2-in. walnut	08/11/99	<b>6.9</b>	<0.1	<0.1	<2	<0.1	<0.1
tw06	3-in. mulberry	08/11/99	<b>15.1</b>	<b>0.5</b>	<0.1	<2	<0.1	<b>0.2</b>
tw07	5-in. birch	08/11/99	<b>8.2</b>	<b>0.4</b>	<0.1	<2	<0.1	<0.1
tw08	10-in. mulberry	07/14/99	<b>16.67</b>	<b>0.11</b>	<0.1	<2	<0.1	<0.1
tw08	10-in. mulberry	08/11/99	<b>32.0</b>	<b>0.8</b>	<0.1	<b>0.5 E</b>	<0.1	<b>0.2</b>
tw09	20-in. hackberry	08/11/99	<b>0.06 E</b>	<0.1	<0.1	<2	<0.1	<b>0.02 E</b>
tw10	3-in. twin Chinese elm	08/11/99	<0.1	<0.1	<0.1	<2	<0.1	<b>0.05 E</b>

**TABLE 13.** Monitoring statistics of the alluvial wells and the field gas chromatography analysis results

[WL, water level (in feet below measuring point); cond, specific conductance (in microseimens per centimeter at 25 degrees Celsius); PCE, tetrachloroethene; TCE, trichloroethene; cis-DCE, cis-1,2-dichloroethene; t-DCE, trans-1,2-dichloroethene; VC, vinyl chloride; River, altitude of Missouri River (in feet above sea level at New Haven); all concentrations in micrograms per liter; <, less than; B, compound detected in blank; E, estimated; --, no data]

Date	WL	Water altitude	Cond	PCE	TCE	cis-DCE	t-DCE	VC	River
<b>Well TW-A</b>									
8/18/99				0.13	0.34	2.7			
8/25/99				<0.1	<0.1	0.12			
8/26/99				0.16	<0.1	0.69			
9/9/99	20.10	483.33	1,513	<0.1	<0.1	<0.1	<0.1	<2	
9/16/99	20.64	482.79	1,432	<0.1	<0.1	.36 B	<0.1	<2	475.91
9/22/99	21.04	482.39	1,425	<0.1	<0.1	<0.1	<0.1	<2	475.40
9/27/99	21.34	482.09	1,450	<0.1	<0.1	<0.1	<0.1	<2	475.31
10/7/99	22.34	481.09	1,433	<0.1	<0.1	.66 B	<0.1	<2	475.54
10/12/99	21.93	481.50	1,399	<0.1	<0.1	4.4 B	<0.1	<2	475.27
10/21/99	21.53	481.90	1,440	<0.1	<0.1	.17 B	<0.1	<2	475.16
11/1/99	22.17	481.26	1,428	<0.1	<0.1	0.976	<0.1	<2	474.88
12/3/99	22.81	480.62							475.18
1/24/00	24.90	478.53							
7/24/00	19.96	483.47	1,403	<0.1	<0.1	<0.1			
<b>Well TW-B</b>									
8/25/99				0.19	0.34	1.59			
8/26/99				0.21	0.21	0.77			
9/9/99	23.08	480.35	1,056	0.34	0.34	1.21			
9/16/99	23.40	480.03	1,076	0.33	0.39	<0.1	0.13	<2	475.91
9/22/99	23.67	479.76	1,077	0.43	0.42	0.94	<0.1	<2	475.40
9/27/99	23.88	479.55	1,096	0.47	0.59	1.9	<0.1	<2	475.31
10/7/99	24.89	478.54	1,084	0.64	0.64	1.24	<0.1	<2	475.54
10/12/99	25.09	478.34	1,080	0.66	0.68	1.05	<0.1	<2	475.27
<b>Well TW-B</b>									
10/21/99	24.41	479.02	1,087	0.76	0.74	2.98	<0.1	<2	475.16
11/1/99	24.71	478.72	1,090	0.80	1.84	3.69	<0.1	<2	474.88
12/3/99	25.18	478.25							475.18
1/24/00	28.13	475.30							
7/25/00	23.95	479.48	1,149	0.39	0.1	2.1			
<b>Well TW-C</b>									
8/25/99				173	62	108			
8/26/99				129	45	65.2			
9/9/99	22.15	481.28	1,175	198	73	60	1.73	<2	
9/16/99	22.53	480.90	1,185	323	114	80	2.1	<10	475.91

Date	WL	Water altitude	COND	PCE	TCE	cis-DCE	t-DCE	VC	River
<b>Well TW-C</b>									
9/22/99	22.81	480.62	1,202	282	97	74	1.7	<10	475.40
9/27/99	23.04	480.39	1,200	265	82	56	1.19	<10	475.31
10/7/99	24.13	479.30	1,185	315	98	53	1.4	<10	475.54
10/12/99	24.29	479.14	1,154	278	81	48	1.13	<10	475.27
10/21/99	23.65	479.78	1,135	178	40	29	0.2 E	<10	475.16
11/1/99	23.97	479.46	1,129	218	42	28			474.88
12/3/99	24.42	479.01							475.18
1/24/00	27.35	476.08							
7/25/00	23.12	480.31	1,176	13.5	3.9	2.1			
<b>Well TW-D</b>									
8/26/99									
9/9/99	19.62	483.81	788	1.42	0.47	1.78	<0.1	<2	
9/16/99	19.99	483.44	803	0.80	0.37	1.97 B	<0.1	2.2 E	475.91
9/22/99	20.29	483.14	819	1.17	0.37	0.78 B	<0.1	<2	475.40
9/27/99	20.51	482.92	780	1.33	0.80	2.83	0.1 E	6.1 B	475.31
10/7/99	21.60	481.83	798	0.82	0.63	1.62	<0.1	<2	475.54
10/12/99	21.77	481.66	808	1.4	0.92	2.59	<0.1	<2	475.27
10/21/99	21.09	482.34	843	1.78	0.64	2.59	<0.1	<2	475.16
11/1/99	21.43	482.00	861	1.46	0.62	2.65			474.88
12/3/99	21.88	481.55							475.18
1/24/00	24.81	478.62							
7/25/00	20.72	482.71	950	0.8	0.1	0.2			
<b>Well TW-E</b>									
8/26/99				365	82	286	16.8	2.4 E	
9/9/99				205	59	204	17.9	3.9 E	
9/16/99				192	56	240	16.1	3.2 E	475.91
9/22/99	23.59	479.84		213	53	244	18.9	6.6 E	475.40
9/27/99	23.85	479.58		162	38	169	<0.5	<10	475.31
10/7/99	24.92	478.51	1,234	327	102	297	<0.5	<10	475.54
10/12/99	25.07	478.36	1,271	257	79	226	<0.5	<10	475.27
10/21/99	24.45	478.98	1,274	182	48	221	4.23	<10	475.16
11/1/99	24.78	478.65	1,257	121	41	133			474.88
12/3/99	25.28	478.15							475.18
1/24/00	27.30	476.13							
7/26/00	24.02	479.41	1,243	197	107	19			

**TABLE 14.** Summary of water-level and water-quality data collected from selected domestic, public-supply, and monitoring wells during April, 1999 in the vicinity of New, Haven Missouri.

[ID, identification; asl, above sea level; als, above land surface; WL, water level; WL Alt., altitude of water level in feet above sea level; TD, total depth of well in feet below land surface; Csg, depth of casing in feet below land surface; Cond, specific conductance in microseimens per centimeter at 25 degrees Celsius; DO, dissolved oxygen in milligrams per liter; PCE, tetrachloroethene; TCE, trichloroethene; concentrations of PCE and TCE were estimated using a portable gas chromatograph unless noted otherwise; Jeff-Cotter, Jefferson City and Cotter Dolomite formations; Gasc, Gasconade Dolomite formation; Rbdx, Roubidoux Sandstone formation; Potosi, Potosi Dolomite formation; Eminence, Eminence Dolomite formation]

Field ID	Measuring										Lowermost producing formation
	Elevation (feet asl)	point (feet als)	WL	WL Alt.	TD	Csg	Cond	DO	PCE <sup>1</sup>	TCE <sup>1</sup>	
DM-01	612.8	1.80	61.95	552.65	250	123	787	4.5	<0.1	<0.1	Jeff-Cotter
DM-02	622	2.50	111.00	513.5	550	--	--	--	--	--	Gasc
DM-03	595.4	1.50	74.50	522.4	--	--	619	6	<0.1	<0.1	--
DM-04	790	0.60	228.90	561.7	--	--	611	2	<0.1	<0.1	--
DM-05	740	0.50	--	--	--	--	617	5	<0.1	<0.1	--
DM-06	660	0.00	--	--	350	--	949	6	<0.1	1.3	Jeff-Cotter
DM-07	594.4	2.50	82.90	514	395	102	604	0.1	<0.1	<0.1	Rbdx
DM-08	722	1.50	164.35	559.15	415	143	671	5	<0.1	<0.1	Jeff-Cotter
DM-09	629.2	1.50	119.20	511.5	406	164	--	--	--	--	Jeff-Cotter
DM-10	545	0.50	22.00	523.5	--	--	526	3	<0.1	<0.1	--
DM-11	745	1.00	189.00	557	395	102	614	4	<0.1	<0.1	Jeff-Cotter
DM-12	730	0.00	--	--	475	40	711	3	<0.1	<0.1	Jeff-Cotter
DM-13	755	1.00	207.90	548.1	--	--	670	3	<0.1	<0.1	--
DM-14	664.3	1.50	88.70	577.1	--	--	983	3.5	<0.1	0.8 a	--
DM-15	625.9	1.00	72.90	554	290	109	670	3	<0.1	<0.1	Jeff-Cotter
DM-16	728.5	0.20	190.00	728.5	527	--	670	2.5	<0.1	<0.1	Rbdx
DM-17	653.2	1.50	148.30	506.4	520	273	624	0.5	<0.1	<0.1	Rbdx
DM-18	740.9	1.50	239.00	503.4	485	--	707	3.5	<0.1	<0.1	Jeff-Cotter
DM-19	695.6	3.00	122.30	576.3	415	120	635	2	<0.1	<0.1	Jeff-Cotter
DM-20	583	0.00	12.00	571	--	--	--	--	--	--	--
DM-21	--	--	--	--	400	--	726	--	<0.1	<0.1	--
DM-22	640	1.00	122.90	518.1	412	81	790	3.5	<0.1	<0.1	Jeff-Cotter
DM-23	666.2	1.70	144.50	523.4	490	100	589	--	<0.1	<0.1	Rbdx
JS-01	743.8	1.30	239.16	505.94	--	--	720	4.33	<0.1	<0.1	--
JS-02	705.4	1.60	187.78	519.22	400	--	665	5.23	<0.1	<0.1	Jeff-Cotter
JS-03	610.6	-2.10	53.40	555.1	330	52	860	2.3	<0.1	0.2	Jeff-Cotter
JS-04	676.7	1.30	96.59	581.41	--	--	870	3.5	<0.1	<0.1	--
JS-05	753.5	1.30	209.50	545.3	--	--	692	--	<0.1	<0.1	--

Field ID	Measuring		WL	WI Alt.	TD	Csg	Cond	DO	PCE <sup>1</sup>	TCE <sup>1</sup>	Lowermost producing formation
	Elevation (feet asl)	point (feet als)									
JS-06	567	1.30	59.60	508.7	400	120	535	--	<0.1	<0.1	Rbdx
JS-07	562.6	0.00	54.20	508.4	415	103	529	--	<0.1	<0.1	Rbdx
JS-08	645.2	1.40	114.15	532.45	--	--	557	0.1	<0.1	<0.1	--
JS-09	631.3	0.50	72.45	559.35	360	106	649	2.8	<0.1	<0.1	Jeff-Cotter
JS-10	599.8	0.60	88.10	512.3	--	--	772	4.1	<0.1	<0.1	--
JS-11	--	0.00	--	--	435	--	652	4.5	<0.1	<0.1	--
JS-12	566.1	1.40	56.03	511.47	--	--	685	5.3	<0.1	<0.1	--
JS-13	560	1.00	53.00	508	--	--	466	4.7	<0.1	<0.1	--
JS-14	588	0.00	--	--	--	--	639	2.5	.3 d	<0.1	--
JS-15	598	1.00	87.42	511.58	425	120	573	--	<0.1	<0.1	Rbdx
JS-16	648.6	1.00	83.45	566.15	395	50	903	0.1	<0.1	4.0 e	Jeff-Cotter
JS-17	--	0.00	--	--	--	--	720	6.7	<0.1	<0.1	--
JS-18	641.2	1.40	137.69	504.91	--	--	712	3.4	<0.1	<0.1	--
JS-19	660	1.30	--	--	580	--	623	3.4	<0.1	<0.1	Gasc
JS-20 <sup>2</sup>	570	-1.00	--	--	--	--	585	1.2	<0.1	<0.1	--
JS-21	626	-2.00	120.40	503.6	400	--	782	7.5	<0.1	<0.1	Jeff-Cotter
JS-22	625	0.00	--	625	1,155	406	--	--	--	--	Potosi
JS-22A	495	0.40	20.45	474.95	--	--	--	--	0.1	<0.1	--
JS-24	656	1.00	145.75	511.25	500	120	716	3.8	<0.1	<0.1	Rbdx
JS-25	618	0.50	97.45	521.05	--	--	--	--	<0.1	<0.1	--
PB-03	540	0.50	49.74	490.76	--	--	--	--	--	--	--
PB-05	535	1.85	30.00	506.85	--	--	499	--	<0.1	<0.1	--
PB-06	670	1.00	151.00	520	330	--	750	--	--	--	Jeff-Cotter
PB-07	740	0.80	151.90	588.9	--	--	603	--	<0.1	<0.1	--
PB-08	770	1.00	235.28	535.72	--	--	634	--	<0.1	<0.1	--
PB-09	640	1.00	128.40	512.6	--	--	553	--	--	--	--
PB-10	620	1.20	117.31	503.89	--	--	781	--	--	--	--
PB-11	580	1.10	82.18	498.92	--	--	563	--	<0.1	<0.1	--
PB-12	630	1.10	129.95	501.15	415	82	--	--	--	--	Rbdx
PB-13	590	0.30	108.00	482.3	250	--	--	--	--	--	Jeff-Cotter
PB-14	720	0.35	196.85	523.5	425	--	717	--	<0.1	<0.1	Jeff-Cotter
PB-15	560	1.50	58.76	502.74	420	--	698	--	<0.1	<0.1	Rbdx
PB-16	510	1.20	30.10	481.1	--	--	639	--	<0.1	<0.1	--
PB-17	656.2	1.00	119.00	538.2	--	--	642	5	<0.1	<0.1	--

Measuring											Lowermost producing formation
Field ID	Elevation (feet asl)	point (feet als)	WL	WI Alt.	TD	Csg	Cond	DO	PCE <sup>1</sup>	TCE <sup>1</sup>	
JS-00	495	0.00	19.03	475.97	27	--	--	--	225 b	58 c	Alluvium Soils
JS-23	540	-1.00	--	--	--	--	491	4.1	<0.1	<0.1	--
PB-16A f	520	0.00	0.00	520	--	--	813	--	<0.1	<0.1	--
PB-00	501	0.00	0.00	--	992	153	--	--	--	--	Potosi
PB-01	598	0.00	210.00	388	885	525	--	--	--	--	Eminence
PB-02	519	2.55	39.08	482.47	1,075	210	--	--	12.5	8.0	Potosi
PB-04	668	1.20	240.00	441.2	982	560	--	--	--	--	Eminence

<sup>1</sup> Concentration estimated using a portable gas chromatograph.

<sup>2</sup> Portable gas chromatograph sample contained 1.7-µg/L toluene.

a Concentration of 1.2 micrograms in a duplicate sample analyzed by gas chromatography-mass spectrometry

b Concentration of 195 µg/L in a duplicate sample analyzed by gas chromatography-mass spectrometry

c Concentration of 43.9 µg/L TCE and 140 µg/L cis-1,2-dichloroethene in a duplicate sample analyzed by gas chromatography-mass spectrometry

d Estimated concentration of 0.1 µg/L in headspace vial using gas chromatography-mass spectrometry.

e Concentration of 4.6 micrograms in a duplicate sample analyzed by gas chromatography-mass spectrometry

f Spring sample.

g Concentration determined by gas chromatography-mass spectrometry.