

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

Distribution of Volatile Organic Compounds in Sediments near Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

Open-File Report 02-138

In cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY



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

Distribution of Volatile Organic Compounds in Sediments near Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

By PETER E. CHURCH, FOREST P. LYFORD, and
SCOTT CLIFFORD, U.S. Environmental Protection Agency

Open-File Report 02-138

Prepared in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

Northborough, Massachusetts
2002

U.S. Department of the Interior
GALE A. NORTON, Secretary

U.S. Geological Survey
Charles G. Groat, Director

The use of trade or product names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

For additional information write to:

Chief, Massachusetts-Rhode Island District
U.S. Geological Survey
Water Resources Division
10 Bearfoot Road
Northborough, MA 01532

or visit our Web site at

<http://ma.water.usgs.gov>

Copies of this report can be purchased from:

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

CONTENTS

Abstract	1
Introduction	2
Data-Collection Methods	6
Distribution of Volatile Organic Compounds	7
References Cited	10

FIGURES

1, 2. Maps showing:	
1. Location of study area, Sutton Brook Disposal Area, Tewksbury, Massachusetts.....	3
2. Data-collection sites and the distribution of petroleum and chlorinated hydrocarbons detected with passive-vapor-diffusion samplers in sediments near the Sutton Brook Disposal Area, May 2001.....	4

TABLES

1. Target compounds and reporting limits for passive-vapor-diffusion samples and surface-water samples from the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001	7
2. Volatile organic compounds detected in surface-water samples from Sutton Brook, tributaries, and wetland, Sutton Brook Disposal Area.....	8
3. Comparison of volatile organic compound concentrations from original and duplicate passive-vapor-diffusion samples in which a volatile organic compound was detected above the reporting limit in both samples, Sutton Brook Disposal Area.....	9
4. Volatile organic compounds detected in passive-vapor-diffusion samples in sediments near the Sutton Brook Disposal Area.....	13

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

CONVERSION FACTORS

Multiply	By	To obtain
acres	0.405	hectares
feet (ft)	0.3048	meters
inches (in.)	2.54	centimeters
miles (mi)	1.609	kilometers
Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows: °F=1.8°C+32		

VERTICAL DATUM

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

ABBREVIATIONS

mL	milliliter
ppb v	parts per billion by volume
µg/L	micrograms per liter
mm	millimeter

Distribution of Volatile Organic Compounds in Sediments near Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

By Peter E. Church, Forest P. Lyford, *and* Scott Clifford

Abstract

Ground water at the Sutton Brook Disposal Area, a former municipal landfill in Tewksbury, Massachusetts, located adjacent to Sutton Brook, a tributary of the Shawsheen River, is contaminated by volatile organic compounds (VOCs). Results from the use of passive-vapor-diffusion samplers show vapor concentrations of petroleum hydrocarbons as high as 500,000 parts per billion by volume in pore waters of streambed sediments along an approximate 2,000-foot reach of Sutton Brook where it flows between lobes of the former landfill. Petroleum hydrocarbons were also

detected in the sediments on the eastern shore of Quarry Pond, which is south of the southern landfill lobe, with a maximum vapor concentration near 2,000 parts per billion by volume. Vapor concentrations of petroleum hydrocarbons in the sediments of Sutton Brook vary by two to three orders-of-magnitude over distances of 50 to 100 feet. Chlorinated hydrocarbons also were detected with passive-vapor-diffusion samplers, but generally at locations downstream of where petroleum hydrocarbons were detected, and mostly at vapor concentrations of less than 100 parts per billion by volume.

INTRODUCTION

Ground water at the Sutton Brook Disposal Area, a former municipal landfill in Tewksbury, Massachusetts, located adjacent to Sutton Brook, a tributary of the Shawsheen River, is contaminated by volatile organic compounds (VOCs) (fig. 1). Previous sampling of water from stream sediments and ground water from monitoring wells identified a mix of VOCs including petroleum hydrocarbons (benzene, toluene, ethylbenzene, and xylenes), several chlorinated hydrocarbons (1,1-dichloroethene, 1,1-dichloroethane, 1,1,1-trichloroethane, *cis*-1,2-dichloroethene, and chloroethane), and tetrahydrofuran (Roy F. Weston, Inc., 2000; Don McElroy, U.S. Environmental Protection Agency, written commun., 2001). Volatile organic compounds also have been detected in surface water (Roy F. Weston, Inc., 2000). Because of the limited number of sampling locations, however, the current extent of contaminated ground water near the landfill is not well defined.

In May 2001 the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (USEPA), used polyethylene-membrane passive-vapor-diffusion (PVD) samplers to identify areas where VOC contaminated ground water could be discharging into Sutton Brook, its tributaries and adjacent wetlands, and the eastern shore of Quarry Pond, a shallow pond just south of the landfill (fig. 2). Seven surface-water samples were collected from Sutton Brook and tributaries to evaluate if upstream waters contribute to VOC concentrations in PVD samplers and to determine the extent that VOC-contaminated ground-water discharge affects downstream water quality.

In this study, PVD samplers were used because of their success as a reconnaissance tool in detecting and defining relative concentrations of VOCs in sediment-pore waters at and near hazardous-waste sites in

various environmental settings in New England, including rivers (Savoie and others, 1999; Church and others, 2000), ponds (Savoie and others, 2000; Church and others, 2002), and a coastal landfill (Lyford and others, 1999). The study at the Sutton Brook Disposal Area provided an opportunity to evaluate the use of PVD samplers in stream and wetland sediment near an inland landfill, an environmental setting that had not been previously studied. This report presents the VOC data collected at and near the Sutton Brook Disposal Area in May 2001.

The 50-acre landfill, commonly known as the Rocco landfill, which received municipal, commercial, and industrial waste during approximately 40 years of operation, includes three landfill lobes, referred to as the northern, eastern, and southern lobes, which form prominent hills in an area of otherwise low relief (fig. 2). The landfill is underlain by extensive wetland sediments and sand and gravel deposits (Castle, 1959). Sutton Brook is a perennial stream that flows westward between the southern and northern/eastern landfill lobes and northwestward to the Shawsheen River, which is about one mile downstream of the landfill. The brook is about 10 to 15 ft wide where it flows between the landfill lobes (Roy F. Weston, Inc., 2000). Wetland areas are east of the landfill, between Sutton Brook and the eastern and northern landfill lobes, west of the landfill, and south of the southern landfill lobe near Quarry Pond. Regional ground-water flow in the surficial aquifer beneath the landfill is to the west/southwest toward the Shawsheen River (Roy F. Weston, Inc., 2000).

The authors thank Don McElroy, USEPA Project Manager of the Sutton Brook Disposal Area and Richard E. Willey, USEPA, for their assistance and advice during this investigation. Don McElroy's help in the field is greatly appreciated.

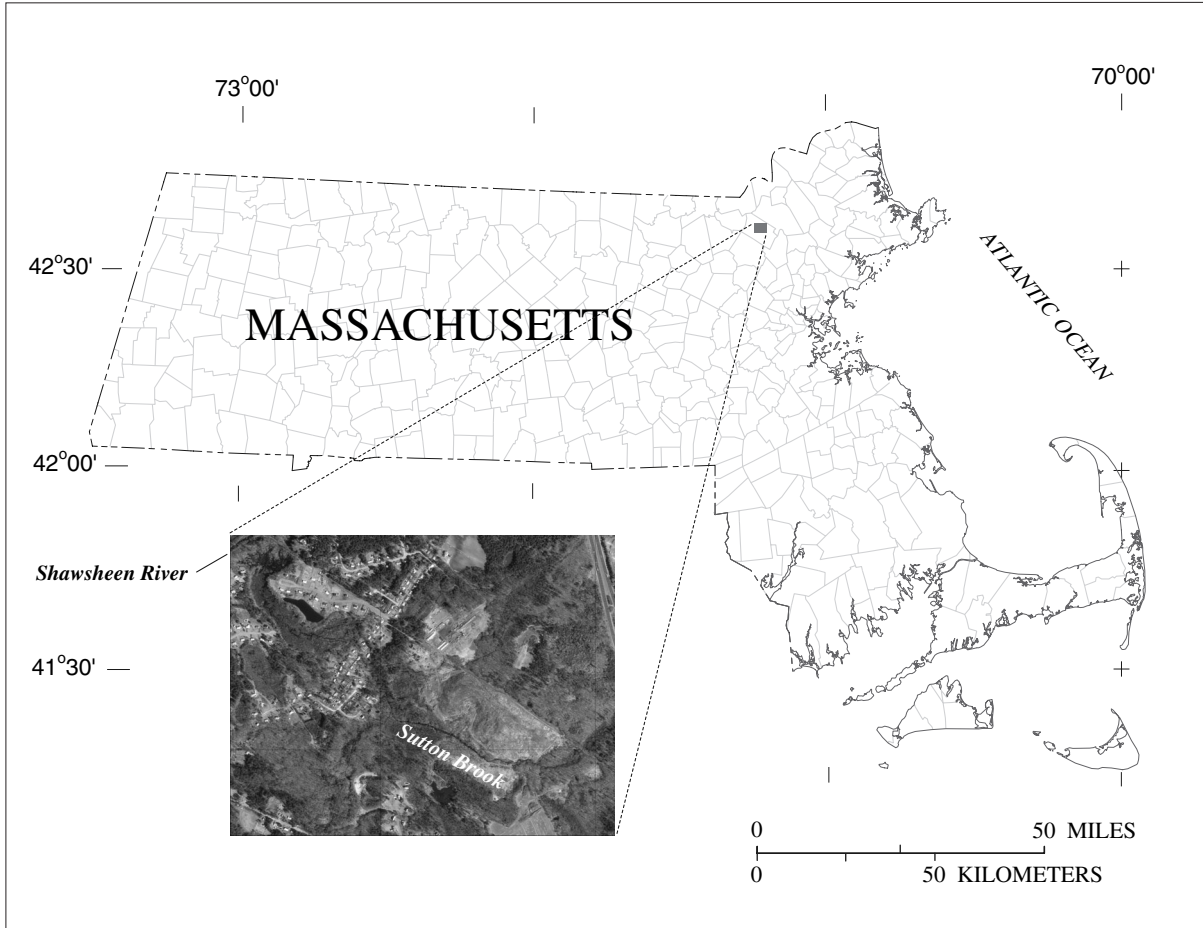


Figure 1. Location of study area, Sutton Brook Disposal Area, Tewksbury, Massachusetts.

Link to plate showing data-collection sites and the distribution of petroleum and chlorinated hydrocarbons detected with passive-vapor-diffusion samplers in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001.

Figure 2. Data-collection sites and the distribution of petroleum and chlorinated hydrocarbons detected with passive-vapor-

Link to plate showing data-collection sites and the distribution of petroleum and chlorinated hydrocarbons detected with passive-vapor-diffusion samplers in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001.

diffusion samplers in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001.

DATA-COLLECTION METHODS

The PVD samplers were constructed with methods described by Vroblesky and others (1996). A sampler consists of a 40-milliliter, uncapped glass bottle secured with plastic cable ties inside two heat-sealed lengths of polyethylene-membrane tubing. Plastic cable ties attach the sampler to the wire of a survey flag, which allows for marking and retrieval of the sampler. Duplicate samples for quality control are obtained by attaching two samplers to the same survey flag.

Samplers are generally placed 8 to 10 in. deep in sediments with the bottle opening facing downward. Organic vapors from VOCs in the saturated sediments diffuse through the two layers of polyethylene and equilibrate with air in the bottle. Equilibration time has been shown to be 24 hours or less in a controlled laboratory setting (Vroblesky and others, 1996). In a field setting, however, two weeks is recommended for equilibration (Don Vroblesky, U.S. Geological Survey, oral commun., 1997). The additional time is needed to allow concentrations of VOCs in ground water to re-equilibrate after the sediment is disturbed by installation of the sampler. After retrieving the sampler, the outer tubing is removed to shed attached sediment, and a cap is immediately screwed onto the bottle over the inner tubing.

The PVD samplers were installed at 143 locations in Sutton Brook, in three small tributaries to Sutton Brook, in wetland areas adjacent to Sutton Brook, and on the eastern shore of Quarry Pond on May 1 and 2, 2001 (fig. 2). During installation, the pre-labeled samplers numbered 66 and 67 were inadvertently skipped, so the last sampler installed was numbered 145. Samplers installed in Sutton Brook sediments extend from about 200 ft upstream of the Northern Access Road to about 500 ft downstream of South Street, for a total distance of about 5,000 ft (fig. 2). A PVD sampler also was installed near the right bank of Sutton Brook just upstream of its confluence with the Shawsheen River, about 3,000 ft downstream of South Street.

Most samplers were installed with a pipe-insertion method (Lyford and others, 2000); in hard bottom sediments, a narrow-bladed steel-reinforced

shovel was used. Samplers were generally placed at 50-ft intervals, and every tenth sampler included a duplicate sampler. Distances between most samplers were determined with a measuring tape during installation. Distances between some samplers in wetland areas, however, were initially determined by pacing. About one third of the sampler locations, several of which were in the wetland areas, were surveyed with a global positioning system (GPS) to more accurately map sampler locations. The accuracy of locating sampler sites with the GPS is estimated to be within 5 ft, and the accuracy of locating sites interpolated between surveyed sites is estimated to be generally within 10 ft.

Samplers were retrieved from May 22 through 24, 2001. Samplers from five locations along Sutton Brook were not recovered. At four of these locations, the samplers were not recovered because the survey flags, submerged in turbid water, were not found. The other sampler was not recovered because the wire of the survey flag broke free of the sampler during recovery. Vapor in the 138 samplers recovered, 14 duplicate samplers, and one equipment blank were analyzed on site by the USEPA for petroleum and chlorinated hydrocarbons. The USEPA Region I standard air-screening method was used in these analyses (U.S. Environmental Protection Agency, 1998a). Concentrations of VOCs in PVD samples are reported in parts per billion by volume (ppb v). Target compounds and reporting limits are listed in table 1.

Surface-water samples were collected at seven locations, five from Sutton Brook between the culvert at the Northern Access Road and the confluence with the Shawsheen River, one from a tributary channel, and one from a wetland channel (fig. 2). Surface-water samples were obtained from near the center of the channels by lowering a 40 mL vial to the center of the water column. Water samples were analyzed on site for VOCs in accordance with the USEPA Region I methods for head-space screening for volatile organic compounds (U.S. Environmental Protection Agency, 1998b). Concentrations of the surface-water samples are reported in micrograms per liter. Target compounds and reporting limits are listed in table 1.

Table 1. Target compounds and reporting limits for passive-vapor-diffusion samples and surface-water samples from the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

Compound	Reporting limits
Passive-vapor-diffusion samples (parts per billion by volume)	
Toluene	40
Ethylbenzene	50
<i>meta/para</i> -Xylene.....	50
<i>ortho</i> -Xylene.....	50
Tetrachloroethene	2
Trichloroethene.....	4
1,1,1-Trichloroethane	3
Surface-water samples (micrograms per liter)	
Toluene	0.5
Benzene5
Ethylbenzene	1.0
<i>meta/para</i> -Xylene.....	1.0
<i>ortho</i> -Xylene.....	2.0
Chlorobenzene.....	1.0
Tetrachloroethene2
Trichloroethene.....	.5
<i>cis</i> -1,2-Dichloroethene	1.0
1,1,1-Trichloroethane1

DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds were detected above reporting limits at 54 of the 138 locations where PVD samplers were recovered (fig. 2, table 4, at back of report). Petroleum hydrocarbons (toluene, ethylbenzene, *meta/para*-xylene, and *ortho*-xylene) were detected at 37 of these locations, 30 of which were along an approximate 2,000-ft reach of Sutton Brook where it flows between the southern and the northern and eastern landfill lobes (fig. 2). Concentrations of total petroleum hydrocarbons detected in this reach range from 52 to nearly 500,000 ppb v. Variations in concentrations of two to three orders-of-magnitude over distances of 50 to 100 ft were observed at several places along this reach of Sutton Brook. Toluene was

detected at five locations further downstream, one of which was at the confluence with the Shawsheen River. Concentrations of toluene in this reach, however, were less than 100 ppb v (concentrations at three of the five locations were at trace levels below the reporting limit of 40 ppb v for toluene). Toluene was also detected at four locations on the eastern shore of Quarry Pond, where concentrations ranged from 128 to 1,960 ppb v (fig. 2). Petroleum hydrocarbons were not detected above reporting limits in the tributaries to Sutton Brook, the wetland area between Sutton Brook and the eastern and northern landfill lobes (with the exception of one location near the brook where a concentration of *meta/para*-xylene less than 100 ppb v was detected), the wetland channel, and the equipment-blank sample.

In the 2,000-ft reach of Sutton Brook, where petroleum hydrocarbons were detected in numerous PVD samplers, 11 of the 30 samples had concentrations greater than 10,000 ppb v. Concentrations of toluene in six of these 11 samples accounted for greater than 50 percent of the total petroleum hydrocarbons concentrations. *Meta/para*-xylene was the principal petroleum hydrocarbon in the 19 samples with concentrations less than 10,000 ppb v. In 16 of these 19 samples, concentrations of *meta/para*-xylene were greater than concentrations of the other petroleum hydrocarbons, or it was the only petroleum hydrocarbon detected.

Chlorinated hydrocarbons (tetrachloroethene, trichloroethene, and 1,1,1-trichloroethane) were detected above reporting limits at 23 locations, six of which were along the reach of Sutton Brook between the eastern and southern landfill lobes where the highest concentrations of petroleum hydrocarbons were detected. Concentrations of these VOCs ranged from 23 to about 8,800 ppb v (fig. 2, table 4). Petroleum hydrocarbons also were detected in five of these six samplers, and they represent over 98 percent of the total VOC concentration in each sample. Chlorinated hydrocarbons were detected at 13 locations along an approximate 1,200-ft reach of Sutton Brook from about 500 ft downstream of where petroleum hydrocarbons are prominent to just downstream of South Street. Concentrations of total chlorinated hydrocarbons detected in this reach ranged from 5 to 41 ppb v (fig. 2, table 4). Chlorinated hydrocarbons also were detected

in the tributaries to Sutton Brook. Concentrations of samples from the two left bank tributaries were less than 100 ppb v, and the concentration of the sample from the right bank tributary was 1,859 ppb v. Chlorinated hydrocarbons were not detected above reporting limits in the wetland area between Sutton Brook and the eastern and northern landfill lobes, the wetland channel, Quarry Pond, and the equipment-blank sample.

Volatile organic compounds were detected in three of the seven surface-water samples: SW2, SW4, and SW6 (fig. 2, table 2). The petroleum hydrocarbons toluene, ethylbenzene, and *meta/para*-xylene were detected in sample SW2 from Sutton Brook just upstream of the southern landfill lobe, where high

concentrations of petroleum hydrocarbons were detected in PVD samplers. Total petroleum hydrocarbon concentration in sample SW2 was 9.7 µg/L. Sample SW4 was located about 700 ft upstream of South Street, an area where only chlorinated hydrocarbons were detected with PVD samplers. Sample SW6 was located just downstream of South Street where petroleum and chlorinated hydrocarbons were detected in a PVD sampler. At both SW4 and SW6, the petroleum hydrocarbon *meta/para*-xylene was detected at a concentration of 1.0 µg/L, and the chlorinated hydrocarbon 1,1,1-trichloroethane was detected at a concentration of 0.8 µg/L. No other VOCs were detected in the surface-water samples.

Table 2. Volatile organic compounds detected in surface-water samples from Sutton Brook, tributaries, and wetland, Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

[Concentrations are in micrograms per liter. (0.5), reporting limit; --, not detected above reporting limit]

Surface-water sample	Petroleum Hydrocarbons				
	Toluene (0.5)	Benzene (0.5)	Ethylbenzene (1.0)	<i>meta/para</i> -Xylene (1.0)	<i>ortho</i> -Xylene (2.0)
SW1	--	--	--	--	--
SW2	6.0	--	1.0	2.7	--
SW3	--	--	--	--	--
SW4	--	--	--	1.0	--
SW5	--	--	--	--	--
SW6	--	--	--	1.0	--
SW7	--	--	--	--	--

Surface-water sample	Chlorinated Hydrocarbons				
	Chlorobenzene (1.0)	Tetrachloroethene (0.2)	Trichloroethene (0.5)	<i>cis</i> -1,2-Dichloroethene (1.0)	1,1,1-Trichloroethane (0.1)
SW1	--	--	--	--	--
SW2	--	--	--	--	--
SW3	--	--	--	--	--
SW4	--	--	--	--	0.8
SW5	--	--	--	--	--
SW6	--	--	--	--	.8
SW7	--	--	--	--	--

For 77 of the 98 duplicate-sample analyses (14 duplicate samples times 7 target compounds), a VOC was not detected above the reporting limit in the original and duplicate sample. In 20 of the 98 duplicate-sample analyses, a VOC was detected above the reporting limit in the original and duplicate samples (table 3). In one duplicate-sample analyses, toluene was detected above the reporting limit of

40 ppb v in the original sample at a concentration of 49 ppb v, but a trace concentration of 34 ppb v was estimated for the duplicate sample. The relative percent differences of concentration between original and duplicate samples in the 20 duplicate-sample analyses where a VOC was detected in both samples ranged from 0 to 72 percent, with a mean and median of 26 percent.

Table 3. Comparison of volatile organic compound concentrations from original and duplicate passive-vapor-diffusion samples in which a volatile organic compound was detected above the reporting limit in both samples, Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

[Concentrations are in parts per billion by volume]

Volatile organic compound	Concentration of original sample	Concentration of duplicate sample	Mean concentration	Relative percent difference
Toluene.....	47,400	78,600	63,000	50
Toluene.....	155,000	125,000	140,000	21
Toluene.....	45,600	45,600	45,600	0
Ethylbenzene.....	9,280	14,800	12,040	46
Ethylbenzene.....	22,800	16,600	19,700	31
Ethylbenzene.....	2,480	2,270	2,375	9
Ethylbenzene.....	228	195	212	16
<i>meta/para</i> -Xylene	17,400	33,400	25,400	63
<i>meta/para</i> -Xylene	91,000	66,100	78,550	32
<i>meta/para</i> -Xylene	4,870	4,860	4,865	0
<i>meta/para</i> -Xylene	615	291	453	72
<i>meta/para</i> -Xylene	70	70	70	0
<i>ortho</i> -Xylene	3,400	4,300	3,850	23
<i>ortho</i> -Xylene	42,100	31,400	36,750	29
<i>ortho</i> -Xylene	2,020	1,800	1,910	12
Tetrachloroethene.....	879	860	870	2
Tetrachloroethene.....	62	93	78	40
Trichloroethene	1,420	1,010	1,215	34
Trichloroethene	342	380	361	11
1,1,1-Trichloroethane.....	31	43	37	32
Minimum				0
Maximum.....				72
Mean				26
Median				26

REFERENCES CITED

- Castle, R.O., 1959, Surficial geology of the Wilmington quadrangle, Massachusetts: U.S. Geological Survey Quadrangle Map GQ-122, Scale 1:31,680.
- Church, P.E., Lyford, F.P., and Clifford, Scott, 2000, Distribution of selected volatile organic compounds determined with water-to-vapor diffusion samplers at the interface between ground water and surface water, Centredale Manor Site, North Providence, Rhode Island, September 1999: U.S. Geological Survey Open-File Report 00-276, 9 p., 1 pl.
- _____, 2002, Volatile organic compounds, specific conductance, and temperature in the bottom sediments of Mill Pond, Ashland, Massachusetts, April 2001: U.S. Geological Survey Open-File Report 02-35, 10 p.
- Lyford, F.P., Kliever, J.D., and Clifford, Scott, 1999, Volatile organic compounds detected in vapor-diffusion samplers placed in sediments along and near the shoreline at Allen Harbor Landfill and Calf Pasture Point, Davisville, Rhode Island, March–April 1998: U.S. Geological Survey Open-File Report 99-74, 9 p.
- Lyford, F.P., Willey, R.E., and Clifford, Scott, 2000, Field tests of polyethylene-membrane diffusion samplers for characterizing volatile organic compounds in stream-bottom sediments, Nyanza Chemical Waste Dump Superfund Site, Ashland, Massachusetts: U.S. Geological Survey Water-Resources Investigations Report 00-4108, 19 p.
- Roy F. Weston, Inc., 2000, Final summary trip report for Roccas's disposal area, Tewksbury, Massachusetts: Burlington, Mass., 92 p.
- Savoie, J.G., LeBlanc, D.R., Blackwood, D.S., McCobb, T.D., Rendigs, R.R., and Clifford, Scott, 2000, Delineation of discharge areas of two contaminant plumes by use of diffusion samplers, Johns Pond, Cape Cod, Massachusetts, 1998: U.S. Geological Survey Water-Resources Investigations Report 00-4017, 30 p.
- Savoie, J.G., Lyford, F.P., and Clifford, Scott, 1999, Potential for advection of volatile organic compounds in ground water to the Cochato River, Baird & McGuire Superfund Site, Holbrook, Massachusetts, March and April 1998: U.S. Geological Survey Water-Resources Investigations Report 98-4257, 19 p.
- U.S. Environmental Protection Agency, 1998a, Ambient air grab sample analysis for volatile organic compounds, Region 1: Internal Standard Operation Procedure no. EIA-FLDGRAB1.SOP, March 1998, 6 p.
- _____, 1998b, Head space screening for volatile organic compounds in aqueous, soil, and drum samples: Lexington, Mass., Region I, Internal Standard Operating Procedure no. EIA-FLDVOA1.SOP, March 1998, 11 p.
- Vroblecky, D.A., Rhodes, L.C., Robertson, J.F., and Harrigan, J.A., 1996, Locating VOC contamination in a fractured-rock aquifer at the ground-water/surface-water interface using passive vapor collectors: *Ground Water*, v. 34, no. 2, p. 223–230.

TABLE 4

Table 4. Volatile organic compounds detected in passive-vapor-diffusion samples in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001

[Concentrations are in parts per billion by volume. (40), reporting limit; D, duplicate sample; NA, no data collected; *, sampler not found; **, detected below reporting limit; --, not detected above reporting limit]

Sampler No.	Petroleum hydrocarbons				Chlorinated hydrocarbons		
	Toluene (40)	Ethylbenzene (50)	<i>meta/para</i> -Xylene (50)	<i>ortho</i> -Xylene (50)	Tetrachloro-ethene (2)	Trichloro-ethene (4)	1,1,1-Trichloro-ethane (3)
1	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--
7	--	--	--	--	--	--	--
8	--	--	--	--	--	--	--
9	--	--	--	--	--	--	--
10	--	--	--	--	--	--	--
10D	--	--	--	--	--	--	--
11	--	--	--	--	--	--	--
12	--	--	--	--	--	--	--
13	--	--	--	--	--	--	--
14	--	--	--	--	--	--	--
15	--	--	--	--	--	--	--
16	--	--	--	--	--	--	--
17	--	--	--	--	--	--	--
18	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--
20D	--	--	--	--	--	--	--
21	--	--	--	--	--	--	--
22	--	--	--	--	28	--	--
23	--	--	--	--	3	--	--
24	--	--	190	--	--	--	--
25	--	--	--	--	--	4	--
26	--	--	--	--	--	--	--
27	--	--	980	--	--	--	--
28	--	--	140	--	--	--	--
29	80	261	1,520	220	--	--	--
30	47,400	9,280	17,400	3,400	--	--	--
30D	78,600	14,800	33,400	4,300	--	--	--
31	1,590	9,280	26,110	3,580	--	--	--
32	360,000	55,700	56,600	16,100	--	--	--
33	280	4,380	6,650	986	--	--	--
34	--	--	140	--	--	--	--
35	--	--	--	--	--	--	--
36	636	9,080	29,600	7,280	--	23	--
37	--	--	--	--	--	--	--

Table 4. Volatile organic compounds detected in passive-vapor-diffusion (PVD) samples in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001—*Continued*

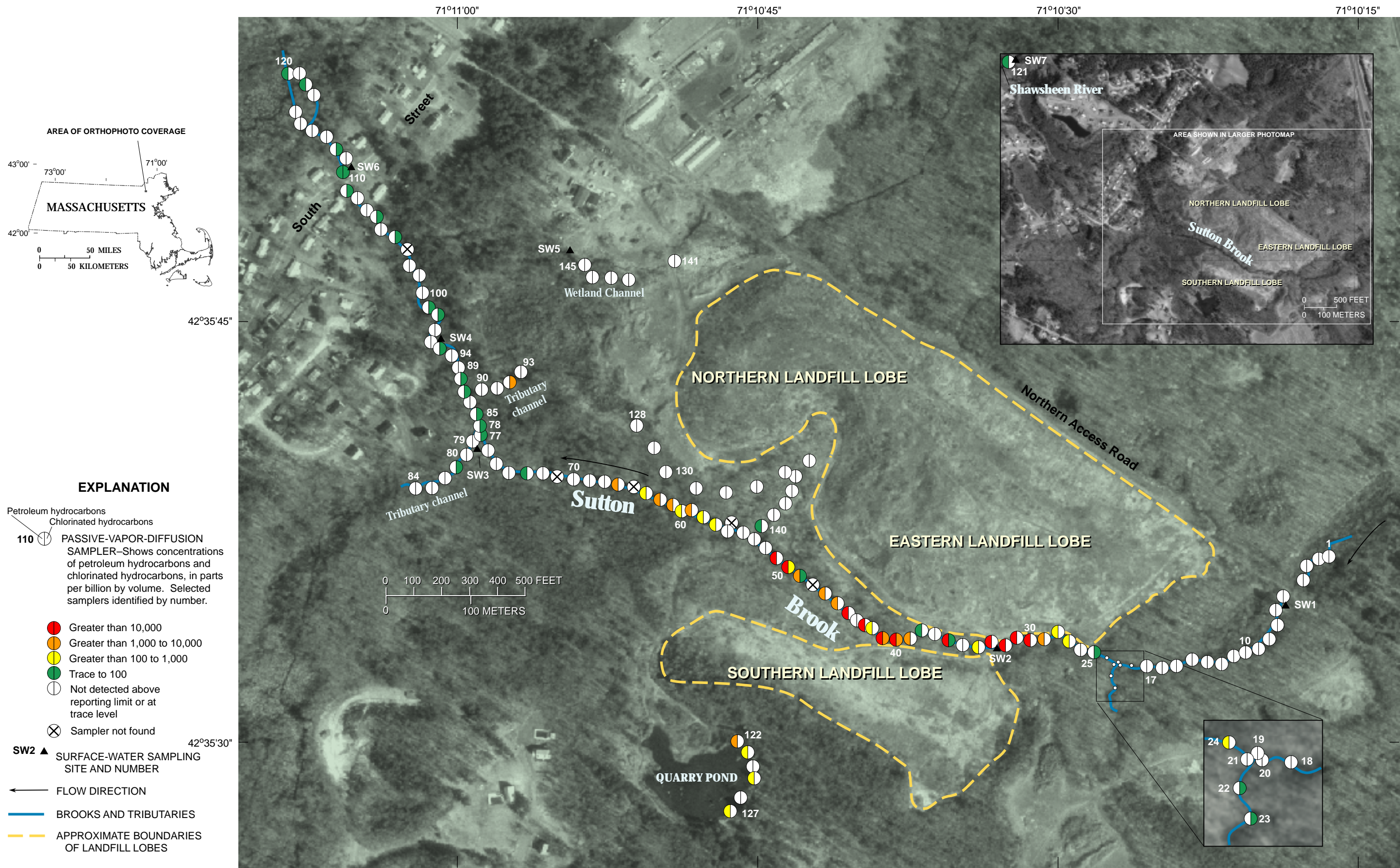
Sampler No.	Petroleum hydrocarbons				Chlorinated hydrocarbons		
	Toluene (40)	Ethylbenzene (50)	<i>meta/para</i> -Xylene (50)	<i>ortho</i> -Xylene (50)	Tetrachloroethene (2)	Trichloroethene (4)	1,1,1-Trichloroethane (3)
38	52	--	--	--	--	--	--
39	185	828	5,630	--	--	--	--
40	155,000	22,800	91,000	42,100	879	1,420	--
40D	125,000	16,600	66,100	31,400	860	1,010	--
41	292,000	47,600	113,000	31,400	52	1,220	7,560
42	106	78	510	--	--	--	--
43	19,600	2,590	17,900	42,100	--	--	--
44	--	--	--	--	--	--	--
45	119,000	4,660	16,500	6,270	--	--	--
46	--	--	1,260	--	--	--	--
47	371	207	1,410	--	--	--	--
*48	NA	NA	NA	NA	NA	NA	NA
49	6,780	140	460	130	--	35	--
50	45,600	2,480	4,870	2,020	62	342	--
50D	45,600	2,270	4,860	1,800	93	380	--
51	233,000	5,800	10,900	5,380	--	--	--
52	--	--	--	--	--	--	--
53	--	--	--	--	--	--	--
54	--	--	--	--	--	--	--
55	--	--	--	--	--	--	--
*56	NA	NA	NA	NA	NA	NA	NA
57	--	350	245	190	--	--	--
58	--	174	435	--	--	--	--
59	53	145	874	426	--	--	--
60	--	228	615	--	--	--	--
60D	--	195	291	--	--	--	--
61	--	198	896	392	--	--	--
62	--	923	5,070	900	--	--	--
63	--	--	247	--	--	--	--
*64	NA	NA	NA	NA	NA	NA	NA
65	--	--	1,270	--	--	--	--
68	--	--	--	--	--	--	--
69	--	--	--	--	--	--	--
70	--	--	--	--	--	--	--
70D	--	--	--	--	--	--	--
*71	NA	NA	NA	NA	NA	NA	NA
72	--	--	--	--	--	--	--
73	**32	--	--	--	--	--	--
74	--	--	--	--	--	--	--
75	--	--	--	--	--	--	--

Table 4. Volatile organic compounds detected in passive-vapor-diffusion (PVD) samples in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001—*Continued*

Sampler No.	Petroleum hydrocarbons				Chlorinated hydrocarbons		
	Toluene (40)	Ethylbenzene (50)	<i>meta/para</i> -Xylene (50)	<i>ortho</i> -Xylene (50)	Tetrachloroethene (2)	Trichloroethene (4)	1,1,1-Trichloroethane (3)
76	--	--	--	--	--	--	--
77	--	--	--	--	--	15	--
78	--	--	--	--	--	24	--
79	--	--	--	--	--	--	--
80	--	--	--	--	--	--	--
80D	--	--	--	--	--	--	--
81	--	--	--	--	--	17	--
82	--	--	--	--	--	--	--
83	--	--	--	--	--	--	--
84	--	--	--	--	--	--	--
85	--	--	--	--	--	12	--
86	--	--	--	--	--	--	--
87	--	--	--	--	--	10	--
88	--	--	--	--	--	14	--
89	--	--	--	--	--	--	--
90	--	--	--	--	--	--	--
90D	--	--	--	--	--	--	--
91	--	--	--	--	--	--	--
92	--	--	--	--	--	9	1,850
93	--	--	--	--	--	--	--
94	--	--	--	--	--	--	--
95	--	--	--	--	--	8	--
96	--	--	--	--	--	--	--
97	--	--	--	--	--	--	--
98	--	--	--	--	--	16	--
99	--	--	--	--	--	10	--
100	--	--	--	--	--	--	--
100D	--	--	--	--	--	--	--
101	--	--	--	--	--	--	--
102	--	--	--	--	--	--	--
*103	NA	NA	NA	NA	NA	NA	NA
104	--	--	--	--	20	21	--
105	--	--	--	--	--	--	--
106	--	--	--	--	--	--	36
107	--	--	--	--	--	--	--
108	--	--	--	--	--	--	--
109	--	--	--	--	--	--	5
110	**24	--	--	--	--	--	31
110D	--	--	--	--	--	--	43
111	--	--	--	--	--	--	--

Table 4. Volatile organic compounds detected in passive-vapor-diffusion (PVD) samples in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001—*Continued*

Sampler No.	Petroleum hydrocarbons				Chlorinated hydrocarbons		
	Toluene (40)	Ethylbenzene (50)	<i>meta/para</i> -Xylene (50)	<i>ortho</i> -Xylene (50)	Tetrachloroethene (2)	Trichloroethene (4)	1,1,1-Trichloroethane (3)
112	--	--	--	--	--	--	30
113	--	--	--	--	--	--	--
114	--	--	--	--	--	--	--
115	--	--	--	--	--	--	--
116	--	--	--	--	--	--	--
117	--	--	--	--	--	--	--
118	71	--	--	--	--	--	--
119	--	--	--	--	--	--	--
120	49	--	--	--	--	--	--
120D	**34	--	--	--	--	--	--
121	**26	--	--	--	--	--	--
122	1,960	--	--	--	--	--	--
123	128	--	--	--	--	--	--
124	--	--	--	--	--	--	--
125	165	--	--	--	--	--	--
126	--	--	--	--	--	--	--
127	190	--	--	--	--	--	--
128	--	--	--	--	--	--	--
129	--	--	--	--	--	--	--
130	--	--	--	--	--	--	--
130D	--	--	--	--	--	--	--
131	--	--	--	--	--	--	--
132	--	--	--	--	--	--	--
133	--	--	--	--	--	--	--
134	--	--	--	--	--	--	--
135	--	--	--	--	--	--	--
136	--	--	--	--	--	--	--
137	--	--	--	--	--	--	--
138	--	--	--	--	--	--	--
139	--	--	--	--	--	--	--
140	--	--	70	--	--	--	--
140D	--	--	70	--	--	--	--
141	--	--	--	--	--	--	--
142	--	--	--	--	--	--	--
143	--	--	--	--	--	--	--
144	--	--	--	--	--	--	--
145	--	--	--	--	--	--	--



Orthophoto from Executive Office of Environmental Affairs: aerial photographs taken in 1995.

Figure 2. Data-collection sites and the distribution of petroleum and chlorinated hydrocarbons detected with passive-vapor-diffusion samplers in sediments near the Sutton Brook Disposal Area, Tewksbury, Massachusetts, May 2001.



Church and others – DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN SEDIMENTS NEAR SUTTON BROOK DISPOSAL AREA,
TEWKSBURY, MASSACHUSETTS, MAY 2001 – OFR 02-138