

Investigation of Polyethylene Passive Diffusion Samplers for Sampling Volatile Organic Compounds in Ground Water at Davis Global Communications, Sacramento, California, August 1998 to February 1999

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CONVERSION FACTORS, TEMPERATURE, VERTICAL DATUM, DEFINITION, AND ABBREVIATIONS

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
Area		
square mile (mi ²)	2.59	square kilometer
Volume		
gallon (gal)	3.785	liter
Flow		
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft ² /d)	0.09294	meter squared per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
inch per year (in/yr)	25.4	millimeter per year
inch per week (in/week)	25.4	millimeter per week

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

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

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

Chemical concentration: In this report, chemical concentration in water is expressed in metric units as milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations used in this report:

1,1-DCE	1,1-dichloroethene
AFB	Air Force Base
AFCEE	U.S. Air Force Center for Environmental Excellence
cDCE	cis-1,2-dichloroethene
GC	gas chromatograph
mL	milliliter
msl	mean sea level
PCE	tetrachloroethene
TCE	trichloroethene
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

Investigation of Polyethylene Passive Diffusion Samplers for Sampling Volatile Organic Compounds in Ground Water at Davis Global Communications, Sacramento, California, August 1998 to February 1999

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ABSTRACT

Fourteen wells were instrumented with diffusion samplers as a test to determine whether the samplers could be used to obtain representative volatile organic compound concentrations at a study site in Sacramento, California. Single diffusion samplers were placed in 10-foot-long well screens, and multiple diffusion samplers were positioned in 20-foot-long well screens. Borehole geophysical logs and electromagnetic flowmeter tests were run in selected wells with 20-foot-long well screens prior to deploying the samplers. The diffusion samplers were recovered after 25 to 30 days, and the wells were then sampled by using the purge-and-sample method. In most wells, the concentrations obtained by using the downhole diffusion samplers closely matched those obtained by using the purge-and-sample method. In seven wells, the concentrations differed between the two methods by only 2 micrograms per liter ($\mu\text{g/L}$) or less. In three wells, volatile organic compounds were not detected in water obtained by using either method. In the four remaining wells, differences

between the methods were less than 2 $\mu\text{g/L}$ in the 0.2- to 8.5- $\mu\text{g/L}$ concentration range and from 1.2 to 8.7 $\mu\text{g/L}$ in the 10- to 26- $\mu\text{g/L}$ concentration range. Greater differences (23 percent or 14.5 $\mu\text{g/L}$, 31 percent or 66 $\mu\text{g/L}$, and 46 percent or 30 $\mu\text{g/L}$) between the two methods were observed for tetrachloroethene concentrations, which ranged between 30 and 211 $\mu\text{g/L}$ in three wells. The most probable explanation for the differences is that in some wells, the purging induced drawdowns and introduced water that differed in volatile organic compound concentrations from the in situ water in contact with the screened interval of the well. Alternate explanations include the possibility of unrecorded changes in nearby contaminant-extraction-well operation during the equilibration period. The data suggest that the combined use of borehole flowmeter tests and diffusion samplers may be useful in optimizing the radius of capture of contaminated ground water by the contaminant-removal wells. Overall, the data suggest that the use of diffusion samplers provided an alternative sampling method to the purge-and-sample approach.

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INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the U.S. Air Force Center for Environmental Excellence (AFCEE), began an initiative in August 1998 to investigate the suitability of using polyethylene water-filled passive diffusion samplers to collect volatile organic compound (VOC) samples from observation wells at Davis Global Communications in Sacramento, California. Passive diffusion samplers have been successfully used to obtain representative water samples for VOC concentrations without the need to purge at a different site (Vroblesky and Hyde, 1997). Thus, the diffusion samplers offer a potential savings in sampling time and expense relative to the purge-and-sample approach. The purpose of this report is to present results comparing VOC concentrations in water obtained from diffusion samplers to concentrations in water obtained by using the purge-and-sample approach.

Site Description

Davis Global Communications (fig. 1) is an annex of McClellan Air Force Base (AFB) in Sacramento, Calif., approximately 4 miles south of the city of Davis. The site, which has been in operation since the 1950's, is used for military communications. In 1985, three underground storage tanks were found to be leaking diesel fuel. During the course of the field investigation for hydrocarbon contamination, the presence of chlorinated solvents also was detected in the ground water. The source of the chlorinated solvents is unknown.

The geology of the site consists of fine-grained flood plain or overbank deposits mixed with lesser amounts of sandy stream deposits containing discontinuous gravels and sands. Driller's logs of the wells indicate that some of the silty and silty clay layers are fractured (CH2M HILL, 1994), possibly providing conduits for the vertical movement of ground water. Hydraulic testing to determine aquifer properties has not been done; however, most of the wells sampled for this investigation yielded little water and recovered slowly, strongly suggesting that the sampled horizons have a relatively low hydraulic conductivity.

Ground-water levels and flow directions at the site vary seasonally because of the influence of nearby agricultural wells, which typically are from 200- to 500-feet (ft) deep. Ground-water levels are

approximately 40 ft below mean sea level (msl) during the growing season when the agricultural wells are actively pumped; water levels rise about 40 ft during the winter when the wells are not used (CH2M HILL, 1994). In addition, onsite contaminant-removal wells are in operation most of the time, resulting in localized flow toward these pumped wells.

Methods

Fourteen wells at the site were instrumented with diffusion samplers during December 15–18, 1998. Of these wells, eight were equipped with screen lengths of 20 ft and six had screen lengths of 10 ft (table 1). In the wells having 10-ft-long screens, a single diffusion sampler was centered vertically in the screened interval. In wells having 20-ft-long screens, 9 or 10 diffusion samplers were placed end-to-end along a vertical profile within the screened interval.

Prior to installing the diffusion samplers, six of the 20-ft-long screened intervals were investigated by using borehole geophysical and flowmeter logging techniques. Logging was performed during the same week that the samplers were deployed (December 15–18, 1998). The depths of the wells and water levels were measured prior to installing the logging equipment. The wells then were logged using an electromagnetic induction and gamma tool and a fluid resistivity and temperature tool. An electromagnetic flowmeter was used under static and pumped conditions to measure vertical flow rates at discrete locations within the screened interval. At each tested well, a submersible pump was placed directly above the screened interval; fluid-resistivity and temperature logs were run, and vertical-flow measurements were made while the well was pumped.

The diffusion samplers were allowed to equilibrate within the screened interval for approximately 25 to 30 days. The samplers were recovered by removing them from the well, cutting open the polyethylene, and gently pouring the contents into 40-milliliter (mL) glass sampling vials with Teflon caps.

Immediately following diffusion-sampler recovery, the wells were purged and sampled in accordance with the ongoing ground-water protocol at the site. Well purging consisted of removing three casing volumes of water using a Grundfos submersible positive-displacement pump. Water samples then were collected from the well by using a bailer.

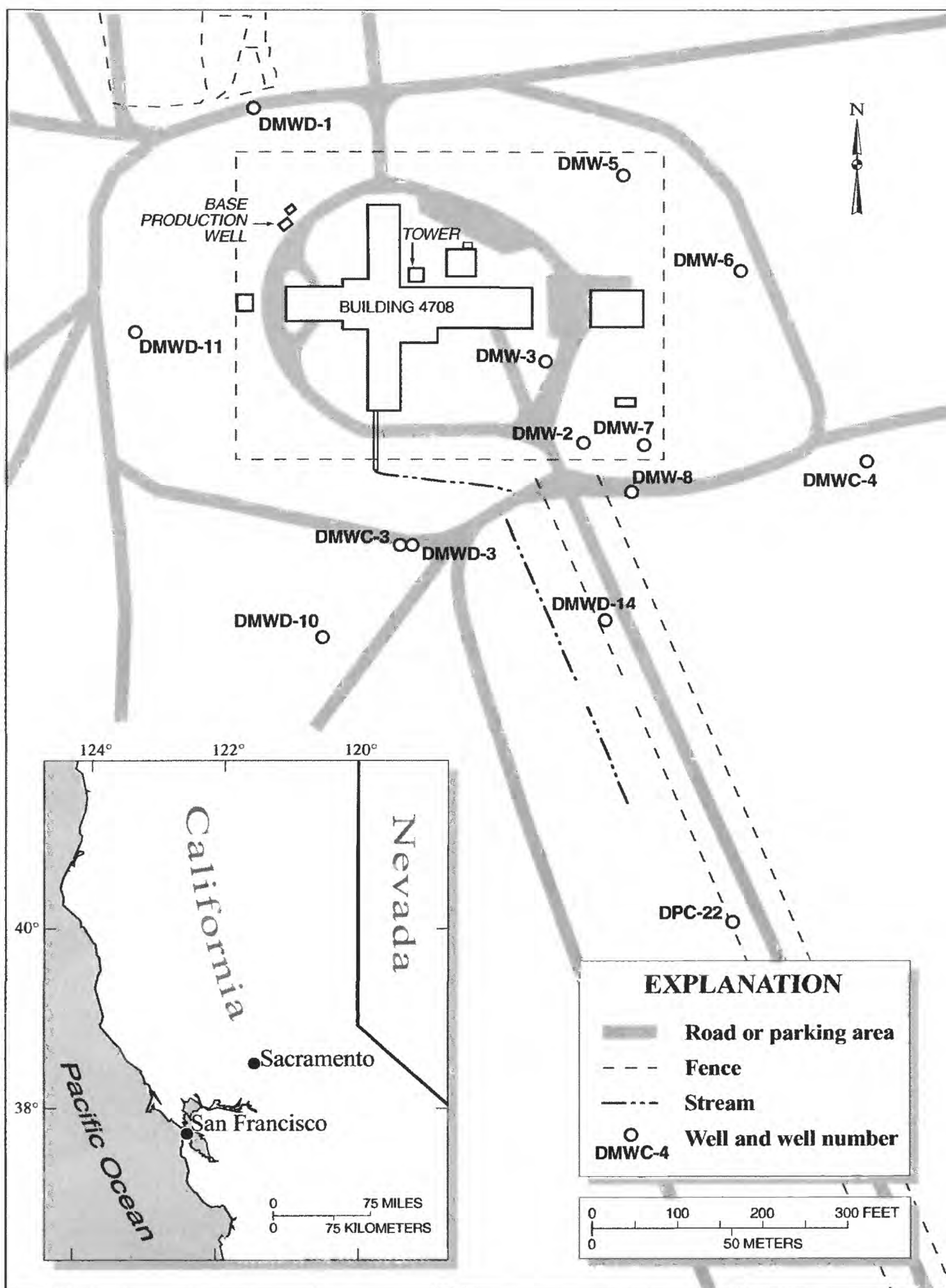


Figure 1. Locations of wells at Davis Global Communications, Sacramento, Calif., January 1999 (modified from Radian International, 1999).

Table 1. Construction data and number of installed diffusion samplers for tested wells at Davis Global Communications, Sacramento, Calif.

[ft, feet; msl, mean sea level; bls, below land surface; in., inches]

Well	Top of casing elevation (ft msl)	Ground-surface elevation (ft msl)	Screened Interval (ft bls)	Casing diameter (in.)	Screen length (ft)	Total well depth (ft)	Number of diffusion samplers recovered
DMW-2	26.88	28.1	61–81	4	20	84	9
DMW-3	28.82	29.86	61–81	4	20	83.5	9
DMW-5	26.47	26.88	59–79	4	20	84	9
DMW-6	25.94	25.26	59–79	4	20	80.5	10
DMW-7	27.02	27.5	61–81	4	20	84	10
DMW-8	26.88	26.5	60–80	4	20	84	10
DMWD-3	28.68	27.06	155–175	4	20	250	10
DMWD-14	28.57	26.33	149–169	5	20	178	10
DMWC-3	29.16	26.94	93–103	4	10	108	1
DMWC-4	27.57	24.64	95–105	4	10	106	1
DMWD-10	29.22	27.02	162–172	5	10	173	1
DMWD-1	31.9	30.2	152–162	4	10	240	1
DMWD-11	29.29	27.42	171–181	5	10	181.5	1
DPC-22	28.11	Not measured	91–101	4	10	104	1

All samples were stored on ice and shipped to the same laboratory for analysis by using the U.S. Environmental Protection Agency (USEPA) Method 8260b. For 20-ft-long screened wells containing multiple diffusion samplers, only one of the diffusion samplers was sent to a USEPA-certified laboratory for analysis by USEPA Method 8260b. To select the representative sample for each 20-ft-long screened well, the sampling vials for each diffusion sampler were stored on ice and sent by overnight mail to the USGS in South Carolina.

Upon arrival at the USGS, an extra vial from each diffusion sampler was analyzed by head-space gas chromatography using a Photovac 10S Plus gas chromatograph. The remaining vials for the diffusion sampler containing the highest VOC concentrations at each well were stored on ice and sent by overnight mail

to the same USEPA-certified laboratory that analyzed the water collected by using the purge-and-sample method. The samples were analyzed by USEPA Method 8260b. The laboratory analytical results for the diffusion samplers were used as a standard for the concentrations obtained using head-space analysis in the respective well. Thus, in the graphs showing vertical concentration differences, the concentrations at one depth (designated in table 2) at each well represents the USEPA Method 8260b analysis of diffusion-sampler water. The remaining samples at that well represent USGS head-space gas chromatography analyses adjusted relative to the head-space analysis of the sampler analyzed by USEPA Method 8260b. Only the samples analyzed by USEPA Method 8260b were used directly to compare the two sampling methods in this investigation.

Table 2. Analytical results from ground-water samples obtained by using diffusion samplers and using the purge-and-sample method, Davis Global Communications, Calif., January 1999

[ft, feet; TCE, trichloroethene; PCE, tetrachloroethene; cDCE, *cis*-1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; µg/L, micrograms per liter; Dif, water-filled diffusion sampler; P&S, purge-and-sample; J, analyte concentration considered an estimated value because one or more quality control specifications were not met; < less than]

Location	Sample type	Date sampled	Sample depth (ft)	TCE (µg/L)	PCE (µg/L)	cDCE (µg/L)	1,1-DCE (µg/L)
20-foot-long well screens							
DMW-2	Dif	1/13/99	67–68	17.3	1.7	4.5	0.8 J
	P&S	1/14/99	61–81	26.0 J	3.5	5.4	.7 J
DMW-3	DIF	1/13/99	71–72	10.7	47.2	.3 J	3.6
	P&S	1/14/99	61–81	10.7	61.7	.3 J	2.5
DMW-5	DIF	1/13/99	69–70	19.8	145.0	.3 J	10.5
	P&S	1/14/99	59–79	23.8	211.0	.2 J	8.8
DMW-6	DIF	1/14/99	61–62	19.7	35.3	1.7	2.9
	P&S	1/14/99	59–79	25.1	65.4	1.9	2.6
DMW-7	DIF	1/13/99	69–70	30.9	2.4	8.5	1.3
	P&S	1/13/99	61–81	31.6	2.3	8.5	1.1 J
DMW-8	DIF	1/13/99	68–69	3.1	<.6	1.0 J	.3 J
	P&S	1/13/99	60–80	2.8	1.0	.7 J	.1 J
DMWD-3	DIF	1/13/99	161–162	3.2	4.0	<.1	.6 J
	P&S	1/14/99	155–175	3.3	4.0	<.1	.4 J
DMWD-14	DIF	1/14/99	153–154	2.5	1.6	.1 J	.4 J
	P&S	1/15/99	149–169	2.3	1.5	.0	.2 J
10-foot-long well screens							
DMWC-3	DIF	1/12/99	97–98	3.3	3.8	0.1 J	0.2 J
	P&S	1/12/99	93–103	4.6	5.8	.2 J	.3 J
DMWC-4	DIF	1/11/99	99–100	<.1	<.1	<.1	<.1
	P&S	1/11/99	95–105	.2 J	<.1	<.1	<.1
DMWD-10	DIF	1/12/99	166–167	5.0	2.7	<.1	.7 J
	P&S	1/12/99	162–172	4.6	2.8	<.1	.4 J
DMWD-1	DIF	1/11/99	156–157	<.1	<.1	<.1	<.1
	P&S	1/11/99	152–162	<.1	<.1	<.1	<.1
DMWD-11	DIF	1/11/99	175–176	<.1	<.1	<.1	<.1
	P&S	1/11/99	171–181	<.1	<.1	<.1	<.1
DPC-22	DIF	1/12/99	95–96	<.1	<.1	<.1	<.1
	P&S	1/13/99	91–101	<.1	<.1	<.1	<.1

RESULTS AND DISCUSSION

In most wells, the concentrations obtained by using downhole diffusion samplers closely matched those obtained using the purge-and-sample method (fig. 2). In 7 of the 14 wells (DMW-7, DMW-8, DMWC-3, DMWC-4, DMWD-10, DMWD-14, and DMWD-3), where VOC concentrations ranged from near the detection limit (0.1 µg/L) to 31.6 µg/L, the concentrations differed by only 2 µg/L or less between the two methods (table 2). For most regulatory

purposes, this difference is negligible. Of these wells, four had 20-ft-long well screens (wells DMW-7, DMW-8, DMWD-3, and DMWD-14), and the remaining had 10-ft-long well screens. No VOCs were detected in ground water collected from wells DMWD-1, DMWD-11, and DPC-22. The lack of VOC detection by either method in these wells indicates that the materials used in constructing the diffusion samplers did not contribute VOCs to the analytical results.

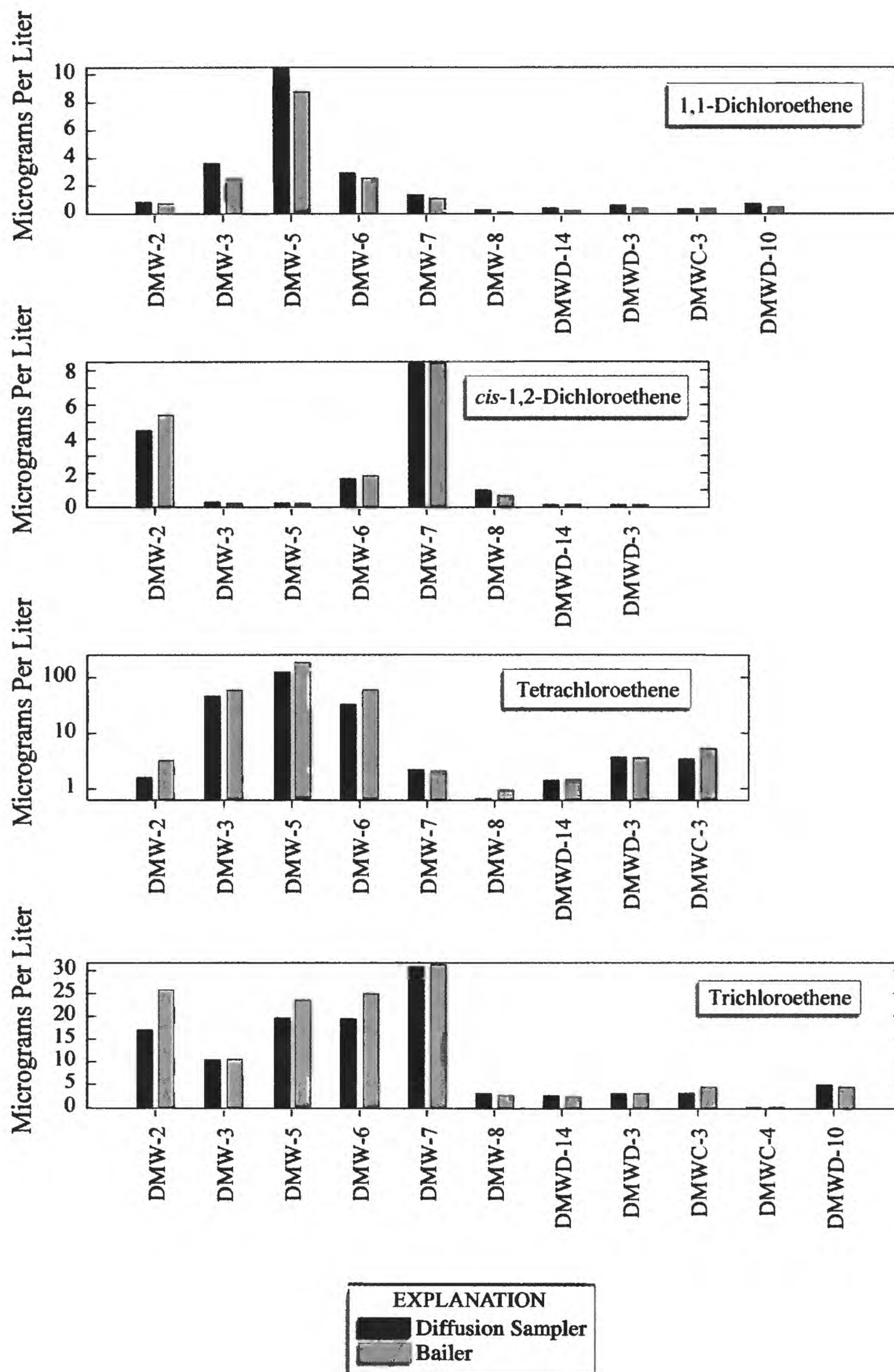


Figure 2. Comparison of volatile organic compound concentrations in ground water obtained from diffusion samplers and from the purge-and-sample method at Davis Global Communications, Sacramento, Calif., January 1999.

Analyses of ground water from the remaining four wells equipped with 20-ft-long screens (DMW-5, DMW-2, DMW-3, and DMW-6) indicated various degrees of comparability between the two sampling methods. In all four of these wells, where concentrations of individual VOCs were approximately 10 µg/L or less, comparisons between the two sampling methods showed differences of less than 2 µg/L. Although some of the comparisons in this low range of concentration values constitute a high percent difference, the actual difference in micrograms per liter is negligible for most regulatory purposes. For concentrations of trichloroethene (TCE) ranging from about 10 to 26 µg/L, the concentration differences also were small (ranging from about 4 to 6 µg/L in three of the wells and 8.7 µg/L in the fourth well, DMW-2). Greater differences were observed between the two methods for tetrachloroethene (PCE) concentrations above 30 µg/L. In wells DMW-3, DMW-5, and DMW-6, the differences were 23 percent (14.5 µg/L), 31 percent (66 µg/L), and 46 percent (30 µg/L), respectively (table 2).

Potential explanations for the differences between concentrations include insufficient well-equilibration time, water-level variations due to the intermittent pumping of onsite contaminant-removal wells, the possibility that the two methods sampled different water, and experimental errors inherent to each method. The hypothesis that insufficient well-equilibration time had elapsed following well testing and sampler installation seems unlikely because two of the three wells where the poorest matches were observed had not been subjected to borehole logging or pumping for electromagnetic flowmeter testing. It is possible, however, that intermittent pumping at nearby contaminant-removal wells during the equilibration period produced changes in hydraulic conditions at the screened intervals. Although contaminant-recovery wells typically operate continuously at the site, none were in operation on the day that geophysical logging and flowmeter testing were performed in well DMW-5 (December 15, 1998); some removal wells were in operation during part of the next day when well DMW-7 was tested; no removal wells were operating on the day that wells DMW-2 and DMW-8 were tested (December 17, 1998); and four removal wells were operating on the day that wells DMWD-3 and DMWD-14 were tested (December 18, 1998). Ground-water flow directions may vary substantially depending on when the contaminant-removal wells are in

operation. Because records of the times that the wells are on and off typically are not kept, it is possible that changes in the operation of contaminant-removal wells during the diffusion-sampler equilibration period resulted in hydraulic conditions that differed from the conditions at the time of sampling. This potentially could result in a discrepancy between the two sampling methods. Alternate explanations include the possibility of unrecorded changes in nearby contaminant-extraction well operation during the equilibration period.

Although insufficient equilibration time and changes in the operation of contaminant-removal wells potentially explain the discrepancies observed between sampling methods at some wells, water chemistry, geophysical logs, borehole flowmeter tests, and historical soil-gas data suggest a more probable scenario. Water chemistry from the diffusion samplers represents water derived from the screened interval, whereas the purge-and-sample method may have induced the infiltration of water from shallower zones above the well screen, thus resulting in the collection of mixed waters. A case in point is well DMW-5, where concentrations of TCE and PCE were higher in samples collected by purging the well than in samples collected by the diffusion samplers.

Analysis of water samples from the nine diffusion samplers positioned in the screened interval of well DMW-5 indicated that under static conditions of equilibration, the highest concentrations of TCE (19.8 µg/L) and PCE (145.0 µg/L) (table 2) in the diffusion samplers were from the center of the screened interval, which was the approximate center of an adjacent sand layer (fig. 3A, B, C). The data suggested that this sand layer was the predominant source of TCE and PCE to the well. However, TCE and PCE concentrations differed between the two sampling methods. TCE and PCE concentrations in water obtained by using the purge-and-sample method were 23.8 µg/L and 211.0 µg/L, respectively (table 2).

A probable explanation for the difference can be postulated by examining supportive data. Analysis of drilling logs and natural gamma logs indicated that the lower 13 ft of the screened interval of well DMW-5 was open to a sand layer extending from a depth of 67 to 80 ft below land surface (fig. 3C, D). Overlying the sand was a fractured silty clay with slickensided surfaces that extended from a depth of 38.5 to 61.5 ft below land surface; sand and gravel composed the remainder of the shallow subsurface. Flowmeter tests

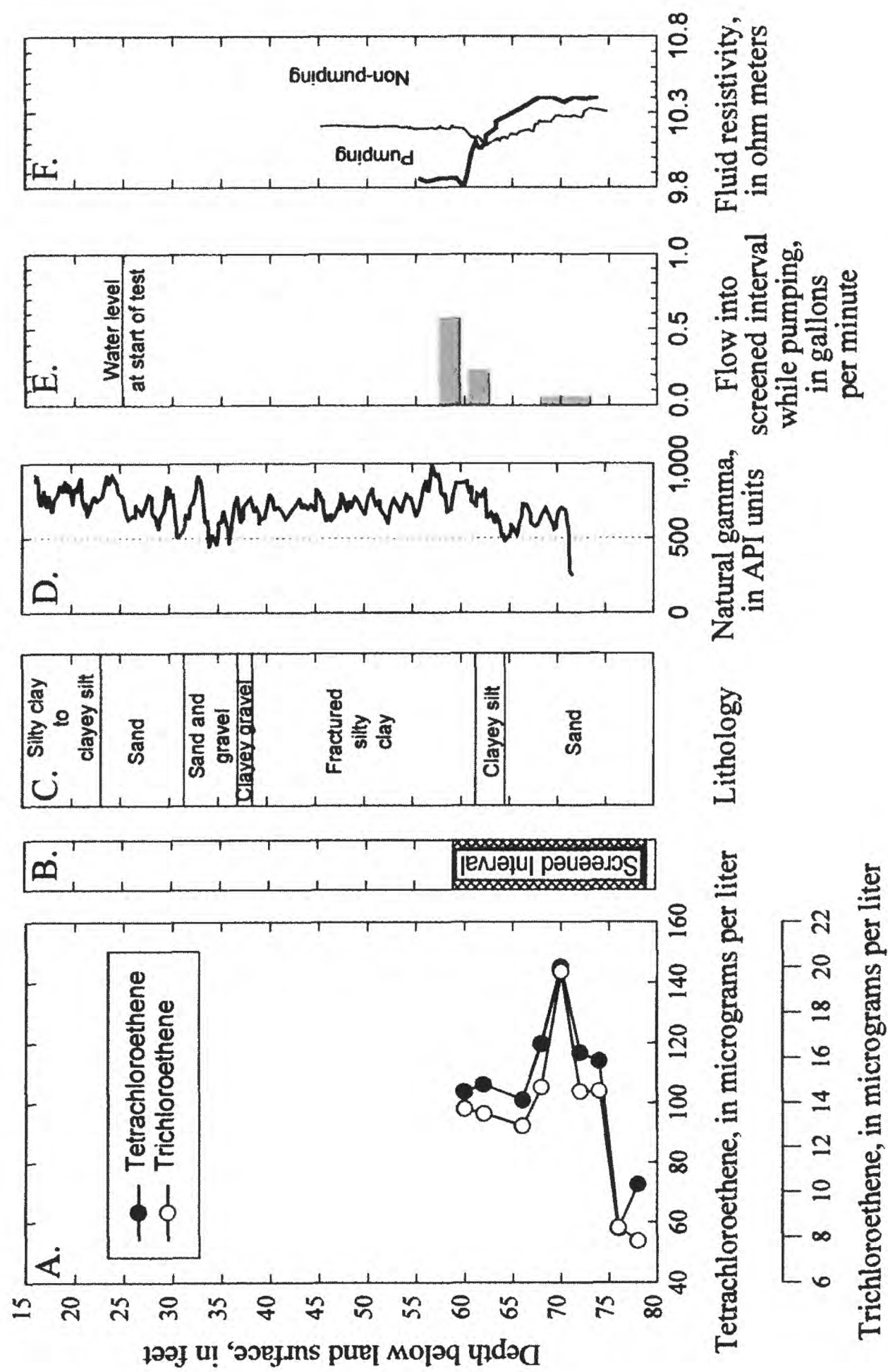


Figure 3. (A) Tetrachloroethene and trichloroethene concentrations in diffusion samplers, (B) screened interval, (C) lithology, (D) natural gamma, (E) borehole flowmeter, and (F) fluid-resistivity data at well DMW-5, Davis Global Communications, Sacramento, Calif., January 1999.

and geophysical logs run in the well indicated that when well DMW-5 was pumped, most of the water entered the well bore near the top of the screened interval at a depth of about 58 to 62 ft, with a smaller volume entering from the adjacent sand layer (fig. 3E). Under static conditions, however, the sand layer contributed the largest percentage of water moving into the screened interval (fig. 3E). Fluid resistivity logs provided further evidence that most water entered near the top of the well screen; during pumping, fluid resistivity increased sharply at the top of the screened interval (fig. 3F). The relatively high percentage of flow entering the well at the top of the screened interval during pumping suggests that purging the well may have induced the downward movement of water along the annular space of the well bore or along fractures within the silty clay material overlying the screened interval.

Results of a soil-gas survey conducted in 1994 showed that substantial amounts of TCE and PCE were

present at depths of 40 to 60 ft in the subsurface materials adjacent to well DMW-5 (CH2M HILL, 1995, site SGB-4). The presence of TCE and PCE in these shallow subsurface materials combined with the fact that pumping well DMW-5 created substantial drawdown, strongly suggests that pumping well DMW-5 resulted in the vertical downward movement of water into the screened interval and, ultimately, the mixing of water from shallower zones with water from the screened interval. Thus, the diffusion samplers probably provided a more representative sample of water from the screened interval.

Of the four wells showing VOC concentration differences that were greater than 2 $\mu\text{g/L}$ between the two sampling methodologies, borehole flowmeter data were only available for wells DMW-5 and DMW-2. For well DMW-2, there were no substantial vertical variations in TCE concentrations within the well screen (fig. 4A, B). The borehole flowmeter data showed that when the well was pumped, approximately the same

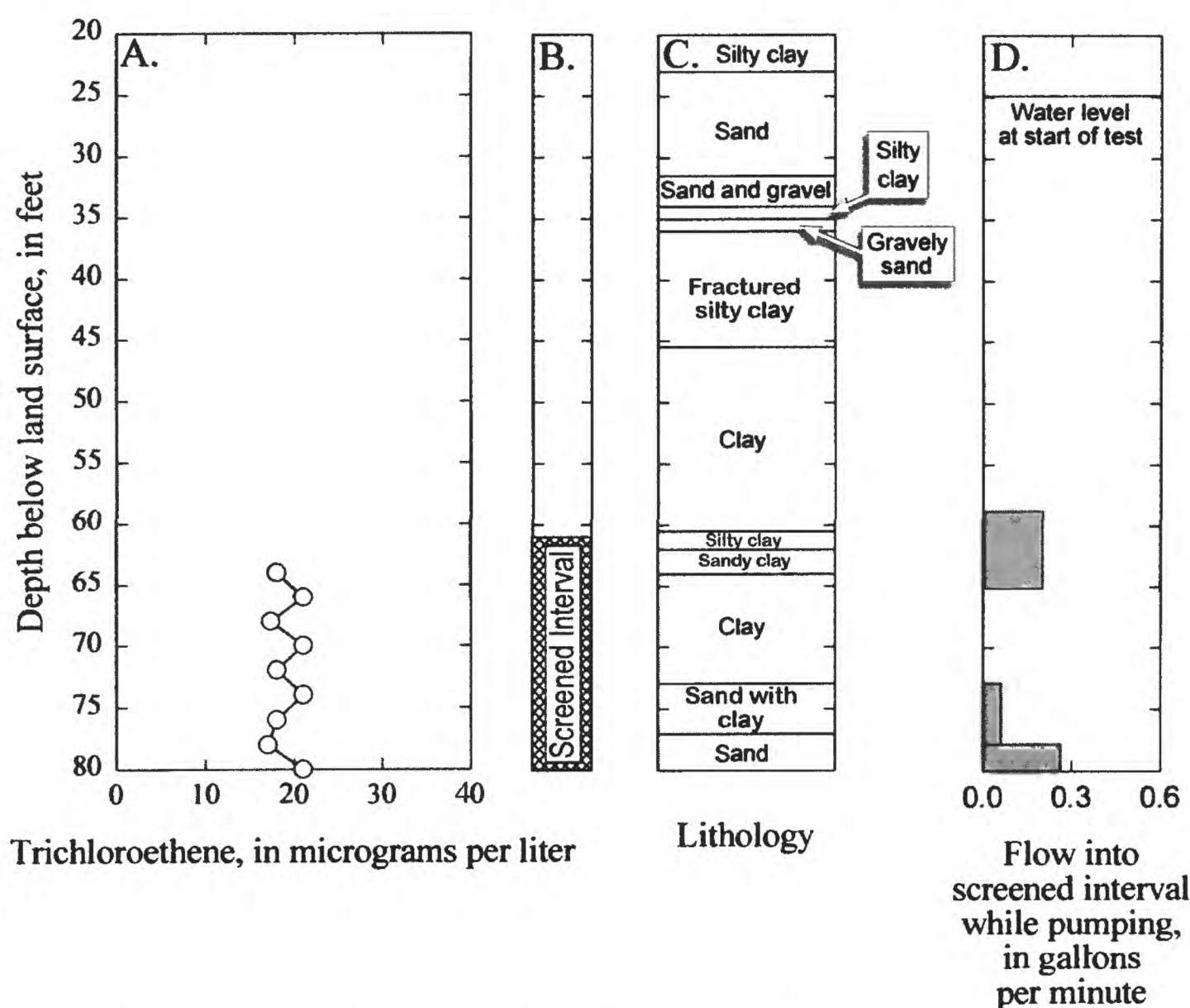


Figure 4. (A) Trichloroethene concentrations in diffusion samplers, (B) screened interval, (C) lithology, and (D) borehole flowmeter data at well DMW-2, Davis Global Communications, Sacramento, Calif., January 1999.

amount of water was obtained from the sand near the bottom of the screened interval as was obtained from the silty clay at the top of the screened interval (fig. 4C, D). As with well DMW-5, the apparent inflow of water from silty clay at the top of the well screen suggests that water may have moved downward from shallower zones to the screened interval along the annular space of the well bore or through fractures in the overlying material. Although no soil-gas profiles were collected at well DMW-2, soil-gas data from approximately 100 ft away showed the presence of TCE and PCE at depths of 40 and 60 ft (CH2M HILL, 1995, site SGB-8). Thus, as in well DMW-5, it is possible that the two methods sampled water from different sources at well DMW-2.

Wells DMW-3 and DMW-6 also showed lower PCE concentrations in the diffusion samplers than in water obtained by the purge-and-sample method

(table 2). No borehole flowmeter data were available for these wells, but the screened intervals for these wells were below fractured clay. The lithologic similarity between the sediment overlying the well screens in these wells with the sediment overlying the screens in wells DMW-5 and DMW-2 again implies the possibility that flow through fractures or the downward leakage of water from shallower zones during pumping influenced the water-quality samples from wells DMW-3 and DMW-6 (figs. 5, 6). At well DMW-6, when the well was not being pumped, the diffusion-sampler data imply that there was a concentration gradient in the screened interval with the highest concentrations occurring in a sand and fractured silt layer near the top of the screened interval.

The combined approach of using diffusion samplers and a borehole flowmeter also provided

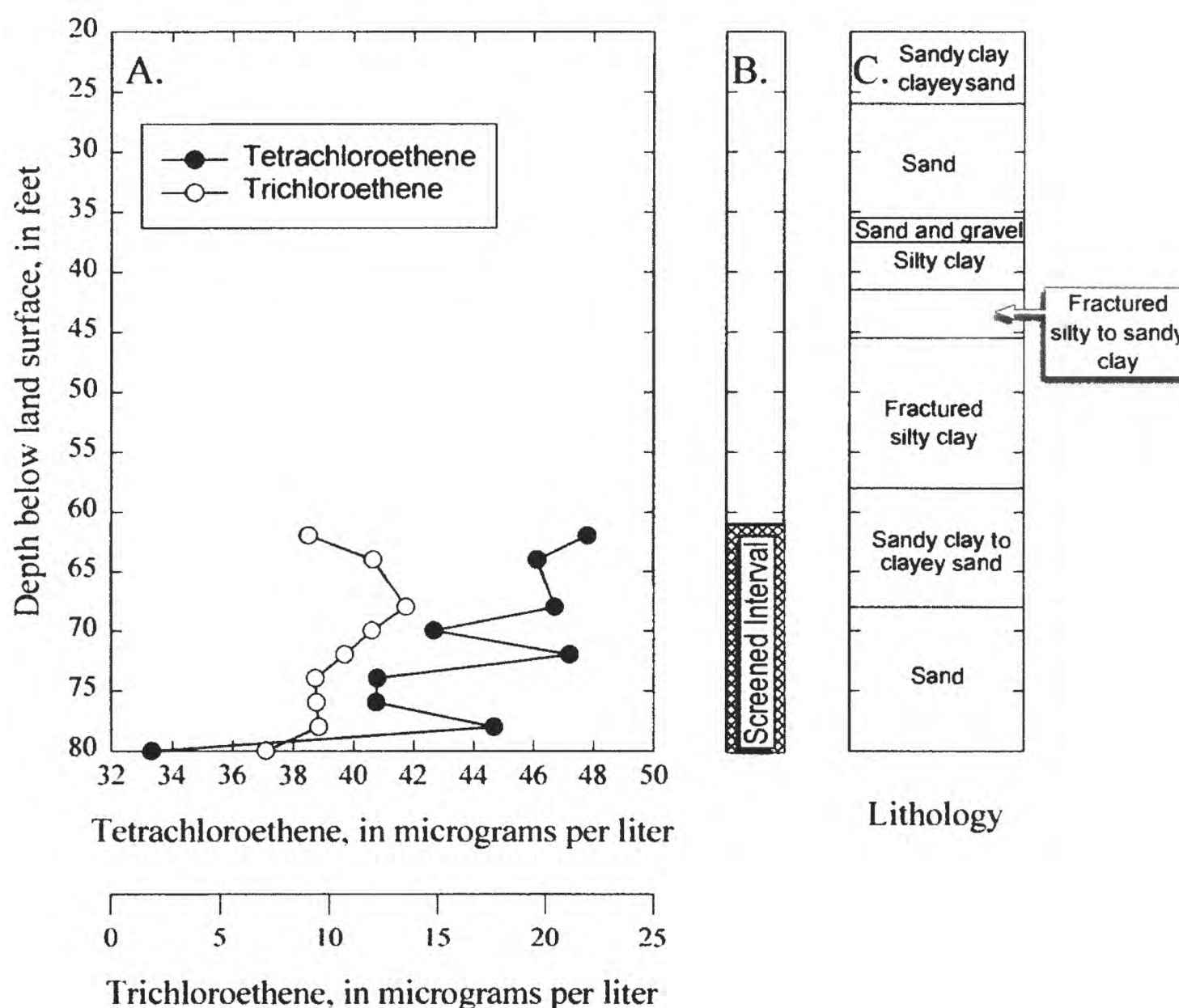


Figure 5. (A) Tetrachloroethene and trichloroethene concentrations in diffusion samplers, (B) screened interval, and (C) lithology at well DMW-3, Davis Global Communications, Sacramento, Calif., January 1999.

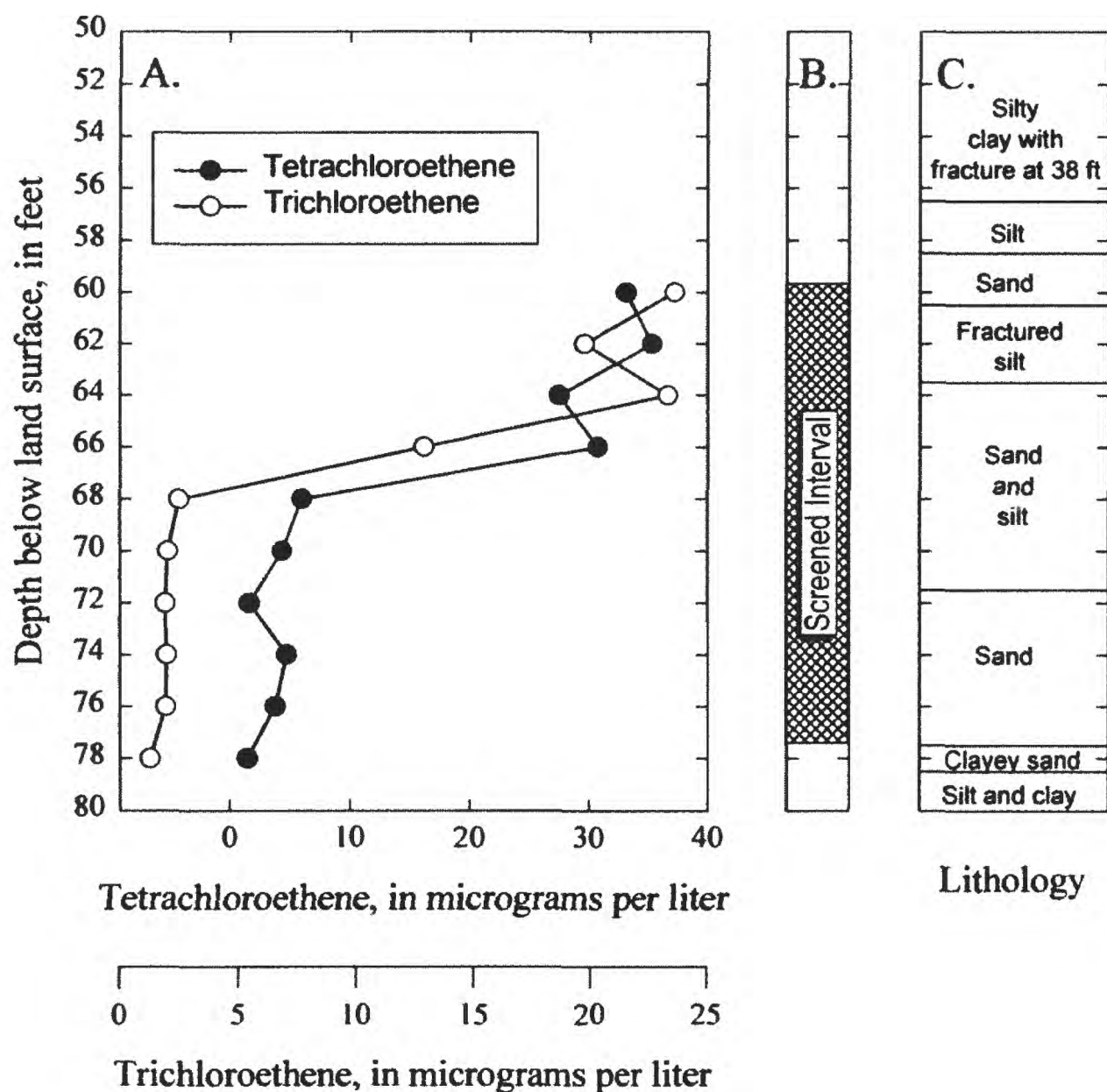


Figure 6. (A) Tetrachloroethene and trichloroethene concentrations in diffusion samplers, (B) screened interval, and (C) lithology at well DMW-6, Davis Global Communications, Sacramento, Calif., January 1999.

information on the source of water being removed from the aquifer by contaminant-removal wells in operation at the site. Water from well DMWD-3 contained low concentrations (less than 5 µg/L) of PCE and TCE in the screened interval, which was installed in a zone of sand and gravel (fig. 7A, B, C). Flowmeter tests conducted within the well, however, showed that water flowed into the well near the bottom of the screened interval and exited the well through the upper half of the screen, even when the well was not being pumped (fig. 7D). When a pump was placed in the well and water was pumped out at 0.96 gallon per minute, water still exited the well through the upper part of the screened interval. A probable explanation is that contaminant-removal well DEWC-3, which was 32.4 ft

south of well DMWD-3, pumped water from a depth of 93–108 ft below land surface and may have caused the flowthrough by capturing water from the horizon screened by well DMWD-3. Because the water in well DMWD-3 contained less than 5 µg/L of the target compounds, the data suggest that some of the water captured by contaminant-removal well DEWC-3 was relatively uncontaminated. Thus, a combination of diffusion samplers and borehole flowmeter tests may be useful in optimizing the contaminant-capture radius of contaminant-removal wells. Overall, the data suggest that the use of diffusion samplers provides an alternative sampling method to the purge-and-sample approach used for ground-water investigations.

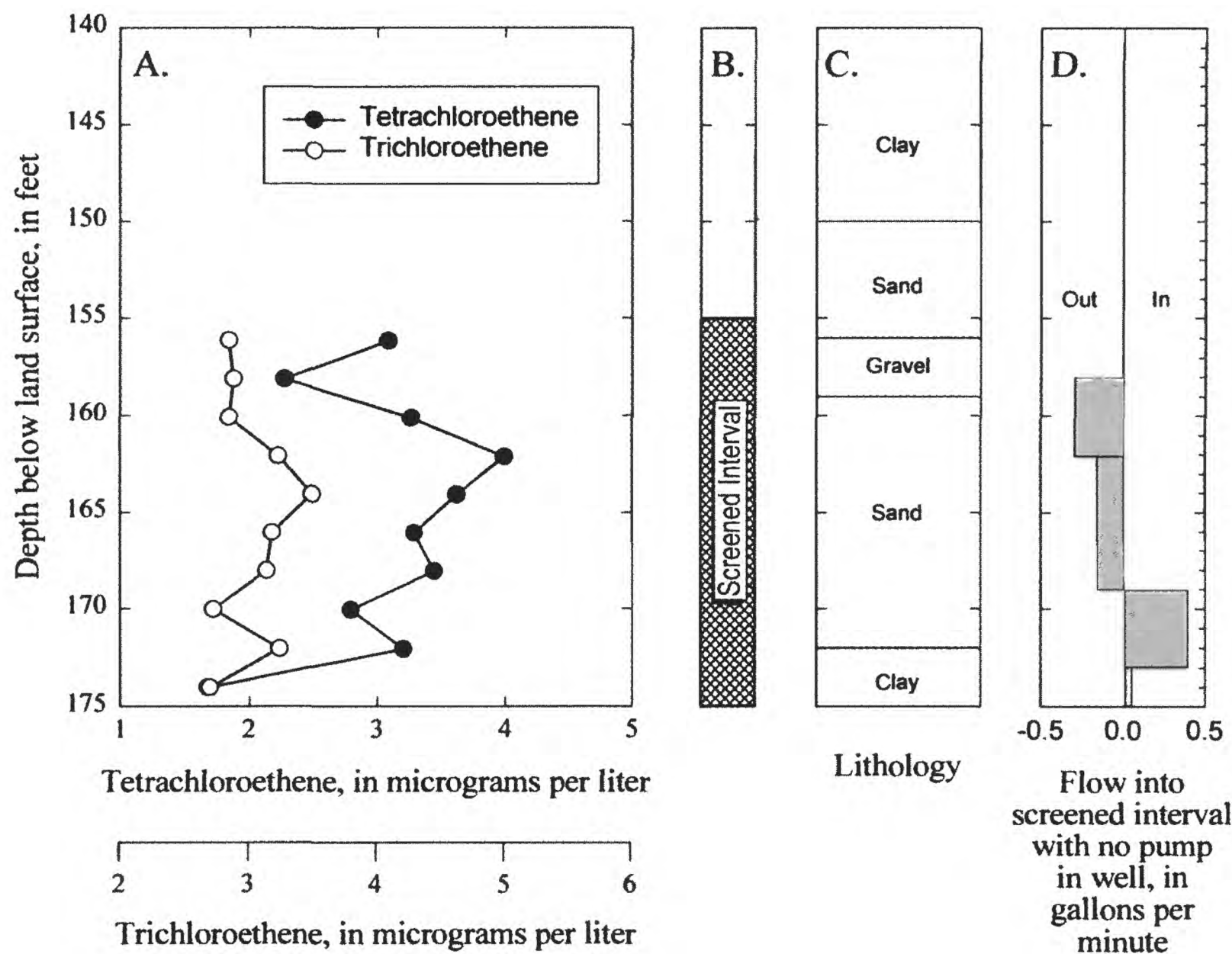


Figure 7. (A) Tetrachloroethene and trichloroethene concentrations in diffusion samplers, (B) screened interval, (C) lithology, and (D) borehole flowmeter data at well DMWD-3, Davis Global Communications, Sacramento, Calif., January 1999.

SUMMARY

Fourteen wells were instrumented with diffusion samplers at Davis Global Communications, Sacramento, Calif., as a test to determine whether the samplers could be used to obtain representative volatile organic compound (VOC) concentrations at the site. Of these wells, eight had screen lengths of 20 ft and two had screen lengths of 10 ft. Single diffusion samplers were placed in the 10-ft-long well screens, and multiple diffusion samplers were placed in the longer screens. The samplers were recovered after a minimum of 14 days, and the wells were then sampled by using the purge-and-sample method.

In most wells, the concentrations obtained by using downhole diffusion samplers closely matched those obtained by using the purge-and-sample method.

In seven wells, the concentrations differed between the two methods by only 2 µg/L or less. For most regulatory purposes, this difference is negligible. In three of the remaining wells, VOCs were not detected in water obtained by using either method.

In the remaining four wells, the degree of comparability between the two sampling methods varied. In these wells, differences between the methods were less than 2 µg/L in the 0.2- to 8.5-µg/L concentration range and from 1.2 to 8.7 µg/L in the 10- to 26-µg/L concentration range. In wells DMW-3, DMW-5, and DMW-6, greater differences (23 percent or 14.5 µg/L, 31 percent or 66 µg/L, and 46 percent or 30 µg/L, respectively) between the two methods were observed for PCE concentrations which ranged between 30 and 211 µg/L.

Potential explanations for the differences include insufficient equilibration time for the diffusion samplers, hydraulic changes during the equilibration period due to possible unrecorded changes in the pumping of onsite contaminant-removal wells, and the possibility that the two methods sampled water from differing sources at some wells. Data collected during this investigation, combined with soil-gas data collected during a previous investigation, implied that at some wells, the two methods sampled water from differing horizons.

At wells DMW-2 and DMW-5, the diffusion samplers seemed to be sampling water representative of the horizon adjacent to the screened interval. Lithologic data, borehole fluid resistivity and natural gamma logs, borehole flowmeter results, water-level measurements, and historical soil-gas data suggest, however, that water obtained while using the purge-and-sampling method at wells DMW-2 and DMW-5 was derived partly from the downward movement of water along the annular space of the well bore or through fractures in the silty clay. Although borehole flowmeter data were not available for the remaining two wells (DMW-3 and DMW-6), the lithologic similarity between the sediments at these wells and the sediments at wells DMW-2 and DMW-5 implied that water could move downward from shallower zones into the well screen while using the purge-and-sample method. Thus, as in this case, the purge-and-sample approach may have overestimated concentrations in the screened interval. Overall, the data suggest that the use of diffusion samplers provided an alternative sampling

method to the purge-and-sample approach used for ground-water investigations.

The data also showed that vertical variations in VOC concentrations can exist within the screened intervals. In addition, the combined use of borehole flowmeter tests and diffusion samplers showed that contaminant-removal well DEWC-3 seemed to be capturing water from the horizon screened by well DMWD-3, indicating that at least some of the water captured by contaminant-removal well DMWC-3 contains VOC concentrations less than 5 µg/L. These data may be useful in optimizing the radius of capture of contaminated ground water by the contaminant-removal wells.

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