Preliminary Assessment of Using Tree-Tissue Analysis and Passive Diffusion Samplers to Evaluate Trichloroethene Contamination of Ground Water at Site SS-34N, McChord Air Force Base, Washington, 2001

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 02-4274

Prepared in cooperation with the
UNITED STATES AIR FORCE
McCHORD AIR FORCE BASE
INSTALLATION RESTORATION PROGRAM

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Tacoma, Washington
2002

U.S. DEPARTMENT OF THE INTERIOR

GALE A. NORTON, *Secretary*

U.S. GEOLOGICAL SURVEY

Charles G. Groat, *Director*

For additional information write to:

Director, Washington Water Science Center
U.S. Geological Survey
1201 Pacific Avenue – Suite 600
Tacoma, Washington 98402
http://wa.water.usgs.gov

Copies of this report can be purchased from:

U.S. Geological Survey
Information Services
Building 810
Box 25286, Federal Center
Denver, CO 80225-0286

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CONVERSION FACTORS

Multiply	By	To obtain
inch (in)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter

Temperature in degrees Celsius (^{o}C) may be converted to degrees Fahrenheit (^{o}F) as follows:

$$^{o}F=1.8\ ^{o}C+32.$$

Information is referenced to the National Geodetic Vertical Datum NGVD 1929.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD27).

Altitudes: In this report, “altitude” is measured in feet above sea level.

Preliminary Assessment of Using Tree-Tissue Analysis and Passive-Diffusion Samplers to Evaluate Trichloroethene Contamination of Ground Water at Site SS-34N, McChord Air Force Base, Washington, 2001

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ABSTRACT

Two low-cost innovative sampling procedures for characterizing trichloroethene (TCE) contamination in ground water were evaluated for use at McChord Air Force Base (AFB) by the U.S. Geological Survey, in cooperation with the U.S. Air Force McChord Air Force Base Installation Restoration Program, in 2001. Previous attempts to characterize the source of ground-water contamination in the heterogeneous glacial outwash aquifer at McChord site SS-34N using soil-gas surveys, direct-push exploration, and more than a dozen ground-water monitoring wells have had limited success. The procedures assessed in this study involved analysis of tree-tissue samples to map underlying ground-water contamination and deploying passive-diffusion samplers to measure TCE concentrations in existing monitoring wells. These procedures have been used successfully at other U.S. Department of Defense sites and have resulted in cost avoidance and accelerated site characterization.

Despite the presence of TCE in ground water at site SS-34N, TCE was not detected in any of the 20 trees sampled at the site during either early spring or late summer sampling. The reason the tree tissue procedure was not successful at the McChord AFB site SS-34N may have been due to an inability of tree roots to extract moisture from a water table 30 feet below the land surface, or that concentrations of TCE in ground water were not large enough to be detectable in the tree tissue at the sampling point.

Passive-diffusion samplers were placed near the top, middle, and bottom of screened intervals in three monitoring wells and TCE was observed in all samplers. Concentrations of TCE from the passive-diffusion samplers were generally similar to concentrations found in samples collected in the same wells using conventional pumping methods. In contrast to conventional pumping methods, the collection of ground-water samples using the passive-diffusion samples did not generate waste purge water that would require hazardous-waste disposal. In addition, the results from the passive-diffusion samplers may show that TCE concentrations are stratified across some screened intervals. The overall results of the limited test of passive-diffusion samplers at site SS-34N were similar to more detailed tests conducted at other contaminated sites across the country and indicate that further evaluation of the use of passive-diffusion samplers at McChord site SS-34N is warranted.

INTRODUCTION

McChord Air Force Base (AFB) occupies approximately 4,600 acres of land located about 7 mi south of downtown Tacoma in the Puget Sound region of western Washington (fig. 1). The facility, initially a county airfield, was deeded by the county to the U.S. Army in 1938 and subsequently renamed McChord Air Base in 1948. At the time of this study the base was operated by the 62nd Airlift Wing of the Air Mobility Command of the U.S. Air Force providing airlift capabilities for troops and equipment throughout the world.

Military industrial operations that produce a variety of hazardous waste have occurred throughout the base's existence. Prior to 1982 military hazardous waste disposal practices included the use of dry wells, disposal in leach pits, burn trenches and fire training areas and have resulted in areas of contaminated soils and ground water.

Clean up of these legacy contamination sites is being addressed through the Department of Defense's Installation Restoration Program. At McChord AFB, 65 sites were identified where historical disposal of hazardous waste had occurred. Extensive remediation efforts have been undertaken at McChord AFB to reduce the extent of contamination. A public health assessment conducted in 1995 concluded that under existing conditions of the assessment, none of the 65 identified hazardous waste disposal sites was an apparent public health issue (U.S. Department of Health and Human Services, 1995).

Background

Trichloroethene (TCE) was detected in ground water beneath McChord AFB during a 1983 investigation of a JP-4 bulk fuel storage area. In 1994, TCE was detected at concentrations above the U.S. Environmental Protection Agency (USEPA) maximum contaminant level (MCL) of 5 µg/L (micrograms per liter) in two ground-water monitoring wells at the site, CW-25 and CW-26 (fig. 2). Soil-gas surveys were conducted at site SS-34N in May 1995 and again in October 2000 to determine the source and areal extent of the TCE contamination. Although TCE was detected at some locations in both surveys, areas of TCE contamination could not be defined from the data. Additional monitoring wells were installed in October 1999 to aid in defining the source and extent of ground-water contamination along the western boundary of the base (CW-38, CW-39, CW-40, and CW-41) and upgradient of areas where TCE was previously detected (CW-37). Well CW-37 was intended to represent background conditions in subsequent sampling, but TCE was detected in all of these wells including CW-37. In March 2000, five additional shallow monitoring wells (CW-45, CW-46, CW-47, CW-48, and CW-49) were installed in a residential area to the west of the base (fig. 2) and TCE was detected at concentrations above the EPA's MCL of 5 µg/L in three of these wells.

The source of the TCE contamination is unknown, but spills and improper disposal of solvents that may have been used in Building 1104 at site SS-34N (fig. 2) are suspected. Concentrations of TCE in ground-water samples collected since 1993 from the monitoring wells located at the site have ranged from less than 0.5 to 340 µg/L. Concentrations in ground water sampled since 2000 beneath the residential area west of the base have ranged from less than 0.2 to 136 µg/L. A flowpath connecting the areas of the large TCE concentrations in wells CW-44, near Building 1104, and CW-46, -located off base about 800 ft northwest of building 1104, has yet to be confirmed.

In recent studies to define areas of TCE contamination in ground water, the U.S. Geological Survey (USGS) has used several innovative sampling procedures that reduce costs of site characterization: analysis of tree-tissue material from trees growing above contaminated ground water and use of passive-diffusion samplers (PDSs) to obtain ground-water samples from existing wells. Tree-tissue analysis has been used at the U.S. Department of Energy's Savannah River site (Vroblesky and others, 1999; Nietch and others, 1999), and at the U.S. Army's Fort Lewis, which is adjacent to McChord AFB. At Fort Lewis, TCE was observed consistently in Douglas Fir trees near a site contaminated with TCE, and the concentration in tree tissue corresponded well with the presence of TCE in ground water near the source of TCE contamination (U.S. Geological Survey, unpublished data).

Using PDSs to collect ground-water samples has been found to reduce cost and eliminate well purging typically required for collecting ground-water samples to be analyzed for selected volatile organic compounds (Vroblesky, 2001b; Vroblesky and Hyde, 1997). In addition, PDSs may provide information on vertical stratification of contaminant concentrations in ground water (Vroblesky, 2001b; R.L. Huffman, 2002). Vroblesky (2001a) prepared a protocol for the deployment and use of low-density polyethylene PDSs for selected volatile organic compounds (VOCs) in ground-water wells. Results of field tests at sites across the country are described by Vroblesky (2001b). Information on this method is disseminated jointly by the U.S. Department of Defense and U.S. Environmental Protection Agency on the Internet through the Interstate Technology Regulatory Cooperation Work Group at URL http://www.itrcweb.org.

In 2001, the USGS, in cooperation with the U.S. Air Force McChord Air Force Base Installation Restoration Program, conducted a preliminary study of the feasibility of using these two innovative sampling procedures to characterize the source and areal extent of TCE contamination in ground water at site SS-34N.

Both processes could reduce the cost of monitoring ground-water quality and provide new information useful for restoration cleanup. Analysis of tree-tissue samples at site SS-34N was of particular interest because tree-tissue samples are believed to provide samples of ground water that integrate a larger area and time interval than typical soil-gas samples and because the depth to ground water at site SS-34N (30-35 ft) was much greater than at the Fort Lewis site (8-10 ft), where TCE was observed in tree-tissue samples.

PURPOSE AND SCOPE

This report presents the results of a preliminary study at site SS-34N on McChord AFB to assess the feasibility of (1) using concentrations of TCE in tree tissue to assess the source and areal extent of TCE contamination in ground water at the site; and (2) using passive-diffusion samplers to collect ground-water samples for analysis of TCE concentrations. Tissue samples were collected from 20 trees at the site, and PDSs were installed in three existing monitoring wells in the study area.

The data collected for both parts of the study were compared with concentrations of TCE measured in samples collected from 18 monitoring wells by the traditional pump-and-purge method using low-flow/limited drawdown procedures. Monitoring-well data were collected and analyzed by McChord's contractor during the period of study.

Description of Study Area

Site SS-34N is located in the western part of the industrial area of McChord AFB, near the base boundary (fig. 1). Immediately adjacent to the boundary is an active single-track railroad line and further west are private residential and apartment buildings of the Springbrook subdivision (fig. 2). Historically, there was a great deal of base activity at the site. Aerial photographs from 1961 indicate as many as 12 buildings in the area, all but one of which have since been removed. At the time of this study (2001), the site was used as a staging area for equipment and materials used by McChord AFB contractors, and the remaining building, Building 1104, was designated as the Combat Arms Training and Maintenance facility, formerly the Small Arms Training Center. This building was used as a small-arms training facility since the mid-1970s. Although not formally documented, the use of TCE as a solvent for the cleaning of weapons was considered a potential source of the TCE contamination present at the site.

About 12 acres of the site is covered with trees (fig. 2), characterized according to Hitchcock and Cronquist (1973) as Douglas fir (*Pseudotsuga menzieisi*), Oregon white oak (*Quercus garryana*, also referred to as Garry oak), and Pacific madrone (*Arbutus menziesii*) (fig. 2). With exception of Building 1104, the roadways, and parking areas, the site is predominantly a regularly mowed flat grassy area interspersed with trees, except along the sloping eastern and northern perimeters, which are covered with dense brush of blackberry, snowberry, and ferns.

McChord AFB is underlain by a thick, complex sequence of heterogeneous unconsolidated glacial and non-glacial sediments. Soil borings at Site SS-34N indicate that the upper 20-30 ft of glacial sediments were composed of well-graded gravels and cobbles with minor amounts of sands (URS and others, 2000). These highly permeable deposits were classified as recessional glacial gravels and sand, beneath which was a layer of low-permeability glacial till composed of compact silty-clayey gravel. Depth to ground water near Building 1104 was somewhere between 27 and 35 ft (table 1). Water levels typically are high during winter and spring and drop 4-6 ft during summer and fall. Based on water-level contours, the direction of ground-water flow is from east to west (URS and others, 2000). However, the inferred direction of contaminant flow based on wells that have the largest TCE concentrations (from CW-44 to CW-46) is more northwesterly.

Concentrations of TCE measured in ground-water samples at some of the monitoring wells have been observed to vary annually, suggesting a seasonal pattern in TCE concentrations that is related to ground-water levels. During winter and spring TCE concentrations are typically below 10 µg/L; however, during summer and fall, TCE concentrations often exceed 100 µg/L.

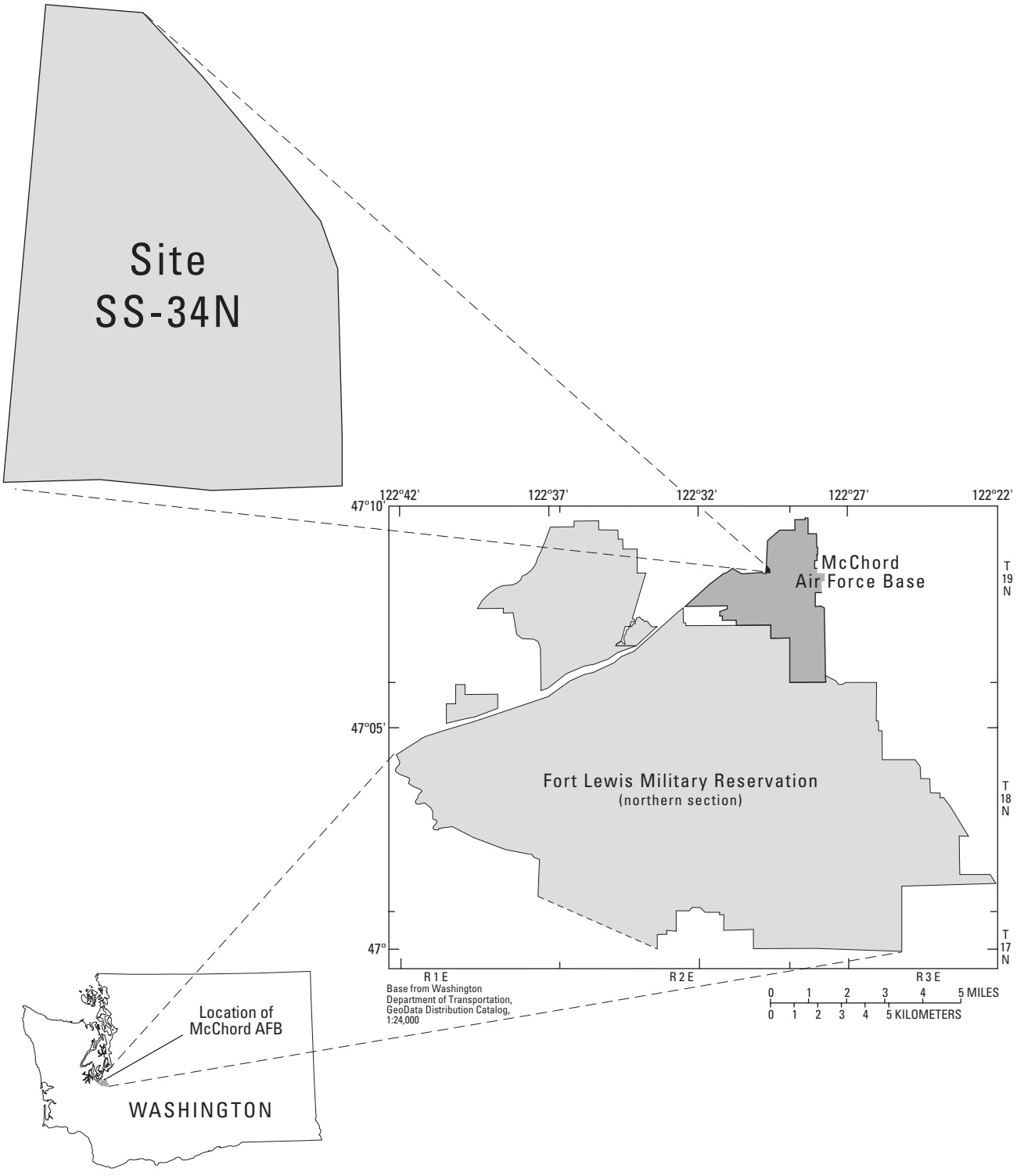

Figure 1. Location of site SS-34N, McChord Air Force Base, Washington.

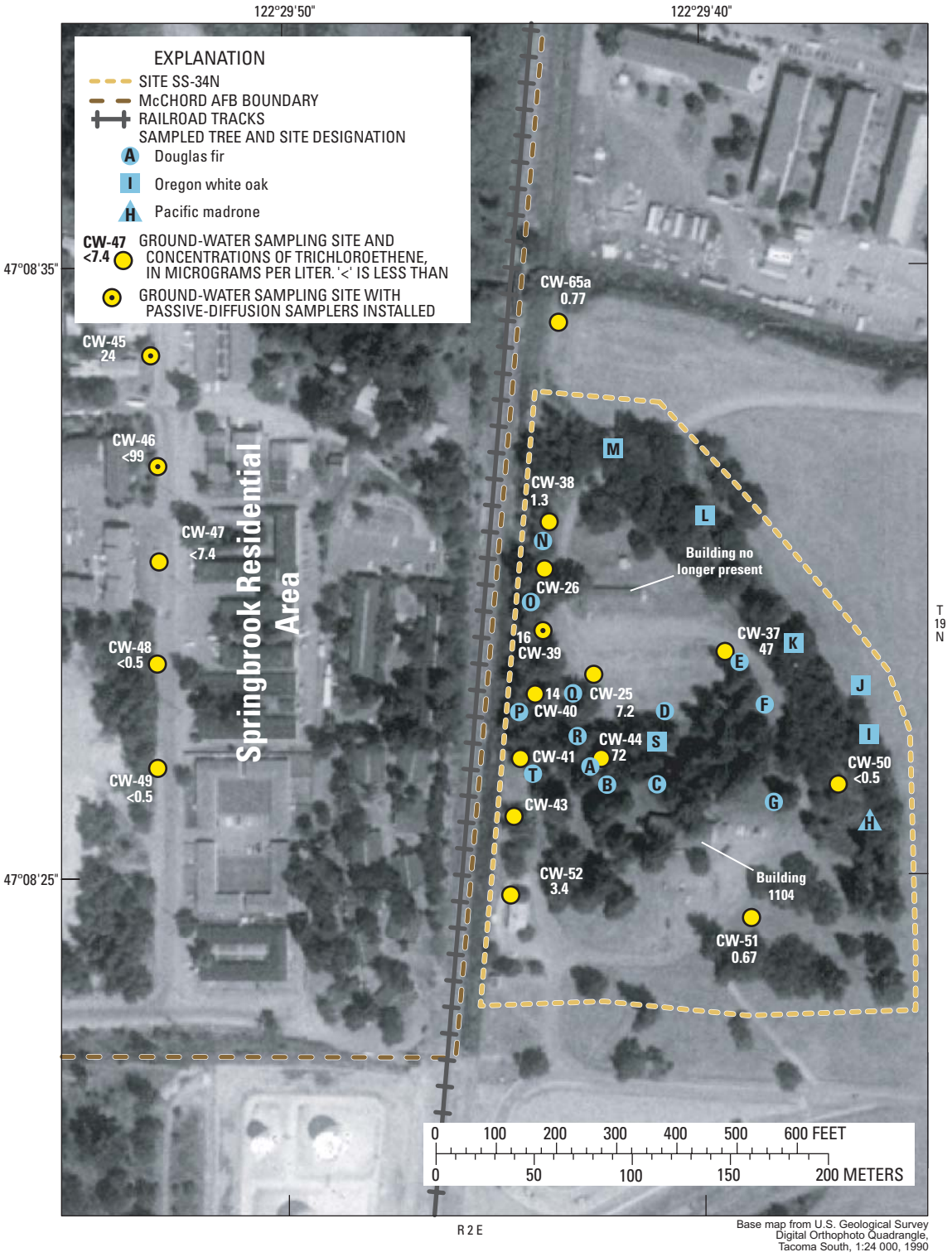

Figure 2. Locations of sampled trees, wells with passive-diffusion samplers, ground-water monitoring wells, and concentrations of trichloroethene in the study area at site SS-34N, McChord Air Force Base, Washington.

(Trichloroethene concentration data from David Burdette, McChord AFB, written commun., 2001.)

Table 1. Water-level measurements in ground-water monitoring wells at site SS-34N, McChord Air Force Base, Washington, December 19, 2000

[Data from Foster Wheeler Environmental Corp., 2001. **Well No.**: Location of wells are shown in figure 2]

Well No.	Altitude of measuring point (feet)	Depth to water (feet below land surface)	Altitude of static water level (feet)
CW-25	292.26	28.84	263.42
CW-26	292.73	29.33	263.40
CW-37	293.77	28.59	265.18
CW-38	292.92	29.50	263.42
CW-39	292.80	29.38	263.42
CW-40	289.32	25.85	263.47
CW-41	295.09	31.78	263.31
CW-43	296.73	33.58	263.15
CW-44	292.47	27.13	265.34
CW-45	288.99	30.34	258.65
CW-46	288.44	29.60	258.84
CW-47	288.34	29.25	259.09
CW-48	289.31	30.75	258.56
CW-49	293.57	34.94	258.63

METHODS OF COLLECTION AND ANALYSIS

Tree-tissue and ground-water samples were collected by U.S. Geological Survey personnel and analyzed for concentrations of TCE between April and August 2001. The results of the analyses were compared with concentrations of TCE in samples collected from the monitoring wells by McChord AFB contractors during the period of study and in 2000.

Tree-Tissue Samples

Tree-tissue samples were obtained twice from 20 trees in the study area (fig. 2). The first round of samples was collected in the spring (April 23, 2001) when ground-water levels were expected to be near their highest. At that time, leaf buds had appeared on oak trees and new growth was apparent on Douglas firs. A second round of samples was collected in late summer (August 17, 2001), when soil-moisture deficit was likely to be greatest and the trees could be expected to extract available moisture through active transpiration from deeper portions of the root zone (Nnyamah and Black, 1977). Tissue samples were collected during the afternoon hours on days when the relative humidity was less than 60 percent and when significant rain had not fallen during the previous 3 days. Meteorological information was obtained from the McChord AFB weather station, located about 0.5 mile southeast of site SS-34N.

Tree-tissue samples were collected using a 4.3-millimeter (mm) inside-diameter incremental tree bore. A single core was collected approximately 4 ft above ground level, and an 8-millimeter-diameter dowel rod was driven into the core hole and covered with tree-wound sealant. The diameter of the tree at the level at which the sample was taken was estimated visually, and a small (2-3 inch, 5-8 cm) paint spot was placed at the base of the tree for identification purposes. Location coordinates for each tree were obtained using a hand-held global positioning system.

After the bark was removed from the core, the next 6 centimeters (cm) of core was placed in a 20-milliliter (ml) headspace vial and was sealed with a Teflon-faced butyl stopper. If samples could not be analyzed within 48 hours after collection, they were refrigerated.

Prior to analysis, samples were held at room temperature for at least 24 hours to permit TCE and other volatile organic compounds to diffuse into the headspace of the vial. One-cubic-centimeter gas samples from the headspace were analyzed for TCE on a gas chromatograph using either an electron-capture or a flame-ionization detector. Chromatographic separation was performed isothermally at 50°C on a Restek® DB624 column (0.53-millimeter inside diameter and 30 meters in length) using 10-cubic-centimeter-per-minute ultra-pure helium as a carrier gas. The temperature of the injector and detector was 60°C.

Two positive control samples and a blank sample were collected as quality-control samples during both the April and August samplings. Two duplicate samples also were collected at each of two sampling sites during each sampling round. Positive control samples were obtained either from a previously sampled tree in which TCE was detected or by first soaking cores in a vial filled with water containing TCE at a concentration of 1 part per million. During the April sampling, a previously analyzed tissue sample reported to have no detectable quantity of TCE was used as a sample blank; the septum on the sample vial was replaced in the laboratory with a new unpunctured septum.

The sample blank for the August sampling was made from a core obtained from a forested area where no contamination had been measured. During the August sampling, an empty sample vial was capped in the field without a core sample to serve as an air-blank quality-assurance sample.

Passive-Diffusion Samplers

Three PDSs each were installed in ground-water monitoring wells CW-39, CW-45, and CW-46 (fig. 2) following procedures described by Vroblesky (2001a) and Vroblesky and others (1999). The PDSs were removed for analysis just prior to the collection of regularly scheduled ground-water-quality monitoring samples using traditional pump-and-purge techniques employing low-flow/limited-drawdown procedures.

The PDSs were constructed of 3.7-centimeter-wide (lay-flat) low-density polyethylene tubing (4-mil thick) filled with 140 milliliters of degassed, deionized water. The PDSs were filled completely and sealed without bubbles or headspace. Protective polyethylene mesh was placed around each PDS. A completed PDS measured about 25 cm in length and about 4 cm in diameter.

The PDSs were installed on June 3, 2001, using a stainless steel weighted line and placed near the middle, top, and bottom of the screened zone in each well. The length of the screened interval in well CW-39 was 20 ft and in wells CW-45 and CW-46 was 10 ft. The upper PDS was placed so that the top of the PDS was 1 ft below the top of the screened interval, and the lower PDS was placed so that the bottom of the PDS was about 1 ft above the bottom of the screen. The middle PDS was placed in the center of the well screen. An additional PDS was used as an equipment-blank sample. The PDSs installed in the wells were allowed to equilibrate with ground water for at least 10 days prior to retrieval on June 13 or 15, 2001.

Samples for analysis were taken from the PDS using the following procedure. The sample from the shallow PDS was collected first, followed by the mid-screen sample and then the deep sample. The equipment blank PDS was transported to the field along with the PDSs for well CW-39. Immediately following installation of the PDSs in CW-39, the equipment blank PDS was opened and processed for sample collection. The PDS was opened by cutting away about 1–2 cm of a corner using stainless steel scissors. Three 40-milliliter sample vials were slowly filled with the contents of the PDS. The samples were preserved with hydrochloric acid and capped without headspace, then packed on ice and shipped by overnight courier to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colo., for analysis of TCE and other volatile organic compounds using purge-and-trap Gas Chromatographic/ Mass Spectrometery (GC/MS) procedures described by Connor and others (1998). The volatile organic compounds included in the analysis and the laboratory reporting limits are listed in appendix 1.

TCE concentration values from the NWQL analysis are stored in the USGS National Water Information System (NWIS) database. In the NWIS database, each well is identified by a single 15-digit identifier as shown below. The location within the well screen (top, middle, bottom) of the individual PDS samples were noted in the remarks to the laboratory.

McChord AFB Monitoring Well No.	NWIS Site Identifier No.
CW-39	470829122294301
CW-45	470833122295301
CW-46	470831122295301

Shortly after the PDSs were removed from wells CW-39, CW-45, and CW-46 on June 15 and 18, 2001, regularly scheduled ground-water monitoring samples were collected and analyzed by McChord's contractor. These monitoring samples were collected with an electric submersible pump set at mid-screen level using low-flow sample-collection procedures. The data from these samples were used for comparison with those from PDS samples.

ASSESSMENT OF TREE-TISSUE ANALYSIS

TCE was not detected in any of the tree-tissue samples collected at site SS-34N in April and August 2001 (table 2) and it is unlikely that tree tissue will be an effective reconnaissance tool for detecting TCE contamination of ground water at the McChord site SS-34N. TCE was observed in all of the positive controls, and also in the blank sample from the April sampling. The concentration in the blank sample was low and was equivalent to the laboratory reporting level. The lack of TCE detections in any of the environmental samples indicates that false positive detections were not a problem. The likely source of TCE in the sample blank was contamination during its preparation. A core sample that had previously been analyzed and found to have no detectable TCE was used, and probably was contaminated when the punctured septum from the previous analysis was replaced in the laboratory for use in the current sample set. No contamination was observed in the blank samples from the second round of sampling.

Table 2. Concentrations of trichloroethene in tree-tissue samples at site SS-34N, McChord Air Force Base, Washington, 2001

[**Site No.**: Location of sites are shown on figure 2. **Latitude/Longitude**: Given in degrees, minutes, and seconds. **Tree species**: DF, Douglas fir; PM, Pacific madrone; WO, Oregon white oak; –, not applicable]

Sample site No. or type	Latitude	Longitude	Tree species	Diameter of tree (inches)	TCE (parts per million by volume)	
					April 23	August 17
McC-A	470826.7	1222942.7	DF	30	<0.05	<0.05
McC-B	470826.4	1222942.3	DF	20	<.05	<.05
McC-C	470826.7	1222941.1	DF	30	<.05	<.05
McC-D	470827.6	1222940.9	DF	24	<.05	<.05
McC-E	470828.4	1222939.1	DF	36	[1]<.05	<.05
McC-F	470827.7	1222938.5	DF	24	<.05	<.05
McC-G	470826.1	1222938.3	DF	30	<.05	<.05
McC-H	470825.8	1222936.0	PM	14	<.05	<.05
McC-I	470827.2	1222936.1	WO	20	<.05	<.05
McC-J	470828.0	1222936.2	WO	16	<.05	<.05
McC-K	470828.7	1222937.8	WO	24	<.05	[1]<.05
McC-L	470830.8	1222939.9	WO	30	<.05	<.05
McC-M	470831.9	1222942.1	WO	20	[1]<.05	<.05
McC-N	470830.4	1222943.8	DF	20	<.05	<.05
McC-O	470829.4	1222944.1	DF	14	<.05	<.05
McC-P	470827.6	1222944.4	DF	30	<.05	<.05
McC-Q	470827.9	1222943.1	DF	36	<.05	<.05
McC-R	470827.2	1222943.0	DF	24	<.05	[1]<.05
McC-S	470827.1	1222941.1	WO	18	<.05	<.05
McC-T	470826.1	1222944.5	DF	30	<.05	<.05
Blank	–	–	–	–	[2]0.05	<.05
Positive control	–	–	–	–	0.9	2.5
Positive control	–	–	–	–	2.5	8.4
Air blank	–	–	–	–	–	<.05

[1]Duplicate sample collected, trichloroethene not detected (0.05).
[2]Suspected contamination occurred during preparation of blank sample in laboratory.

Ground-water samples collected from the monitoring wells in the study area had concentrations of TCE ranging from below the detection limit (0.5 µg/L) to 99 µg/L (see fig. 2). The samples were collected between June 15 and 18, 2001, except for wells CW-41, CW-43, CW-44, CW-47, CW-48, and CW-49, which were sampled during spring of 2000. It is not known conclusively why TCE was not observed in tree cores from site SS-34N when TCE was clearly present in ground water at the site. It is possible that the depth to ground water at site SS-34N (about 30 ft) is below the depth that can be reached by the roots of the trees growing at the site. The depth to ground water at McChord site SS-34N is roughly three times greater than that at a nearby site at Fort Lewis, where TCE was detected in samples from Douglas fir. Several others mechanisms may explain the lack of detectable concentrations in the tree-tissue samples. The concentration of TCE in ground water at site SS-34N may have been so small that the cumulative effects of plant-related processes reduced the TCE concentration to below the laboratory detection limits. Some of these processes include enhanced microbial degradation within the root zone, diffusion across into the root cell walls, diffusion out of the sap into the surrounding atmosphere once the sap has moved above the ground water system, and enzymatic catalysis within plant cells and have been described by Burken and Schnoor (1998) for hybrid poplar trees. Ground-water stratification of TCE concentrations also might explain why TCE was not observed in site SS-34N tree-tissue samples. For example, if TCE-contaminated ground water moves away from the source area and additional recharge creates a layer of uncontaminated water that is above the contaminated ground water, then the trees are more likely to transpire the uncontaminated ground water from the water-table surface than the deeper ground water containing TCE. However, this explanation does not seen likely because the concentration of TCE in samples from the upper PDS at well CW-39, within 1 ft of the water table, was 14.2 µg/L (see section "Assessment of Passive-Diffusion Samplers".

ASSESSMENT OF PASSIVE-DIFFUSION SAMPLERS

TCE was detected in all ground-water samples collected using the PDSs at wells CW-39, CW-45, and CW-46 and also in the samples collected at those wells using the pump-and-purge method. Concentrations of TCE measured in the PDS samples were generally similar in range to the concentrations measured in the pumped samples (table 3). The similarity between TCE concentrations in samples collected using PDSs and using traditional pump-and-purge methods has been demonstrated at other sites throughout the country (Vroblesky, 2001a) and in a recent study conducted in a similar aquifer in western Washington at the Whidbey Island Naval Air Station (Huffman, 2002).

Comparison of samples from the upper, middle, and lower PDSs in each well showed a variation in TCE concentration of 7.7 percent in well CW-39, 40 percent in well CW-45, and 7.8 percent in well CW-46 when expressed as the percent of the relative standard deviation (standard deviation divided by the mean). These variations were larger than would be expected from laboratory and sampling variations alone and may indicate stratified contamination within the aquifer, as has been described at other sites (Vroblesky 2001a). Variation in TCE concentrations as a result of laboratory analytical procedures has been reported to range from 1 to 6 percent relative standard deviation (Connor and others, 1998). Variation in TCE concentration data from duplicate environmental samples also was less than 6 percent in seven sets of environmental duplicate samples collected from similarly contaminate aquifers in 2000 (R.L. Huffman, U.S. Geological Survey, written commun., 2001). The variations in samples from wells CW-39 and CW-46 were only slightly larger than the expected variation from sampling and analysis alone, and provide only tentative indications of contaminant stratification that could be confirmed by additional sampling, as is suggested by Vroblesky's protocol (2001b).

Table 3. Concentrations of volatile organic compounds in ground-water samples collected with passive-diffusion samplers and by submersible pump from selected ground-water monitoring wells at site SS-34N, McChord Air Force Base, Washington, June 3-15, 2001

[**Well No.**: Locations of wells are shown in figure 2. **Sampling method**: **PDS**, passive-diffusion sample; **SUB**, submersible-pump sample. **Concentration**: Drinking water maximum allowable contaminant levels are shown in parenthesis. **Acronyms**: TCE, trichloroethene; DCE, dichloroethene; TCA, 1,1,1-trichloroethane; na, not analyzed; <, actual value is less than value shown]

Well No.	Location in well screen	Sampling method	Concentration, in micrograms per liter				
			TCE (5)	*cis*-1,2 DCE (70)	Chloroform (100)	TCA (200)	Benzene (5)
CW-39	Upper	PDS	14.2	<0.1	<0.1	<0.1	0.51
	Middle	PDS	16.5	.22	<.1	<.1	1.85
	Lower	PDS	16.0	<.1	<.1	<.1	<.1
	Middle	SUB	16	<.5	<.5	na	na
CW-45	Upper	PDS	24.1	<.1	.11	.18	<.1
	Middle	PDS	43.4	<.1	.15	.18	<.1
	Lower	PDS	21.8	<.1	.15	.17	<.1
	Middle	SUB	24	<.5	<.5	na	na
CW-46	Upper	PDS	90.3	<.1	.24	.10	<.1
	Middle	PDS	90.5	.10	.23	.10	<.1
	Lower	PDS	78.7	.10	.24	.10	<.1
	Middle	SUB	99	<.5	<.5	na	na

However, the variation in TCE concentrations in samples from the three PDSs in CW-45 is much greater than from sampling and analysis alone, and indicates stratification of TCE in the screened interval at this location. The presence of stratified contamination should be confirmed by additional sampling.

Four other VOCs were detected in ground-water samples from the PDSs, all at concentrations less than USEPA MCLs: *cis*-1,2 dichloroethene (*cis*-1,2 DCE); chloroform; 1,1,1-trichloroethane (TCA); and benzene. The presence of low concentrations of *cis*-1,2-DCE in association with TCE contamination is expected, because *cis*-1,2-DCE is the primary microbial degradation product of TCE. Chloroform and TCA were also detected at very low concentrations in wells CW-45 and CW-46, which were located in a residential area. Chloroform had previously been detected in June 2000 at a concentration of 0.82 µg/L in another well (CW-48) in the same residential area (Foster Wheeler Environmental Corp., 2000). Both TCA and chloroform frequently have been observed in ground water from urban environments throughout the continental United States (Squillace and others, 1999), and they have also been detected in ground water from urban areas of Puget Sound (Inkpen and others, 2000). Low concentrations of benzene, a component of gasoline and other petroleum products, were found in well CW-39. Previous analyses of ground-water samples collected in June 2000 from two nearby wells (CW-41 and CW-25) had detected total petroleum hydrocarbons at concentrations of 140 and 550 µg/L (Foster Wheeler Environmental Corp., 2000).

SUMMARY

Two low-cost, innovative sampling procedures for characterizing trichloroethene (TCE) contamination in ground water were evaluated for use at site SS-34N at McChord Air Force Base in a cooperative study in 2001 between the U.S. Geological Survey and the U.S. Air Force McChord Air Force Base Installation Restoration Program. Tree-tissue samples were collected for analysis of TCE in ground water and passive-diffusion samplers (PDSs) were installed in existing ground-water monitoring wells for measuring TCE. These procedures have been successful at other sites and have resulted in cost avoidance and accelerated site characterization. Hydrologic conditions were not considered optimum at site SS-34N for using the tree-tissue analysis technique. The feasibility of using the methods was tested because they have the potential to substantially reduce investigation costs and provide new information useful for remediation/cleanup.

The tree-tissue procedure was not successful at McChord AFB. Despite the presence of TCE in ground water beneath the site, TCE was not detected in any of the 20 trees sampled at site SS-34N during either the early spring or late summer sampling. The most likely reason for failure of the tree-tissue sampling was that the depth to ground water was too great for tree roots to reach contaminated water. Therefore, it is unlikely that the tree-tissue sampling technique will be useful as a reconnaissance tool for TCE contamination at McChord AFB site SS-34N.

Use of PDSs was successful at McChord AFB. TCE was observed in ground-water samples collected using PDSs in three existing monitoring wells. Samplers were placed near the top, middle, and bottom of the screened intervals in the three monitoring wells. Concentrations of TCE measured from PDS samplers were generally similar to concentrations found in samples collected during the same period by traditional pump-and-purge methods. These results suggest that PDSs provide comparable data to pumped samples and may provide additional data about the vertical stratification of TCE concentrations in ground water. Further evaluation of the use of PDSs at McChord AFB site SS-34N is warranted.

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APPENDIX 1. LIST OF ANALYTES INCLUDED IN VOLATILE ANALYSIS FROM PASSIVE-DIFFUSION SAMPLERS

Appendix 1. Analytes included in analysis of volatile organic compounds in ground water from passive-diffusion samplers at site SS-34N, McChord Air Force Base, Washington, 2001

[µg/L, microgram per liter; <, actual value is less than value shown]

Compound name	Reporting level (µg/L)
Bromoform	<0.2
Chloroform	<.1
Methylene chloride	<.2
Carbon tetrachloride	<.2
Bromodichloromethane	<.1
Dibromochloromethane	<.2
Dichlorodifluoromethane	<.2
Trichlorofluoromethane	<.2
1,1-Dichloroethane	<.1
1,2-Dichloroethane	<.2
1,1,1-Trichloroethane	<.1
Vinyl chloride	<.2
1,1-Dichloroethene	<.1
cis-1,2-Dichloroethene	<.1
trans-1,2-Dichloroethene	<.1
Trichloroethene	<.1
Tetrachloroethene	<.1
1,2-Dichloropropane	<.1
Benzene	<.1
Chlorobenzene	<.1
Toluene	<.1
Ethylbenzene	<.1
m & *p*-Xylene	<.2
o-Xylene	<.1
Styrene	<.1
Diethylethe	<.2
1,1,2-Trichloro-1,2,2-triflouroethane	<.1
Methyl-t-butyl ether (MTBE)	<.2
Diisopropylether	<.2
Ethyl-t-butyl ether (ETBE	<.1
tert-Amyl methyl ether (TAME)	<.2