

In cooperation with the
United States Air Force
Dover Air Force Base

Analytical Results From Ground-Water Sampling Using a Direct-Push Technique at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

Open-File Report 03-380

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

Analytical Results From Ground-Water Sampling Using a Direct-Push Technique at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

by

William R. Guertal, Marie Stewart, and Jeffrey R. Barbaro
(U.S. Geological Survey)

and

Timothy J. McHale
(Dover National Test Site)

Open-File Report 03-380

In cooperation with the
United States Air Force
Dover Air Force Base

Baltimore, Maryland
2004

U.S. Department of the Interior

GALE A. NORTON, Secretary

U.S. Geological Survey

Charles G. Groat, Director

The use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. Government.

For additional information contact:

District Chief
U.S. Geological Survey
8987 Yellow Brick Road
Baltimore, MD 21237

Copies of this report can be purchased from:

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

CONTENTS

| | |
|---|----|
| Abstract | 1 |
| Introduction | 1 |
| Purpose and scope | 2 |
| Description of study area | 2 |
| Acknowledgments | 2 |
| Methods of investigation | 5 |
| Drilling | 5 |
| Ground-water sample collection | 5 |
| Quality-control samples and methods | 5 |
| Sample handling procedures and analytical methods | 5 |
| Analytical results of ground-water samples | 8 |
| Water-level measurements | 9 |
| Quality-control results | 9 |
| Summary | 31 |
| References cited | 31 |

Figures

| | |
|--|----|
| 1a. Map showing location of Dover Air Force Base and the Delaware Coastal Plain, Delaware | 2 |
| 1b. Map showing location of Dover National Test Site at Dover Air Force Base | 3 |
| 1c. Map showing location of Dover National Test Site boundaries, Dover Air Force Base | 4 |
| 2. Map showing locations of direct-push sampling sites at the Dover National Test Site, Dover Air Force Base | 6 |
| 3a. Map showing location of ground-water level measurements in the upper part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, July 1, 2001 | 10 |
| 3b. Map showing location of ground-water level measurements in the lower part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, July 1, 2001 | 11 |

Tables

| | |
|---|----|
| 1. Field and laboratory methods for direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001 | 7 |
| 2. Method reporting limits and maximum contaminant levels for volatile organic compounds | 8 |
| 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, June–July 2001 | 12 |
| 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, June–July 2001 | 18 |
| 5. Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, June–July 2001 | 24 |
| 6. Ground-water level measurements in the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001 | 28 |
| 7. Concentrations of volatile organic compounds in quality-control blank samples collected at the Dover National Test Site, Dover Air Force Base, June–July 2001 | 29 |

Tables—Continued

8. Relative percent differences from duplicate ground-water samples collected at the Dover National Test Site, Dover Air Force Base, June–July 200130

Conversion Factors and Vertical Datum

| Multiply | By | To obtain |
|------------|--------|-----------------|
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| gallon | 3.785 | liter (L) |

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

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

Vertical datum: 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 the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$ at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter ($\mu\text{g}/\text{L}$).

Acronyms and Abbreviations

| | | | |
|---------------------|--|-------------------------|--|
| °C | degrees Celsius | mg/L | milligram per liter |
| <i>cis</i> -1,2-DCE | <i>cis</i> -1,2-dichloroethene | mL | milliliter |
| DAFB | Dover Air Force Base | msl | mean sea level |
| DI | de-ionized | MTBE | methyl <i>tert</i> -butyl ether |
| DNAPL | dense non-aqueous phase liquids | ND | not detected |
| DNTS | Dover National Test Site | PCE | tetrachloroethene |
| DO | dissolved oxygen | QC | quality control |
| ft | feet | SERDP | Strategic Environmental Research and Development Program |
| ft bls | feet below land surface | TCE | trichloroethene |
| ft msl | feet mean sea level | USEPA | U.S. Environmental Protection Agency |
| GRFL | Groundwater Remediation Field Laboratory | USGS | U.S. Geological Survey |
| MCL | maximum contaminant level | VOC | volatile organic compound |
| MDL | method detection limit | $\mu\text{g}/\text{L}$ | microgram per liter |
| MRL | method reporting limit | $\mu\text{S}/\text{cm}$ | microsiemens per centimeter at 25 °Celsius |

Analytical Results From Ground-Water Sampling Using a Direct-Push Technique at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

By William R. Guertal, Marie Stewart, Jeffrey R. Barbaro, and Timothy J. McHale

Abstract

A joint study by the Dover National Test Site and the U.S. Geological Survey was conducted from June 27 through July 18, 2001 to determine the spatial distribution of the gasoline oxygenate additive methyl *tert*-butyl ether and selected water-quality constituents in the surficial aquifer underlying the Dover National Test Site at Dover Air Force Base, Delaware. The study was conducted to support a planned enhanced bio-remediation demonstration and to assist the Dover National Test Site in identifying possible locations for future methyl *tert*-butyl ether remediation demonstrations.

This report presents the analytical results from ground-water samples collected during the direct-push ground-water sampling study. A direct-push drill rig was used to quickly collect 115 ground-water samples over a large area at varying depths. The ground-water samples and associated quality-control samples were analyzed for volatile organic compounds and methyl *tert*-butyl ether by the Dover National Test Site analytical laboratory.

Volatile organic compounds were above the method reporting limits in 59 of the 115 ground-water samples. The concentrations ranged from below detection limits to maximum values of 12.4 micrograms per liter of *cis*-1,2-dichloroethene, 1.14 micrograms per liter of trichloroethene, 2.65 micrograms per liter of tetrachloroethene, 1,070 micrograms per liter of methyl *tert*-butyl ether, 4.36 micrograms per liter of benzene, and 1.8 micrograms per liter of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this investigation. Methyl *tert*-butyl ether was detected in 47 of the 115 ground-water samples. The highest methyl *tert*-butyl ether

concentrations were found in the surficial aquifer from -4.6 to 6.4 feet mean sea level, however, methyl *tert*-butyl ether was detected as deep as -9.5 feet mean sea level. Increased methane concentrations and decreased dissolved oxygen concentrations were found in samples that contained methyl *tert*-butyl ether.

Introduction

Dover Air Force Base (DAFB) in Dover, Delaware was selected as the site for the Strategic Environmental Research and Development Program's (SERDP) Ground-Water Remediation Field Laboratory (GRFL). The GRFL is also known as the Dover National Test Site (DNTS), and is one of the National Environmental Technology Test Sites, which was established and funded by SERDP. The purpose of the DNTS is to investigate technologies for detecting and remediating chlorinated solvent source areas under controlled experimental conditions.

In 1999, a study was conducted by the Air Force Center for Environmental Excellence (AFCEE) to evaluate natural attenuation of ground water contaminated by petroleum hydrocarbons for the Installation Restoration Program Site SS27/XYZ, which is located near the DNTS (Air Force Center for Environmental Excellence, 1999). During that study, the gasoline oxygenate additive methyl *tert*-butyl ether (MTBE) was detected in the ground-water samples collected from monitoring wells located on and near the DNTS property. Concentrations ranged from 10.9 to 1,430 µg/L (micrograms per liter) of MTBE.

The U.S. Geological Survey (USGS) is providing continuing technical assistance on ground-water quality issues for DNTS. The USGS assesses ground-water flow in the surficial aquifer, and assists the DNTS in providing support to principal investigators who are developing and field-testing technologies for the characterization and cleanup of soil and ground water contaminated with solvents, fuels, and the fuel additive MTBE. As part of this support, the USGS conducted a plume-mapping study to better determine the distribution of MTBE at the site.

The objectives of this study were to determine the distribution of organic contaminants in the surficial aquifer, and to use this information to improve existing conceptual models and plan additional site-characterization work. Data collection was based on field-screening methodologies that are appropriate for plume mapping. The analytical data obtained during this investigation are consistent with U.S. Environmental Protection Agency (USEPA) analytical level III (U.S. Environmental Protection Agency, 1989). This level refers to laboratory analyses performed in accordance with standard USEPA procedures, and is appropriate for site characterization. In addition, the intended use of these data was to identify ground-water areas contaminated with MTBE near the DNTS to host potential demonstrations of MTBE remedial technologies.

Purpose and Scope

From June 27 through July 18, 2001, the USGS conducted a plume-mapping study to assist the DNTS in determining the distribution of MTBE and in identifying possible locations for a planned enhanced bioremediation demonstration and other future MTBE demonstrations. The purpose of this report is to present the analytical results from ground-water samples collected during this direct-push ground-water sampling study. The ground-water samples and associated quality-control (QC) samples were analyzed for volatile organic compounds (VOCs), MTBE, and selected field constituents by the DNTS analytical laboratory.

Description of Study Area

The DNTS is located in the northwestern corner of DAFB, Dover, Delaware (figs. 1a–1c). It is designed to support the needs of principal investigators developing and field-testing remediation technologies for the clean-up of soil and ground water contaminated with fuels and solvents. The primary focus of the DNTS is field-testing of technologies that remediate dense non-aqueous phase liquids (DNAPLs). The DNTS maintains the capability to conduct contained releases of DNAPLs into the surficial aquifer (Air Force Center for Environmental Excellence, 1999).

The DAFB is in the Coastal Plain Physiographic Province, and is underlain by unconsolidated clastic sedimentary deposits. These deposits are comprised of medium to fine sands that contain lenses of gravels, silts, and clays, and are collectively known as the Columbia Formation. Deposits in the area of the DNTS are between 36 and 47 ft (feet) thick (Dames and Moore, Inc., 2000). Underlying these deposits is an approximately 28-ft-thick unit of gray, firm, dense marine clay known as the Calvert Formation. This unit is an aquitard for the Columbia aquifer, which is an unconfined surficial aquifer (Dames and Moore, Inc., 2000).

Acknowledgments

The authors would like to thank Dale Williams of the Groundwater Remediation Field Laboratory, Dover National Test Site for the VOC analyses and project support. In addition, the authors thank the following U.S. Geological Survey personnel: Pat Mills for direct-push drilling support;

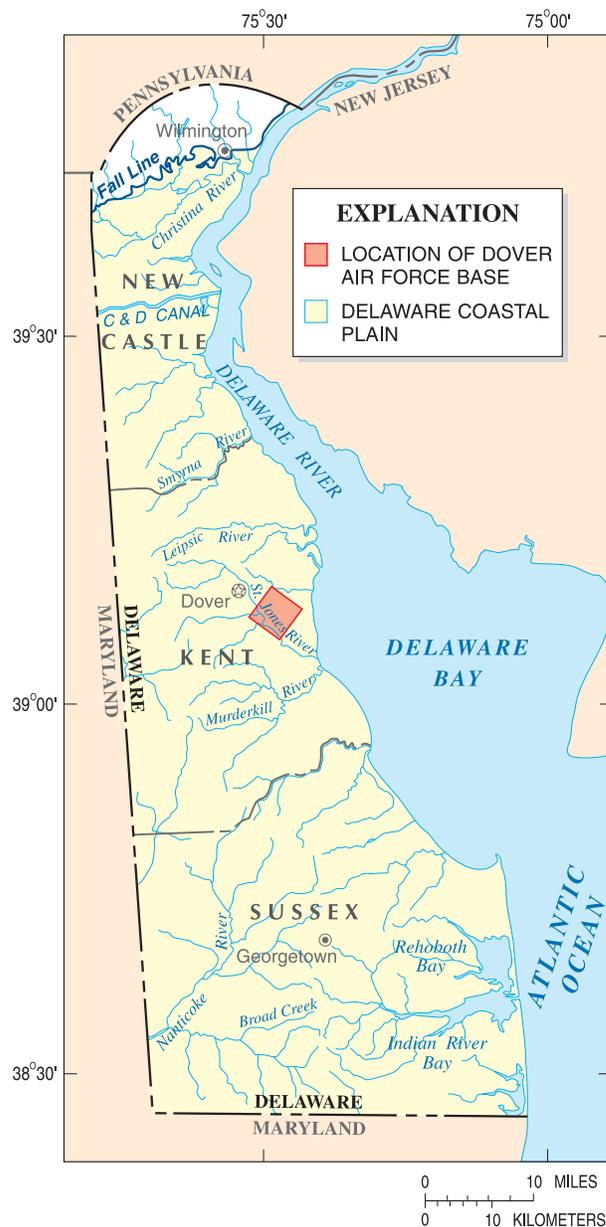


Figure 1a. Location of Dover Air Force Base and the Delaware Coastal Plain, Delaware.

William Stearns, Al Ruddy, and Pradumna Neupane for assisting in the collection of the water-quality samples; Kristen Alexander for field analyses for irons, nitrates, and sulfates; Jonathan Dillow for collection of water-level data and surveying; Lisa Olsen and Tracey Spencer for the methane analyses; Valerie Gainé for editorial review; and Timothy Auer for graphics. In addition, the authors would like to thank Cherie Miller and Michael Moran of the U.S. Geological Survey for their technical reviews.

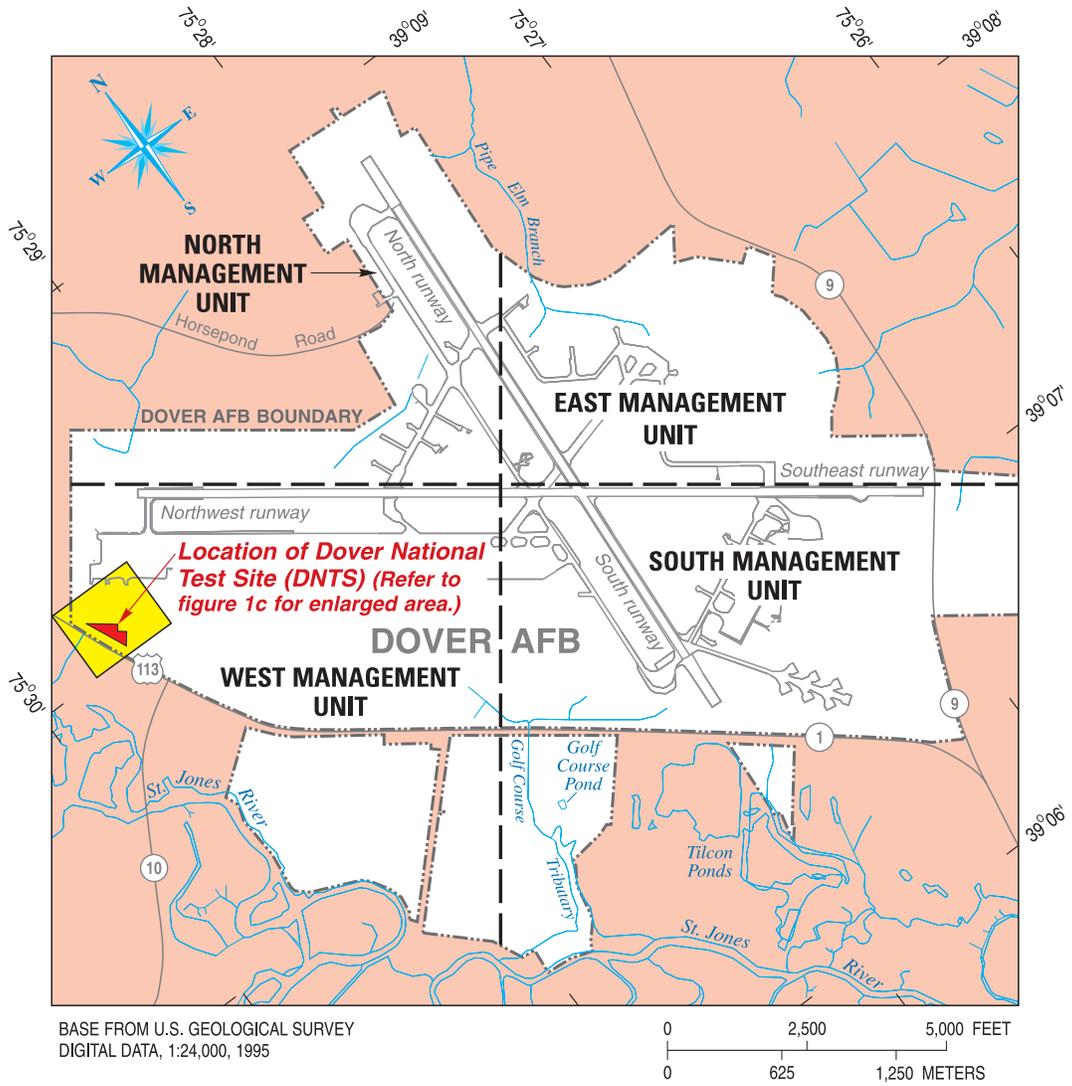


Figure 1b. Location of Dover National Test Site (DNTS) at Dover Air Force Base, Delaware.

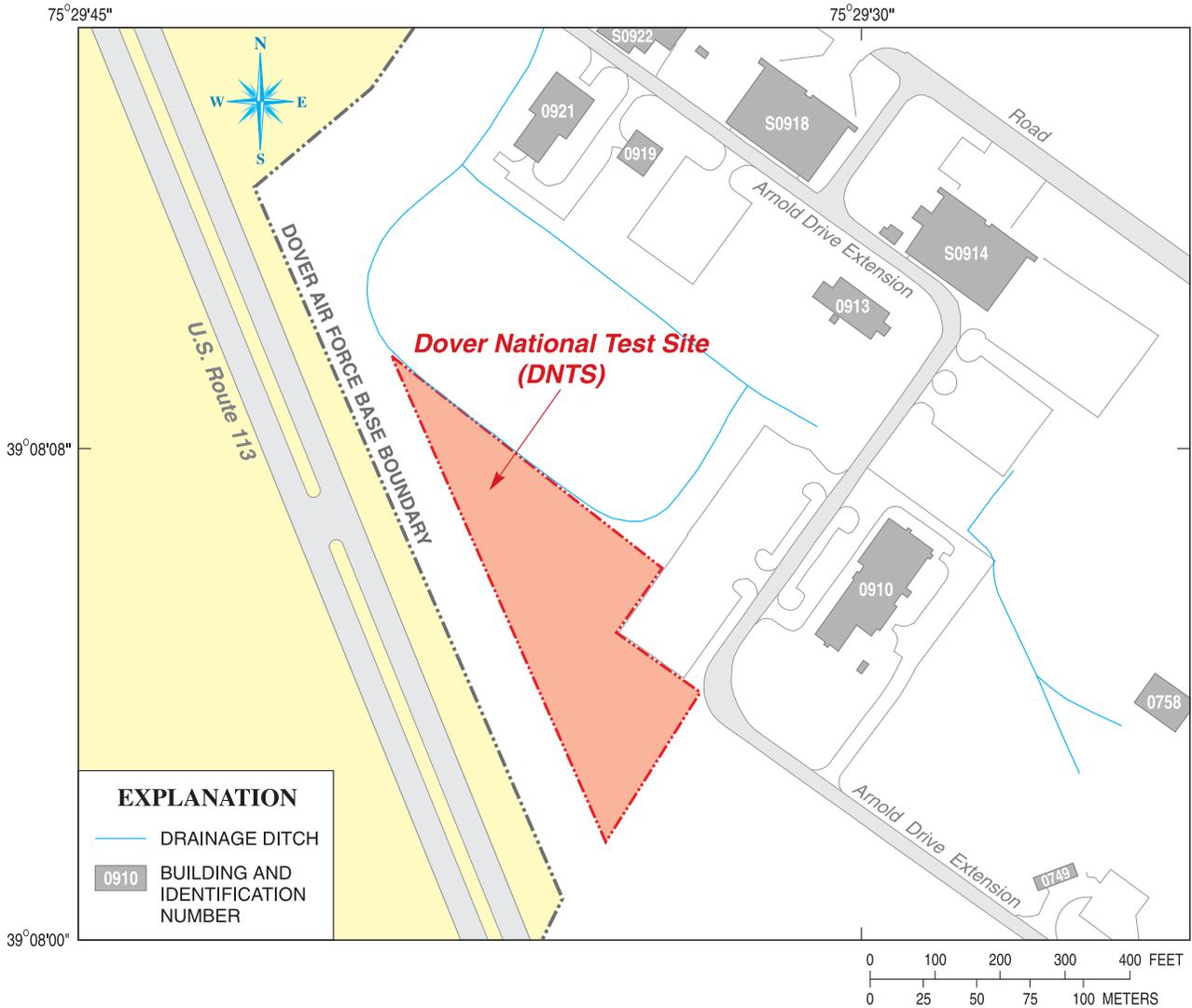


Figure 1c. Location of Dover National Test Site (DNTS) boundaries, Dover Air Force Base, Delaware.

Methods of Investigation

Data collection was based on field-screening methodologies commonly used for plume mapping. The study focused on the measurement of the geochemical conditions that could potentially affect the natural attenuation of MTBE at the DNTS. In addition, the degradation of VOCs can affect the geochemical conditions in the surficial aquifer. To determine geochemical conditions in the surficial aquifer, concentrations of dissolved oxygen (DO), ferrous and total iron, sulfate, and sulfide were measured in most ground-water samples. Methane was analyzed in selected ground-water samples.

Drilling

Drilling was performed with a direct-push Geoprobe drilling rig. The drilling rods (1.5-inch outer diameter by 0.625-inch inner diameter) were pushed into the ground with a hydraulically powered percussion machine until the deepest sample depth was reached. A 4-ft stainless steel well screen was then exposed for ground-water sample collection. After the sample was collected, the drilling rod with the exposed screen was pulled up to the next sample depth; as the exposed screen is pulled up, the hole below the screen collapses. At each drilling location, the deepest samples were typically collected from 36–40 ft below ground surface, then about every 8 ft moving upward. The final sample for each borehole was obtained near the water table. Each sample identification number includes the borehole number and an alphabetical suffix to indicate the depth of the sample, where “A” represents the deepest sample. The aquifer is predominantly sand and smearing of contamination is not an issue of concern. The screen, rod, and all drilling equipment that could potentially come in contact with the sample were thoroughly cleaned with soap and de-ionized (DI) water, then rinsed with DI water between each sample location.

The direct-push locations were used only to collect ground-water samples, and no permanent wells were installed. This drilling method did not generate any cuttings or fluids. Each borehole was backfilled to ground surface with bentonite grout. After the study was completed, all drilling locations were surveyed for spatial position and ground-surface altitude.

Ground-Water Sample Collection

A total of 147 ground-water samples (115 VOC samples and 32 quality-assurance samples) were collected from various depths at 48 locations at the DNTS (fig. 2). Field constituents were measured using a Hydrolab when there was sufficient ground-water yield. The Hydrolab is a multiprobe meter that was connected to a flow-through cell on the discharge line of a peristaltic pump. Purging was stopped when temperature, pH, DO, and specific conductance stabilized. At 11 of the 115 VOC sample intervals, there was insufficient yield for the collection of field constituents. In addition, selected samples were analyzed in the field for ferrous and total iron, sulfate, sulfite, and methane.

A peristaltic pump equipped with a short piece of silicone pump tubing was used for purging and sampling. Reusable 1/4-inch-diameter Teflon tubing in line with the pump was placed downhole to collect the ground-water samples. Three drops of concentrated hydrochloric acid were used as a sample preservative for all field blanks and ground-water samples, which were collected in 40-mL (milliliter) VOC septum vials with no headspace. The ground-water samples were analyzed for tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), vinyl chloride, MTBE, benzene, toluene, ethylbenzene, and the xylene isomers.

Because reusable sample tubing was used at each sampling location, it was decontaminated between samples to avoid cross-contamination. After samples were collected, the outside of the tubing was washed using soapy DI water. In addition, soapy DI water was pumped through the tubing for approximately 2–3 minutes using a peristaltic pump. A new piece of flexible tubing was used with the peristaltic pump for each sample.

Quality-Control Samples and Methods

The QC sample group consisted of 14 field blanks (DI water samples collected after the field sampling equipment is cleaned), 10 sequential duplicate samples (sequential aquifer water samples), 7 screen blanks (DI water samples collected after the drilling equipment is cleaned) and 1 equipment blank (a DI water sample collected from the equipment at the start of the study). Field blanks are clean samples that are collected after field equipment is cleaned to verify that the cleaning methods were performed correctly. Field blanks were collected to check the effectiveness of the sample tubing cleaning procedure. The flexible tubing on the peristaltic pump was replaced before each sample location and the Teflon tubing was cleaned. The field blank was collected using the peristaltic pump, the new piece of flexible tubing, and the clean Teflon tubing. The 10 duplicate samples were collected in a separate VOC vial in sequence after the environmental sample was collected. Screen blanks were collected to ensure that the well screen was clean after decontamination. After all drilling equipment was thoroughly cleaned, the screen was placed in the drill rod. DI water was poured into the screen and rod. The screen blank sample was then dispensed directly into the VOC vial. All of the field blanks were collected with DI water from the USGS Delaware Subdistrict Laboratory in Dover, Delaware. All blanks were analyzed at the DNTS laboratory for VOCs. To minimize cross-contamination, the Hydrolab, flow-through cell, and glassware were rinsed with DI water between samples.

Sample Handling Procedures and Analytical Methods

The laboratory and field analytical methods and preservatives for ground-water samples collected from direct-push ground-water sampling at the DNTS are listed in table 1. VOC samples were placed on ice in a cooler and delivered to the DNTS laboratory on the day of sample collection. All samples and blanks were analyzed using method SW-846

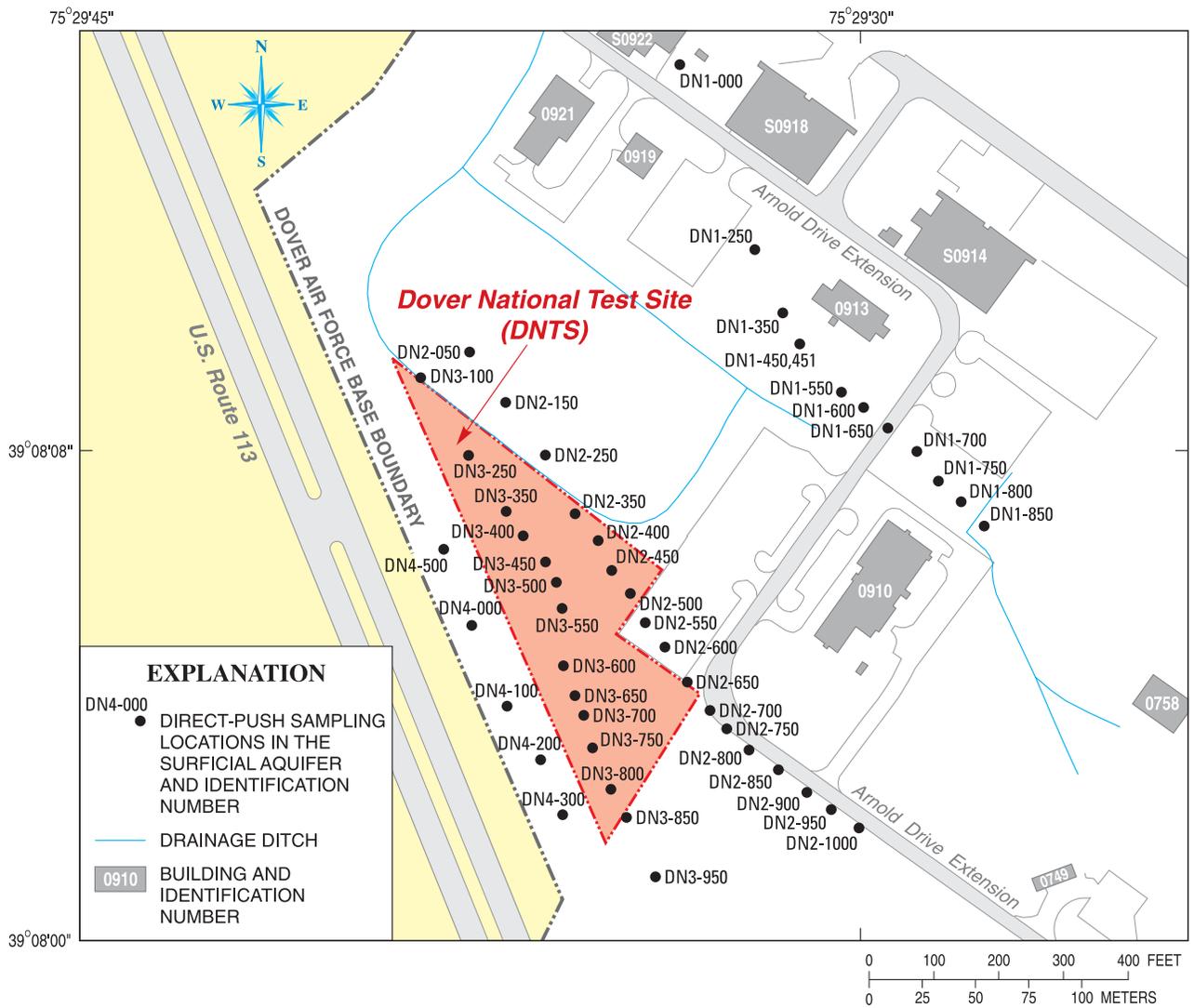


Figure 2. Locations of direct-push sampling sites at the Dover National Test Site, Dover Air Force Base, Delaware.

Table 1. *Field and laboratory methods for direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[HCl, hydrochloric acid; HgCl₂, mercuric chloride]

| Constituent | Analytical Method | Preservative |
|---------------------------------------|-------------------------------------|--------------------|
| Laboratory | | |
| Volatile organic compounds | ¹ SW-846 8021B | HCl |
| Methane | ² U.S. Geological Survey | Hg Cl ₂ |
| Field | | |
| pH, specific conductance, temperature | Hydrolab/Direct Measurement | None |
| Dissolved oxygen | Hydrolab/Winkler Titration | None |
| Total iron | HACH DR2000/Colorimetric | None |
| Ferrous iron | HACH DR2000/Colorimetric | None |
| Sulfide | HACH DR2000/Colorimetric | None |
| Sulfate | HACH DR2000/Colorimetric | None |

¹ SW-846, U.S. Environmental Protection Agency, 1996.

² Baedecker and Cozzarelli, 1992.

8021B (U.S. Environmental Protection Agency, 1996). Method reporting limits (MRLs) for the VOCs of interest are shown in table 2.

Temperature, pH, specific conductance, and DO were analyzed in the field with a Hydrolab multiprobe connected to a flow-through cell on the discharge line of the pump. The pH and specific conductance probes of the Hydrolab were calibrated daily with standard solutions prepared at the USGS laboratory in Ocala, Florida. When the DO level reached 2 mg/L (milligrams per liter) or less with the multiprobe, a modified Winkler titration was used to determine the DO concentration. This method is more accurate and reproducible at low DO concentrations (Baedecker and Cozzarelli, 1992). The MRL for DO is 0.2 mg/L.

Ferrous and total iron, sulfide, and sulfate were measured colorimetrically in unfiltered samples immediately after collection in the DNTS laboratory. These analyses were performed with spectrophotometers that contain pre-programmed calibration curves. Iron was analyzed with a Hach DR2000 spectrophotometer. One total iron and one ferrous iron check standard were run daily along with ground-water samples. Sulfide was analyzed with a Chemetrics sulfide kit and sulfate was analyzed with a Hach sulfate kit. Spectrophotometers were zeroed with raw ground water before each sample was read in the instrument. The method detection limits (MDLs) for ferrous and total iron are 0.02 mg/L. The instrument detection limit for sulfide is 0.01 mg/L and the lowest calibration standard used for sulfate is 7 mg/L. Seven duplicate field analyses were run on ferrous and total iron, sulfate, and sulfide. In addition, check standards were run

daily on sulfate. Twenty-one field blank samples were run for ferrous and total iron, sulfate, and sulfide.

Methane samples were not collected at all sampling locations, although samples were generally collected from locations where the DO concentrations were less than 1.0 mg/L. Some samples were collected in locations where DO concentrations were greater than 1.0 mg/L to determine whether methane was present at these locations. The methane samples were injected by syringe into sealed serum vials, which had been preserved with mercuric chloride and purged with nitrogen gas prior to sample collection. All methane samples were collected in duplicate. Methane samples were analyzed using a gas chromatograph with a flame-ionization detector. This procedure is described in detail in Baedecker and Cozzarelli (1992). The USGS field laboratory at Aberdeen Proving Ground, Maryland analyzed the methane samples, and uses internal standards and surrogates on every sample and blank that is analyzed. In addition, the field laboratory participates in a blind sampling program (Spencer and others, 2000).

VOCs were analyzed at the DNTS at DAFB. Samples were analyzed using the U.S. Environmental Protection Agency (USEPA) Method 8021B procedure (U.S. Environmental Protection Agency, 1996), Headspace Method 5021 (U.S. Environmental Protection Agency, December 1996). Samples were analyzed on a Hewlett Packard 6890A gas chromatograph (GC) equipped with flame ionization and electron capture detectors, a Hewlett Packard 7694 automatic headspace sampler, and a Supelco SPB-624 capillary

Table 2. Method reporting limits and maximum contaminant levels for volatile organic compounds

[MTBE, methyl *tert*-butyl ether; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-1,2-DCE, *cis*-1,2-dichloroethene; µg/L, micrograms per liter; DNTS, Dover National Test Site; --, no data]

| Target Analyte | DNTS Modified 8021B Method Reporting Limit ¹ (µg/L) | Maximum Contaminant Levels (µg/L) |
|---------------------|--|--------------------------------------|
| MTBE | 0.5 | -- |
| PCE | 1.3 | 5 |
| TCE | 0.8 | 5 |
| <i>cis</i> -1,2-DCE | 0.6 | 70 |
| Benzene | 0.6 | 5 |
| Toluene | 1.4 | 1,000 |
| Ethylbenzene | 1.3 | 700 |
| <i>p,m</i> -xylene | 2.6 | 10,000 |
| <i>o</i> -xylene | 1.2 | 10,000 |

¹ U.S. Environmental Protection Agency, 1996.

column. To prepare samples and standards for analyses, 5 mL of sample was transferred to 20-mL headspace vials and sealed. For quality control, check standards (Supelco custom VOC mixture and MTBE standards) were run approximately every 10 samples during each sample run, and laboratory blanks prepared with reagent grade DI water were run periodically, as needed. A five-point calibration curve was used to determine VOC concentrations (Barbaro and Neupane, 2002). Analytical MRLs are shown in table 2. According to USEPA Method 8021B, Method 5021 for headspace GC recoveries must be below a 20-percent difference, which means that standards must be monitored frequently and compared against the initial calibration curve. If the recoveries ever exceed a 20-percent difference, the standards need to be replaced, the initial calibration has to be recomputed, and then the samples are rerun. Standards are routinely replaced according to the manufacturers' specifications. A detailed explanation of the standard preparation can be found in the USEPA Method 8021B documentation (U.S. Environmental Protection Agency, December 1996).

Analytical Results of Ground-Water Samples

The analytical results from the direct-push sampling program are summarized in this section. Field measurements (pH, temperature, specific conductance, and DO) and sampling depths for each sample are presented in table 3. The lack of field parameters for some samples is due to low ground-water yield at those locations. pH values ranged

from 4.3 to 5.9. The DO concentrations ranged from below the MRL (0.2 mg/L) to 7.0 mg/L. Results below the MRL for DO are listed as less than (<) 0.2 mg/L.

Concentrations of VOCs from all wells are shown in table 4. Maximum contaminant levels (MCLs) were not exceeded for benzene, toluene, ethylbenzene, xylenes, *cis*-1,2-DCE, TCE, or PCE. The MCLs for selected VOCs are shown in table 2. Currently, there is no MCL for MTBE. However, the USEPA has a drinking-water advisory of 20–40 µg/L (micrograms per liter) for MTBE that is based on taste and odor (U.S. Environmental Protection Agency, 1997). Values for compounds that were detected but had concentrations below the MRL of a given compound are listed as less than (<) the detection limit. This means that the compound was identified but not quantifiable. Compounds that were not detected are listed as not detected (ND). In addition, vinyl chloride was not detected in any samples.

VOCs were above the MRLs in 59 ground-water samples. The concentrations ranged from below the MRLs to maximum values of 12.4 µg/L of *cis*-1,2-DCE, 1.14 µg/L of TCE, 2.65 µg/L of PCE, 1,070 µg/L of MTBE, 4.36 µg/L of benzene, and 1.8 µg/L of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this study. MTBE was detected above the MRL in 47 of the 115 ground-water samples with a maximum concentration of 1,070 µg/L.

Concentrations of ferrous iron, total iron, sulfide, sulfate, and methane in ground-water samples from direct-push sampling are shown in table 5. All analyses were performed on unfiltered samples. Ferrous iron concentrations ranged from <0.02 to 6.0 mg/L. Total iron concentrations ranged from

<0.02 to 25.2 mg/L. When unfiltered samples are collected using a direct-push drilling method and analyzed using a colorimetric method in the field, turbidity can interfere with the analyses when low levels of total and ferrous iron are present. Therefore, for selected samples the ferrous iron value may exceed the total iron value for low-level detections. The exact extent to which the precision of the method was influenced was not determined, however, because the iron data are only being used as a screening tool. Sulfide concentrations were below the MDL for all samples, except for those from sites DN3-400A and DN3-450A. Sulfate concentrations ranged from <7 to 149 mg/L. Methane concentrations ranged from below the MDL to 741.1 µg/L.

Twenty-one sets of DI blank water samples were analyzed for total iron, ferrous iron, sulfate, and sulfide. Total iron, ferrous iron and sulfide were below the MDL for all DI blank water samples. Two DI blank water samples had sulfate concentrations of 8 mg/L; the other 19 were below the MDL. Check standards of 7, 20, 50, and 70 mg/L of sulfate were used daily. All check standards agreed consistently with the meter readings.

Water-Level Measurements

Water-level measurements were collected on July 1, 2001 from wells in and around the DNTS. The locations of ground-water level measurements in the upper and lower parts of the surficial aquifer are shown in figures 3a and 3b. Ground-water elevation data for the surficial aquifer are shown in table 6.

Quality-Control Results

QC samples collected from June 27 through July 18, 2001 consisted of 1 equipment blank, 14 field blanks, 10 duplicates, and 7 screen blanks (table 7). VOCs were not detected in most of the QC samples. TCE and PCE were detected in some QC samples, but the concentrations were below the laboratory reporting limits. The low VOC concentrations in the blanks may have been the result of internal laboratory contamination or the tubing-cleaning procedure. However, concentrations in the blanks were not high enough to bias the interpretation of environmental concentrations of VOCs. The median for TCE and *cis*-1,2-DCE in the QC samples was <8 µg/L and not detected, respectively, which means that the median for TCE was not detected and the median *cis*-1,2-DCE was not quantifiable. MTBE was detected in one of the screen blanks. It is unlikely that this contamination affected the next sample, because that location had the highest MTBE concentration in the study area (DN1-850B).

For detected compounds, the consistency between concentrations in duplicate samples is indicated by the relative percent difference (RPD) and is shown in table 8. The equation used to calculate the RPD is as follows:

$$\frac{|(x1 - x2)|}{ave(x1, x2)} * 100,$$

where *x1* is a sample value, *x2* is the duplicate sample value, and *ave* is average.

Estimates of measurement reproducibility for some analytes were limited because the concentration of one or both duplicates in the pair was frequently below the method reporting limit. RPDs were not calculated for these pairs. All RPD values were less than or equal to 22.1 percent, with the exception of one site (DN1-650A; the RPD for the concentrations of the duplicate pair for *cis*-1,2-DCE was 104 percent, and the concentrations were 0.9 µg/L and 2.84 µg/L).

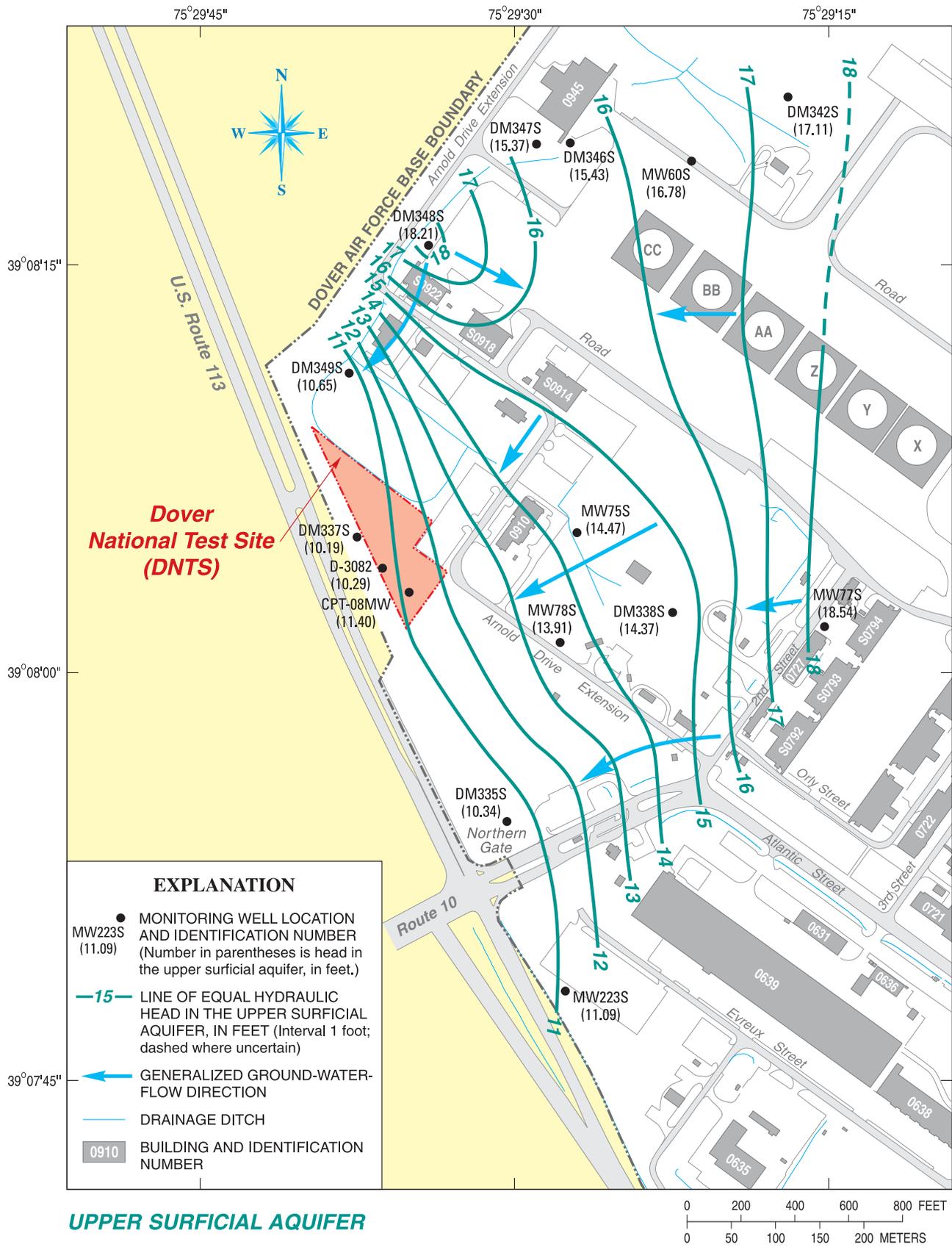


Figure 3a. Location of ground-water level measurements in the upper part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.

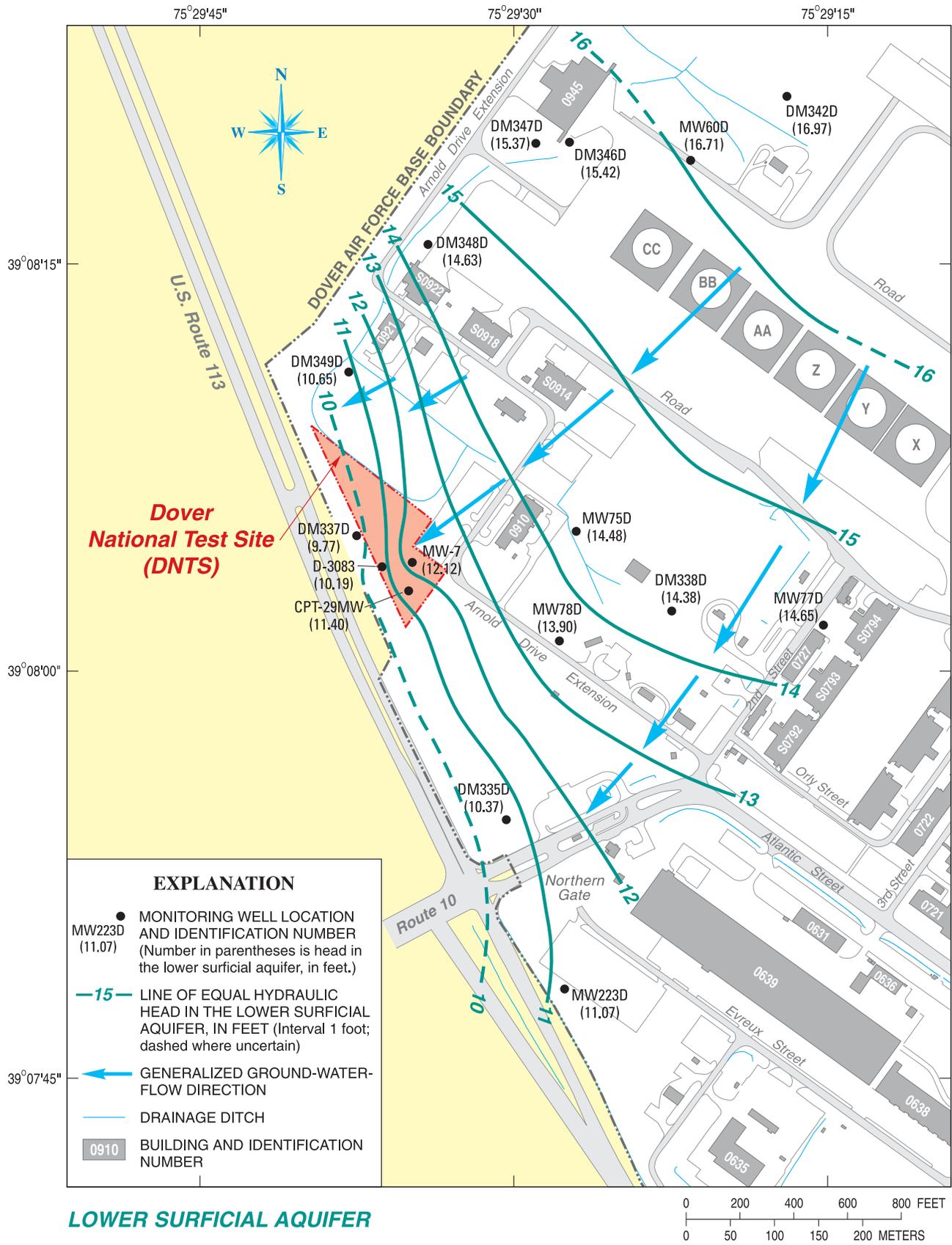


Figure 3b. Location of ground-water level measurements in the lower part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[ft, feet; bls, below land surface; msl, mean sea level; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; --, no data; <, less than]

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN1-000C | 06/29/2001 | 27.6 | 20 | 11.6 | 7.6 | 4.9 | 17.0 | 188 | 3.3 |
| DN1-000B | 06/29/2001 | 27.6 | 28 | 3.6 | -0.4 | 5.7 | 17.3 | 153 | 0.27 |
| DN1-000A | 06/29/2001 | 27.6 | 36 | -4.4 | -8.4 | 4.9 | 18.6 | 71 | 0.30 |
| DN1-250C | 06/29/2001 | 29.3 | 20 | 13.3 | 9.3 | 5.4 | 17.6 | 335 | 1.1 |
| DN1-250B | 06/29/2001 | 29.3 | 28 | 5.3 | 1.3 | 4.9 | 18.7 | 170 | 0.50 |
| DN1-250A | 06/29/2001 | 29.3 | 36 | -2.7 | -6.7 | 4.8 | 20.0 | 91 | 0.40 |
| DN1-350C | 06/29/2001 | 28.4 | 20 | 12.4 | 8.4 | 5.2 | 17.4 | 248 | 0.39 |
| DN1-350B | 06/29/2001 | 28.4 | 28 | 4.4 | 0.4 | 4.8 | 19.1 | 165 | 0.74 |
| DN1-350A | 06/29/2001 | 28.4 | 36 | -3.6 | -7.6 | 4.9 | 18.4 | 105 | 0.31 |
| DN1-450C | 06/27/2001 | 27.9 | 16 | 12.9 | 11.9 | -- | -- | -- | -- |
| DN1-450B | 06/27/2001 | 27.9 | 24 | 4.9 | 3.9 | -- | -- | -- | -- |
| DN1-450A | 06/27/2001 | 27.9 | 32 | -3.1 | -4.1 | 5.0 | 20.6 | 146 | 0.26 |
| DN1-451B | 06/27/2001 | 27.9 | 24 | 7.9 | 3.9 | 5.1 | 19.4 | 245 | 0.57 |
| DN1-451A | 06/27/2001 | 27.9 | 32 | -0.1 | -4.1 | 4.9 | 18.2 | 169 | 0.32 |
| DN1-550C | 06/28/2001 | 28.2 | 19 | 13.2 | 9.2 | 4.6 | 18.1 | 156 | 2.0 |
| DN1-550B | 06/28/2001 | 28.2 | 27 | 5.2 | 1.2 | 5.0 | 19.4 | 172 | 0.34 |
| DN1-550A | 06/28/2001 | 28.2 | 36 | -3.8 | -7.8 | 4.9 | 18.3 | 115 | 0.33 |
| DN1-600C | 07/16/2001 | 27.3 | 20 | 11.3 | 7.3 | 4.9 | 18.9 | 299 | 0.25 |
| DN1-600B | 07/16/2001 | 27.3 | 28 | 3.3 | -0.7 | 5.1 | 19.6 | 210 | 0.24 |
| DN1-600A | 07/16/2001 | 27.3 | 36 | -4.7 | -8.7 | 5.2 | 19.4 | 124 | 0.30 |

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN1-650C | 06/28/2001 | 27.1 | 19 | 12.1 | 8.1 | 4.9 | 19.0 | 2 | 0.45 |
| DN1-650B | 06/28/2001 | 27.1 | 27 | 4.1 | 0.1 | 5.3 | 19.8 | 713 | 2.8 |
| DN1-650A | 06/28/2001 | 27.1 | 36 | -4.9 | -8.9 | 4.8 | 20.6 | 215 | 0.21 |
| DN1-700C | 07/16/2001 | 26.2 | 20 | 10.2 | 6.2 | 5.1 | 18.3 | 155 | 0.28 |
| DN1-700B | 07/16/2001 | 26.2 | 28 | 2.2 | -1.8 | 5.2 | 18.6 | 142 | 0.28 |
| DN1-700A | 07/16/2001 | 26.2 | 36 | -5.8 | -9.8 | 5.2 | 18.9 | 220 | 0.26 |
| DN1-750C | 06/28/2001 | 25.6 | 20 | 9.6 | 5.6 | 4.9 | 17.7 | 134 | 0.41 |
| DN1-750B | 06/28/2001 | 25.6 | 28 | 1.6 | -2.4 | 4.9 | 18.3 | 158 | 0.24 |
| DN1-750A | 06/28/2001 | 25.6 | 36 | -6.4 | -10.4 | 5.3 | 19.5 | 595 | 3.5 |
| DN1-800C | 07/16/2001 | 25.5 | 20 | 9.5 | 5.5 | 4.9 | 16.8 | 127 | 0.28 |
| DN1-800B | 07/16/2001 | 25.5 | 28 | 1.5 | -2.5 | 5.2 | 17.3 | 151 | 0.14 |
| DN1-800A | 07/16/2001 | 25.5 | 36 | -6.5 | -10.5 | 5.3 | 18.0 | 140 | 0.52 |
| DN1-850C | 06/28/2001 | 24.5 | 20 | 8.5 | 4.5 | 5.1 | 15.5 | 156 | 0.26 |
| DN1-850B | 06/28/2001 | 24.5 | 28 | 0.5 | -3.5 | 5.1 | 16.6 | 20 | <0.20 |
| DN1-850A | 06/28/2001 | 24.5 | 36 | -7.5 | -11.5 | 4.8 | 17.7 | 108 | 0.54 |
| DN2-050B | 07/03/2001 | 31.0 | 24 | 11.0 | 7.0 | 5.2 | 20.6 | 227 | 1.2 |
| DN2-050A | 07/03/2001 | 31.0 | 32 | 3.0 | -1.0 | 5.2 | 19.9 | 182 | 0.21 |
| DN2-150B | 07/03/2001 | 30.6 | 20 | 14.6 | 10.6 | 5.0 | 22.6 | 178 | 1.9 |
| DN2-150A | 07/03/2001 | 30.6 | 32 | 2.6 | -1.4 | 4.9 | -- | 189 | 1.2 |
| DN2-250B | 07/03/2001 | 30.0 | 24 | 10.0 | 6.0 | 4.6 | 17.6 | 173 | 3.2 |
| DN2-250A | 07/03/2001 | 30.0 | 32 | 2.0 | -2.0 | 4.9 | 20.1 | 174 | 2.0 |

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN2-350B | 07/03/2001 | 30.9 | 24 | 10.9 | 6.9 | 4.8 | 17.5 | 244 | 3.0 |
| DN2-350A | 07/03/2001 | 30.9 | 32 | 2.9 | -1.1 | 4.8 | 16.6 | 235 | 1.0 |
| DN2-400B | 07/13/2001 | 30.6 | 28 | 6.6 | 2.6 | 5.1 | 17.9 | 246 | 1.7 |
| DN2-400A | 07/13/2001 | 30.6 | 36 | -1.4 | -5.4 | 5.0 | 17.6 | 171 | 0.44 |
| DN2-450B | 07/02/2001 | 31.0 | 24 | 11.0 | 7.0 | 5.3 | 17.9 | 177 | 2.6 |
| DN2-450A | 07/02/2001 | 31.0 | 32 | 3.0 | -1.0 | 5.3 | 17.7 | 175 | 0.55 |
| DN2-500C | 07/14/2001 | 29.9 | 22 | 11.9 | 7.9 | -- | -- | -- | -- |
| DN2-500B | 07/14/2001 | 29.9 | 27 | 6.9 | 2.9 | 5.7 | 20.5 | 167 | 0.79 |
| DN2-500A | 07/14/2001 | 29.9 | 36 | -2.1 | -6.1 | 5.6 | 19.4 | 143 | 0.40 |
| DN2-550C | 07/14/2001 | 30.3 | 22 | 12.3 | 8.3 | 5.5 | 19.2 | 174 | 6.1 |
| DN2-550B | 07/14/2001 | 30.3 | 28 | 6.3 | 2.3 | 5.7 | 17.7 | 176 | 0.75 |
| DN2-550A | 07/14/2001 | 30.3 | 36 | -1.7 | -5.7 | 5.6 | 17.7 | 151 | 0.49 |
| DN2-600B | 07/13/2001 | 31.0 | 24 | 11.3 | 7.3 | 4.8 | 18.0 | 173 | 6.4 |
| DN2-600A | 07/13/2001 | 31.0 | 31.3 | 3.7 | -0.7 | 4.9 | 17.9 | 157 | 0.48 |
| DN2-650B | 07/13/2001 | 31.3 | 24 | 11.3 | 7.3 | 4.8 | 18.1 | 173 | 6.4 |
| DN2-650A | 07/13/2001 | 31.3 | 32 | 3.3 | -0.7 | 5.0 | 18.0 | 157 | 0.48 |
| DN2-700C | 07/16/2001 | 31.3 | 22 | 13.3 | 9.3 | 5.3 | 18.5 | 415 | 5.4 |
| DN2-700B | 07/16/2001 | 31.3 | 28 | 7.3 | 3.3 | 5.3 | 16.0 | 291 | 2.9 |
| DN2-700A | 07/16/2001 | 31.3 | 36 | -0.7 | -4.7 | 5.2 | 16.1 | 165 | 0.33 |
| DN2-750B | 07/02/2001 | 31.2 | 24 | 11.2 | 7.2 | 5.0 | 16.5 | 421 | 5.8 |
| DN2-750A | 07/02/2001 | 31.2 | 32 | 3.2 | -0.8 | 5.1 | -- | 188 | 1.3 |

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN2-800C | 07/12/2001 | 31.0 | 22 | 13.0 | 9.0 | 4.4 | -- | 548 | -- |
| DN2-800B | 07/12/2001 | 31.0 | 28 | 7.0 | 3.0 | 4.4 | 17.7 | 262 | 4.4 |
| DN2-800A | 07/12/2001 | 31.0 | 36 | -1.0 | -5.0 | 4.7 | 18.9 | 1 | 0.50 |
| DN2-850C | 07/18/2001 | 30.6 | 20 | 14.6 | 10.6 | -- | -- | -- | -- |
| DN2-850B | 07/18/2001 | 30.6 | 28 | 6.6 | 2.6 | 4.8 | 17.4 | 148 | 0.83 |
| DN2-850A | 07/18/2001 | 30.6 | 36 | -1.4 | -5.4 | 4.8 | 16.9 | 136 | 0.54 |
| DN2-900C | 07/12/2001 | 30.2 | 20 | 14.2 | 10.2 | 4.5 | 17.3 | 346 | 5.5 |
| DN2-900B | 07/12/2001 | 30.2 | 28 | 6.2 | 2.2 | 4.7 | 17.4 | 142 | 1.7 |
| DN2-900A | 07/12/2001 | 30.2 | 36 | -1.8 | -5.8 | 4.7 | 17.8 | 93 | 0.51 |
| DN2-950C | 07/18/2001 | 29.9 | 20 | 13.9 | 9.9 | -- | -- | -- | -- |
| DN2-950B | 07/18/2001 | 29.9 | 28 | 5.9 | 1.9 | 4.8 | 17.2 | 154 | 2.4 |
| DN2-950A | 07/18/2001 | 29.9 | 36 | -2.1 | -6.1 | 4.7 | 17.7 | 120 | 0.68 |
| DN2-1000C | 07/12/2001 | 29.5 | 20 | 13.5 | 9.5 | 5.4 | 16.8 | 598 | 3.8 |
| DN2-1000B | 07/12/2001 | 29.5 | 28 | 5.5 | 1.5 | 4.7 | 17.8 | 133 | 0.48 |
| DN2-1000A | 07/12/2001 | 29.5 | 36 | -2.5 | -6.5 | 4.6 | 16.7 | 117 | 0.28 |
| DN3-100B | 07/05/2001 | 28.7 | 24 | 8.7 | 4.7 | 4.9 | 17.8 | 177 | 2.7 |
| DN3-100A | 07/05/2001 | 28.7 | 32 | 0.7 | -3.3 | 4.9 | 17.9 | 134 | 0.80 |
| DN3-250B | 07/05/2001 | 32.4 | 28 | 8.4 | 4.4 | 4.9 | 20.7 | 204 | 2.6 |
| DN3-250A | 07/05/2001 | 32.4 | 36 | 0.4 | -3.6 | 4.9 | 17.2 | 191 | 2.3 |
| DN3-350B | 07/05/2001 | 32.8 | 24 | 12.8 | 8.8 | 4.6 | 19.3 | 174 | 3.3 |
| DN3-350A | 07/05/2001 | 32.8 | 32 | 4.8 | 0.8 | 4.7 | 17.6 | 171 | 1.6 |

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN3-400B | 07/10/2001 | 33.5 | 28 | 9.5 | 5.5 | 4.3 | 21.1 | 2 | 3.3 |
| DN3-400A | 07/10/2001 | 33.5 | 32 | 5.5 | 1.5 | 4.7 | 23.7 | 240 | 2.8 |
| DN3-450B | 07/05/2001 | 33.5 | 28 | 9.5 | 5.5 | 5.0 | 22.4 | 190 | 1.7 |
| DN3-450A | 07/05/2001 | 33.5 | 36 | 1.5 | -2.5 | 5.0 | -- | 199 | 1.2 |
| DN3-500B | 07/13/2001 | 33.5 | 26 | 11.5 | 7.5 | -- | -- | -- | 2.6 |
| DN3-500A | 07/13/2001 | 33.5 | 32 | 5.5 | 1.5 | 4.9 | 21.2 | 161 | 0.91 |
| DN3-550B | 07/05/2001 | 33.6 | 28 | 9.6 | 5.6 | 5.2 | 19.1 | 146 | 3.8 |
| DN3-550A | 07/05/2001 | 33.6 | 36 | 1.6 | -2.4 | 5.0 | 20.8 | 152 | 0.50 |
| DN3-600B | 07/13/2001 | 35.4 | 28 | 11.4 | 7.4 | 5.1 | 20.4 | 165 | 4.1 |
| DN3-600A | 07/13/2001 | 35.4 | 36 | 3.4 | -0.6 | 5.2 | 19.5 | 167 | 0.51 |
| DN3-650B | 07/06/2001 | 35.6 | 28 | 11.6 | 7.6 | -- | -- | -- | -- |
| DN3-650A | 07/06/2001 | 35.6 | 36 | 3.6 | -0.4 | 4.9 | 20.0 | 139 | 0.40 |
| DN3-700B | 07/13/2001 | 35.4 | 28 | 11.4 | 7.4 | 5.0 | 21.2 | 753 | 7.0 |
| DN3-700A | 07/13/2001 | 35.4 | 36 | 3.4 | -0.6 | 4.9 | 19.4 | 259 | 0.59 |
| DN3-750B | 07/06/2001 | 34.8 | 28 | 10.8 | 6.8 | 4.3 | 23.4 | 188 | 4.8 |
| DN3-750A | 07/06/2001 | 34.8 | 36 | 2.8 | -1.2 | 4.8 | 21.4 | 113 | 0.85 |
| DN3-800B | 07/12/2001 | 35.2 | 28 | 11.2 | 7.2 | 4.9 | 20.5 | 190 | 5.5 |
| DN3-800A | 07/12/2001 | 35.2 | 36 | 3.2 | -0.8 | 4.5 | 17.7 | 100 | 0.62 |
| DN3-850B | 07/10/2001 | 34.8 | 28 | 10.8 | 6.8 | 4.9 | 20.1 | 147 | 4.6 |
| DN3-850A | 07/10/2001 | 34.8 | 36 | 2.8 | -1.2 | -- | -- | -- | -- |

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

| Sample identification number | Sampling date | Ground surface (ft msl) | Total depth (ft bls) | Altitude of top of sample interval (ft msl) | Altitude of bottom of sample interval (ft msl) | pH | Temperature (°C) | Specific conductance (µS/cm) | Dissolved oxygen (mg/L) |
|------------------------------|---------------|-------------------------|----------------------|---|--|-----|------------------|------------------------------|-------------------------|
| DN3-950B | 07/10/2001 | 34.2 | 28 | 10.2 | 6.2 | 4.7 | 21.5 | 156 | 3.2 |
| DN3-950A | 07/10/2001 | 34.2 | 36 | 2.2 | -1.8 | 4.8 | 18.8 | 106 | 0.37 |
| DN4-000A | 07/10/2001 | 36.8 | 36 | 4.8 | 0.8 | -- | -- | -- | -- |
| DN4-100C* | 07/11/2001 | 36.5 | -- | -- | -- | -- | -- | -- | -- |
| DN4-100B | 07/11/2001 | 36.5 | 28 | 12.5 | 8.5 | -- | -- | -- | -- |
| DN4-100A | 07/11/2001 | 36.5 | 32 | 8.5 | 4.5 | 5.4 | 21.0 | 232 | 4.7 |
| DN4-200B | 07/11/2001 | 37.4 | 32 | 9.4 | 5.4 | 5.4 | 21.8 | 347 | 0.65 |
| DN4-200A | 07/11/2001 | 37.4 | 40 | 1.4 | -2.6 | -- | -- | -- | -- |
| DN4-300B | 07/11/2001 | 36.8 | 32 | 8.8 | 4.8 | 5.9 | 20.5 | 254 | 0.2 |
| DN4-300A | 07/11/2001 | 36.8 | 40 | 0.8 | -3.2 | 5.2 | 19.9 | 119 | 1.2 |
| DN4-500B | 07/17/2001 | 36.0 | 36 | 4.0 | 0.0 | 5.6 | 22.0 | 192 | <0.20 |
| DN4-500A | 07/17/2001 | 36.0 | 40 | 0.0 | -4.0 | 5.1 | 22.0 | 213 | <0.20 |

* Field parameters were not collected due to insufficient sample volume.

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[*cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; $\mu\text{g/L}$, micrograms per liter; ND, not detected; <, less than; detections of MTBE in **bold**]

| Sample identification number | <i>cis</i> -1,2-DCE ($\mu\text{g/L}$) | TCE ($\mu\text{g/L}$) | PCE ($\mu\text{g/L}$) | Vinyl chloride ($\mu\text{g/L}$) | | | Ethylbenzene ($\mu\text{g/L}$) | | | |
|------------------------------|---|-------------------------|-------------------------|------------------------------------|-----------------------------|-----------------------------|--|--------------------------------------|----|----|
| | | | | MTBE ($\mu\text{g/L}$) | Benzene ($\mu\text{g/L}$) | Toluene ($\mu\text{g/L}$) | <i>p,m</i> -xylene ($\mu\text{g/L}$) | <i>o</i> -xylene ($\mu\text{g/L}$) | | |
| DN1-000C | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN1-000B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-000A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-250C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-250B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-250A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-350C | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-350B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-350A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-450C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-450B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-450A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-451B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-451A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-550C | 4.63 | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-550B | 3.86 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-550A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-600C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-600B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-600A | ND | ND | ND | ND | 1.54 | ND | ND | ND | ND | ND |

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|--------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN1-650C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-650B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-650A | 0.9 | ND | ND | ND | 6.27 | ND | ND | ND | ND | ND |
| DN1-700C | ND | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN1-700B | ND | ND | ND | ND | 22.5 | ND | ND | ND | ND | ND |
| DN1-700A | ND | ND | ND | ND | 4.64 | ND | 1.8 | ND | ND | ND |
| DN1-750C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN1-750B | ND | ND | ND | ND | ND | 3.24 | ND | ND | ND | ND |
| DN1-750A | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN1-800C | ND | ND | <1.3 | ND | 248 | ND | ND | ND | ND | ND |
| DN1-800B | ND | ND | ND | ND | 74.1 | 3.06 | 1.7 | ND | ND | ND |
| DN1-800A | ND | ND | ND | ND | 87.3 | 4.13 | <1.4 | ND | ND | ND |
| DN1-850C | ND | ND | ND | ND | 551 | 1.02 | <1.4 | ND | ND | ND |
| DN1-850B | ND | <0.8 | ND | ND | 1,070 | 3.81 | <1.4 | ND | ND | ND |
| DN1-850A | ND | ND | ND | ND | 290 | 4.36 | 1.67 | ND | ND | ND |
| DN2-050B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-050A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-150B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-150A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-250B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-250A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|-------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN2-350B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-350A | ND | ND | ND | ND | 3.45 | ND | ND | ND | ND | ND |
| DN2-400B | ND | ND | ND | ND | 7.75 | ND | ND | ND | ND | ND |
| DN2-400A | ND | <0.8 | ND | ND | 25.6 | 1.41 | ND | ND | ND | ND |
| DN2-450B | ND | ND | ND | ND | 37.2 | ND | ND | ND | ND | ND |
| DN2-450A | ND | ND | ND | ND | 127 | <0.6 | <1.4 | ND | ND | ND |
| DN2-500C | ND | ND | ND | ND | 29.2 | ND | ND | ND | ND | ND |
| DN2-500B | ND | ND | ND | ND | 200 | ND | ND | ND | ND | ND |
| DN2-500A | ND | ND | ND | ND | 213 | 0.63 | ND | ND | ND | ND |
| DN2-550C | ND | ND | ND | ND | 2.87 | ND | ND | ND | ND | ND |
| DN2-550B | ND | ND | ND | ND | 111 | ND | ND | ND | ND | ND |
| DN2-550A | ND | <0.8 | <1.3 | ND | 84.7 | 0.79 | <1.4 | ND | ND | ND |
| DN2-600B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-600A | ND | ND | ND | ND | 4.19 | <0.6 | ND | ND | ND | ND |
| DN2-650B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-650A | ND | ND | ND | ND | 5.69 | ND | ND | ND | ND | ND |
| DN2-700C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-700B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-700A | ND | ND | ND | ND | 8.18 | 0.81 | ND | ND | ND | ND |
| DN2-750B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-750A | 3.19 | ND | ND | ND | 4.49 | ND | ND | ND | ND | ND |

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|-------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN2-800C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-800B | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-800A | ND | ND | ND | ND | 14.7 | ND | ND | ND | ND | ND |
| DN2-850C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-850B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-850A | ND | ND | ND | ND | 16.5 | ND | ND | ND | ND | ND |
| DN2-900C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-900B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-900A | ND | ND | ND | ND | 7.23 | ND | ND | ND | ND | ND |
| DN2-950C | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-950B | ND | ND | ND | ND | 2.15 | ND | ND | ND | ND | ND |
| DN2-950A | ND | ND | ND | ND | 6.88 | ND | ND | ND | ND | ND |
| DN2-1000C | ND | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-1000B | ND | <0.8 | <1.3 | ND | 19.1 | ND | ND | ND | ND | ND |
| DN2-1000A | ND | <0.8 | <1.3 | ND | 20.4 | ND | ND | ND | ND | ND |
| DN3-100B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-100A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-250B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-250A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-350B | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-350A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|-------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN3-400B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-400A | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-450B | ND | ND | ND | ND | 17.4 | ND | ND | ND | ND | ND |
| DN3-450A | ND | ND | ND | ND | 42.7 | ND | ND | ND | ND | ND |
| DN3-500B | ND | ND | ND | ND | 104 | ND | ND | ND | ND | ND |
| DN3-500A | ND | ND | ND | ND | 139 | ND | ND | ND | ND | ND |
| DN3-550B | ND | ND | ND | ND | 26.1 | ND | ND | ND | ND | ND |
| DN3-550A | ND | ND | ND | ND | 230 | 0.79 | ND | ND | ND | ND |
| DN3-600B | ND | ND | ND | ND | 3.08 | ND | ND | ND | ND | ND |
| DN3-600A | ND | ND | <1.3 | ND | 17.2 | ND | ND | ND | ND | ND |
| DN3-650B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-650A | ND | <0.8 | <1.3 | ND | 11.3 | ND | ND | ND | ND | ND |
| DN3-700B | ND | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-700A | ND | ND | <1.3 | ND | 7.91 | ND | ND | ND | ND | ND |
| DN3-750B | 2.1 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-750A | 1.76 | ND | ND | ND | 11.3 | ND | ND | ND | ND | ND |
| DN3-800B | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-800A | 0.93 | ND | ND | ND | 8.21 | ND | ND | ND | ND | ND |
| DN3-850B | 1.77 | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-850A | 6.33 | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|-------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN3-950B | 1.12 | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-950A | 1.81 | 1.14 | 2.65 | ND | ND | ND | ND | ND | ND | ND |
| DN4-000A | ND | ND | ND | ND | 63.0 | ND | ND | ND | ND | ND |
| DN4-100C | 1.45 | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN4-100B | 1.42 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN4-100A | 12.4 | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN4-200B | 4.01 | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN4-200A | 3.42 | ND | ND | ND | 7.01 | ND | ND | ND | ND | ND |
| DN4-300B | 4.79 | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| DN4-300A | 1.46 | <0.8 | ND | ND | 1.4 | ND | ND | ND | ND | ND |
| DN4-500B | ND | ND | ND | ND | ND | ND | <1.4 | ND | ND | ND |
| DN4-500A | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |

Table 5. *Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[Samples for ferrous iron were unfiltered and turbidity may have interfered with sample analysis; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data available; <, less than]

| Sample identification number | Ferrous iron (mg/L) | Total iron (mg/L) | Sulfide (mg/L) | Sulfate (mg/L) | Methane (µg/L) |
|-------------------------------------|----------------------------|--------------------------|-----------------------|-----------------------|-----------------------|
| DN1-000C | 1.85 | 3.26 | -- | 9 | <25.4 |
| DN1-000B | 1.11 | 0.60 | -- | 11 | 534.8 |
| DN1-000A | 1.03 | 7.50 | -- | 8 | <27.1 |
| DN1-250C | 3.90 | 4.80 | -- | 11 | -- |
| DN1-250B | 1.10 | 0.78 | -- | 17 | <26.4 |
| DN1-250A | 0.40 | 1.00 | -- | 15 | -- |
| DN1-350C | 4.70 | 4.50 | -- | 37 | -- |
| DN1-350B | 1.64 | 2.49 | -- | 18 | -- |
| DN1-350A | 0.50 | 1.09 | -- | 15 | 160.2 |
| DN1-450C | 3.50 | 5.50 | -- | 29 | 87.8 |
| DN1-450B | 2.37 | 8.40 | -- | <7 | -- |
| DN1-450A | 3.22 | 9.20 | -- | 54 | -- |
| DN1-451B | 1.99 | 3.70 | -- | 30 | -- |
| DN1-451A | 2.35 | 2.83 | -- | 44 | -- |
| DN1-550C | 2.82 | 25.20 | -- | <7 | -- |
| DN1-550B | 6.00 | 7.20 | -- | 27 | 65.9 |
| DN1-550A | 2.42 | 6.70 | -- | 128 | -- |
| DN1-600C | 1.39 | 1.20 | <0.01 | 16 | -- |
| DN1-600B | 2.14 | 2.21 | <0.01 | 15 | -- |
| DN1-600A | 0.45 | 0.76 | <0.01 | 14 | 183.9 |
| DN1-650C | 1.22 | 1.80 | -- | 34 | -- |
| DN1-650B | 3.28 | 4.50 | -- | 33 | -- |
| DN1-650A | 1.70 | -- | -- | 72 | 290.6 |
| DN1-650A DUP | 3.08 | -- | -- | 56 | -- |
| DN1-700C | 1.91 | 1.59 | <0.01 | 19 | -- |
| DN1-700B | 2.13 | 3.40 | <0.01 | 13 | -- |
| DN1-700A | 0.90 | 1.14 | <0.01 | 53 | 184.7 |
| DN1-750C | -- | 2.12 | -- | 23 | -- |
| DN1-750B | 1.17 | 5.50 | -- | 23 | 179.3 |
| DN1-750A | 1.59 | 3.27 | -- | 62 | -- |
| DN1-800C | 1.11 | 1.00 | <0.01 | 23 | -- |
| DN1-800B | 1.06 | 0.86 | <0.01 | 23 | 82.1 |
| DN1-800B DUP | 0.80 | 0.83 | <0.01 | 23 | -- |
| DN1-800A | 0.17 | 0.31 | <0.01 | 18 | 164.3 |

Table 5. Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | Ferrous iron (mg/L) | Total iron (mg/L) | Sulfide (mg/L) | Sulfate (mg/L) | Methane (µg/L) |
|------------------------------|---------------------|-------------------|----------------|----------------|----------------|
| DN1-850C | 2.25 | 9.30 | -- | 36 | 741.1 |
| DN1-850B | 2.10 | 4.70 | -- | 30 | -- |
| DN1-850A | 0.57 | -- | -- | 21 | -- |
| DN2-050B | <0.02 | 0.03 | -- | 41 | <27.0 |
| DN2-050A | 1.21 | 0.32 | -- | 9 | -- |
| DN2-150A | 0.09 | 2.15 | -- | 17 | -- |
| DN2-250B | 1.05 | 1.81 | -- | 4 | <27.1 |
| DN2-250B DUP | 1.69 | 3.12 | -- | 14 | -- |
| DN2-250A | 0.75 | 2.68 | -- | 30 | -- |
| DN2-350B | 0.23 | 1.63 | -- | 35 | -- |
| DN2-350A | 0.31 | 0.93 | -- | 25 | -- |
| DN2-400B | 2.01 | 14.30 | <0.01 | 31 | -- |
| DN2-400A | 2.17 | 2.50 | <0.01 | 21 | 97.1 |
| DN2-400A DUP | 1.63 | 2.63 | <0.01 | 22 | -- |
| DN2-450B | 0.13 | 1.13 | -- | 13 | -- |
| DN2-450A | 2.11 | 2.52 | -- | 34 | -- |
| DN2-500C | -- | -- | -- | -- | -- |
| DN2-500B | 1.49 | 1.32 | <0.01 | 13 | <26.9 |
| DN2-500A | 1.27 | 2.38 | <0.01 | 33 | 59.3 |
| DN2-550C | 0.20 | 0.15 | <0.01 | 12 | -- |
| DN2-550B | 0.47 | 1.17 | <0.01 | 13 | -- |
| DN2-550A | 0.38 | 0.55 | <0.01 | 11 | -- |
| DN2-600B | 0.56 | 0.73 | <0.01 | 21 | -- |
| DN2-600A | 1.17 | 2.20 | <0.01 | 23 | 121.3 |
| DN2-650B | 0.71 | 1.01 | -- | 25 | -- |
| DN2-650A | 1.10 | 1.67 | -- | 45 | -- |
| DN2-700C | 1.48 | 2.01 | <0.01 | 9 | -- |
| DN2-700B | 3.60 | 5.80 | <0.01 | 33 | -- |
| DN2-700A | 3.30 | 5.60 | <0.01 | 28 | 34.8 |

Table 5. Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | Ferrous iron (mg/L) | Total iron (mg/L) | Sulfide (mg/L) | Sulfate (mg/L) | Methane (µg/L) |
|------------------------------|---------------------|-------------------|----------------|----------------|----------------|
| DN2-750B | 0.46 | 0.55 | -- | 23 | -- |
| DN2-750B DUP | 0.72 | 0.84 | -- | 19 | -- |
| DN2-750A | 3.60 | 1.17 | -- | 26 | -- |
| DN2-800C | 1.86 | 2.82 | <0.01 | 13 | -- |
| DN2-800B | 0.07 | 1.05 | <0.01 | 22 | <26.3 |
| DN2-800A | 1.04 | 1.05 | <0.01 | 17 | -- |
| DN2-850C | 0.12 | <0.02 | <0.01 | 20 | -- |
| DN2-850B | 1.54 | 1.40 | <0.01 | 23 | <26.3 |
| DN2-850A | 0.24 | 0.21 | <0.01 | 30 | 37.5 |
| DN2-900C | 0.79 | 0.90 | <0.01 | 30 | -- |
| DN2-900B | 0.87 | 1.77 | <0.01 | 23 | -- |
| DN2-900A | 0.36 | 2.83 | <0.01 | 12 | 83.4 |
| DN2-950C | 3.04 | 3.70 | <0.01 | 26 | <26.7 |
| DN2-950B | 0.79 | 1.16 | <0.01 | 29 | 31.5 |
| DN2-950B DUP | 0.75 | 1.21 | <0.01 | 28 | -- |
| DN2-950A | 1.16 | 2.51 | <0.01 | 15 | -- |
| DN2-1000C | 0.72 | 0.61 | <0.01 | 15 | -- |
| DN2-1000B | 1.10 | 1.10 | <0.01 | 23 | -- |
| DN2-1000A | 0.21 | <0.02 | <0.01 | 16 | -- |
| DN3-100B | 0.55 | 1.65 | -- | -- | -- |
| DN3-100A | 0.50 | 0.87 | -- | 16 | <26.4 |
| DN3-250B | 1.01 | 3.09 | -- | 36 | -- |
| DN3-250A | 0.61 | 2.28 | -- | 32 | -- |
| DN3-350B | 0.34 | 0.04 | -- | 25 | -- |
| DN3-350B DUP | 0.34 | 0.09 | -- | 26 | -- |
| DN3-350A | 0.66 | 1.25 | -- | 25 | <26.0 |
| DN3-400B | 0.34 | 0.40 | <0.01 | 37 | -- |
| DN3-400A | 0.36 | 0.10 | 0.03 | 30 | -- |
| DN3-450B | <0.02 | 0.03 | <0.01 | 23 | -- |
| DN3-450A | 1.23 | 1.99 | 0.29 | 28 | -- |
| DN3-500B | 0.43 | 1.83 | <0.01 | 20 | -- |
| DN3-500A | 1.27 | 2.38 | <0.01 | 33 | -- |

Table 5. Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

| Sample identification number | Ferrous iron (mg/L) | Total iron (mg/L) | Sulfide (mg/L) | Sulfate (mg/L) | Methane (µg/L) |
|------------------------------|---------------------|-------------------|----------------|----------------|----------------|
| DN3-550B | <0.02 | 0.44 | <0.01 | 22 | -- |
| DN3-550A | 1.41 | 1.94 | <0.01 | 16 | 40.6 |
| DN3-600B | 1.41 | 2.63 | <0.01 | 24 | -- |
| DN3-600A | 4.30 | 5.10 | <0.01 | <7 | 164.7 |
| DN3-650B | 1.70 | 1.88 | <0.01 | 23 | -- |
| DN3-650A | 1.69 | 2.86 | <0.01 | 10 | 81.8 |
| DN3-700B | 0.55 | 0.97 | <0.01 | 149 | -- |
| DN3-700A | 0.22 | 1.16 | <0.01 | 57 | <25.9 |
| DN3-750B | 1.64 | 1.60 | <0.01 | 21 | 21.0 |
| DN3-750A | 1.16 | 2.01 | <0.01 | <7 | -- |
| DN3-800B | <0.02 | 0.03 | -- | 21 | -- |
| DN3-800A | 0.75 | 1.58 | <0.01 | 13 | -- |
| DN3-850B | 1.22 | 1.89 | <0.01 | 12 | <26.8 |
| DN3-850A | -- | -- | -- | -- | 46.6 |
| DN3-950B | 0.21 | 0.90 | <0.01 | 36 | -- |
| DN3-950A | <0.02 | 1.87 | <0.01 | 12 | <26.7 |
| DN4-000A | -- | -- | -- | -- | -- |
| DN4-100C | -- | -- | -- | -- | -- |
| DN4-100B | -- | -- | -- | -- | -- |
| DN4-100A | <0.02 | 1.41 | <0.01 | 36 | -- |
| DN4-200B | 0.64 | 0.88 | <0.01 | 70 | -- |
| DN4-200A | 0.11 | 0.60 | <0.01 | 13 | -- |
| DN4-300B | 4.5 | 8.90 | <0.01 | 17 | <26.4 |
| DN4-300A | 2.68 | 3.21 | <0.01 | 19 | 154.9 |
| DN4-500B | <0.02 | 1.23 | <0.01 | <7 | -- |
| DN4-500A | 0.44 | 2.12 | <0.01 | 23 | -- |

Table 6. *Ground-water level measurements in the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001*

[msl, mean sea level; --, no data available]

| Upper part of the surficial aquifer | | Lower part of the surficial aquifer | |
|-------------------------------------|------------------------------|-------------------------------------|------------------------------|
| Well identification number | Ground-water elevation (msl) | Well identification number | Ground-water elevation (msl) |
| CPT-08MW | 11.40 | -- | -- |
| -- | -- | CPT-29MW | 11.40 |
| D-3082 | 10.29 | -- | -- |
| -- | -- | D-3083 | 10.19 |
| DM335S | 10.34 | DM335D | 10.37 |
| DM337S | 10.19 | DM337D | 9.77 |
| DM338S | 14.37 | DM338D | 14.38 |
| DM342S | 17.11 | DM342D | 16.97 |
| DM346S | 15.43 | DM346D | 15.42 |
| DM347S | 15.37 | DM347D | 15.37 |
| DM348S | 18.21 | DM348D | 14.63 |
| DM349S | 10.65 | DM349D | 10.65 |
| MW60S | 16.78 | MW60D | 16.71 |
| -- | -- | MW-7 | 12.12 |
| MW75S | 14.47 | MW75D | 14.48 |
| MW77S | 18.54 | MW77D | 14.65 |
| MW78S | 13.91 | MW78D | 13.90 |
| MW223S | 11.09 | MW223D | 11.07 |

Table 7. Concentrations of volatile organic compounds in quality-control blank samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[*cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; ND, not detected; <, less than]

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | Vinyl chloride (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) | <i>p,m</i> -xylene (µg/L) | <i>o</i> -xylene (µg/L) |
|------------------------------|----------------------------|------------|------------|-----------------------|------------------------------|----------------|----------------|---------------------|---------------------------|-------------------------|
| DN1-450.F00 | ND | ND | ND | ND | Equipment Blank ND | ND | ND | ND | ND | ND |
| DN1-250-F36 | ND | <0.8 | <1.3 | ND | Field Blanks ND | ND | ND | ND | ND | ND |
| DN1-550-F20 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN1-600-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-350-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-550-F40 | ND | ND | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-650-F32 | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN2-800-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-850-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-250-F32 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-500-F50 | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-650-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-750-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-800-F40 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN4-300-F50 | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN1-750-SC | ND | ND | ND | ND | Screen Blanks 7.77 | ND | ND | ND | ND | ND |
| DN1-800-SC | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-650-SC | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN2-850-SC | ND | <0.8 | ND | ND | ND | ND | ND | ND | ND | ND |
| DN3-600-SC | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN3-650-SC | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |
| DN4-000-SC | ND | <0.8 | <1.3 | ND | ND | ND | ND | ND | ND | ND |

Table 8. *Relative percent differences (RPDs) from duplicate ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[--, Data not shown in concentrations where one or both replicates were below minimum reporting limit; values in **bold** are RPDs; %, percent; *cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; ND, not detected]

| Sample identification number | <i>cis</i> -1,2-DCE (µg/L) | TCE (µg/L) | PCE (µg/L) | MTBE (µg/L) | Benzene (µg/L) | Toluene (µg/L) | Ethylbenzene (µg/L) |
|------------------------------|----------------------------|------------|------------|-------------|----------------|----------------|---------------------|
| DN1-650A | 0.9 | ND | ND | 6.27 | ND | ND | ND |
| DN1-650A.DUP | 2.84 | ND | ND | 5.45 | ND | ND | ND |
| RPD (%) | 104 | | | 14.0 | | | |
| DN1-800B | ND | ND | ND | 74.1 | 3.06 | 1.66 | ND |
| DN1-800B.DUP | ND | ND | ND | 72.2 | 2.89 | 1.33 | ND |
| RPD (%) | | | | 2.6 | 5.7 | 22.1 | |
| DN1-850A | ND | ND | ND | 290 | 4.36 | 1.67 | ND |
| DN1-850A.DUP | ND | ND | ND | 327 | 5.42 | ND | ND |
| RPD (%) | | | | 11.7 | 21.7 | | |
| DN1-850B | ND | -- | -- | 1,070 | 3.81 | ND | ND |
| DN1-850B.DUP | ND | -- | -- | 1,018 | ND | ND | ND |
| RPD (%) | | | | 5.0 | | | |
| DN2-250B | ND | ND | ND | ND | ND | ND | ND |
| DN2-250B.DUP | ND | ND | ND | ND | ND | ND | ND |
| RPD (%) | | | | | | | |
| DN2-400A | ND | <0.8 | ND | 25.6 | 1.41 | ND | ND |
| DN2-400A.DUP | ND | ND | ND | 26.5 | 1.42 | ND | ND |
| RPD (%) | | | | 3.5 | 0.7 | | |
| DN2-750B | ND | ND | ND | ND | ND | ND | ND |
| DN2-750B.DUP | ND | ND | ND | ND | ND | ND | ND |
| RPD (%) | | | | | | | |
| DN2-950B | ND | ND | ND | 2.15 | ND | ND | ND |
| DN2-950B.DUP | ND | ND | ND | 2.18 | ND | ND | ND |
| RPD (%) | | | | 1.4 | | | |
| DN3-350B | ND | <0.8 | ND | ND | ND | ND | ND |
| DN3-350B.DUP | ND | <0.8 | ND | ND | ND | ND | ND |
| RPD (%) | | | | | | | |
| DN4-300B | 4.79 | ND | ND | ND | ND | ND | ND |
| DN4-300B.DUP | 5.96 | ND | ND | ND | ND | ND | ND |
| RPD (%) | 21.8 | | | | | | |

Summary

The objectives of this study were to determine the distribution of organic contaminants in the surficial aquifer, and to use this information to improve existing conceptual models and plan additional site-characterization work. This report presents the analytical results from ground-water samples collected during a direct-push ground-water sampling investigation. A total of 147 ground-water samples were collected from various depths at 48 locations from June 27 through July 18, 2001. The 147 samples included 115 volatile organic compound samples and 32 quality-control samples.

Drilling was performed with a direct-push Geoprobe drilling rig. Ground-water samples and associated quality-control samples were analyzed for volatile organic compounds, ferrous iron, total iron, sulfate, sulfide, dissolved oxygen, pH, specific conductance, temperature, and methane. Volatile organic compound samples were analyzed at the Dover National Test Site, Groundwater Remediation Field Laboratory at Dover Air Force Base. Water-level measurements were collected in July 2001 from wells in and around the Dover National Test Site.

Concentrations of volatile organic compounds were detected above the method reporting limits in 59 of the ground-water samples. The concentrations ranged from below detection limits to maximum values of 12.4 micrograms per liter of *cis*-1,2-dichloroethene, 1.14 micrograms per liter of trichloroethene, 2.65 micrograms per liter of tetrachloroethene, 1,070 micrograms per liter of methyl *tert*-butyl ether, 4.36 micrograms per liter of benzene, and 1.8 micrograms per liter of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this investigation. Methyl *tert*-butyl ether was detected above the method reporting limit in 47 of the 115 ground-water samples. Ferrous iron concentrations ranged from less than 0.02 to 6.0 milligrams per liter. Total iron concentrations ranged from less than 0.02 to 25.2 milligrams per liter. Sulfide concentrations were below the method detection limit for all samples, except for those from sites DN3-400A and DN3-450A. Sulfate concentrations ranged from less than 7 to 149 milligrams per liter. Methane concentrations ranged from below method reporting limit to 741.1 micrograms per liter. pH values ranged from 4.3 to 5.9. Dissolved oxygen concentrations ranged from below the method detection limit to 7.0 milligrams per liter.

References Cited

- Air Force Center for Environmental Excellence (1999)**, Intrinsic remediation engineering evaluation/cost analyses for site SS27/XYZ: Parsons Engineering Science, Inc., 33 p.
- Baedecker, M.J., and Cozzarelli, I.M., 1992**, The determination and fate of unstable constituents in contaminated groundwater, *in* Lesage, S., and Jackson, R.E. (eds.), Groundwater contamination and analyses at hazardous waste sites: New York, Marcel Dekker, p. 425–461.
- Barbaro, J.R., and Neupane, P.P., 2002**, Distribution and mass loss of volatile organic compounds in the surficial aquifer at sites FT03, LF13, and WP14/LF15, Dover Air Force Base, Delaware, November 2000–February 2001: U.S. Geological Survey Water-Resources Investigations Report 02–4121, 63 p.
- Dames and Moore, Inc., 2000**, MTBE plume delineation, Dover Air Force Base, Dover, Delaware: General Order No. 70B-99296C, 25 p.
- Spencer, T.A., Olsen, L.D., Lorah, M.M., and Mount, M.M., 2000**, Water-quality and water-level data for a freshwater tidal wetland, West Branch Canal Creek, Aberdeen Proving Ground, Maryland, October 1998–September 1999: U.S. Geological Survey Open-File Report 00–208, 189 p.
- U.S. Environmental Protection Agency, 1989**, Guidance for conducting remedial investigation and feasibility studies under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): Washington, D.C., EPA/540/G-89/004, [variously paged].
- _____, **1996**, Test methods for evaluating solid waste, physical/chemical methods, SW-846, 3d ed., update III: Washington, D.C., U.S. Environmental Protection Agency, [variously paged].
- _____, **December 1996**, Test methods for evaluating solid waste, physical/chemical methods, SW-846, 3d ed., update III; Method 8021B Aromatic and halogenated volatiles by gas chromatography using photoionization and/or electrolytic conductivity detectors, Revision 2: Washington, D.C., U.S. Environmental Protection Agency, [variously paged].
- _____, **1997**, Drinking water advisory—consumer acceptability advice and health effects analyses on methyl tertiary-butyl ether: Washington, D.C., EPA/822/F-97/009, 2 p.