

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

# Distribution of Methyl *Tert*-Butyl Ether (MTBE) and Selected Water-Quality Constituents in the Surficial Aquifer at the Dover National Test Site, Dover Air Force Base, Delaware, 2001

Scientific Investigations Report 2004-5011



**Cover.** Aerial photograph showing the Dover National Test Site, Dover Air Force Base, Delaware.  
*(Courtesy of Dover National Test Site)*

# **Distribution of Methyl *Tert*-Butyl Ether (MTBE) and Selected Water-Quality Constituents in the Surficial Aquifer at the Dover National Test Site, Dover Air Force Base, Delaware, 2001**

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United States Air Force  
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**U.S. Department of the Interior**

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## 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 ( $^{\circ}\text{C}$ ) may be converted to degrees Fahrenheit ( $^{\circ}\text{F}$ ) 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  $25^{\circ}\text{C}$ ).

**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

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

# Distribution of Methyl *Tert*-Butyl Ether (MTBE) and Selected Water-Quality Constituents in the Surficial Aquifer at the Dover National Test Site, Dover Air Force Base, Delaware, 2001

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## Abstract

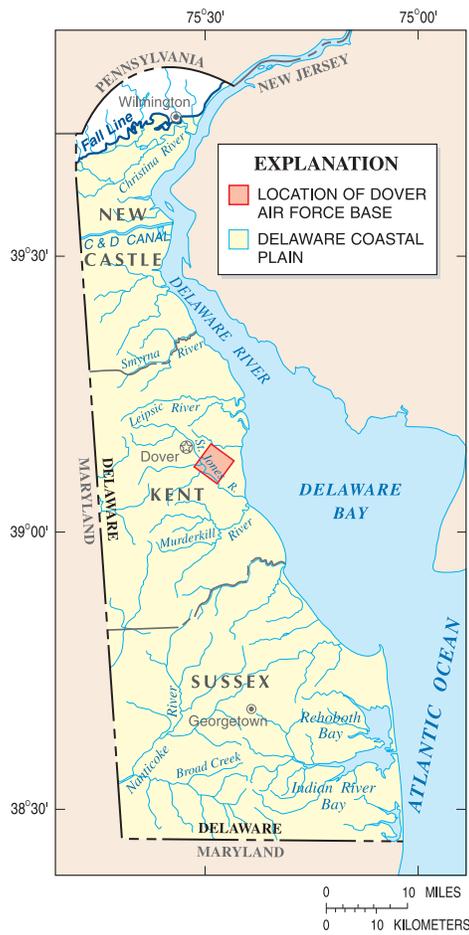
A joint study by the Dover National Test Site, Dover Air Force Base, Delaware, and the U.S. Geological Survey was conducted from June 27 through July 18, 2001, to determine the spatial distribution of the gasoline oxygenate additive methyl *tert*-butyl ether and selected water-quality constituents in the surficial aquifer underlying the Dover National Test Site. This report provides a summary assessment of the distribution of methyl *tert*-butyl ether and a preliminary screening of selected constituents that may affect natural attenuation and remediation demonstrations at the Dover National Test Site. The information gathered during this study is designed to assist potential remedial investigators who are considering conducting a methyl *tert*-butyl ether remedial demonstration at the test site. In addition, the study supported a planned enhanced bioremediation demonstration and assisted the Dover National Test Site in identifying possible locations for future methyl *tert*-butyl ether remediation demonstrations.

A direct-push drill rig was used to collect a total of 147 ground-water samples (115 VOC samples and 32 quality-assurance samples) at varying depths. 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

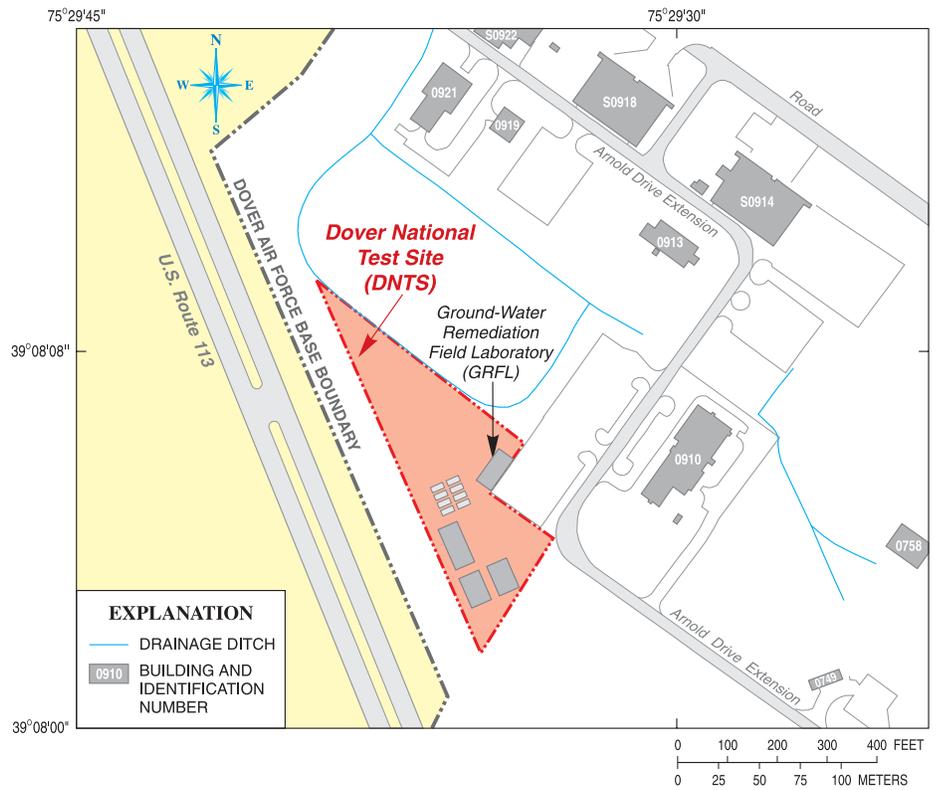
during this investigation. Methyl *tert*-butyl ether was detected in 47 of the 115 ground-water samples. The highest concentrations of methyl *tert*-butyl ether were detected in the surficial aquifer from -4.6 to 6.4 feet mean sea level; however, methyl *tert*-butyl ether was detected as deep as -9.5 feet mean sea level. Increased methane concentrations and decreased dissolved oxygen concentrations that were found in association with the ground-water samples that contained methyl *tert*-butyl ether are preliminary indicators that will assist in determining if natural attenuation of methyl *tert*-butyl ether is occurring in the surficial aquifer. A full assessment of natural attenuation of methyl *tert*-butyl ether at the site is beyond the scope of this study, but the data collected during the study will be useful in selecting appropriate remedial methyl *tert*-butyl ether demonstrations.

## Introduction

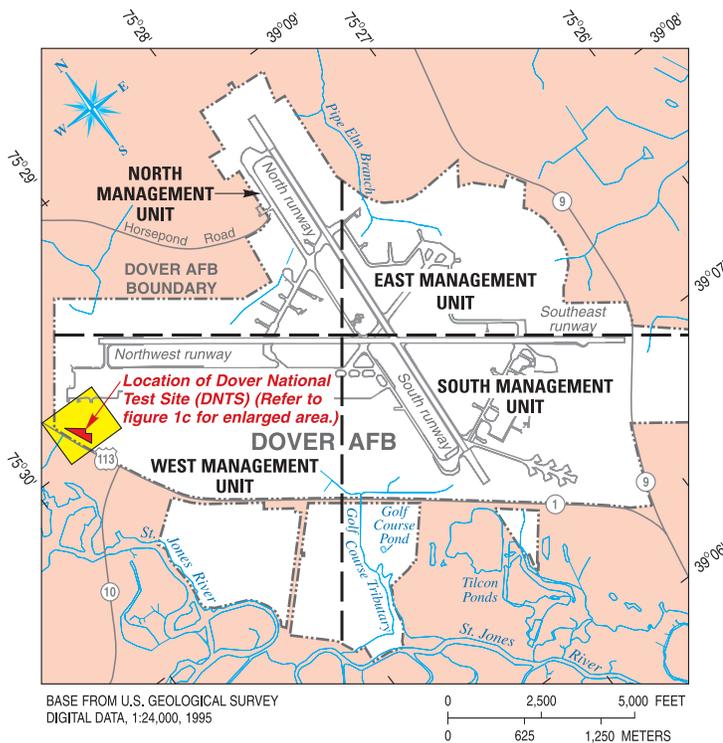
The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's corporate environmental research and development program, executed in partnership with the Department of Energy and the U.S. Environmental Protection Agency (USEPA). Numerous other Federal and non-Federal organizations participate in the program. Dover Air Force Base (DAFB) (fig. 1a) was selected as one of the sites for SERDP's National Environmental Technology Test Site (NETTS). The NETTS Program is a comprehensive technology demonstration, evaluation, and transfer program. The Dover National Test Site (DNTS) (fig. 1b) is one of the NETTS locations. Located within DNTS is the Ground-Water Remediation Field Laboratory (GRFL) (fig. 1c). An aerial photograph of the DNTS is shown in figure 1d.



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



**Figure 1c.** Location of the Ground-Water Remediation Field Laboratory (GRFL) at the Dover National Test Site (DNTS), Dover Air Force Base, Delaware.



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



**Figure 1d.** Aerial photograph showing the Dover National Test Site, Dover Air Force Base, Delaware. (Courtesy of Dover National Test Site)

DNTS is charged with demonstrating emerging concepts, processes, and technologies under controlled conditions. DNTS also is designed to support the needs of principal investigators in developing and field-testing remediation technologies for the cleanup of soil and ground water contaminated with fuels and chlorinated solvents. Many of the studies are performed in sealed, sheet-piling cells that are isolated hydraulically from the Columbia aquifer, which is a surficial aquifer. Routine compliance sampling showed that the gasoline oxygenate additive methyl *tert*-butyl ether (MTBE) was present in the surficial aquifer outside of the sheet-piling cells. MTBE was never released nor detected inside of the test cells.

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. In addition to the plume-mapping study, the USGS is continuing to provide technical support on ground-water quality issues for DNTS. The USGS also assesses ground-water flow in the surficial aquifer. The USGS 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.

### **Purpose and Scope**

The purpose of this report is to provide data showing the distribution of MTBE in the surficial aquifer at the DNTS from June 27 through July 18, 2001. In addition, the intended use of these data is to identify ground-water areas contaminated with MTBE for the DNTS to host potential demonstrations of MTBE remedial technologies. This report also provides a preliminary screening of the geochemical constituents that potentially affect the natural attenuation of MTBE at the DNTS. 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.

Field-screening methodologies were used to map the MTBE plume. In addition, field-screening methodologies were utilized to provide an initial screening of total iron, ferrous iron, sulfate, and sulfite. The study methods were designed to rapidly collect large numbers of samples over a large area. Sample collection was accomplished with a direct-push drill rig and the samples were analyzed at the DNTS. The data were used for contaminant plume mapping. In addition, the data can be used to determine if preliminary indicators of natural attenuation of MTBE are present in the aquifer. Natural attenuation of MTBE is the breakdown or reduction of MTBE levels in an aquifer by natural processes. 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.

### **Description of Study Area**

The DNTS is located in the northwestern corner of DAFB (fig. 1b). DAFB is in the Coastal Plain Physiographic Province, and is underlain by unconsolidated clastic sedimentary deposits (Dames and Moore, Inc. 2000). The generalized direction of ground-water flow in the surficial aquifer at DNTS is east-northeast to west-southwest. A detailed description of the study area can be found in Guertal and others, 2004.

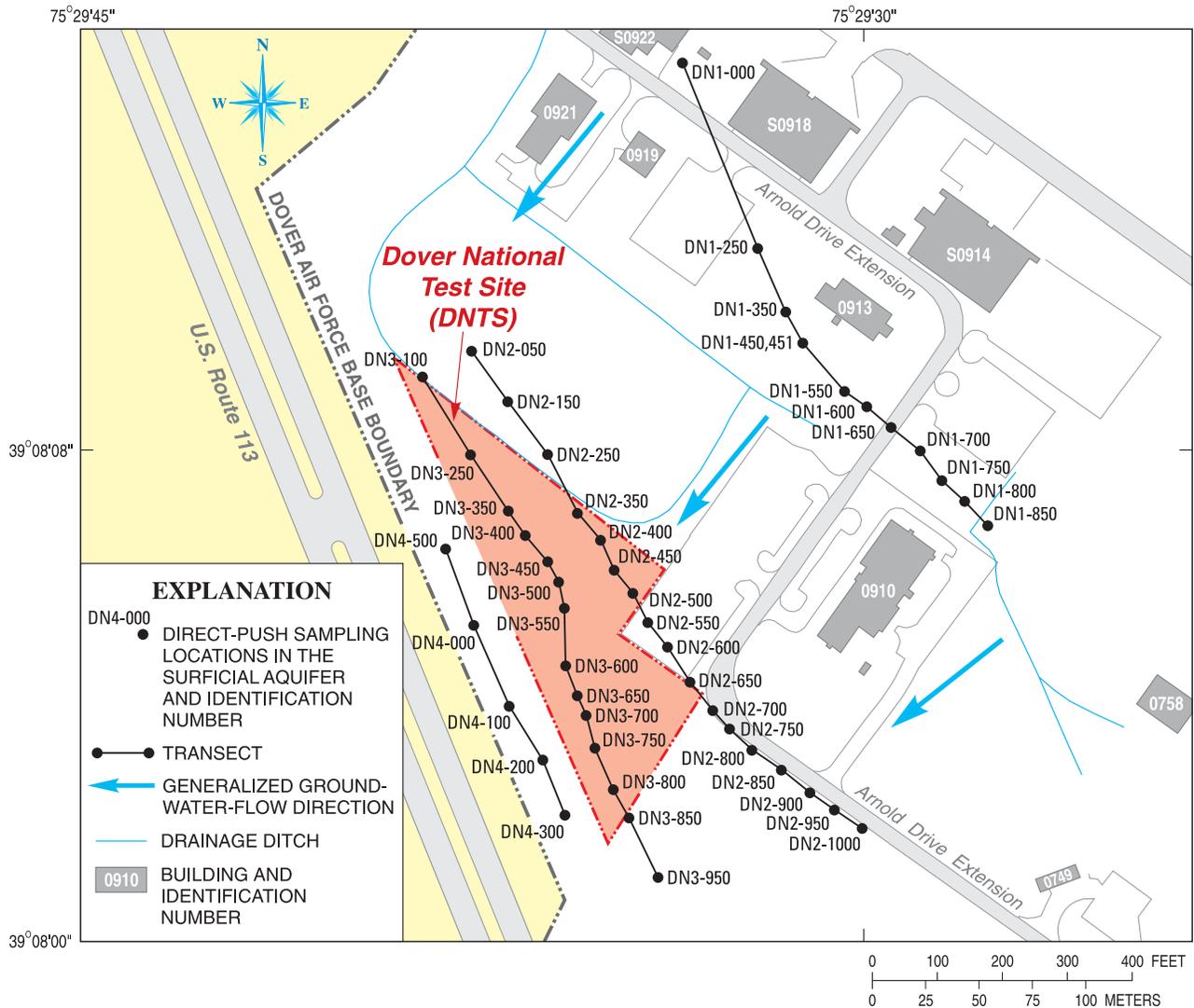
A previous ground-water study was conducted by the U.S. Air Force (USAF) in an area upgradient of DNTS to evaluate the natural attenuation of ground water contaminated by petroleum hydrocarbons for the Installation Restoration Program Site SS27/XYZ Parking Apron (Air Force Center for Environmental Excellence, 1999). During this study, MTBE was detected in ground-water samples collected upgradient of DNTS. Concentrations ranged from 10.9 to 1,430 µg/L (micrograms per liter) of MTBE. In addition, routine compliance sampling at the DNTS indicated that MTBE is present near the DNTS at concentrations ranging from below the reporting limit of 0.05 µg/L to 250 µg/L.

### **Methods of Investigation**

To determine geochemical conditions in the surficial aquifer, dissolved oxygen (DO), total and ferrous iron, sulfate, sulfide, and methane were measured in most ground-water samples. This method was used to determine if electron acceptors and electron donors that are required for oxidation-reduction (redox) reactions to occur were present in the aquifer. An electron acceptor is a chemical entity that accepts electrons transferred to it from another compound and an electron donor is a chemical entity that donates electrons to another compound. Redox is a chemical reaction consisting of an oxidation reaction in which a substance loses or donates electrons, and a substance gains or accepts electrons. DO, ferrous iron, and sulfate levels assist in determining if natural attenuation of MTBE is occurring. The presence of methane assists in determining if anaerobic (oxygen-free) natural attenuation is occurring. Methanogenic conditions result when anaerobic bacterial fermentation produces methane (U.S. Environmental Protection Agency, 1995).

### **Drilling**

Ground-water samples were collected using a direct-push drill rig. Ground-water samples were collected along four transects of direct-push boreholes oriented perpendicular to the general ground-water-flow direction. Samples were collected from multiple depths. The direct-push drilling methods are listed in Guertal and others, 2004.



**Figure 2.** Locations of transects of direct-push sampling sites and generalized ground-water-flow direction at the Dover National Test Site, Dover Air Force Base, Delaware.

### 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 from June 27 through July 18, 2001 (fig. 2). Ground-water samples were collected along four transects of direct-push boreholes oriented perpendicular to the general direction of ground-water flow.

Field constituents (DO, specific conductance, pH, and temperature) were measured with a Hydrolab multi-probe meter at 104 of the 115 sample intervals. The Hydrolab was connected to a flow-through cell on the discharge line of a peristaltic pump. Total iron, ferrous iron, sulfide, and sulfate were analyzed colorimetrically in unfiltered samples with

spectrophotometers that contain pre-programmed calibration curves in the field. 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 limit (MDL) for total and ferrous iron was 0.02 mg/L, and the MDL for methane was 25.4 µg/L. The MDL for sulfide was 0.01 mg/L for the instrument, and the lowest calibration standard that was used for sulfate was 7 mg/L.

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 down-hole to collect the ground-water samples. 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 de-ionized (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. 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 samples were analyzed for MTBE, benzene, toluene, ethylbenzene, xylenes, *cis*-1,2-dichloroethene, trichloroethene, tetrachloroethene, vinyl chloride and methane. Methane was run on only 39 samples.

The following QC samples were collected: 1 equipment blank (DI water samples collected from the equipment at the start of the study), 14 field blanks (DI water samples collected after the field sampling equipment is cleaned), 10 sequential duplicates (sequential aquifer water samples) and 7 screen blanks (DI water samples collected after the drilling equipment is cleaned). The QC sample results for the direct-push ground-water sampling at the DNTS are listed in Guertal and others, 2004. In addition, seven sequential duplicate field analyses were run on ferrous and total iron, sulfate, and sulfide, and check standards were run on sulfate daily. Twenty-one field blank samples were run for ferrous and total iron, sulfate, and sulfide.

### Analytical Methods

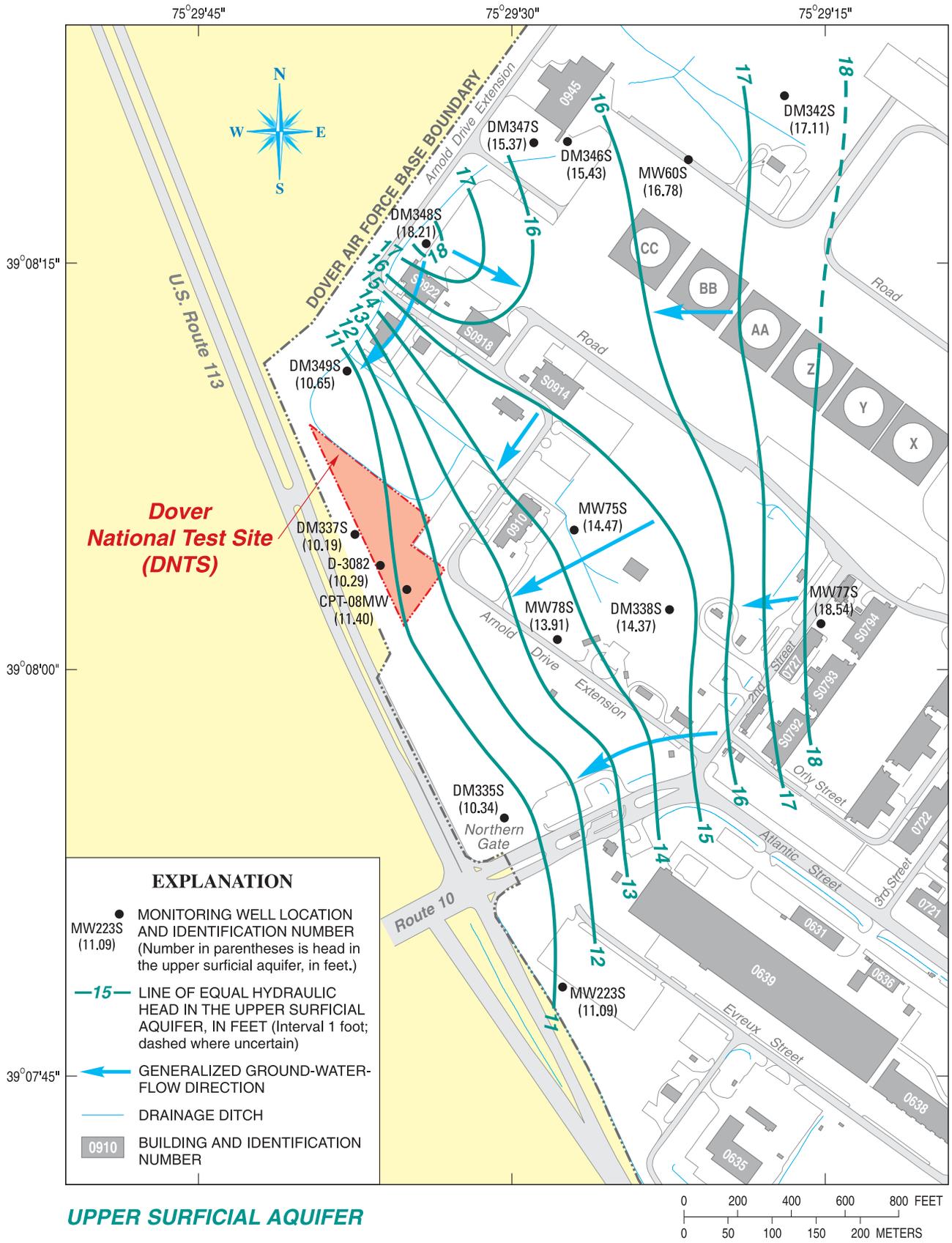
VOCs were analyzed at the DNTS at DAFB. Samples were analyzed using the USEPA Method 8021B procedure (U.S. Environmental Protection Agency, 1996), Headspace Method 5021 (U.S. Environmental Protection Agency, December 1996). Samples were analyzed on a Hewlett Packard 6890A gas chromatograph (GC) equipped with flame-ionization and electron-capture detectors, a Hewlett Packard 7694 automatic headspace sampler, and a Supelco SPB-624 capillary column. To prepare samples and standards for analyses, 5 mL of sample was transferred to 20-mL headspace vials and sealed. For QC, check standards (Supelco custom VOC mixture and MTBE standards) were analyzed 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 method reporting limits (MRLs) are shown in table 1. The maximum contaminant levels (MCLs) or primary standards are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. The USEPA has a drinking-water advisory of 20–40 µg/L for MTBE that is based on taste and odor (U.S. Environmental Protection Agency, 1997).

According to USEPA Method 8021B, Method 5021 for headspace GC, recoveries must be below 20-percent difference, meaning that standard must be monitored frequently and compared against the initial calibration curve. If the recoveries ever exceed 20-percent difference, the standards need to be replaced, the initial calibration should be recomputed, and then the samples are rerun. Standards are replaced routinely according to the manufacturers' specifications. A detailed explanation of the standard preparation can be found in the USEPA Method 8021B document (U.S. Environmental Protection Agency, December 1996).

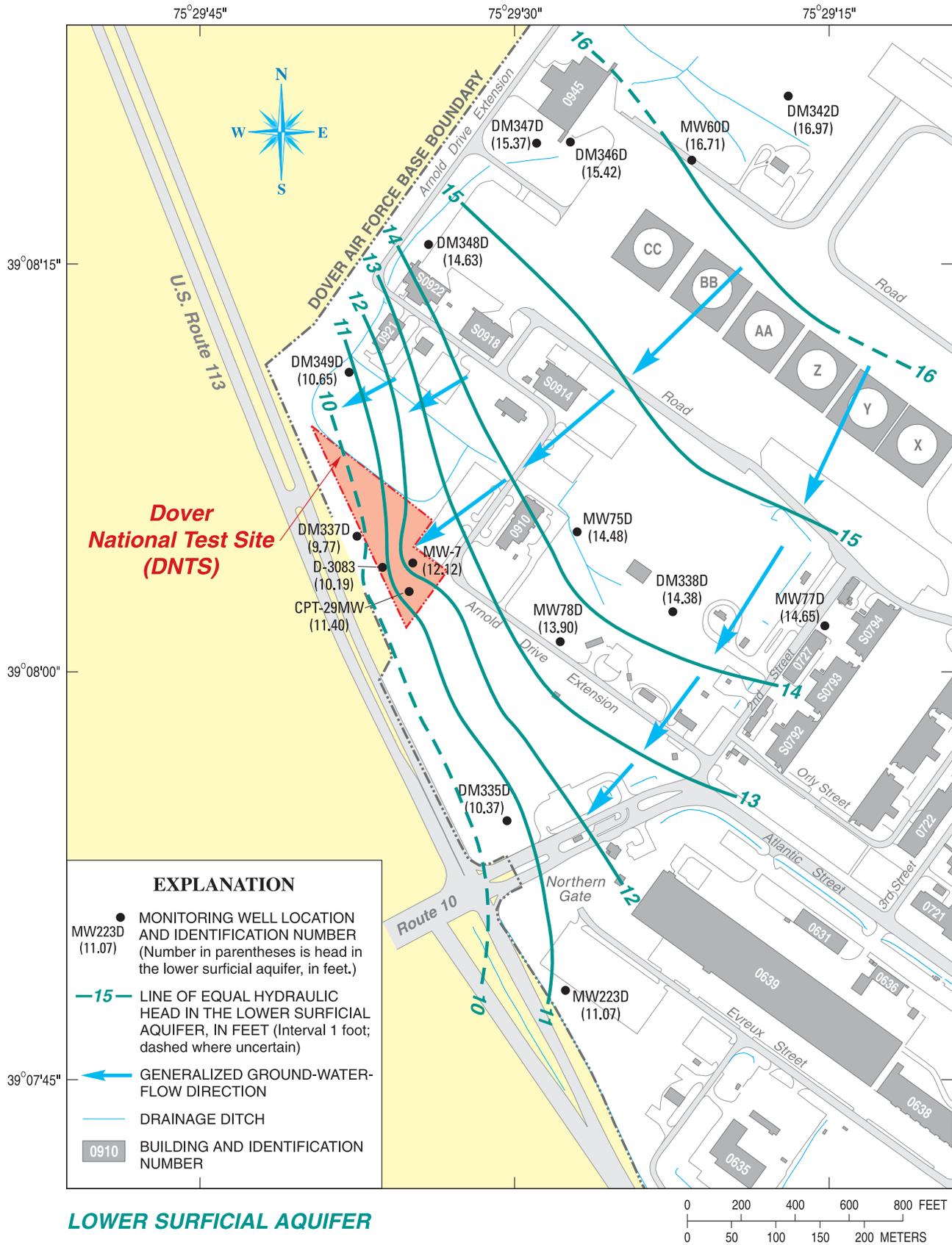
Samples were analyzed for methane at the USGS field laboratory at Aberdeen Proving Ground, Maryland. All methane samples were collected in duplicate. Methane samples were analyzed using a GC with a flame-ionization detector. The procedure is described in detail in Baedeker and Cozzarelli (1992). The field laboratory at Aberdeen Proving Ground 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).

### Water-Level Measurements

To determine the direction of ground-water flow in the surficial aquifer, water-level measurements were collected on July 1, 2001, from wells in and around the DNTS. The water levels in the lower surficial aquifer ranged from 9.77 to 16.97 ft (feet) mean sea level (msl). In the upper surficial aquifer, the water levels ranged from 10.19 to 18.54 ft msl. Hydraulic-head (water-level) distribution in the upper and lower parts of the surficial aquifer is shown in figures 3a–b. Ground-water flow in the upper and lower parts of the surficial aquifer generally was from the east-northeast to the west-southwest toward the St. Jones River, which is approximately 1,800 ft downgradient of the study area. Clay lenses located intermittently throughout the Columbia Formation caused minor variations in localized flow patterns; however, it is assumed that these heterogeneities in the formation do not affect the general direction of flow in the surficial aquifer.



**Figure 3a.** Hydraulic-head distribution in the upper part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.



**Figure 3b.** Hydraulic-head distribution in the lower part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.

**Table 1.** Method reporting limits and maximum contaminant levels for volatile organic compounds at Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[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/Volatile Organic Compound	DNTS Modified 8021B Method Reporting Limit <sup>1</sup> (µg/L)	Maximum Contaminant Level (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

<sup>1</sup> U.S. Environmental Protection Agency, 1996.

## Analytical Results of Ground-Water Sampling

VOCs were detected above the MRLs in 59 ground-water samples. The concentrations ranged from below reporting limits to maximum values of 1,070 µg/L of MTBE (MTBE was detected in 47 of the 115 ground-water samples), 4.36 µg/L of benzene, 1.8 µg/L of toluene, 12.4 µg/L of *cis*-1,2-dichloroethene, 1.14 µg/L of trichloroethene, and 2.65 µg/L of tetrachloroethene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this investigation. The analytical data tables are shown in Guertal and others (2004). All VOC concentrations were below their respective MCLs. The MCLs for selected VOCs are given in table 1. There currently is no MCL for MTBE in drinking water. The USEPA has a drinking-water advisory of 20–40 µg/L for MTBE that is based on taste and odor (U.S. Environmental Protection Agency, 1997).

## Vertical and Horizontal Distribution of Methyl *Tert*-Butyl Ether and Selected Water-Quality Constituents in the Surficial Aquifer

The MTBE plume identified during this study is approximately 900 ft long and 200 ft wide, based on the 50-µg/L line of equal MTBE concentration (fig. 4). The MTBE source area was not located during this study. The northern boundary of the plume is well defined, but the southern boundary is not as defined. On the southern boundary, levels of less than 20 µg/L of MTBE were present. The MTBE concentrations from samples collected at the DNTS are listed in table 2. The highest concentrations of MTBE were found in the surficial aquifer from –4.6 to 6.4 ft msl. This depth range constitutes the middle part of the surficial aquifer, as shown in section A–A' (fig. 5). However, MTBE was found as deep as –9.5 ft msl and as shallow as 12.3 ft msl. The land-surface elevations ranged from 27.6 ft msl in the upgradient portion of the plume to 37.4 ft msl in the downgradient portion of the plume.

In most locations, the lower boundary of the plume was not determined. In the core of the plume, the deepest samples that were collected all contained MTBE (fig. 5). It is assumed that the top of the Calvert Formation forms the lower boundary of the contaminant plume, because the Calvert Formation is a dense clay that is just below the Columbia Formation forming the lower boundary of the surficial aquifer.

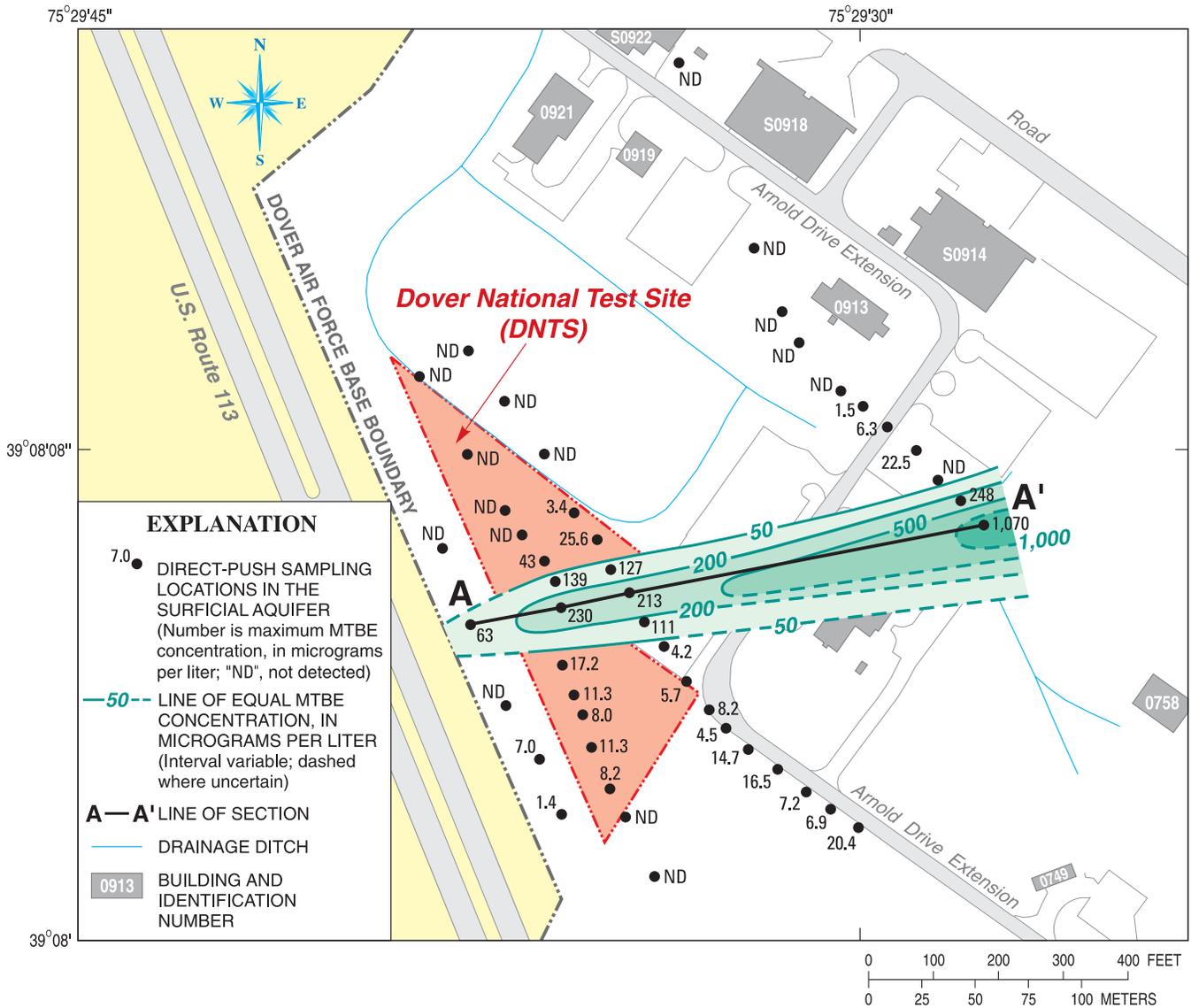
Oxidation-reduction trends are found in association with natural attenuation of contamination in most aquifers. In the presence of organic contaminants, the naturally occurring microorganisms consume electron acceptors such as DO and sulfate, and produce metabolic by-products such as ferrous iron, sulfide, and methane. The presence of ferrous iron, methane, and sulfide in samples containing MTBE indicates that ground water in the MTBE plume is anaerobic. All analyses for ferrous iron, total iron, sulfide, sulfate, and methane were performed on unfiltered samples to avoid aeration.

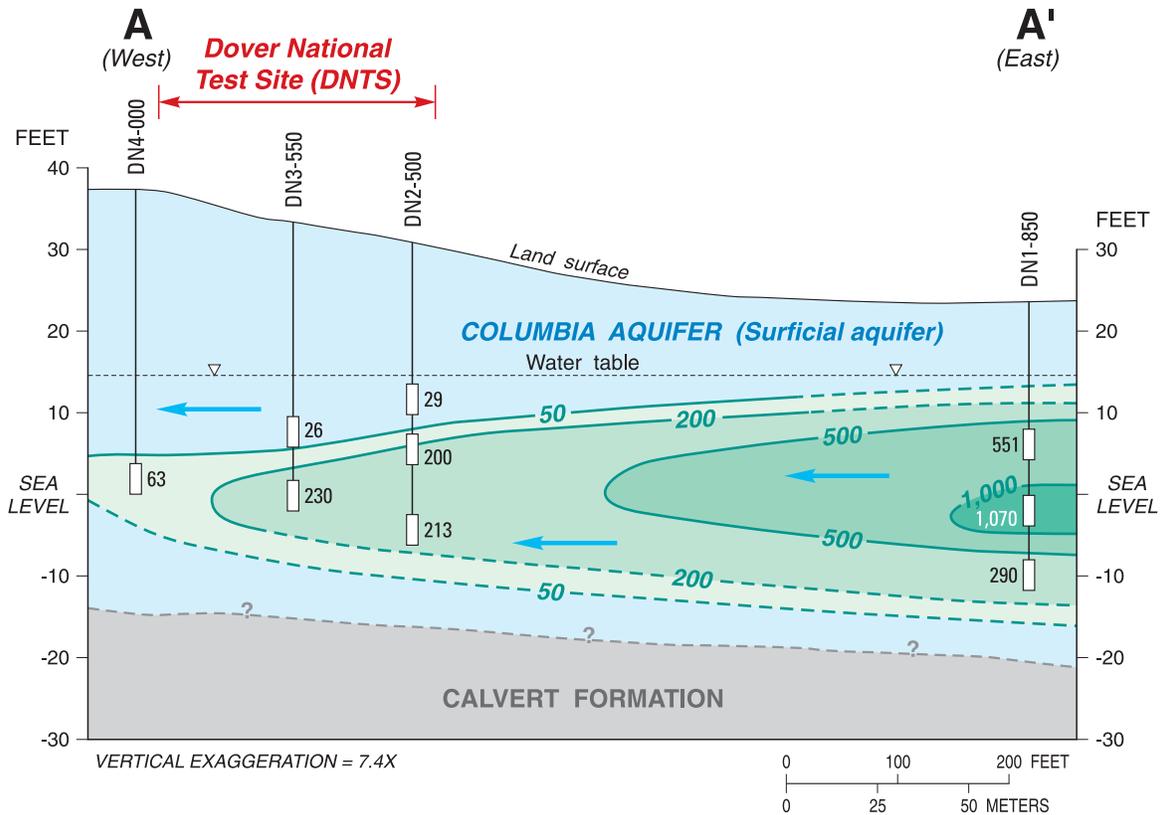
Reduced DO levels generally were present in samples that contained greater than or equal to 0.5 µg/L of MTBE (fig. 6). In addition, the DO concentrations varied with depth, and ranged from below the reporting limit (0.2 mg/L) to 7.0 mg/L. In samples that were collected at shallow depths ranging from 6.5 ft to 12.6 ft msl, which also contained less than 5 µg/L of MTBE, DO concentrations ranged from less than 0.20 mg/L to 7.0 mg/L, whereas the samples collected within the MTBE plume contained 0.26 mg/L to 3.8 mg/L of DO. At medium depths ranging from –4.6 ft to 6.4 ft msl, in samples that were not collected in the MTBE plume, DO concentrations ranged from less than 0.20 mg/L to 4.4 mg/L. The samples collected within the MTBE plume contained less than 0.20 mg/L to 1.72 mg/L of DO. At greater depths ranging from –9.5 ft to –4.7 ft msl, in samples that were not collected in the MTBE plume, DO concentrations ranged from 0.26 mg/L to 3.5 mg/L. In samples that

**Table 2.** Concentrations of methyl tert-butyl ether in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[MTBE, methyl tert-butyl ether; µg/L, micrograms per liter; ND, not detected; values above the method reporting limit are in **bold**]

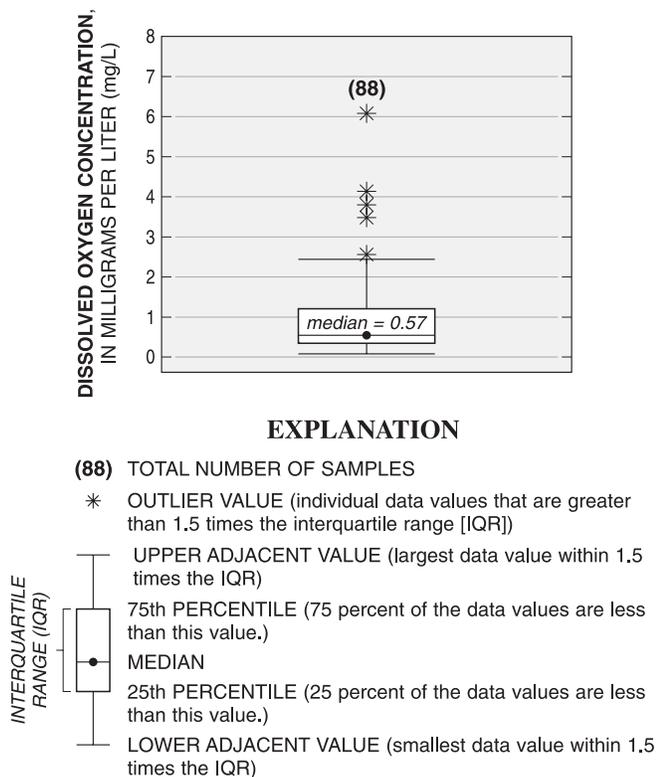
Sample identification number	MTBE (µg/L)	Sample identification number	MTBE (µg/L)	Sample identification number	MTBE (µg/L)	Sample identification number	MTBE (µg/L)	Sample identification number	MTBE (µg/L)
DN1-000C	ND	DN1-650C	ND	DN2-750B	ND	DN3-250B	ND	DN3-750B	ND
DN1-000B	ND	DN1-650B	ND	DN2-750A	<b>3.45</b>	DN3-250A	ND	DN3-750A	<b>11.3</b>
DN1-000A	ND	DN1-650A	<b>6.27</b>	DN2-800C	ND	DN3-350B	ND	DN3-800B	ND
DN1-250C	ND	DN1-700C	ND	DN2-800B	<b>7.75</b>	DN3-350A	ND	DN3-800A	<b>8.21</b>
DN1-250B	ND	DN1-700B	<b>22.5</b>	DN2-800A	<b>14.7</b>	DN3-400B	ND	DN3-850B	ND
DN1-250A	ND	DN1-700A	<b>4.64</b>	DN2-850C	ND	DN3-400A	ND	DN3-850A	ND
DN1-350C	ND	DN1-750C	ND	DN2-850B	ND	DN3-450B	<b>17.4</b>	DN3-950B	ND
DN1-350B	ND	DN1-750B	ND	DN2-850A	<b>16.5</b>	DN3-450A	<b>42.7</b>	DN3-950A	ND
DN1-350A	ND	DN1-750A	ND	DN2-900C	ND	DN3-500B	<b>104</b>	DN4-000A	<b>63.0</b>
DN1-450C	ND	DN1-800C	<b>248</b>	DN2-900B	ND	DN3-500A	<b>139</b>	DN4-100C	ND
DN1-450B	ND	DN1-800B	<b>74.1</b>	DN2-900A	<b>7.23</b>	DN3-550B	<b>26.1</b>	DN4-100B	ND
DN1-450A	ND	DN1-800A	<b>87.3</b>	DN2-950C	ND	DN3-550A	<b>230</b>	DN4-100A	ND
DN1-451B	ND	DN1-850C	<b>551</b>	DN2-950B	<b>2.15</b>	DN3-600B	<b>3.08</b>	DN4-200B	ND
DN1-451A	ND	DN1-850B	<b>1,070</b>	DN2-950A	<b>6.88</b>	DN3-600A	<b>17.2</b>	DN4-200A	<b>7.01</b>
DN1-550C	ND	DN1-850A	<b>290</b>	DN2-1000C	ND	DN3-650B	ND	DN4-300B	ND
DN1-550B	ND	DN2-050B	ND	DN2-1000B	<b>19.1</b>	DN3-650A	<b>11.3</b>	DN4-300A	<b>1.41</b>
DN1-550A	ND	DN2-050A	ND	DN2-1000A	<b>20.4</b>	DN3-700B	ND	DN4-500B	ND
DN1-600C	ND	DN2-150B	ND	DN3-100B	ND	DN3-700A	<b>7.91</b>	DN4-500A	ND
DN1-600B	ND	DN2-150A	ND	DN3-100A	ND				
DN1-600A	<b>1.54</b>	DN2-700A	<b>8.18</b>	DN2-700A	<b>8.18</b>				
		DN2-250B	ND						
		DN2-250A	ND						





- EXPLANATION**
- |                                    |  |                        |  |
|------------------------------------|--|------------------------|--|
| <p>DN4-000<br/>63</p> <p>— ? —</p> | <p>LOCATION OF DIRECT-PUSH SAMPLING SITES AND IDENTIFICATION NUMBER (Number is MTBE concentration, in micrograms per liter.)</p> <p>GEOLOGIC CONTACT (Dashed and queried where inferred)</p> | <p>— 50 —</p> <p>←</p> | <p>LINE OF EQUAL MTBE CONCENTRATION, IN MICROGRAMS PER LITER (Interval variable. Datum is sea level. Dashed where uncertain.)</p> <p>GENERALIZED GROUND-WATER-FLOW DIRECTION</p> |
|------------------------------------|--|------------------------|--|

**Figure 5.** Vertical distribution of methyl *tert*-butyl ether (MTBE) along cross section A-A', Dover National Test Site, Dover Air Force Base, Delaware, June-July 2001. (Refer to figure 4 for line of section A-A'.)



**Figure 6.** Boxplot of concentrations of dissolved oxygen for samples that contained greater than 0.50 micrograms per liter of methyl *tert*-butyl ether, Dover National Test Site, Dover Air Force Base, Delaware, June-July 2001.

were collected from the area within the MTBE plume, DO concentrations ranged from 0.21 mg/L to 0.68 mg/L.

Microbial iron reduction typically occurs after DO reduction (Weidemeier and others, 1999; Chapelle and others, 1995). Ferrous iron concentrations ranged from below the MDL to 6.0 mg/L. Total iron concentrations ranged from below the MDL to 25.2 mg/L. When analyses are performed on unfiltered samples using direct-push technologies and analyzing with a colorimetric method in the field, turbidity can interfere with the analyses of total and ferrous iron. As a result, for low-level detections, the ferrous iron exceeded the total iron on occasion.

Methane concentrations ranged from below the MDL to 741.1  $\mu\text{g/L}$ . Methane concentrations were elevated in some samples that contained MTBE. Methane ranged from below the MDL to 534.8  $\mu\text{g/L}$  in samples that were not collected from areas in the MTBE plume, and from below the MDL to 741.1  $\mu\text{g/L}$  in samples containing MTBE. In samples containing higher levels of MTBE, higher concentrations of methane were found. These data indicate that methanogenic conditions are present in the surficial aquifer.

Sulfide concentrations were below the MDL for all samples with the exception of sites DN3-400A and DN3-450A. Sulfate concentrations ranged from below the MDL to 149 mg/L. Sulfate reduction does not appear to affect natural attenuation of MTBE in this aquifer.

## Summary and Conclusions

The U.S. Geological Survey provides technical assistance on ground-water quality issues for Dover National Test Site. The U.S. Geological Survey assesses ground-water flow in the surficial aquifer, and assists the Dover National Test Site 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 methyl *tert*-butyl ether. As part of this support, the U.S. Geological Survey conducted a plume mapping study to better determine the distribution of methyl *tert*-butyl ether at the site. The objectives of this plume mapping 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 study from June 27 through July 18, 2001. 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. 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 compounds above the method reporting limit were detected in 59 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 methyl *tert*-butyl ether plume identified in this study is approximately 900 ft long and 200 feet wide, based on the 50-microgram per liter line of equal methyl *tert*-butyl ether concentration. The methyl *tert*-butyl ether source area was not located during this investigation.

Increased methane concentrations and decreased dissolved oxygen concentrations found in association with elevated concentrations of methyl *tert*-butyl ether are preliminary indicators that will assist in determining if natural

attenuation is occurring at the Dover National Test Site. However, additional data are needed to determine whether natural attenuation is occurring at a rate that will cause the plume to shrink or stabilize.

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## Related Web Links

- Strategic Environmental Research and Development Program (SERDP)**, <http://www.serdp.org/> (Accessed on July 24, 2003)
- National Environmental Technology Test Sites (NETTS) Program**, <http://www.serdp.org/NETTS/> (Accessed on July 24, 2003)
- Dover National Test Site, (DNST)**, <http://www.dnts.org/> (Accessed on July 24, 2003)
- Environmental Behavior and Fate of Methyl Tert-Butyl Ether (MTBE)**, U.S. Geological Survey Fact Sheet FS–203–96 (Revised 2/98), <http://ca.water.usgs.gov/mtbe/fs20396/ref.html> (Accessed on July 24, 2003)