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# **MTBE Concentrations in Ground Water in Pennsylvania**

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## CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
	<u>Length</u>	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	<u>Area</u>	
square mile (mi <sup>2</sup> )	2.590	square kilometer
	<u>Flow</u>	
gallon per minute (gal/min)	0.06308	liter per second per meter
	<u>Flow rate</u>	
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	<u>Temperature</u>	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius

### Other Abbreviations

Abbreviated water-quality units used in this report:

- meter (m)
- microgram per liter (µg/L)
- milliliter (mL)
- part per billion by volume (ppbv)

# MTBE CONCENTRATIONS IN GROUND WATER IN PENNSYLVANIA

by Steven D. McAuley

## ABSTRACT

The distribution, concentrations, and detection frequency of methyl tert-butyl-ether (MTBE), a gasoline additive used in reformulated gasoline to improve air quality, were characterized in Pennsylvania's ground water. Two sources of MTBE in ground water, the atmosphere and storage-tank release sites, were examined. An analysis of atmospheric MTBE concentrations shows that MTBE detections (MTBE greater than or equal to 0.2 micrograms per liter) in ground water are more likely the result of storage-tank releases than atmospheric deposition. A comparison of 86 ground-water samples near storage-tank releases and 359 samples from ambient ground water (not thought to be affected by point-source releases of MTBE or BTEX compounds) shows that samples within about 0.5 mile downgradient of storage-tank release sites have significantly greater MTBE detection frequency than ambient ground-water samples.

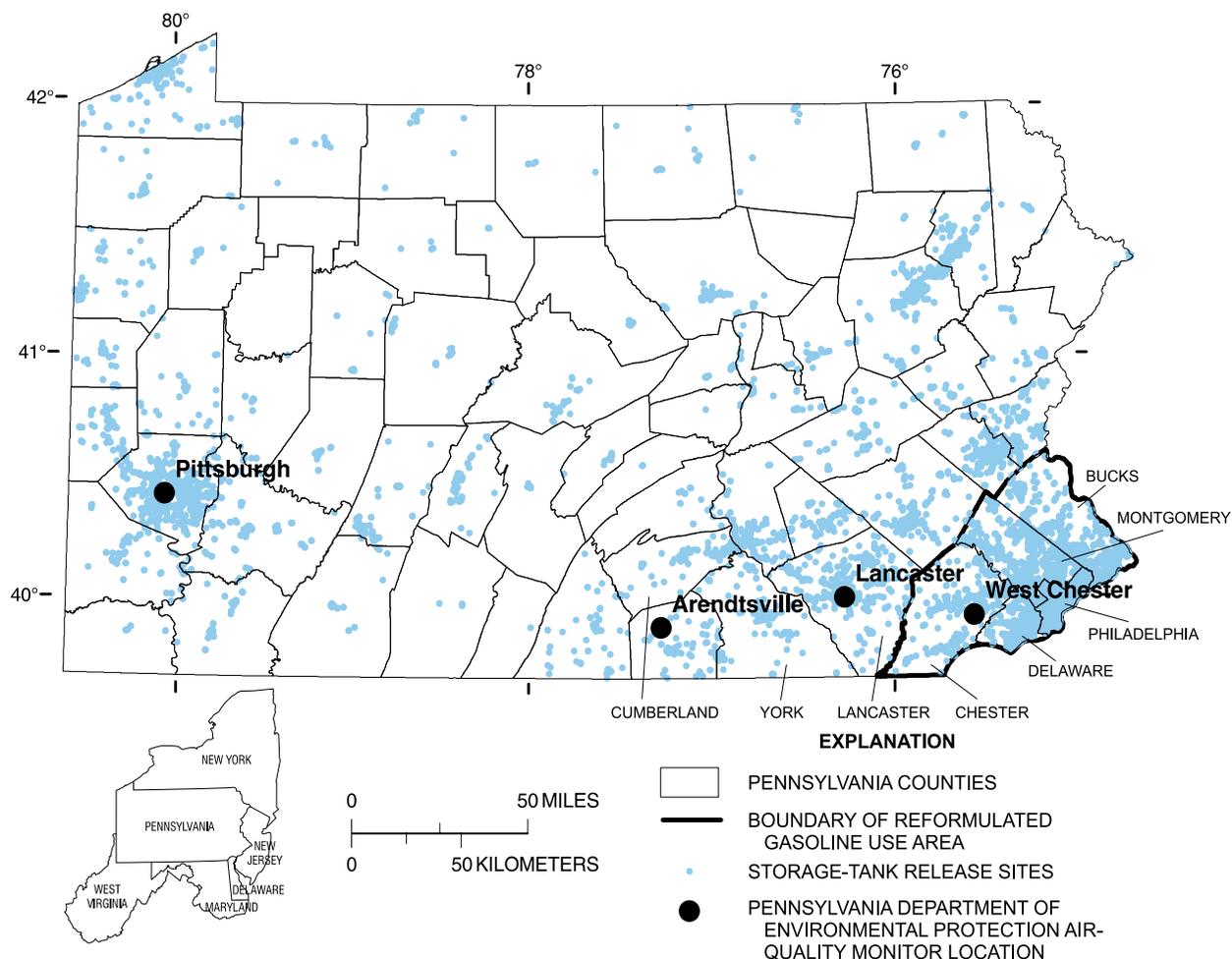
Aquifer type, land use, and the use of Reformulated Gasoline (RFG) are associated with high rates of occurrence of MTBE in ground water in Pennsylvania. Ground-water samples from wells in crystalline-rock aquifers near storage-tank release sites have a significantly greater MTBE detection frequency (57 percent) compared to other aquifers. Samples from wells in urban areas have a significantly greater MTBE detection frequency compared to ambient samples in agricultural and forested areas. Samples from the RFG-use areas in the five southeastern counties of Pennsylvania have a significantly greater MTBE detection frequency than samples outside of the RFG-use area. MTBE detection frequency of samples near storage-tank release sites in the RFG-use area (45 percent) are significantly greater than ambient samples in the RFG-use area.

## INTRODUCTION

Methyl tert-butyl-ether (MTBE) is a synthetic chemical that has been added to gasoline since 1979 as an octane enhancer to replace lead. The Clean Air Act Amendments of 1990 created the Oxygenated Fuels Program and the Reformulated Gas Program to add oxygen to gasoline in areas that do not meet National Ambient Air Quality standards for carbon monoxide and ozone. In the mid-1990s, MTBE began to be used as an oxygenate (referred to as an oxyfuel) to reduce carbon monoxide, and as part of Reformulated Gasoline (RFG), to reduce ground-level ozone in many areas of the Nation. The RFG Program, begun in 1995 in many Northeastern and Mid-Atlantic States, requires that gasoline sold throughout the year in the areas having the highest levels of tropospheric ozone must contain a minimum of 2 percent oxygen by weight. The program does not specify which oxygenate must be added to gasoline to meet the standard, but MTBE commonly is used. The use of RFG lowers the emissions of unburned aromatic compounds and therefore the formation of ozone in air. In areas where MTBE is used in RFG or in oxyfuel, MTBE commonly constitutes 10–15 percent of the gasoline by volume (Johnson and others, 2000). To meet the requirements of the Clean Air Act Amendments, gasoline in RFG areas must contain 11 percent MTBE by volume (if MTBE is the oxygenate used).

RFG is used in the five southeastern counties of Pennsylvania (Bucks, Chester, Delaware, Montgomery, and Philadelphia) to reduce ground-level ozone (fig. 1). In all other areas, including the Pittsburgh area, where Reid Low Vapor Pressure gasoline is used to combat ozone concerns, smaller amounts of MTBE (generally about 1 percent or less) are used in most gasoline, usually as an octane booster.

Thousands of releases of petroleum products (mostly gasoline) from storage tanks, above and below ground, have been reported in Pennsylvania (Stuart Reese, Pennsylvania Department of Environmental Protection, written commun.,



**Figure 1.** Distribution of known releases from storage tanks in Pennsylvania, 1988-2001. (Data from Storage Tanks Division of Pennsylvania Department of Environmental Protection.)

2001). Nationally, 330,000 point-source releases from leaking underground storage tanks have been reported to U.S. Environmental Protection Agency (USEPA) (Moran and others, 1999).

MTBE can move into the ground water from point sources such as a leaking storage tank or petroleum pipeline (above or below ground), from spills or evaporative losses at refueling stations, from vehicle accidents, or from homeowner releases. MTBE also can move into the ground water from nonpoint sources such as vehicle emissions, atmospheric deposition (especially via infiltration of precipitation), and urban storm-water runoff (U.S. Environmental Protection Agency, 1999; National Science and Technology

Council, 1997). MTBE, unlike benzene, is very soluble in water, very mobile in ground-water systems, and more resistant to biodegradation than the toxic gasoline components benzene, toluene, ethyl benzene, and xylene (referred to as BTEX compounds). Because of these properties, MTBE plumes can spread for kilometer-scale distances (several thousand feet to miles) in the subsurface. Because of its use as an octane booster, MTBE may be found in ground water at or near any leaking underground storage tank in the United States, even in areas where MTBE is not used to meet RFG or oxyfuel requirements.

During the 1990s, MTBE was detected in 5 percent or more of private or public drinking water supplies nationally, and the percentage of MTBE detections was greater than 5 percent in high-MTBE-use areas (Zogorski and others, 2001; National Science and Technology Council, 1997)<sup>1</sup>. Although most of the detections nationally were at low (<20 µg/L) concentrations, 1 percent of MTBE concentrations were above the USEPA Consumer Advisory threshold of 20 µg/L. MTBE has been reported in ground water at concentrations as high as 200,000 µg/L near releases from storage tanks (National Science and Technology Council, 1997).

The USEPA Consumer Advisory recommends MTBE control levels of 20 to 40 µg/L to prevent adverse odor and taste (U.S. Environmental Protection Agency, 2003). These levels are not enforceable legally. Human-health effects from MTBE remain uncertain; however, USEPA tentatively has classified MTBE as a possible human carcinogen but, because of insufficient toxicity studies, has not instituted a drinking-water health advisory (Zogorsky and others, 2001).

Pennsylvania relies heavily on ground water for public drinking-water supplies. In 1995, about 243 Mgal/d of ground water were used for drinking-water supply, which constitute 15.7 percent of all water used for public drinking water in Pennsylvania. The combined populations served by (1) community systems with ground water as a primary source of drinking water; (2) community systems with at least one ground-water source; and (3) private on-lot wells account for nearly half of the population of Pennsylvania (P. Bowling, Pennsylvania Department of Environmental Protection, written commun., 2002). Ground water, commonly the principal source of drinking water in most rural areas and an important source in some urban areas, continues to be a principal source of drinking water in areas where urban development recently has increased. Increased development in urban areas results in increased use of gasoline storage tanks and refueling gas stations. Recent reports

in Pennsylvania of MTBE in ground water used for drinking-water supply have raised concerns of citizens and water-resource managers. Many private wells in the five southeastern Pennsylvania counties and, to a lesser extent, in other areas of Pennsylvania, have been contaminated by MTBE, as indicated in numerous reports of investigations of MTBE contamination, overseen by or submitted to the Pennsylvania Department of Environmental Protection (PADEP) (Pennsylvania Department of Environmental Protection, various staff, oral commun.), and newspaper articles.

Because of concerns over concentrations of MTBE in ground water, PADEP and the U.S. Geological Survey (USGS) initiated a cooperative study to assess the distribution and concentrations of MTBE in ground water used for water supply, to compare the concentrations of MTBE to drinking-water standards or advisories, and to determine whether there are factors associated with high rates of occurrence of MTBE in ground water. The PADEP is interested in determining if there are certain areas or aquifers that are more susceptible to MTBE or that have greater concentrations of MTBE to assist in targeting the PADEP sampling program for MTBE in drinking-water wells and in prioritizing storage-tank inspections. The USGS is interested in adding to the knowledge of the occurrence of MTBE in ground water.

### **Purpose and Scope**

This report (1) examines sources of MTBE in ground water from atmospheric deposition and near release sites and compares the concentrations and frequency of detection of MTBE in ground water from wells topographically down-gradient of known release sites to wells in areas where the location of release sites is not known or release sites may not exist, and (2) examines the MTBE concentrations and frequency of detection in aquifers across Pennsylvania, among land uses, and in the RFG-use area. In each case, MTBE concentrations near release sites are compared to MTBE concentrations in ambient ground water (ground water that is not thought to be associated with point-source releases of MTBE or BTEX compounds). Finally, areas at risk for high detection frequencies of MTBE are identified.

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<sup>1</sup> The results reported in Zogorski and others (2001) are a synthesis of results from individual study units in the U.S. Geological Survey National Water-Quality Assessment Program. Study-unit reports that include MTBE analysis are available at <http://www.sd.cr.usgs.gov/nawqa/vocns> or at <http://water.usgs.gov/nawqa>

During this study, MTBE data from previous USGS studies in Pennsylvania between 1993 and 2001 were compiled and interpreted. A total of 359 wells across Pennsylvania were sampled for MTBE during these previous studies. These samples were collected to meet the objectives of the previous studies and therefore were not equally distributed statewide. In addition, no areas near release sites were targeted for sampling.

As part of the current study, samples from 86 wells were collected during June 2001 through February 2002. To fill in the data gap from the previously collected samples, all the 86 wells are within about 0.5 mi of a storage-tank release and are downgradient of the release site, as indicated by topographic contours. Although an attempt was made to sample equally from the areal extent of each of the major aquifer types in Pennsylvania, samples were not collected in some areas because the release sites are not distributed evenly across the state, and neither is use of ground water for drinking-water supplies. The density of the release sites is greatest in urban areas but there are release sites throughout much of Pennsylvania (fig. 1).

### **Description of Study Area**

The climate of Pennsylvania is temperate. The statewide mean annual precipitation ranged from 35 to 40 in. during 1971 to 2000. During 1971 to 2000, the wettest month was June, and the driest month was February. The statewide mean annual temperature ranged from 45 to 50°F during this same period (National Oceanic and Atmospheric Administration, 2003).

Pennsylvania has a diverse distribution of geology (Schultz, 1999). Ground water from most of the geologic formations is used for water supply. Aquifers across the state of Pennsylvania were classified into four generalized types: (1) crystalline rock, (2) carbonate rock, (3) siliciclastic rock, and (4) unconsolidated sediments, after Lindsey and Bickford (1999). The unconsolidated sediments include alluvium, glaciofluvial deposits, and deposits in the Cretaceous Coastal Plain near Philadelphia.

Three major land uses in Pennsylvania—urban, agricultural, and forested—account for most of the land area of the state. Pennsylvania has vast areas dominated by forested land use

(about 65 percent) and substantial areas dominated by agricultural land use (about 28 percent). Urban areas account for only about 4 percent of the state area. The remainder of the state area is covered by water or wetlands (about 2 percent) or by transitional, mining, or barren areas (about 1 percent).

Urban areas in Pennsylvania, although having only a small percentage of the total land area, have the greatest number of vehicles and, subsequently, the greatest number of refueling stations. Counties with large urban areas have the greatest number of registered passenger vehicles in Pennsylvania. The 20 counties with the greatest number of registered passenger vehicles all include large metropolitan or urban areas within or near to their boundaries. The five counties that compose the RFG-use area are the second, third, fourth, fifth, and seventh highest ranking of 67 counties in terms of number of registered passenger vehicles in the state in 2002 (Kurt Myers, Pennsylvania Department of Transportation, written commun., 2003). In fact, nearly 28 percent of the more than 7.4 million registered passenger vehicles in the state are registered in the five counties of the RFG-use area.

### **Acknowledgments**

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## APPROACH AND METHODS

### Sampling Strategy and Well-Selection Criteria

Data collected as part of several projects conducted by the USGS in Pennsylvania during 1993-2001 were compiled (table 1A)<sup>1</sup>. Sampling sites for all previous samples collected in Pennsylvania for the National Water-Quality Assessment Program (NAWQA) had been determined by a stratified random process and were designed to examine ambient ground water. Wells near known releases of petroleum products were not targeted for sampling in other previous studies. Usually, the ground water of an area or of a particular aquifer was the target of the study. The data from other USGS studies in Pennsylvania are referred to as ambient ground-water samples in this report. In a few cases, the data may not be truly ambient because the samples were collected from wells used to monitor for non-MTBE and non-BTEX contaminants. To complement the ambient MTBE data, water samples were collected as part of this study from wells near storage-tank release sites and analyzed for MTBE during July 2001 through February 2002 (table 1B). The sampling network was designed to examine MTBE distribution and concentration near known source locations and to compare those concentrations to ambient ground-water concentrations.

An effort was made to collect samples from an equal number of wells from each of the four different types of aquifers in the state. The areal extent of each aquifer was divided into subareas and one or two wells were sampled from each subarea if wells that met the criteria could be located.

To be selected for sampling, a well had to be within about 0.5 mi and topographically down-gradient from a known release site. Well depths of 250 ft or less were preferred, but if data such as geologic logs showed that water-bearing zones were less than 250 ft deep, that also was accept-

able. The depth criteria was used to focus on shallow water-supply wells. A few wells exceeded the depth criteria but were sampled because of difficulty in locating wells in some areas. Well depths were reported by well owners or drillers. Wells used to monitor releases were not sampled. Wells with low yields (<50 gal/min) were preferred, but some higher-yielding wells were sampled. Only untreated water from wells was sampled, and no springs were sampled.

The locations of known release sites in Pennsylvania from about 1988 to 2001 were acquired from the PADEP Storage Tank Division. The release sites did not have latitude and longitude coordinates, only addresses. Because geo-referencing software was used on the addresses to determine latitude and longitude, the accuracy of this determination is dependent on the accuracy of the address. Although data on about 15,000 storage-tank releases were stored in the PADEP database, only about 7,000 had addresses with sufficient information for the software to calculate a latitude and longitude accurate enough for the location to be found in the field by USGS personnel, if necessary. The location accuracy was determined to be either an exact location or a location known to within a few hundred feet.

Data from the PADEP database on storage-tank releases originally contained only location of the storage-tank release, brief information or no information about the contaminant, and no information about the existence of nearby wells used for drinking water. Information about the age, mass, and contaminant plume extent is not in the database. Not all storage-tank releases were identified as containing benzene, gasoline, or MTBE; instead, there may have been some releases of home heating oil. The type of contaminant reported was not taken into account when the sampling effort began, so some sites sampled could have been near heating-oil releases, though these releases are a small percentage of the total releases documented in the database. The great majority of the releases were labeled as releases from gas stations or releases with benzene, gasoline, or MTBE listed as the contaminant.

Initially, the search for qualified wells near release sites was not very successful. Subsequently, a revised PADEP database was compiled that included only release sites where

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<sup>1</sup> Data collected by the USGS also are available in the USGS National Water Information System (NWIS) computer databases at <http://waterdata.usgs.gov/nwis/>

MTBE had been reported and where PADEP investigators reported wells used for water supply within about 0.5 mi of the release site. Using this revised database enabled greater success of locating wells that met sampling criteria. Nearly 80 percent of the 86 wells sampled were located using the revised database.

The MTBE data may be biased or not agree with data in the PADEP database of release sites for several reasons.

1. Where sampling was done near a release site without confirmed MTBE, no MTBE might have been present. However, the listing of contaminants in the release database is not complete or accurate.
2. At some release sites, the database may list heating oil as the source contaminant but MTBE could be present because of cross contamination during transportation (Hinchev and others, 2001).
3. At older release sites, MTBE was not analyzed for but may have been present.
4. MTBE will almost always be present near the release sites because of its use in most gasoline, but remediation may have removed the MTBE prior to sampling for this study.

### **Sampling and Data Analysis**

The sample plan was designed to locate about 30 samples from each of 4 aquifer rock types in Pennsylvania. Poor success in finding suitable wells in some areas resulted in an unequal number of samples for the four aquifers. The final distribution of samples by aquifer type was 21 samples from the carbonate-rock aquifers, 21 samples from the crystalline-rock aquifers, 28 samples from the siliciclastic-rock aquifers, and 16 samples from the unconsolidated sediments.

Parts per billion sampling protocols described by Koterba and others (1995) were followed but modified for several factors such as one-person sampling where possible, sampling from high volume supply wells, and sampling only for MTBE and BTEX compounds and selected field constituents (temperature, specific conductance, and pH). The modifications do not affect any results or laboratory analyses because the modifications were made to protocols written for sampling nonvolatile organic compounds

(such as pesticides) or trace metals. The current study called for sampling only MTBE and BTEX compounds. One of the modifications permitted the use of copper fittings and tubing, instead of teflon, to connect to water sources. The procedures used were discussed with and agreed to by members of the NAWQA VOC Team. Clean, parts per billion sampling protocols significant to sampling VOCs were followed.

Most commonly, the well owner's pump provided the sample water when a satisfactory tap into the plumbing could be located. A low volume sampling pump was used to obtain the water sample from a few wells. After monitoring pH, specific conductance, and temperature until readings were stable, the unfiltered samples were collected from untreated well water into completely full (no entrapped air bubbles) 40-mL glass vials, chilled, and sent to the laboratory.

The minimum reporting level (MRL) for MTBE used by the USGS laboratory is different among the ambient samples. To analyze all the samples, a common MRL had to be selected. For this study, 0.2 µg/L was selected. Any data reported at concentrations below 0.2 µg/L were considered to have MTBE concentrations of <0.2 µg/L for this study. Any data reported at an MRL greater than 0.2 µg/L were eliminated from the data set. Very few samples (7 of 366 samples) had an MRL greater than 0.2 µg/L.

The 86 samples collected were analyzed at the USGS National Water Quality Laboratory near Denver, Colo., using purge and trap gas chromatography/mass spectrometry (GC/MS) methods (Rose and Schroeder, 1995). These methods are comparable to USEPA method 524.2 (U.S. Environmental Protection Agency, 1992).

Categorical methods were used to perform statistical analysis with groups of the data (Helsel and Hirsch, 1992). More than 50 percent of the data were below the MRL of 0.2 µg/L, rendering analysis of data with statistical tests based on means or medians infeasible. The number of detections and nondetections were compared, and a Kruskal-Wallis test for ordered categorical responses was conducted. The data are ordinal in that the response variable, MTBE concentration, is listed only as either above the MTBE MRL for this study (an MTBE detection) or below the MRL (an MTBE nondetection). The procedure includes a ranking of the data where all detections are tied in ranking and all nonde-

tections are tied in ranking. As used in the analysis for this study, the test determines whether groups or categories, such as land use or aquifer types, etc., are found to have significantly different proportions of detections to nondetections of MTBE. The proportions are then expressed as percentages, or as frequency of MTBE detection expressed as a percentage. An alpha of 0.05 (95-percent confidence level) was used as the significance level of the statistical tests.

Some of the categories used for statistical analysis contained multiple subcategories; for example, the land-use category consists of subcategories for urban area, agricultural area, and forested area. If a significant difference was found in detection frequency for one or more subcategories, a determination of which subcategories differ from others was made by performing multiple comparisons with Kruskal-Wallis tests between groups of subcategories until all subcategories that are significantly different from other subcategories are identified (Helsel and Hirsch, 1992).

#### **Quality-Assurance Data**

The sampling effort included a quality-assurance (QA) plan to evaluate any bias or contamination issues in the samples. Thirteen QA samples were analyzed, which included two equipment blanks, two trip blanks, two field blanks, four replicate samples, and three field spikes.

Blanks are used to assess bias in environmental samples because of contamination. Equipment blanks were collected in a controlled environment (the District laboratory) prior to initial sampling to assure that equipment is contaminant-free after cleaning. Equipment includes fittings and tubing used to collect samples. Both equipment blanks showed no detection of MTBE or BTEX compounds at the 0.2 µg/L MRL. Trip blanks were never opened in the field and were intended to measure any contamination during sample transport. Both trip blanks showed no detection of MTBE or BTEX compounds. Field blanks also measure contamination, and the two field blank samples showed no detections of MTBE or BTEX compounds.

For replicate samples, the concentrations of MTBE and BTEX compounds were below the MRL in the environmental and the replicate samples.

Two field spikes showed recoveries of 91 percent and 86 percent. The favorable recoveries of field spikes indicate good precision in the sample analysis.

### **MTBE CONCENTRATIONS IN GROUND WATER IN PENNSYLVANIA**

Atmospheric deposition (nonpoint source) and releases from storage tanks (point sources) are significant sources of MTBE in ground water in Pennsylvania. MTBE concentrations and frequency of detection were examined to determine if certain aquifers, land uses, or RFG uses are associated with high occurrence of MTBE.

#### **Sources of MTBE in Ground Water**

Nonpoint and point sources contribute MTBE to ground water. Nonpoint sources include atmospheric deposition, particularly from precipitation; vehicle exhaust emissions; and stormwater runoff (National Science and Technology Council, 1997). Point sources include storage-tank (above or below ground) releases, overfilling gas tanks at gasoline stations, vehicle accidents, pipeline releases, refinery releases, watercraft engine releases, homeowner spills, and evaporative losses at refueling.

#### **Atmospheric Concentrations of MTBE**

Atmospheric deposition is one of the most likely nonpoint sources for MTBE. Low concentrations in ground water are considered to be the result of atmospheric deposition of MTBE that infiltrates the unsaturated zone and travels to the water table (Baehr and others, 1999, 2001; Zogorski and others, 1998). Infiltration and dispersion can transport MTBE from the air into the unsaturated zone and into the ground water (Pankow and others, 1997).

In a study in southern New Jersey of the atmosphere as a source of VOCs in shallow ground water, Baehr and others (1999, 2001) used atmospheric concentrations of MTBE to calculate concentrations of MTBE in equilibrium with aqueous phase MTBE concentrations and to assess the relevance of atmospheric concentrations of MTBE to ground-water quality. They observed that mean atmospheric MTBE levels near Glassboro, N.J., equated to about 0.1 µg/L when converted to equivalent aqueous MTBE concentrations. The MRL for the MTBE in the

atmosphere was 0.05 ppbv in the New Jersey study. The wells sampled in the New Jersey study are all shallow monitor wells that tap into unconsolidated sediments in an RFG-use area.

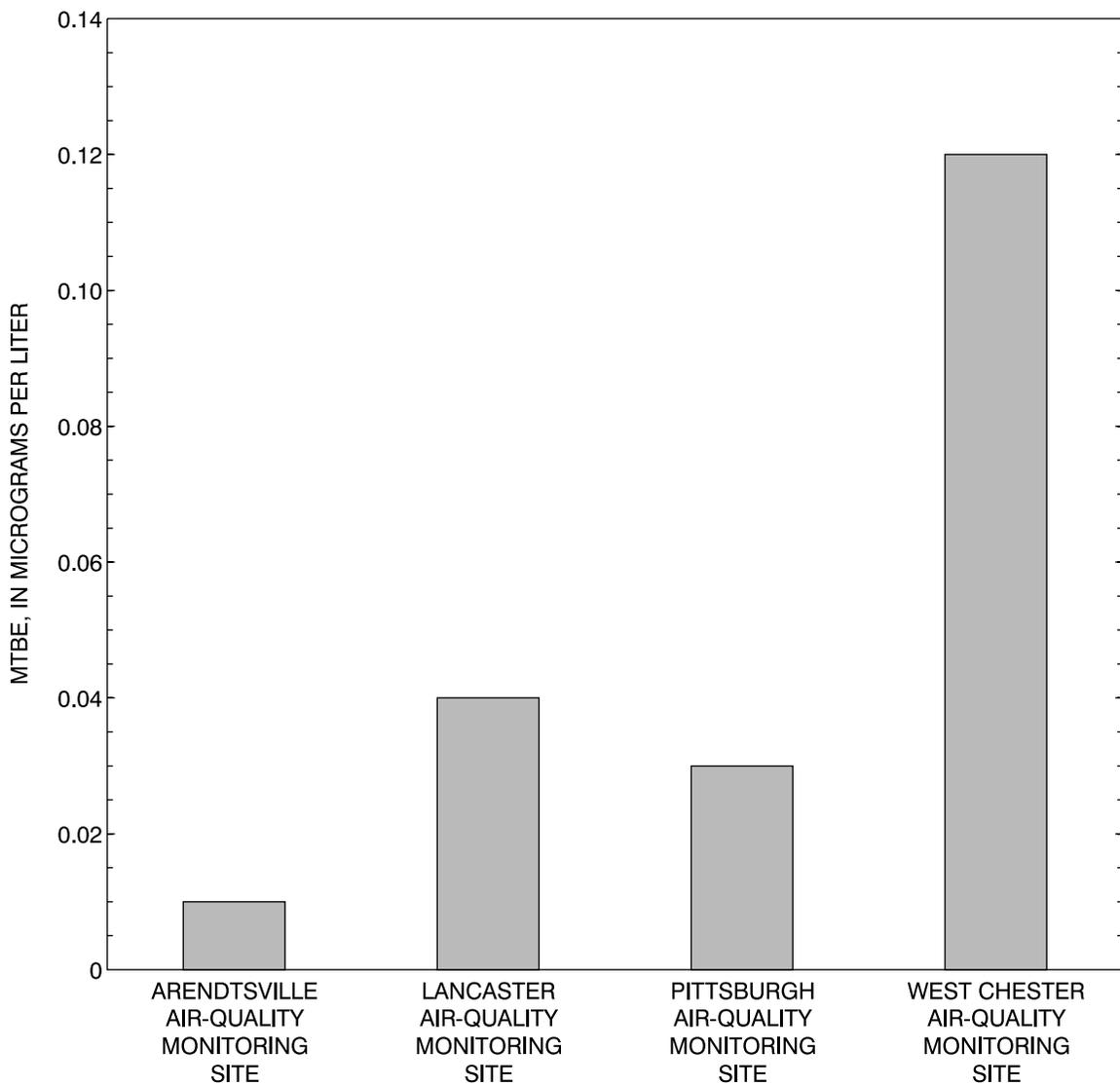
Atmospheric MTBE data are examined in this report to estimate MTBE in ground water contributed by atmospheric deposition and to determine whether MTBE concentrations less than 20 µg/L are likely from atmospheric (non-point) sources. The PADEP Bureau of Air Quality collects atmospheric MTBE data at some of the air-quality monitoring sites in Pennsylvania (Ralph Scanlon, Pennsylvania Department of Environmental Protection, written commun., March 2001). Atmospheric MTBE data were obtained from PADEP air-quality monitoring sites at Pittsburgh, Lancaster, West Chester, and Arendtsville, Pa. (Gary LaBelle, Pennsylvania Department of Environmental Protection, written commun., July 2002) (table 1C). Data from the four sites were used to determine the data distribution and an approximate regional value of atmospheric MTBE for Pennsylvania. The time period over which the samples were collected varies from site to site; however, data were used for this report from Pittsburgh (during 4/01/01–12/21/01), Lancaster (during 4/01/01–3/31/02), West Chester (during 4/01/01–12/3/01), and Arendtsville (during 5/13/01–3/31/02) (table 1C). Other time periods for these four sites and one other sample location (Presque Isle in Erie County) were not used because of problems identified in the data sets (Gary LaBelle, Pennsylvania Department of Environmental Protection, written commun., July 2002). The atmospheric data consist of results of analysis of 24-hour composite samples collected every 6 days. The detection level used in this analysis of the data from the air-quality sites for the above time periods ranged from 0.01 to 0.02 ppbv. These time periods provide nearly three-fourths of a year of data for two sites and nearly a year of data for two sites. Three of the sites are in urbanized areas (Pittsburgh, West Chester, and Lancaster) and one site is in a rural setting (Arendtsville, 10 mi north of Gettysburg, Pa.) (fig. 1). The Lancaster and West Chester sampling sites are in a parking lot for a school and therefore may not be representative of the air everywhere in Lancaster and West Chester.

The method described by Baehr and others (1999) was used to calculate the equivalent aqueous MTBE concentrations from atmospheric

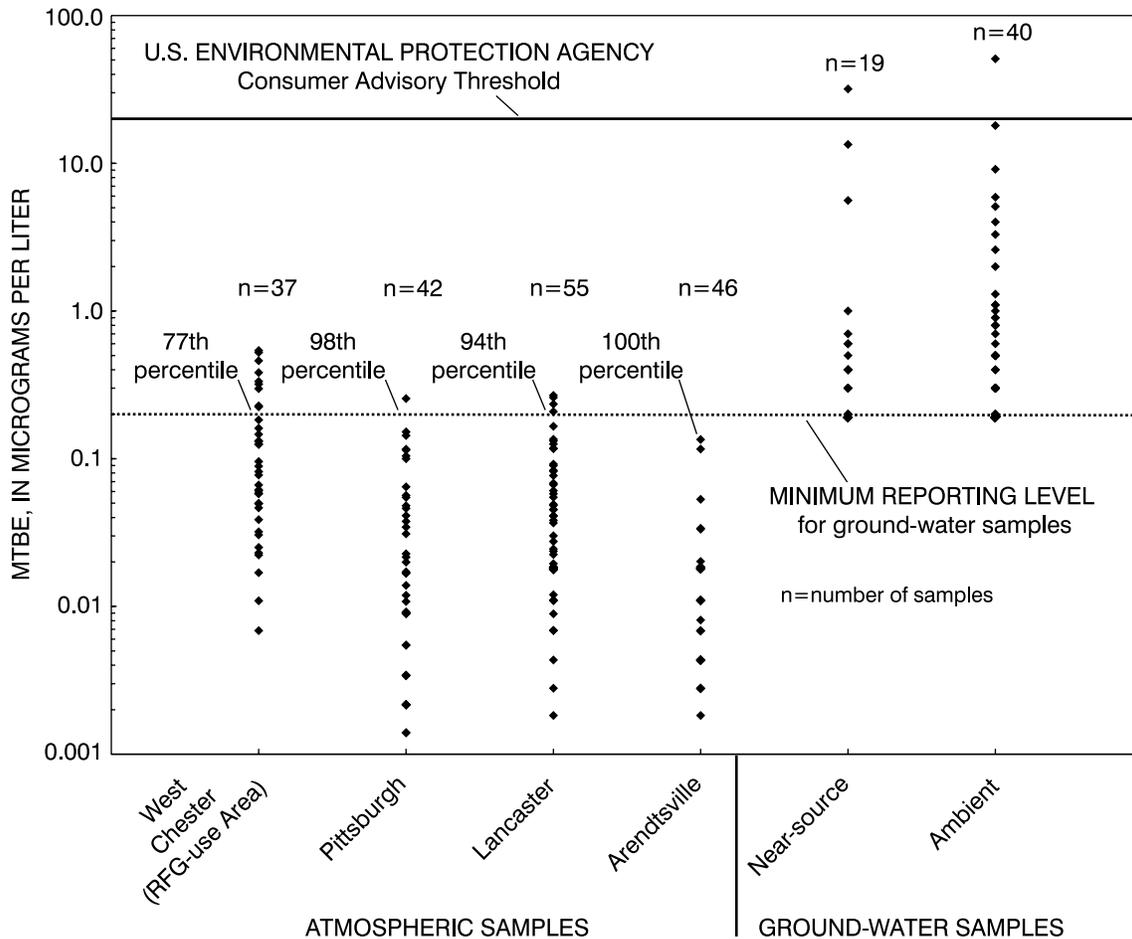
MTBE data and temperature collected at the four sites in Pennsylvania (Appendix 2). The temperature data were obtained from a PADEP air-quality monitoring site where available and from the nearest National Oceanic and Atmospheric Administration (NOAA) air-quality sites elsewhere (Harrisburg for Arendtsville as needed and Philadelphia for West Chester as needed). Equivalent aqueous MTBE concentrations vary across Pennsylvania as measured by the PADEP air-quality monitoring sites. The mean equivalent aqueous MTBE concentration for the period of available data for West Chester (0.12 µg/L) was at least three times greater than the means for the other sites (Arendtsville, 0.01 µg/L; Pittsburgh, 0.03 µg/L; Lancaster, 0.04 µg/L) (fig. 2). Of the four sites, West Chester is the only air-quality monitoring site in the RFG-use area. The higher use of MTBE in that area likely results in greater atmospheric levels of MTBE.

All MTBE detections in ground water presented in this report are above the calculated mean equivalent aqueous MTBE concentrations in the atmosphere and, therefore, are unlikely to be solely the result of atmospheric deposition of MTBE (fig. 3). Instead, they are most likely from the point sources sampled near releases and other types of point sources. Certainly, some MTBE detections may be the result of atmospheric input in whole or in part. Atmospheric MTBE levels do vary in time and space. The samples with MTBE reported at the MRL (0.2 µg/L) could be from either nonpoint (atmospheric) sources or from point sources or a combination. The MTBE concentrations are censored above the level needed to compare ground-water data to atmospheric MTBE data to determine more exactly if there is a concentration lower than 0.2 µg/L at which the ground-water samples are likely from point sources. Based on available atmospheric MTBE data for Pennsylvania, ground-water samples with MTBE concentrations of 0.2 µg/L or greater are likely from point sources.

Baehr and others (1999) stated that many of the MTBE detections in ground water in New Jersey could be the result of atmospheric input; however, the MTBE MRL for ground-water samples for his study was 0.1 µg/L, which was equal to the 50<sup>th</sup> percentile of the equivalent aqueous atmospheric MTBE data. The lowest reported MTBE concentration in the current study



**Figure 2.** Mean equivalent aqueous MTBE concentrations calculated from atmospheric MTBE data at four air-quality monitoring sites in Pennsylvania (Arendtsville, Lancaster, Pittsburgh, and West Chester), April 2001 to April 2002. (Minimum reporting level ranges from 0.01 to 0.02 ppbv.)



**Figure 3.** MTBE concentrations above the minimum reporting level in near-source samples and ambient samples and equivalent aqueous MTBE concentrations calculated from atmospheric data. (The minimum reporting level is 0.2 µg/L for ground-water samples and ranges from 0.01 to 0.02 ppbv for atmospheric samples.)

(0.2 µg/L) is equal to about the 77<sup>th</sup> percentile of the atmospheric data (in equivalent aqueous concentration) from West Chester, which has the highest mean atmospheric levels and is in the RFG-use area (fig. 3). The median equivalent aqueous concentration of MTBE calculated from the West Chester data, 0.05 µg/L, is much less than the median MTBE concentration of 0.4 µg/L for the samples that are above the MRL (MTBE detections) in near-source samples and the median MTBE concentration of 0.5 µg/L for the ambient samples above the MRL.

The effect of attenuation can further demonstrate that the MTBE concentrations above the MRL in ground water are not likely the result of atmospheric deposition of MTBE. The calculations of equivalent aqueous MTBE concentra-

tions from the atmosphere do not take into account the attenuation that may occur during transport through the unsaturated zone. Thus, the contribution of atmospheric MTBE to ground water may be less than shown in the current study by calculations of equivalent aqueous MTBE concentrations. Baehr and others (1999) have concluded that residence time of the atmospheric MTBE in the unsaturated zone and temperature effects can decrease the amount of MTBE that reaches the zone of saturation and may result in nondetects of MTBE in ground water, even though the atmospheric data show that MTBE is present. In addition to dilution from mixing, adsorption, biotic and abiotic transformation, and volatilization (Buxton and others, 1997), MTBE can be attenuated by

remediation efforts. If the concentrations of MTBE in ground water that exceed the MRL, as examined in this study, were attenuated from MTBE concentrations that were contributed originally and directly, as by point source, to the unsaturated zone and the ground-water system, then the difference between pre-attenuated concentrations of MTBE in ground water and atmospheric MTBE concentrations would be greater than shown in the current study.

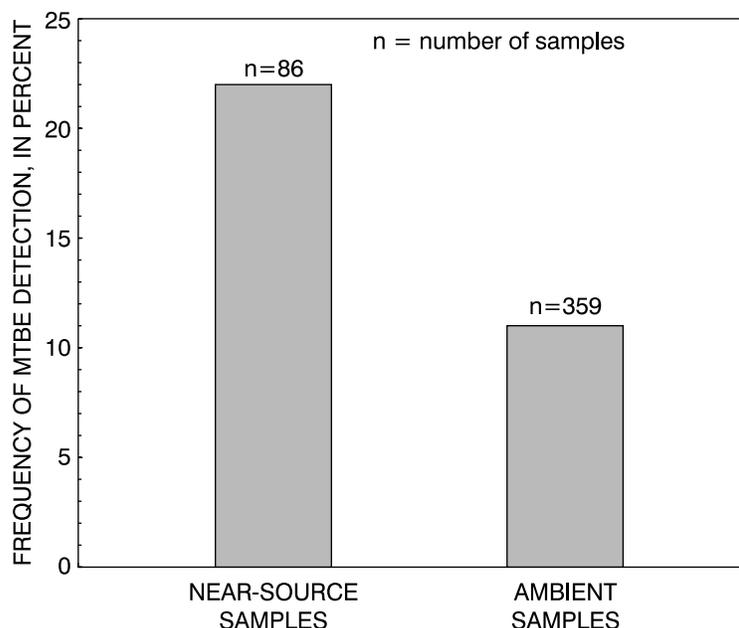
#### MTBE Detections and Concentrations in Ground Water Near Known Storage-Tank Releases and in Ambient Ground Water

MTBE was detected more frequently in near-source samples compared to ambient samples, indicating that releases are a significant source of MTBE in ground water. MTBE was detected in 22 percent of near-source samples compared to 11 percent of ambient samples (fig. 4 and table 1). The Kruskal-Wallis test results indicate a significant difference between the near-source samples and the ambient samples. The detection

frequency of near-source samples is significantly greater than the detection frequency of the ambient samples.

The MTBE concentrations observed in this study are at low levels. Only one near-source sample and one ambient sample exceeded the USEPA Consumer Advisory threshold of 20 µg/L. MTBE concentrations ranged from 0.2 to 31 µg/L for near-source samples and from 0.2 to 51 µg/L for ambient samples (fig. 3). The median concentrations of all near-source samples and all ambient samples are both equal to the MRL. Median concentrations of samples above the MRL were 0.4 µg/L for near-source samples and 0.5 µg/L for ambient samples.

The MTBE detection frequency in near-source samples in this study (22 percent) is higher than those in ambient samples in two other studies with similar MRLs (table 1). The MTBE detection frequency for ambient samples from the USGS NAWQA Program (5 percent) is less than the detection frequency for ambient



**Figure 4.** MTBE detection frequency in near-source and ambient ground-water samples in Pennsylvania. (The minimum reporting limit is 0.2 µg/L.)

**Table 1.** Comparison of MTBE detection frequencies in ground water, minimum reporting levels, and type and number of samples from studies in Pennsylvania, Maine, New Jersey, and nationwide for the NAWQA Program

Study	MTBE in ground water in Pennsylvania	MTBE in ground water in Pennsylvania	NAWQA Program <sup>1</sup>	Maine study <sup>2</sup>	New Jersey study <sup>3</sup>
Type of samples:	Near-source samples	Ambient samples <sup>4</sup>	Ambient samples <sup>5</sup>	Ambient samples <sup>5</sup>	Ambient samples <sup>5</sup>
MTBE detection frequency (in percent)	22	11	5	16	45
Minimum reporting level (micrograms per liter)	.2	.2	.2	.1	.1
Number of samples	86	359	thousands	946	72

<sup>1</sup> Zogorski and others, 2001.

<sup>2</sup> State of Maine, 1998.

<sup>3</sup> Stackelberg and others, 1997.

<sup>4</sup> Samples considered ambient with regard to MTBE concentrations.

<sup>5</sup> Samples are selected randomly and assumed to be ambient.

samples for this study (11 percent). The MRL is 0.2 µg/L for both data sets (Zogorski and others, 2001). A study in Maine (State of Maine, 1998) and a study in New Jersey (Stackelberg and others, 1997) showed higher MTBE detection frequencies for ambient samples than the current study, but the MRL for both those studies was 0.1 µg/L. The ambient ground-water sources sampled in Maine included springs, dug wells, and drilled wells.

The data suggest that the likelihood of detecting MTBE is significantly greater when sampling near known releases than the likelihood of detecting MTBE in ambient ground water. Two factors may explain low MTBE concentrations in samples collected at near-source sites.

1. Attenuation of MTBE concentrations will likely occur over time. The time and mass of contaminant released is not known for many release sites, but if the release happened several years prior to collection of the sample for this study, MTBE concentrations likely were once greater than reported here because of attenuation. MTBE tends to attenuate naturally at the half-life rate ranging from 0.2 to 2.2 years in the unsaturated zone in unconsolidated sediments in New Jersey (Baehr and others, 1999). Data from other studies have shown a similar range of MTBE half-life (U.S. Environmental Protection Agency, 1999). Remediation efforts also could

reduce the MTBE concentrations over time.

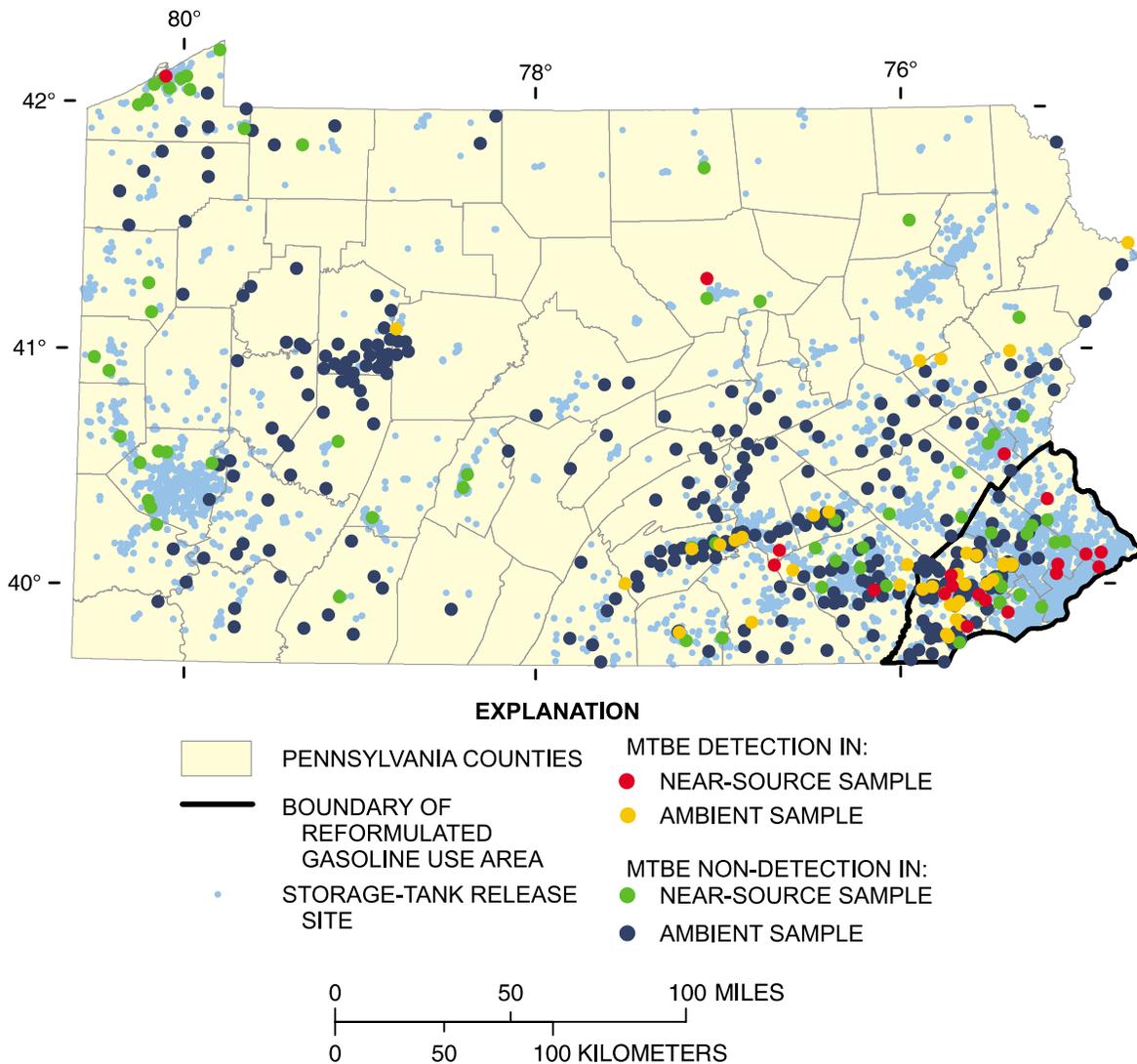
2. The well may be near the edge of a MTBE plume. In this case, either intermittent pumping of the domestic well results in capturing low concentrations of MTBE or domestic wells distant (>1,000 ft) from the release could contain low concentrations of MTBE (<20 µg/L) that are not affected by a remediation effort. MTBE remediation efforts tend to focus on high MTBE concentrations (>20 µg/L) near the release site. Distant wells may not get sampled for MTBE unless a complaint is received from well owners or basement owners.

**Relation of MTBE Concentrations to Distance From Storage-Tank Release Sites**

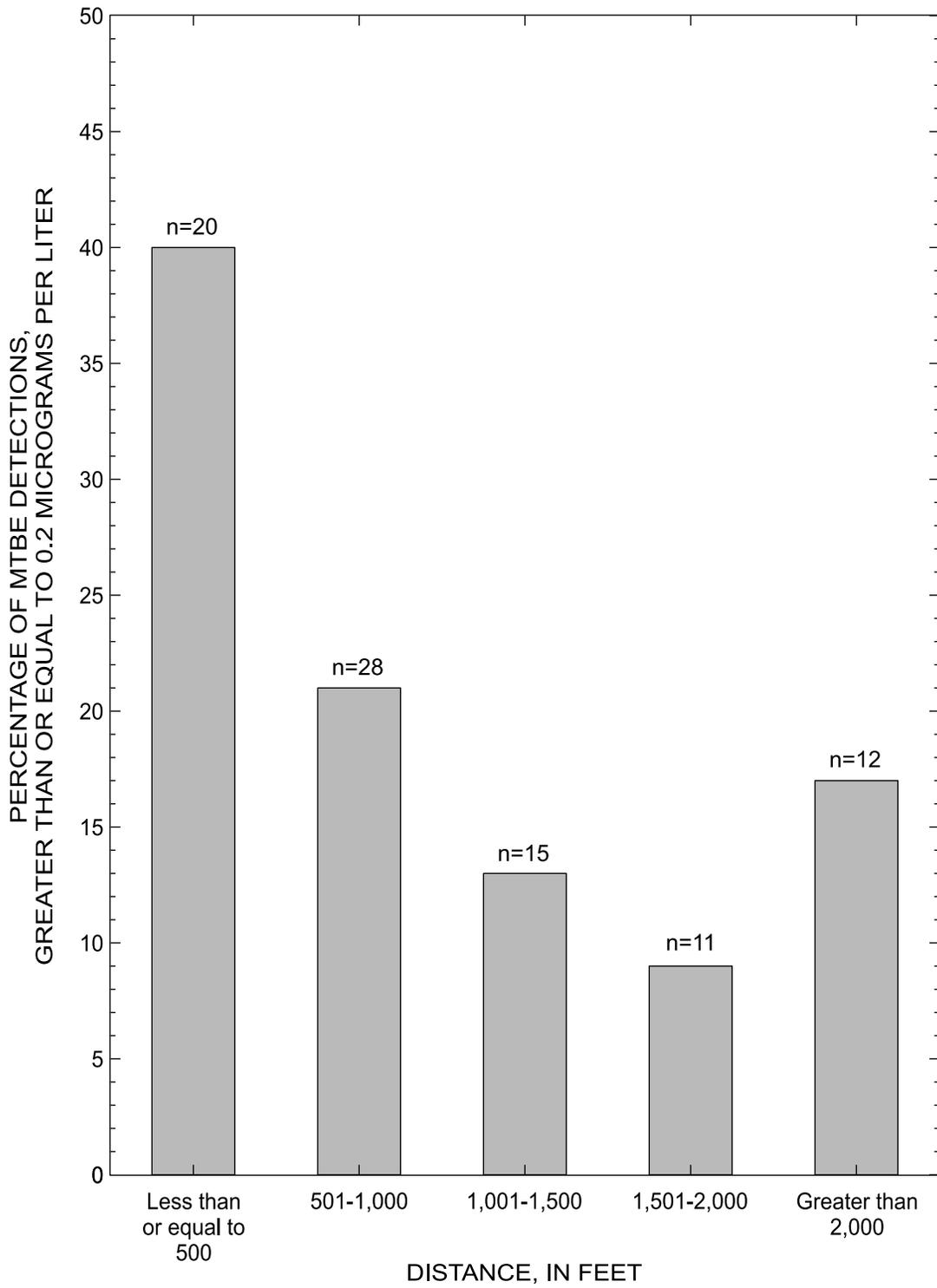
The 86 near-source samples were collected at distances up to about 0.5 mi downgradient from a known release (fig. 5).

The number of MTBE detections decreases with increased distance from a release (fig. 6). The number of detections of MTBE decreases from 8 of 20 samples within 500 ft of a release, to 6 of 28 samples from 501 to 1,000 ft from a release,

to 2 of 15 samples from 1,001 to 1,500 ft from a release, to 1 of 11 samples from 1,501 to 2,000 ft from a release, to 2 of 12 samples beyond 2,000 ft of a release. The number of nondetection sampling points seems to be distributed relatively evenly throughout the distance from releases. It should be made clear that these samples are collected near 86 different release sites and do not represent the decrease that may be expected in a particular plume of MTBE.



**Figure 5.** MTBE detection data from all ground-water samples, storage-tank release sites, and Reformulated Gasoline use areas in Pennsylvania. (The minimum reporting limit is 0.2 µg/L.)



**Figure 6.** The relation between number of MTBE detections and distance downgradient of storage-tank releases. (The minimum reporting limit is 0.2 µg/L.)

The relation between the MTBE concentration and distance from a release can be affected by the sample location in a MTBE plume and MTBE attenuation depending on the time elapsed since the release. Decreasing MTBE detections with increasing distance from a release for the 86 samples at 86 different release sites lends some additional support to the hypothesis that the detections are the result of point sources.

The properties of MTBE permit long-range transport (Moran and others, 1999, Buxton and others, 1997). MTBE can be transported farther and deeper than BTEX compounds. Very few detections of BTEX compounds have been found concurrently with MTBE in ambient samples collected as part of the NAWQA Program (Zogorski and others, 1998). Although the BTEX data are not presented in this report, only 1 of 86 near-source samples had concurrent detections of BTEX compounds and MTBE. The lack of co-occurrence of MTBE and BTEX compounds may be associated with the high solubility and mobility and low biodegradation properties of MTBE relative to BTEX compounds, which results in detection of MTBE, but not BTEX compounds, at distal portions of gasoline contaminant plumes (Grady and Casey, 2000).

## **Occurrence of MTBE**

### **MTBE Detections and Concentrations Among Aquifer Types**

This study was designed to permit sampling of an equal number of wells, if possible, in each of the four generalized aquifer types in Pennsylvania (fig. 7). Given the uncertainties in locating wells near known release sites, the results of the sampling yielded different numbers of samples in each of the four aquifer types, but the differences are not considered too great to make comparisons among the aquifer types. Twenty-one samples were obtained from carbonate-rock aquifers, 21 samples were obtained from crystalline-rock aquifers, 28 samples were obtained from the siliciclastic-rock aquifers, and 16 samples were obtained from unconsolidated aquifers.

Results from the Kruskal-Wallis statistical tests show that the frequency of MTBE detections in near-source crystalline-rock aquifer samples is significantly greater (57 percent)

than either near-source or ambient samples from any other aquifer type. The two greatest frequencies of detections are in samples from the crystalline-rock aquifer (fig. 8); however, the detection rate from ambient samples from the crystalline-rock aquifer is not significantly different from detection frequencies in any other aquifer except the near-source crystalline-rock aquifer samples and the ambient siliciclastic-rock aquifer samples.

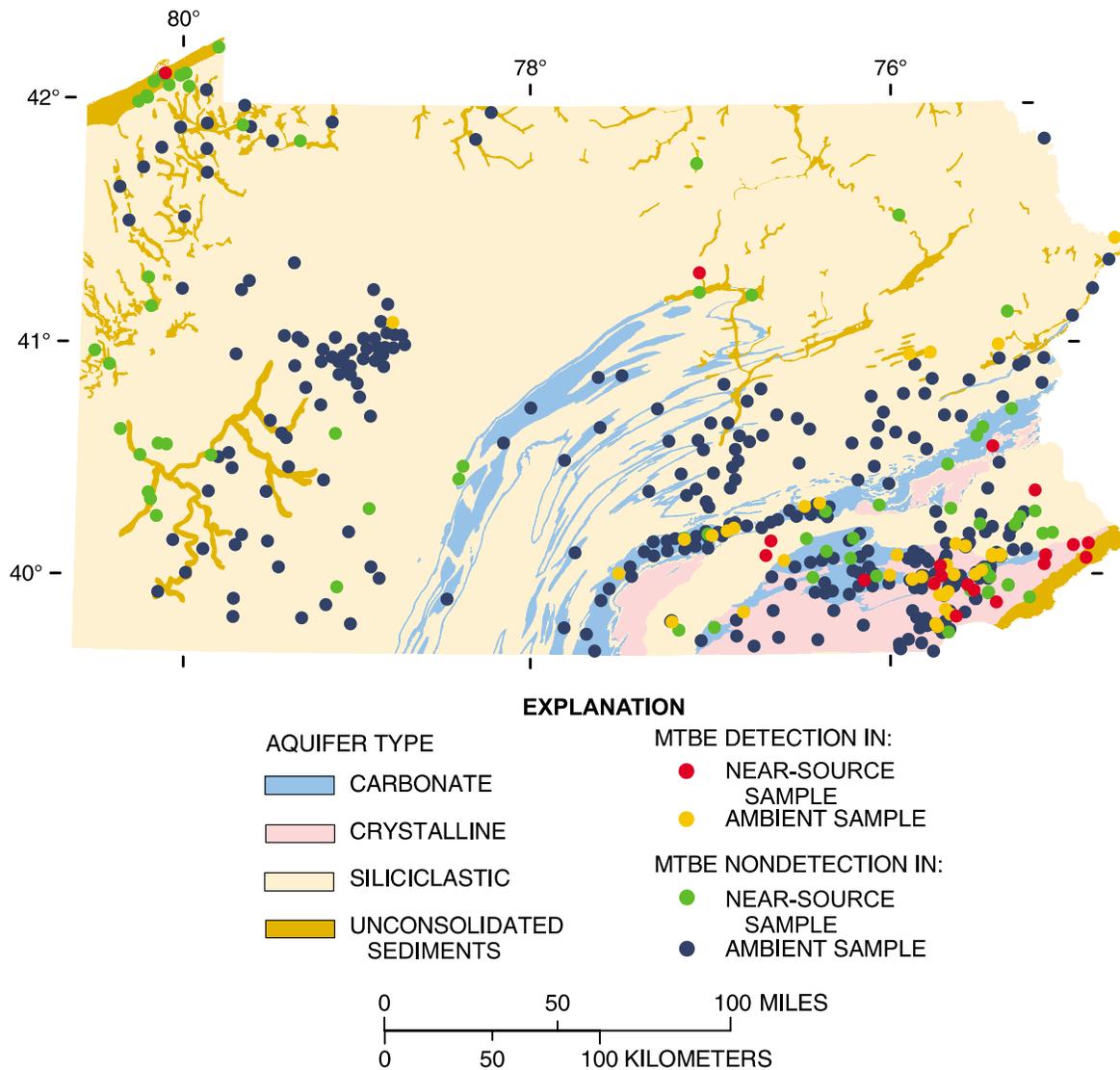
Properties of the crystalline-rock aquifers, and the low permeability of the overlying saprolite, may slow movement of MTBE plumes and lessen dilution and dispersion, resulting in MTBE being transported at a slow rate and therefore remaining near a release site for a longer time than it would in areas without saprolite.

It is also possible that physical properties of the crystalline-rock aquifer may not be reasons for higher MTBE detection rates. The percentage of the total areal extent of the crystalline-rock aquifer in Pennsylvania that underlies the RFG area (40 percent) is much greater than the percentages of extents of the other aquifers that underlie the RFG area (3, 3, and 12 percent for the carbonate rock, siliciclastic rock, and unconsolidated sediments aquifer types, respectively).

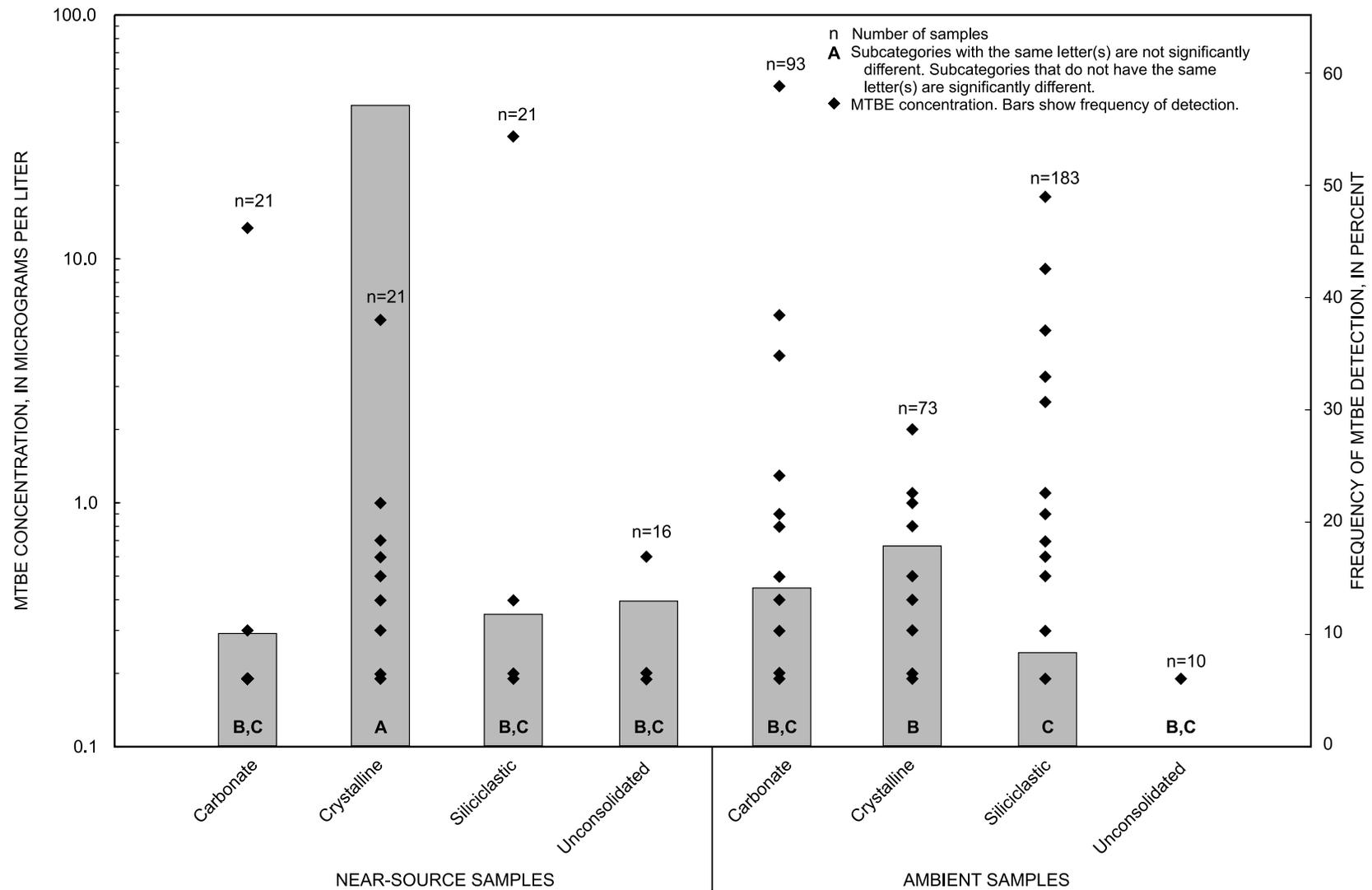
Determination of the effects of physical properties of an aquifer on the extent and fate of a plume of MTBE would require detailed site-specific hydrogeologic information for many release sites and a study of the transport of MTBE over time at many sites. Aquifers with higher permeability, such as unconsolidated sediments, showed a lower frequency of detection, perhaps indicating greater movement of MTBE. Aquifers with lower permeabilities, such as the crystalline rocks, generally showed a greater frequency of detection; however, the number of samples from the unconsolidated sediments aquifer type was small and may not be representative. The unconsolidated sediments aquifer is used less than others in the RFG-use area.

### **MTBE Detections and Concentrations Among Land-Use Categories**

The samples were identified as being from urban, agricultural, or forested land use on the basis of the location of the sample site in the land-cover data set for Pennsylvania, which is commonly referred to as the Multi-Resolution



**Figure 7.** MTBE detections and major aquifer types in Pennsylvania (Major aquifer types modified from Berg and others, 1980; Soller and Packard, 1998; and Lindsey and Bickford, 1999). (The minimum reporting limit is 0.2 µg/L.)

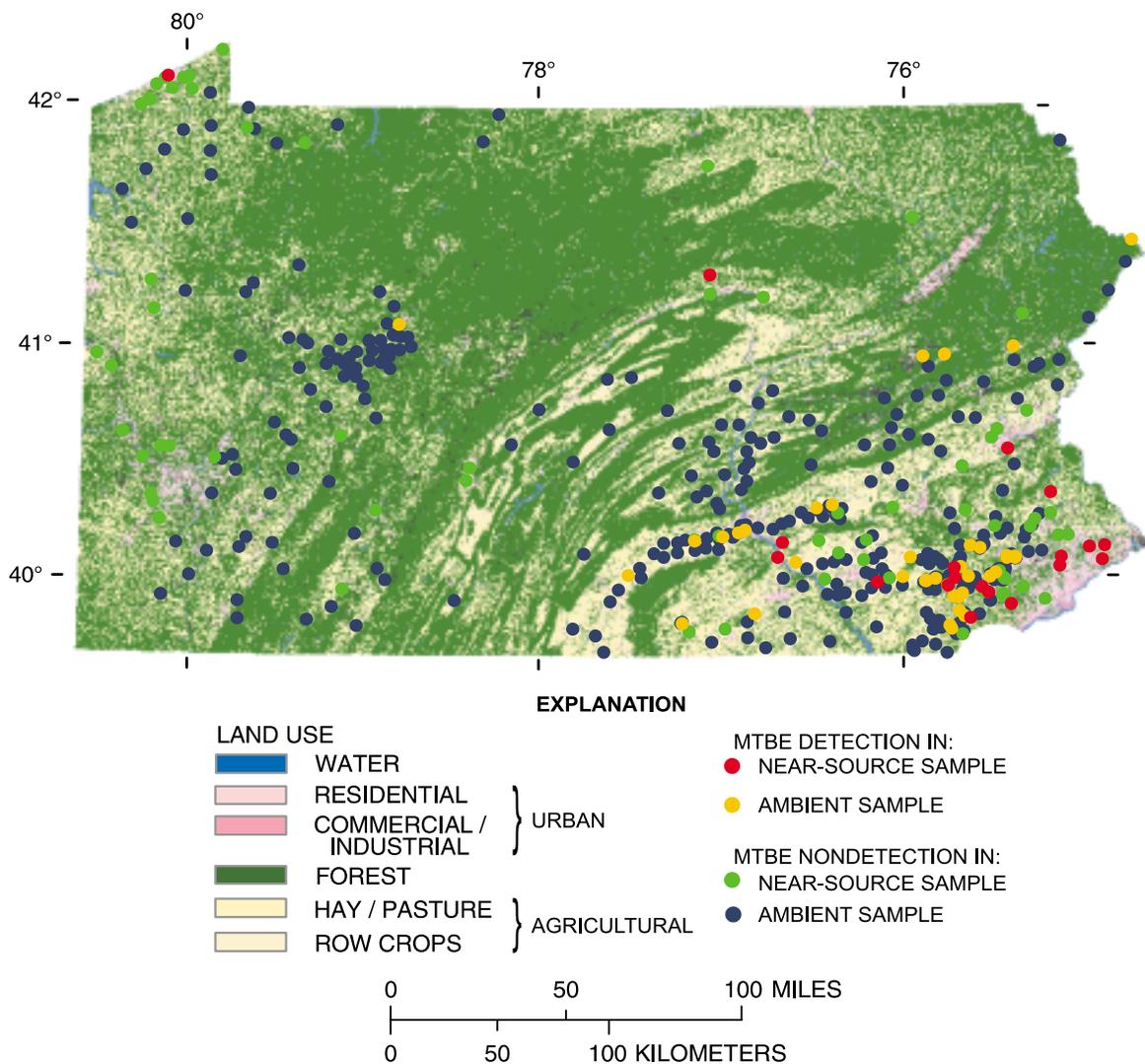


**Figure 8.** MTBE concentrations and detection frequency by carbonate rock, crystalline rock, siliciclastic rock, and unconsolidated sediment aquifer types in near-source and ambient ground-water samples. (The minimum reporting limit is 0.2 µg/L; values below minimum reporting limit are plotted as 0.19 µg/L.)

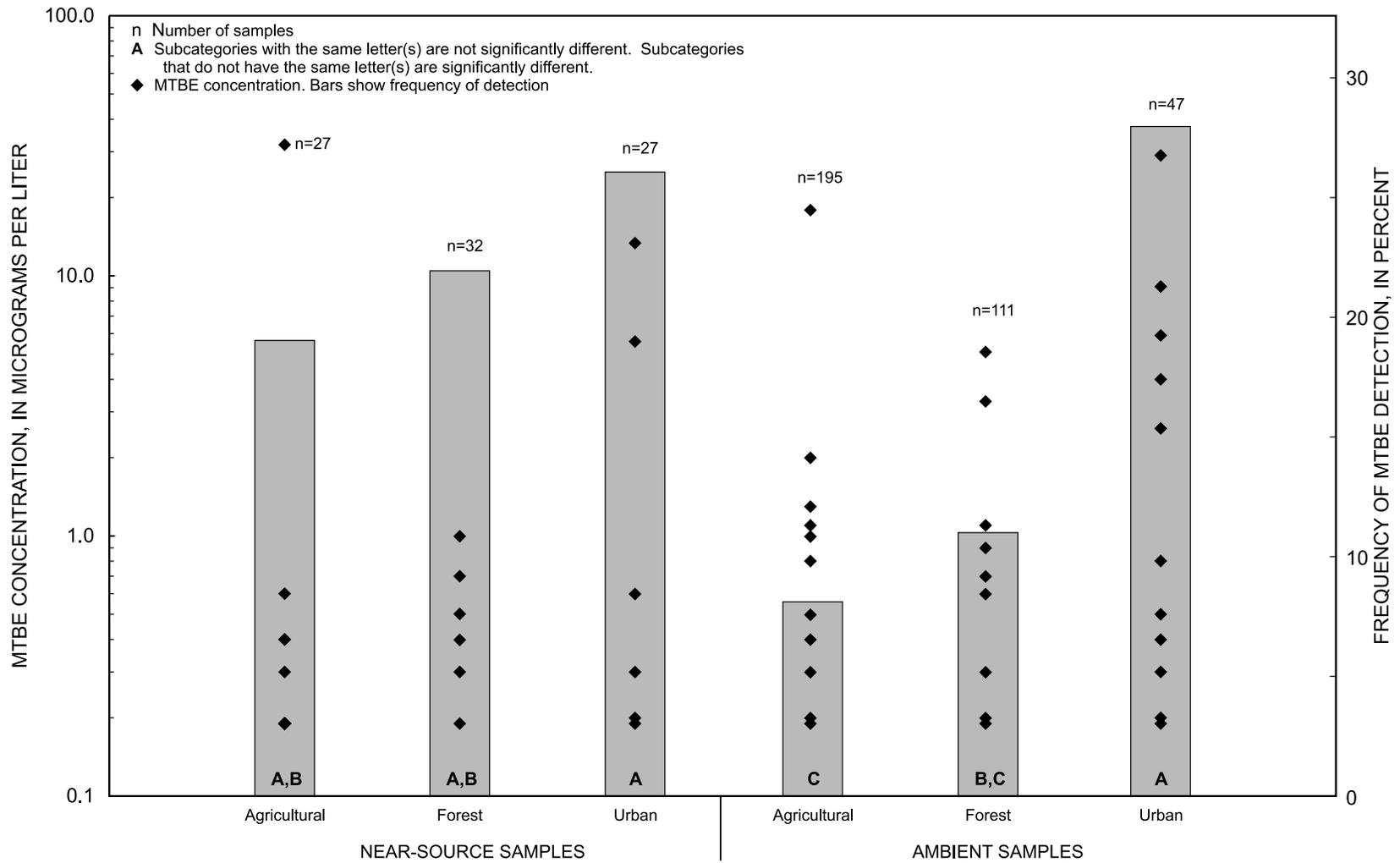
Land Cover data set (fig. 9). The land-cover data set was produced as a cooperative effort between the USGS and the USEPA using data purchased by the multi-federal-agency Multi-Resolution Land Characterization (MLRC) Consortium. The data were compiled from satellite imagery circa 1992 with a spatial resolution of 30 m (U.S. Geological Survey, 1992).

MTBE detections do not significantly differ among land-use categories for near-source samples; however, frequency of MTBE detection in ambient samples is significantly greater in urban areas than in agricultural and forested areas based on Kruskal-Wallis statistical test

results (fig. 10). MTBE is detected more frequently in ambient urban samples (28 percent) than in near-source urban samples (26 percent), but the difference is not significant. The statistical test results suggest that location of the sampling site relative to a release appears to be more significant than the surrounding land use. However, the likelihood of detecting MTBE in near-source or ambient samples is significantly greater in urban areas than in ambient samples from agricultural or forested areas. This suggests further that MTBE occurrence is linked to urban land use.



**Figure 9.** MTBE ground-water sample sites and MTBE detections among land-use categories. (Land-use/land-cover data from U.S. Geological Survey, 1992.)



**Figure 10.** MTBE concentrations and detection frequency in agricultural, forest, and urban land-use categories for near-source and ambient ground-water samples. (The minimum reporting limit is 0.2 µg/L; values below minimum reporting limit are plotted as 0.19 µg/L.)

Three points suggest further that high MTBE detections in ground water are linked to urban areas, although statistical tests do not confirm it in this study.

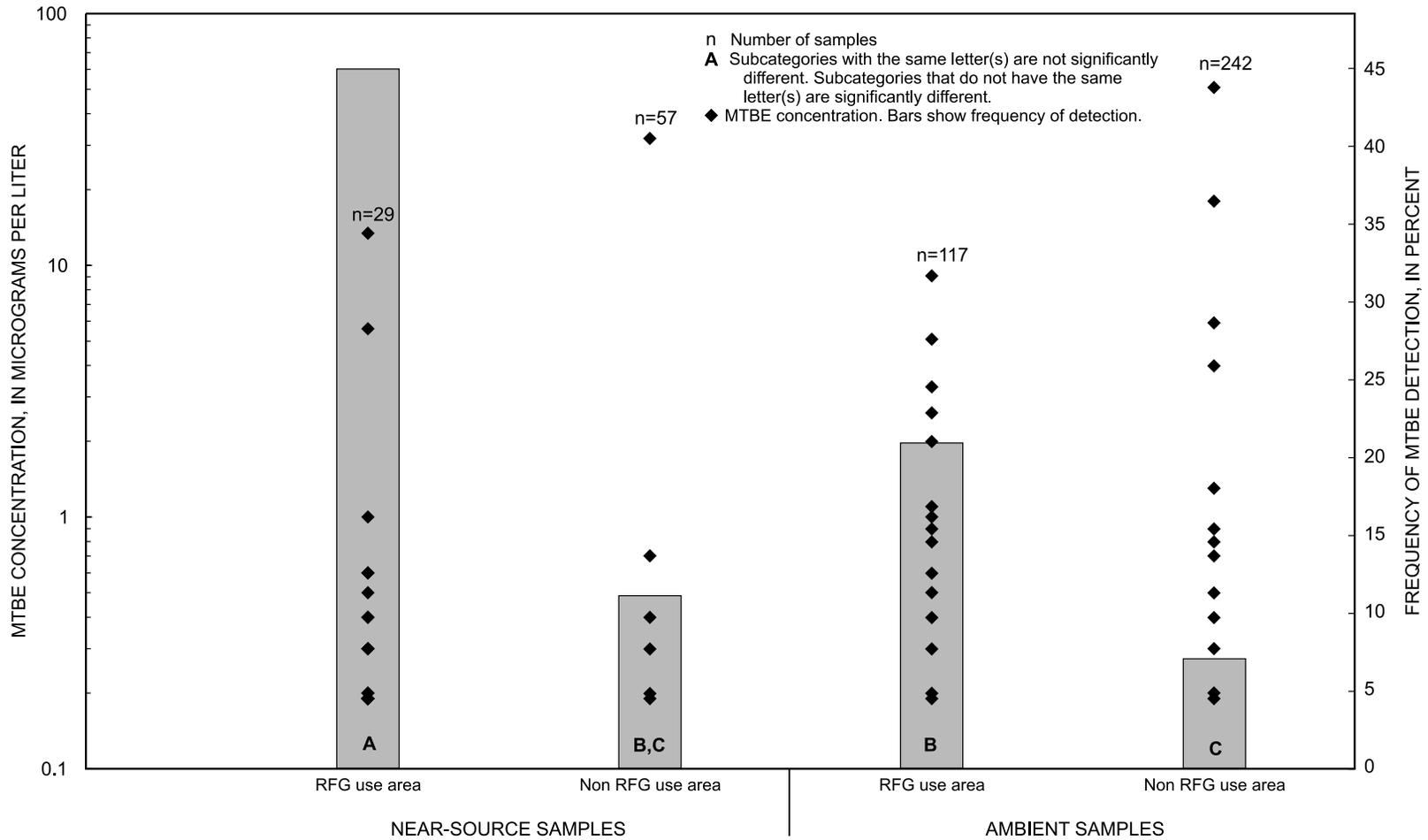
1. There may be a bias in the land-cover data for forested areas over urban areas where canopy is mature. Near-source samples in forested areas have MTBE detections more frequently (22 percent) than all other groups except the near-source urban and the ambient urban samples. The samples that are considered to be from forested areas may well be from urban, suburban, or small areas of clustered population in a rural setting. None of the 86 samples actually was collected from a well in a forest area where there are few people and storage tanks. Many rural areas in Pennsylvania have sufficient tree canopy to be labeled as forested area by the land-cover data set and may be small towns or villages with gas stations and other commercial activities present in a small area, where the houses commonly are surrounded by a mature tree canopy.
2. Wells could not be located to sample in some urban areas in Pennsylvania where there is high release density (figs. 2 and 9). These areas included the Wilkes-Barre–Scranton area, the Pittsburgh city area, the Allentown area, and the Harrisburg city area.
3. The detection frequency of MTBE in samples from urban areas in Pennsylvania was high and exceeded that in samples collected nationwide for the NAWQA Program. MTBE was detected in about 14 percent of wells sampled in urban areas for the NAWQA Program during 1991 to 2000, which had an MRL of 0.2 µg/L (Zogorski and others, 2001). MTBE detection frequency was 28 percent in ambient samples and 26 percent in near-source samples in the current study. Some urban areas sampled during the NAWQA Program had much greater detection rates of MTBE than in the overall NAWQA national database or in the database for the current study. For example, MTBE was detected in 79 percent of shallow wells in Denver, Colo., and in 37 percent of shallow wells in New

England (including Connecticut, Massachusetts, and Vermont) during the 1991-94 NAWQA sampling efforts (Squillace and others, 1995). The MRL was 0.2 µg/L. During the NAWQA study of the Lower Susquehanna River Basin in Pennsylvania, a detection frequency of 50 percent in an urban area (20 wells sampled) was reported, with an MTBE detection level of 0.06 µg/L (Lindsey and others, 1997; Daly and Lindsey, 1997).

#### **MTBE Detections and Concentrations in the Reformulated Gasoline Use Area**

The RFG-use area has a greater density of release sites (fig. 1). Results from a Kruskal-Wallis statistical test show that the MTBE detection frequency in near-source samples in the RFG-use area (45 percent) was significantly greater than detection frequencies from all other sample groupings, whether within or outside the RFG-use area and whether the samples are near-source or ambient (fig. 11). The detection frequency for ambient samples in the RFG-use area (21 percent) was significantly greater than that of non-RFG-use area ambient samples (7 percent). There was no significant difference in detection frequencies between ambient samples in the RFG-use area and near-source samples in the non-RFG-use area. The MTBE detection frequency in the RFG-use area in Pennsylvania is three times the MTBE detection frequency in non-RFG-use areas of Pennsylvania for ambient samples. For near-source samples, the MTBE detection frequency in the RFG area of Pennsylvania is more than four times the MTBE detection frequency in non-RFG areas of Pennsylvania.

The frequency of detection of MTBE among near-source samples collected in the RFG-use area (45 percent) is greater than the MTBE detection frequency other studies have reported for samples within RFG-use or other high MTBE-use areas (Moran and others, 2002; State of Maine, 1998; Zogorski and others, 1998; Sloto and McManus, 1997). The studies reported in Moran and others (2002), however, did not sample near known release sites. The detections of MTBE among ambient samples in the RFG-use area (21 percent) in this study are similar to MTBE detections reported from nationwide data of the NAWQA Program with an MRL of 0.2 µg/L (Moran and others, 2002, Zogorski and others, 2001). In the NAWQA sampling program, MTBE



**Figure 11.** MTBE concentrations and detection frequency in near-source and ambient ground-water samples from Reformulated Gasoline (RFG)-use and non-RFG-use areas. (The minimum reporting limit is 0.2 µg/L; values below minimum reporting limit are plotted as 0.19 µg/L.)

was detected in about 20 percent of ambient samples in areas designated as high MTBE-use areas, whether they were RFG-use areas or Oxygenated Fuels Program areas. In high MTBE-use areas, the MTBE detection frequency is about twice that of areas that do not have high MTBE use in the NAWQA Program's ambient ground-water data set. The MTBE detection frequency found in non-RFG areas in Pennsylvania in near-source samples (11 percent) and in ambient samples (7 percent) both exceed that for the NAWQA ambient sample data (2 percent). Results from the Maine study indicated that the MTBE detection frequency in high-MTBE-use areas is nearly twice the frequency of MTBE detections in areas that do not have high MTBE use in ambient samples (State of Maine, 1998). The Maine study used a MRL of 0.1 µg/L. In a study of community water supplies in the northeastern United States by Grady and Casey (2000), MTBE detections were five times more likely in high MTBE-use areas, but these samples included water supply from ground-water and surface-water sources.

Several factors contribute to greater MTBE detection rates in the RFG-use area in Pennsylvania.

1. Philadelphia, located in the RFG area, generally has a greater percent volume of MTBE in gasoline compared to Pittsburgh in the non-RFG area. The National Institute for Petroleum and Energy Research (NIPER) compiled data on various grades and blends of gasoline from selected cities throughout the United States (R. Clawges, U.S. Geological Survey, written commun., 2001). The NIPER data include MTBE content, as percentage by volume, in gasoline. The NIPER data are summarized by season of collection into winter (December through March) and summer (all other months). The NIPER data include many cities in which samples may have been collected only once, or very few times. In Pennsylvania, only two cities, Pittsburgh (597 samples) and Philadelphia (391 samples), have had more than 3 samples collected during 1990-99. The mean percent volume of MTBE in the samples from Philadelphia during the 1990-99 sampling was 7.6 percent, and the median was 7.7 percent. The maximum percent

volume reported during any seasonal sampling effort was 16.80 percent, and the seasonal minimum percent volume is 0 percent. The mean percent volume of MTBE in the samples from Pittsburgh during the 1990-99 sampling was 1.7 percent, and the median was 1.2 percent. The seasonal maximum percent volume was 13.4 percent, and the seasonal minimum percent volume was 0 percent.

2. The RFG-use area has a greater density of release sites compared to non-RFG-use areas (fig. 1). The release density in the 2,200-mi<sup>2</sup> RFG-use area is about 1.6 releases per square mile, compared to a release density of about 0.1 release per square mile in the non-RFG-use area. The greater release density is likely related to the greater population, vehicle, and storage-tank density in the RFG-use area.
3. The high density of ground-water wells in the five-county RFG-use area contributes to the likelihood that MTBE will be detected in ground water because there are many locations where ground water is withdrawn.

In Pennsylvania, Chester County ranks as the number one county in terms of population served by self-supplied ground water; Bucks County had the third highest population and Montgomery County had the sixth highest population served by self-supplied ground water in 1995 (Pennsylvania Department of Environmental Protection, written commun., 1995).

In addition to self-supplied ground-water use, the counties in the RFG-use area have some of the highest populations that use ground water from public systems in Pennsylvania. Montgomery County has the highest population served by public-supplied ground water in Pennsylvania, Bucks County had the fourth highest, Delaware County had the fifth highest, and Chester County had the eighth highest population among the 67 counties in Pennsylvania. The pumpage of ground water from the large number of wells also will contribute to the movement of MTBE. The large number of wells in these RFG-use counties likely results in many wells being located near urbanized areas and storage-tank release sites, creating a situation of potential vulnerability to MTBE contamination.

MTBE content in gasoline can be high if a town or city is near an RFG-use area and receives the same gasoline as the RFG-use area or if cross contamination occurs during transportation. There were many detects of MTBE in neighboring counties to the RFG area such as Lancaster, York, and more distant Cumberland Counties (fig. 1). These three counties have a large population served by ground water from self-supplied sources. In 1995, Lancaster County had the second highest county population in Pennsylvania served by self-supplied ground water, York County had the fifth highest, and Cumberland County had the fourteenth highest population served by self-supplied ground water. The self-supplied ground-water use in these three counties is similar to the usage in most of the five counties within the RFG area.

### Areas with Frequent MTBE Detections

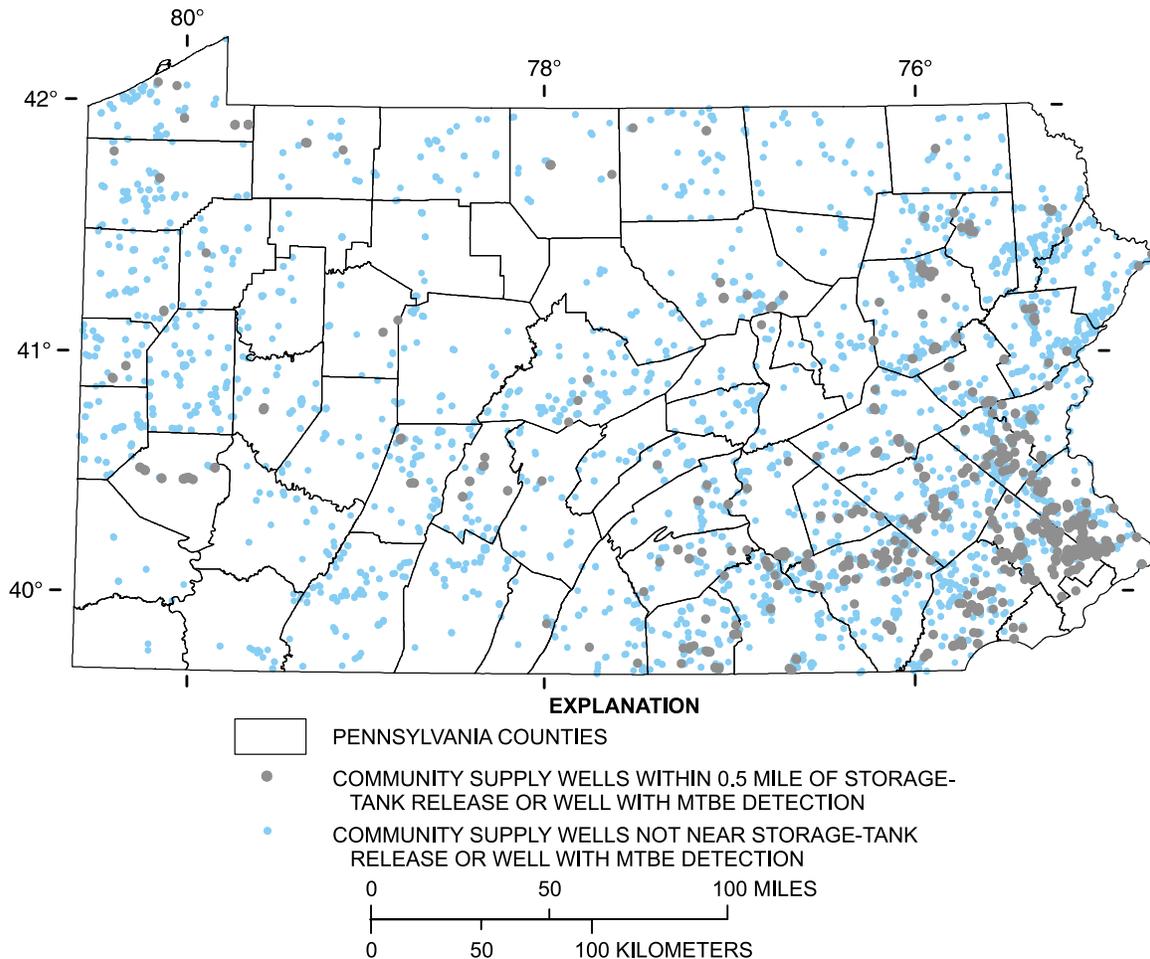
Several factors are associated with high MTBE detection frequencies in ground water in Pennsylvania (table 2). The near-source areas within about 0.5 mi downgradient of release sites are at high risk for MTBE in ground water (figs. 4 and 5). Samples from the RFG-use areas had significantly higher MTBE detection frequencies than samples from non-RFG-use areas (fig. 11). Samples in urban areas had significantly greater MTBE detection rates compared to ambient ground-water samples in agriculture and forest land-use categories (fig. 10). Near-source samples from the crystalline-rock aquifer, particularly when the sample was from the

RFG-use area, had a significantly greater MTBE detection frequency compared to samples from other aquifers (fig. 8). These areas—near-source areas, the crystalline-rock aquifer, the RFG-use area, and urban areas—appear to be more susceptible to MTBE detection in ground water in Pennsylvania.

About 99 percent of MTBE samples collected for this study had MTBE concentrations below the USEPA Consumer Advisory threshold of 20 µg/L (for taste and odor prevention). This study has shown, however, that MTBE detections (MTBE ≥ 0.2 µg/L) are more likely the result of storage-tank releases than atmospheric deposition. MTBE concentrations are likely to increase if an MTBE plume is sampled over time, although MTBE concentrations may also decrease over time if attenuation has begun. Community water system (CWS) wells in areas at risk for MTBE detection—near releases, in the RFG-use area, urban areas, and the crystalline-rock aquifer—could be monitored to provide an early warning of movement of MTBE and BTEX plumes. Many people rely on CWS wells, which provide water year-round to at least 25 people or have a minimum of 15 residential service connections, for drinking water supplies. In the RFG-use area, a population of more than 600,000 depends on public water supply from ground water. Pennsylvania has 6,696 CWS wells, and 819 are within 0.5 mi of a release site or within 0.5 mi of a well where MTBE was detected in Pennsylvania (fig. 12).

**Table 2.** MTBE detection frequency in ground water statewide, and by RFG-use, land-use, and aquifer-type categories

Location of wells sampled	Detection frequency, in percent									
	Statewide	RFG usage		Land use			Aquifer type			
		RFG area	Non-RFG area	Agricultural	Forested	Urban	Carbonate	Crystalline	Siliciclastic	Unconsolidated
Near source	22	45	11	19	22	26	10	57	11	13
Ambient	11	21	7	8	11	28	14	18	8	0



**Figure 12.** Community water system wells near either storage-tank releases or sample sites with MTBE detections. (Minimum reporting limit is 0.2 µg/L.)

## SUMMARY AND CONCLUSIONS

Methyl tert-butyl-ether (MTBE) is a gasoline additive that is used in Reformulated Gasoline (RFG) in areas that do not meet National Ambient Air Quality Standards for carbon monoxide and ozone. The U.S. Environmental Protection Agency (USEPA) has issued a consumer advisory that recommends control levels of 20 to 40 µg/L of MTBE to prevent adverse odor and taste effects and is investigating the toxicity threat to human health. Because of its use in gasoline as an octane enhancer, MTBE can be detected near most leaking underground gasoline storage tanks. Thousands of releases from leaking storage tanks have been reported to the

Pennsylvania Department of Environmental Protection (PADEP). MTBE has high solubility and mobility and low biodegradation properties in water and, therefore, can be more persistent and travel greater distances in ground water than other gasoline constituents such as benzene, toluene, ethyl benzene, and xylene (BTEX) compounds. MTBE has been reported in wells used for drinking water in many areas of Pennsylvania but it is most commonly reported in the five southeastern counties (Bucks, Chester, Delaware, Montgomery, and Philadelphia) that use RFG to reduce year-round ozone levels.

This study, which was done in cooperation with PADEP, examined the distribution and concentrations of MTBE in Pennsylvania's ground water used for drinking water supply. MTBE concentrations and detection frequency from two sources of MTBE in ground water, the atmosphere and storage-tank release sites (release sites), also were examined. MTBE in ground water was reported as detected when concentrations were at or above the minimum reporting limit (MRL) or 0.2 µg/L. MTBE in the atmosphere was reported by the PADEP Air Quality Bureau as detected when concentrations were at or above the quantitation limit, which ranged from 0.01 to 0.02 parts per billion by volume (ppbv). The study also compared MTBE concentrations between 86 samples collected near release sites and 359 samples collected from ambient ground water (ground water not thought to be associated with point-source releases of MTBE or BTEX compounds) and examined whether factors, such as aquifer types, land use, or RFG-use areas were associated with elevated MTBE occurrence in the ambient and release sites sample sets.

Atmospheric deposition is a source of MTBE commonly associated with low concentrations of MTBE in ground water, but data from this study suggest that MTBE concentrations above the MRL (0.2 µg/L) are likely from point sources such as release sites. Although atmospheric deposition is one of the most likely forms of nonpoint sources for MTBE in ground water, analysis of atmospheric MTBE data shows that most atmospheric contributions to ground water, when calculated as equivalent aqueous concentrations of MTBE, would amount to less than the MRL used for MTBE in ground water in this study.

Release sites are a major source of MTBE to ground water. To evaluate release sites, ground-water samples from near these sites were compared to ambient ground-water samples. The MTBE detection frequency for near-source samples (22 percent) was significantly greater than the MTBE detection frequency for the ambient samples (11 percent). The MTBE concentrations examined in this study ranged from 0.2 to 51 µg/L. MTBE was detected at levels greater than the USEPA Consumer Advisory threshold of 20 µg/L in only one near-source sample and one ambient sample.

Among the four generalized aquifer types (carbonate rock, crystalline rock, siliciclastic rock, and unconsolidated sediments), MTBE

detection frequency for near-source samples in crystalline-rock aquifers (57 percent) was significantly greater than in other aquifer types. Properties of the crystalline-rock aquifers, and the low permeability of the overlying saprolite, may slow movement of the MTBE and result in MTBE detections near release sites for a longer time period than in aquifers of higher permeability. Another factor, however, may also be involved in the high frequency of MTBE detections in the crystalline-rock aquifers. Forty percent of the total area of the crystalline aquifer type exists within the boundary of the RFG-use area, compared to 3, 3, and 12 percent for the carbonate, siliciclastic, and unconsolidated sediments aquifer types, respectively.

The MTBE detection frequency in urban areas, whether near-source or ambient samples, is significantly greater than the MTBE detection frequency in ambient samples in forested and agricultural land-use areas. MTBE was detected in 28 percent of ambient samples and in 26 percent of near-source samples in urban areas.

The MTBE detection frequency in near-source samples (45 percent) in the RFG-use area is significantly greater than the detection frequency from all other sample groups whether within or outside of the RFG-use area and whether ambient samples or near-source samples. The detection frequency for ambient samples in the RFG-use area (21 percent) is significantly greater than the MTBE detection frequency for ambient samples in non-RFG-use areas (7 percent). Several factors may contribute to greater MTBE detection frequency in the RFG-use area compared to the non-RFG-use area: (1) greater volume of MTBE in gasoline, (2) greater density of storage-tank releases, (3) large population using ground water, (4) large number of vehicles, and (5) greater storage-tank density.

Areas within 0.5 mi of release sites, the RFG-use area, crystalline-rock aquifers, and urban areas are areas of elevated risk for high MTBE detection frequency in ground water in Pennsylvania. Development of a network using CWS wells, which provide a population of 600,000 in the RFG area with public water supply, to monitor MTBE concentrations in the areas of high MTBE detection frequency could provide early warning of migration of MTBE plumes.

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**APPENDIX 1—Concentrations of MTBE in ambient ground-water samples,  
in wells near storage-tank release sites, and in atmospheric samples**

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Table 1A. Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania

1B. Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from wells sampled near storage-tank releases

1C. Collection date, lab quality code, atmospheric MTBE concentration, mean daily temperature, and calculated equivalent aqueous MTBE concentration for four Air Quality Monitoring sites of the Pennsylvania Department of Environmental Protection

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
CH 6401	Yes	Crystalline rocks	agriculture	<0.2	220
CH 6404	Yes	Crystalline rocks	agriculture	<.2	50
FR 537	No	Carbonate rocks	agriculture	<.2	65
CH 1730	Yes	Crystalline rocks	agriculture	<.2	54
YO 1197	No	Crystalline rocks	agriculture	<.2	140
CH 6403	Yes	Crystalline rocks	agriculture	<.2	120
CH 5450	Yes	Crystalline rocks	agriculture	<.2	302
CH 5477	Yes	Crystalline rocks	agriculture	<.2	345
YO 1208	No	Crystalline rocks	agriculture	<.2	200
AD 653	No	Carbonate rocks	agriculture	<.2	150
YO 1206	No	Crystalline rocks	agriculture	<.2	140
YO 1198	No	Crystalline rocks	agriculture	<.2	125
CH 4808	Yes	Crystalline rocks	agriculture	<.2	125
CH 4807	Yes	Crystalline rocks	agriculture	<.2	--
FR 807	No	Carbonate rocks	agriculture	<.2	255
CH 4345	Yes	Crystalline rocks	agriculture	<.2	100
CH 5562	Yes	Crystalline rocks	urban	<.2	250
CH 5479	Yes	Crystalline rocks	agriculture	<.2	105
CH 4551	Yes	Crystalline rocks	agriculture	1.0	100
CH 5555	Yes	Crystalline rocks	urban	<.2	126
CH 5474	Yes	Crystalline rocks	agriculture	<.2	--
CH 5471	Yes	Crystalline rocks	forest	<.2	--
FR 811	No	Carbonate rocks	agriculture	<.2	75
LN 2052	No	Crystalline rocks	agriculture	<.2	180
CH 5478	Yes	Crystalline rocks	agriculture	.2	325
SO 851	No	Siliciclastic rocks	forest	<.2	44
CH 4809	Yes	Crystalline rocks	agriculture	<.2	--
AD 691	No	Siliciclastic rocks	agriculture	18.0	175
CH 2769	Yes	Crystalline rocks	agriculture	<.2	--
AD 660	No	Siliciclastic rocks	urban	<.2	167
YO 1194	No	Carbonate rocks	agriculture	<.2	140
AD 690	No	Siliciclastic rocks	forest	<.2	298
CH 6407	Yes	Crystalline rocks	agriculture	<.2	325
SO 124	No	Siliciclastic rocks	agriculture	<.2	75
FA 509	No	Siliciclastic rocks	forest	<.2	200
CH 2033	Yes	Crystalline rocks	agriculture	.8	84
CH 6405	Yes	Crystalline rocks	forest	<.2	--
CH 5559	Yes	Crystalline rocks	agriculture	<.2	200
CH 2311	Yes	Crystalline rocks	agriculture	<.2	88
CH 5480	Yes	Crystalline rocks	urban	.3	166
YO 1195	No	Carbonate rocks	agriculture	1.3	160
LN 2049	No	Crystalline rocks	forest	<.2	186
YO 1201	No	Crystalline rocks	agriculture	<.2	170
SO 852	No	Siliciclastic rocks	agriculture	<.2	70
CH 5259	Yes	Crystalline rocks	forest	<.2	--
CH 5260	Yes	Crystalline rocks	forest	<.2	--
CH 5261	Yes	Crystalline rocks	urban	<.2	--

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
FA 507	No	Siliciclastic rocks	urban	<0.2	65
FR 808	No	Carbonate rocks	agriculture	<.2	85
BD 530	No	Carbonate rocks	agriculture	<.2	100
CH 5220	Yes	Crystalline rocks	urban	<.2	--
CH 5090	Yes	Crystalline rocks	agriculture	.5	--
CH 5475	Yes	Crystalline rocks	agriculture	.8	--
GR 903	No	Unconsolidated sediments	forest	<.2	125
LN 2022	No	Carbonate rocks	agriculture	<.2	75
CH 5160	Yes	Crystalline rocks	forest	.2	--
LN 2012	No	Carbonate rocks	agriculture	<.2	175
LN 2011	No	Carbonate rocks	agriculture	<.2	200
LN 2013	No	Carbonate rocks	agriculture	<.2	150
CH 4779	Yes	Crystalline rocks	forest	<.2	24
CH 5472	Yes	Crystalline rocks	forest	<.2	95
CH 5563	Yes	Crystalline rocks	agriculture	<.2	145
CH 5227	Yes	Crystalline rocks	forest	<.2	--
FR 812	No	Carbonate rocks	agriculture	<.2	200
LN 2021	No	Carbonate rocks	agriculture	<.2	150
LN 2023	No	Carbonate rocks	agriculture	<.2	175
CH 4778	Yes	Crystalline rocks	agriculture	.5	170
LN 2026	No	Carbonate rocks	agriculture	<.2	175
YO 1196	No	Carbonate rocks	agriculture	<.2	200
CH 4772	Yes	Crystalline rocks	forest	<.2	73.5
LN 2010	No	Carbonate rocks	agriculture	<.2	175
CH 4802	Yes	Carbonate rocks	urban	<.2	250
CH 5091	Yes	Crystalline rocks	forest	<.2	98
CH 6400	Yes	Crystalline rocks	forest	<.2	120
CH 4261	Yes	Crystalline rocks	agriculture	<.2	100
CH 1110	Yes	Crystalline rocks	forest	<.2	--
CH 5938	Yes	Crystalline rocks	forest	<.2	430
CH 4771	Yes	Crystalline rocks	forest	1.1	210
CH 4767	Yes	Crystalline rocks	forest	.3	217
LN 2025	No	Carbonate rocks	agriculture	<.2	200
CH 5089	Yes	Crystalline rocks	agriculture	<.2	51
CH 4573	Yes	Crystalline rocks	agriculture	<.2	65
CH 5088	Yes	Crystalline rocks	agriculture	2.0	--
CH 5087	Yes	Crystalline rocks	urban	<.2	96
CH 4828	Yes	Carbonate rocks	urban	<.2	125
SO 125	No	Siliciclastic rocks	forest	<.2	85
CH 5473	Yes	Crystalline rocks	forest	<.2	75
CH 3859	Yes	Carbonate rocks	urban	.3	--
CH 5243	Yes	Crystalline rocks	urban	<.2	--
CH 5244	Yes	Crystalline rocks	urban	.5	--
CH 5238	Yes	Crystalline rocks	forest	<.2	170
CH 4539	Yes	Crystalline rocks	agriculture	<.2	--
LN 2027	No	Carbonate rocks	agriculture	.5	175
YO 1202	No	Crystalline rocks	agriculture	<.2	140

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
CH 4339	Yes	Crystalline rocks	agriculture	<0.2	120
CH 4805	Yes	Carbonate rocks	agriculture	<.2	210
CH 2543	Yes	Carbonate rocks	forest	<.2	60
FA 506	No	Siliciclastic rocks	forest	<.2	175
CU 907	No	Carbonate rocks	agriculture	<.2	129
LN 2024	No	Carbonate rocks	agriculture	<.2	150
CH 245	Yes	Crystalline rocks	forest	<.2	560
LN 2031	No	Carbonate rocks	agriculture	<.2	150
CH 2402	Yes	Carbonate rocks	forest	.9	--
CH 4804	Yes	Carbonate rocks	forest	<.2	82
CU 675	No	Carbonate rocks	urban	51.0	150
LN 2014	No	Carbonate rocks	agriculture	<.2	195
CH 2611	Yes	Carbonate rocks	forest	<.2	--
CH 2676	Yes	Carbonate rocks	forest	<.2	--
CH 202	Yes	Carbonate rocks	forest	<.2	--
CH 204	Yes	Carbonate rocks	forest	<.2	170
LN 2028	No	Carbonate rocks	agriculture	<.2	200
FA 508	No	Siliciclastic rocks	agriculture	<.2	135
CH 4815	Yes	Crystalline rocks	agriculture	.4	90
LN 2009	No	Carbonate rocks	agriculture	<.2	175
SO 853	No	Siliciclastic rocks	forest	<.2	115
CU 908	No	Carbonate rocks	agriculture	<.2	182
CH 5996	Yes	Crystalline rocks	agriculture	<.2	120
CH 1281	Yes	Crystalline rocks	agriculture	<.2	94
CH 4817	Yes	Crystalline rocks	agriculture	<.2	--
LN 2008	No	Carbonate rocks	agriculture	<.2	175
CH 5481	Yes	Crystalline rocks	forest	<.2	--
LN 2007	No	Carbonate rocks	agriculture	<.2	150
LN 2005	No	Carbonate rocks	agriculture	.5	100
CH 5995	Yes	Crystalline rocks	forest	<.2	--
MG 1399	Yes	Siliciclastic rocks	forest	<.2	500
MG 1395	Yes	Siliciclastic rocks	forest	<.2	530
MG 1397	Yes	Siliciclastic rocks	agriculture	<.2	--
MG 1400	Yes	Siliciclastic rocks	urban	<.2	497
CH 5554	Yes	Crystalline rocks	forest	<.2	133
MG 1163	Yes	Siliciclastic rocks	urban	.3	190
MG 1408	Yes	Siliciclastic rocks	urban	<.2	--
MG 1390	Yes	Siliciclastic rocks	agriculture	1.1	--
MG 1403	Yes	Siliciclastic rocks	urban	<.2	282
MG 1162	Yes	Siliciclastic rocks	urban	<.2	145
MG 1161	Yes	Siliciclastic rocks	urban	<.2	298
MG 1368	Yes	Siliciclastic rocks	urban	<.2	--
MG 1392	Yes	Siliciclastic rocks	urban	<.2	222
MG 1384	Yes	Siliciclastic rocks	forest	<.2	--
MG 1393	Yes	Siliciclastic rocks	urban	2.6	--
LN 2015	No	Carbonate rocks	agriculture	<.2	150
MG 1409	Yes	Siliciclastic rocks	forest	.6	120

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
MG 1404	Yes	Siliciclastic rocks	urban	<0.2	207
MG 1405	Yes	Siliciclastic rocks	forest	3.3	85
MG 1410	Yes	Siliciclastic rocks	forest	<.2	--
CH 1435	Yes	Crystalline rocks	agriculture	<.2	85
MG 1352	Yes	Siliciclastic rocks	forest	<.2	147
LN 2019	No	Carbonate rocks	agriculture	<.2	200
MG 1412	Yes	Siliciclastic rocks	forest	<.2	170
CH 4498	Yes	Siliciclastic rocks	urban	9.1	--
LN 2006	No	Carbonate rocks	agriculture	<.2	125
CH 1283	Yes	Crystalline rocks	agriculture	<.2	90
LN 2029	No	Carbonate rocks	agriculture	.3	140
MG 1411	Yes	Siliciclastic rocks	forest	<.2	225
CU 913	No	Carbonate rocks	agriculture	<.2	162
MG 225	Yes	Siliciclastic rocks	urban	<.2	486
LN 2030	No	Carbonate rocks	agriculture	<.2	97
MG 1724	Yes	Siliciclastic rocks	forest	<.2	92
LN 2018	No	Carbonate rocks	agriculture	<.2	160
FR 810	No	Carbonate rocks	agriculture	<.2	90
WE 312	No	Siliciclastic rocks	agriculture	<.2	150
CU 912	No	Carbonate rocks	agriculture	<.2	162
CU 915	No	Carbonate rocks	agriculture	<.2	160
CH 5269	Yes	Siliciclastic rocks	urban	<.2	97
CH 5272	Yes	Siliciclastic rocks	urban	<.2	--
CH 5270	Yes	Siliciclastic rocks	agriculture	.5	85
CU 926	No	Carbonate rocks	agriculture	<.2	100
CH 5556	Yes	Siliciclastic rocks	forest	<.2	217
CU 922	No	Carbonate rocks	agriculture	<.2	120
WE 309	No	Siliciclastic rocks	agriculture	<.2	55
CH 1567	Yes	Siliciclastic rocks	agriculture	<.2	105
CH 4409	Yes	Siliciclastic rocks	forest	5.1	65.7
CH 2317	Yes	Crystalline rocks	forest	<.2	86
CU 923	No	Carbonate rocks	agriculture	<.2	225
CH 4803	Yes	Siliciclastic rocks	agriculture	<.2	108
WS 973	No	Siliciclastic rocks	agriculture	<.2	98
WE 310	No	Siliciclastic rocks	forest	<.2	250
LN 2016	No	Carbonate rocks	agriculture	<.2	122
CU 911	No	Carbonate rocks	agriculture	<.2	176
CU 918	No	Carbonate rocks	forest	<.2	203
MG 1713	Yes	Siliciclastic rocks	forest	<.2	240
CU 904	No	Carbonate rocks	urban	5.9	200
CU 903	No	Carbonate rocks	urban	<.2	170
CU 905	No	Carbonate rocks	urban	<.2	125
WE 313	No	Siliciclastic rocks	forest	<.2	135
CH 4801	Yes	Siliciclastic rocks	forest	<.2	120
CU 921	No	Carbonate rocks	agriculture	<.2	62
MG 1712	Yes	Siliciclastic rocks	agriculture	<.2	150
CU 898	No	Carbonate rocks	agriculture	<.2	30

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
LN 2017	No	Carbonate rocks	agriculture	<0.2	160
CU 278	No	Carbonate rocks	urban	.2	116
MG 1726	Yes	Siliciclastic rocks	agriculture	<.2	93.4
SO 126	No	Siliciclastic rocks	forest	<.2	114
CU 902	No	Carbonate rocks	urban	<.2	41.1
CU 899	No	Carbonate rocks	urban	<.2	42
CU 901	No	Carbonate rocks	urban	.8	46
CU 920	No	Carbonate rocks	agriculture	<.2	102
MG 1714	Yes	Siliciclastic rocks	urban	<.2	210
BE 1698	No	Siliciclastic rocks	agriculture	<.2	95
CU 906	No	Carbonate rocks	urban	.2	175
DA 841	No	Carbonate rocks	agriculture	<.2	180
MG 1449	Yes	Siliciclastic rocks	agriculture	<.2	114
DA 842	No	Carbonate rocks	urban	<.2	61.5
CU 285	No	Siliciclastic rocks	urban	<.2	69
DA 487	No	Siliciclastic rocks	urban	<.2	150
DA 840	No	Carbonate rocks	agriculture	<.2	40
DA 839	No	Carbonate rocks	urban	<.2	50
MG 1728	Yes	Siliciclastic rocks	forest	<.2	150
LB 1167	No	Carbonate rocks	agriculture	<.2	158
LB 1163	No	Carbonate rocks	agriculture	<.2	100
MG 917	Yes	Siliciclastic rocks	wetlands	<.2	500
LB 1164	No	Carbonate rocks	agriculture	<.2	150
LB 1166	No	Carbonate rocks	forest	<.2	87
BE 1699	No	Siliciclastic rocks	agriculture	<.2	260
LB 1160	No	Carbonate rocks	urban	<.2	180
LB 1165	No	Carbonate rocks	agriculture	<.2	115
LB 1162	No	Carbonate rocks	agriculture	<.2	220
LB 1159	No	Carbonate rocks	urban	4.0	48.9
PE 676	No	Siliciclastic rocks	forest	<.2	120
LB 1157	No	Carbonate rocks	agriculture	<.2	100
LB 1158	No	Carbonate rocks	urban	<.2	149
LB 1156	No	Carbonate rocks	urban	.4	225
PE 678	No	Siliciclastic rocks	agriculture	<.2	140
PE 677	No	Siliciclastic rocks	forest	<.2	165
AG 714	No	Siliciclastic rocks	forest	<.2	55
WE 413	No	Siliciclastic rocks	agriculture	<.2	140
MG 1715	Yes	Siliciclastic rocks	agriculture	<.2	200
PE 682	No	Siliciclastic rocks	forest	<.2	140
PE 679	No	Siliciclastic rocks	agriculture	<.2	200
DA 830	No	Siliciclastic rocks	forest	<.2	160
BE 1708	No	Carbonate rocks	agriculture	<.2	175
BE 1707	No	Siliciclastic rocks	agriculture	<.2	90
IN 915	No	Siliciclastic rocks	forest	<.2	95
DA 833	No	Siliciclastic rocks	agriculture	<.2	200
PE 681	No	Siliciclastic rocks	forest	<.2	100
PE 680	No	Siliciclastic rocks	forest	<.2	200

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
WE 315	No	Siliciclastic rocks	forest	<0.2	30
IN 914	No	Siliciclastic rocks	agriculture	<.2	160
BE 1617	No	Siliciclastic rocks	agriculture	<.2	128
DA 832	No	Siliciclastic rocks	agriculture	<.2	80
LE 1418	No	Siliciclastic rocks	agriculture	<.2	400
LB 1155	No	Siliciclastic rocks	forest	<.2	96
DA 834	No	Siliciclastic rocks	forest	<.2	200
MF 402	No	Carbonate rocks	agriculture	<.2	102
AG 705	No	Siliciclastic rocks	forest	<.2	215
WE 311	No	Siliciclastic rocks	forest	<.2	220
BE 1703	No	Siliciclastic rocks	agriculture	<.2	120
PE 683	No	Siliciclastic rocks	agriculture	<.2	173
DA 836	No	Siliciclastic rocks	agriculture	<.2	120
SC 634	No	Siliciclastic rocks	agriculture	<.2	120
SC 613	No	Siliciclastic rocks	agriculture	<.2	200
HU 421	No	Carbonate rocks	agriculture	<.2	65
DA 835	No	Siliciclastic rocks	agriculture	<.2	150
JU 369	No	Siliciclastic rocks	agriculture	<.2	125
BE 1704	No	Siliciclastic rocks	agriculture	<.2	300
JU 370	No	Siliciclastic rocks	agriculture	<.2	150
IN 917	No	Siliciclastic rocks	forest	<.2	82
DA 837	No	Siliciclastic rocks	agriculture	<.2	200
NU 520	No	Siliciclastic rocks	agriculture	<.2	155
AR 106	No	Unconsolidated sediments	agriculture	<.2	55
BE 1705	No	Siliciclastic rocks	forest	<.2	245
SC 614	No	Siliciclastic rocks	agriculture	<.2	120
SC 637	No	Siliciclastic rocks	forest	<.2	164
MF 404	No	Carbonate rocks	agriculture	<.2	200
SN 245	No	Siliciclastic rocks	agriculture	<.2	100
SN 246	No	Siliciclastic rocks	agriculture	<.2	200
AR 105	No	Siliciclastic rocks	agriculture	<.2	110
LE 1420	No	Siliciclastic rocks	agriculture	<.2	130
SC 615	No	Siliciclastic rocks	agriculture	<.2	180
LE 1419	No	Siliciclastic rocks	agriculture	<.2	220
IN 861	No	Siliciclastic rocks	agriculture	<.2	85
NU 524	No	Siliciclastic rocks	agriculture	<.2	205
SC 636	No	Siliciclastic rocks	agriculture	<.2	275
SN 249	No	Siliciclastic rocks	agriculture	<.2	114
CE 669	No	Carbonate rocks	forest	<.2	210
IN 913	No	Siliciclastic rocks	agriculture	<.2	123
NU 522	No	Siliciclastic rocks	agriculture	<.2	201
NP 816	No	Siliciclastic rocks	agriculture	<.2	150
SC 296	No	Siliciclastic rocks	forest	<.2	242
IN 918	No	Siliciclastic rocks	forest	<.2	65
CB 338	No	Siliciclastic rocks	agriculture	<.2	150
SC 635	No	Siliciclastic rocks	forest	<.2	306
NU 523	No	Siliciclastic rocks	agriculture	<.2	100

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
AR 108	No	Siliciclastic rocks	agriculture	<0.2	100
NP 818	No	Siliciclastic rocks	agriculture	<.2	260
IN 916	No	Siliciclastic rocks	forest	<.2	165
SN 247	No	Siliciclastic rocks	agriculture	<.2	199
CB 334	No	Siliciclastic rocks	forest	<.2	440
CB 335	No	Siliciclastic rocks	forest	<.2	220
CE 671	No	Carbonate rocks	agriculture	<.2	200
IN 911	No	Siliciclastic rocks	forest	<.2	--
IN 107	No	Siliciclastic rocks	forest	<.2	124
CE 672	No	Carbonate rocks	agriculture	<.2	200
MO 684	No	Siliciclastic rocks	forest	<.2	260
AR 107	No	Siliciclastic rocks	agriculture	<.2	154
CB 337	No	Siliciclastic rocks	agriculture	<.2	500
JE 384	No	Siliciclastic rocks	forest	<.2	--
JE 411	No	Siliciclastic rocks	agriculture	<.2	--
JE 397	No	Siliciclastic rocks	agriculture	<.2	--
MO 689	No	Carbonate rocks	agriculture	<.2	64
NP 817	No	Siliciclastic rocks	forest	<.2	200
JE 409	No	Siliciclastic rocks	forest	<.2	--
JE 386	No	Siliciclastic rocks	forest	<.2	--
MO 682	No	Siliciclastic rocks	forest	<.2	340
JE 393	No	Siliciclastic rocks	agriculture	<.2	--
JE 415	No	Siliciclastic rocks	forest	<.2	--
JE 418	No	Siliciclastic rocks	quarries/mines	<.2	--
JE 399	No	Siliciclastic rocks	forest	<.2	--
JE 388	No	Siliciclastic rocks	agriculture	<.2	--
AR 104	No	Siliciclastic rocks	forest	<.2	60
CH 5364	Yes	Siliciclastic rocks	forest	.3	160
JE 400	No	Siliciclastic rocks	agriculture	<.2	--
CB 336	No	Siliciclastic rocks	forest	.9	88
JE 389	No	Siliciclastic rocks	agriculture	<.2	--
JE 410	No	Siliciclastic rocks	agriculture	<.2	--
JE 395	No	Siliciclastic rocks	agriculture	<.2	--
MO 683	No	Siliciclastic rocks	forest	.3	160
JE 317	No	Siliciclastic rocks	agriculture	<.2	--
JE 402	No	Siliciclastic rocks	agriculture	<.2	--
JE 401	No	Siliciclastic rocks	agriculture	<.2	--
CF 310	No	Siliciclastic rocks	forest	<.2	--
CR 725	No	Siliciclastic rocks	forest	<.2	30
JE 417	No	Siliciclastic rocks	forest	<.2	--
JE 407	No	Siliciclastic rocks	forest	<.2	--
JE 406	No	Siliciclastic rocks	forest	<.2	--
CR 726	No	Siliciclastic rocks	quarries/mines	<.2	70
JE 422	No	Siliciclastic rocks	agriculture	<.2	60
CR 723	No	Siliciclastic rocks	agriculture	<.2	80
CF 309	No	Siliciclastic rocks	agriculture	<.2	--
CF 314	No	Siliciclastic rocks	forest	<.2	--

**Table 1A.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from ambient ground-water samples in Pennsylvania—Continued

[µg/L, micrograms per liter; <, less than; --, unknown]

Local identification number	Location within RFG area Yes / No <sup>1</sup>	Aquifer type <sup>2</sup>	Land use / Land cover <sup>3</sup>	MTBE (µg/L) <sup>4</sup>	Well depth (feet below land surface)
JE 405	No	Siliciclastic rocks	transitional	<0.2	--
CF 320	No	Siliciclastic rocks	forest	.3	110
JE 423	No	Siliciclastic rocks	agriculture	<.2	98
PI 308	No	Unconsolidated sediments	forest	<.2	108
JE 424	No	Siliciclastic rocks	agriculture	<.2	50
PI 520	No	Unconsolidated sediments	urban	<.2	200
CR 727	No	Siliciclastic rocks	forest	<.2	178
VE 58	No	Siliciclastic rocks	agriculture	<.2	63
JE 421	No	Siliciclastic rocks	agriculture	<.2	75
CR 722	No	Siliciclastic rocks	forest	<.2	58
PI 480	No	Unconsolidated sediments	forest	<.2	213
CR 724	No	Siliciclastic rocks	agriculture	<.2	120
PI 519	No	Siliciclastic rocks	forest	.7	120
CW 2409	No	Siliciclastic rocks	urban	<.2	60
CW 2415	No	Siliciclastic rocks	agriculture	<.2	35
CW 2410	No	Siliciclastic rocks	agriculture	<.2	172
CW 2414	No	Siliciclastic rocks	wetlands	<.2	32
CW 2411	No	Siliciclastic rocks	forest	<.2	110
CW 2413	No	Siliciclastic rocks	forest	<.2	75
CW 2412	No	Unconsolidated sediments	agriculture	<.2	90
WN 209	No	Siliciclastic rocks	forest	<.2	142
WR 835	No	Siliciclastic rocks	transitional	<.2	50
MC 123	No	Siliciclastic rocks	agriculture	<.2	130
ER 7001	No	Unconsolidated sediments	forest	<.2	68
ER 2501	No	Siliciclastic rocks	agriculture	<.2	170
ER 5003	No	Unconsolidated sediments	agriculture	<.2	87
WR 836	No	Unconsolidated sediments	agriculture	<.2	60
MC 124	No	Unconsolidated sediments	agriculture	<.2	135
ER 2004	No	Siliciclastic rocks	agriculture	<.2	80
ER 4007	No	Siliciclastic rocks	forest	<.2	130

<sup>1</sup> RFG is the Reformulated Gasoline-use area that consists of five counties (Bucks, Chester, Delaware, Montgomery, and Philadelphia) in Pennsylvania.

<sup>2</sup> Aquifer type is determined by intersection of well location with generalized aquifer digital spatial information data set (Lindsey and Bickford, 1999).

<sup>3</sup> Land use / land cover is determined by intersection of well location with USGS digital spatial information data set on land use/land cover (U.S. Geological Survey, 1992).

<sup>4</sup> Minimum reporting level (MRL) used for data in this report is 0.2 µg/L. MTBE concentrations are rounded to nearest tenth of a microgram.

**Table 1B.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from wells sampled near storage tank releases

[<, less than; µg/L, micrograms per liter; --, unknown]

Local identification number	Location within RFG-use area <sup>1</sup>	Aquifer type <sup>2</sup>	Land use/land cover <sup>3</sup>	MTBE, (µg/L) <sup>4</sup>	Well depth, in feet below land surface
CH 6509	Yes	crystalline rock	forest	<0.2	200
AD 1072	No	crystalline rock	forest	<.2	125
AD 1073	No	carbonate rock	agriculture	<.2	143
CH 6506	Yes	crystalline rock	urban	.2	250
DE 855	Yes	crystalline rock	forest	1.0	110
DE 484	Yes	unconsolidated sediments	urban	<.2	100
CH 6508	Yes	crystalline rock	forest	<.2	100
CH 6507	Yes	crystalline rock	forest	<.2	258
CH 1134	Yes	crystalline rock	forest	.3	120
CH 104	Yes	crystalline rock	urban	<.2	55
DE 862	Yes	crystalline rock	forest	<.2	--
DE 791	Yes	crystalline rock	forest	<.2	180
CH 6497	Yes	crystalline rock	forest	.5	100
SO 855	No	siliciclastic rock	forest	<.2	47
CH 6512	Yes	crystalline rock	forest	.3	100
LN 2110	No	carbonate rock	agriculture	.3	36
CH 5446	Yes	crystalline rock	forest	<.2	285
CH 6510	Yes	crystalline rock	forest	<.2	260
CH 6511	Yes	crystalline rock	forest	.4	85
LN 2107	No	carbonate rock	forest	<.2	400
LN 2109	No	carbonate rock	urban	<.2	80
CH 2634	Yes	carbonate rock	agriculture	<.2	110
PH 1039	Yes	unconsolidated sediments	urban	.2	26
CH 5052	Yes	crystalline rock	agriculture	.6	120
BK 3000	Yes	unconsolidated sediments	urban	.6	90
MG 1908	Yes	carbonate rock	urban	13.4	400
LN 2112	No	carbonate rock	agriculture	<.2	162
LN 2106	No	crystalline rock	agriculture	.4	200
LN 2108	No	carbonate rock	agriculture	<.2	44
BK 2787	Yes	crystalline rock	urban	5.6	37
BK 2997	Yes	crystalline rock	urban	.3	180
DA 527	No	crystalline rock	agriculture	.4	300
LN 2111	No	carbonate rock	agriculture	<.2	40
LN 2104	No	siliciclastic rock	urban	<.2	80
MG 1674	Yes	siliciclastic rock	forest	<.2	285
MG 958	Yes	siliciclastic rock	urban	<.2	271
CU 950	No	carbonate rock	agriculture	<.2	180
CU 949	No	carbonate rock	agriculture	<.2	175
MG 1761	Yes	siliciclastic rock	agriculture	<.2	225
MG 1673	Yes	siliciclastic rock	forest	<.2	120
MG 1180	Yes	siliciclastic rock	urban	<.2	189
WS 974	No	siliciclastic rock	agriculture	<.2	55
BK 2998	Yes	siliciclastic rock	agriculture	<.2	110
LB 191	No	carbonate rock	agriculture	<.2	80
BE 1718	No	carbonate rock	urban	<.2	223
CA 457	No	siliciclastic rock	forest	<.2	225
BE 1426	No	carbonate rock	forest	<.2	350

**Table 1B.** Identification number, RFG area location, aquifer type, land-use group, MTBE concentration, and well-depth data from wells sampled near storage tank releases—Continued

[<, less than; µg/L, micrograms per liter; --, unknown]

Local identification number	Location within RFG-use area <sup>1</sup>	Aquifer type <sup>2</sup>	Land use/land cover <sup>3</sup>	MTBE, (µg/L) <sup>4</sup>	Well depth, in feet below land surface
AG 711	No	siliciclastic rock	forest	<0.2	108
AG 708	No	siliciclastic rock	forest	<.2	80
BK 2999	Yes	siliciclastic rock	forest	.4	100
BA 640	No	carbonate rock	urban	<.2	80
BE 619	No	carbonate rock	urban	<.2	248
BA 641	No	carbonate rock	forest	<.2	100
AG 712	No	unconsolidated sediments	urban	<.2	60
AG 707	No	unconsolidated sediments	agriculture	<.2	60
LE 1424	No	crystalline rock	forest	.7	100
AG 710	No	siliciclastic rock	urban	<.2	131
AG 709	No	siliciclastic rock	forest	<.2	185
LE 1422	No	carbonate rock	forest	<.2	152
IN 920	No	siliciclastic rock	agriculture	<.2	60
BV 226	No	siliciclastic rock	urban	<.2	100
LE 1423	No	carbonate rock	urban	<.2	150
NP 821	No	carbonate rock	agriculture	<.2	110
LA 1202	No	unconsolidated sediments	agriculture	<.2	79
LA 1203	No	siliciclastic rock	forest	<.2	100
MO 693	No	siliciclastic rock	forest	<.2	300
MR 3308	No	unconsolidated sediments	forest	<.2	64
LY 684	No	carbonate rock	agriculture	<.2	250
LY 683	No	siliciclastic rock	urban	<.2	250
MR 3307	No	unconsolidated sediments	agriculture	<.2	65
LY 685	No	siliciclastic rock	agriculture	31.9	90
WY 180	No	siliciclastic rock	urban	<.2	200
TI 575	No	siliciclastic rock	urban	<.2	79
WR 837	No	unconsolidated sediments	urban	<.2	51
ER 2513	No	siliciclastic rock	agriculture	<.2	80
ER 2512	No	unconsolidated sediments	agriculture	<.2	45
ER 2508	No	siliciclastic rock	agriculture	<.2	43
ER 8544	No	unconsolidated sediments	forest	<.2	83
ER 2514	No	unconsolidated sediments	agriculture	<.2	20
ER 2509	No	siliciclastic rock	forest	<.2	100
ER 2505	No	unconsolidated sediments	urban	<.2	24
ER 2507	No	unconsolidated sediments	urban	<.2	25
ER 2510	No	unconsolidated sediments	forest	<.2	24.1
ER 2506	No	siliciclastic rock	urban	.2	19
ER 2515	No	siliciclastic rock	urban	<.2	90
ER 2511	No	unconsolidated sediments	agriculture	<.2	88

<sup>1</sup> RFG is the Reformulated Gasoline-use area that consists of five counties (Bucks, Chester, Delaware, Montgomery, and Philadelphia) in Pennsylvania.

<sup>2</sup> Aquifer type is determined by intersection of well location with generalized aquifer digital spatial information data set, after Lindsey and Bickford (1999).

<sup>3</sup> Land use / land cover is determined by intersection of well location with USGS digital spatial information data set on land use/land cover (U.S. Geological Survey, 1992).

<sup>4</sup> Minimum reporting level (MRL) is 0.2 µg/L and all estimated values below 0.2 µg/L are listed as MRL. MTBE concentrations are rounded to nearest tenth of a microgram.

**Table 1C.** Collection date, lab quality code, atmospheric MTBE concentration, mean daily temperature, and calculated equivalent aqueous MTBE concentration for four Air Quality Monitoring sites of the Pennsylvania Department of Environmental Protection

[ppbv, part per billion by volume; deg F, degrees Fahrenheit; µg/L, micrograms per liter; --, missing data]

Date collected <sup>1</sup>	West Chester				Pittsburgh			
	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>3</sup>	Mean daily temperature (deg F) <sup>4</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>6</sup>	Mean daily temperature (deg F) <sup>7</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>
4/1/01	—	0.33	43	0.298	J	0.06	41.2	0.055
4/7/01	—	.83	47	.460	J	.05	68.2	.011
4/13/01	—	.39	62	.132	U	.01	61.7	.003
4/19/01	—	.25	41	.224	—	.12	41.4	.104
4/25/01	—	.23	47	.126	J	.04	46.5	.020
5/1/01	—	.28	64	.061	—	.53	66.4	.114
5/7/01	—	.24	51	.131	—	.11	62.3	.038
5/13/01	U	.02	58	.007	J	.03	49.1	.017
5/19/01	—	.18	65	.039	—	.16	65	.034
5/25/01	—	.47	61	.161	J	.05	56.3	.017
5/31/01	U	.02	54	.011	U	.01	53.4	.005
6/6/01	—	.27	66	.058	—	.06	63.1	.022
6/12/01	—	.22	72	.046	—	.22	73.1	.031
6/18/01	—	.14	71	.030	—	.21	68.5	.046
6/24/01	J	.10	67	.022	—	.17	62.5	.056
6/30/01	—	.36	80	.050	—	.10	75.6	.014
7/6/01	—	.11	64	.023	—	--	62.7	--
7/12/01	—	.15	66	.032	—	--	66.4	--
7/18/01	—	.44	71	.096	U	.01	74.1	.001
7/24/01	—	.12	79	.017	—	.09	78.8	.012
7/30/01	—	--	--	--	—	.08	68.8	.017
8/5/01	—	.44	78	.062	—	.16	77.8	.022
8/11/01	—	.58	72	.125	U	.01	75.8	.001
8/17/01	—	.18	75	.025	U	.01	71.3	.002
8/23/01	—	.38	71	.082	U	.01	68.5	.002
8/29/01	—	.36	72	.077	—	.19	68	.041
9/4/01	—	.23	70	.050	U	.01	71.2	.002
9/10/01	—	--	--	--	U	.01	70.6	.002
9/16/01	—	--	--	--	J	.14	57.2	.050
9/22/01	Q	.27	69	.058	U	.01	62.6	.003
9/28/01	—	--	--	--	U	.01	51.5	.005
10/4/01	—	.84	65	.183	U	.01	66.8	.002
10/10/01	—	.58	49	.319	—	.29	55.5	.100
10/16/01	—	.70	52	.383	J	.21	48.1	.116
10/22/01	—	.43	62	.146	J	.19	62.4	.064
10/28/01	—	--	--	--	U	.01	39.3	.010
11/3/01	—	.26	59	.089	—	--	54.5	--
11/9/01	J	.12	47	.066	U	.01	44.4	.009
11/15/01	—	.61	53	.333	U	.01	57.6	.003
11/21/01	—	.25	34	.228	—	.28	33.9	.255
11/27/01	—	.95	48	.524	—	.26	48.4	.143
12/3/01	—	.60	40	.540	J	.17	44	.152
12/9/01	—	--	--	--	U	.01	39	.009
12/15/01	—	--	--	--	U	.01	41.1	.009

**Table 1C.** Collection date, lab quality code, atmospheric MTBE concentration, mean daily temperature, and calculated equivalent aqueous MTBE concentration for four Air Quality Monitoring sites of the Pennsylvania Department of Environmental Protection—Continued

[ppbv, part per billion by volume; deg F, degrees Fahrenheit; µg/L, micrograms per liter; --, missing data]

Lancaster				Arendtsville			
Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>8</sup>	Mean daily temperature (deg F) <sup>4</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>9</sup>	Mean daily temperature (deg F) <sup>10</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>
--	0.092	41	0.082	--	--	--	--
--	.472	49	.260	--	--	--	--
--	.144	62	.049	--	--	--	--
--	.075	44	.067	--	--	--	--
J	.044	48	.024	--	--	--	--
--	.208	66	.045	--	--	--	--
--	.125	53	.068	--	--	--	--
U	.02	57	.007	U	0.02	59.5	0.007
--	.139	67	.030	--	.244	66.5	.053
--	.388	62	.132	--	--	--	--
U	.02	57	.007	U	.02	58.2	.007
U	.02	68	.004	--	--	--	--
--	.161	75	.022	U	.02	76	.003
--	.064	75	.009	--	--	--	--
--	--	--	--	U	.02	68.2	.004
--	.277	81	.038	U	.02	81.8	.002
--	--	--	--	U	.02	67.1	.004
--	--	--	--	U	.02	72.3	.004
--	.225	72	.048	--	.144	75	.020
U	.02	82	.002	--	.089	83.2	.008
--	.128	71	.028	U	.02	68.6	.004
--	.128	79	.018	--	--	--	--
--	--	--	--	U	.02	76.1	.003
--	.14	77	.019	U	.02	78.6	.003
--	.21	71	.045	U	.02	72.5	.004
U	.02	75	.003	U	.02	73.9	.003
--	--	--	--	--	--	--	--
--	.11	72	.024	--	--	--	--
J	.16	58	.055	--	--	--	--
J	.17	70	.037	U	.02	70.9	.004
U	.02	53	.011	U	.02	53.1	.011
Q	.28	67	.061	U	.02	67.4	.004
J	.23	53	.126	U	.02	51.7	.011
J	.14	51	.077	--	--	--	--
J	.17	62	.058	U	.02	60.2	.007
--	--	--	--	U	.02	42.9	.018
J	.12	62	.041	U	.02	64.9	.004
U	.02	48	.011	U	.02	52.9	.011
--	.49	52	.268	U	.02	52	.011
J	.13	37	.118	U	.02	36.7	.018
--	.3	48	.166	J	.21	46.2	.116
--	.26	40	.234	U	.02	41.2	.018
J	.15	39	.135	U	.02	40.9	.018
U	.02	42	.018	U	.02	48.4	.011

**Table 1C.** Collection date, lab quality code, atmospheric MTBE concentration, mean daily temperature, and calculated equivalent aqueous MTBE concentration for four Air Quality Monitoring sites of the Pennsylvania Department of Environmental Protection—Continued

[ppbv, part per billion by volume; deg F, degrees Fahrenheit; µg/L, micrograms per liter; --, missing data]

Date collected <sup>1</sup>	West Chester				Pittsburgh			
	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>3</sup>	Mean daily temperature (deg F) <sup>4</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>6</sup>	Mean daily temperature (deg F) <sup>7</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>
12/21/01	—	--	--	--	U	0.01	30.7	0.009
12/27/01	—	--	--	--	—	--	--	--
1/2/02	—	--	--	--	—	--	--	--
1/8/02	—	--	--	--	—	--	--	--
1/14/02	—	--	--	--	—	--	--	--
1/20/02	—	--	--	--	—	--	--	--
1/26/02	—	--	--	--	—	--	--	--
2/1/02	—	--	--	--	—	--	--	--
2/7/02	—	--	--	--	—	--	--	--
2/13/02	—	--	--	--	—	--	--	--
2/19/02	—	--	--	--	—	--	--	--
2/25/02	—	--	--	--	—	--	--	--
3/3/02	—	--	--	--	—	--	--	--
3/9/02	—	--	--	--	—	--	--	--
3/15/02	—	--	--	--	—	--	--	--
3/21/02	—	--	--	--	—	--	--	--
3/27/02	—	--	--	--	—	--	--	--

<sup>1</sup> Data were scheduled for collection over a 24-hour period once every 6 days.

<sup>2</sup> PA DEP Air Quality organics laboratory quality codes are as follows:

U - Indicates compound was analyzed for but not detected. The sample quantitation limit is reported.

J - Indicates an estimated value, below the quantification limit, but above the method detection limit.

Q - This flag identifies the average of multiple results from multiple analysis, or the average of the averages of dual column analysis methods.

— - Indicates no quality code needed.

<sup>3</sup> West Chester air-quality sampling site is at West Chester University South campus, latitude 395624 longitude 753600.

<sup>4</sup> Mean daily temperatures from DEP air quality monitor site.

<sup>5</sup> See Appendix 2 for equation used to calculate equivalent aqueous MTBE concentrations.

<sup>6</sup> Pittsburgh air quality station located at 39th and Penn Streets in Pittsburgh.

<sup>7</sup> Mean daily temperature from NOAA data at Pittsburgh.

<sup>8</sup> Lancaster air quality data from latitude 400249 longitude 761700.

<sup>9</sup> Arendtsville data from air quality station at PSU Experimental Orchard at latitude 395525 longitude 771829.

<sup>10</sup> Mean daily temperatures from NOAA data at Harrisburg.

**Table 1C.** Collection date, lab quality code, atmospheric MTBE concentration, mean daily temperature, and calculated equivalent aqueous MTBE concentration for four Air Quality Monitoring sites of the Pennsylvania Department of Environmental Protection—Continued

[ppbv, part per billion by volume; deg F, degrees Fahrenheit; µg/L, micrograms per liter; --, missing data]

Lancaster				Arendtsville			
Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>8</sup>	Mean daily temperature (deg F) <sup>4</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>	Quality code <sup>2</sup>	Atmospheric MTBE (ppbv) <sup>9</sup>	Mean daily temperature (deg F) <sup>10</sup>	Equivalent aqueous MTBE (µg/L) <sup>5</sup>
U	0.02	36	0.018	U	0.02	37.8	0.018
U	.02	26	.019	U	.02	26.7	.018
U	.02	26	.019	U	.02	25.6	.019
U	.02	28	.018	U	.02	28.5	.018
J	.092	37	.083	U	.02	34.5	.018
J	.1	29	.092	U	.02	27.8	.018
J	.1	40	.090	U	.02	39.6	.018
U	.02	45	.018	U	.02	43.4	.018
J	.23	36	.209	U	.02	36.3	.018
U	.02	34	.018	U	.02	37.9	.018
U	.02	39	.018	U	.02	33.4	.018
J	.13	41	.117	J	.15	40.6	.135
U	.02	49	.011	U	.02	48.2	.011
J	.035	58	.012	J	.062	54.5	.034
J	.12	57	.041	J	.097	56.8	.033
U	.02	45	.018	U	.02	46.3	.011
U	.02	41	.018	U	.02	41.8	.018

## Appendix 2—Equations used to calculate equivalent aqueous MTBE concentration

The equation used to calculate equivalent aqueous concentration of MTBE from atmospheric concentration of MTBE is as follows from Baehr and others (1999, p. 131):

$$C = \bar{w} \times A \times P / H \times 10^6 \times R \times T \quad (1)$$

where:

C is equivalent aqueous concentration of MTBE, in micrograms per liter;

$\bar{w}$  is molecular weight of MTBE = 88.15;

A is atmospheric concentration of MTBE, in parts per billion by volume;

P is atmospheric pressure = 1.0 atmospheres;

H is Henry's Law coefficient, dimensionless. This coefficient is temperature dependent and is calculated according to the van Hoff equation:

$$d \ln (H) / dT = \Delta H_{\text{Henry}} / RT^2.$$

Data used for calculations in this report are from tabled data of H in Baehr and others (1999, p.131, table 3).

R is gas constant =  $8.205783 \times 10^{-5}$  (meter<sup>3</sup> atmospheres)/(moles Kelvin)

T is temperature in Kelvin degrees