National Water-Quality Assessment Program

Quality of Volatile Organic Compound Data from Groundwater and Surface Water for the National Water-Quality Assessment Program, October 1996–December 2008

Scientific Investigations Report 2011–5204

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

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Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with reliable scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). The NAWQA Program is designed to answer: What is the quality of our Nation's streams and groundwater? How are conditions changing over time? How do natural features and human activities affect the quality of streams and groundwater, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991 to 2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/studies/study_units.html).

National and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are selectively reassessed. These assessments extend the findings in the Study Units by determining water-quality status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and groundwater. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Included are studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

William H. Werkheiser
USGS Associate Director for Water

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Volume	
liter (L)	0.2642	gallon (gal)
milliliter (mL)	0.03382	ounce, fluid (fl. oz.)

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

$$°F=(1.8\times°C)+32$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Abbreviations and Acronyms

µg/L	microgram per liter
90-percent UCL	90-percent upper confidence limit
α	significance level
B	binomial function
E	concentration is estimated
GC/MS	gas chromatography/mass spectrometry
GCV	glass chilled vial
HCl	hydrochloric acid
ks	Kolmogorov-Smirnov statistical test
LT–MDL	long-term method detection level
MCL	Maximum Contaminant Level
NAWQA	National Water-Quality Assessment
NFM	U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data
NWIS	U.S. Geological Survey National Water Information System database
NWQL	National Water Quality Laboratory
QC	quality-control
SWQA	Source Water-Quality Assessment
UCL	upper confidence limit
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound
VPBW	volatile-pesticide grade blank water

Quality of Volatile Organic Compound Data from Groundwater and Surface Water for the National Water-Quality Assessment Program, October 1996–December 2008

By David A. Bender, John S. Zogorski, David K. Mueller, Donna L. Rose, Jeffrey D. Martin, and Cassandra K. Brenner

Abstract

This report describes the quality of volatile organic compound (VOC) data collected from October 1996 to December 2008 from groundwater and surface-water sites for the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. The VOC data described were collected for three NAWQA site types: (1) domestic and public-supply wells, (2) monitoring wells, and (3) surface-water sites. Contamination bias, based on the 90-percent upper confidence limit (UCL) for the 90th percentile of concentrations in field blanks, was determined for VOC samples from the three site types. A way to express this bias is that there is 90-percent confidence that this amount of contamination would be exceeded in no more than 10 percent of all samples (including environmental samples) that were collected, processed, shipped, and analyzed in the same manner as the blank samples. This report also describes how important native water rinsing may be in decreasing carryover contamination, which could be affecting field blanks.

The VOCs can be classified into four contamination categories on the basis of the 90-percent upper confidence limit (90-percent UCL) concentration distribution in field blanks. Contamination category 1 includes compounds that were not detected in any field blanks. Contamination category 2 includes VOCs that have a 90-percent UCL concentration distribution in field blanks that is about an order of magnitude lower than the concentration distribution of the environmental samples. Contamination category 3 includes VOCs that have a 90-percent UCL concentration distribution in field blanks that is within an order of magnitude of the distribution in environmental samples. Contamination category 4 includes VOCs that have a 90-percent UCL concentration distribution in field blanks that is at least an order of magnitude larger than the concentration distribution of the environmental samples.

Fifty-four of the 87 VOCs analyzed in samples from domestic and public-supply wells were not detected in field blanks (contamination category 1), and 33 VOC were detected in field blanks. Ten of the 33 VOCs had a 90-percent UCL concentration distribution in field blanks that was at least an order of magnitude lower than the concentration distribution in environmental samples (contamination category 2). These 10 VOCs may have had some contamination bias associated with the environmental samples, but the potential contamination bias was negligible in comparison to the environmental data; therefore, the field blanks were assumed to be representative of the sources of contamination bias affecting the environmental samples for these 10 VOCs. Seven VOCs had a 90-percent UCL concentration distribution of the field blanks that was within an order of magnitude of the concentration distribution of the environmental samples (contamination category 3). Sixteen VOCs had a 90-percent UCL concentration distribution in the field blanks that was at least an order of magnitude greater than the concentration distribution of the environmental samples (contamination category 4). Field blanks for these 16 VOCs appear to be nonrepresentative of the sources of contamination bias affecting the environmental samples because of the larger concentration distributions (and sometimes higher frequency of detection) in field blanks than in environmental samples.

Forty-three of the 87 VOCs analyzed in samples from monitoring wells were not detected in field blanks (contamination category 1), and 44 VOCs were detected in field blanks. Eight of the 44 VOCs had a 90-percent UCL concentration distribution in field blanks that was at least an order of magnitude lower than concentrations in environmental samples (contamination category 2). These eight VOCs may have had some contamination bias associated with the environmental samples, but the potential contamination bias was negligible in comparison to the environmental data; therefore, the field blanks were assumed to be representative. Seven VOCs had a 90-percent UCL concentration distribution in field blanks that was of the same order of magnitude as the concentration distribution of the environmental samples (contamination category 3). Twenty-nine VOCs had a 90-percent UCL

concentration distribution in the field blanks that was an order of magnitude greater than the distribution of the environmental samples (contamination category 4). Field blanks for these 29 VOCs appear to be nonrepresentative of the sources of contamination bias to the environmental samples.

Fifty-four of the 87 VOCs analyzed in surface-water samples were not detected in field blanks (category 1), and 33 VOC were detected in field blanks. Sixteen of the 33 VOCs had a 90-percent UCL concentration distribution in field blanks that was at least an order of magnitude lower than the concentration distribution in environmental samples (contamination category 2). These 16 VOCs may have had some contamination bias associated with the environmental samples, but the potential contamination bias was negligible in comparison to the environmental data; therefore, the field blanks were assumed to be representative. Ten VOCs had a 90-percent UCL concentration distribution in field blanks that was similar to the concentration distribution of environmental samples (contamination category 3). Seven VOCs had a 90-percent UCL concentration distribution in the field blanks that was greater than the concentration distribution in environmental samples (contamination category 4). Field-blank samples for these seven VOCs appear to be nonrepresentative of the sources of contamination bias to the environmental samples.

The relation between the detection of a compound in field blanks and the detection in subsequent environmental samples appears to be minimal. The median minimum percent effectiveness of native water rinsing is about 79 percent for the 19 VOCs detected in more than 5 percent of field blanks from all three site types. The minimum percent effectiveness of native water rinsing (10 percent) was for toluene in surface-water samples, likely because of the large detection frequency of toluene in surface-water samples (about 79 percent) and in the associated field-blank samples (46.5 percent).

The VOCs that were not detected in field blanks (contamination category 1) from the three site types can be considered free of contamination bias, and various interpretations for environmental samples, such as VOC detection frequency at multiple assessment levels and comparisons of concentrations to benchmarks, are not limited for these VOCs. A censoring level for making comparisons at different assessment levels among environmental samples could be applied to concentrations of 9 VOCs in samples from domestic and public-supply wells, 16 VOCs in samples from monitoring wells, and 9 VOCs in surface-water samples to account for potential low-level contamination bias associated with these selected VOCs. Bracketing the potential contamination by comparing the detection and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to benchmarks are done in a study.

The results described in this report can be applied to interpretation of environmental data collected from October 1996 to December 2008 from NAWQA Study Units. These results also provide a basis for comparison with quality-control results for samples collected in U.S. Geological Survey studies by using the protocols outlined in the National Field Manual for Collection of Water-Quality Data as a guide for cleaning, collection, and processing of samples.

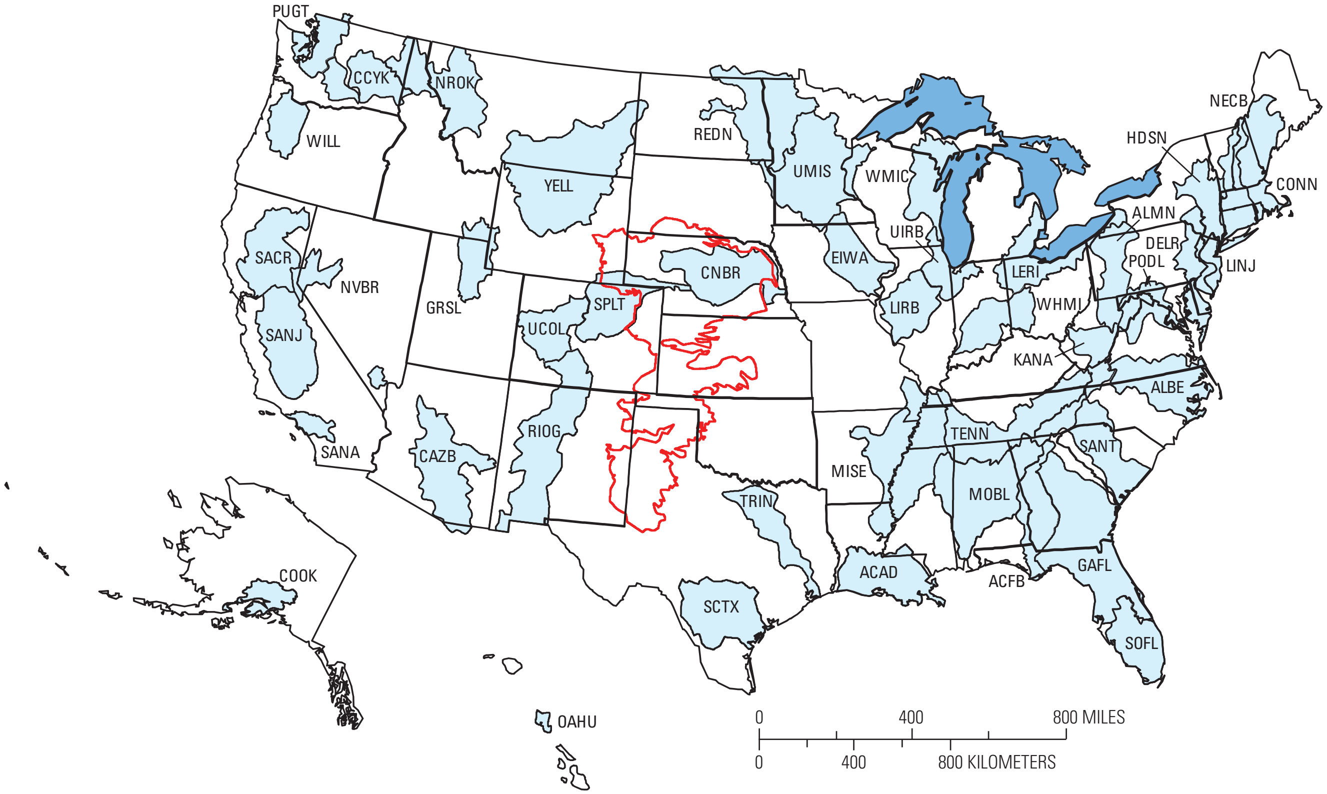
Introduction

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program was implemented in 1991. The goals of the NAWQA Program are to describe water-quality conditions and trends in the Nation’s rivers, streams, and groundwater and to understand the natural and anthropogenic influences that affect water quality (Hirsch and others, 1988a, 1988b).

The NAWQA Program continues to assess the water quality in the Nation’s largest river basins and aquifers (fig. 1), known as NAWQA Study Units. These NAWQA Study Units account for about one-half the land area of the conterminous United States and 60 to 70 percent of the Nation’s water use and population served by public-water supplies (Leahy and Wilber, 1991). Study-Unit investigations are divided into three groups that assess water quality on a rotational schedule. The first 20 Study-Unit investigations began in 1991, and additional Study-Unit investigations were started in 1994 and 1997. Many of the Study Units were sampled again during NAWQA’s second decade of assessments (2001, 2004, and 2007). Study-Unit investigations and national synthesis are the major operational components of the NAWQA Program that allow water-quality information that is collected and interpreted locally to be integrated into a national description of water quality (Gilliom and others, 1995).

One of the major tasks of the NAWQA Program is to assess the occurrence and distribution of volatile organic compounds (VOCs) in groundwater and surface water. The focus of Study-Unit investigations is to identify which VOCs occur in the water resources of the Study Unit and to characterize and explain the geographic and seasonal distributions of VOCs (Gilliom and others, 1995, p. 4–6). The focus of national synthesis is to characterize, compare, and explain the geographic and seasonal distributions of VOCs among the wide variety of land-use and hydrologic settings in the United States, and to place the occurrence findings in a human-health and aquatic-life context.

Estimates are needed of the bias that may result from sample collection, processing, shipment, and laboratory analysis to quantify how much **contamination bias** in water-quality measurements can be explained by field and laboratory methods, as compared to environmental factors. (A ***glossary*** at the back of this report defines data-quality terms, shown in bold, used in this report.) **Bias** is the systematic error inherent in sampling and laboratory methods, and can be either positive (concentration greater than the true concentration) or negative. A common source of positive bias that can affect water-quality data is contamination of samples. Contamination of samples



Base modified from U.S. Geological Survey digital data, 1990, 1:2,000,000
Albers Equal-Area Conic projection
Standard parallels 29°30'N and 45°30'N
Central meridian 90°W
North American Datum of 1983

EXPLANATION

🟦 **Study unit**

— **High Plains groundwater study boundary**

EXPLANATION

Study unit abbreviation

ACAD	Acadian-Pontchartrain
ACFB	Apalachicola-Chattahoochee-Flint River Basin
ALBE	Albemarle-Pamlico Drainage
ALMN	Allegheny/Monongahela
CAZB	Central Arizona Basins
CCYK	Central Columbia Plateau Yakima River Basin
CNBR	Central Nebraska Basins
CONN	Connecticut, Housatonic, and Thames River Basins
COOK	Cook Inlet Basin
DELR	Delaware River Basin
EIWA	Eastern Iowa Basins
GAFL	Georgia-Florida Coastal Plain
GRSL	Great Salt Lake Basins
HDSN	Hudson River Basin
HPGW	High Plains Regional Ground Water Study
KANA	Kanawha-New River Basin
LERI	Lake Erie-Lake St. Clair Drainage
LINJ	Long Island-New Jersey Coastal Drainages
LIRB	Lower Illinois River Basin
MISE	Mississippi Embayment
MOBL	Mobile River and Tributaries
NECB	New England Coastal Basins
NROK	Northern Rockies Intermontane Basins
NVBR	Nevada Basin and Range
OAHU	Oahu
PODL	Potomac River Basin and Delmarva Peninsula
PUGT	Puget Sound Basin
REDN	Red River of the North Basin
RIOG	Rio Grande Valley
SACR	Sacramento Basin
SANA	Santa Ana Basin
SANJ	San Joaquin-Tulare Basins
SANT	Santee Basin and Coastal Drainages
SCTX	South Central Texas
SOFL	Southern Florida
SPLT	South Platte River Basin
TENN	Tennessee River Basin
TRIN	Trinity River Basin
UCOL	Upper Colorado River Basin
UIRB	Upper Illinois River Basin
UMIS	Upper Mississippi River Basin
WHMI	White and Great and Little Miami River Basins
WILL	Willamette Basin
WMIC	Western Lake Michigan Drainages
YELL	Yellowstone Basin

Figure 1. Locations of National Water-Quality Assessment Study Units contributing data for this report.

can be introduced during sample collection, processing, shipping, or laboratory analysis by exposure to airborne gases and particulates, sampling supplies, or from inadequately cleaned sampling or analytic equipment. This contamination bias may be **systematic** (that is, the contamination introduces a positive error in all the analytical results) but also can be random and might not affect all samples equally. Contamination bias is evaluated by collecting and analyzing **quality-control** (QC) samples (for example, field-blank water samples) in relation to measurements of the environmental samples collected as part of a water-quality assessment.

A **blank sample** is a QC water sample intended to be free of the compounds of interest. Blank samples are used to test for contamination during sample collection, field processing, shipment, and laboratory analysis. Contamination in a blank sample is indicated when a compound of interest is detected. Contamination produces a positive bias in the analytical results and may need to be considered in subsequent analysis and interpretation of the environmental data (Martin and others, 1999). Field equipment blanks, referred to as **field blanks**, are a specific type of blank-water sample used to demonstrate that (1) the equipment has been adequately cleaned to remove contamination introduced from a previous site(s) or during transport of equipment; (2) sample collection and processing have not resulted in contamination; and (3) sample shipping and laboratory analysis have not introduced contamination. **Source-solution blanks**, which are simply samples of the water used to process field blanks, are collected in the field and used to characterize the quality of the water before contacting sampling equipment.

The analytical method for VOCs used during the first 20 Study-Unit investigations (Rose and Schroeder, 1995) was refined during 1995, and the low-level VOC analytical method (Connor and others, 1998) was incorporated into the Program’s data collection starting in October 1996. Environmental and QC samples collected after the refinements in the analytical method are the focus of this report; thus VOC data collected from October 1996 to December 2008 from groundwater and surface-water sites for the NAWQA Program were used to evaluate the quality of the VOC data.

Purpose and Scope

The primary purpose of this report is to describe the quality of VOC data collected from October 1996 to December 2008 from groundwater and surface-water sites located in NAWQA Study Units. The groundwater dataset was further classified into data from (1) domestic and public-supply wells and (2) monitoring wells. The aspect of quality considered in this report includes bias caused by potential contamination and is based on an analysis of field blanks to determine 90-percent upper confidence limits (UCL) for percentiles of the distribution of VOC concentrations in field blanks. The results of this QC analysis are compared to the distribution of environmental concentrations to determine (1) the likely effect, if any, of the contamination bias on the environmental concentrations, and (2) which VOCs have field blank concentrations that markedly exceed environmental concentrations and, therefore, the field blank data are not representative of the sources of contamination to the environmental samples. A related objective of this QC analysis is to describe the implications of the findings, for example, to occurrence applications including comparisons of environmental concentrations to drinking-water benchmarks and aquatic-life criteria, one-tenth of drinking-water benchmarks and aquatic-life criteria, and at various **assessment levels**. The secondary objective of the report is to describe how important native water rinsing before the collection of environmental samples was in reducing or eliminating contamination evident in field blanks for the time period of this QC review.

This report summarizes concentrations of 87 VOCs in field blanks collected from domestic and public-supply wells, monitoring wells, and surface water for the USGS NAWQA Program from October 1, 1996, to December 31, 2008. **Laboratory set blanks** (bracketing set blanks) and source-solution blanks (collected in the field) were used to help support the evaluation and interpretation of the field blank data. Analytical data for 225 source-solution blanks and 278 field blanks from domestic and public-supply wells, 193 source-solution blanks and 297 field blanks from monitoring wells, and 54 source-solution blanks and 129 field blanks from surface water, collected from October 1996 to December 2008 are summarized in this report. All VOC samples were analyzed by the USGS National Water Quality Laboratory (NWQL) by purge and trap, capillary column, gas chromatography/mass spectrometry (GC/MS) (Connor and others, 1998).

Volatile Organic Compounds in Groundwater and Surface Water

Volatile organic compounds are organic chemicals with low molecular weights and composed of carbon, hydrogen, and other atoms. Most of the VOCs included in this report are man-made and can be grouped into specific use groups (or sources) including gasoline hydrocarbons, halogenated solvents, disinfection by-products (that is, trihalomethanes), organic synthesis compounds, fumigants, and refrigerants. Many of the VOCs have human-health benchmarks for drinking water, but few have aquatic-life criteria because VOCs may partition from surface water to the atmosphere.

The presence of VOCs in drinking water may be of concern to human health because of the potential carcinogenicity and other adverse human-health effects to the liver, kidney, spleen, stomach, and heart, as wells as the nervous, circulatory, reproductive, and respiratory systems (Zogorski and others, 2006). The U.S. Environmental Protection Agency (USEPA) has established Maximum Contaminant Levels (MCLs) for 29 VOCs because of the known or suspected human-health concerns. In addition, the presence of VOCs in groundwater implies that the aquifer is vulnerable and denotes that a pathway exists by which other persistent and potentially toxic compounds may reach drinking-water supply wells (Zogorski and others, 2006).

Previous Quality-Assurance Studies for Volatile Organic Compounds

A study was completed in 1996 to evaluate the stability of low concentrations of VOCs in water samples (Love and others, 1999). A groundwater and a surface-water matrix were spiked with 87 VOCs to achieve a theoretical concentration of 0.5 microgram per liter (µg/L) for most VOCs. Five replicate spike samples from each water matrix were preserved and stored, then analyzed at selected time intervals of as much as 216 days. Results of this stability study showed that VOCs typically are stable, with minimal analyte loss/gain, for as many as 216 days when preserved with hydrochloric acid to a pH of 2 and chilled to 4 degrees Celsius (Love and others, 1999).

Taglioli and others (2001) evaluated the potential of VOC carryover contamination in surface-water and groundwater sampling procedures. The study showed that when contaminated equipment (exposed previously to low (about 0.1 µg/L) concentrations of VOCs) is used to collect a subsequent environmental sample, the conditioning of the sampling equipment with the native water (that is, rinsing with the water that is to be sampled) is sufficient to remove/reduce concentrations of the VOCs to less than current (2011) analytical detection levels when the field rinsing/well purging protocols outlined in the USGS National Field Manual for the Collection of Water Quality Data (NFM) (U.S. Geological Survey, variously dated) are followed.

Rowe and others (2005) described the results of field matrix spike samples, laboratory matrix spike samples, and laboratory reagent spike samples. Recovery results for 85 VOCs, spiked to achieve a theoretical fortification concentration of about 0.5 µg/L for most of the VOCs, were used to broadly characterize the overall recovery of all VOCs combined. Median recoveries for 149 field matrix spike samples, 107 field matrix spike replicate samples, 20 laboratory matrix spike samples, and 152 laboratory reagent spike samples were 79.9, 83.3, 113.1, and 103.5 percent, respectively. In addition, median recoveries for individual VOCs ranged from 63.7 to 101.5 percent in field matrix spike samples; 63.1 to 101.4 percent in field matrix spike replicate samples; 101.7 to 135.0 percent in laboratory matrix spike samples; and 91.0 to 118.7 percent in laboratory reagent spike samples. The median recovery for each spike type was within the range of 60 to 140 percent, a range that is considered acceptable by the U.S. Environmental Protection Agency's established analytical method (Rose and Schroeder, 1995). For all spike types, 87 percent of the individual VOC recoveries were within the range of 60 to 140 percent. The excellent VOC recoveries from laboratory matrix spike samples and laboratory reagent spike samples demonstrate that low concentrations (less than 0.5 µg/L) of VOCs can routinely and accurately be measured by the analytical methods used by the NWQL (Rowe and others, 2005).

A field contamination study also was conducted in 2008–09 to better understand the shipping, field protocols, and analytical-related bias associated with the source-solution and field blanks (Thiros and others, 2011). This study showed that if the source-solution water does not contain VOCs at concentrations greater than current (2011) analytical detection levels, the subsequent field blanks are contaminant free at these levels. The study also showed that if the current (2011) field protocols in the NFM (U.S. Geological Survey, variously dated) for equipment cleaning and sample collection and processing are followed (particularly the minimum rinsing volumes) and new supplies (for example, fresh unexpired source-solution water and fresh sample bottles) are used for collection of source-solution and field blanks, then the contamination associated with these sample types is much less than that seen in prior NAWQA field QC datasets.

Quality Reviews for National-Scale Occurrence Assessments

Zogorski and others (2006) provided a summary and implications of groundwater VOC data collected during 1985–2001 across the United States by the NAWQA Program. Moran and others (2006) described the data compilation and QC review of the dataset used by Zogorski and others (2006). The QC review included a screening of the groundwater dataset for systematic field contamination (for example, carryover contamination), which was indicated when concentrations in a sample were similar to concentrations in the previously collected sample. If contamination was suspected, the results were excluded from the national assessment of VOCs. Zogorski and others (2006) also applied two assessment levels for computing detection frequencies. The first assessment level of 0.2 µg/L was selected to be consistent with historical NWQL Practical Quantitation Levels (Moran and others, 2006) used in the first 20 NAWQA Study-Unit investigations (referred to as historical reporting levels in this report). The second assessment level of 0.02 µg/L was selected on the basis of the low-level analytical method incorporated into the NAWQA Program in 1996. This lower assessment level was only applied to concentrations determined from the low-level analytical method (Moran and others, 2006).

The selection of a common assessment level of 0.02 µg/L was based on several observations including, for example, (1) most quantified concentrations of VOCs in field blanks and groundwater were greater than or equal to this assessment value, and (2) the limit of quantitation standards, which are spiked reagent water with concentrations near the long-term method detection level (LT–MDL), analyzed at the NWQL showed good analytical performance with almost 100-percent identification of most spiked compounds. The latter indicated the risk of false negatives was minimal.

Bender and others (2009) reported detection frequency and concentration statistics for source-solution and field blanks collected at urban stream sampling sites during 1995–2003. The QC review included a screening of the urban stream dataset for suspected systematic field contamination (for example, carryover), and if indicated, the results were excluded from the national assessment of VOCs in urban streams (Bender and others, 2009). The study by Bender and others (2009) also applied an assessment level of 0.02 µg/L, following the lower assessment level applied by Zogorski and others (2006). The concentrations detected in field-blank samples typically were less than 0.02 µg/L for most of the VOCs.

A new assessment activity during the second decade of NAWQA are Source Water-Quality Assessments (SWQAs) that focus on characterizing the quality of source water and finished water of aquifers and major rivers used by some of the larger community water systems in the United States (Carter and others, 2007). Source-solution and field blanks also are collected in SWQA studies. These QC samples were reviewed to evaluate potential bias (primarily systematic) associated with sample collection, processing, transport, and analysis (Carter and others, 2007). If the field QC data indicated the results for environmental data were potentially biased as a result of contamination, the environmental data were removed from the dataset for the SWQA studies.

An assessment of the quality of water from domestic wells in principal aquifers of the United States (DeSimone, 2009) and source water from public-supply wells (Toccalino and others, 2010) applied higher assessment levels for two VOCs (0.03 µg/L for toluene and 0.05 µg/L for 1,2,4-trimethylbenzene) (John Zogorski, U.S. Geological Survey, written commun., 2009) than used previously by NAWQA to address potential random contamination associated with field protocols (other VOCs did not require setting a higher assessment level for contamination). The assessment levels were determined from an analysis of field blank and environmental sample pairs for those VOCs detected in 1 percent or more of field blanks. This analysis was adequate to limit the estimated probability of false detections caused by random contamination to less than 1 percent (DeSimone, 2009).

Acknowledgments

This report summarizes data collected by hydrologists and hydrologic technicians in NAWQA Study Units and chemists at the NWQL. Without their efforts and long hours of data collection and laboratory analysis, this report would not have been possible. The authors also wish to thank Miranda S. Fram, USGS California Water Science Center; Galen Hoogestraat, USGS South Dakota Water Science Center; and Thomas Imbrigiotta, USGS New Jersey Water Science Center, for providing reviews of the report.

Procedures for the Collection and Laboratory Analysis of Source-Solution and Field Blanks

This section of the report describes the collection guidelines and field procedures for QC samples. The analytical method used by the NWQL to analyze water samples for VOCs also is described.

Collection Guidelines

Collection and analysis of field QC samples are mandated components of USGS water-quality studies (U.S. Geological Survey, 2006). The goal of QC sampling is to identify, quantify, and document bias and variability in data that result from the collection, processing, shipping, handling, and analysis of samples. The guidelines in the NFM indicate that field blanks are to be (1) collected routinely during the period of environmental sampling; (2) collected during periods when contamination is most probable, such as after field equipment has been in contact with high concentrations of contaminants of interest or during the seasons of high usage; and (3) distributed among sites to assess a broad range of locations, hydrologic conditions, and water types (Martin and others, 1999). A VOC source-solution blank also is to be collected and submitted with each field blank for VOC analyses.

Field Procedures

Sampling and processing protocols for QC and environmental samples are available in chapters A4 and A5 of the USGS NFM (U.S. Geological Survey, variously dated). Following are brief descriptions of sampling and processing protocols for source-solution blanks (collected in the field) and field blanks for groundwater and surface-water sites that were used for QC data summarized in this report.

VOC source-solution and field blanks are prepared by using commercially obtained volatile-pesticide grade blank water (VPBW) that has been purged with ultra-pure nitrogen for 2 hours at the NWQL before shipment to the field.

The collection procedures for source-solution blanks are described in U.S. Geological Survey (2006). The collection procedure for source-solution blanks is the same for groundwater and surface-water sites. Briefly, VOC source-solution blanks are collected by (1) placing a bottle of the VPBW, the sample vials, which consist of three 40-milliliter (mL) glass chilled vials (GCVs), and 1:1 hydrochloric acid (HCl) preservative in the sample processing chamber; (2) opening the VPBW bottle and sample vial; (3) pouring the VPBW into the GCV until overflowing (for VOC samples, a convex meniscus will need to be left); (4) capping the VPBW bottle; (5) adding about 2 drops of 1:1 HCl to a pH of 2 to the GCV; (6) capping the GCV and checking for any bubbles in the GCV (discarding vial if bubble is present); and (7) repeating steps 3 to 6 to fill the remaining GCVs. A sample processing chamber serves as a collection chamber into which sample water is pumped and either filtered or directly collected in sample bottles reducing the possibility of random atmospheric contamination during sample bottling, filtering, and preserving with chemical reagents (Lane and others, 2003).

Groundwater field blanks for VOCs are collected by using the same VPBW shipped to the field. The collection procedures described in U.S. Geological Survey (2006) are for domestic and public-supply wells and monitoring wells. Briefly, groundwater field blanks for VOCs are collected by (1) placing the sampling pump in a clean standpipe (for example, glass/Teflon™ graduated cylinder); (2) pouring the VPBW into the standpipe to cover the pump; (3) starting the pump, (4) continuing to add VPBW to the standpipe to reduce pump cavitation; and (5) after the required amount of VPBW has been pumped through the sampling line to waste (3 tubing volumes), continuing to add VPBW for the collection of the field blank (note that the collection of the field blank from the last 2 liters of the last bottle of VPBW is preferable); (6) filling a 40-mL GCV from the bottom up to overflowing, leaving a convex meniscus; (7) adding about 2 drops of 1:1 HCl to a pH of 2 to the GCV; (8) capping the GCV and checking for any bubbles in the GCV (discarding if bubble is present); and (9) repeating steps 6 to 8 for the remaining GCVs.

Surface-water field blanks for VOCs were collected by using the same VPBW shipped to the field. Field blank collection was done by using a USGS VOC hand sampler, which is described in Shelton (1997) and U.S. Geological Survey (2006). Surface-water field blanks for VOCs are collected by (1) rinsing a stainless-steel canister and VOC hand sampler with VPBW; (2) loading four 40-mL GCVs into the sampler; (3) pouring VPBW into the stainless-steel canister; (4) submerging the VOC hand sampler containing four GCVs into the canister; (5) continuing to add VPBW to maintain a level above the sample inlet ports; (6) allowing the GCVs to fill; (7) removing the sampler from the canister; (8) carefully opening the sampler; (9) by using metal tongs, carefully removing a GCV from the hand sampler to avoid losing the convex meniscus; (10) adding about 2 drops of 1:1 HCl to lower the pH to less than 2; (11) capping the GCV and checking for any bubbles (discarding GCV if bubble is present); and (12) repeating steps 9 to 11 for the remaining GCVs.

Analytical Method for Volatile Organic Compounds

The VOC samples were analyzed at the NWQL by using the low-level analytical method described in Connor and others (1998). The analytical method analyzed for 87 VOCs (table 1) by purge and trap, capillary column GC/MS and tentatively identified unknown VOCs in the sample. Because *m*- and *p*-xylene co-elute in the method, the reported concentration is the sum for these two compounds and reported as one analyte in the analyses. The use of GC/MS provides enhanced compound identification (that is, qualification) before the determination of the compound concentration (that is, quantitation). The reporting by NWQL of low-level concentrations is supported, in part, by the use of laboratory quality-assurance/quality-control samples including, for example, **instrument blanks** and laboratory set blanks (**bracketing set blanks)**. The method also includes a LT–MDL that accounts for the long-term variance of multiple instruments, multiple operators, and multiple calibrations for individual compounds during several months in a year (Connor and others, 1998; Childress and others, 1999). The LT–MDL varies for each compound and also can vary with time. The analytical method allows reporting of concentrations less than the lowest calibration standard as estimated by using an “E” remark code (Childress and others, 1999).

Vinyl acetate was removed during the method approval process because of poor reproducibility (Connor and others, 1998). The latest sampling date with a vinyl acetate result in the dataset used for this report is June 5, 1997. Acrolein was removed in April 1998 from the method because an update in analytical instrumentation changed the ability to consistently detect this compound (Rose and Connor, 1998).The analytical data for these two compounds, although few, are included in this report.

Compilation of Environmental and Quality-Control Data

The VOC data for this report are based on samples collected from October 1996 to December 2008 from the NAWQA Study Units shown in figure 1. The numbers of source-solution blanks, field blanks, and environmental samples summarized in this report are listed in table 2. The sample results were retrieved from the USGS NAWQA data warehouse (*http://water.usgs.gov/nawqa/data*) on January 15, 2009. Because of the different types of equipment and sampling methods for the environmental samples and field blanks, the data were distributed into the three NAWQA site types sampled—domestic and public-supply wells, monitoring wells, and surface-water sites. The source-solution blanks for the three site types were combined for the 90-percent upper confidence limit (90-percent UCL) for the figures in appendix 1 because the collection method for the source-solution blanks is the same for all groundwater and surface-water samples. The source-solution blanks for the three site types were paired with the corresponding field blanks for comparisons between the source-solution blanks and field blanks and the figures in appendix 2.

The laboratory set blank data were requested from the NWQL for the VOC method for the period of October 1996 to December 2008. The laboratory set blank data are presented in this report to provide an estimate of the laboratory contamination bias. This potential for laboratory contamination is

Table 1. Volatile organic compounds included in the U.S. Geological Survey's National Water-Quality Assessment Program and human-health benchmarks and aquatic-life criteria.

[USGS, U.S. Geological Survey; VOC, volatile organic compound; µg/L, microgram per liter; HBSL, USGS Health-Based Screening Level; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level; --, not applicable]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	VOC group	Human-health benchmark (µg/L)	Human-health benchmark type	Aquatic-life criteria (µg/L)	Alternate name or abbreviation
Bromomethane	74–83–9	34413	Fumigant	100	HBSL[2]	--	--
Dibromochloropropane	96–12–8	82625	Fumigant	.2	MCL[3]	--	DBCP; 1,2-dibromo-3-chloropropane.
1,4-Dichlorobenzene	106–46–7	34571	Fumigant	75	MCL[3]	[4]26	--
1,2-Dichloropropane	78–87–5	34541	Fumigant	5	MCL[3]	--	--
cis-1,3-Dichloropropene	10061–01–5	34704	Fumigant	[5].3–30	HBSL[2]	--	--
trans-1,3-Dichloropropene	10061–02–6	34699	Fumigant	[5].3–30	HBSL[2]	--	--
1,2-Dibromoethane	106–93–4	77651	Fumigant	.05	MCL[3]	--	Ethylene dibromide; EDB.
1,2,3-Trichloropropane	96–18–4	77443	Fumigant	40	HBSL[2]	--	--
Benzene	71–43–2	34030	Gasoline hydrocarbon	5	MCL[3]	[4]370	--
n-Butylbenzene	104–51–8	77342	Gasoline hydrocarbon	--	--	--	--
sec-Butylbenzene	135–98–8	77350	Gasoline hydrocarbon	--	--	--	--
tert-Butylbenzene	98–06–6	77353	Gasoline hydrocarbon	--	--	--	--
Ethylbenzene	100–41–4	34371	Gasoline hydrocarbon	700	MCL[3]	[4]90	--
2-Ethyltoluene	611–14–3	77220	Gasoline hydrocarbon	--	--	--	1-Ethyl-2-methylbenzene.
Isopropylbenzene	98–82–8	77223	Gasoline hydrocarbon	700	HBSL[2]	--	--
4-Isopropyltoluene	99–87–6	77356	Gasoline hydrocarbon	--	--	--	--
Naphthalene	91–20–3	34696	Gasoline hydrocarbon	100	HBSL[2]	[4]1.1	--
Styrene	100–42–5	77128	Gasoline hydrocarbon	100	MCL[3]	--	Ethenylbenzene.
Toluene	108–88–3	34010	Gasoline hydrocarbon	1,000	MCL[3]	[4]2	Methylbenzene.
1,2,3-Trimethylbenzene	526–73–8	77221	Gasoline hydrocarbon	--	--	--	--
1,2,4-Trimethylbenzene	95–63–6	77222	Gasoline hydrocarbon	--	--	--	--
1,3,5-Trimethylbenzene	108–67–8	77226	Gasoline hydrocarbon	--	--	--	--
1,2,3,4-Tetramethylbenzene	488–23–3	49999	Gasoline hydrocarbon	--	--	--	--
1,2,3,5-Tetramethylbenzene	527–53–7	50000	Gasoline hydrocarbon	--	--	--	--
o-Xylene	95–47–6	77135	Gasoline hydrocarbon	[6]10,000	MCL[3]	--	1,2-Dimethylbenzene.
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	Gasoline hydrocarbon	[6]10,000	MCL[3]	--	1,3- and 1,4-Dimethylbenzene.

Table 1. Volatile organic compounds included in the U.S. Geological Survey's National Water-Quality Assessment Program and human-health benchmarks and aquatic-life criteria. —Continued

[USGS, U.S. Geological Survey; VOC, volatile organic compound; µg/L, microgram per liter; HBSL, USGS Health-Based Screening Level; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level; --, not applicable]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	VOC group	Human-health benchmark (µg/L)	Human-health benchmark type	Aquatic-life criteria (µg/L)	Alternate name or abbreviation
tert-Amyl methyl ether	994–05–8	50005	Gasoline oxygenate	--	--	--	TAME.
Diisopropyl ether	108–20–3	81577	Gasoline oxygenate	--	--	--	DIPE.
Ethyl *tert*-butyl ether	637–92–3	50004	Gasoline oxygenate	--	--	--	ETBE.
Methyl *tert*-butyl ether	1634–04–4	78032	Gasoline oxygenate	--	--	--	MTBE; 2-methoxy-2-methyl propane.
Acrolein[7]	107–02–8	34210	Organic synthesis compound	4	HBSL[2]	[8]3	2-Propenal.
Acrylonitrile	107–13–1	34215	Organic synthesis compound	.06–6	HBSL[2]	--	2-Propenenitrile.
Bromochloromethane	74–97–5	77297	Organic synthesis compound	90	HBSL[2]	--	--
Carbon disulfide	75–15–0	77041	Organic synthesis compound	700	HBSL[2]	--	--
3-Chloro-1-propene	107–05–1	78109	Organic synthesis compound	--	--	--	--
trans-1,4-Dichloro-2-butene	110–57–6	73547	Organic synthesis compound	--	--	--	--
1,1-Dichloroethene	75–35–4	34501	Organic synthesis compound	7	MCL[3]	--	--
1,3-Dichloropropane	142–28–9	77173	Organic synthesis compound	--	--	--	--
2,2-Dichloropropane	594–20–7	77170	Organic synthesis compound	--	--	--	--
1,1-Dichloropropene	563–58–6	77168	Organic synthesis compound	--	--	--	--
Ethyl methacrylate	97–63–2	73570	Organic synthesis compound	600	HBSL[2]	--	--
Hexachlorobutadiene	87–68–3	39702	Organic synthesis compound	1	HBSL[2]	[4]1.3	--
Iodomethane	74–88–4	77424	Organic synthesis compound	--	--	--	Methyl iodide.
Methyl acrylate	96–33–3	49991	Organic synthesis compound	200	HBSL[2]	--	--
Methyl acrylonitrile	126–98–7	81593	Organic synthesis compound	.7	HBSL[2]	--	--
Methyl methacrylate	80–62–6	81597	Organic synthesis compound	10,000	HBSL[2]	--	--
1,2,3-Trichlorobenzene	87–61–6	77613	Organic synthesis compound	--	--	[4]8	--
Vinyl acetate[9]	108–05–4	77057	Organic synthesis compound	--	--	--	--
Vinyl bromide	593–60–2	50002	Organic synthesis compound	--	--	--	Bromoethene.
Vinyl chloride	75–01–4	39175	Organic synthesis compound	2	MCL[3]	--	Chloroethene.
Dichlorodifluoromethane	75–71–8	34668	Refrigerant	1,000	HBSL[2]	--	CFC–12.
Trichlorofluoromethane	75–69–4	34488	Refrigerant	2,000	HBSL[2]	--	CFC–11.

Table 1. Volatile organic compounds included in the U.S. Geological Survey's National Water-Quality Assessment Program and human-health benchmarks and aquatic-life criteria. —Continued

[USGS, U.S. Geological Survey; VOC, volatile organic compound; µg/L, microgram per liter; HBSL, USGS Health-Based Screening Level; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level; --, not applicable]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	VOC group	Human-health benchmark (µg/L)	Human-health benchmark type	Aquatic-life criteria (µg/L)	Alternate name or abbreviation
Trichlorotrifluoroethane	76–13–1	77652	Refrigerant	200,000	HBSL[2]	--	CFC–113; 1,1,2-trichloro-1,2,2-trifluoroethane.
Acetone	67–64–1	81552	Solvent	6,000	HBSL[2]	--	2-Propanone.
Bromobenzene	108–86–1	81555	Solvent	--	--	--	--
Carbon tetrachloride	56–23–5	32102	Solvent	5	MCL[3]	[4]13.3	Tetrachloromethane.
Chlorobenzene	108–90–7	34301	Solvent	100	MCL[3]	[4]1.3	--
Chloroethane	75–00–3	34311	Solvent	--	--	--	--
Chloromethane	74–87–3	34418	Solvent	30	HBSL[2]	--	Methyl chloride.
2-Chlorotoluene	95–49–8	77275	Solvent	100	HBSL[2]	--	--
4-Chlorotoluene	106–43–4	77277	Solvent	100	HBSL[2]	--	--
1,2-Dichlorobenzene	95–50–1	34536	Solvent	600	MCL[3]	[4].7	--
1,3-Dichlorobenzene	541–73–1	34566	Solvent	600	HBSL[2]	[4]150	--
1,1-Dichloroethane	75–34–3	34496	Solvent	70	HBSL[2]	--	--
1,2-Dichloroethane	107–06–2	32103	Solvent	5	MCL[3]	[4]100	--
cis-1,2-Dichloroethene	156–59–2	77093	Solvent	70	MCL[3]	--	--
trans-1,2-Dichloroethene	156–60–5	34546	Solvent	100	MCL[3]	--	--
Diethyl ether	60–29–7	81576	Solvent	1,000	HBSL[2]	--	--
Dibromomethane	74–95–3	30217	Solvent	--	--	--	Methylene bromide.
Hexachloroethane	67–72–1	34396	Solvent	1	HBSL[2]	--	1,1,1,2,2,2-Hexachloroethane.
Methyl butyl ketone	591–78–6	77103	Solvent	--	--	--	2-Hexanone.
Dichloromethane	75–09–2	34423	Solvent	5	MCL[3]	[4]98.1	Methylene chloride.
Methyl ethyl ketone	78–93–3	81595	Solvent	4,000	HBSL[2]	--	2-Butanone.
Methyl isobutyl ketone	108–10–1	78133	Solvent	--	--	--	4-Methyl-2-pentanone.
Perchloroethene	127–18–4	34475	Solvent	5	MCL[3]	[4]111	PCE; tetrachloroethene.
n-Propylbenzene	103–65–1	77224	Solvent	--	--	--	--
1,1,1,2-Tetrachloroethane	630–20–6	77562	Solvent	70	HBSL[2]	--	--
1,1,2,2-Tetrachloroethane	79–34–5	34516	Solvent	.3	HBSL[2]	--	--
Tetrahydrofuran	109–99–9	81607	Solvent	--	--	--	--

Table 1. Volatile organic compounds included in the U.S. Geological Survey's National Water-Quality Assessment Program and human-health benchmarks and aquatic-life criteria. —Continued

[USGS, U.S. Geological Survey; VOC, volatile organic compound; µg/L, microgram per liter; HBSL, USGS Health-Based Screening Level; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level; --, not applicable]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	VOC group	Human-health benchmark (µg/L)	Human-health benchmark type	Aquatic-life criteria (µg/L)	Alternate name or abbreviation
1,2,4-Trichlorobenzene	120–82–1	34551	Solvent	70	MCL[3]	[4]24	--
1,1,1-Trichloroethane	71–55–6	34506	Solvent	200	MCL[3]	--	--
1,1,2-Trichloroethane	79–00–5	34511	Solvent	5	MCL[3]	--	--
Trichloroethene	79–01–6	39180	Solvent	5	MCL[3]	[4]21	TCE.
Bromoform	75–25–2	32104	Trihalomethane (THM)	[10]80	MCL[3]	--	Tribromomethane.
Bromodichloromethane	75–27–4	32101	Trihalomethane (THM)	[10]80	MCL[3]	--	--
Chloroform	67–66–3	32106	Trihalomethane (THM)	[10]80	MCL[3]	[4]1.8	Trichloromethane.
Dibromochloromethane	124–48–1	32105	Trihalomethane (THM)	[10]80	MCL[3]	--	--

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

[2] Toccalino and others (2008).

[3] U.S. Environmental Protection Agency (2009a).

[4] Canadian Interim Aquatic Criteria from Canadian Council of Resource and Environment Ministers (1991).

[5] Sum of concentrations from *cis*-1,3- and *trans*-1,3-dichloropropene may be compared to the HBSL range of 0.3–30 µg/L for the mixed isomer of 1,3-dichloropropene, CASRN 542–75–6.

[6] Sum of concentrations from *m*-, *p*-, and *o*-xylene may be compared to the MCL of 10,000 µg/L for mixed xylenes, CASRN 1330–20–7.

[7] Acrolein was removed from the VOC method April 30, 1998 (Rose and Connor, 1998).

[8] U.S. Environmental Protection Agency (2009b).

[9] Vinyl acetate was on the analytical method but was removed during method approval because of poor reproducibility (Connor and others, 1998). The last date of any sample with vinyl acetate in the dataset for this report is June 5, 1997.

[10] Sum of concentrations from the trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) may be compared to the MCL of 80 µg/L.

Table 2. Number of source-solution blanks, field blanks, and environmental samples collected by National Water-Quality Assessment Study Units from October 1996 to December 2008 and used for the data analysis in this report.

Sample medium	NAWQA site type	Source-solution blanks	Field blanks	Environmental samples
Groundwater	Domestic and public-supply wells	225	278	3,042
Groundwater	Monitoring wells	193	297	2,639
Surface water	Surface water	54	129	1,497
Total		472	704	7,178

removed from field-related data through the laboratory's use of set blanks to censor analyses on the basis of potential contamination carryover measured by these **bracketing set blanks** (Connor and others, 1998). A total of 5,167 VOC-method laboratory set blanks were analyzed during this time period. Because an analytical run may contain groundwater, surface-water, and field and laboratory QC samples, the laboratory set blanks were analyzed as a group for figures in appendix 1.

Methods of Data Analysis

This section describes three methods or procedures that are used to understand the quality of VOC data collected for NAWQA studies of groundwater and surface water. The groundwater studies were classified into two site types: (1) domestic and public-supply wells and (2) monitoring wells. The statistical method used to describe the potential bias in environmental samples from contamination is described first. Field blanks are used to understand and describe this bias for the environmental samples; however, the statistical method also is applied for source-solution blanks (collected in the field) and laboratory blanks for comparisons to the field blank results.

First, the **detection frequency** was used to help describe the extent of contamination bias in the field-blank samples and to help categorize the samples into specific categories of contamination. The detection frequency was calculated by dividing the number of detections (quantified concentrations passing all qualification criteria in a sample; described in Connor and others,1998) by the total number of samples (for example, total number of field blanks) for each individual VOC.

Second, for each of NAWQA's three site types, the procedure used to place each VOC into one of four "contamination categories" is described along with the general interpretation of each category with regard to the degree that contamination bias might affect environmental data. Third, a procedure is described to calculate the effectiveness of a native water rinse in minimizing contamination in subsequent environmental samples for paired field blank and environmental samples. The field blank and environmental sample pairs provide a convenient dataset for evaluating the effectiveness of native water rinsing.

Graphs of VOC concentrations for paired field blanks and source-solution blanks were prepared (appendix 2) and used to visually examine the relations of detections in the two types of blank samples. If the concentrations of a VOC detected in the paired field and source-solution blanks are similar, either the VPBW was contaminated before collection of these blanks or a source of contamination affected both blank sample types similarly during sampling, shipment to the laboratory, or laboratory analysis.

Graphs of VOC concentrations for paired field blanks and environmental samples were prepared (appendix 2) and used to visually examine the relations of detections in the two types of paired samples. These visual comparisons were used in conjunction with the calculation of the minimum percent effectiveness of native water rinsing (see section "Effectiveness of Native Water Rinsing") to evaluate possible sources of contamination.

Methods of Data Analysis Used to Determine Contamination Bias

The objective in analyzing data from blank samples is to characterize the frequency and magnitude of contamination in field blanks and then infer what that distribution of contamination means for environmental samples (Mueller and Titus, 2005). This objective can be achieved by constructing an upper confidence limit (UCL) for a high percentile of contamination in the population of samples that includes environmental samples and blank samples (source-solution, field, and laboratory blanks) (Mueller and Titus, 2005). This UCL is the maximum contamination expected in the specified percentage of samples. For example, the 90-percent UCL for the 90th-percentile concentration in blank samples is the maximum contamination expected, with 90-percent confidence, in 90 percent of all samples. The 90-percent confidence level indicates that there is only a 10-percent chance that contamination for this high percentile has been underestimated. Another explanation is that there is 90-percent confidence that this amount of contamination would be exceeded in no more than 10 percent of all samples (including environmental samples) that were collected, processed, shipped, and analyzed in the same manner as the blank samples.

Because the distribution of concentrations in blank samples can be highly skewed, statistical techniques that rely on assumptions of normality are not applicable. Hahn and Meeker (1991) describe a method for determining a distribution-free UCL for a percentile, which is appropriate for skewed data. This method uses order statistics, based on ranking the data values from small to large, and binomial probability to determine the UCL. The binomial probability density function (*B*) is used to calculate the probability that no more than *n* minus *u* values from a total of *n* observations exceed the (100*p*)th percentile of the sampled population, where *p* is the probability (p-value) of interest.

$$B_{n,p}(u) = \left(\frac{n}{u}\right) p^{u}(1-p)^{n-u}, \qquad (1)$$

where $\left(\frac{n}{u}\right) = \frac{n!}{u!(n-u)!}$. This density function gives the probability that exactly *u* successes occur in *n* Bernoulli trials (TIBCO Software, Inc., 2008). The rank (*u*) is selected as the smallest integer such that:

$$B(u-1, n, p) \geq 1-\alpha \quad , \qquad (2)$$

where α is the significance level. The $100(1–\alpha)$ percent UCL for the (100*p*)th percentile of contamination in the population then is determined by the measured value of the *u* ranked observation. For example, in a group of 100 blank samples, the 90-percent UCL for the 90th percentile can be determined as follows. First, find the smallest value of *u* that meets the criterion:

$$B(u-1, 100, 0.90) \geq 0.90 \quad , \qquad (3)$$

For $u = 94$, $B = 0.883$, which is less than the criterion of 0.90, but for $u = 95$, $B = 0.942$, which meets or exceeds the criterion of 0.90 (TIBCO Software, Inc., 2008). Thus, the 90-percent UCL for the 90th percentile is the concentration of the 95th ranked blank sample.

Potential contamination bias in the environmental samples is estimated from the UCL calculated by using blank sample data. In the example, if the concentration of compound Y in the 95th ranked blank was 0.1 µg/L, contamination bias can be described as follows: “Contamination by compound Y is estimated, with at least 90-percent confidence, to exceed 0.1 µg/L in no more than 10 percent of all samples.” This amount of contamination then can be compared to environmentally important concentrations of compound Y to determine the likelihood that contamination has affected interpretation of the environmental data. Examples of important concentrations include concentrations expected in various land uses, drinking-water standards or health advisories, and aquatic-life criteria. Continuing with the example, suppose compound Y has a drinking-water standard of 10 µg/L. Contamination as great as 0.1 µg/L in 90 percent of all samples is unlikely to affect a measurement that exceeds this drinking-water standard. The true environmental concentration would have to be more than 9.9 µg/L (but less than 10 µg/L) for this amount of contamination to produce a false exceedance. However, if the drinking-water standard for compound Y was 0.2 µg/L, contamination in as many as 10 percent of all samples might account for one-half or more of a measured exceedance. In this example, false exceedances likely would be enough that utility of the data would be compromised (Mueller and Titus, 2005). Figure 2 shows a conceptual example of the distribution of concentrations in environmental samples and at the 90-percent UCL for percentiles in field blanks. Nondetections are not shown on the figure, therefore, the 90-percent UCL line begins at the 86th percentile. The 90th-percentile concentration of the 90-percent UCL is about 0.015 µg/L, therefore, there is 90-percent confidence that this amount of contamination would be exceeded in no more than 10 percent of all samples.

Classification of Potential Contamination in Environmental Samples

One assumption for the UCL method is that the blanks and environmental samples are part of the same population with regards to the potential sources of bias from contamination. A second assumption is that both sample populations have the potential to experience the same degree/magnitude of contamination.

A conceptual relation between the 90-percent UCL for percentiles of concentration in field blanks and the distribution of concentrations in environmental samples was used to place a compound into a contamination category, as described in table 3 and illustrated in figure 3. Contamination category 1 includes compounds that were not detected in any field blanks. For compounds in contamination category 2, the 90-percent UCL concentration distribution of potential contamination, based on the field blanks, is at least an order of magnitude lower than concentrations in the environmental samples (for example, the contamination is negligible in comparison to environmentally relevant concentrations). For compounds in contamination category 3, the distributions of potential contamination in the field blanks and concentrations in environmental samples are similar (within an order of magnitude). For compounds in contamination category 4, the distribution of 90-percent UCL concentrations in field blanks markedly exceeds by an order of magnitude or more the distribution of concentrations in environmental samples; therefore, field blanks are considered to be nonrepresentative of the potential sources of contamination for these compounds.

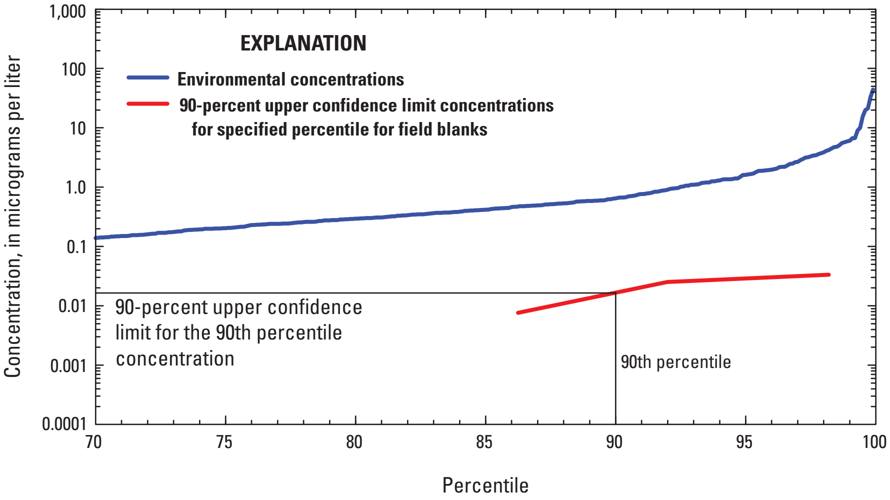


Figure 2. Conceptual examples of the distribution of concentrations in environmental samples and at the 90-percent upper confidence limit for percentiles of concentrations in field blanks for a specific site type. Nondetections are not shown.

Table 3. Description of contamination categories and the potential of contamination bias in environmental samples based on the relation between the 90-percent upper confidence limit for percentiles of concentrations in field blanks and the distribution of concentrations measured in environmental samples.

[VOC, volatile organic compound]

Contamination category	Relation between field blanks and environmental samples	Interpretation of the potential for contamination in environmental samples	Number of VOCs in contamination category: Domestic and public-supply wells	Number of VOCs in contamination category: Monitoring wells	Number of VOCs in contamination category: Surface-water sites
1	No detections in any of the field blanks.	Quantified results for environmental samples are essentially free of contamination bias.	54	43	54
2	Detections in field blanks, but the distribution is lower (at least an order of magnitude) and negligible in comparison to concentrations in environmental samples.	Quantified results for environmental samples with larger concentrations are not markedly affected, but low concentrations might be affected by contamination.	10	8	16
3	Detections in both field blanks and environmental samples and the distributions of concentrations are similar (within an order of magnitude).	Quantified results for environmental samples are likely affected by contamination bias.	7	7	10
4	Detections in field blanks have a distribution of concentrations markedly higher (at least an order of magnitude) than the concentration distribution of environmental samples.	The potential for contamination bias in environmental samples cannot be determined by this method. Field blanks are considered nonrepresentative of the potential sources of contamination to the environmental samples.	16	29	7

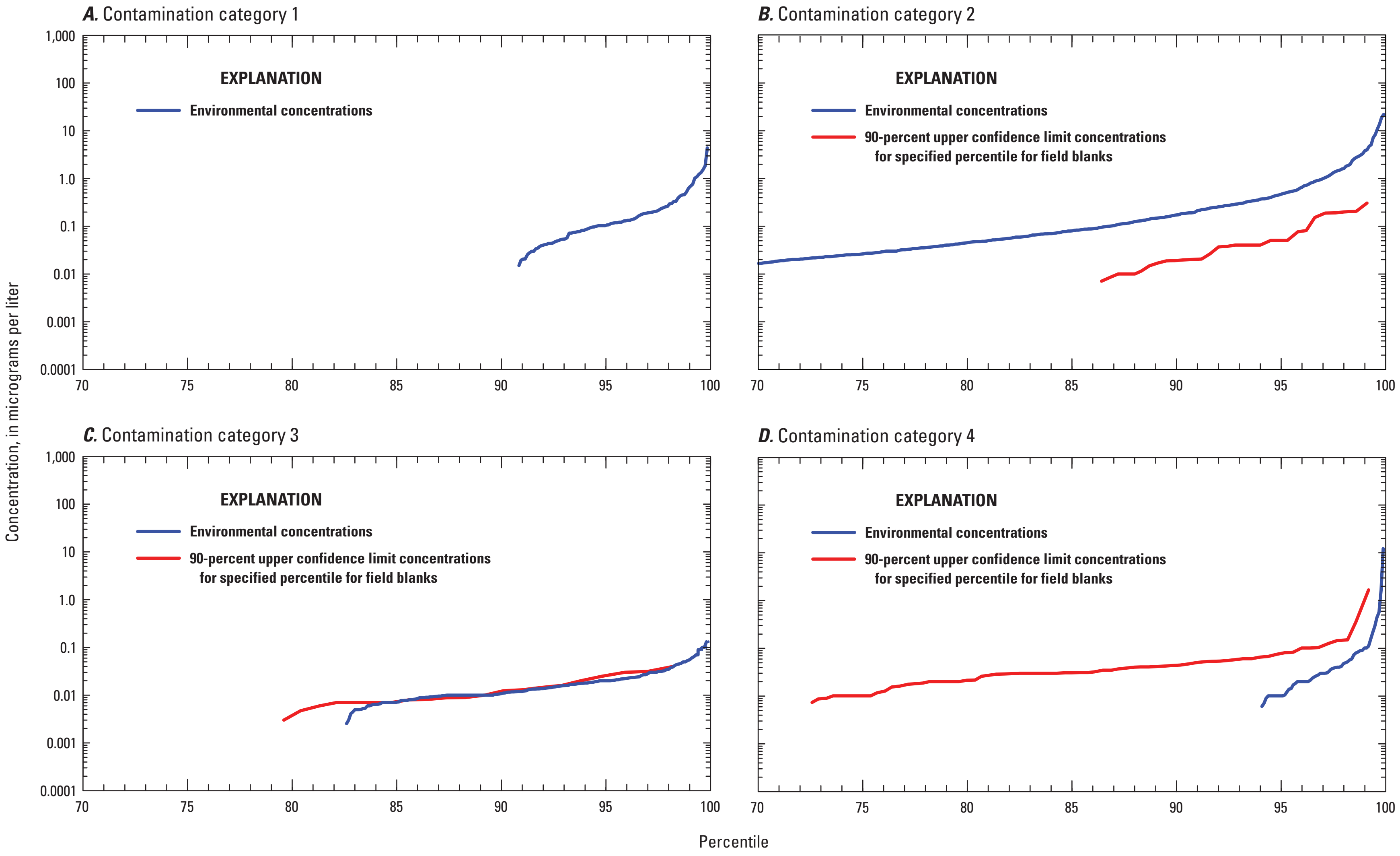


Figure 3. Conceptual relations between the 90-percent upper confidence limit for percentiles of concentrations in field blanks, and the distribution of concentrations measured in environmental samples, for a specific site type, that were used to place a compound into one of the following “contamination categories”: *A*, contamination category 1, no detection in any of the field blanks; *B*, contamination category 2, detections in field blanks but negligible in comparison to the environmental concentrations; *C*, contamination category 3, detections in the field blanks with similar environmental concentrations; and *D*, contamination category 4, concentrations in the field blanks markedly larger than those in the environmental samples. Nondetections are not shown.

Effectiveness of Native Water Rinsing

The origin of VOC contamination evident in some field-blank samples collected in the NAWQA Program from October 1996 to December 2008 is not known explicitly but may be inferred from findings from a field contamination study (Thiros and others, 2011) and anecdotal information about cleaning and sampling procedures. When fresh supplies (ordered and received within a few days of sampling) were used and the protocols in the USGS NFM (U.S. Geological Survey, variously dated) were closely followed during the field contamination study, VOCs rarely were detected in field blanks. Furthermore, the frequency of detection of VOCs in field blanks in this special field contamination study was markedly less than the frequency of detection in NAWQA's field blanks collected during the 13-year period from October 1996 to December 2008. Importantly, the (1) the NWQL analysis of samples and (2) NFM protocols for supplies, cleaning protocols, sampling procedures, and shipping procedures have been essentially constant from 1996 to the present (2011) and, as such, the difference observed for field blanks between the field contamination study (Thiros and others, 2011) and the NAWQA dataset must be attributed to some deviation from either analyses at the NWQL or the protocols specified in the NFM. The quality of VOC analyses at the NWQL has not deviated; however, anecdotal information indicates that less methanol and less VPBW than specified in the NFM protocols have been used by some field staff. Either of these practices could cause more frequent detection of VOCs in field blanks, but especially if lesser amounts of VPBW were used in equipment cleaning (Wilde, 2004) and in the collection of a field blank. In summary, the greater detection frequency of VOCs in NAWQA's field blanks most likely is a result of inconsistent adherence to the specified field protocols described in the NFM.

The inference about the causes of contamination observed in field blanks is especially important because this helps describe the nature of contamination to environmental samples. Potential carryover can be evaluated by comparing any pair of samples, but only if the true concentration of the subsequent sample is known. This procedure is the purpose of field blanks. If a field blank is contaminated (either by carryover or other sources), but the subsequent environmental sample is not, this result indicates that the decontamination before collection of the field blank might have been insufficient or that the source-solution water was contaminated, and that the native-water rinse after collection of the field blank removed any remaining contamination before collection of the environmental sample. This possible carryover from the field blanks provides the basis to use NAWQA's paired field blank and environmental samples to assess the effectiveness of native water rinsing (after a field blank is collected) in decreasing the potential for carryover contamination to the environmental sample.

One measure of the effectiveness of native water rinsing for a specific VOC is to determine how frequently a detection in a field blank is followed by a nondetection in the subsequently collected environmental sample. This measure only accounts for the detections or nondetections in samples and does not account for concentrations in the samples. This result is termed the "minimum percent effectiveness of native water rinsing" in this report. This effectiveness is calculated as follows:

$$Minimum\ Percent\ Effectiveness = \frac{Number\ of\ FB_D - ES_{ND}\ pairs}{Number\ of\ FB_D} * 100, \quad (4)$$

where $FB_D – ES_{ND}$ denotes a detection in the field blank (FB_D) but a nondetection in the paired environmental sample (ES_{ND}), and FB_D denotes all the pairs of field blanks and environmental samples with a detection in the field blank.

The calculated minimum percent effectiveness describes how frequently a VOC detected in a field blank was not detected in the corresponding environmental sample, independent of concentrations. The calculated value is considered a minimum because native water rinsing also might have been 100 percent effective in decreasing carryover contamination from the field blank for some or all the paired samples with a detection in the field blank and environmental sample. That is, the detection in the environmental sample of these paired samples may have been a true environmental detection not affected by carryover. Observations from 1-to-1 concentration plots of field blank and environmental sample pairs (appendix 2) help support the minimum percent effectiveness of native water rinsing.

Quality of Volatile Organic Compound Data from Groundwater and Surface Water

The sampling of groundwater and surface water, including the QC samples (source-solution and field blanks) was presumed to follow the standard protocols described in the USGS NFM (U.S. Geological Survey, variously dated) for the purposes of this report. The QC samples collected to evaluate the quality of the NAWQA VOC data included field blanks prepared by using groundwater and surface-water sampling equipment.

The quality of field blank data was determined separately for domestic and public-supply wells, monitoring wells, and surface-water sites because of the different equipment used to collect environmental samples for these three NAWQA site types. Sources of VOC contamination in field blanks were compared to concentrations in source-solution blanks prepared by using the same water(s) as the field blanks. Field blanks were exposed to the same sampling equipment and conditions as environmental samples, and the source-solution blanks were exposed only to shipping and laboratory analysis. If the source-solution blank was contaminated, the field blank(s) may over represent the calculated potential sources of contamination to the environmental sample.

The detection frequencies in field blanks from the three NAWQA site types (domestic and public-supply wells, monitoring wells, and surface water) are shown in table 4. Thirty-nine of the 87 VOCs analyzed were not detected in field blanks from any of the three NAWQA site types summarized for this report. Forty-eight of the 87 VOCs analyzed were detected in at least one field blank from one or more of the three NAWQA site types. Nineteen of these 48 VOCs were detected in 5 percent or more of field blanks in at least one of the three site types.

The distributions of the detection frequencies are statistically different between the three site types using a two-sample Kolmogorov-Smirnov goodness-of fit statistical test (ks) (TIBCO Software, Inc., 2008). The ks tests whether the two data samples come from the same distribution without specifying what the distribution is. The null hypothesis tests that the two data samples are from the same distribution. At an alpha (α) value of 0.05 (p-value of less than 0.05 indicates the same distribution), the detection frequencies for monitoring wells compared to domestic and public-supply wells (ks = 0.1379, p-value = 0.3812); monitoring wells compared to surface-water sites (ks = 0.1264, p-value = 0.4924), and domestic and public-supply wells compared to surface-water sites (ks = 0.1494, p-value = 0.287) are not from the same distribution. Statistically, the ks provides additional information that characterization of contamination by the three NAWQA site types (domestic and public-supply, monitoring wells, and surface water) is warranted.

The VOCs analyzed can be classified on the basis of the 90-percent UCL plots for the three NAWQA site types as VOCs not detected in field blanks (contamination category 1) and VOCs detected in field blanks. VOCs detected in field blanks can be further classified into three categories. Contamination category 2 includes VOCs for which the concentration distribution in the field blanks has little to no effect on the concentration distribution of the environmental samples (that is, the concentration distribution of environmental samples was much larger than the 90-percent UCL distribution of the field blanks). Contamination category 3 includes VOCs for which the concentration distributions in the field blanks and environmental samples were similar (within an order of magnitude). Contamination category 4 includes VOCs for which the concentration distribution (and in many cases the frequency of detection) in the field blanks was much larger than the distribution in the environmental samples. VOCs in contamination categories 2 and 3 have field blanks that are assumed to be representative of the sources of contamination to the environmental samples. VOCs in contamination category 4 have field blanks that are not assumed to be representative because of the larger concentration distribution (and in many cases a larger frequency of detection) in field blanks in comparison to environmental samples. A way to estimate the potential contamination bias associated with these VOCs has not been endorsed by the USGS Office of Water Quality to date (October 2011); however, Thiros and others (2011) provide insights on ways to minimize the potential for contamination bias for many of these VOCs.

Characterization of Volatile Organic Compound Contamination in Field Blanks

Field blanks collected for groundwater and surface-water sites were evaluated to characterize VOC contamination. The field blanks were characterized by site type (domestic and public-supply wells, monitoring wells, and surface-water sites) and also by the four contamination categories described in table 3.

Domestic and Public-Supply Wells

Fifty-four of the 87 VOCs analyzed were not detected in field blanks from domestic and public-supply wells (contamination category 1; table 5). The concentration data for environmental samples for these 54 VOCs are considered to be free of contamination bias, and various interpretations, such as VOC detection frequency at multiple assessment levels and comparisons of concentrations to benchmarks, for environmental samples from domestic and public-supply wells are not limited for these VOCs in contamination category 1.

Thirty-three of the 87 VOCs were detected in at least one field blank from domestic and public-supply wells. For 10 of these 33 VOCs detected in field blanks, the 90-percent UCL plots (appendix 1) show the concentration distribution for field blanks to be at least an order of magnitude smaller in comparison to the environmental concentration distribution (contamination category 2; table 5). Chloroform is used an example VOC in figure 4*B* to show the comparison between the concentration distributions for blanks and environmental samples for contamination category 2. Only 1 of these 10 VOCs, chloroform, has a quantified concentration for the 90-percent UCL of the 90th percentile (0.02 μg/L, table 5). The 10 VOCs in contamination category 2 may have some contamination bias in analytical results for samples from domestic and public-supply wells, but based on the distribution of concentrations in the field blanks, this contamination is not likely to have a large effect on the concentrations reported for environmental samples.

The 90-percent UCL plots for 7 of the 33 VOCs detected in field blanks in domestic and public-supply wells (appendix 1) show the concentration distribution of field blanks to be similar to the environmental concentration distribution (contamination category 3; table 5). Perchloroethene is used as an example VOC in figure 4*C* to show the comparison between the concentration distributions for blanks and environmental samples for contamination category 3. One of these 7 VOCs, carbon disulfide, has a quantified concentration for the 90-percent UCL for the 90th percentile (0.01 μg/L, table 5). The 7 VOCs in contamination category 3 may have some contamination bias associated with the environmental data based on the 90-percent UCL plots.

Table 4. Detection frequency of volatile organic compounds in field-blank samples from domestic and public-supply wells, monitoring wells, and surface-water sites sampled from October 1996 to December 2008.

[**Boldface** values indicate that the compound was not detected in environmental samples for the site type. USGS, U.S. Geological Survey; Detects, number of detections based on compound passing all qualification and quantitation criteria at the National Water Quality Laboratory; N, number of field blanks]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Domestic and public-supply wells			Monitoring wells			Surface water		
			Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)
Toluene	108–88–3	34010	92	272	33.8	123	296	41.6	60	129	46.5
Chloroform	67–66–3	32106	31	278	11.2	82	296	27.7	27	129	20.9
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	27	277	9.7	72	297	24.2	23	129	17.8
Ethylbenzene	100–41–4	34371	23	277	8.30	48	297	16.2	21	129	16.3
Acetone	67–64–1	81552	22	278	7.91	44	297	14.8	19	129	14.7
1,2,4-Trimethylbenzene	95–63–6	77222	48	278	17.3	42	297	14.1	5	129	3.9
Carbon disulfide	75–15–0	77041	20	278	7.2	33	297	11.1	8	129	6.2
1,4-Dichlorobenzene	106–46–7	34571	5	278	1.8	33	297	11.1	10	129	7.8
Benzene	71–43–2	34030	19	278	6.8	32	297	10.8	7	129	5.4
Tetrahydrofuran	109–99–9	81607	7	278	2.5	31	297	10.4	8	128	6.3
Styrene	100–42–5	77128	28	278	10.1	29	297	9.8	17	129	13.2
Dichloromethane	75–09–2	34423	24	278	8.6	29	297	9.8	10	129	7.8
Chlorobenzene	108–90–7	34301	12	278	4.32	29	297	9.8	7	129	5.4
o-Xylene	95–47–6	77135	16	277	5.78	28	296	9.5	14	129	10.9
Methyl ethyl ketone	78–93–3	81595	5	277	1.81	27	297	9.1	9	129	7.0
1,2-Dichloropropane	78–87–5	34541	3	278	1.1	23	297	7.7	7	129	5.4
Tetrachloroethene	127–18–4	34475	12	278	4.3	20	297	6.7	4	129	3.1
Bromodichloromethane	75–27–4	32101	2	278	.7	20	297	6.7	5	129	3.9
Chloromethane	74–87–3	34418	6	278	2.2	17	297	5.7	7	129	5.4
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	2	278	.7	9	297	3.0	1	129	.78
2-Ethyltoluene	611–14–3	77220	1	278	.36	8	296	2.7	0	128	0
Methyl *tert*-butyl ether	1634–04–4	78032	1	278	.4	8	297	2.7	3	129	2.3
Trichloroethene	79–01–6	39180	3	278	1.1	6	297	2.0	2	129	1.6
1,1,1-Trichloroethane	71–55–6	34506	2	278	.7	5	297	1.7	4	129	3.1
Trichlorofluoromethane	75–69–4	34488	2	278	.7	5	297	1.7	2	129	1.6
Naphthalene	91–20–3	34696	1	278	.36	5	297	1.7	1	129	.78

Table 4. Detection frequency of volatile organic compounds in field-blank samples from domestic and public-supply wells, monitoring wells, and surface-water sites sampled from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound was not detected in environmental samples for the site type. USGS, U.S. Geological Survey; Detects, number of detections based on compound passing all qualification and quantitation criteria at the National Water Quality Laboratory; N, number of field blanks]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Domestic and public-supply wells			Monitoring wells			Surface water		
			Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)
n-Propylbenzene	103–65–1	77224	0	278	0	5	297	1.7	1	129	0.78
1,2-Dichlorobenzene	95–50–1	34536	1	278	.36	4	297	1.3	0	129	0
1,3,5-Trimethylbenzene	108–67–8	77226	0	278	0	4	297	1.3	0	129	0
Dibromochloromethane	124–48–1	32105	1	278	.4	3	297	1.0	0	129	0
Vinyl chloride	75–01–4	39175	0	278	0	3	297	1.0	2	129	1.6
Isopropylbenzene	98–82–8	77223	0	277	0	3	297	1.0	1	129	.78
1,2-Dichloroethane	107–06–2	32103	2	278	.72	2	297	.67	0	129	0
1,2,3-Trimethylbenzene	526–73–8	77221	1	278	.36	2	297	.67	0	128	0
1,2,3,4-Tetramethylbenzene	488–23–3	49999	0	278	0	2	297	.67	0	128	0
4-Isoproyplytoluene	99–87–6	77356	1	278	.36	1	296	.34	2	129	1.6
Methyl isobutyl ketone	108–10–1	78133	3	277	1.08	1	297	.34	0	129	0
Bromomethane	74–83–9	34413	**0**	**278**	**0**	1	297	.34	**0**	**129**	**0**
n-Butylbenzene	104–51–8	77342	0	278	0	1	297	.34	0	129	0
sec-Butylbenzene	135–98–8	77350	0	278	0	1	297	.34	0	129	0
2-Chlorotoluene	95–49–8	77275	0	278	0	1	297	.34	0	129	0
Dibromomethane	74–95–3	30217	0	278	0	1	296	.34	0	128	0
Iodomethane	74–88–4	77424	0	278	0	1	297	.34	0	128	0
1,2,3,5-Tetramethylbenzene	527–53–7	50000	0	278	0	1	297	.34	0	128	0
Dichlorodifluoromethane	75–71–8	34668	2	278	.7	0	297	0	1	129	.78
1,1-Dichloroethene	75–35–4	34501	0	278	0	0	297	0	1	129	.78
Diethyl ether	60–29–7	81576	0	278	0	0	297	0	1	128	.78
Ethyl *tert*-butyl ether	637–92–3	50004	0	278	0	0	297	0	1	128	.78
Acrolein	107–02–8	34210	**0**	**31**	**0**	**0**	**48**	**0**	0	29	0
Acrylonitrile	107–13–1	34215	0	278	0	**0**	**297**	**0**	**0**	**129**	**0**
tert-Amyl methyl ether	994–05–8	50005	0	278	0	0	297	0	0	128	0
Bromobenzene	108–86–1	81555	0	278	0	0	297	0	0	129	0
Bromochloromethane	74–97–5	77297	0	278	0	0	297	0	0	129	0

Table 4. Detection frequency of volatile organic compounds in field-blank samples from domestic and public-supply wells, monitoring wells, and surface-water sites sampled from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound was not detected in environmental samples for the site type. USGS, U.S. Geological Survey; Detects, number of detections based on compound passing all qualification and quantitation criteria at the National Water Quality Laboratory; N, number of field blanks]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Domestic and public-supply wells			Monitoring wells			Surface water		
			Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)
tert-Butylbenzene	98–06–6	77353	0	278	0	0	297	0	**0**	**129**	**0**
Chloroethane	75–00–3	34311	0	278	0	0	297	0	0	129	0
3-Chloro-1-propene	107–05–1	78109	0	278	0	**0**	**297**	**0**	**0**	**128**	**0**
4-Chlorotoluene	106–43–4	77277	0	278	0	**0**	**297**	**0**	**0**	**129**	**0**
Dibromochloropropane	96–12–8	82625	0	278	0	0	297	0	**0**	**129**	**0**
1,2-Dibromoethane	106–93–4	77651	0	278	0	0	297	0	**0**	**129**	**0**
1,3-Dichlorobenzene	541–73–1	34566	0	278	0	0	297	0	0	129	0
trans-1,4-Dichloro-2-butene	110–57–6	73547	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**128**	**0**
1,1-Dichloroethane	75–34–3	34496	0	278	0	0	297	0	0	129	0
cis-1,2-Dichloroethene	156–59–2	77093	0	278	0	0	297	0	0	129	0
trans-1,2-Dichloroethene	156–60–5	34546	0	278	0	0	297	0	0	129	0
1,3-Dichloropropane	142–28–9	77173	0	278	0	0	297	0	**0**	**129**	**0**
2,2-Dichloropropane	594–20–7	77170	0	278	0	**0**	**297**	**0**	**0**	**129**	**0**
1,1-Dichloropropene	563–58–6	77168	0	278	0	0	297	0	**0**	**129**	**0**
cis-1,3-Dichloropropene	10061–01–5	34704	0	278	0	0	297	0	**0**	**129**	**0**
trans-1,3-Dichloropropene	10061–02–6	34699	**0**	**278**	**0**	0	297	0	**0**	**129**	**0**
Diisopropyl ether	108–20–3	81577	0	275	0	0	282	0	0	119	0
Ethyl methacrylate	97–63–2	73570	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**128**	**0**
Hexachlorobutadiene	87–68–3	39702	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**129**	**0**
Hexachloroethane	67–72–1	34396	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**129**	**0**
Methyl acrylate	96–33–3	49991	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**128**	**0**
Methyl acrylonitrile	126–98–7	81593	0	278	0	**0**	**297**	**0**	**0**	**128**	**0**
Methyl butyl ketone	591–78–6	77103	0	278	0	**0**	**297**	**0**	0	129	0
Methyl methacrylate	80–62–6	81597	0	278	0	**0**	**297**	**0**	**0**	**128**	**0**
1,1,1,2-Tetrachloroethane	630–20–6	77562	0	278	0	0	297	0	**0**	**129**	**0**
1,1,2,2-Tetrachloroethane	79–34–5	34516	**0**	**278**	**0**	**0**	**297**	**0**	0	129	0

Table 4. Detection frequency of volatile organic compounds in field-blank samples from domestic and public-supply wells, monitoring wells, and surface-water sites sampled from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound was not detected in environmental samples for the site type. USGS, U.S. Geological Survey; Detects, number of detections based on compound passing all qualification and quantitation criteria at the National Water Quality Laboratory; N, number of field blanks]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Domestic and public-supply wells			Monitoring wells			Surface water		
			Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)	Detects	N	Detection frequency (percent)
Tetrachloromethane	56–23–5	32102	0	278	0	0	297	0	0	129	0
Tribromomethane	75–25–2	32104	0	278	0	0	297	0	0	129	0
1,2,3-Trichlorobenzene	87–61–6	77613	0	278	0	0	297	0	0	129	0
1,2,4-Trichlorobenzene	120–82–1	34551	0	278	0	**0**	**297**	**0**	0	129	0
1,1,2-Trichloroethane	79–00–5	34511	0	278	0	0	297	0	**0**	**129**	**0**
1,2,3-Trichloropropane	96–18–4	77443	0	278	0	0	297	0	0	129	0
Vinyl acetate	108–05–4	77057	**0**	**6**	**0**	**0**	**29**	**0**	**0**	**21**	**0**
Vinyl bromide	593–60–2	50002	**0**	**278**	**0**	**0**	**297**	**0**	**0**	**128**	**0**

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

Table 5. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from domestic and public-supply wells, October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile.USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
		Contamination category 1			
Acrolein	107–02–8	34210	ND	No	--
Acrylonitrile	107–13–1	34215	ND	Yes	--
tert-Amyl methyl ether	994–05–8	50005	ND	Yes	--
Bromobenzene	108–86–1	81555	ND	Yes	--
Bromochloromethane	74–97–5	77297	ND	Yes	--
Bromoform	75–25–2	32104	ND	Yes	--
Bromomethane	74–83–9	34413	ND	No	A1–4
n-Butylbenzene	104–51–8	77342	ND	Yes	A1–5
sec-Butylbenzene	135–98–8	77350	ND	Yes	A1–6
tert-Butylbenzene	98–06–6	77353	ND	Yes	--
Chloroethane	75–00–3	34311	ND	Yes	--
3-Chloro-1-propene	107–05–1	78109	ND	Yes	--
2-Chlorotoluene	95–49–8	77275	ND	Yes	A1–11
4-Chlorotoluene	106–43–4	77277	ND	Yes	--
Dibromochloropropane	96–12–8	82625	ND	Yes	--
1,2-Dibromoethane	106–93–4	77651	ND	Yes	--
Dibromomethane	74–95–3	30217	ND	Yes	A1–13
1,3-Dichlorobenzene	541–73–1	34566	ND	Yes	--
trans-1,4-Dichloro-2-butene	110–57–6	73547	ND	No	--
1,1-Dichloroethane	75–34–3	34496	ND	Yes	--
1,1-Dichloroethene	75–35–4	34501	ND	Yes	A1–18
cis-1,2-Dichloroethene	156–59–2	77093	ND	Yes	--
trans-1,2-Dichloroethene	156–60–5	34546	ND	Yes	--
1,3-Dichloropropane	142–28–9	77173	ND	Yes	--
2,2-Dichloropropane	594–20–7	77170	ND	Yes	--
1,1-Dichloropropene	563–58–6	77168	ND	Yes	--
cis-1,3-Dichloropropene	10061–01–5	34704	ND	Yes	--
trans-1,3-Dichloropropene	10061–02–6	34699	ND	No	--
Diethyl ether	60–29–7	81576	ND	Yes	A1–21
Diisopropyl ether	108–20–3	81577	ND	Yes	--
Ethyl *tert*-butyl ether	637–92–3	50004	ND	Yes	A1–23
Ethyl methacrylate	97–63–2	73570	ND	No	--
Hexachlorobutadiene	87–68–3	39702	ND	No	--
Hexachloroethane	67–72–1	34396	ND	No	--
Iodomethane	74–88–4	77424	ND	Yes	A1–25
Isopropylbenzene	98–82–8	77223	ND	Yes	A1–26

Table 5. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from domestic and public-supply wells, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile.USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 1—Continued					
Methyl acrylate	96–33–3	49991	ND	No	--
Methyl acrylonitrile	126–98–7	81593	ND	Yes	--
Methyl butyl ketone	591–78–6	77103	ND	Yes	--
Methyl methacrylate	80–62–6	81597	ND	Yes	--
n-Propylbenzene	103–65–1	77224	ND	Yes	A1–33
1,1,1,2-Tetrachloroethane	630–20–6	77562	ND	Yes	--
1,1,2,2-Tetrachloroethane	79–34–5	34516	ND	No	--
Tetrachloromethane	56–23–5	32102	ND	Yes	--
1,2,3,4-Tetramethylbenzene	488–23–3	49999	ND	Yes	A1–36
1,2,3,5-Tetramethylbenzene	527–53–7	50000	ND	Yes	A1–37
1,2,3-Trichlorobenzene	87–61–6	77613	ND	Yes	--
1,2,4-Trichlorobenzene	120–82–1	34551	ND	Yes	--
1,1,2-Trichloroethane	79–00–5	34511	ND	Yes	--
1,2,3-Trichloropropane	96–18–4	77443	ND	Yes	--
1,3,5-Trimethylbenzene	108–67–8	77226	ND	Yes	A1–45
Vinyl acetate	108–05–4	77057	ND	No	--
Vinyl bromide	593–60–2	50002	ND	No	--
Vinyl chloride	75–01–4	39175	ND	Yes	A1–46
Contamination category 2					
Bromodichloromethane	75–27–4	32101	<0.01	Yes	A1–3
Chloroform	67–66–3	32106	**.02**	Yes	A1–9
Dibromochloromethane	124–48–1	32105	<.01	Yes	A1–12
1,2-Dichlorobenzene	95–50–1	34536	<.012	Yes	A1–14
4-Isoproyplytoluene	99–87–6	77356	<.0055	Yes	A1–27
Methyl *tert*-butyl ether	1634–04–4	78032	<.024	Yes	A1–28
Naphthalene	91–20–3	34696	<.13	Yes	A1–31
1,1,1-Trichloroethane	71–55–6	34506	<.01	Yes	A1–39
Trichloroethene	79–01–6	39180	<.006	Yes	A1–40
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	<.028	Yes	A1–42
Contamination category 3					
Carbon disulfide	75–15–0	77041	**0.01**	Yes	A1–7
Chloromethane	74–87–3	34418	<.01	Yes	A1–10
1,4-Dichlorobenzene	106–46–7	34571	<.007	Yes	A1–15
Dichlorodifluoromethane	75–71–8	34668	<.012	Yes	A1–16
1,2-Dichloropropane	78–87–5	34541	<.01	Yes	A1–20
Perchloroethene	127–18–4	34475	<.006	Yes	A1–32
Trichlorofluoromethane	75–69–4	34488	<.032	Yes	A1–41

Table 5. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from domestic and public-supply wells, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile.USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 4					
Acetone	67–64–1	81552	**1**	Yes	A1–1
Benzene	71–43–2	34030	<.006	Yes	A1–2
Chlorobenzene	108–90–7	34301	<.005	Yes	A1–8
1,2-Dichloroethane	107–06–2	32103	<.26	Yes	A1–17
Dichloromethane	75–09–2	34423	**.02**	Yes	A1–19
Ethylbenzene	100–41–4	34371	**.008**	Yes	A1–22
2-Ethyltoluene	611–14–3	77220	<.016	Yes	A1–24
Methyl ethyl ketone	78–93–3	81595	<.3	Yes	A1–29
Methyl isobutyl ketone	108–10–1	78133	<.18	Yes	A1–30
Styrene	100–42–5	77128	**.01**	Yes	A1–34
Tetrahydrofuran	109–99–9	81607	<.3	Yes	A1–35
Toluene	108–88–3	34010	**.05**	Yes	A1–38
1,2,3-Trimethylbenzene	526–73–8	77221	<.02	Yes	A1–43
1,2,4-Trimethylbenzene	95–63–6	77222	**.03**	Yes	A1–44
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	**.02**	Yes	A1–47
o-Xylene	95–47–6	77135	<.006	Yes	A1–48

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

The 90-percent UCL plots for 16 of the 33 VOCs detected in field blanks in domestic and public-supply wells (appendix 1) show the concentration distribution for field blanks to be markedly greater than the environmental concentration distribution (contamination category 4; table 5). Toluene is used as an example VOC in figure 4*D* to show the comparison between the concentration distributions for blanks and environmental samples for contamination category 4. Seven of these 16 VOCs have a quantified concentration for the 90-percent UCL for the 90th percentile: acetone (1 µg/L); dichloromethane (0.02 µg/L); ethylbenzene (0.008 µg/L); styrene (0.01 µg/L); toluene (0.05 µg/L); 1,2,4-trimethylbenzene (0.03 µg/L); and *m*- and *p*-xylene (0.02 µg/L) (table 5). The field blanks for the 16 VOCs in contamination category 4 appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions (and in many cases higher frequency of detection) in field blanks than in environmental samples.

Monitoring Wells

Forty-three of the 87 VOCs analyzed were not detected in field blanks from monitoring wells (contamination category 1; table 6). The concentration data for environmental samples for these 43 VOCs are considered to be free of contamination bias, and various interpretations for environmental samples from monitoring wells are not limited for these VOCs in contamination category 1.

Forty-four of the 87 VOCs were detected in at least one field blank from monitoring wells. The 90-percent UCL plots for 8 of the 44 VOCs detected in field blanks (appendix 1) show the concentration distribution for field blanks to be at least an order of magnitude smaller in comparison to the environmental concentration distribution (contamination category 2; table 6). Chloroform is used as an example VOC in figure 5*B* to show the comparison between the concentration distributions for blanks and environmental samples for contamination category 2. Two of these 8 VOCs have a quantified concentration for the 90-percent UCL for the 90th percentile:

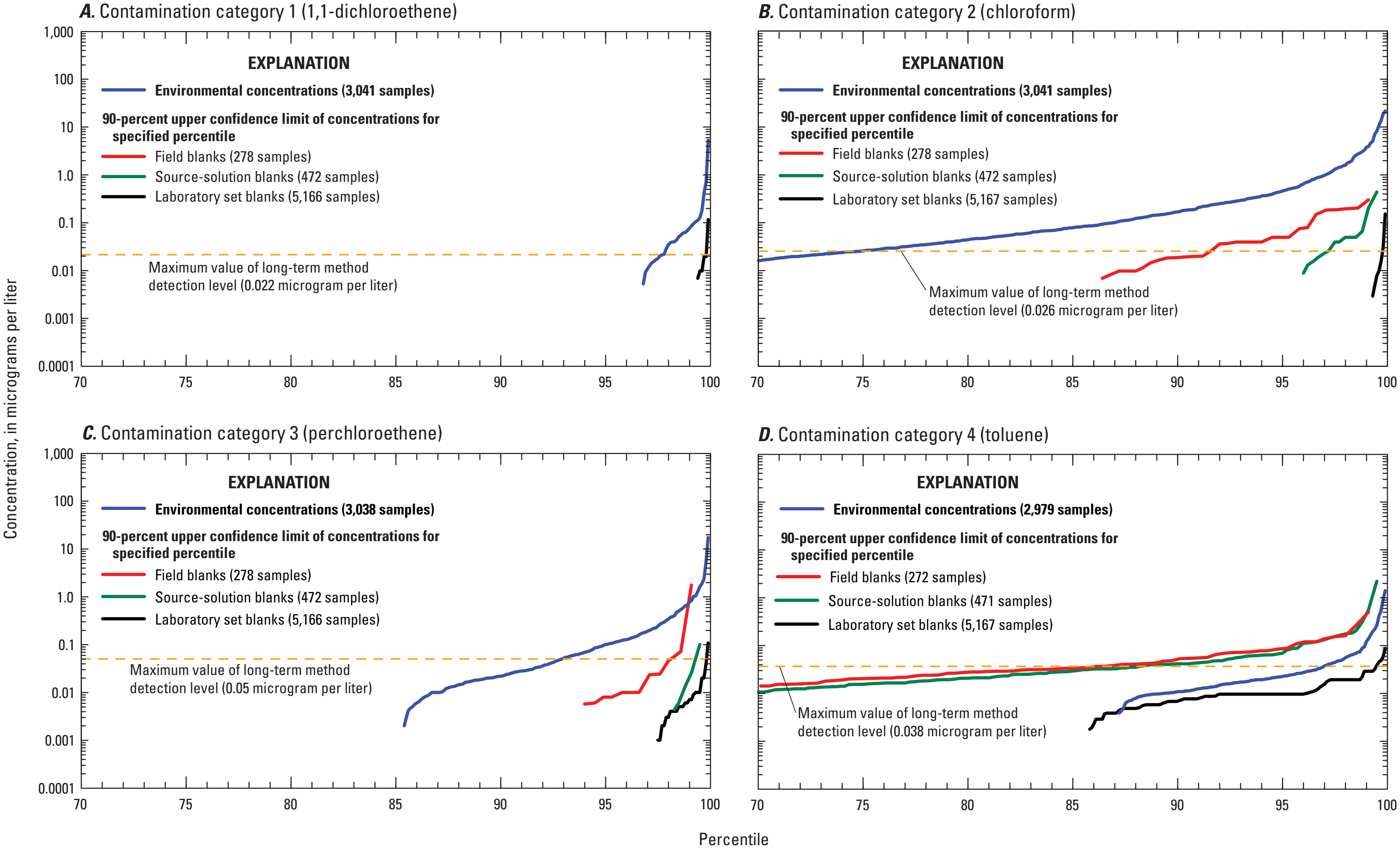


Figure 4. Distribution of environmental concentrations and 90-percent upper confidence limits of concentrations in field blanks, source-solution blanks, and laboratory set blanks for example compounds in each contamination category for domestic and public-supply wells. *A*, contamination category 1 (1,1-dichlorethene); *B*, contamination category 2 (chloroform); *C*, contamination category 3 (perchloroethene); and *D*, contamination category 4 (toluene). Nondetections are not shown.

chloroform (0.07 µg/L) and 1,2-dichloropropane (0.01 µg/L) (table 6). The eight VOCs in contamination category 2 may have some contamination bias in analytical results for samples from monitoring wells, but based on the distribution of concentrations in the field blanks, this contamination is not likely to have a large effect on the concentrations reported for environmental samples.

The 90-percent UCL plots for 7 of the 44 VOCs detected in field blanks from monitoring wells (appendix 1) show the concentration distribution of field blanks to be similar to the environmental concentration distribution (contamination category 3; table 6). The VOC 1,2,4-trimethylbenzene is used as an example VOC in figure 5*C* to show the comparison between the concentrations distributions for blanks and environmental samples for contamination category 3. Two of the seven VOCs in contamination category 3 for monitoring wells (carbon disulfide and 1,2,4-trimethylbenzene) have quantified concentrations of 0.02 µg/L for the 90-percent UCL for the 90th percentile (table 6). The seven VOCs in contamination category 3 may have some contamination bias associated with the environmental data based on the 90-percent UCL plots.

The 90-percent UCL plots for 29 of the 44 VOCs detected in field blanks from monitoring wells (appendix 1) show the concentration distribution for field blanks to be markedly greater than the environmental concentration distribution (contamination category 4; table 6). Toluene is used as an example VOC in figure 5*D* to show the comparison between the concentration distributions for field blanks and environmental samples for contamination category 4. Twelve of these 29 VOCs have a quantified concentration for the 90-percent UCL for the 90th percentile: acetone (3.1 µg/L); benzene (0.013 µg/L); chlorobenzene (0.004 µg/L); 1,4-dichlorobenzene (0.007 µg/L); dichloromethane (0.04 µg/L); ethylbenzene (0.015 µg/L); methyl ethyl ketone (0.3 µg/L); styrene (0.005 µg/L); tetrahydrofuran (0.3 µg/L); toluene (0.08 µg/L); *m*- and *p*-xylene (0.04 µg/L); and *o*-xylene (0.009 µg/L) (table 6). The field blanks for the 29 VOCs in contamination category 4 appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions (and in many cases higher frequency of detection) in field blanks than in environmental samples.

Surface-Water Sites

Fifty-four of the 87 VOCs analyzed were not detected in field blanks from surface-water sites (contamination category 1; table 7). The concentration data for environmental samples for these 54 VOCs are considered to be free of contamination bias, and various interpretations for environmental samples from surface-water sites are not limited for these VOCs in contamination category 1.

Thirty-three of 87 VOCs were detected in at least one field blank from surface-water sites. The 90-percent UCL plots for 16 of the 33 VOCs detected in field blanks (appendix 1) show the concentration distribution for field blanks to be at least an order of magnitude smaller in comparison to the environmental concentration distribution (contamination category 2; table 7). Chloroform is used as an example VOC in figure 6*B* to show the comparison between the concentration distributions for blanks and environmental samples for contamination category 2. Chloroform is the only VOC in category 2 for surface-water sites to have a quantified concentration (0.05 µg/L) for the 90-percent UCL for the 90th percentile (table 7). The 16 VOCs in contamination category 2 may have some contamination bias in analytical results for samples from surface-water sites, but based on the distribution of concentration in field blanks, this contamination is not likely to have a large effect on the concentrations reported in environmental samples.

The 90-percent UCL plots for 10 of the 33 VOCs detected in field blanks (appendix 1) show the concentration distribution for field blanks to be similar to the environmental concentration distribution (contamination category 3; table 7). Carbon disulfide is used as an example VOC in figure 6*C* to show the comparison between the concentration distributions for the blanks and environmental samples for contamination category 3. Six of these 10 VOCs have a quantified concentration for the 90-percent UCL for the 90th percentile: acetone (3 µg/L); ethylbenzene (0.01 µg/L); methyl ethyl ketone (0.2 µg/L); toluene (0.09 µg/L); *m*- and *p*-xylene (0.03 µg/L); and *o*-xylene (0.01 µg/L) (table 7). The 10 VOCs in contamination category 3 may have some contamination bias associated with the environmental data based on the 90-percent UCL plots.

The 90-percent UCL plots for 7 of the 33 VOCs detected in field blanks (appendix 1) show the concentration distribution for field blanks to be markedly greater than the environmental concentration distribution (contamination category 4; table 7). Toluene is used as an example VOC in figure 6*D* to show the comparison between the distributions for field blanks and environmental samples for contamination category 4. Two of the seven VOCs in category 4 for surface-water sites, dichloromethane and styrene, have quantified concentrations of 0.01 µg/L for the 90-percent UCL for the 90th percentile (table 7). The field blanks for these seven VOCs in contamination category 4 appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions (and in many cases higher frequency of detection) in field blanks than in environmental samples.

Contamination Categories

The 87 VOCs analyzed in NAWQA samples from October 1996 to December 2008 were classified into four contamination categories on the basis of the 90-percent UCL for percentiles of concentration in field blanks (table 3; fig. 3). The following sections describe VOC contamination by the four contamination categories considering data from all three site types combined.

Table 6. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from monitoring wells, October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
		Contamination category 1			
Acrolein	107–02–8	34210	ND	No	--
Acrylonitrile	107–13–1	34215	ND	No	--
tert-Amyl methyl ether	994–05–8	50005	ND	Yes	--
Bromobenzene	108–86–1	81555	ND	Yes	--
Bromochloromethane	74–97–5	77297	ND	Yes	--
Bromoform	75–25–2	32104	ND	Yes	--
tert-Butylbenzene	98–06–6	77353	ND	Yes	--
Chloroethane	75–00–3	34311	ND	Yes	--
3-Chloro-1-propene	107–05–1	78109	ND	No	--
4-Chlorotoluene	106–43–4	77277	ND	No	--
Dibromochloropropane	96–12–8	82625	ND	Yes	--
1,2-Dibromoethane	106–93–4	77651	ND	Yes	--
1,3-Dichlorobenzene	541–73–1	34566	ND	Yes	--
trans-1,4-Dichloro-2-butene	110–57–6	73547	ND	No	--
Dichlorodifluoromethane	75–71–8	34668	ND	Yes	A1–16
1,1-Dichloroethane	75–34–3	34496	ND	Yes	--
1,1-Dichloroethene	75–35–4	34501	ND	Yes	A1–18
cis-1,2-Dichloroethene	156–59–2	77093	ND	Yes	--
trans-1,2-Dichloroethene	156–60–5	34546	ND	Yes	--
1,3-Dichloropropane	142–28–9	77173	ND	Yes	--
2,2-Dichloropropane	594–20–7	77170	ND	No	--
1,1-Dichloropropene	563–58–6	77168	ND	Yes	--
cis-1,3-Dichloropropene	10061–01–5	34704	ND	Yes	--
trans-1,3-Dichloropropene	10061–02–6	34699	ND	Yes	--
Diethyl ether	60–29–7	81576	ND	Yes	A1–21
Diisopropyl ether	108–20–3	81577	ND	Yes	--
Ethyl *tert*-butyl ether	637–92–3	50004	ND	Yes	A1–23
Ethyl methacrylate	97–63–2	73570	ND	No	--
Hexachlorobutadiene	87–68–3	39702	ND	No	--
Hexachloroethane	67–72–1	34396	ND	No	--
Methyl acrylate	96–33–3	49991	ND	No	--
Methyl acrylonitrile	126–98–7	81593	ND	No	--
Methyl butyl ketone	591–78–6	77103	ND	No	--
Methyl methacrylate	80–62–6	81597	ND	No	--

Table 6. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from monitoring wells, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 1—Continued					
1,1,1,2-Tetrachloroethane	630–20–6	77562	ND	Yes	--
1,1,2,2-Tetrachloroethane	79–34–5	34516	ND	No	--
Tetrachloromethane	56–23–5	32102	ND	Yes	--
1,2,3-Trichlorobenzene	87–61–6	77613	ND	Yes	--
1,2,4-Trichlorobenzene	120–82–1	34551	ND	No	--
1,1,2-Trichloroethane	79–00–5	34511	ND	Yes	--
1,2,3-Trichloropropane	96–18–4	77443	ND	Yes	--
Vinyl acetate	108–05–4	77057	ND	No	--
Vinyl bromide	593–60–2	50002	ND	No	--
Contamination category 2					
Chloroform	67–66–3	32106	**0.07**	Yes	A1–9
Dibromochloromethane	124–48–1	32105	<.01	Yes	A1–12
1,2-Dichloropropane	78–87–5	34541	**.01**	Yes	A1–20
4-Isoproyplytoluene	99–87–6	77356	<.0095	Yes	A1–27
Perchloroethene	127–18–4	34475	<.004	Yes	A1–32
1,2,3,5-Tetramethylbenzene	527–53–7	50000	<.02	Yes	A1–37
1,1,1-Trichloroethane	71–55–6	34506	<.006	Yes	A1–39
1,2,3-Trimethylbenzene	526–73–8	77221	<.012	Yes	A1–43
Contamination category 3					
Bromodichloromethane	75–27–4	32101	<0.01	Yes	A1–3
Carbon disulfide	75–15–0	77041	**.02**	Yes	A1–7
Chloromethane	74–87–3	34418	<.009	Yes	A1–10
Methyl *tert*-butyl ether	1634–04–4	78032	<.048	Yes	A1–28
Trichloroethene	79–01–6	39180	<.007	Yes	A1–40
Trichlorofluoromethane	75–69–4	34488	<.011	Yes	A1–41
1,2,4-Trimethylbenzene	95–63–6	77222	**.02**	Yes	A1–44
Contamination category 4					
Acetone	67–64–1	81552	**3.1**	Yes	A1–1
Benzene	71–43–2	34030	**.013**	Yes	A1–2
Bromomethane	74–83–9	34413	<.96	Yes	A1–4
n-Butylbenzene	104–51–8	77342	<.22	Yes	A1–5
sec-Butylbenzene	135–98–8	77350	<.28	Yes	A1–6
Chlorobenzene	108–90–7	34301	**.004**	Yes	A1–8
2-Chlorotoluene	95–49–8	77275	<.048	Yes	A1–11

Table 6. Contamination categories and the 90-percent upper confidence limit for the 90th percentile of concentrations for volatile organic compounds in field blanks collected from monitoring wells, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 4—Continued					
Dibromomethane	74–95–3	30217	<0.06	Yes	A1–13
1,2-Dichlorobenzene	95–50–1	34536	<.002	Yes	A1–14
1,4-Dichlorobenzene	106–46–7	34571	**.007**	Yes	A1–15
1,2-Dichloroethane	107–06–2	32103	<.17	Yes	A1–17
Dichloromethane	75–09–2	34423	**.04**	Yes	A1–19
Ethylbenzene	100–41–4	34371	**.015**	Yes	A1–22
2-Ethyltoluene	611–14–3	77220	<.005	Yes	A1–24
Iodomethane	74–88–4	77424	<1.68	Yes	A1–25
Isopropylbenzene	98–82–8	77223	<.005	Yes	A1–26
Methyl ethyl ketone	78–93–3	81595	**.3**	Yes	A1–29
Methyl isobutyl ketone	108–10–1	78133	<.38	Yes	A1–30
Naphthalene	91–20–3	34696	<.036	Yes	A1–31
n-Propylbenzene	103–65–1	77224	<.015	Yes	A1–33
Styrene	100–42–5	77128	**.005**	Yes	A1–34
Tetrahydrofuran	109–99–9	81607	**.3**	Yes	A1–35
1,2,3,4-Tetramethylbenzene	488–23–3	49999	<.017	Yes	A1–36
Toluene	108–88–3	34010	**.08**	Yes	A1–38
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	<.01	Yes	A1–42
1,3,5-Trimethylbenzene	108–67–8	77226	<.01	Yes	A1–45
Vinyl chloride	75–01–4	39175	<.05	Yes	A1–46
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	**.04**	Yes	A1–47
o-Xylene	95–47–6	77135	**.009**	Yes	A1–48

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

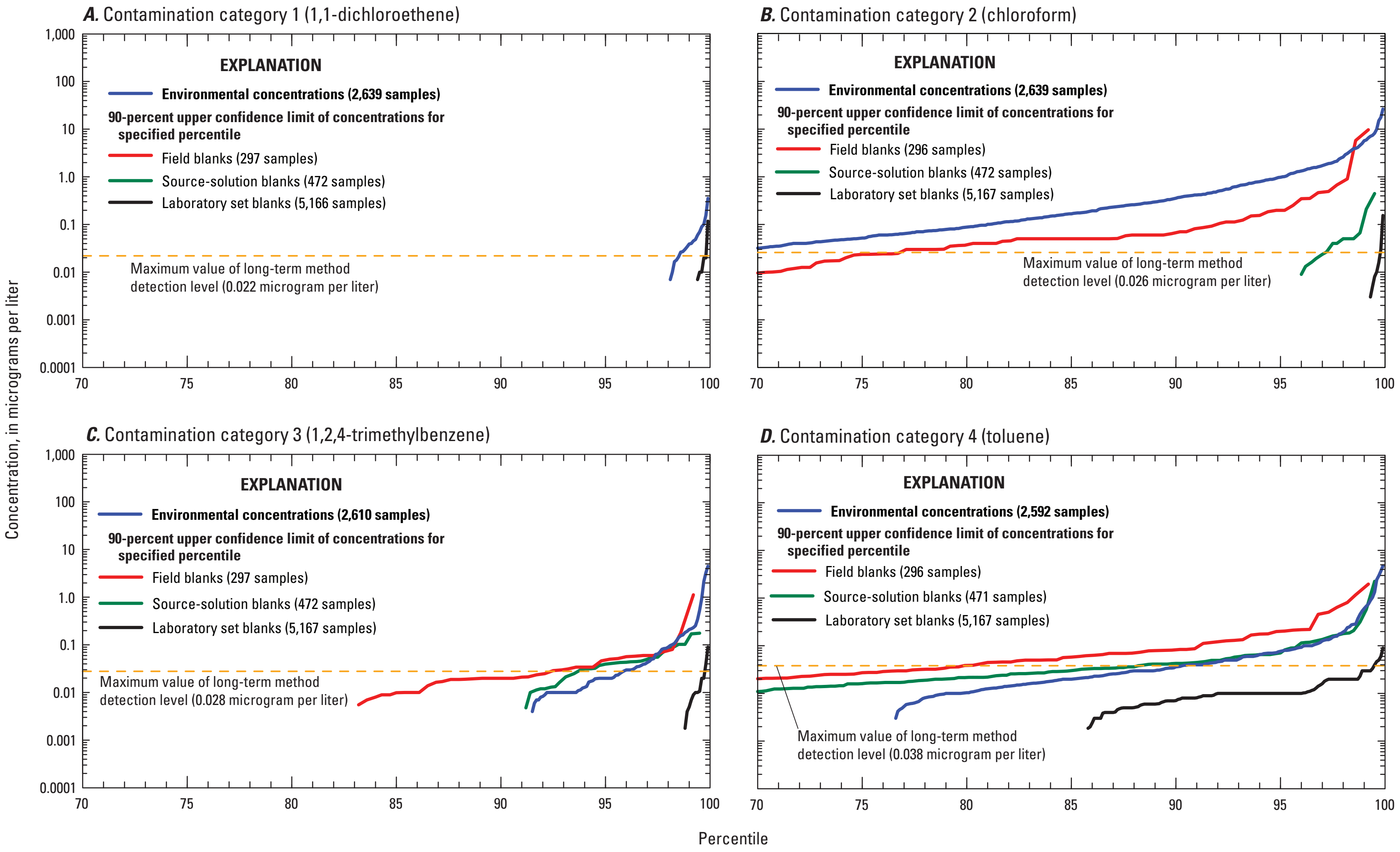


Figure 5. Distribution of environmental concentrations and 90-percent upper confidence limits of contamination in field blanks, source-solution blanks, and laboratory set blanks for example compounds in each contamination category for monitoring wells. *A*, contamination category 1 (1,1-dichlorethene); *B*, contamination category 2 (chloroform); *C*, contamination category 3 (1,2,4-trimethylbenzene); and *D*, contamination category 4 (toluene). Nondetections are not shown.

Contamination Category 1

Thirty-nine of the 87 compounds were not detected in field blanks from any site type (table 4). Three additional VOCs (1,1-dichloroethene, diethyl ether, and ethyl *tert*-butyl ether) were not detected in field blanks from domestic and public-supply wells or monitoring wells. Nine additional VOCs (1,3,5-trimethylbenzene, 1,2,3,4-tetramethylbenzene, bromomethane, *n*-butylbenzene, *sec*-butylbenzene, 2-chlorotoluene, dibromomethane, iodomethane, and 1,2,3,5-tetramethylbenzene) were not detected in field blanks from domestic and public-supply wells or surface-water sites. No contamination bias is indicated for the field procedures, supplies, shipping, and laboratory analyses, and no revisions to sampling protocols are warranted for the VOCs in contamination category 1. The concentration data for NAWQA samples stored in the USGS National Water Information System (NWIS) database (*http://waterdata.usgs.gov/nwis/*) for environmental samples for these VOCs for the three site types (domestic and public-supply wells, monitoring wells, and surface-water sites) are considered to be free of contamination bias, and various interpretations for environmental samples are not limited for the VOCs in contamination category 1.

Seven of the 39 VOCs not detected in field blanks from any NAWQA site type also were not detected in any environmental sample from the three NAWQA site types (domestic and public-supply wells, monitoring wells, and surface-water sites) summarized in this report (*trans*-1,4-dichloro-2-butene, ethyl methacrylate, hexachloroethane, hexachlorobutadiene, methyl acrylate, vinyl acetate, and vinyl bromide) (table 4). Rowe and others (2005) showed that the analytical method is capable of detecting these compounds in water samples at low concentrations (less than 0.5 µg/L). Twelve of the 39 VOCs not detected in field blanks were detected in environmental samples from all the three site types summarized in this report (*tert*-amyl methyl ether, bromochloromethane, bromoform, chloroethane, 1,3-dichlorobenzene, 1,1-dichloroethane, 1,1-dichloroethene, 1,1-dichloropropene, diisopropyl ether, tetrachloromethane, 1,2,3-trichlorobenzene, and 1,2,3-trichloropropane) (table 5). Nine of the 39 VOCs not detected in field blanks were only detected in environmental samples from domestic and public-supply wells and monitoring wells (bromobenzene, *tert*-butylbenzene, dibromochloropropane, 1,2-dibromoethane, *cis*-1,2-dichloroethene, 1,3-dichloropropane, 1,1,-dichloropropene, 1,1,1,2-tetrachloroethane, and 1,1,2-trichloroethane) (tables 5 and 6). One of the 39 VOCs not detected in field blanks was only detected in environmental samples from monitoring wells (*trans*-1,3-dichloropropene) (table 6). Six of the 39 VOCs not detected in field blanks were only detected in environmental samples from domestic and public-supply wells (acrylonitrile, 3-chloro-1-propene, 4-chlorotoluene, 2,2-dichloropropane, methyl acrylonitrile, methyl methacrylate) (table 5). Two of the 39 VOCs not detected in field blanks were only detected in environmental samples from domestic and public-supply wells and surface-water sites (methyl butyl ketone and 1,2,4-trichlorobenzene) (tables 5 and 7). Two of the 39 VOCs not detected in field blanks were only detected environmental samples from surface-water sites (acrolein and 1,1,2,2-tetrachloroethane) (table 7).

Contamination Category 2

VOCs with detections in field blanks, but with concentration distributions that are lower by at least an order of magnitude than the concentration distributions in environmental samples are in contamination category 2. Ten VOCs are in contamination category 2 for one or more of the site types. Chloroform, 4-isopropyltoluene, and 1,1,1-trichloroethane are in contamination category 2 for field blanks from all three site types. Dibromochloromethane is in contamination category 2 for domestic and public-supply and monitoring wells. Perchloroethene is in contamination category 2 for monitoring wells and surface-water sites. Bromodichloromethane, methyl *tert*-butyl ether, naphthalene, trichloroethene, and 1,1,2-trichloro-1,2,2-trifluoroethane are in contamination category 2 for domestic and public-supply wells and surface-water sites.

The field blanks for the VOCs in contamination category 2 are assumed to be representative of potential sources of contamination to environmental samples; however, the concentration distribution for field blanks has little or no effect on the concentration distribution for environmental samples. The quantified concentrations for VOCs in environmental samples from domestic and public-supply wells, monitoring wells, and surface-water sites potentially were affected by contamination at low concentrations but the effect at larger environmentally important concentrations would be negligible. An example for the VOCs in contamination category 2 is shown in figure 7 for chloroform. The figure shows the similar distributions of concentrations in field blanks and environmental samples for all three site types through at least the 90th percentile.

Contamination Category 3

Compounds detected in field blanks with a concentration distribution for the field blanks that is similar to the distribution for the environmental samples based on the 90-percent UCL plots (appendix 1) are in contamination category 3. Nineteen VOCs are in contamination category 3 for one or more of the site types. Carbon disulfide is in contamination category 3 in all three site types. Chloromethane and trichlorotrifluoroethane are in this category for domestic and public-supply wells and monitoring wells. The VOC 1,4-dichlorobenzene is in this category for domestic and public-supply wells and surface-water sites. Three VOCs (dichlorodifluoromethane, 1,2-dichloropropane, and perchloroethene) are in contamination category 3 for only domestic and public-supply wells. Four VOCs (bromodichloromethane, methyl *tert*-butyl ether, trichloroethene, and 1,2,4-trimethylbenzene) are in contamination category 3 for only monitoring wells. Eight VOCs (acetone, chlorobenzene, ethylbenzene, methyl ethyl ketone, toluene, vinyl chloride, *m*- and *p*-xylene, and *o*-xylene) are in contamination category 3 for only surface-water sites.

Table 7. Contamination categories and the 90-percent upper confidence limit for the 90th-percentile concentrations for volatile organic compound in field blanks collected from surface-water sites, October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
		Contamination category 1			
Acrolein	107–02–8	34210	ND	Yes	--
Acrylonitrile	107–13–1	34215	ND	No	--
tert-Amyl methyl ether	994–05–8	50005	ND	Yes	--
Bromobenzene	108–86–1	81555	ND	No	--
Bromochloromethane	74–97–5	77297	ND	Yes	--
Bromoform	75–25–2	32104	ND	Yes	--
Bromomethane	74–83–9	34413	ND	No	A1–4
n-Butylbenzene	104–51–8	77342	ND	Yes	A1–5
sec-Butylbenzene	135–98–8	77350	ND	Yes	A1–6
tert-Butylbenzene	98–06–6	77353	ND	No	--
Chloroethane	75–00–3	34311	ND	Yes	--
3-Chloro-1-propene	107–05–1	78109	ND	No	--
2-Chlorotoluene	95–49–8	77275	ND	Yes	A1–11
4-Chlorotoluene	106–43–4	77277	ND	No	--
Dibromochloromethane	124–48–1	32105	ND	Yes	A1–12
Dibromochloropropane	96–12–8	82625	ND	No	--
1,2-Dibromoethane	106–93–4	77651	ND	No	--
Dibromomethane	74–95–3	30217	ND	Yes	A1–13
1,2-Dichlorobenzene	95–50–1	34536	ND	Yes	A1–14
1,3-Dichlorobenzene	541–73–1	34566	ND	Yes	--
trans-1,4-Dichloro-2-butene	110–57–6	73547	ND	No	--
1,1-Dichloroethane	75–34–3	34496	ND	Yes	--
1,2-Dichloroethane	107–06–2	32103	ND	Yes	A1–17
cis-1,2-Dichloroethene	156–59–2	77093	ND	Yes	--
trans-1,2-Dichloroethene	156–60–5	34546	ND	Yes	--
1,3-Dichloropropane	142–28–9	77173	ND	No	--
2,2-Dichloropropane	594–20–7	77170	ND	No	--
1,1-Dichloropropene	563–58–6	77168	ND	No	--
cis-1,3-Dichloropropene	10061–01–5	34704	ND	No	--
trans-1,3-Dichloropropene	10061–02–6	34699	ND	No	--
Diisopropyl ether	108–20–3	81577	ND	Yes	--
Ethyl methacrylate	97–63–2	73570	ND	No	--
2-Ethyltoluene	611–14–3	77220	ND	Yes	A1–24
Hexachlorobutadiene	87–68–3	39702	ND	No	--
Hexachloroethane	67–72–1	34396	ND	No	--

Table 7. Contamination categories and the 90-percent upper confidence limit for the 90th-percentile concentrations for volatile organic compound in field blanks collected from surface-water sites, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 1—Continued					
Iodomethane	74–88–4	77424	ND	Yes	A1–25
Methyl acrylate	96–33–3	49991	ND	No	--
Methyl acrylonitrile	126–98–7	81593	ND	No	--
Methyl butyl ketone	591–78–6	77103	ND	Yes	--
Methyl isobutyl ketone	108–10–1	78133	ND	Yes	A1–30
Methyl methacrylate	80–62–6	81597	ND	No	--
1,1,1,2-Tetrachloroethane	630–20–6	77562	ND	No	--
1,1,2,2-Tetrachloroethane	79–34–5	34516	ND	Yes	--
Tetrachloromethane	56–23–5	32102	ND	Yes	--
1,2,3,4-Tetramethylbenzene	488–23–3	49999	ND	Yes	A1–36
1,2,3,5-Tetramethylbenzene	527–53–7	50000	ND	Yes	A1–37
1,2,3-Trichlorobenzene	87–61–6	77613	ND	Yes	--
1,2,4-Trichlorobenzene	120–82–1	34551	ND	Yes	--
1,1,2-Trichloroethane	79–00–5	34511	ND	No	--
1,2,3-Trichloropropane	96–18–4	77443	ND	Yes	--
1,2,3-Trimethylbenzene	526–73–8	77221	ND	Yes	A1–43
1,3,5-Trimethylbenzene	108–67–8	77226	ND	Yes	A1–45
Vinyl acetate	108–05–4	77057	ND	No	--
Vinyl bromide	593–60–2	50002	ND	No	--
Contamination category 2					
Benzene	71–43–2	34030	<0.007	Yes	A1–2
Bromodichloromethane	75–27–4	32101	<.006	Yes	A1–3
Chloroform	67–66–3	32106	**.05**	Yes	A1–9
Chloromethane	74–87–3	34418	<.004	Yes	A1–10
Dichlorodifluoromethane	75–71–8	34668	<.041	Yes	A1–16
1,1-Dichloroethene	75–35–4	34501	<.004	Yes	A1–18
Isopropylbenzene	98–82–8	77223	<.003	Yes	A1–26
4-Isoproyplytoluene	99–87–6	77356	<.0083	Yes	A1–27
Methyl *tert*-butyl ether	1634–04–4	78032	<.03	Yes	A1–28
Naphthalene	91–20–3	34696	<.02	Yes	A1–31
Perchloroethene	127–18–4	34475	<.003	Yes	A1–32
n-Propylbenzene	103–65–1	77224	<.003	Yes	A1–33
1,1,1-Trichloroethane	71–55–6	34506	<.001	Yes	A1–39
Trichloroethene	79–01–6	39180	<.008	Yes	A1–40
1,2,4-Trimethylbenzene	95–63–6	77222	<.007	Yes	A1–44
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	<.007	Yes	A1–42

Table 7. Contamination categories and the 90-percent upper confidence limit for the 90th-percentile concentrations for volatile organic compound in field blanks collected from surface-water sites, October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; µg/L, microgram per liter; ND, not detected in any field blank for the site type; --, not applicable; <, less than]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	90-percent upper confidence limit for the 90th percentile (µg/L)	Detected in environmental samples	Appendix 1 figure number
Contamination category 3					
Acetone	67–64–1	81552	**3**	Yes	A1–1
Carbon disulfide	75–15–0	77041	<.003	Yes	A1–7
Chlorobenzene	108–90–7	34301	<.004	Yes	A1–8
1,4-Dichlorobenzene	106–46–7	34571	<.007	Yes	A1–15
Ethylbenzene	100–41–4	34371	**.01**	Yes	A1–22
Methyl ethyl ketone	78–93–3	81595	**.2**	Yes	A1–29
Toluene	108–88–3	34010	**.09**	Yes	A1–38
Vinyl chloride	75–01–4	39175	<.05	Yes	A1–46
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	**.03**	Yes	A1–47
o-Xylene	95–47–6	77135	**.01**	Yes	A1–48
Contamination category 4					
Dichloromethane	75–09–2	34423	**0.01**	Yes	A1–19
1,2-Dichloropropane	78–87–5	34541	<.007	Yes	A1–20
Diethyl ether	60–29–7	81576	<.376	Yes	A1–21
Ethyl *tert*-butyl ether	637–92–3	50004	<.044	Yes	A1–23
Styrene	100–42–5	77128	**.01**	Yes	A1–34
Tetrahydrofuran	109–99–9	81607	<.2	Yes	A1–35
Trichlorofluoromethane	75–69–4	34488	<.126	Yes	A1–41

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

These VOCs in contamination category 3 may have some contamination bias associated with the environmental samples based on the 90-percent UCL plots. Carbon disulfide is used as an example in figure 8 for these compounds in contamination category 3. The figure shows that the concentration distributions are similar, or within an order of magnitude, between the field blanks and environmental samples. Figure 8 also shows the concentration distribution for the source-solution blanks to be much less than the concentration distribution for field blanks. This observation indicates that the source-solution water was not a major source of contamination to the field blank samples.

None of the 19 compounds in category 3 had carryover from contaminated equipment to the subsequent environmental samples according to the study by Taglioli and others (2001). The study showed that when contaminated equipment is used to collect a subsequent environmental sample, the conditioning of the sampling equipment with the native water is sufficient to remove/reduce concentrations of the VOCs to less than current (2011) analytical quantitative levels when the field rinsing/well purging protocols are followed. In addition, a field contamination study was completed to better understand the shipping, field protocols, and analytical-related bias associated with the source-solution and field blanks (Thiros and others, 2011). This study showed that if source-solution water does not contain VOCs at concentrations greater than current (2011) analytical levels, the subsequent field blanks are contaminant free at these levels. The study also showed that if the current (2011) field protocols are followed and new supplies—for example, fresh unexpired source-solution water (used less than 14 days after receiving for VPBW) and fresh sample bottles (stored less than a month)—are used

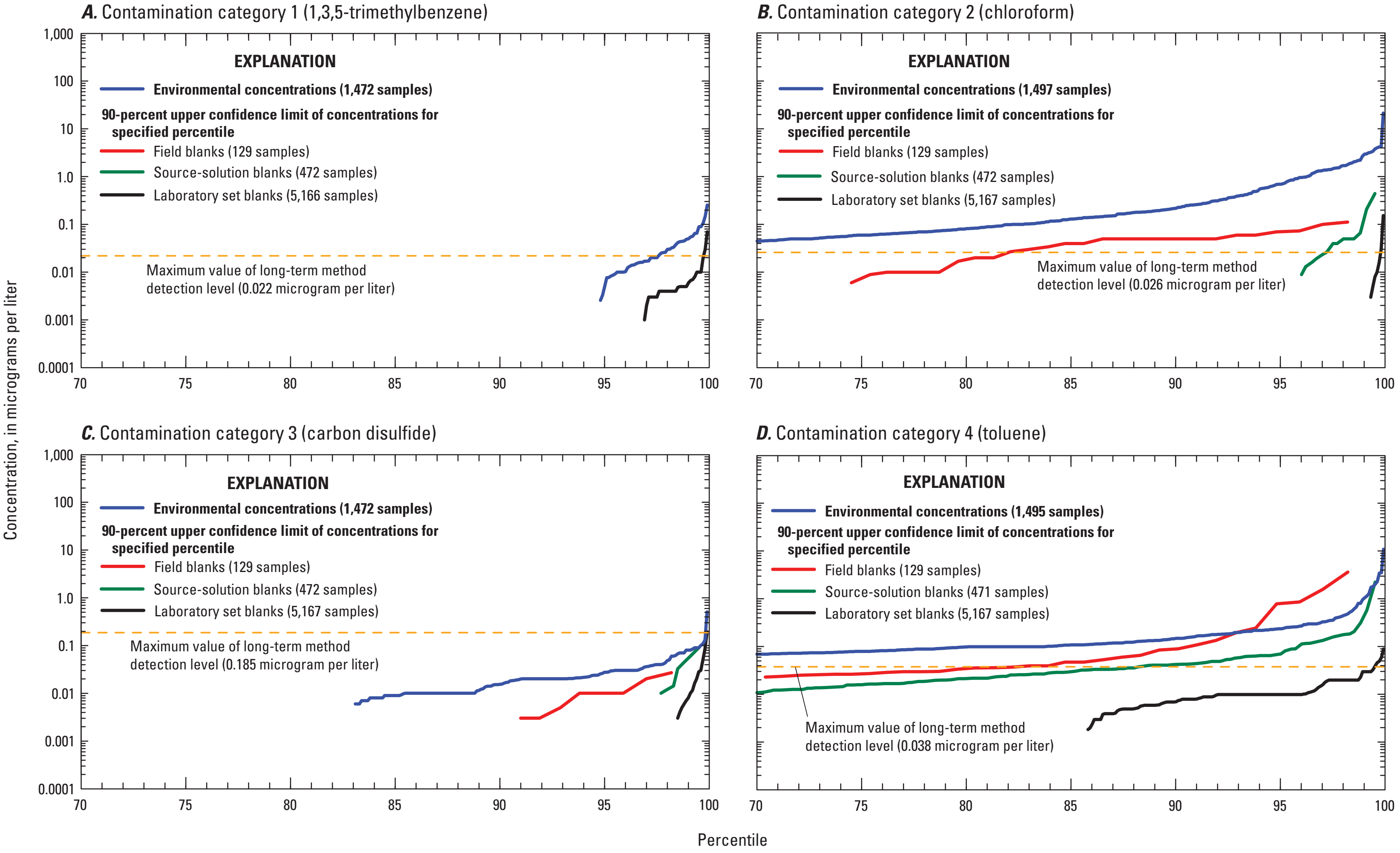
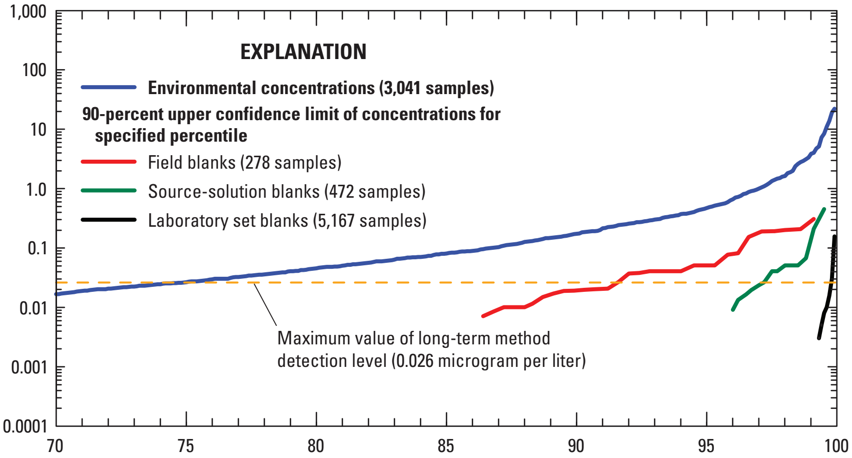
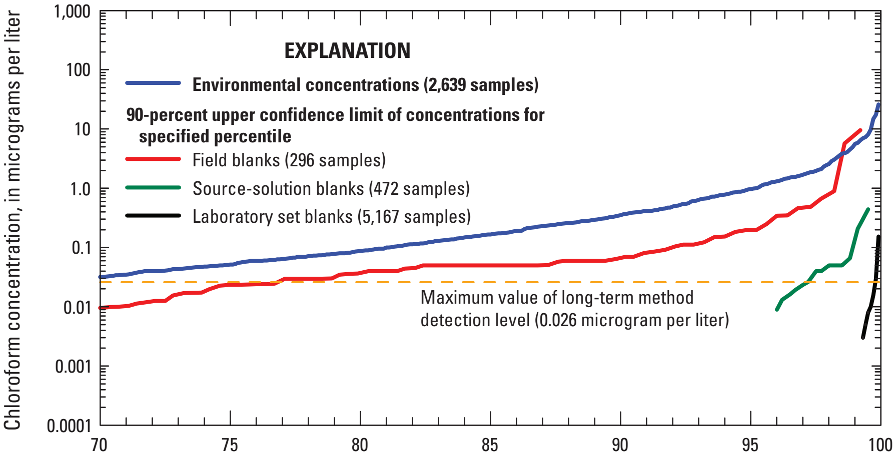


Figure 6. Distribution of environmental concentrations and 90-percent upper confidence limits of concentrations in field blanks, source-solution blanks, and laboratory set blanks for example compounds in each contamination category for surface-water sites. *A*, contamination category 1 (1,3,5-trimethylbenzene); *B*, contamination category 2 (chloroform); *C*, contamination category 3 (carbon disulfide); and *D*, contamination category 4 (toluene). Nondetections are not shown.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

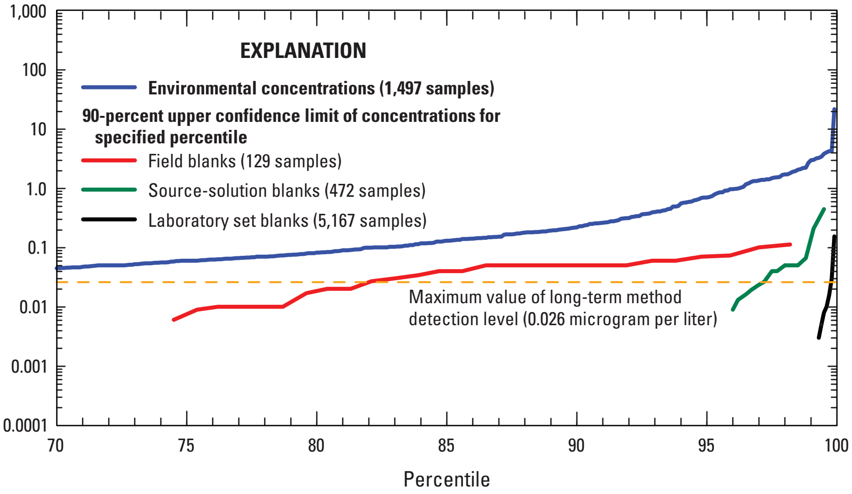


Figure 7. Distribution of environmental concentrations and 90-percent upper confidence limits of chloroform concentrations, representing contamination category 2, in field blanks, source-solution blanks, and laboratory set blanks for *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

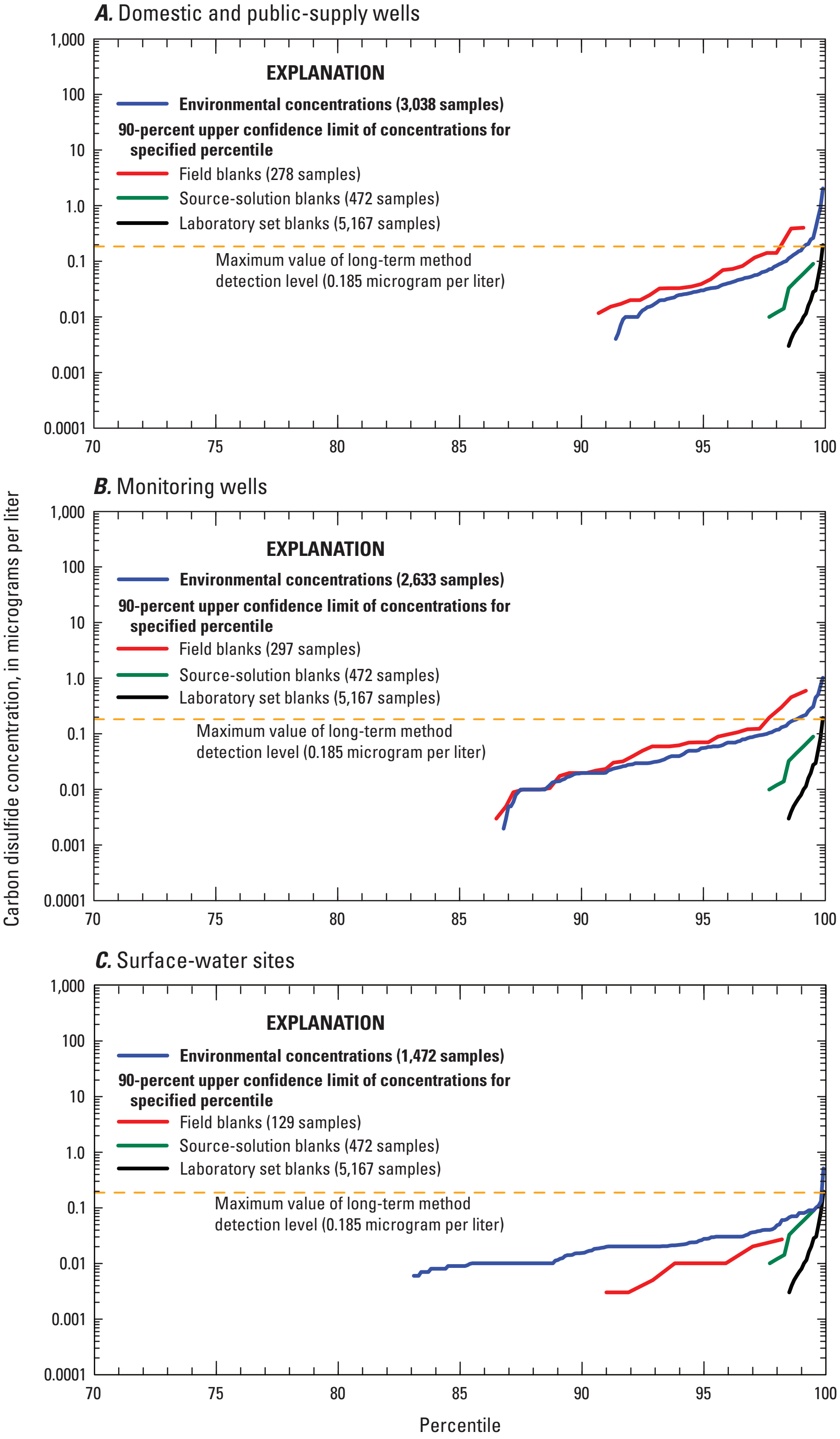
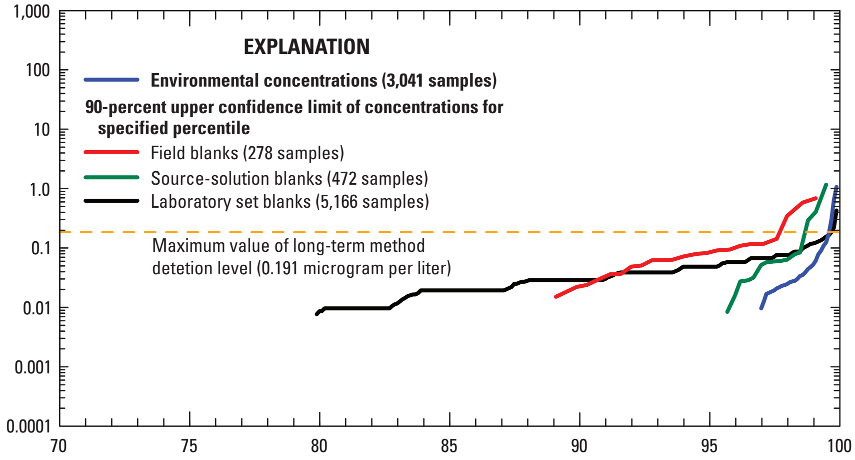
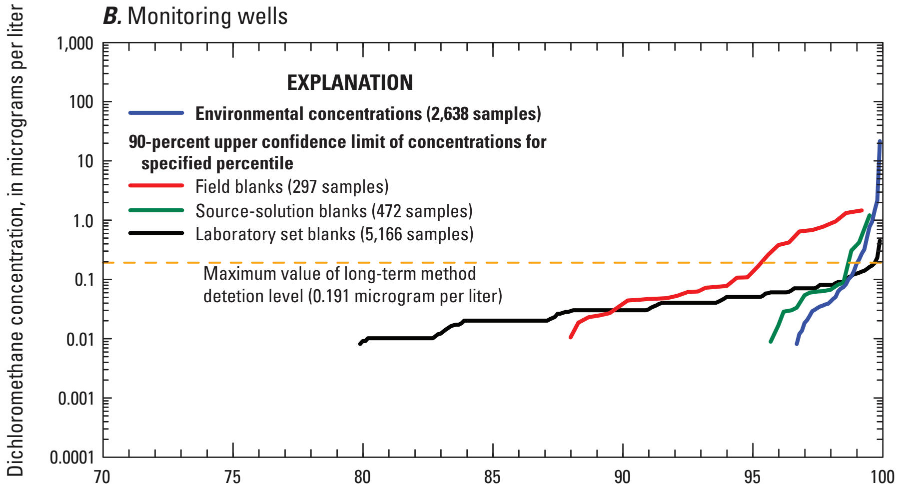


Figure 8. Distribution of environmental concentrations and 90-percent upper confidence limits of carbon disulfide concentrations, representing contamination category 3, in field blanks, source-solution blanks, and laboratory set blanks for *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

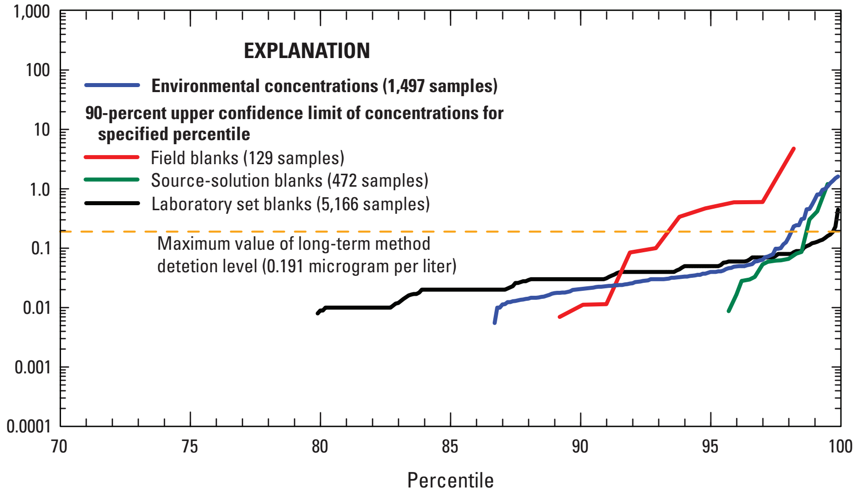


Figure 9. Distribution of environmental concentrations and 90-percent upper confidence limits of dichloromethane concentrations, representing contamination category 4, in field blanks, source-solution blanks, and laboratory set blanks for *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

for collection of source-solution and field blanks, then the contamination associated with these samples is much less than the historical detection frequency and concentrations in field blanks described in this report.

Contamination Category 4

Compounds detected in field blanks with a concentration distribution for field blanks that is at least an order of magnitude higher than the concentration distribution for the environmental samples based on the 90-percent UCL plots (appendix 1) are in contamination category 4. Thirteen VOCs are in contamination category 4 for one or more of the site types. Dichloromethane, styrene, and tetrahydrofuran are in contamination category 4 for all three site types. Acetone, benzene, chlorobenzene, 1,2-dichloroethane, ethylbenzene, 2-ethyltoluene, methyl ethyl ketone, toluene, *m*- and *p*-xylene, and *o*-xylene are in this category for domestic and public-supply wells and monitoring wells.

Dichloromethane is used as an example of the VOCs in contamination category 4 in figure 9. The figure shows that the concentration distribution for the 90-percent UCL for dichloromethane for the field blanks is much larger than the concentration distribution of the environmental samples. The larger concentration distribution for the 90-percent UCL for the field blanks indicates that the field blanks were exposed to sources of contamination bias not associated with the environmental data and are not representative of these sources of contamination to the environmental data.

The 90-percent UCL plots for the other VOCs in contamination category 4 are similar to the dichloromethane plots with the 90-percent UCL concentration distribution of the field blanks being much larger than the concentration distribution of the environmental samples. The concentration distribution for the 90-percent UCL of the source-solution blanks for many of the VOCs in contamination category 4 are not markedly different than the concentration distribution for the 90-percent UCL of the field blanks for one or more site types. This distribution may indicate that either the source-solution water was contaminated before preparation of the field blanks or that contamination resulted during shipping or in the laboratory that only affected the field blanks and source-solution blanks. A few of the VOCs in contamination category 4 have minimal or no detection in the source-solution blanks, which may indicate a source of contamination to the field blanks related to the equipment.

VOCs in contamination category 4 have concentration distributions in field blanks that appear to overstate the potential sources of contamination bias to environmental samples. The field blanks appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions (and in many cases higher frequency of detection) for field blanks than for environmental samples. For many of these compounds, similar distributions are seen in the source-solution blanks for one or more site types, which may indicate that the VPBW was contaminated before use or had a similar contamination source as the field blanks.

The previous conclusions related to contamination category 3 from Taglioli and others (2001) and Thiros and others (2011) also can be applied to the VOCs in contamination category 4. These conclusions include that when contaminated equipment is used to collect a subsequent environmental sample, the conditioning of the sampling equipment with the native water is sufficient to remove/reduce concentrations of the VOCs to less than current (2011) analytical quantitative levels when the field rinsing/well purging protocols are followed and if the current (2011) field protocols are followed and new supplies—for example, fresh unexpired source-solution water (used less than 14 days after receiving for VPBW) and fresh sample bottles (stored less than a month)—are used for collection of source-solution and field blanks, then the contamination associated with these samples is much less than the historical detection frequency and concentrations in field blanks described in this report.

Comparison of Contamination in Source-Solution and Field Blanks Among Site Types

The USGS NWQL has certified the volatile-pesticide grade blank water (VPBW) for use when sampling for VOCs. These certificates of analysis show that the VPBW is free of contaminants of interest before shipment to the field for use in the cleaning protocols (Wilde, 2004) and during the collection of blank samples.

The section “Procedures for the Collection and Laboratory Analysis of Source-Solution and Field Blanks,” states that a source-solution blank collected in the field is used to characterize the quality of the water (VPBW) before contacting sampling equipment. If the source-solution blank contains the contaminants of interest, either the VPBW was contaminated before use or the source-solution blank became contaminated during preservation, shipment to the NWQL, storage, or analysis at the NWQL. If the VPBW was contaminated before use, the field blank would be expected to have a similar detection pattern as the source-solution blank. Table 8 summarizes the similarities and differences in contamination in paired field blanks and source-solution blanks for 19 VOCs that were detected in more than 5 percent of field blanks for the three site types. When a compound has similar contamination in source-solution and field blanks, then similar sources of contamination likely are affecting these samples (for example, source-solution water). When a compound has dissimilar contamination in source-solution and field blanks, then different sources likely are affecting the samples (for example, insufficient rinsing of collection equipment with VPBW, residual contamination associated with the equipment, or a contamination source associated with the preservation, shipment to the NWQL, or storage and analysis at the NWQL. The 1-to-1 concentration plots of the paired field blanks and source-solution blanks and environmental samples corresponding to 19 VOCs that were detected in more than 5 percent of field blanks are available in appendix 2 (figs. A2–1 to A2–19).

The VOCs chloromethane and *o*-xylene had differences in the detections and concentrations between the field blanks and the paired source-solution blanks (table 8) for all three NAWQA site types. Bromodichloromethane, 1,2-dichloropropane, and toluene had similar detections and concentrations between the field blanks and the paired source-solution blanks (table 8) for all three site types. The remaining 14 VOCs that were detected in more than 5 percent of field blanks had a mix of similarities and differences among the three site types. Acetone, benzene, chlorobenzene, dichloromethane, methyl ethyl ketone, tetrahydrofuran, and *m*- and *p*-xylene had similar detections and concentrations between the field blanks and the paired source-solution blanks for domestic and public-supply wells and surface-water sites, but differences for the monitoring wells. One VOC, 1,4-dichlorobenzene, had similarities for monitoring wells and surface-water sites, but differences for domestic and public-supply wells. Styrene had similarities for only domestic and public-supply wells. Carbon disulfide, chloroform, ethylbenzene, perchloroethene, and 1,2,4-trimethylbenzene had similarities for only surface-water sites.

The 1-to-1 concentration plots for many of the VOCs that are in contamination category 2 (tables 5–7; appendix 2) of the paired source-solution and field blanks show the lack of, or infrequent, detections in the source-solution blanks for at least one site type. Chloroform is used as an example of a VOC in contamination category 2 in figure 10*A* to illustrate this lack of detections. The lack of the detection in the source-solution blanks indicates the source-solution water was not contaminated and the detection in the field blank could be from residual contamination in the equipment, which could include insufficient rinsing of the equipment with VPBW prior to the collection of the VOC field blank. When a VOC is detected in the source-solution blank, the VOC typically is detected in the corresponding field blank at similar concentrations.

The 1-to-1 concentration plots for many of the VOCs that are in contamination category 3 (tables 5–7; appendix 2) of the paired source-solution and field blanks show the lack of, or infrequent, detections in the source-solution blanks similar to those VOCs in contamination category 2 for at least one site type. Carbon disulfide is used as an example of a VOC in contamination category 3 in figure 11*A* to illustrate this lack of detections. The lack of the detection in the source-solution blanks indicates the source-solution water was not contaminated and the detection in the field blank could be from residual contamination in the equipment, which could include insufficient rinsing of the equipment with VPBW prior to the collection of the VOC field blank.

The 1-to-1 concentration plots for many of the VOCs that are in contamination category 4 (tables 5–7; appendix 2) of the paired source-solution and field blanks have similar detections and concentrations between the field blanks and source-solution blanks for at least one site type, generally for more sample pairs than in contamination categories 2 and 3. Toluene is used as an example of a VOC in contamination category 4 in figure 12*A* to illustrate this similarity.

The detection frequencies and concentration distributions of the source-solution blanks for many of the compounds in contamination category 4 are similar to or slightly less than those concentration distributions of the field blanks. Paired source-solution and field blanks indicate that when present in a source-solution blank, the VOC typically is detected in the subsequent field blank at similar concentration for many of the VOCs in contamination category 4 (figs. A2−1, A2−8, A2−9, A2−11, A2−12, A2−14, A2−16, A2−17, A2−18, A2−19). If the source-solution water (VPBW) was contaminated before the collection of the field blanks, then the environmental samples would not be affected, and the calculated potential contamination is too large for these VOCs. However, if the contamination resulted during shipment from the field to the laboratory or in the laboratory, then the environmental samples would likely be affected the same as the blank samples, and the calculated potential contamination would be valid. The 1-to-1 plots show the similar concentrations in the paired source-solution blank and field blank data indicating that the source-solution water may be a dominant source of contamination bias across all site types for select VOCs in contamination category 4.

Implications of Contamination Bias for Interpretation of Environmental Sample Data

The concentration data in NWIS for environmental samples for the 39 VOCs that were not detected in field blanks (contamination category 1) (table 4) from domestic and public-supply wells, monitoring wells, and surface-water sites are considered to be free of contamination bias and interpretations (such as VOC detection frequency at multiple assessment levels and comparisons of concentrations to benchmarks) for environmental samples are not limited for these VOCs. Bracketing the potential contamination for all 48 VOCs detected in field blanks in one or more of the three site types by comparing the occurrence and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to human-health benchmarks or aquatic-life criteria (table 1) are done in a study. Applying a common assessment level to the VOCs also is described. A common assessment level also allows comparisons between individual VOCs.

Table 8. Similarities and differences of contamination in paired source-solution blanks and field blanks from domestic and public-supply wells, monitoring wells, and surface-water sites for volatile organic compounds that were detected in more than 5 percent of field blanks, October 1996 to December 2008.

[**Boldface** values indicate that contamination was similar between source-solution and field blanks. ND, not detected; FB, field blank; SSB, source-solution blank; DF, detection frequency]

Compound name	Domestic and public-supply wells	Monitoring wells	Surface-water sites
Acetone	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Benzene	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Bromodichloromethane	**Similar. All NDs in FBs. All NDs in SSB.**	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	**Similar. All NDs in FBs. All NDs in SSB.**
Carbon disulfide	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. All NDs in SSB.**
Chlorobenzene	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Chloroform	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Chloromethane	Dissimilar. Mostly NDs in FBs. When detected in FB, not detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.
1,4-Dichlorobenzene	Dissimilar. Mostly NDs in FBs. Only FB detections.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Dichloromethane	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
1,2-Dichloropropane	**Similar. All NDs in FBs. Only SSB detections.**	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Ethylbenzene	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Methyl ethyl ketone	**Similar. Mostly NDs in FBs. All NDs in SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Perchloroethene	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. All NDs in SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Styrene	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.
Tetrahydrofuran	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
Toluene	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	**Similar. Mostly Detects in FBs. When detected in FB, typically detected in paired SSB.**
1,2,4-Trimethylbenzene	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, not detected in paired SSB.**
m- and *p*-Xylene	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	**Similar. Mostly NDs in FBs. When detected in FB, typically detected in paired SSB.**
o-Xylene	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.	Dissimilar. Mostly NDs in FBs. When detected in FB, not typically detected in paired SSB.

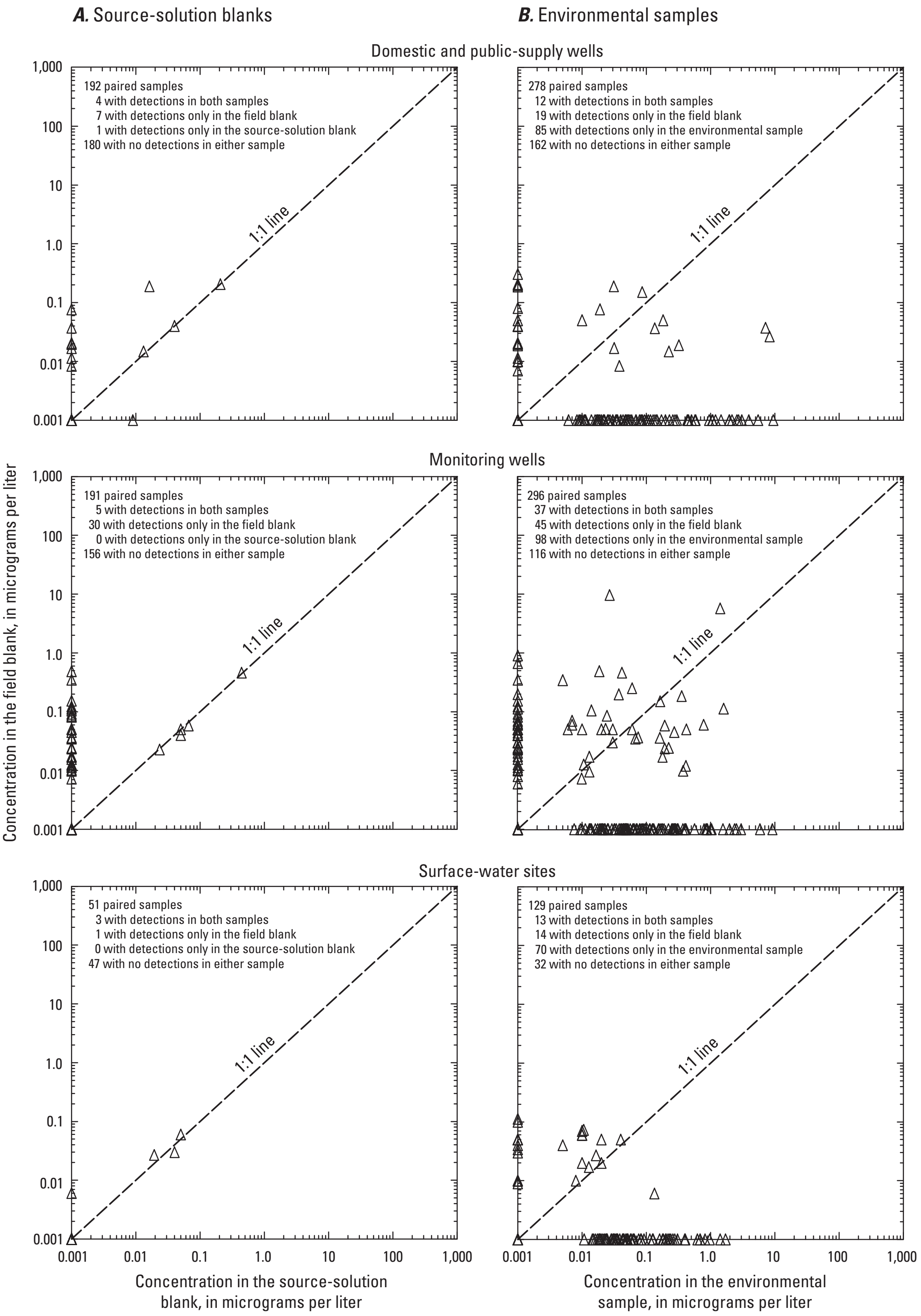


Figure 10. Relation of chloroform concentrations, representing contamination category 2, between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.026 microgram per liter.

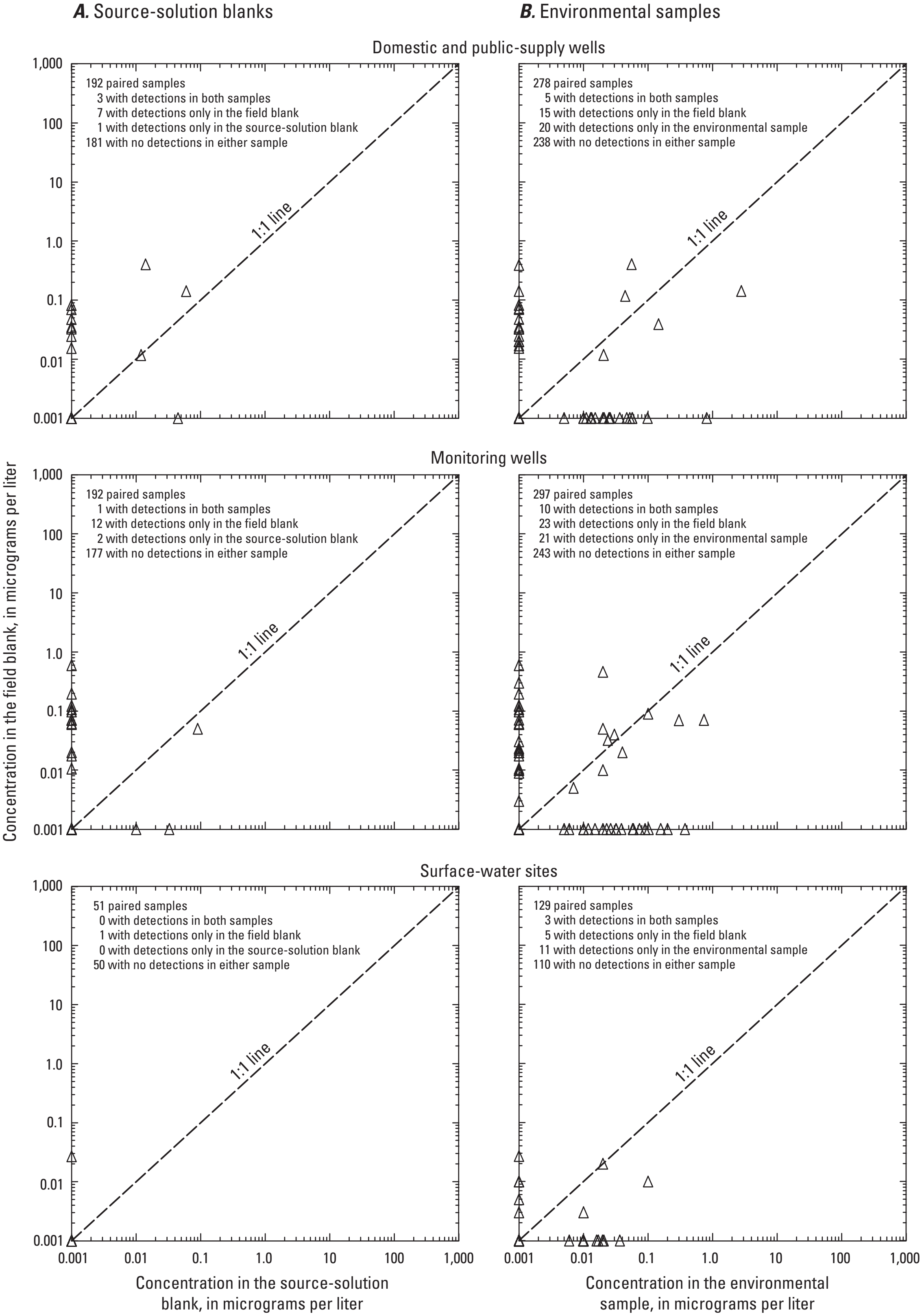


Figure 11. Relation of carbon disulfide concentrations, representing contamination category 3, between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.185 microgram per liter.

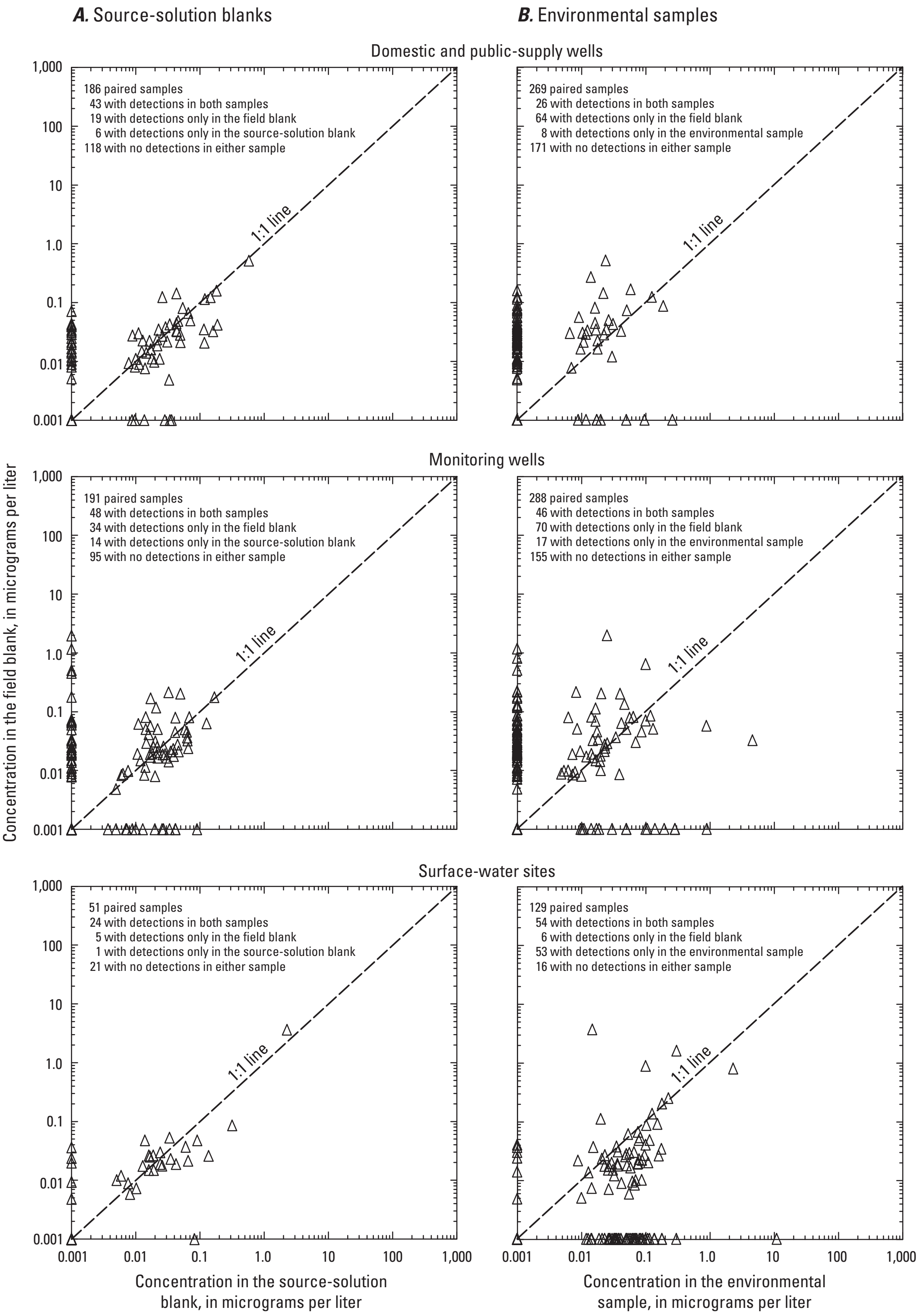


Figure 12. Relation of toluene concentrations, representing contamination category 4, between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.191 microgram per liter.

Domestic and Public-Supply Wells

Environmental concentrations can be compared to benchmarks without any potential for bias for the 54 VOCs not detected in field blanks (contamination category 1) collected from domestic and public-supply wells (table 5). Thus, application of a **censoring level** is not warranted for these 54 VOCs on the basis of the results described in this report.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the 10 compounds detected in field blanks and grouped into contamination category 2 (table 9). Environmental concentrations can be compared to benchmarks for these 10 VOCs without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. A censoring level of 0.02 µg/L could be applied to chloroform concentrations for comparisons by using no assessment level or for an assessment level of 0.02 µg/L.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the seven VOCs detected in field blanks and grouped into contamination category 3 (table 9). Environmental concentrations can be compared to benchmarks for these seven VOCs without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. A censoring level of 0.01 µg/L could be applied to carbon disulfide concentrations for comparisons by using no assessment level.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the 16 VOCs detected in field blanks and grouped into contamination category 4 (table 9). Environmental concentrations can be compared to benchmarks for the 16 VOCs without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. The following censoring levels could be applied to concentrations of 7 of these 16 VOCs for comparisons at different assessment levels: acetone (1 µg/L); dichloromethane (0.02 µg/L); ethylbenzene (0.008 µg/L); styrene (0.01 µg/L); toluene (0.05 µg/L); 1,2,4-trimethylbenzene (0.03 µg/L); and *m*- and *p*-xylene (0.02 µg/L).

In summary for environmental samples from domestic and public-supply wells, censoring levels are not warranted for any of the VOCs for comparisons to human-health benchmarks and 0.1 human-health benchmarks because any low-level contamination bias is at least an order of magnitude less than human-health benchmarks. Censoring levels could be applied to concentrations of nine VOCs for comparisons at different assessment levels for domestic and public-supply wells to account for potential low-level contamination bias associated with these selected VOCs.

Detections and concentrations of environmental samples at the historical NAWQA reporting level of 0.2 µg/L would have a small potential for contamination bias based on the 90-percent UCL for the 90th-percentile concentrations in field blanks and would not affect interpretation for most of the VOCs in samples from domestic and public-supply wells. Environmental concentrations of acetone, methyl ethyl ketone, and tetrahydrofuran may have the potential for some contamination bias at this historical reporting level of 0.2 µg/L because these VOCs have larger laboratory LT–MDLs than other VOCs (4, 2.5, and 4.5 µg/L, respectively).

Bracketing the potential contamination by comparing the detection and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to benchmarks are done in a study. For the nine VOCs detected in field blanks with a 90-percent UCL for the 90th-percentile concentration larger than a nondetection value, this provides an estimate of the potential contamination for these select VOCs.

Monitoring Wells

Environmental concentrations for the 43 VOCs not detected in field blanks (contamination category 1) collected from monitoring wells (table 6) can be compared to benchmarks without any potential for bias. Thus, application of a censoring level is not warranted for these 43 VOCs on the basis of the results described in this report.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the eight compounds detected in field blanks and grouped into contamination category 2 (table 10). Environmental concentrations of these eight VOCs can be compared to benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. Censoring levels could be applied at 0.07 µg/L for chloroform and at 0.01 µg/L for 1,2-dichloropropane, for comparisons by using no assessment level or at 0.07 µg/L for chloroform for an assessment level of 0.02 µg/L.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the seven VOCs detected in field blanks and grouped into contamination category 3 (table 10). Environmental concentrations of these seven VOCs can be compared to benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. A censoring level of 0.02 µg/L could be applied to environmental concentrations of carbon disulfide and 1,2,4-trimethylbenzene for comparisons by using no assessment level or for an assessment level of 0.02 µg/L.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the 29 VOCs detected in field blanks and grouped into contamination category 4 (table 10). Environmental concentrations for these 29 VOCs can be compared to benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. The following censoring levels could be applied to concentrations of 12 of these 29 VOCs for comparisons at different assessment levels: acetone (3.1 µg/L); benzene (0.013 µg/L); chlorobenzene

Table 9. Characterization of the need for censoring of environmental concentrations in samples from domestic and public-supply wells for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey, BM, human-health benchmark; μg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for environmental concentrations				
			For benchmark comparisons		For various assessment levels		
			1.0 x BM	0.1 x BM	0.2 μg/L	0.02 μg/L	No AL
Contamination category 2							
Bromodichloromethane	75–27–4	32101	None	None	None	None	None.
Chloroform	67–66–3	32106	None	None	None	**0.02**	**0.02**
Dibromochloromethane	124–48–1	32105	None	None	None	None	None.
1,2-Dichlorobenzene	95–50–1	34536	None	None	None	None	None.
4-Isoproyplytoluene	99–87–6	77356	--	--	None	None	None.
Methyl *tert*-butyl ether	1634–04–4	78032	--	--	None	None	None.
Naphthalene	91–20–3	34696	None	None	None	None	None.
1,1,1-Trichloroethane	71–55–6	34506	None	None	None	None	None.
Trichloroethene	79–01–6	39180	None	None	None	None	None.
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	None	None	None	None	None.
Contamination category 3							
Carbon disulfide	75–15–0	77041	None	None	None	None	**0.01**
Chloromethane	74–87–3	34418	None	None	None	None	None.
1,4-Dichlorobenzene	106–46–7	34571	None	None	None	None	None.
Dichlorodifluoromethane	75–71–8	34668	None	None	None	None	None.
1,2-Dichloropropane	78–87–5	34541	None	None	None	None	None.
Perchloroethene	127–18–4	34475	None	None	None	None	None.
Trichlorofluoromethane	75–69–4	34488	None	None	None	None	None.
Contamination category 4							
Acetone	67–64–1	81552	None	None	**1**	**1**	**1**
Benzene	71–43–2	34030	None	None	None	None	None.
Chlorobenzene	108–90–7	34301	None	None	None	None	None.
1,2-Dichloroethane	107–06–2	32103	None	None	None	None	None.
Dichloromethane	75–09–2	34423	None	None	None	**.02**	**.02**
Ethylbenzene	100–41–4	34371	None	None	None	None	**.008**
2-Ethyltoluene	611–14–3	77220	--	--	None	None	None.
Methyl ethyl ketone	78–93–3	81595	None	None	None	None	None.
Methyl isobutyl ketone	108–10–1	78133	--	--	None	None	None.
Styrene	100–42–5	77128	None	None	None	None	**.01**
Tetrahydrofuran	109–99–9	81607	--	--	None	None	None.
Toluene	108–88–3	34010	None	None	None	**.05**	**.05**

Table 9. Characterization of the need for censoring of environmental concentrations in samples from domestic and public-supply wells for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey, BM, human-health benchmark; µg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for environmental concentrations				
			For benchmark comparisons		For various assessment levels		
			1.0 x BM	0.1 x BM	0.2 µg/L	0.02 µg/L	No AL
			Contamination category 4—Continued				
1,2,3-Trimethylbenzene	526–73–8	77221	--	--	None	None	None.
1,2,4-Trimethylbenzene	95–63–6	77222	--	--	None	**0.03**	**0.03**
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	None	None	None	**.02**	**.02**
o-Xylene	95–47–6	77135	None	None	None	None	None.

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services℠.

(0.004 µg/L); 1,4-dichlorobenzene (0.007 µg/L); dichloromethane (0.04 µg/L); ethylbenzene (0.015 µg/L); methyl ethyl ketone (0.3 µg/L); styrene (0.005 µg/L); tetrahydrofuran (0.3 µg/L); toluene (0.08 µg/L); *m*- and *p*-xylene (0.04 µg/L); and *o*-xylene (0.009 µg/L).

In summary for environmental samples from monitoring wells, censoring levels are not warranted for any of the VOCs for comparisons to human-health benchmarks and 0.1 human-health benchmarks because any low-level contamination bias is at least an order of magnitude less than human-health benchmarks. Censoring levels could be applied to concentrations of 16 VOCs for comparisons at different assessment levels for monitoring wells to account for potential low-level contamination bias associated with these selected VOCs.

Detections and concentrations of VOCs in environmental samples at the historical NAWQA reporting level of 0.2 µg/L would have a small potential for contamination bias based on the 90-percent UCL for the 90th-percentile concentrations in field blanks and would not affect interpretation for most of the VOCs in samples from monitoring wells. Environmental concentrations of acetone, methyl ethyl ketone, and tetrahydrofuran may have the potential for some contamination bias at this historical reporting level of 0.2 µg/L because these VOCs have larger laboratory LT–MDLs than other VOCs (4, 2.5, and 4.5 µg/L, respectively).

Bracketing the potential contamination by comparing the detection and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to benchmarks are done in a study. For the 16 VOCs detected in field blanks with a 90-percent UCL for the 90th-percentile concentration larger than a nondetection value, this provides an estimate of the potential contamination for these select VOCs.

Surface-Water Sites

Environmental concentrations can be compared to benchmarks without any potential for bias for the 54 VOCs not detected in field blanks (contamination category 1) collected from surface-water sites (table 7). Thus, application of a censoring level is not warranted for these 54 VOCs on the basis of the results described in this report.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the 16 compounds detected in field blanks and grouped into contamination category 2 (table 11). Environmental concentrations of these 16 VOCs can be compared to benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. A censoring level of 0.05 µg/L could be applied to chloroform concentrations for comparisons by using no assessment level or for an assessment level of 0.02 µg/L.

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the 10 VOCs detected in field blanks and grouped into contamination category 3 (table 11). Environmental concentrations of these 10 VOCs can be compared to

Table 10. Characterization of the need for censoring of environmental concentrations in samples from monitoring wells for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey, BM, human-health benchmark; µg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for monitoring well concentrations				
			For benchmark comparisons		For various assessment levels		
			1.0 x BM	0.1 x BM	0.2 µg/L	0.02 µg/L	No AL
Contamination category 2							
Chloroform	67–66–3	32106	None	None	None	**0.07**	**0.07**
Dibromochloromethane	124–48–1	32105	None	None	None	None	None.
1,2-Dichloropropane	78–87–5	34541	None	None	None	None	**.01**
4-Isoproyplytoluene	99–87–6	77356	--	--	None	None	None.
Perchloroethene	127–18–4	34475	None	None	None	None	None.
1,2,3,5-Tetramethylbenzene	527–53–7	50000	--	--	None	None	None.
1,1,1-Trichloroethane	71–55–6	34506	None	None	None	None	None.
1,2,3-Trimethylbenzene	526–73–8	77221	--	--	None	None	None.
Contamination category 3							
Bromodichloromethane	75–27–4	32101	None	None	None	None	None.
Carbon disulfide	75–15–0	77041	None	None	None	**0.02**	**0.02**
Chloromethane	74–87–3	34418	None	None	None	None	None.
Methyl *tert*-butyl ether	1634–04–4	78032	--	--	None	None	None.
Trichloroethene	79–01–6	39180	None	None	None	None	None.
Trichlorofluoromethane	75–69–4	34488	None	None	None	None	None.
1,2,4-Trimethylbenzene	95–63–6	77222	--	--	None	**.02**	**.02**
Contamination category 4							
Acetone	67–64–1	81552	None	None	**3.1**	**3.1**	**3.1**
Benzene	71–43–2	34030	None	None	None	None	**.01**
Bromomethane	74–83–9	34413	None	None	None	None	None.
n-Butylbenzene	104–51–8	77342	--	--	None	None	None.
sec-Butylbenzene	135–98–8	77350	--	--	None	None	None.
Chlorobenzene	108–90–7	34301	None	None	None	None	**.004**
2-Chlorotoluene	95–49–8	77275	None	None	None	None	None.
Dibromomethane	74–95–3	30217	--	--	None	None	None.
1,2-Dichlorobenzene	95–50–1	34536	None	None	None	None	None.
1,4-Dichlorobenzene	106–46–7	34571	None	None	None	None	**.007**
1,2-Dichloroethane	107–06–2	32103	None	None	None	None	None.
Dichloromethane	75–09–2	34423	None	None	None	**.04**	**.04**
Ethylbenzene	100–41–4	34371	None	None	None	**.02**	**.02**
2-Ethyltoluene	611–14–3	77220	--	--	None	None	None.
Iodomethane	74–88–4	77424	--	--	None	None	None.

Table 10. Characterization of the need for censoring of environmental concentrations in samples from monitoring wells for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey, BM, human-health benchmark; µg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for monitoring well concentrations				
			For benchmark comparisons		For various assessment levels		
			1.0 x BM	0.1 x BM	0.2 µg/L	0.02 µg/L	No AL
Contamination category 4—Continued							
Isopropylbenzene	98–82–8	77223	None	None	None	None	None.
Methyl ethyl ketone	78–93–3	81595	None	None	**0.3**	**0.3**	**0.3**
Methyl isobutyl ketone	108–10–1	78133	--	--	None	None	None.
Naphthalene	91–20–3	34696	None	None	None	None	None.
n-Propylbenzene	103–65–1	77224	--	--	None	None	None.
Styrene	100–42–5	77128	None	None	None	None	**.005**
Tetrahydrofuran	109–99–9	81607	--	--	**.3**	**.3**	**.3**
1,2,3,4-Tetramethylbenzene	488–23–3	49999	--	--	None	None	None.
Toluene	108–88–3	34010	None	None	None	**.08**	**.08**
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	None	None	None	None	None.
1,3,5-Trimethylbenzene	108–67–8	77226	--	--	None	None	None.
Vinyl chloride	75–01–4	39175	None	None	None	None	None.
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	None	None	None	**.04**	**.04**
o-Xylene	95–47–6	77135	None	None	None	None	**.009**

[1] This report contains Chemical Abstracts Service Registry numbers (CASRN)®, which is a Registered Trademark of the American Chemical Society. A CASRN is a numeric identifier that can contain up to nine digits, divided by dashes into three parts. For example, 67–66–3 is the CASRN for chloroform. The online database provides a source for the latest registry number information: *http://www.cas.org/*. Chemical Abstracts Service recommends the verification of the CASRNs through CAS Client Services^{SM}.

benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. The following censoring levels could be applied to concentrations of six VOCs for comparisons by using various assessment levels: acetone (3 µg/L); ethylbenzene (0.01 µg/L); methyl ethyl ketone (0.2 µg/L); toluene (0.09 µg/L); *m*- and *p*-xylene (0.03 µg/L); and *o*-xylene (0.01 µg/L).

The 90-percent UCL for the 90th-percentile concentration is at least an order of magnitude less than human-health benchmarks for the seven VOCs detected in field blanks and grouped into contamination category 4 (table 11). Environmental concentrations of these seven VOCs can be compared to benchmarks without any potential for bias for exceedances of a benchmark or within 0.1 of a benchmark. A censoring level of 0.01 µg/L could be applied to concentrations of 2 of these 7 VOCs, dichloromethane and styrene, for comparison by using different assessment levels.

In summary for environmental samples from surface-water sites, censoring levels are not warranted for any of the VOCs for comparisons to human-health benchmarks and 0.1 human-health benchmarks because any low-level contamination bias is at least an order of magnitude less than human-health benchmarks. A censoring level could be applied to concentrations of nine VOCs for comparisons at different assessment levels for surface-water samples to account for potential low-level contamination bias associated with these selected VOCs.

Detections and concentrations of environmental samples at the historical NAWQA reporting level of 0.2 µg/L would have a small potential for contamination bias based on the

Table 11. Characterization of the need for censoring environmental concentrations in samples from surface-water sites for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; BM, human-health benchmark; AQCR, aquatic-life criteria; µg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for surface-water concentrations						
			For benchmark comparisons				For various assessment levels		
			1.0 x BM	0.1 x BM	1.0 AQCR	0.1 AQCR	0.2 µg/L	0.02 µg/L	No AL
Contamination category 2									
Benzene	71–43–2	34030	None	None	None	None	None	None	None.
Bromodichloromethane	75–27–4	32101	None	None	--	--	None	None	None.
Chloroform	67–66–3	32106	None	None	None	None	None	**0.05**	**0.05**
Chloromethane	74–87–3	34418	None	None	--	--	None	None	None.
Dichlorodifluoromethane	75–71–8	34668	None	None	--	--	None	None	None.
1,1-Dichloroethene	75–35–4	34501	None	None	--	--	None	None	None.
Isopropylbenzene	98–82–8	77223	None	None	--	--	None	None	None.
4-Isoproyplytoluene	99–87–6	77356	--	--	--	--	None	None	None.
Methyl *tert*-butyl ether	1634–04–4	78032	--	--	--	--	None	None	None.
Naphthalene	91–20–3	34696	None	None	None	None	None	None	None.
Perchloroethene	127–18–4	34475	None	None	None	None	None	None	None.
n-Propylbenzene	103–65–1	77224	--	--	--	--	None	None	None.
1,1,1-Trichloroethane	71–55–6	34506	None	None	--	--	None	None	None.
Trichloroethene	79–01–6	39180	None	None	None	None	None	None	None.
1,2,4-Trimethylbenzene	95–63–6	77222	--	--	--	--	None	None	None.
1,1,2-Trichloro-1,2,2-trifluoroethane	76–13–1	77652	None	None	--	--	None	None	None.
Contamination category 3									
Acetone	67–64–1	81552	None	None	--	--	**3**	**3**	**3**
Carbon disulfide	75–15–0	77041	None	None	--	--	None	None	None.
Chlorobenzene	108–90–7	34301	None	None	None	None	None	None	None.
1,4-Dichlorobenzene	106–46–7	34571	None	None	None	None	None	None	None.
Ethylbenzene	100–41–4	34371	None	None	None	None	None	None	**.01**
Methyl ethyl ketone	78–93–3	81595	None	None	--	--	**.2**	**.2**	**.2**
Toluene	108–88–3	34010	None	None	None	None	None	**.09**	**.09**
Vinyl chloride	75–01–4	39175	None	None	--	--	None	None	None.
m- and *p*-Xylene	*m*:108–38–3 *p*:106–42–3	85795	None	None	--	--	None	**.03**	**.03**
o-Xylene	95–47–6	77135	None	None	--	--	None	None	**.01**

Table 11. Characterization of the need for censoring environmental concentrations in samples from surface-water sites for comparison to benchmarks and various assessment levels for volatile organic compounds analyzed from October 1996 to December 2008.—Continued

[**Boldface** values indicate that the compound has a quantified concentration for the 90-percent upper confidence limit for the 90th percentile. USGS, U.S. Geological Survey; BM, human-health benchmark; AQCR, aquatic-life criteria; µg/L, microgram per liter; AL, assessment level; None, additional censoring not needed to account for contamination bias; --, not available]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Censoring levels for surface-water concentrations						
			For benchmark comparisons				For various assessment levels		
			1.0 x BM	0.1 x BM	1.0 AQCR	0.1 AQCR	0.2 µg/L	0.02 µg/L	No AL
			Contamination category 4						
Dichloromethane	75–09–2	34423	None	None	None	None	None	None	**0.01**
1,2-Dichloropropane	78–87–5	34541	None	None	--	--	None	None	None.
Diethyl ether	60–29–7	81576	None	None	--	--	None	None	None.
Ethyl *tert*-butyl ether	637–92–3	50004	--	--	--	--	None	None	None.
Styrene	100–42–5	77128	None	None	--	--	None	None	**.01**
Tetrahydrofuran	109–99–9	81607	--	--	--	--	None	None	None.
Trichlorofluoromethane	75–69–4	34488	None	None	--	--	None	None	None.

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90-percent UCL for the 90th-percentile concentrations in field blanks and would not affect interpretation for most of the VOCs in surface-water samples. Environmental concentrations of acetone, methyl ethyl ketone, and tetrahydrofuran may have the potential for some contamination bias at this historical reporting level of 0.2 µg/L because these VOCs have larger laboratory LT–MDLs than other VOCs (4, 2.5, and 4.5 µg/L, respectively).

Bracketing the potential contamination by comparing the detection and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to benchmarks are done in a study. For the nine VOCs detected in field blanks with a 90-percent UCL for the 90th-percentile concentration larger than a nondetection value, this provides an estimate of the potential contamination for these select VOCs.

Effectiveness of Native Water Rinsing in Reducing Potential Contamination to Environmental Samples

The effectiveness of the native water rinse in removing potential contamination from the sampling equipment is crucial to the sampling process. An inference about the causes of contamination observed in field blanks is especially important, because the source of contamination helps describe the nature of contamination to environmental samples; specifically, contamination evident in field blanks is carried over to subsequently collected environmental samples. This process also provides the basis to use NAWQA's paired field blank and environmental samples to assess the effectiveness of native water rinsing (after a field blank is collected) in reducing or eliminating contamination in environmental samples. One measure of the effectiveness of native water rinsing for a specific VOC is to determine how frequently a detection in a field blank is followed by a nondetection in the subsequently collected environmental sample, which is termed the “minimum percent effectiveness” of native water rinsing in this report. The calculated minimum percent effectiveness describes how frequently a VOC detected in a field blank was not detected in the subsequently collected environmental sample. The calculated value is considered a minimum because native water rinsing may have been 100 percent effective in reducing carryover contamination from the field blank for some (or all) of the paired samples with a detection in the field blank and environmental samples. That is, the detection in the environmental sample of these paired samples was a true environmental detection.

The concentration plots of field blank and environmental samples (appendix 2) can be used to describe some general observations about the relation between the detection of select VOCs in field blanks and environmental samples. For most VOCs, the detection of a compound in a field blank did not mean the VOC was detected in subsequent environmental samples. An example is chloroform (fig. 10), which was detected more frequently in environmental samples from the three site types than in the paired field blanks. Figure 10 also shows that when chloroform was detected in a field blank, a visual 1:1 relation between the concentrations in the subsequent environmental sample for all three site types is not apparent. This pattern is evident for the selected VOCs shown in appendix 2.

The minimum percent effectiveness of native water rinsing for select VOCs for the three NAWQA site types is listed in table 12. Overall, the median of the minimum percent effectiveness of native water rinsing is about 79 percent for the 19 VOCs detected in more than 5 percent of field blanks from all three site types. Surface-water sites had the smallest median minimum percent effectiveness of native water rinsing of about 70 percent followed by monitoring wells (about 81 percent). Domestic and public-supply wells had the largest median minimum percent effectiveness of native water rinsing (about 88 percent). Native water rinsing had the smallest minimum percent effectiveness for toluene for surface-water sites (10 percent), which likely is because of the large detection frequency of toluene in surface-water samples (about 79 percent) and the associated field blanks (46.5 percent).

The median values of the minimum percent effectiveness of native water rinsing show that even if a VOC is detected in a field blank, there is about a 79-percent chance that the compound is not going to be detected in the subsequent environmental sample. These findings collaborate well with the study by Taglioli and others (2001) that showed even when sampling equipment is contaminated at low levels; the potential for carryover contamination to the environmental samples is markedly reduced to less than current (2011) analytical levels because of native water rinsing.

Summary

This report describes the quality of volatile organic compound (VOC) data collected from October 1996 to December 2008 from groundwater and surface-water sites located in National Water-Quality Assessment (NAWQA) Study Units. The quality of data is described for 87 VOCs collected for three NAWQA site types: domestic and public-supply wells, monitoring wells, and surface-water sites. Contamination bias, based on the 90-percent upper confidence limit (UCL) for the 90th percentile of concentrations in field blanks, was determined for VOC samples from these three site types. A secondary objective was to describe how important native water rinsing may be in decreasing carryover contamination, which could be affecting detections in field blanks.

The VOCs can be classified into four contamination categories on the basis of the 90-percent UCL concentration distribution in field blanks. Contamination category 1 includes compounds that were not detected in any field blanks. Contamination category 2 includes VOCs that had a 90-percent UCL concentration distribution in field blanks that was at least an order of magnitude lower than the concentration distribution in the environmental samples. Contamination category 3 includes VOCs that had a 90-percent UCL concentration distribution in field blanks that was of the same order of magnitude to the distribution in environmental samples. Contamination category 4 includes VOCs that had a 90-percent UCL concentration distribution in field blanks that was at least an order of magnitude larger than the concentration distribution of environmental samples. The results described in this report can be applied to interpretation of the environmental data collected from October 1996 to December 2008 from NAWQA Study Units. The results also provide a basis for comparison with quality-control results for samples collected in U.S. Geological Survey studies by using the protocols outlined in the National Field Manual for Collection of Water-Quality Data as a guide for cleaning, collection, and processing of samples.

Fifty-four of the 87 VOCs analyzed in field blanks from domestic and public-supply wells were not detected (contamination category 1), and 33 VOCs were detected in field blanks. Ten of the 33 VOCs had a 90-percent UCL concentration distribution in field blanks that was much lower than the concentration distribution in environmental samples (contamination category 2). These 10 VOCs may have had some contamination bias associated with the environmental samples, but the potential bias was negligible in comparison to the concentration distribution of the environmental samples; therefore, the field blanks were assumed to be representative of the sources of contamination bias affecting the environmental samples for these 10 VOCs. Seven of the 33 VOCs detected in field blanks had a 90-percent UCL concentration distribution of field blanks that was similar to the concentration distribution of the environmental samples (contamination category 3). Sixteen of the 33 VOCs had a 90-percent UCL concentration distribution of the field blanks that was markedly greater than the concentration distribution of the environmental samples

Table 12. Minimum percent effectiveness of native water rinsing in eliminating contamination evident from field blanks for samples collected from domestic and public-supply wells, monitoring wells, and surface-water sites for selected volatile organic compounds analyzed from October 1996 to December 2008.

[USGS, U.S. Geological Survey; NAWQA, U.S. Geological Survey National Water-Quality Assessment Program]

Compound name	Chemical Abstracts Service Registry number[1]	USGS parameter code	Minimum percent effectiveness of native water rinsing for NAWQA site types[2]		
			Domestic and public-supply wells	Monitoring wells	Surface-water sites
Acetone	67–64–1	81552	90.9	95.5	47.4
Benzene	71–43–2	34030	100	80.6	42.9
Bromodichloromethane	75–27–4	32101	100	100	100
Carbon disulfide	75–15–0	77041	75	69.7	62.5
Chlorobenzene	108–90–7	34301	100	100	71.4
Chloroform	67–66–3	32106	61.3	54.9	51.9
Chloromethane	74–87–3	34418	33.3	60	57.1
1,4-Dichlorobenzene	106–46–7	34571	80	75.8	77.8
Dichloromethane	75–09–2	34423	87.5	82.8	70
1,2-Dichloropropane	78–87–5	34541	100	100	100
Ethylbenzene	100–41–4	34371	100	78.7	85.7
Methyl ethyl ketone	78–93–3	81595	80	88.9	50
Perchloroethene	127–18–4	34475	60	35.0	25
Styrene	100–42–5	77128	85.2	85.2	76.5
Tetrahydrofuran	109–99–9	81607	100	93.5	100
Toluene	108–88–3	34010	71.1	60.3	10
1,2,4-Trimethylbenzene	95–63–6	77222	67.4	73.0	100
m- and *p*-Xylene	*m:*108–38–3 *p:*106–42–3	85795	100	76.8	47.8
o-Xylene	95–47–6	77135	100	81.5	78.6

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[2] For those paired field blanks and environmental samples that have a detection in the field blank, effectiveness is defined as reducing the detection in the field blank to a nondetection in the subsequent environmental sample.

(contamination category 4). Field blanks for these 16 VOCs appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions and in many cases higher frequency of detection in field blanks than in environmental samples. Nine of the 33 VOCs detected in field blanks from domestic and public-supply wells may have some contamination bias associated with the environmental samples based on the 90-percent UCL. Censoring levels could be applied to concentrations of these nine VOCs for comparisons at different assessment levels for domestic and public-supply wells to account for potential low-level contamination bias associated with these selected VOCs: chloroform at 0.02 µg/L from contamination category 2; carbon disulfide at 0.01 µg/L from contamination category 3; and acetone at 1 µg/L, dichloromethane at 0.02 µg/L, ethylbenzene at 0.008 µg/L, styrene at 0.01 µg/L, toluene at 0.05 µg/L, 1,2,4-trimethylbenzene at 0.03 µg/L, and *m*- and *p*-xylene at 0.02 µg/L from contamination category 4.

The concentration distributions of the 90-percent UCL have a visually similar relation for some VOCs between paired source-solution and field blanks from domestic and public-supply wells. These VOCs include acetone, benzene, bromodichloromethane, chlorobenzene, dichloromethane, 1,2-dichloropropane, methyl ethyl ketone, styrene, tetrahydrofuran, toluene, and *m*- and *p*-xylene. This relation for these 11 VOCs may indicate that source-solution water (that is, the volatile-pesticide grade blank water) became contaminated during shipment to the field or during storage before use, or that the source-solution and field blanks had a similar contamination source that may be associated with the preservation, shipment back to the National Water Quality Laboratory (NWQL), or storage and analysis at the NWQL. Detections for a few compounds were dissimilar between the paired source-solution and field blanks. This result could be caused by (1) insufficient rinsing of collection equipment with volatile-pesticide grade blank water before the collection of the field blank, (2) residual contamination associated with the equipment, or (3) a contamination source associated with the preservation, shipment back to the NWQL, or storage and analysis at the NWQL.

Forty-three of the 87 VOCs analyzed in field blanks from monitoring wells were not detected (contamination category 1), and 44 VOCs were detected in field blanks. Some contamination bias may be associated with the environmental samples for 8 of the 44 VOCs detected in field blanks. However, the contamination bias was negligible in comparison to the concentration distribution of the environmental samples based on the 90-percent UCL, and the field blanks were assumed to be representative of the sources of contamination bias to the environmental samples (contamination category 2). Seven of the 44 VOCs had a concentration distribution for the 90-percent UCL of the field blanks that was within the same order of magnitude of the concentration distribution of the environmental samples (contamination category 3). Twenty-nine of the 44 VOCs had a concentration distribution for the 90-percent UCL of the field blanks that was at least an order of magnitude greater than the concentration distribution of the environmental samples (contamination category 4). Field blanks for these 29 VOCs appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions and in most cases higher frequency of detection in field blanks than in environmental samples. Sixteen of the 44 VOCs detected in field blanks may have some contamination bias associated with the environmental samples based on the 90-percent UCL. Censoring levels could be applied to concentrations of these 16 VOCs for comparisons at different assessment levels for monitoring wells to account for potential low-level contamination bias associated with these selected VOCs. The censoring levels for these 16 VOCs follow: chloroform (0.07 µg/L) and 1,2-dichloropropane (0.01 µg/L) from contamination category 2; carbon disulfide (0.02 µg/L) and 1,2,4-trimethylbenzene (0.02 µg/L) from contamination category 3; and acetone (3.1 µg/L), benzene (0.013 µg/L), chlorobenzene (0.004 µg/L), 1,4-dichlorobenzene (0.007 µg/L), dichloromethane (0.04 µg/L), ethylbenzene (0.015 µg/L), methyl ethyl ketone (0.3 µg/L), styrene (0.005 µg/L), tetrahydrofuran (0.3 µg/L), toluene (0.08 µg/L), *m*- and *p*-xylene (0.04 µg/L), and *o*-xylene (0.009 µg/L) from contamination category 4.

The concentration distributions of the 90-percent UCL have a visually similar relation for some VOCs between paired source-solution and field blanks from monitoring wells. These VOCs include bromodichloromethane, 1,4-dichlorobenzene, 1,2-dichloropropane, and toluene. This similar relation for these four VOCs may indicate that source-solution water became contaminated during shipment to the field or storage before use, or that the source-solution and field blanks had a similar contamination source that may be associated with the preservation, shipment back to the NWQL, or storage and analysis at the NWQL. Detections for a few compounds were dissimilar between the paired source-solution and field blanks. This dissimilarity could be caused by (1) insufficient rinsing of the collection equipment with volatile-pesticide grade blank water being before the collection of the field blank, (2) residual contamination associated with the equipment, or (3) a contamination source associated with the preservation, shipment back to the NWQL, or storage and analysis at the NWQL.

Fifty-four of the 87 VOCs analyzed field blanks from surface-water sites were not detected (contamination category 1), and 33 VOC were detected in field blanks. Some contamination bias may be associated with the environmental samples for 16 of the 33 VOCs detected in field blanks. However, the contamination bias was negligible, on the basis of the 90-percent UCL, in comparison to the concentration distribution of the environmental samples, and the field blanks were assumed to be representative of the sources of contamination bias to the environmental samples (contamination category 2). Ten of the 33 VOCs had a concentration distribution for the 90-percent UCL of the field blanks that was of the same order of magnitude to the concentration distribution of the environmental samples (contamination category 3). Seven of the 33 VOCs had a concentration distribution for the 90-percent UCL of the field blanks that was at least an order of magnitude greater than the concentration distribution of the environmental samples (contamination category 4). Field blanks for these seven VOCs appear to be nonrepresentative of the sources of contamination bias to the environmental samples because of the larger concentration distributions (and in most cases frequency of detections) in field blanks than in environmental samples. Nine of the 33 VOCs detected in field blanks may have some contamination bias associated with the environmental samples based on the 90-percent UCL. Censoring levels could be applied to concentrations of these nine VOCs for comparisons at different assessment levels for surface-water sites to account for potential low-level contamination bias associated with these selected VOCs. The censoring levels for these nine VOCs follow: chloroform (0.05 µg/L) from contamination category 2; acetone (3 µg/L), ethylbenzene (0.01 µg/L), methyl ethyl ketone (0.2 µg/L), toluene (0.09 µg/L), *m*- and *p*-xylene (0.03 µg/L), and *o*-xylene (0.01 µg/L) from contamination category 3; and dichloromethane (0.01 µg/L) and styrene (0.01 µg/L) from contamination category 4. Bracketing the potential contamination by comparing the detection and concentration statistics with no censoring applied to the potential for contamination bias on the basis of the 90-percent UCL for the 90th-percentile concentrations in field blanks may be useful when comparisons to benchmarks are done in a study.

The concentration distributions of the 90-percent UCL have a visually similar relation for some VOCs between paired source-solution and field blanks from surface-water sites. These select VOCs include acetone, benzene, bromodichloromethane, carbon disulfide, chlorobenzene, chloroform, 1,4-dichlorobenzene, dichloromethane, 1,2-dichloropropane, ethylbenzene, methyl ethyl ketone, perchloroethene, tetrahydrofuran, toluene, 1,2,4-trimethylbenzene, and *m*- and *p*-xylene. The similar relation for these 16 VOCs may indicate that source-solution water became contaminated during shipment to the field or storage before use, or that the source-solution blank and field blank had a similar contamination source that may be associated with the preservation, shipment back to the NWQL, or storage and analysis at the NWQL. A few compounds have dissimilar detection patterns between the paired source-solution blanks and field blanks. This dissimilarity could be caused by (1) insufficient rinsing of the collection equipment with volatile-pesticide grade blank water before the collection of the field blank, (2) residual contamination associated with the equipment, or (3) a contamination source associated with the preservation, shipment back to the NWQL, or storage and analysis at the NWQL.

The relation between the detection of a compound in field blanks and detection in subsequent environmental samples appears to be minimal. The median minimum percent effectiveness of native water rinsing is about 79 percent for the 19 VOCs detected in more than 5 percent in field blanks from all three site types. The smallest minimum percent effectiveness of native water rinsing (10 percent) was for toluene in surface-water samples, likely because of the high detection frequency of toluene in surface-water samples (about 79 percent) and in the associated field-blank samples (46.5 percent). A previous study of contamination carryover found that most of the VOCs do not carry over from contaminated equipment to the subsequent environmental samples. A previous field contamination study showed that if protocols are rigorously followed and fresh field sampling supplies are used, a marked decrease in contamination (detections and concentrations) of field blanks is observed.

Comparison of the detection frequency and concentrations of environmental samples at the historical reporting level of 0.2 µg/L would have a small potential for contamination bias based on the 90-percent UCL for the 90th percentile of concentrations in field blanks and would not affect interpretation for the majority of the VOCs. Acetone, methyl ethyl ketone, and tetrahydrofuran may have a larger potential for contamination bias at this historical reporting level of 0.2 µg/L because these three compounds have larger laboratory reporting levels than other VOCs.

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Glossary of Data-Quality Terms

Assessment level A concentration selected by a hydrologist and applied to water-quality data that have variable laboratory reporting levels either for a specific compound or between individual compounds. The assessment level is applied to data received from the laboratory and is applied subsequent to the laboratory reporting level. Concentrations reported by the laboratory but less than the assessment level are considered as "nondetections" in the calculation of occurrence statistics. The primary purpose of the assessment level is for accurate comparison of detection frequencies and median concentrations between individual VOCs, groups of VOCs, and to previous studies.

Bias The systematic error inherent in a method; the error can be either positive or negative.

Blank sample A sample prepared from water that is free of the analyte(s) of interest for determining contamination.

Bracketing set blank A laboratory continuing set blank sample analyzed periodically throughout the analytical sequence to confirm the continued absence of contamination in the instrument and subsequent samples. Sample bracketing blanks are used to help distinguish between true low-concentration environmental contamination and blank contamination.

Censoring level An arbitrary concentration applied to specific VOCs. In this report these censoring levels are based on the 90-percent upper confidence limit for the 90th percentile of concentrations. The VOC data would be censored to a nondetection for concentrations less than this level.

Contamination bias A positive bias caused by the inadvertent introduction of analytes into water samples during sample collection, processing, shipment, or analysis.

Detection frequency The frequency of detection of an individual VOC that was computed as the number of samples with a detection of an individual VOC (VOC passing all qualification criteria) divided by the number of samples in which the VOC was analyzed, times 100.

Field blank A blank sample that has been exposed in the field to all sampling equipment and conditions that normally are associated with the collection of an environmental sample.

Instrument blank A laboratory set blank sample analyzed to verify the instrument does not have unacceptable background or instrument problems.

Laboratory set blank A laboratory continuing set blank (bracketing blank) sample analyzed periodically throughout the analytical sequence to confirm the continued absence of contamination in the instrument and subsequent samples. These continuing set blanks bracket a set of samples and are used to help distinguish between true low-concentration environmental contamination and blank contamination.

Quality assessment The overall process of assessing the quality of environmental data by reviewing the application of the quality-assurance elements and the analysis of the quality-control data.

Quality assurance (QA) Procedures used to control the nonquantifiable components of a study, such as sampling at the correct location with the proper equipment and by using the appropriate methods.

Quality-control (QC) Data generated to estimate the magnitude of the bias and variability in the process of obtaining environmental data.

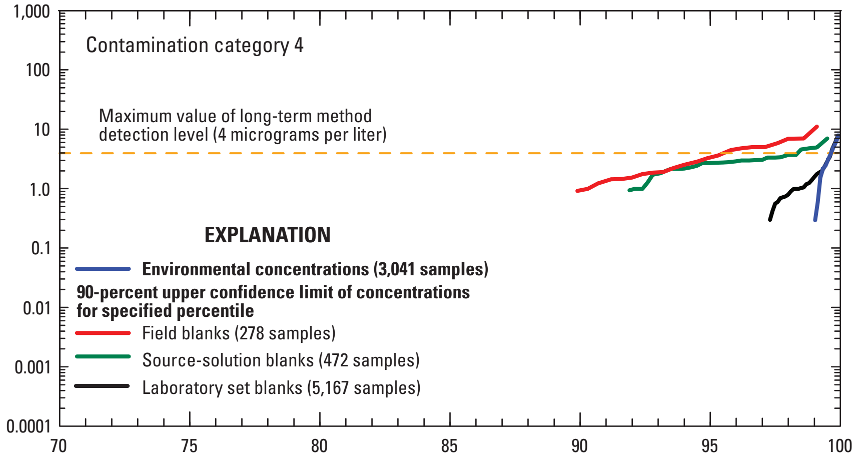
Source-solution blank A sample of blank water taken directly from the source container without exposure to sampling equipment or conditions.

Systematic contamination Contamination that is one directional and similar in magnitude. Contamination from a single source has these characteristics (one directional and similar in magnitude) and usually results in associated samples with the same direction and similar magnitude. Whether the contamination detected in the associated blanks is systematic is best determined before attempting to account for the contamination in the interpretation of the environmental values.

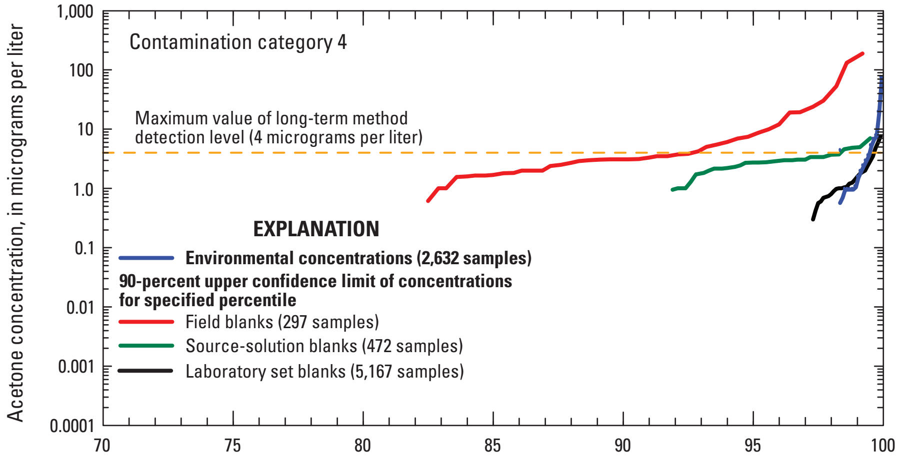
Appendix 1. Concentration Distributions for the 90-Percent Upper Confidence Limit for 48 Volatile Organic Compounds Detected in Field-Blank Samples

Figures A1–1 to A1–49. Distribution of environmental concentrations and 90-percent upper confidence limits of concentrations in field blanks, source-solution blanks, and laboratory set blanks for *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites for the following volatile organic compounds. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

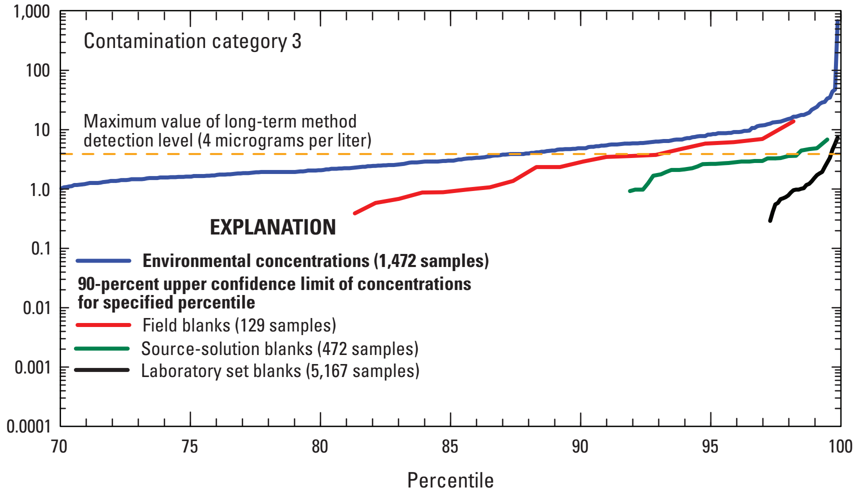


Figure A1–1. Distribution of environmental concentrations and 90-percent upper confidence limits of acetone concentrations in field blanks, source-solution blanks, and laboratory set blanks for *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

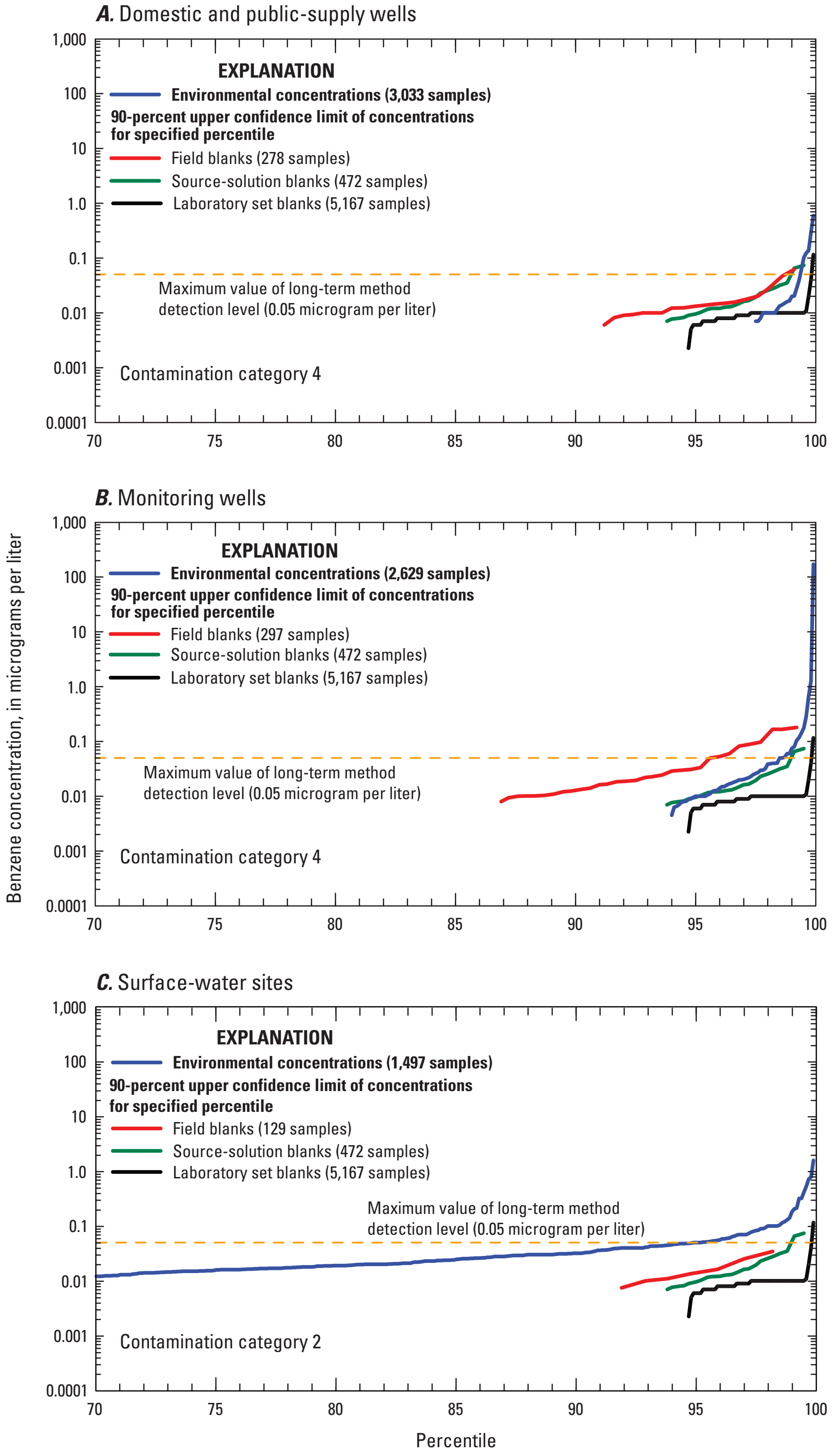


Figure A1–2. Distribution of environmental concentrations between field blanks and paired samples of benzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

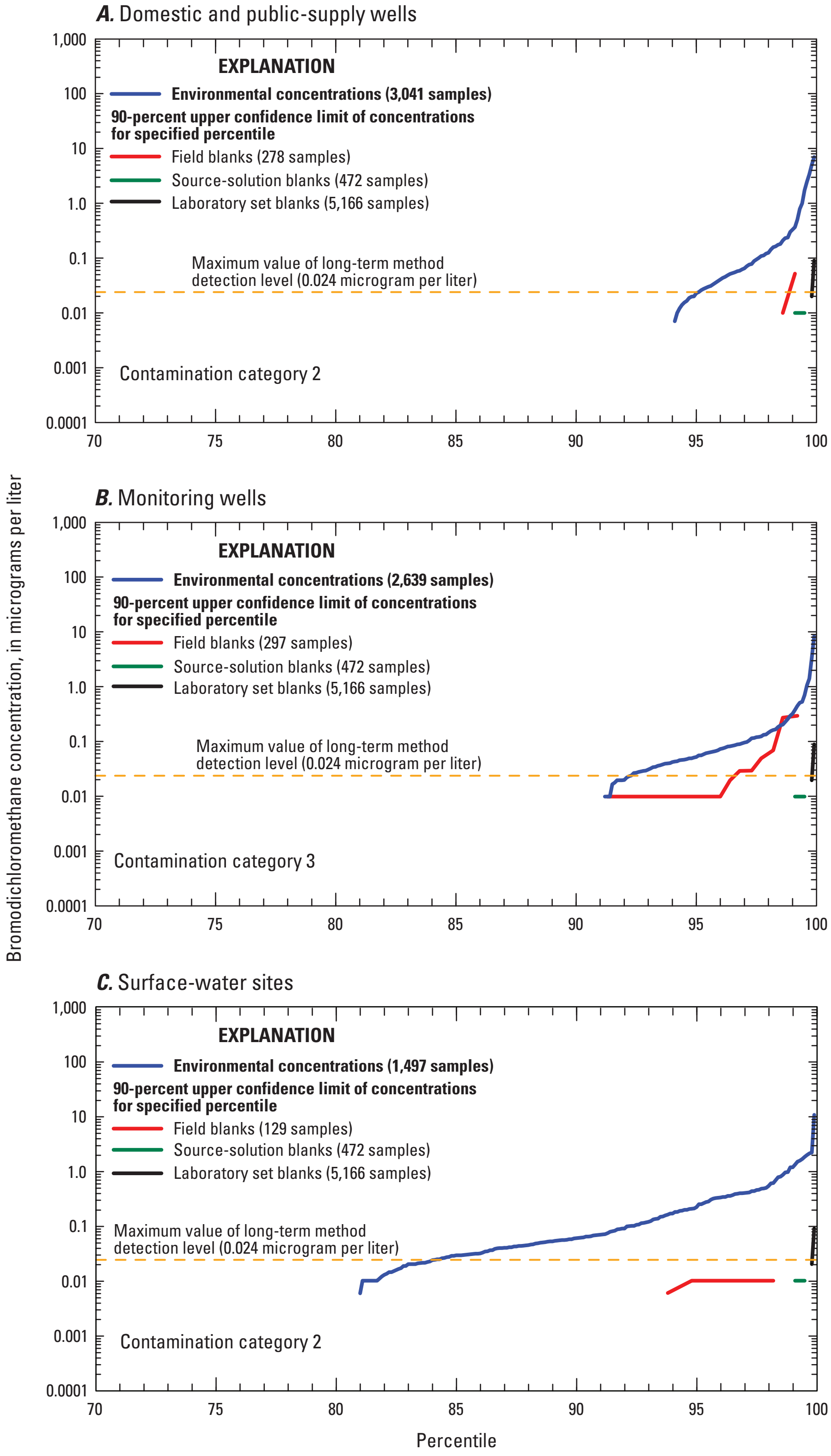


Figure A1–3. Distribution of environmental concentrations and 90-percent upper confidence limits of bromodichloromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

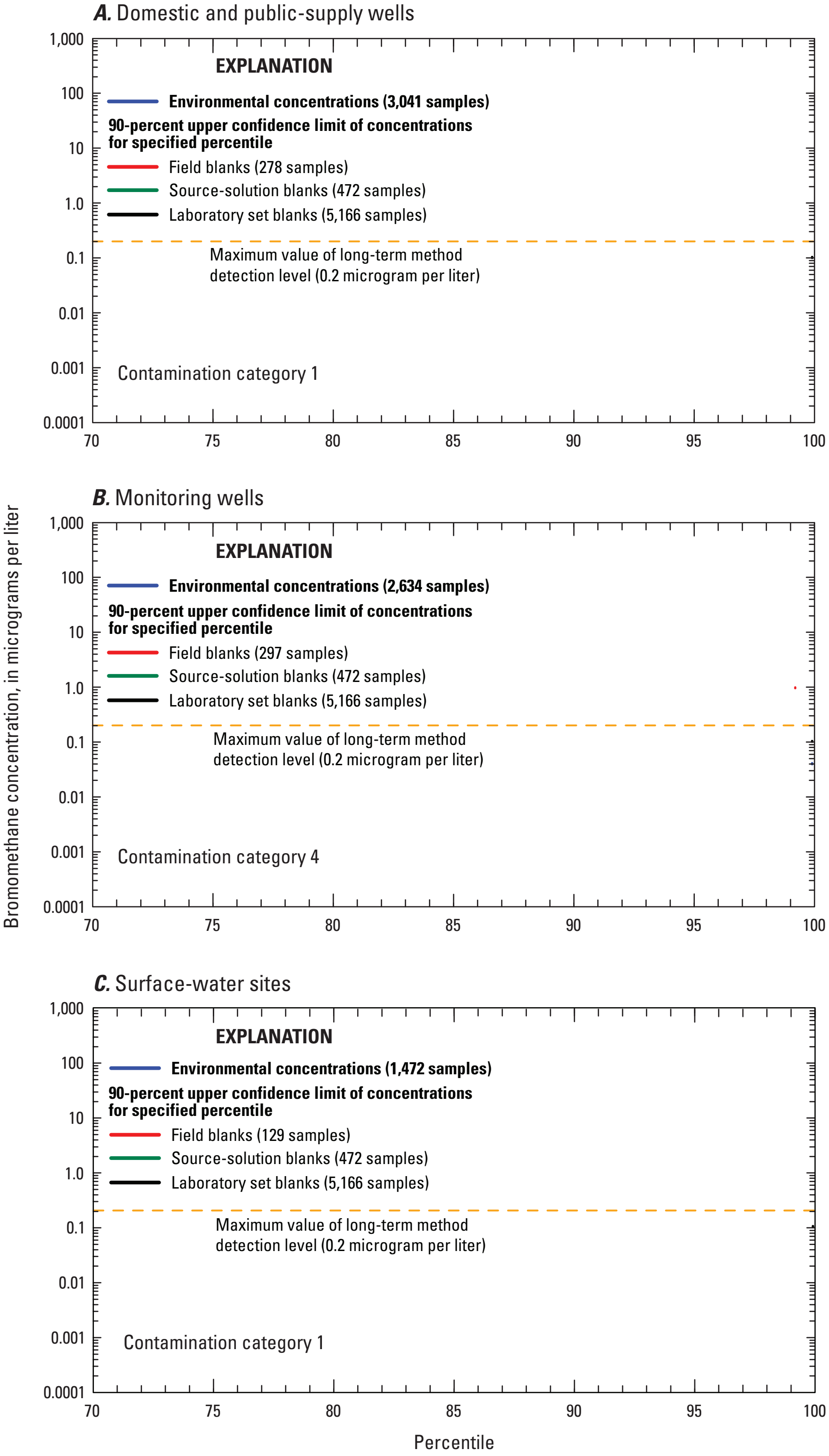


Figure A1–4. Distribution of environmental concentrations and 90-percent upper confidence limits of bromomethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

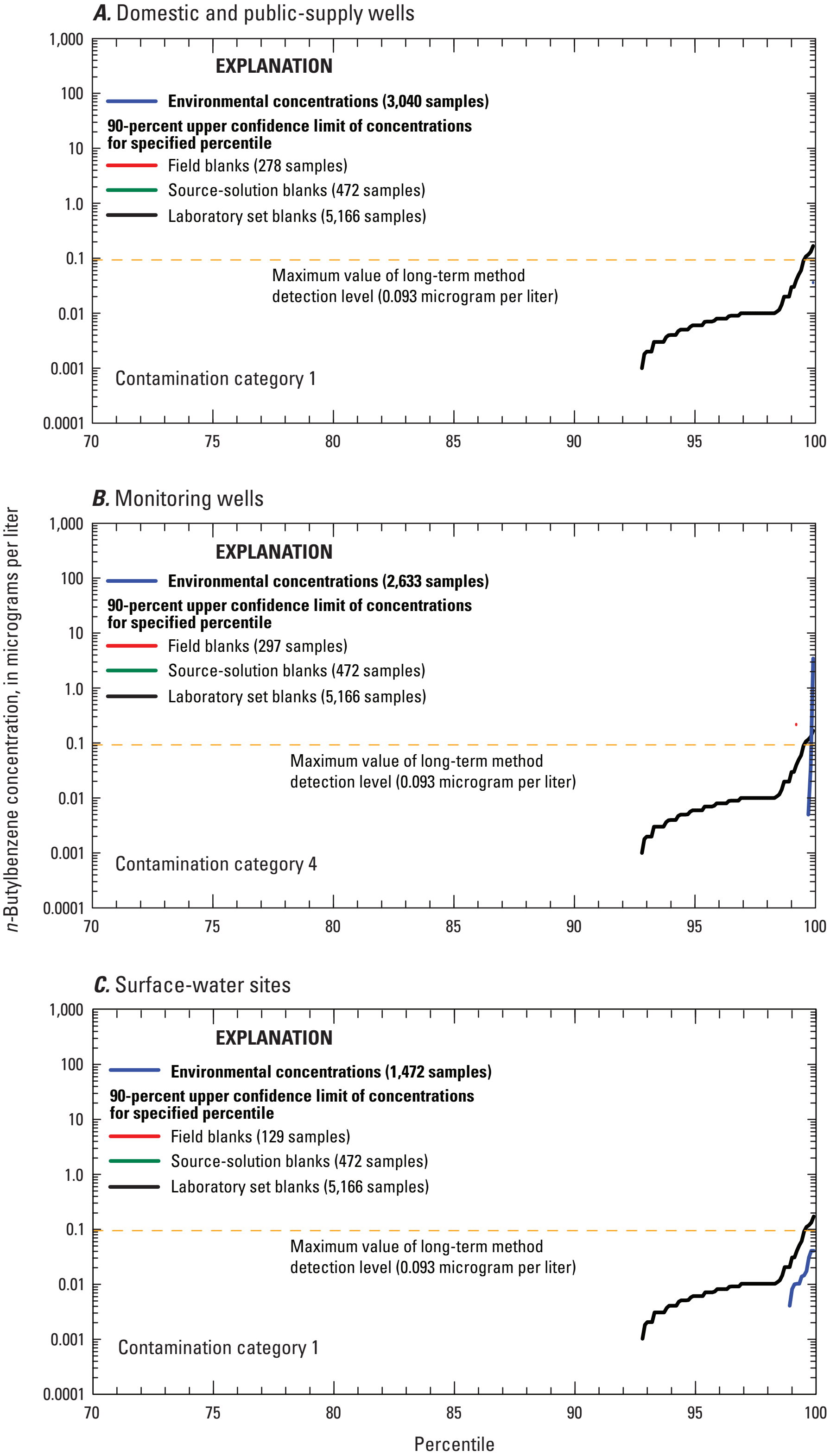


Figure A1–5. Distribution of environmental concentrations of and 90-percent upper confidence limits of *n*-butylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

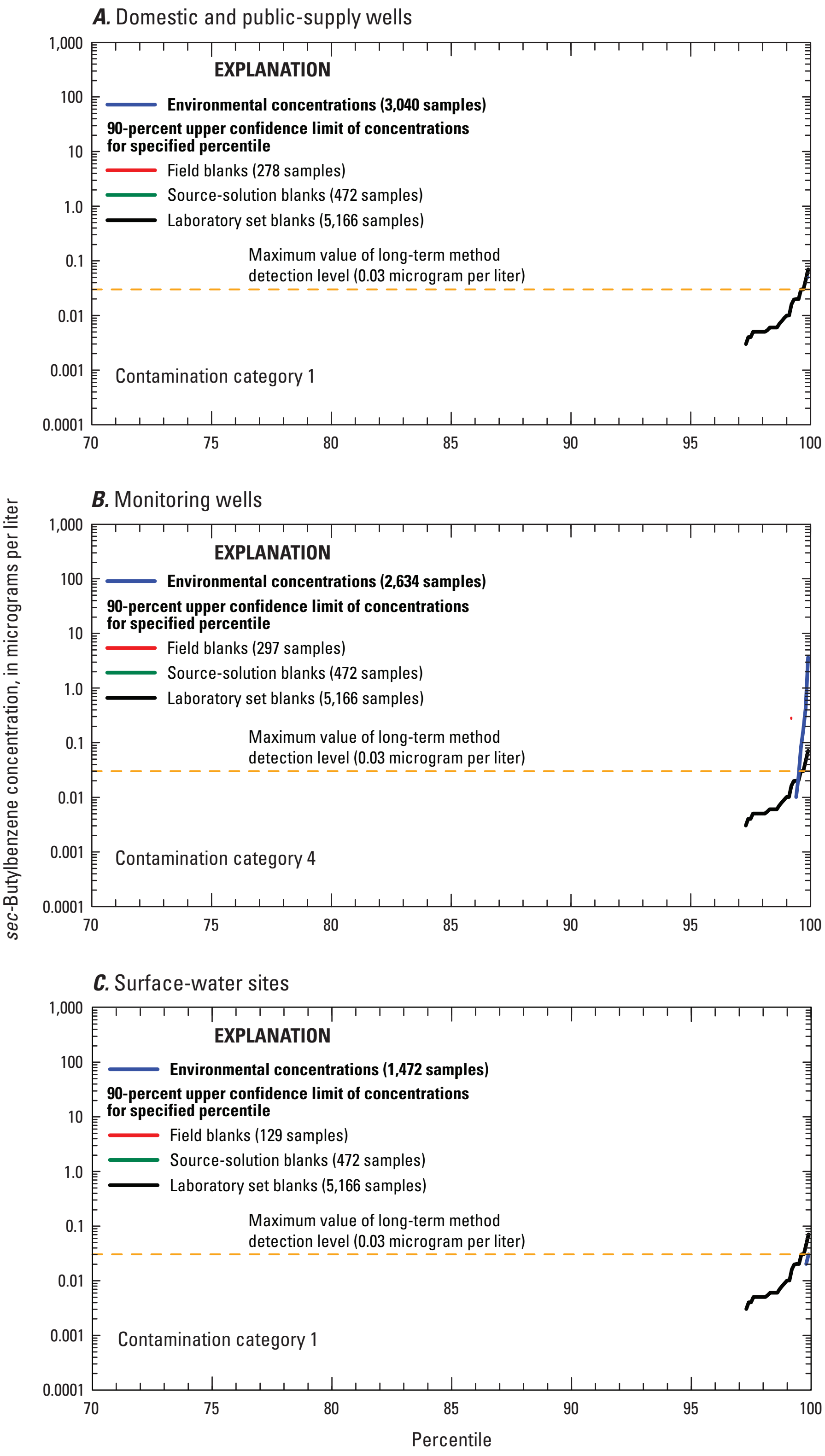


Figure A1–6. Distribution of environmental concentrations and 90-percent upper confidence limits of *sec*-butylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

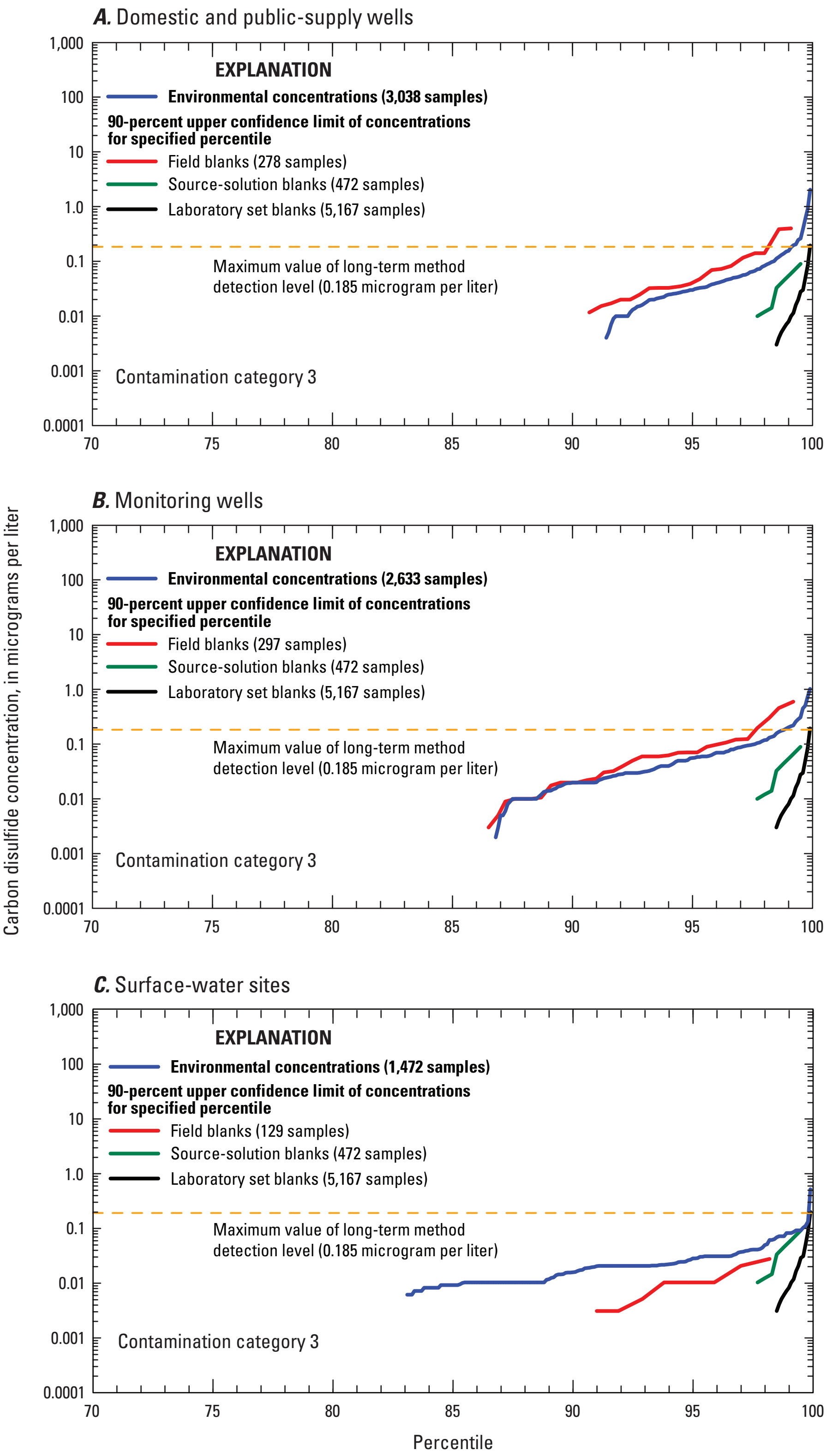


Figure A1–7. Distribution of environmental concentrations of and 90-percent upper confidence limits of carbon disulfide concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

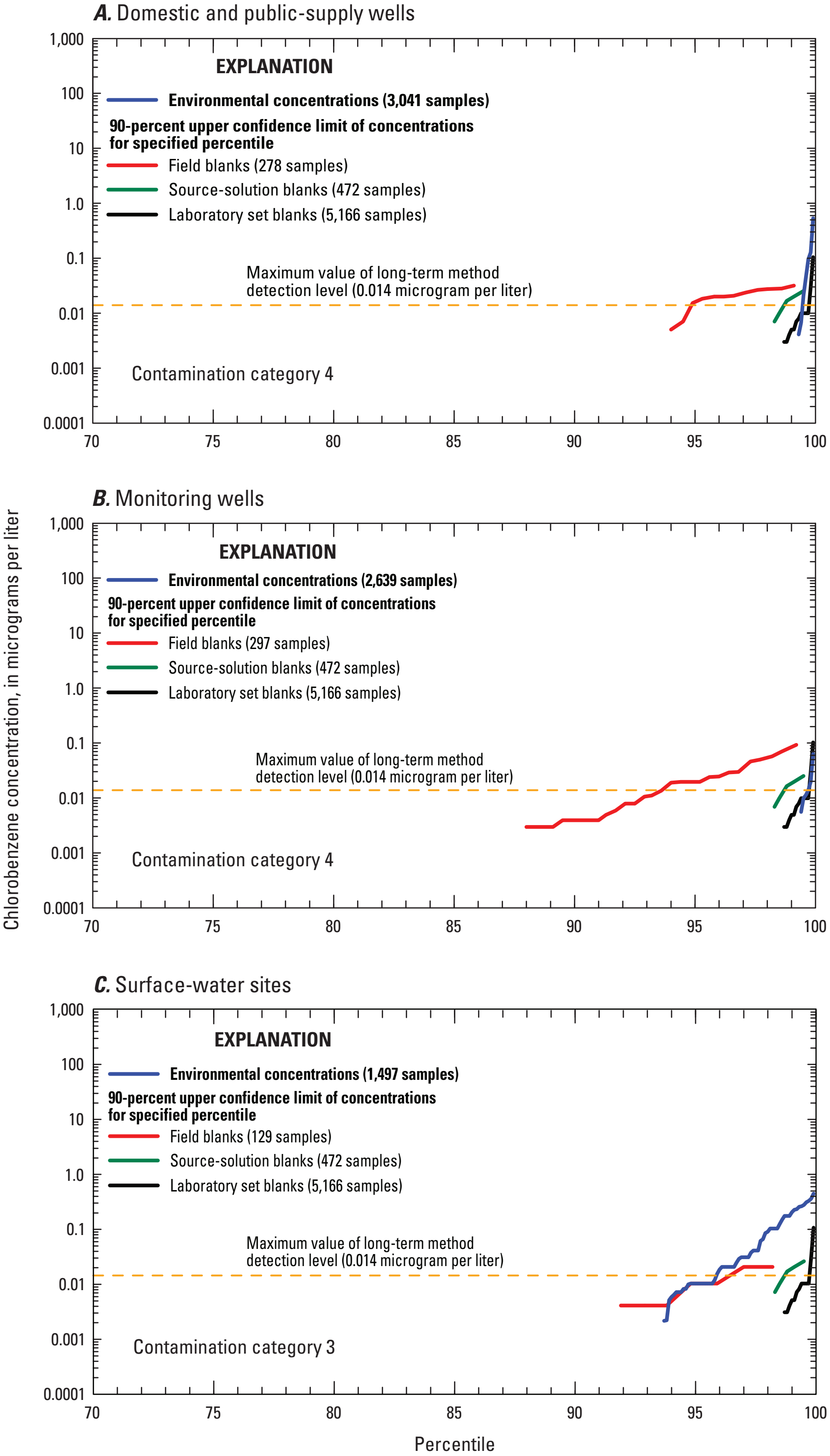
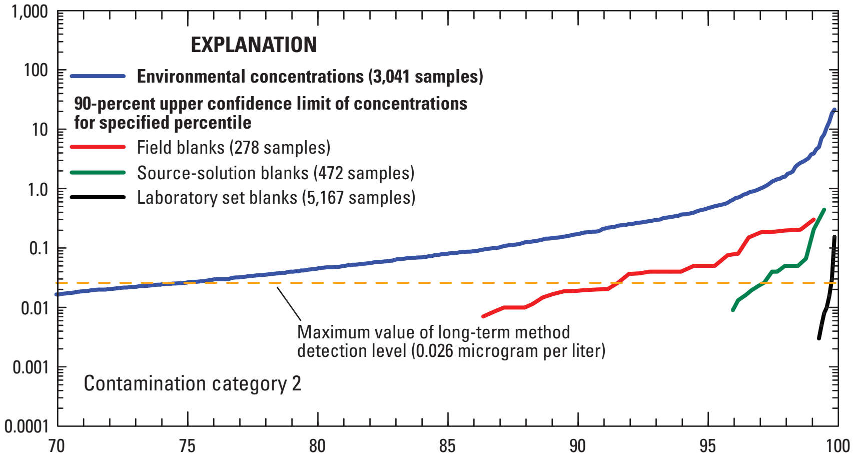
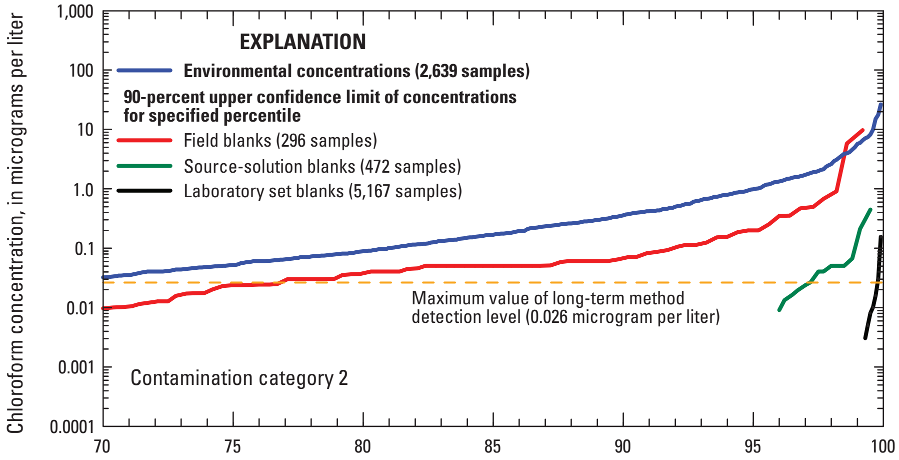


Figure A1–8. Distribution of environmental concentrations and 90-percent upper confidence limits of chlorobenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

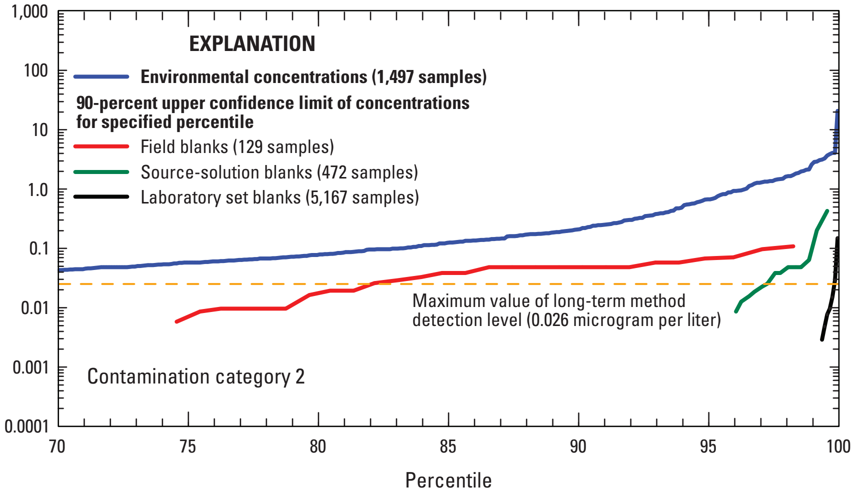


Figure A1–9. Distribution of environmental concentrations and 90-percent upper confidence limits of chloroform concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

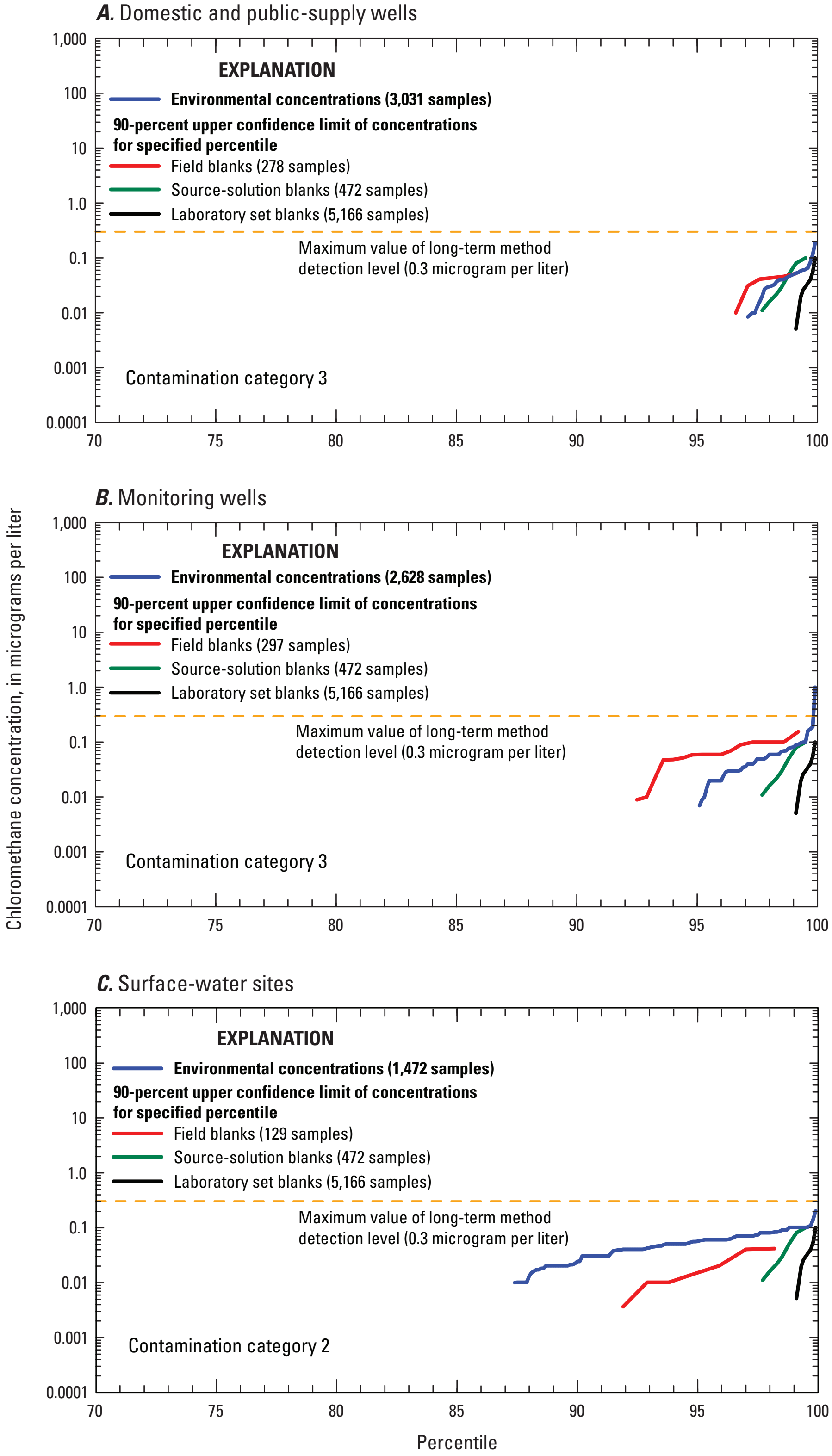


Figure A1–10. Distribution of environmental concentrations and 90-percent upper confidence limits of chloromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

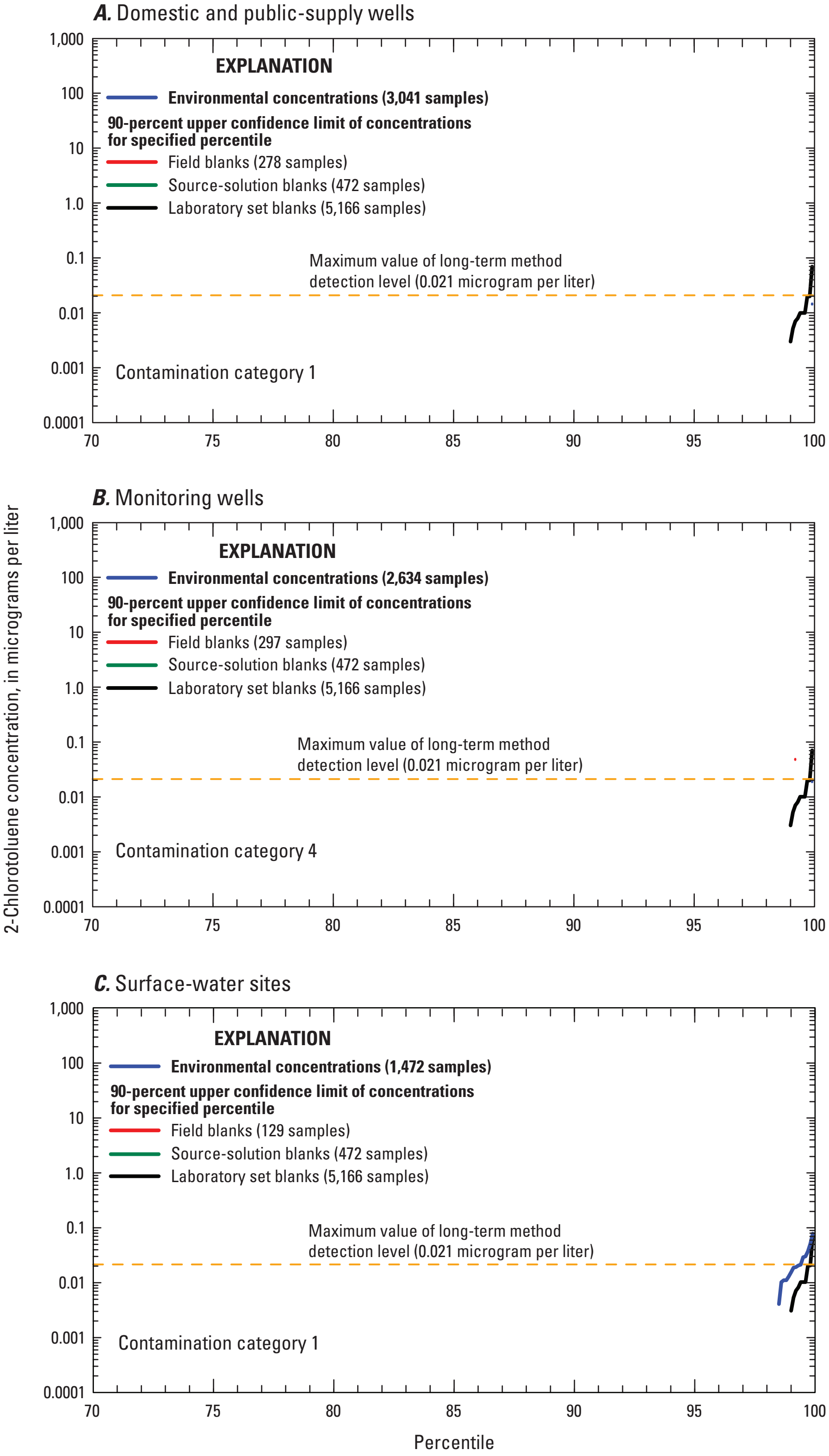


Figure A1–11. Distribution of environmental concentrations and 90-percent upper confidence limits of 2-chlorotoluene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

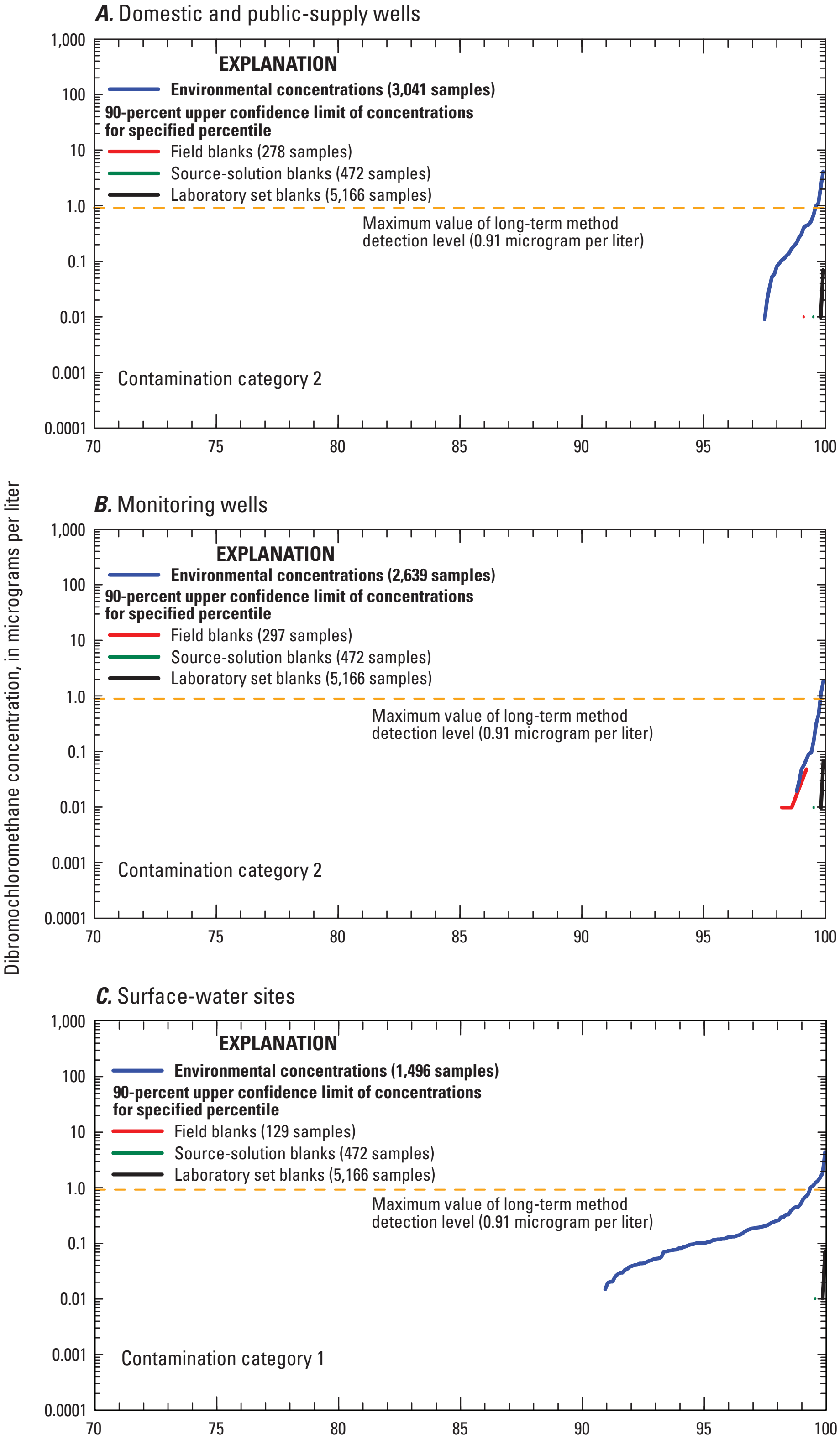


Figure A1–12. Distribution of environmental concentrations and 90-percent upper confidence limits of dibromochloromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

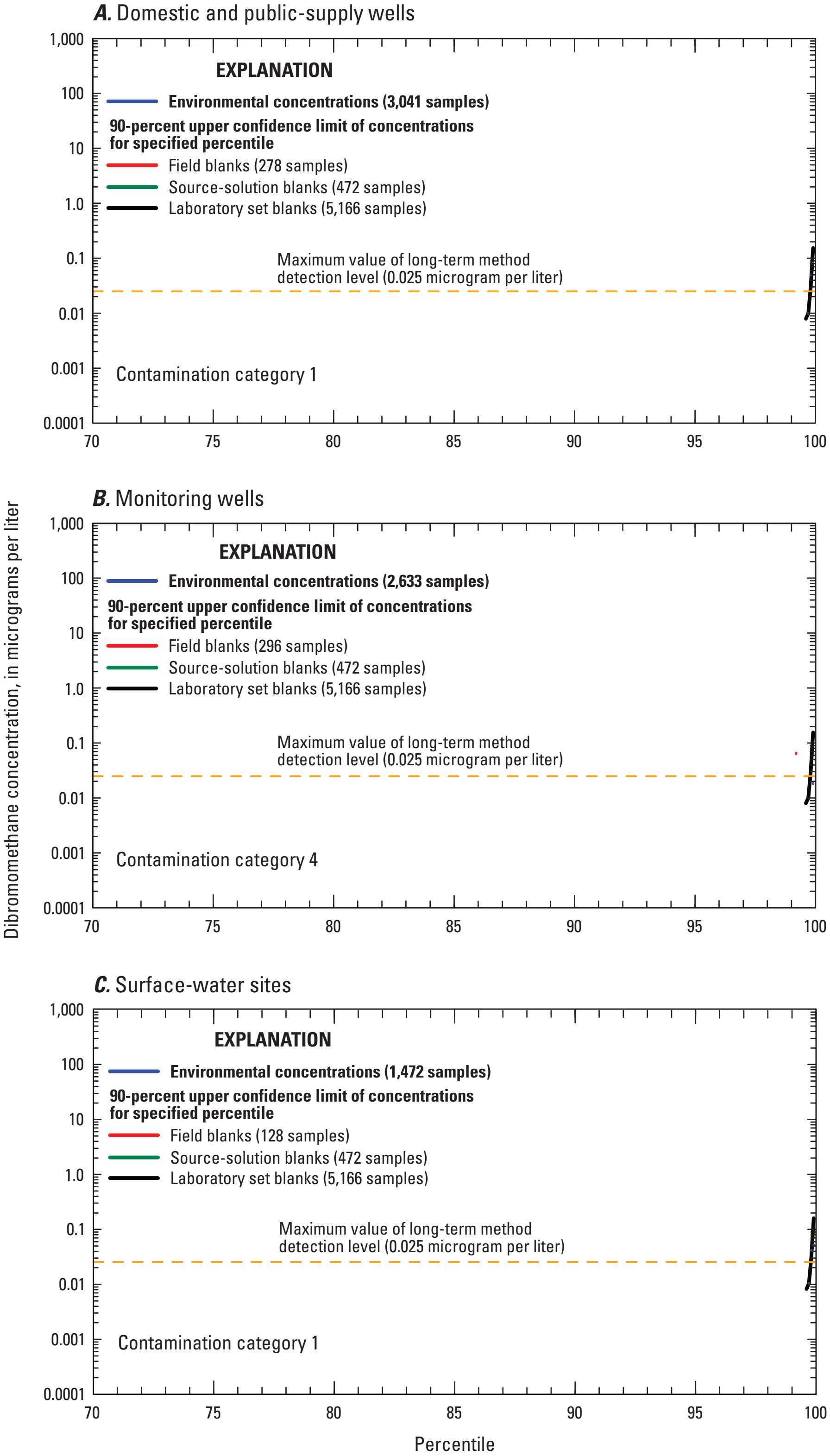


Figure A1–13. Distribution of environmental concentrations and 90-percent upper confidence limits of dibromomethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

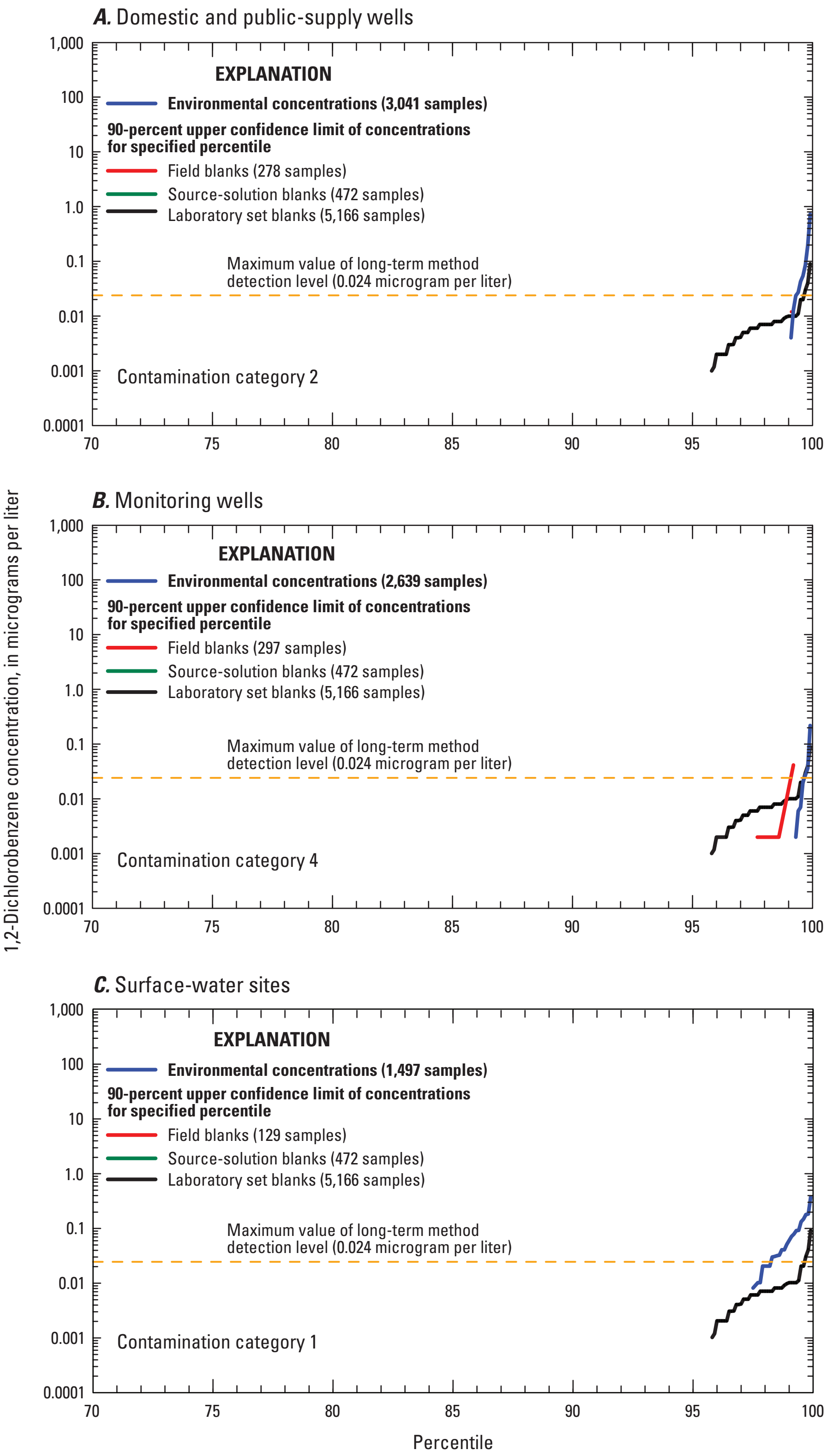


Figure A1–14. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2-dichlorobenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

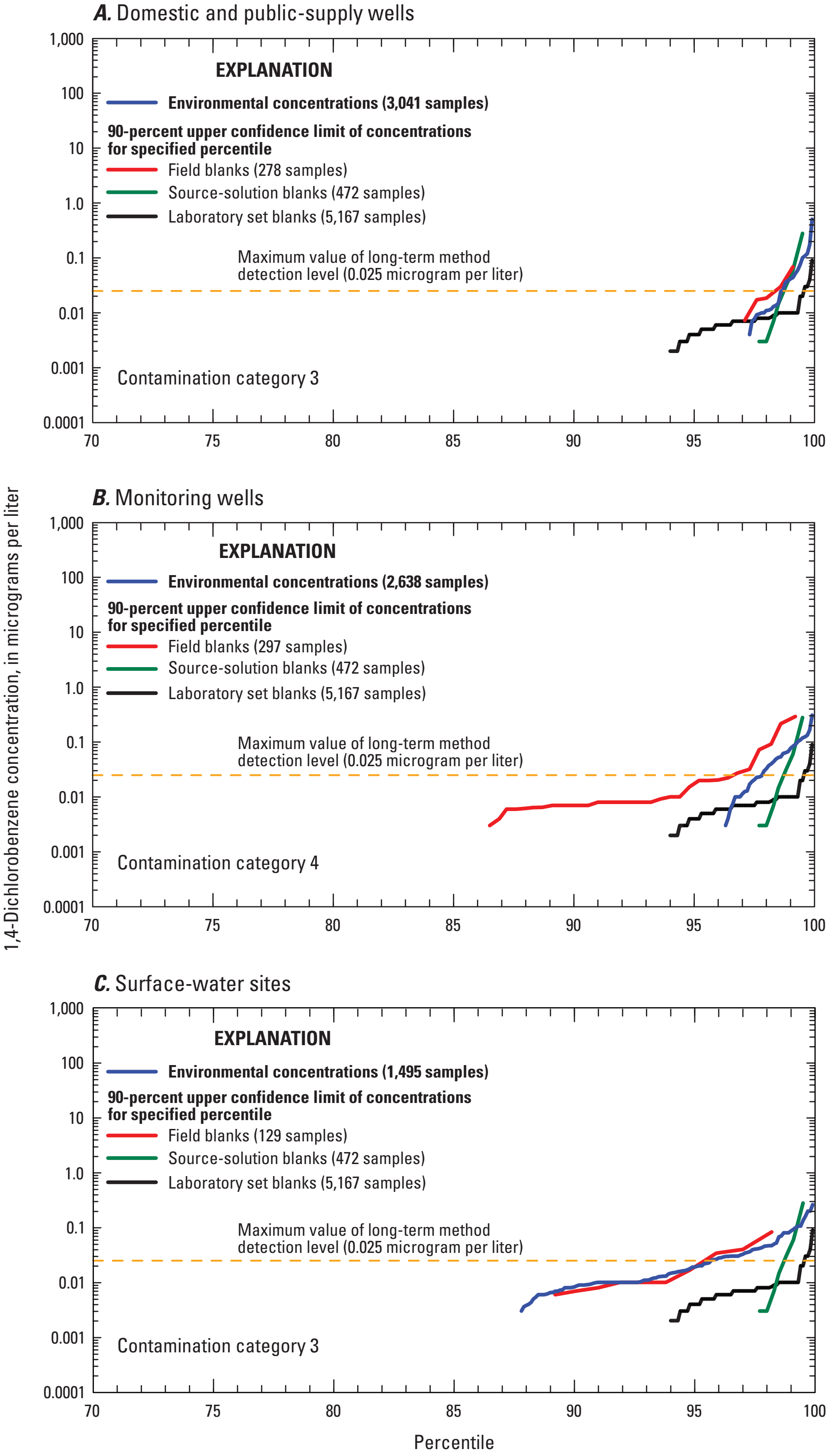


Figure A1–15. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,4-dichlorobenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

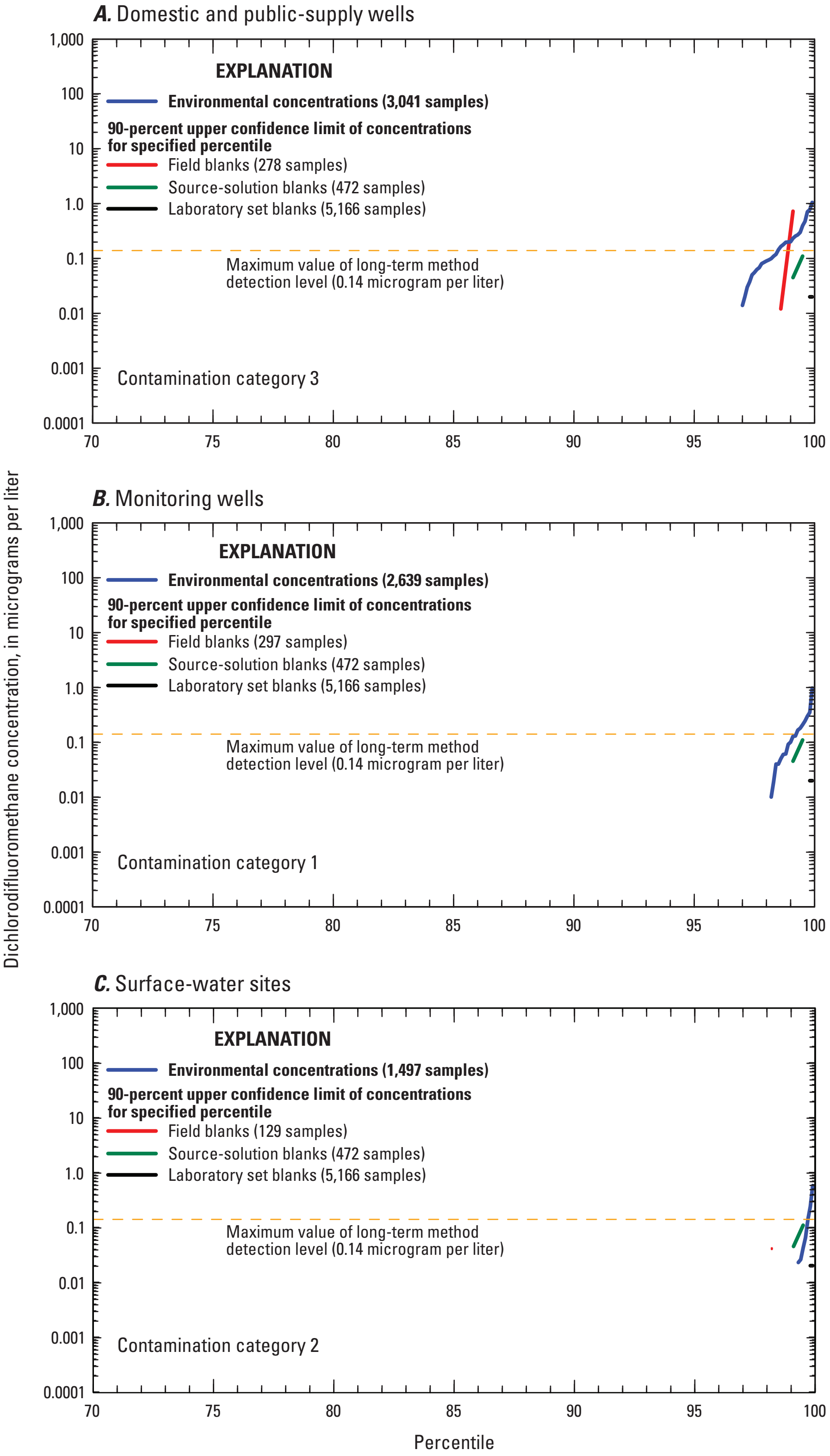
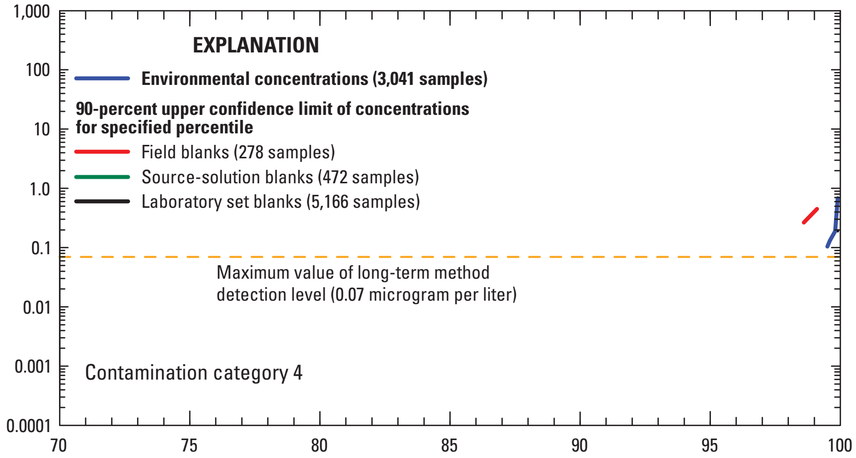
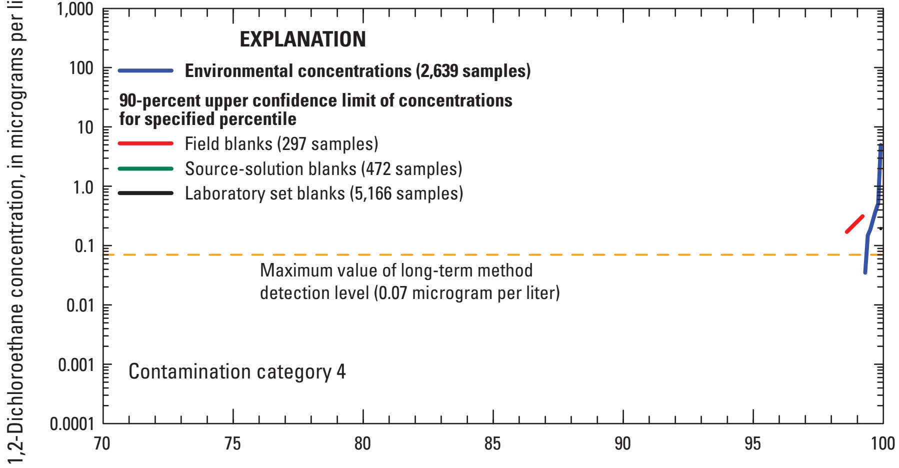


Figure A1–16. Distribution of environmental concentrations and 90-percent upper confidence limits of dichlorodifluoromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

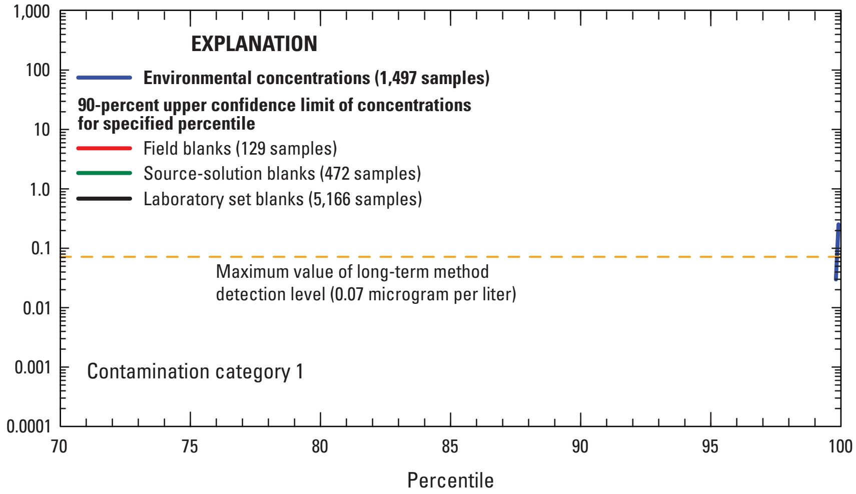


Figure A1–17. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2-dichloroethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

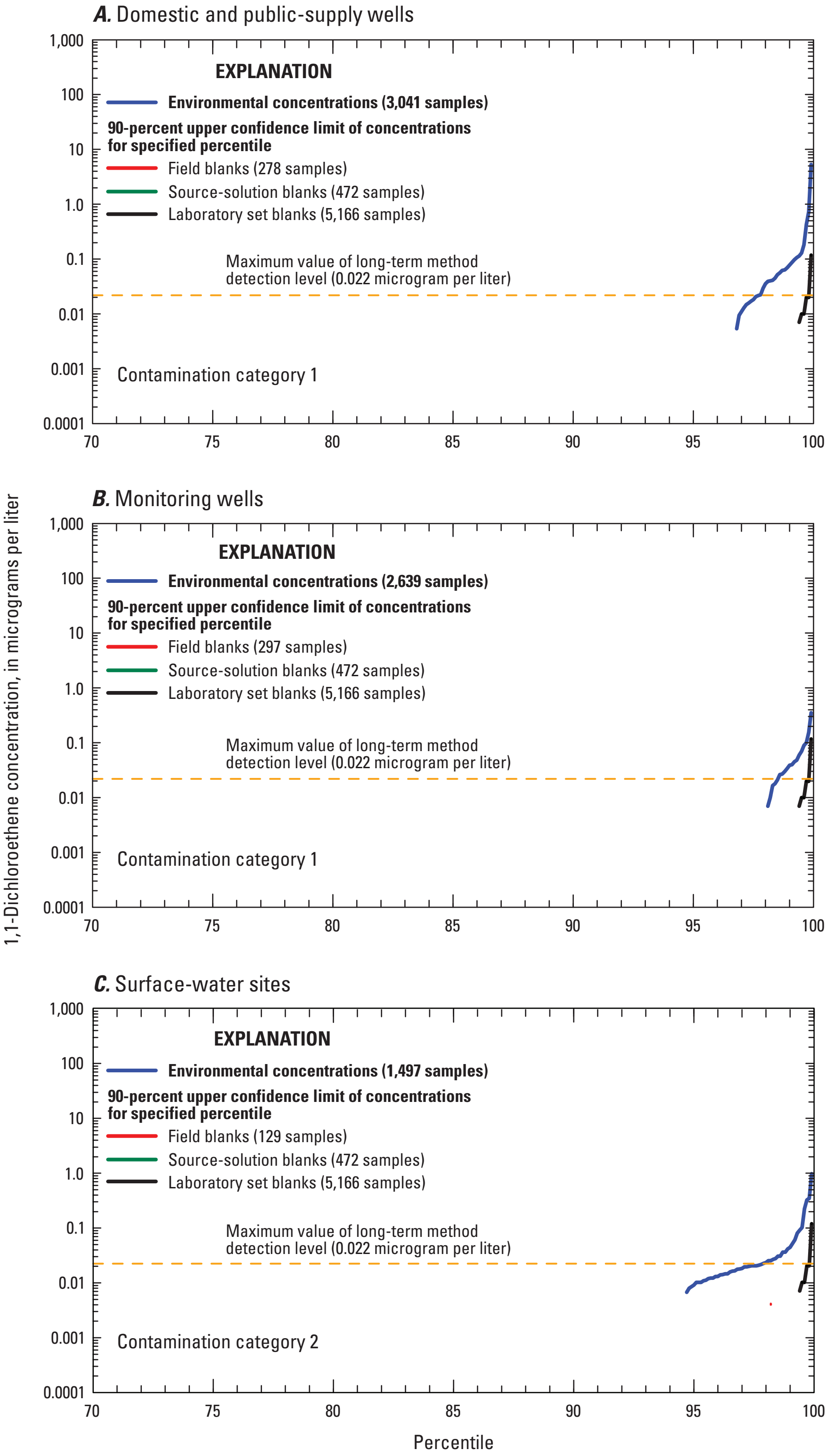


Figure A1–18. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,1-dichloroethene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

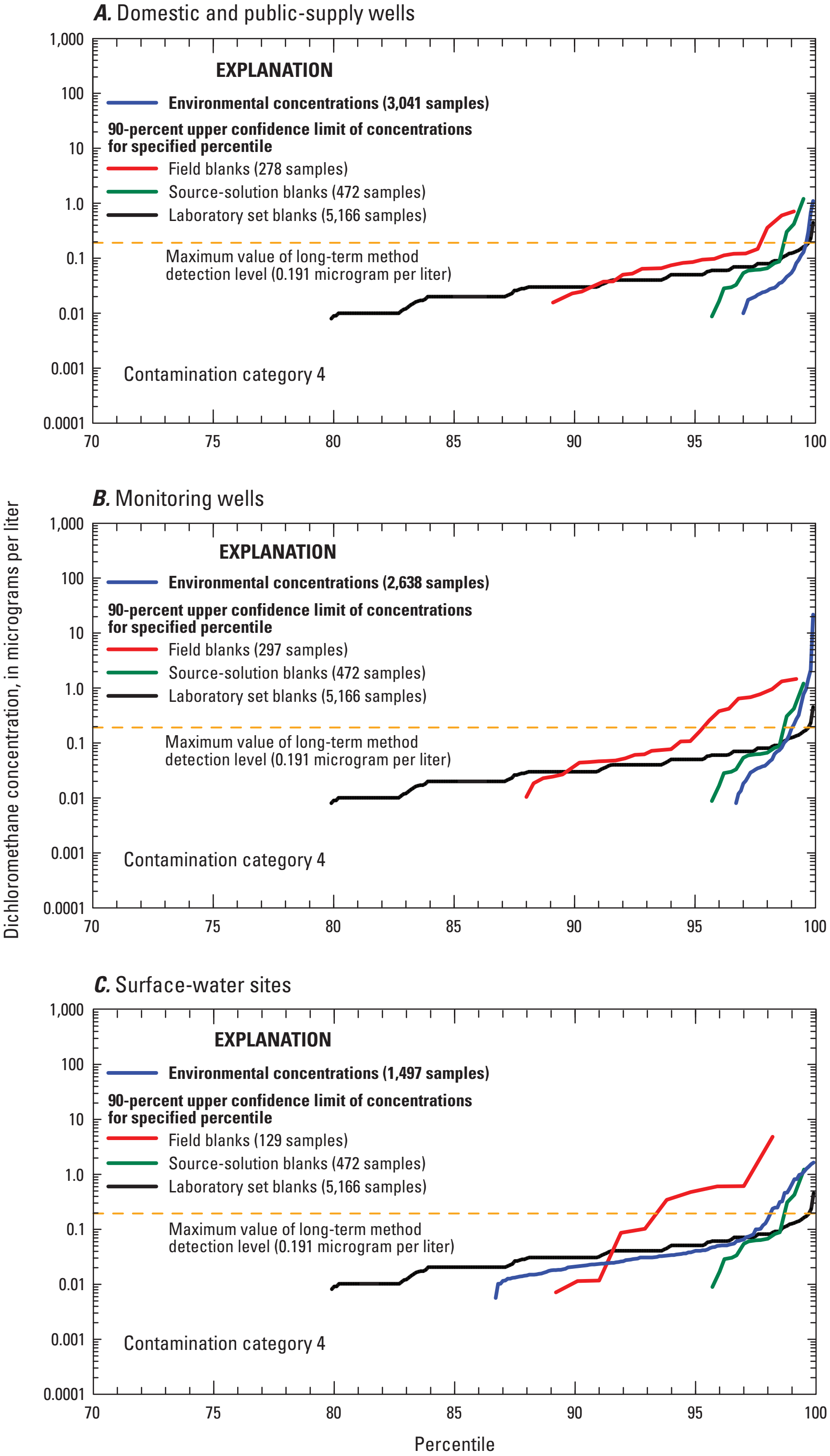


Figure A1–19. Distribution of environmental concentrations and 90-percent upper confidence limits of dichloromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

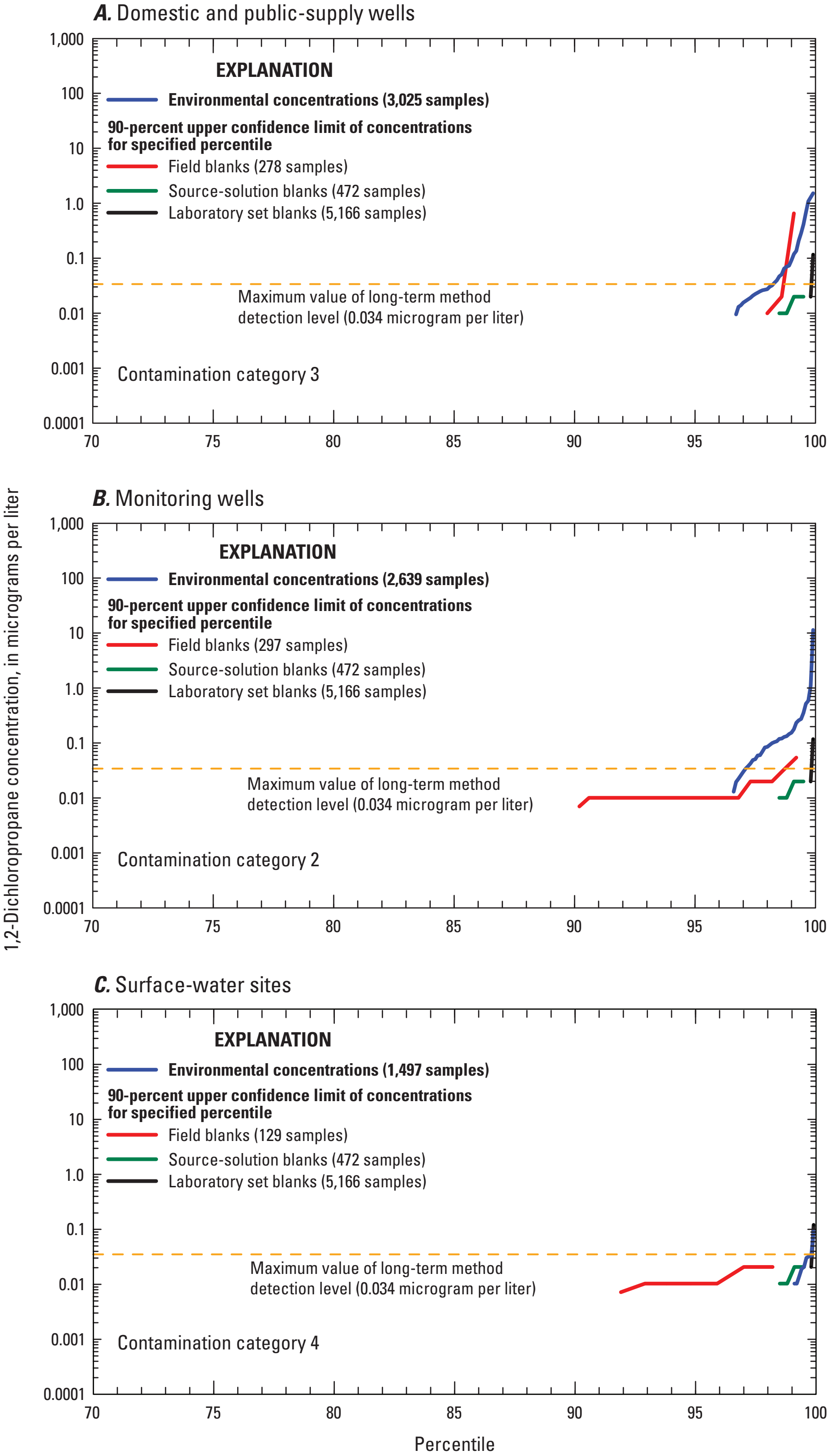
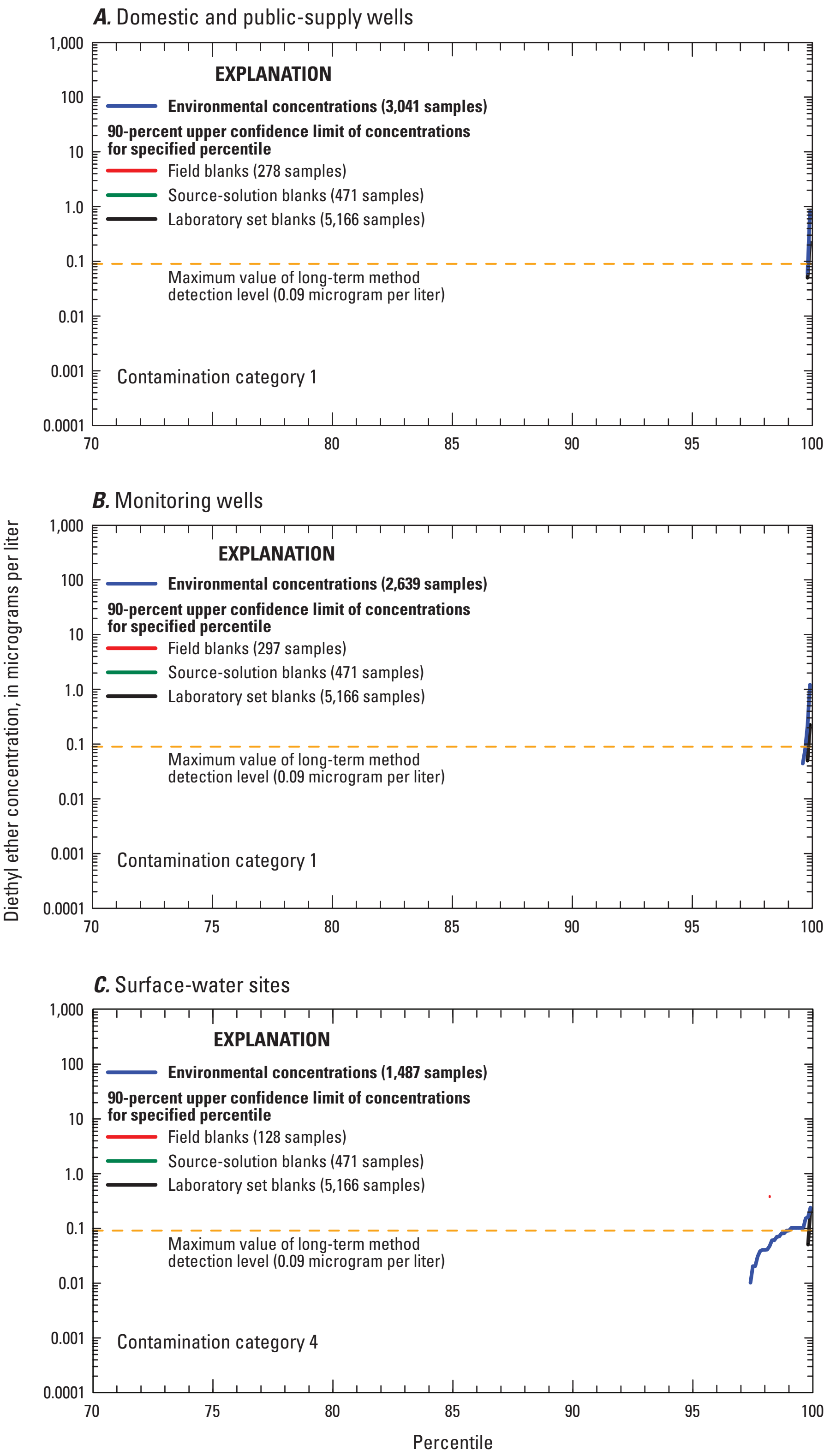


Figure A1–20. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2-dichloropropane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.



A. Domestic and public-supply wells

B. Monitoring wells

C. Surface-water sites

Figure A1–21. Distribution of environmental concentrations and 90-percent upper confidence limits of diethyl ether concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

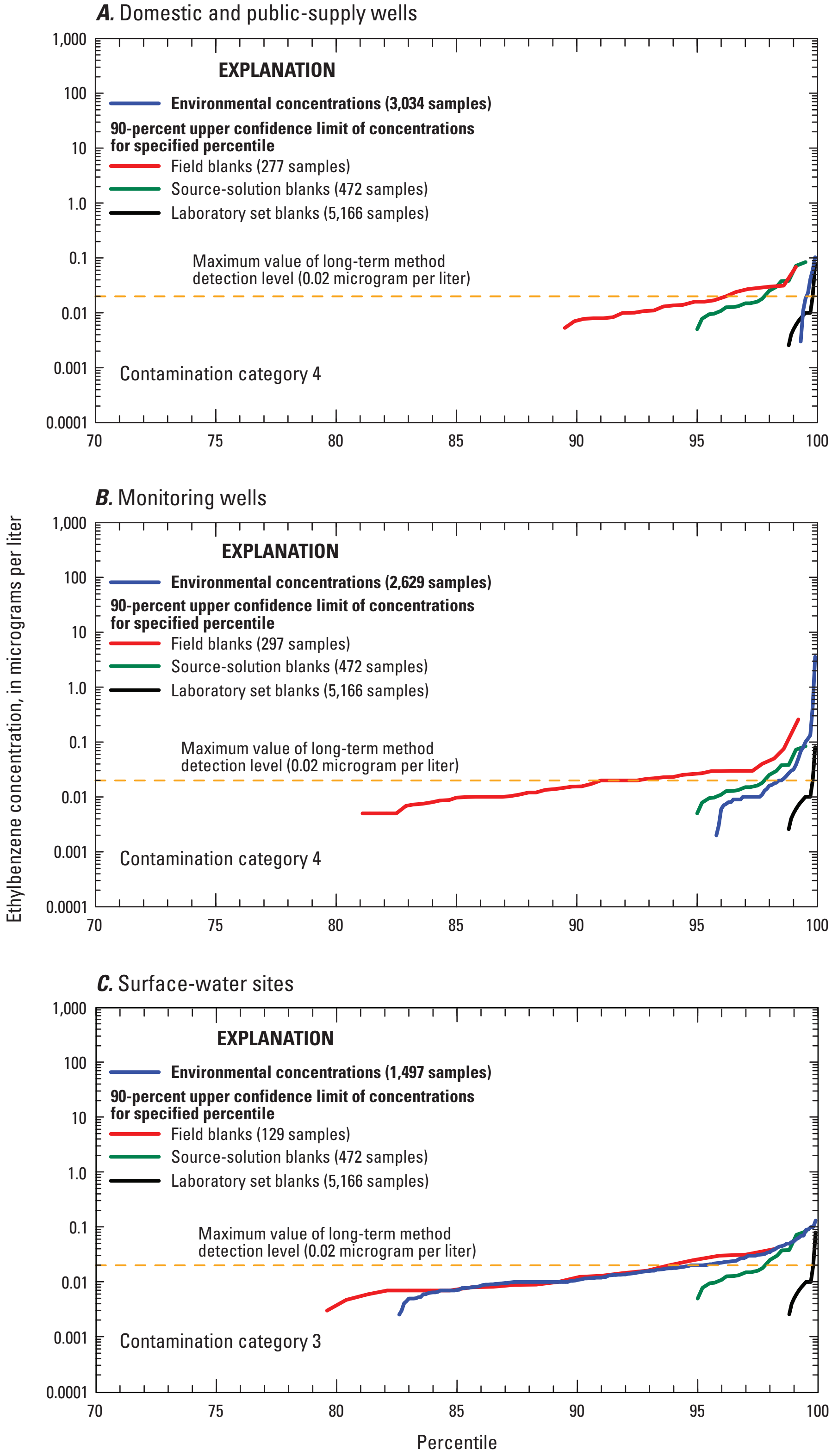


Figure A1–22. Distribution of environmental concentrations and 90-percent upper confidence limits of ethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

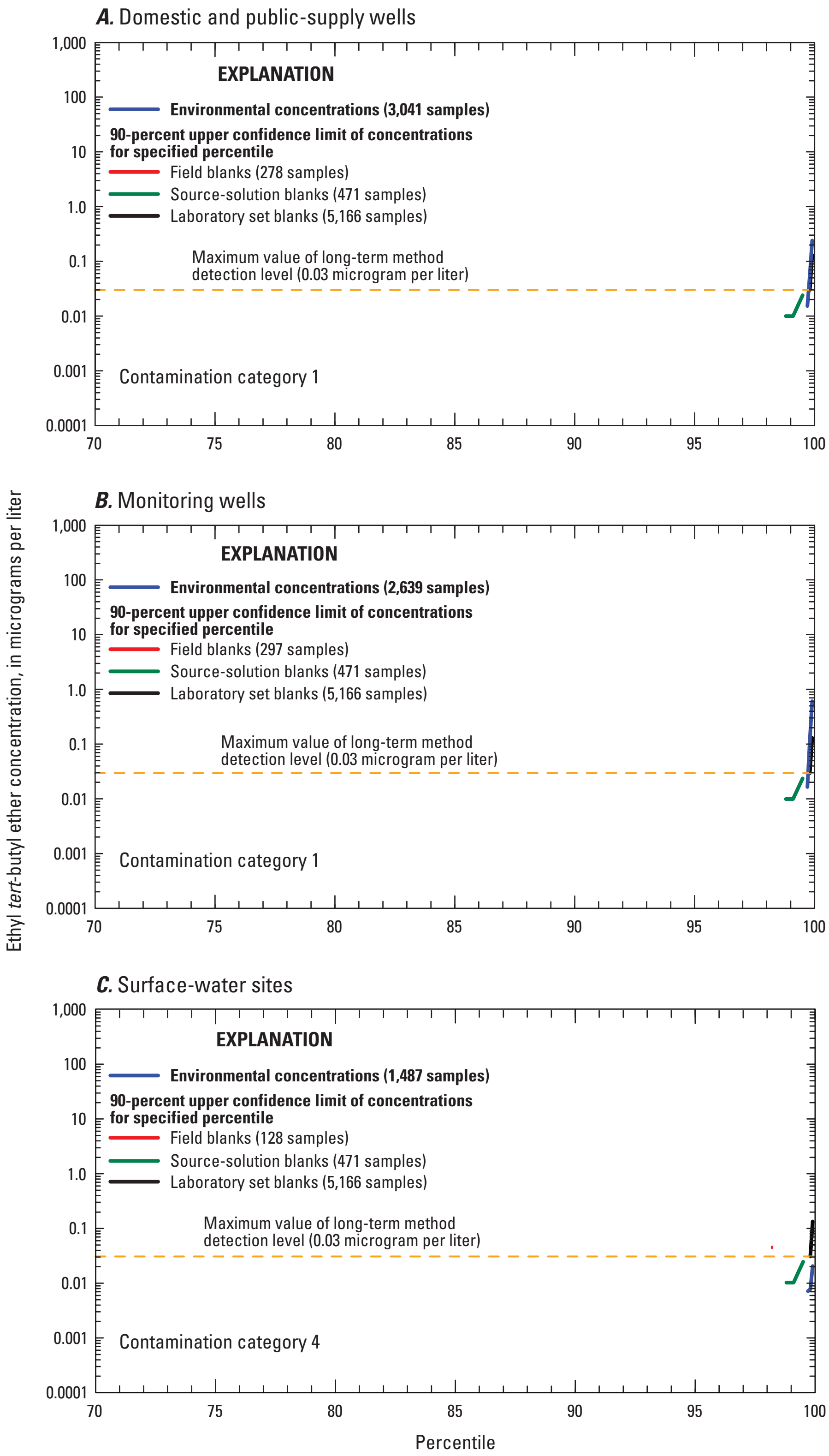


Figure A1–23. Distribution of environmental concentrations and 90-percent upper confidence limits of ethyl *tert*-butyl ether concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

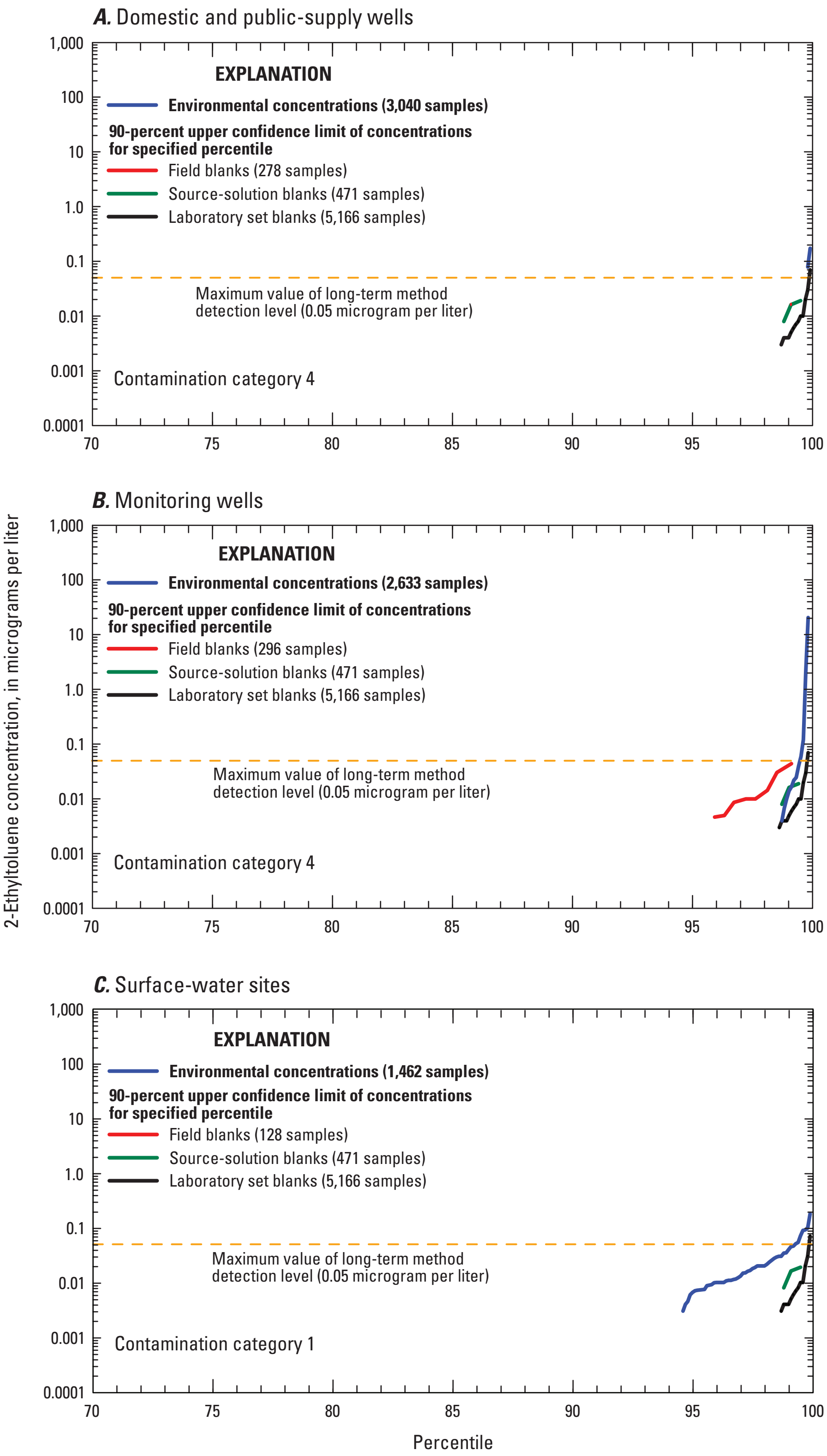


Figure A1–24. Distribution of environmental concentrations of and 90-percent upper confidence limits of 2-ethyltoluene in concentrations field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

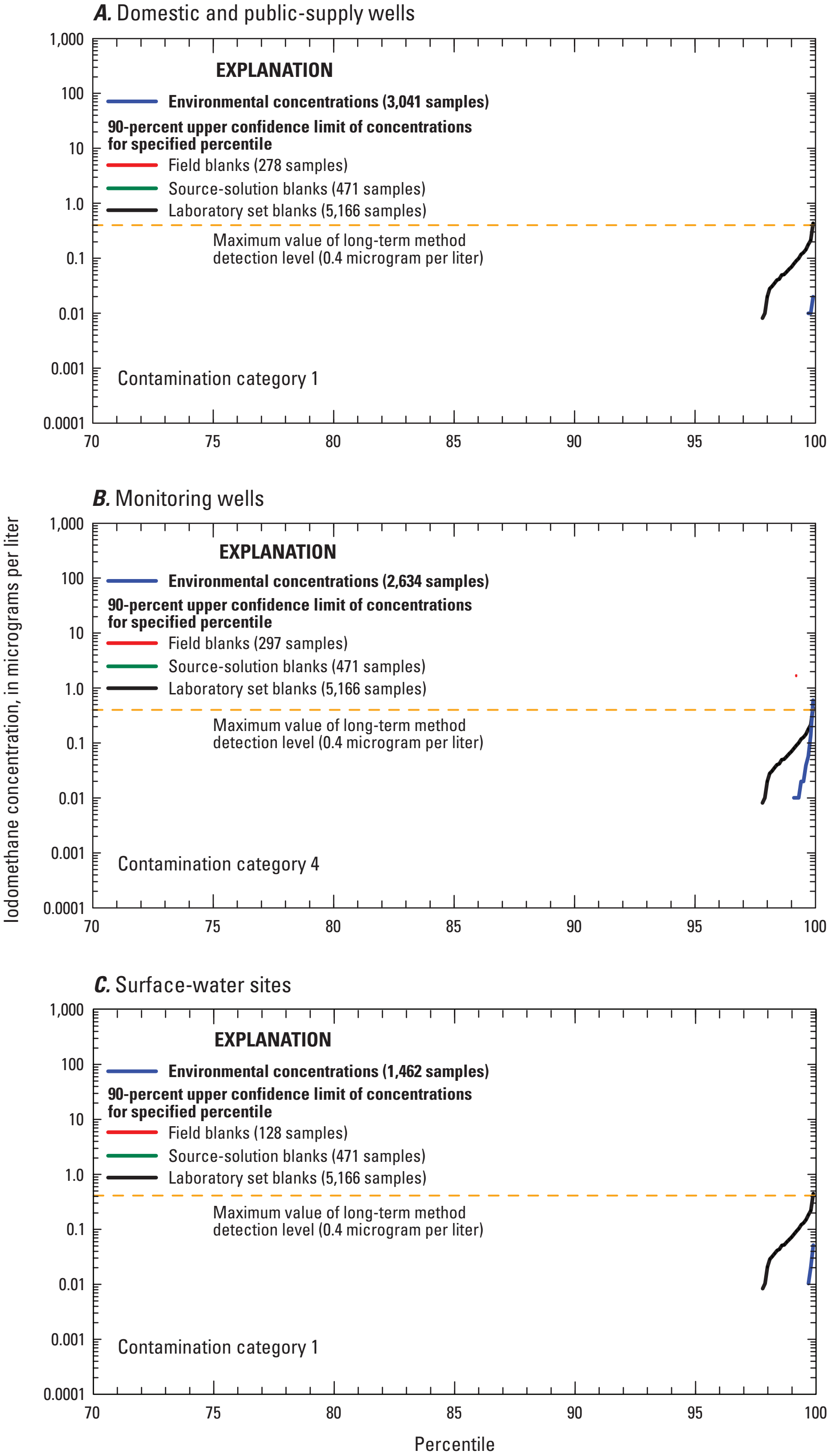


Figure A1–25. Distribution of environmental concentrations and 90-percent upper confidence limits of iodomethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

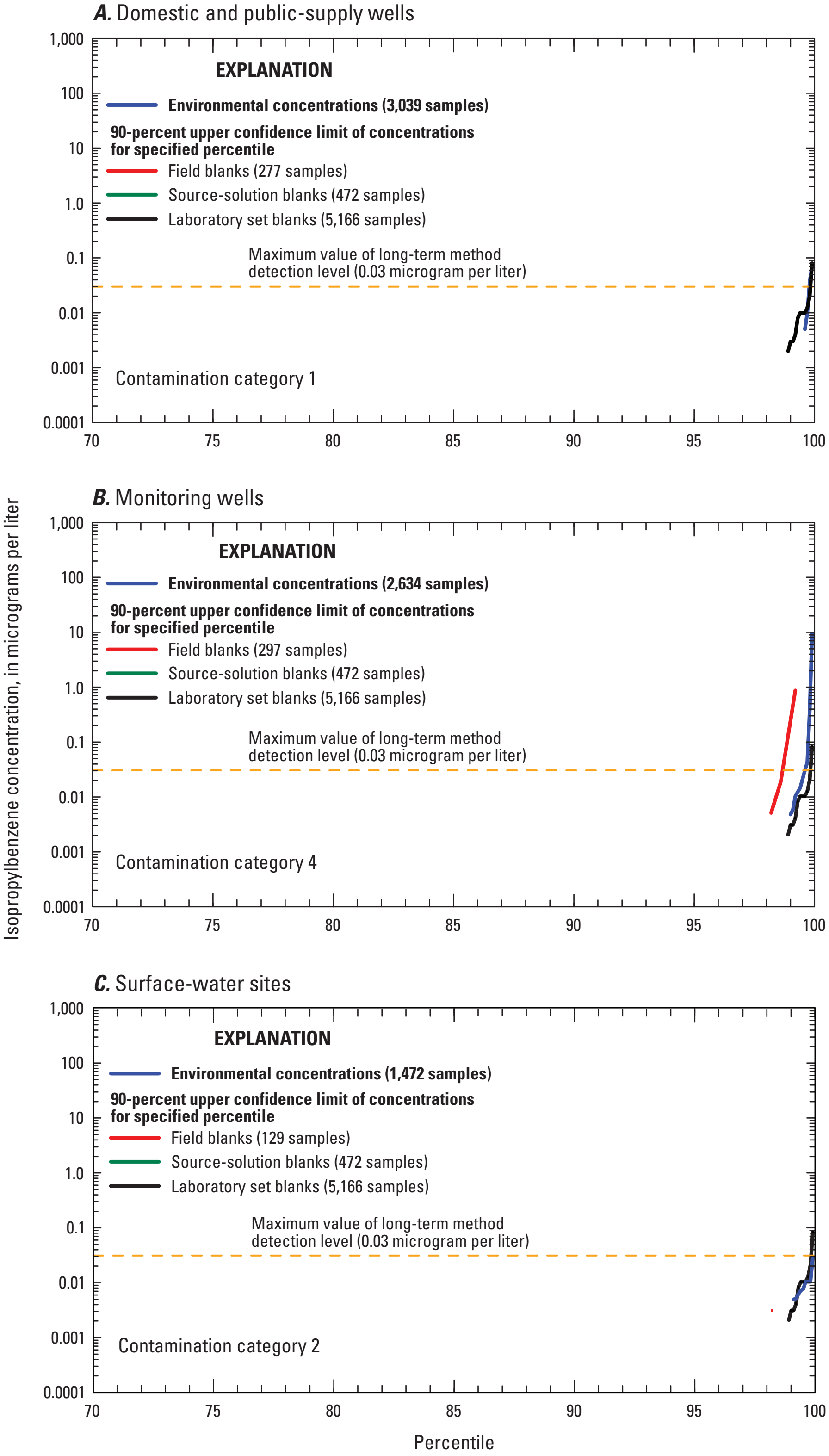


Figure A1–26. Distribution of environmental concentrations and 90-percent upper confidence limits of isopropylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

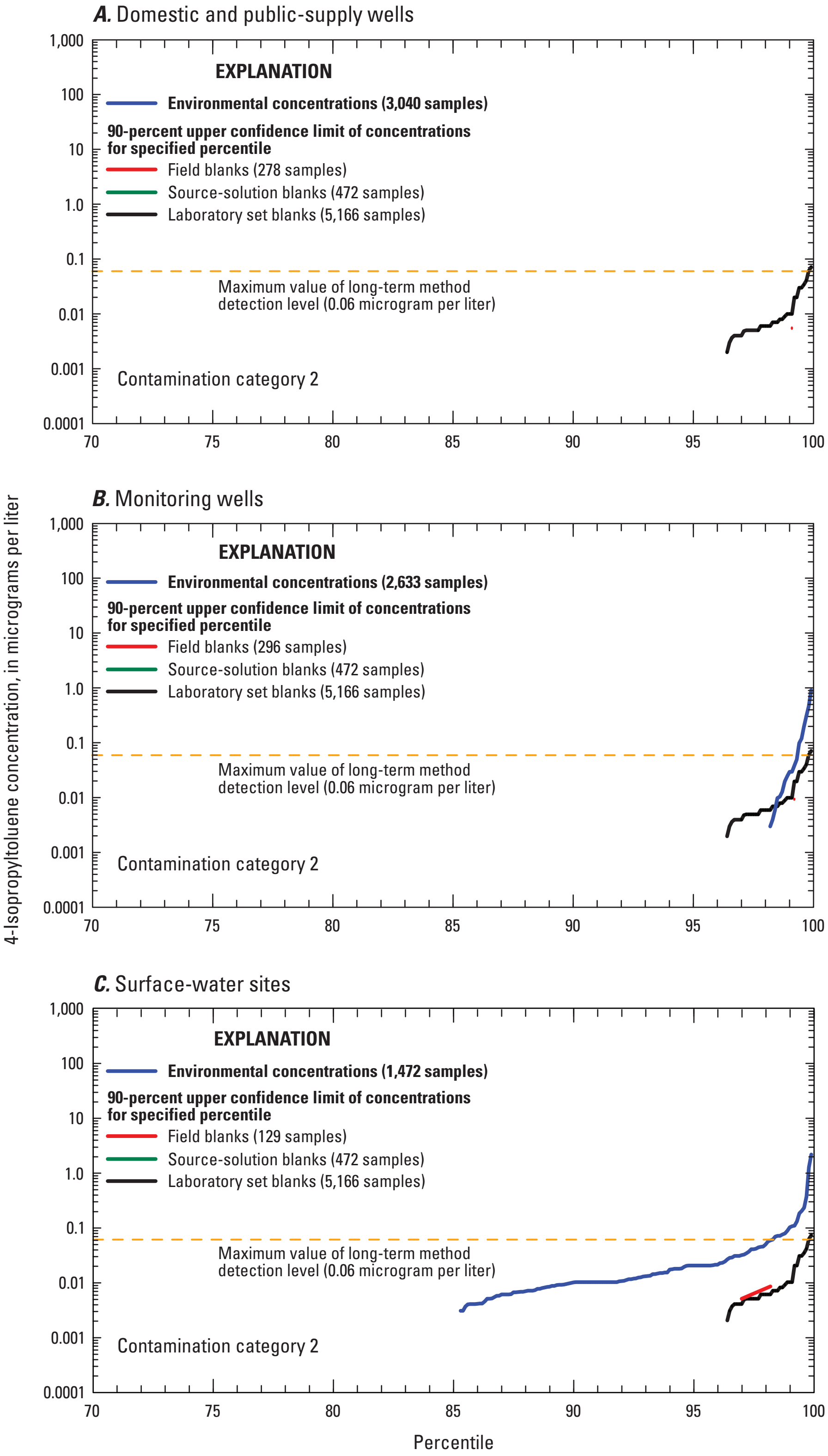


Figure A1–27. Distribution of environmental concentrations and 90-percent upper confidence limits of 4-isopropyltoluene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

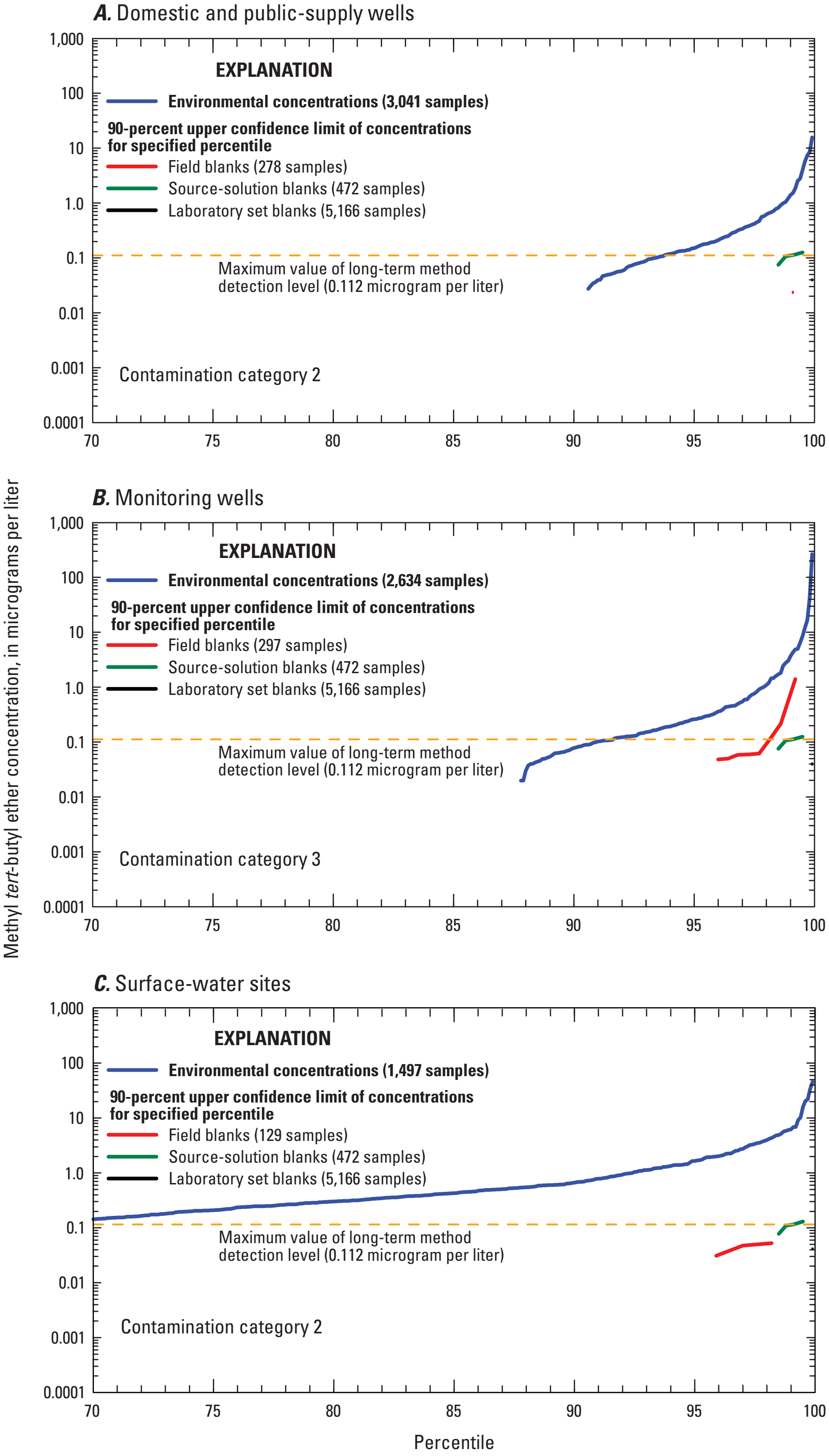


Figure A1–28. Distribution of environmental concentrations and 90-percent upper confidence limits of methyl *tert*-butyl ether concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

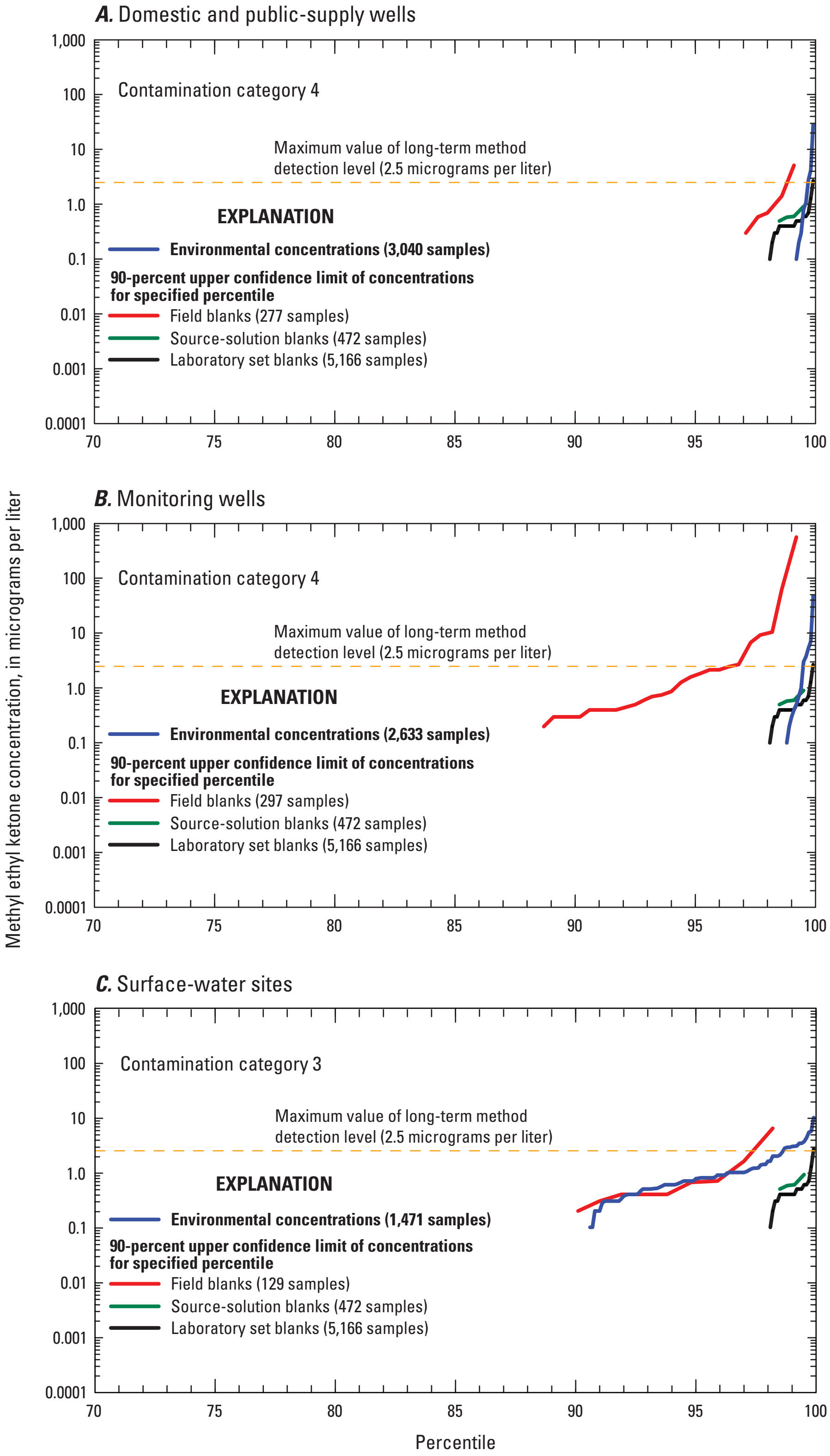


Figure A1–29. Distribution of environmental concentrations and 90-percent upper confidence limits of metyl ethyl ketone concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

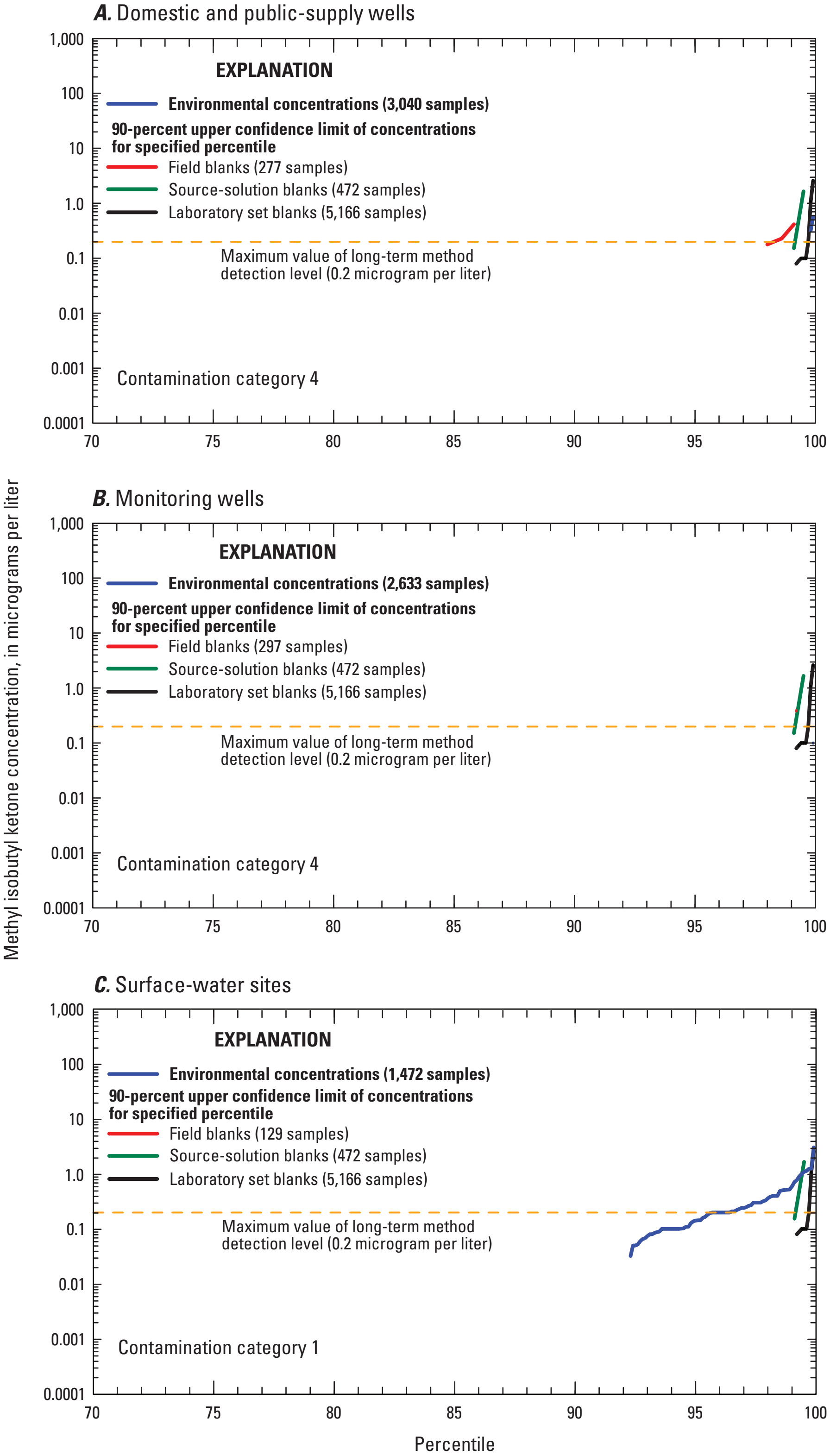


Figure A1–30. Distribution of environmental concentrations and 90-percent upper confidence limits of methyl isobutyl ketone concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

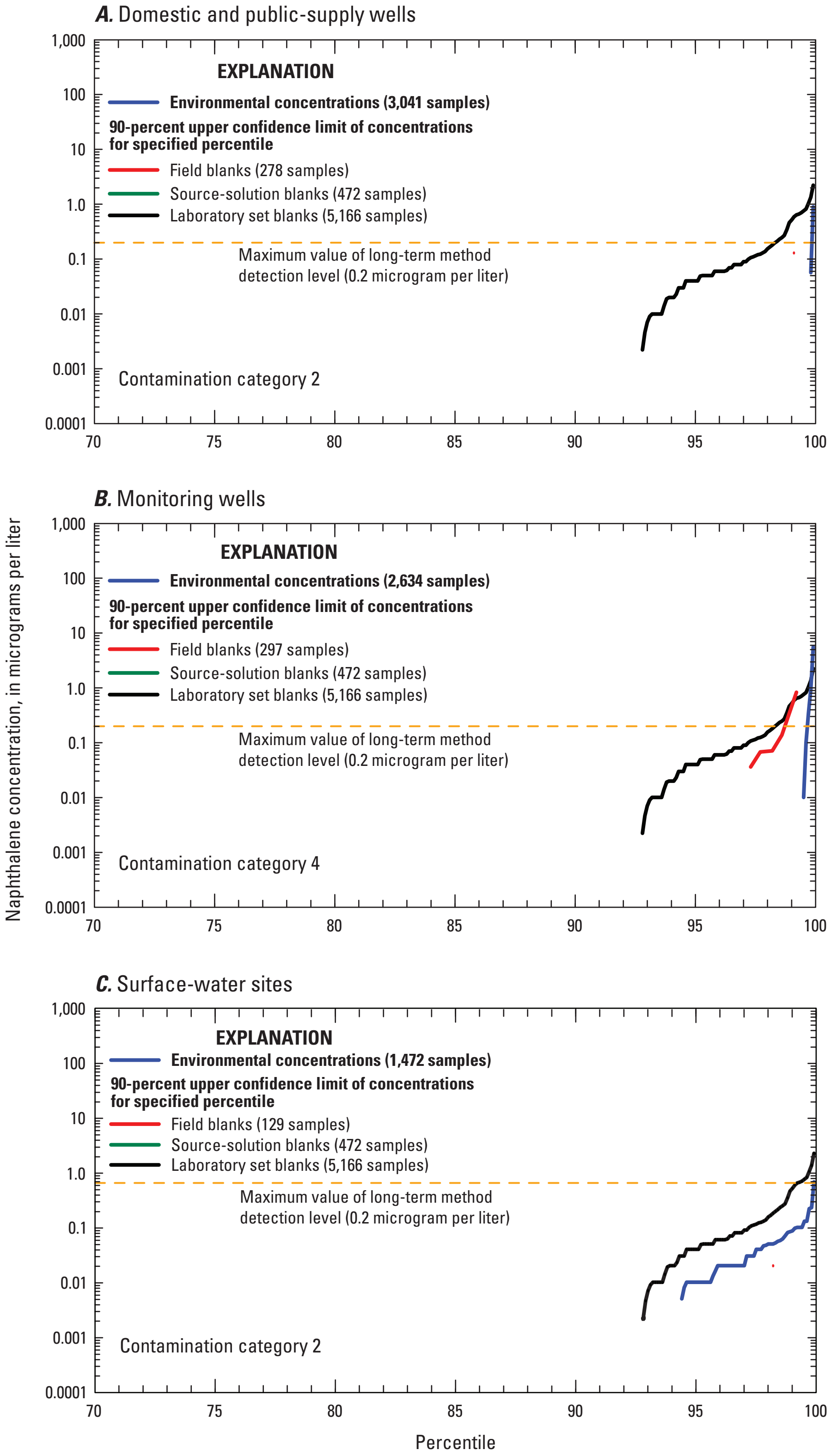


Figure A1–31. Distribution of environmental concentrations and 90-percent upper confidence limits of naphthalene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

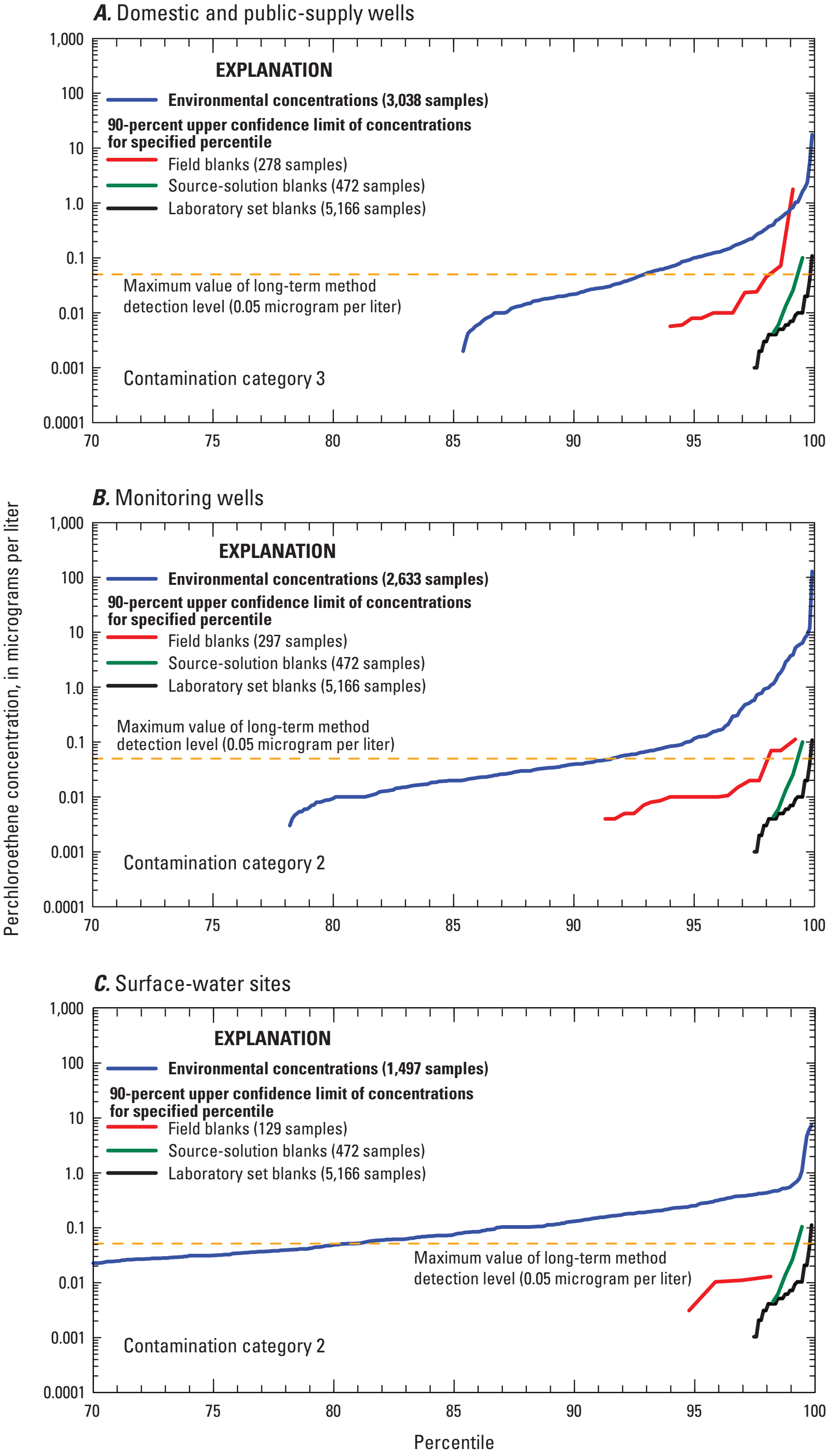


Figure A1–32. Distribution of environmental concentrations and 90-percent upper confidence limits of perchloroethene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

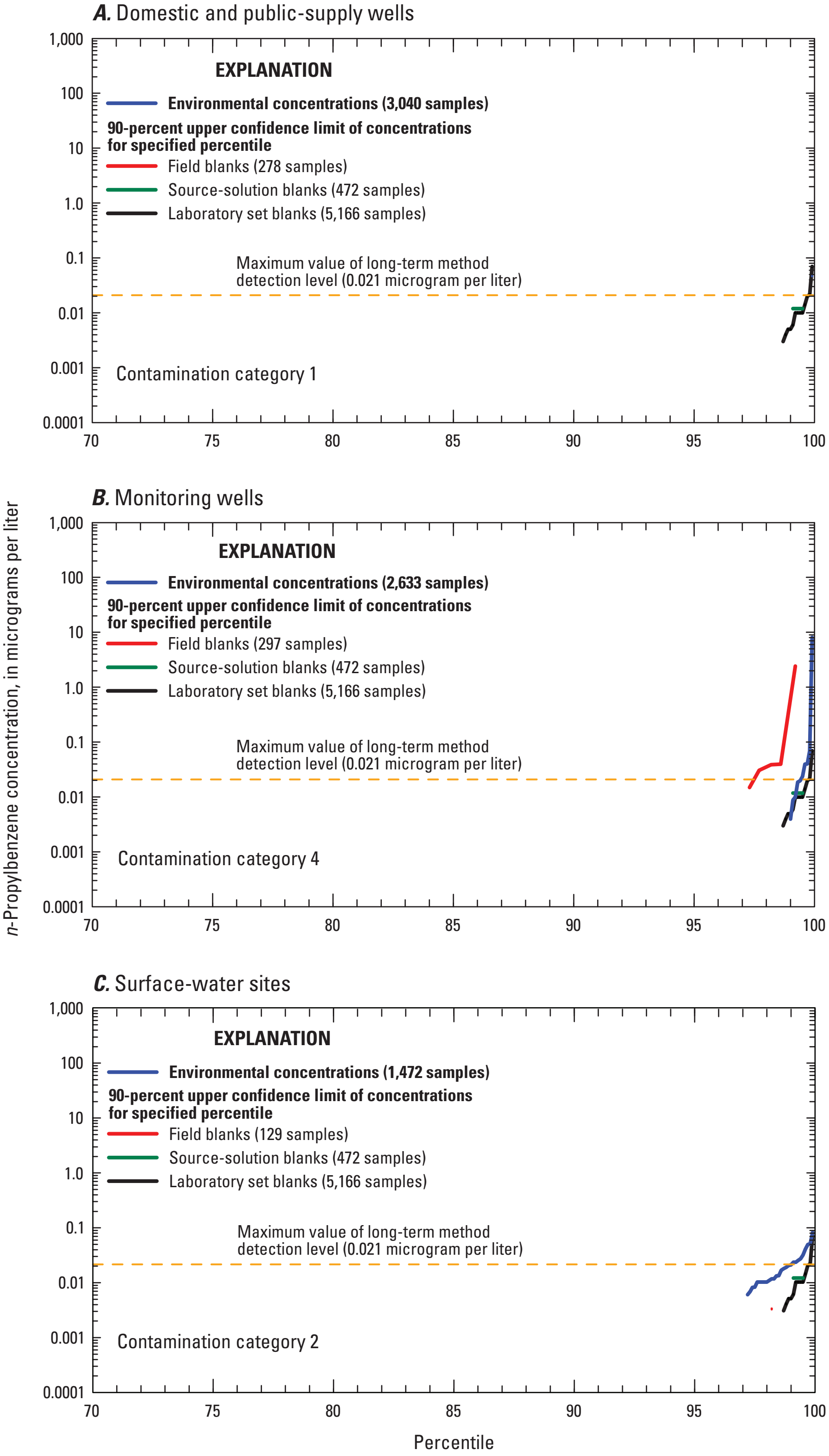


Figure A1–33. Distribution of environmental concentrations and 90-percent upper confidence limits of *n*-propylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

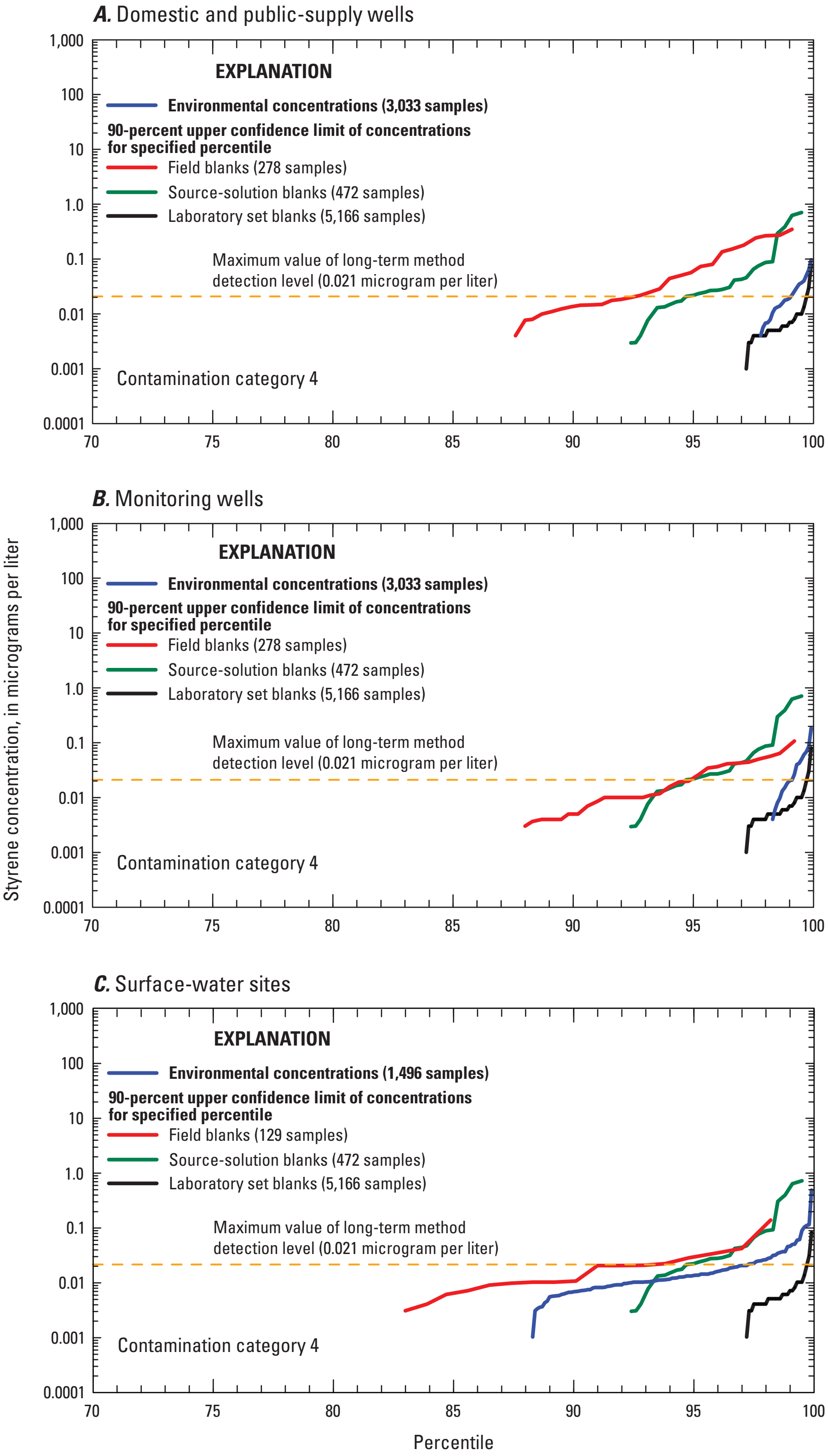


Figure A1–34. Distribution of environmental concentrations and 90-percent upper confidence limits of styrene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

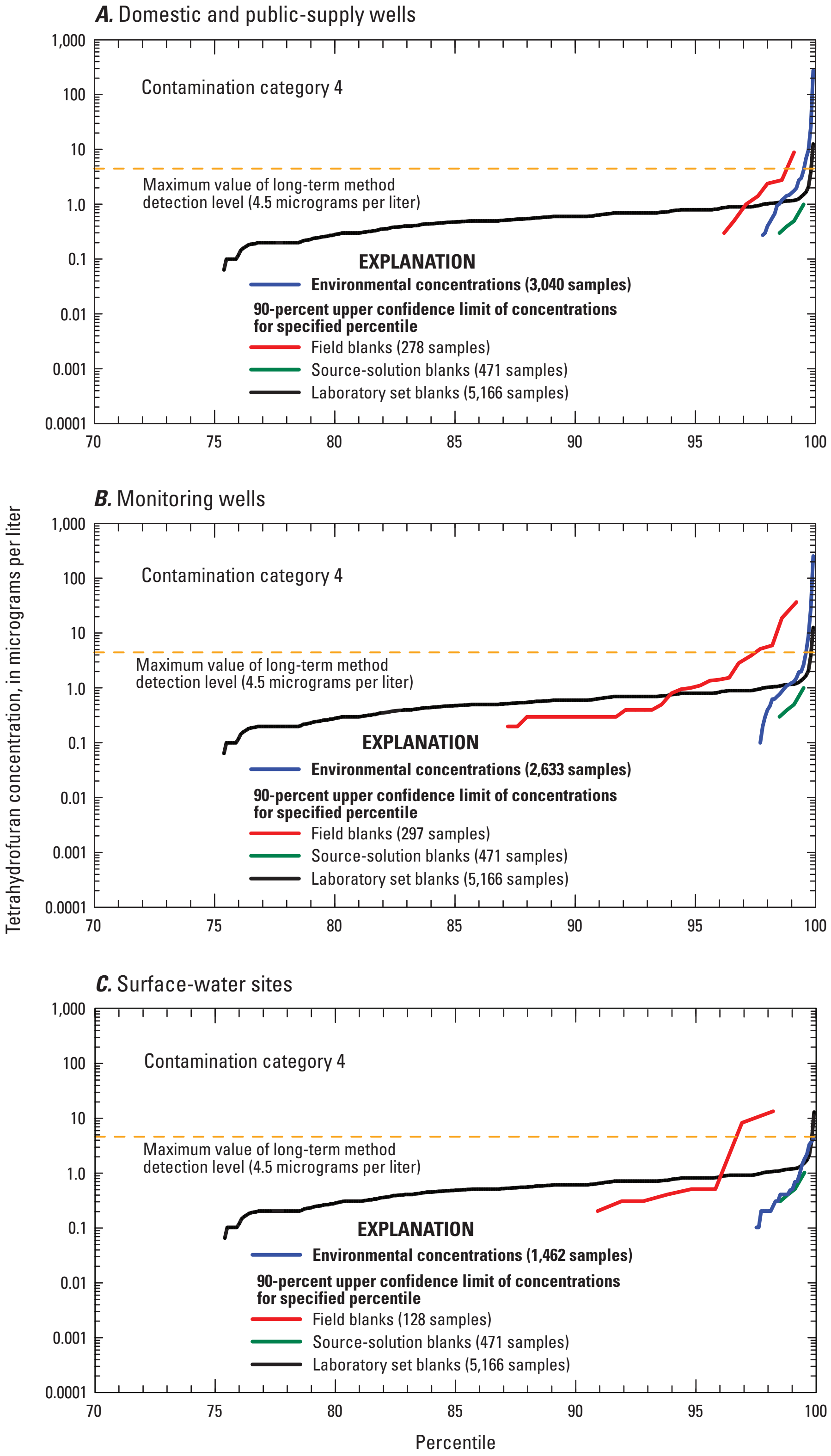
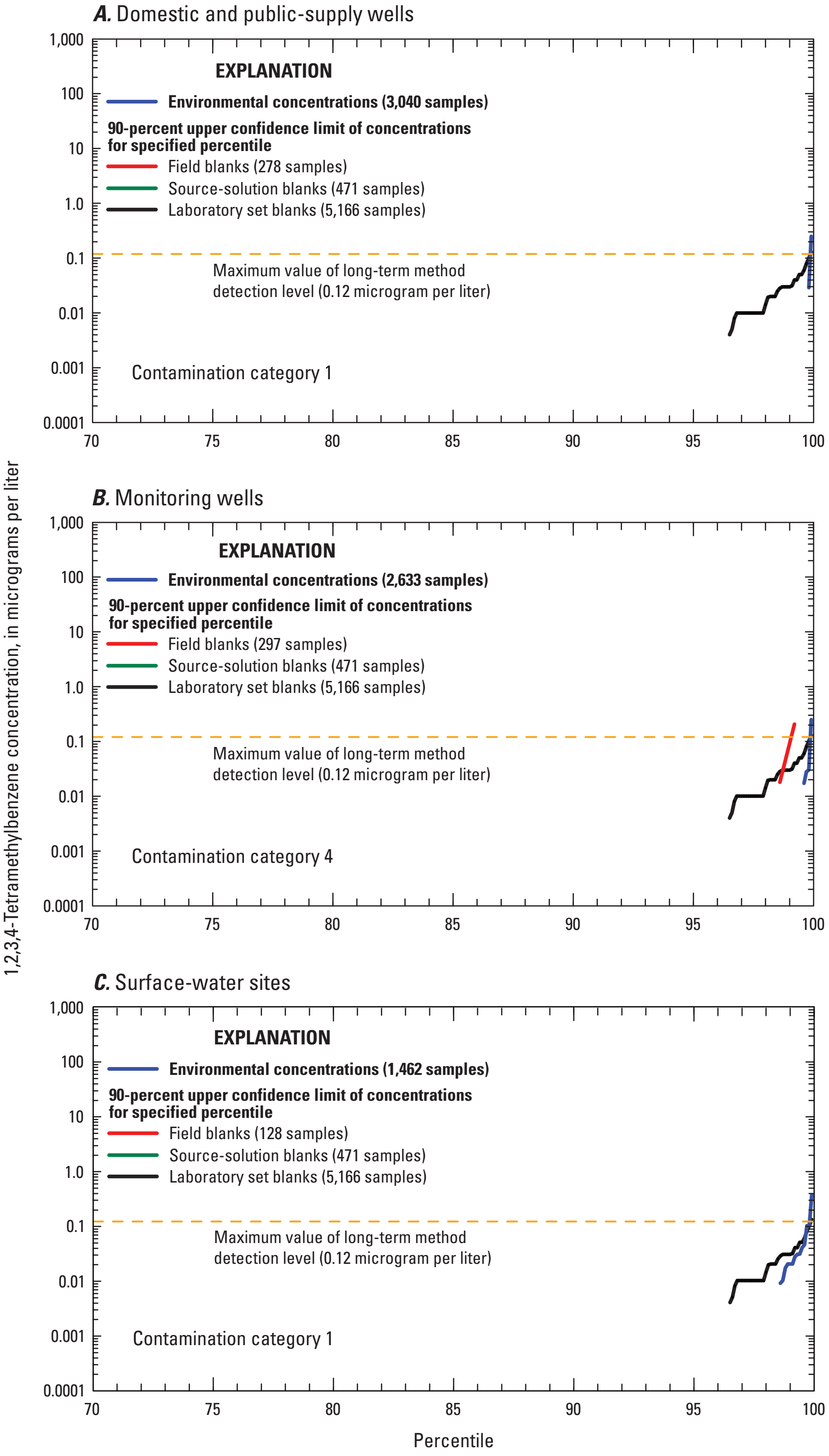


Figure A1–35. Distribution of environmental concentrations and 90-percent upper confidence limits of tetrahydrofuran concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.



igure A1–36. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2,3,4-tetramethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

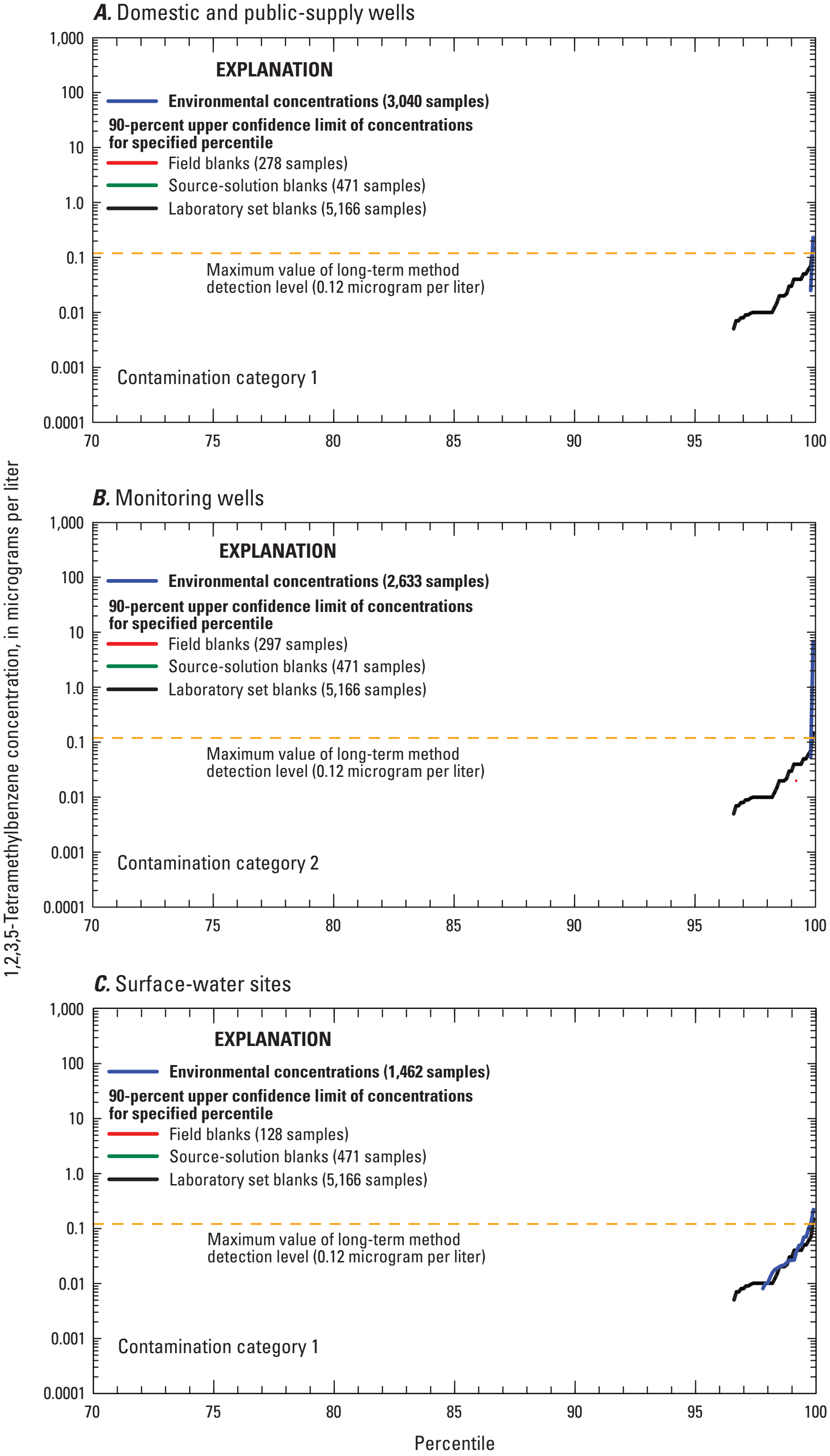


Figure A1–37. Distribution of environmental concentrations and 90-percent confidence limits of 1,2,3,5-tetramethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

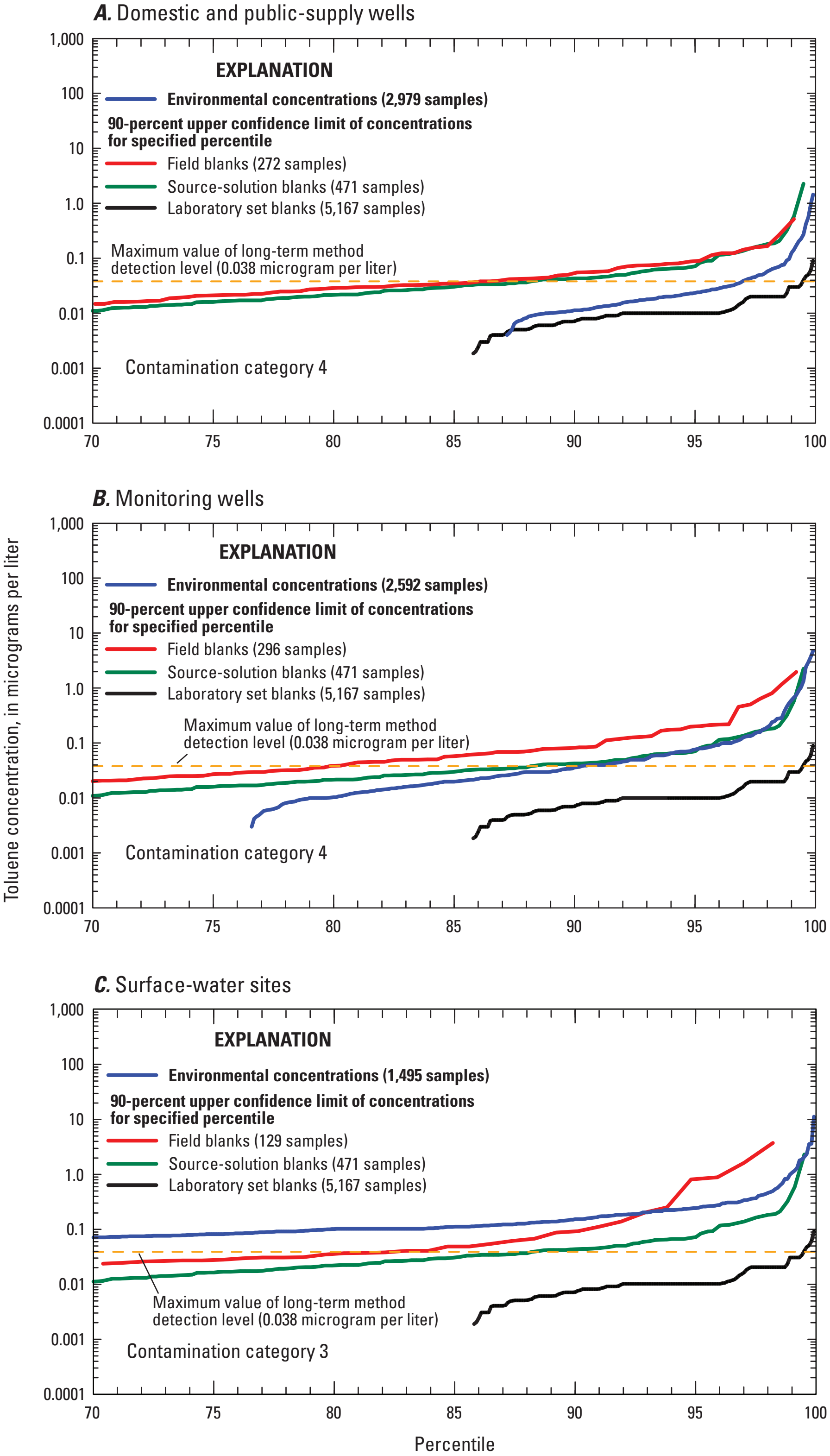


Figure A1–38. Distribution of environmental concentrations and 90-percent upper confidence limits of toluene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

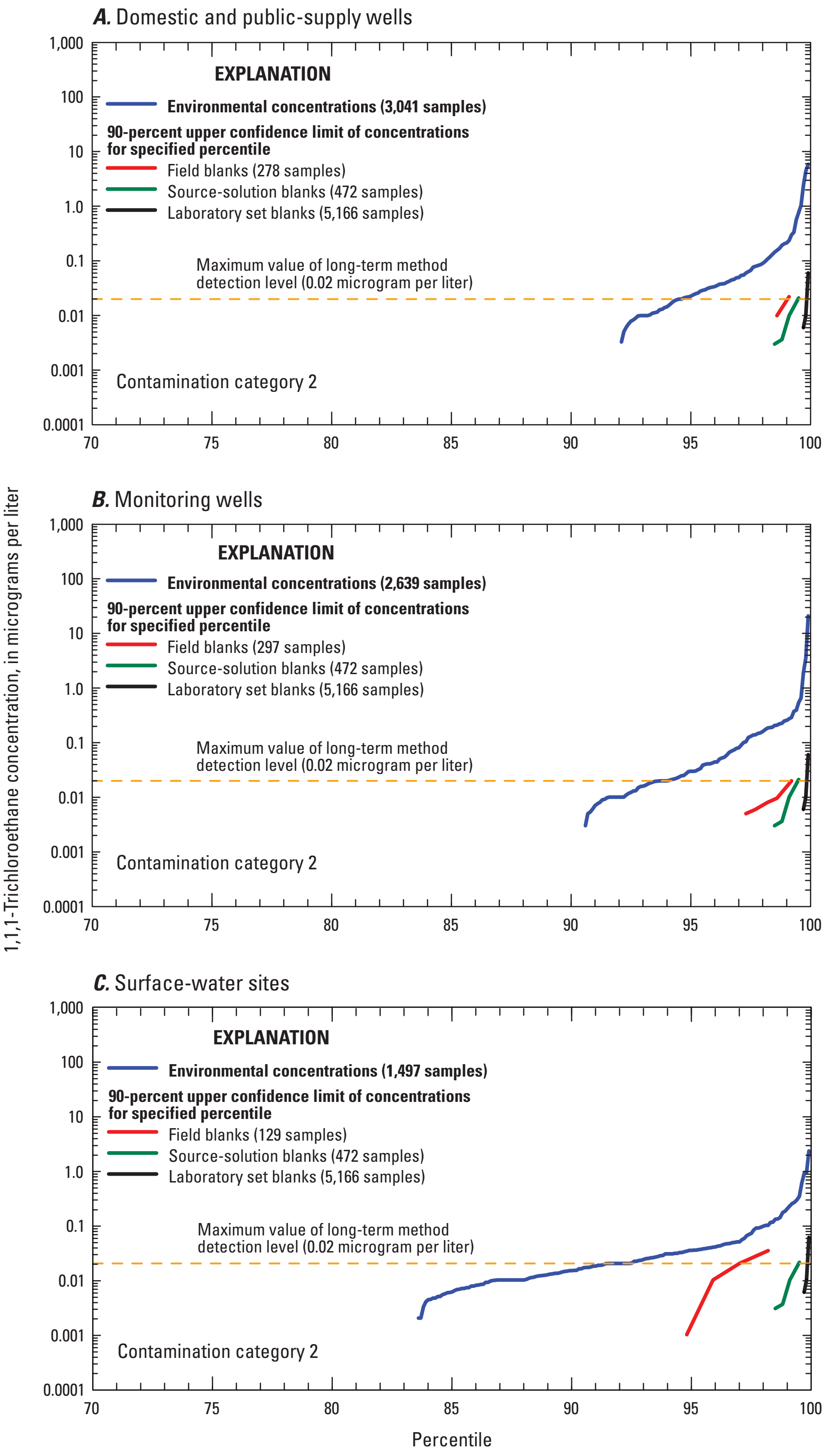


Figure A1–39. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,1,1-trichloroethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

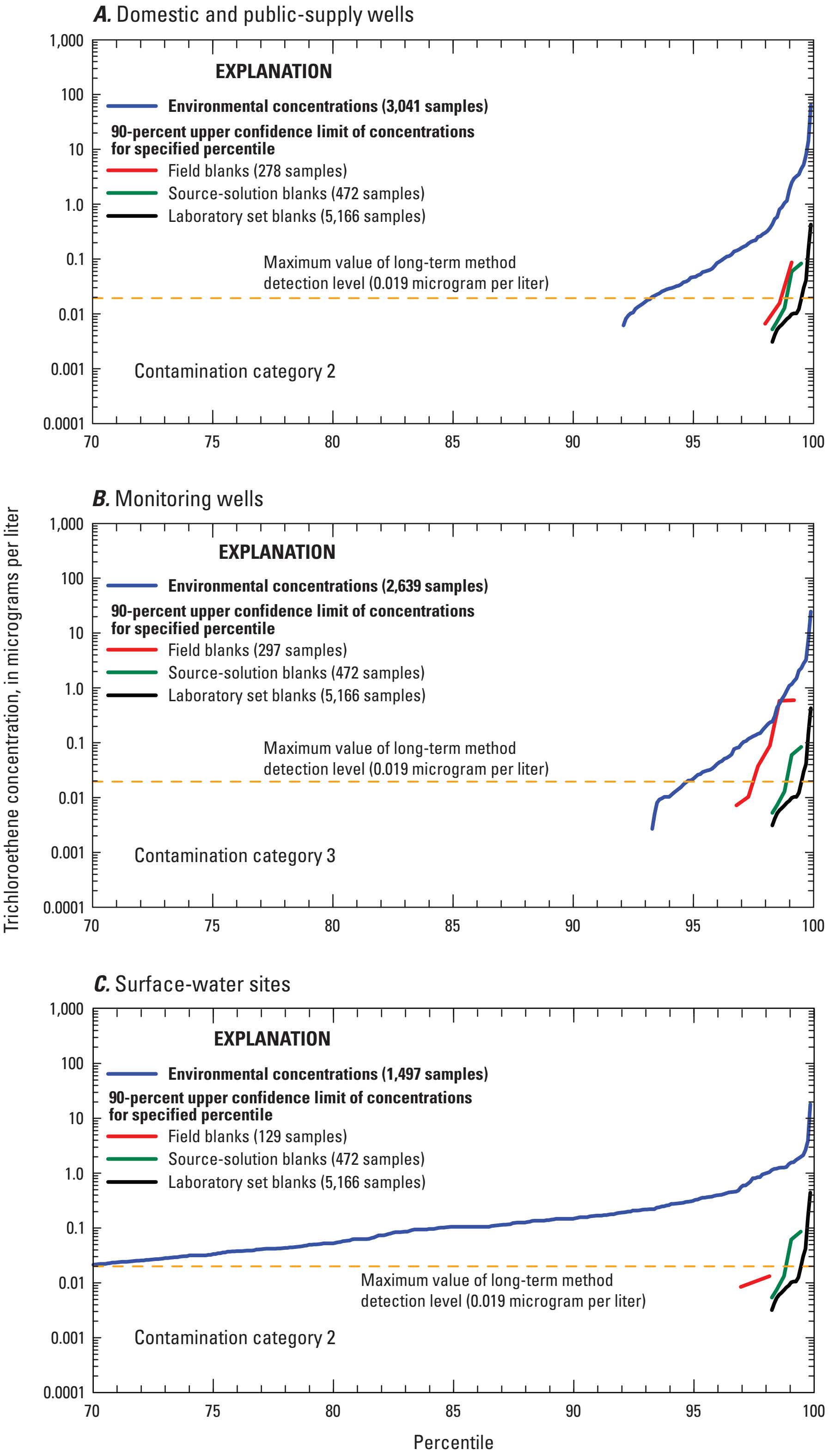


Figure A1–40. Distribution of environmental concentrations and 90-percent upper confidence limits of trichloroethene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

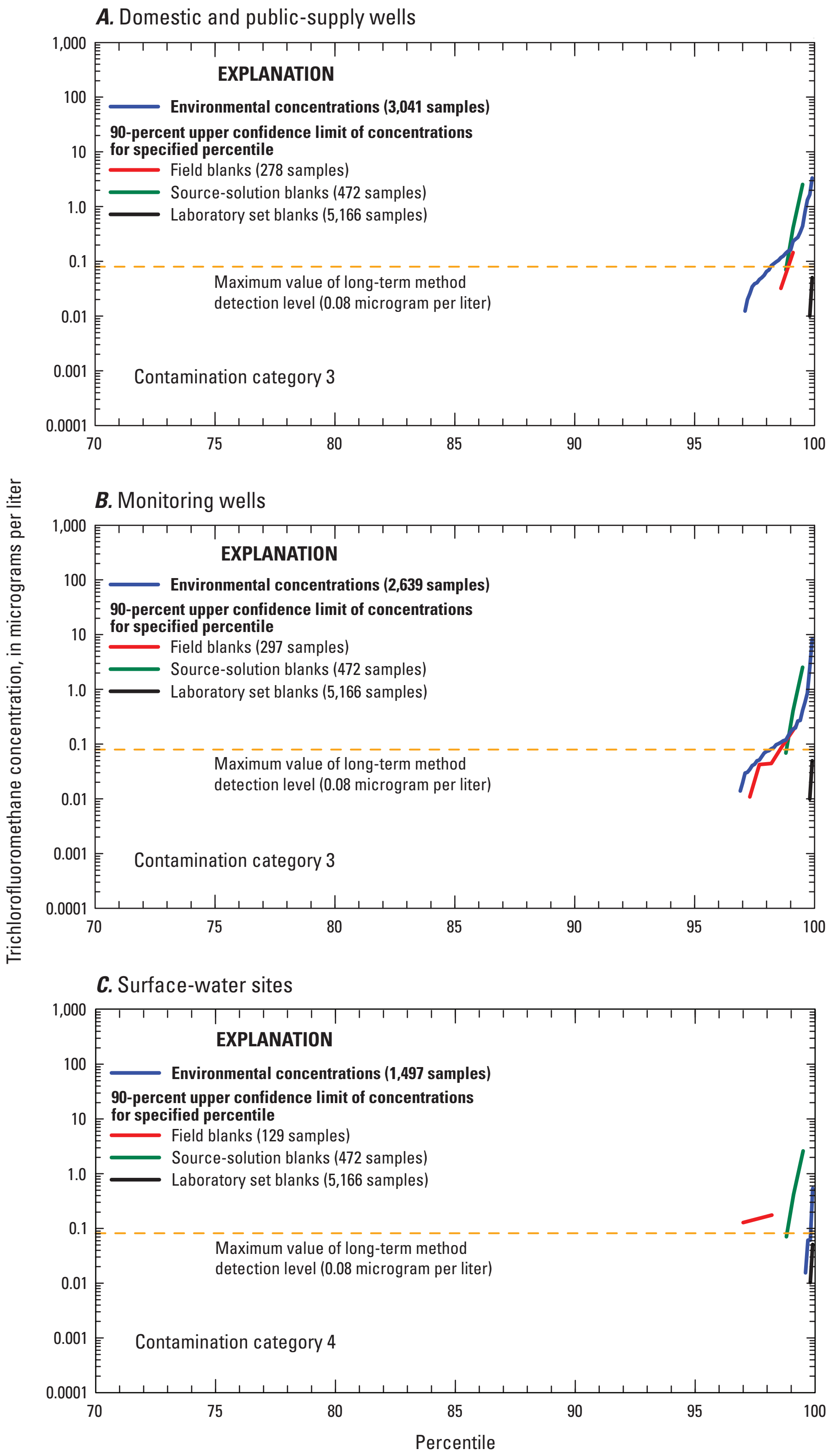


Figure A1–41. Distribution of environmental concentrations and 90-percent upper confidence limits of trichlorofluoromethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

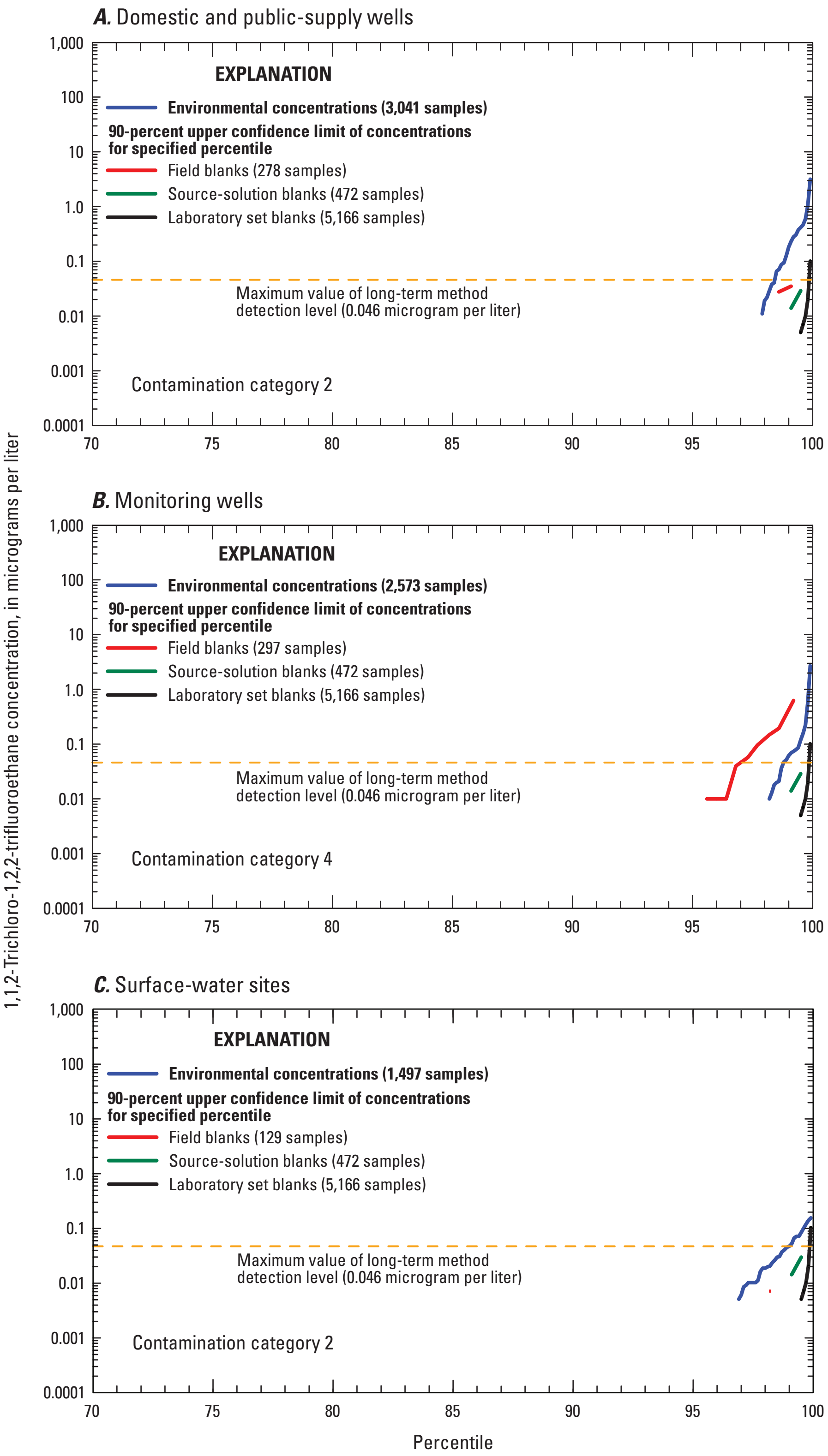


Figure A1–42. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,1,2-trichloro-1,2,2-trifluoroethane concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

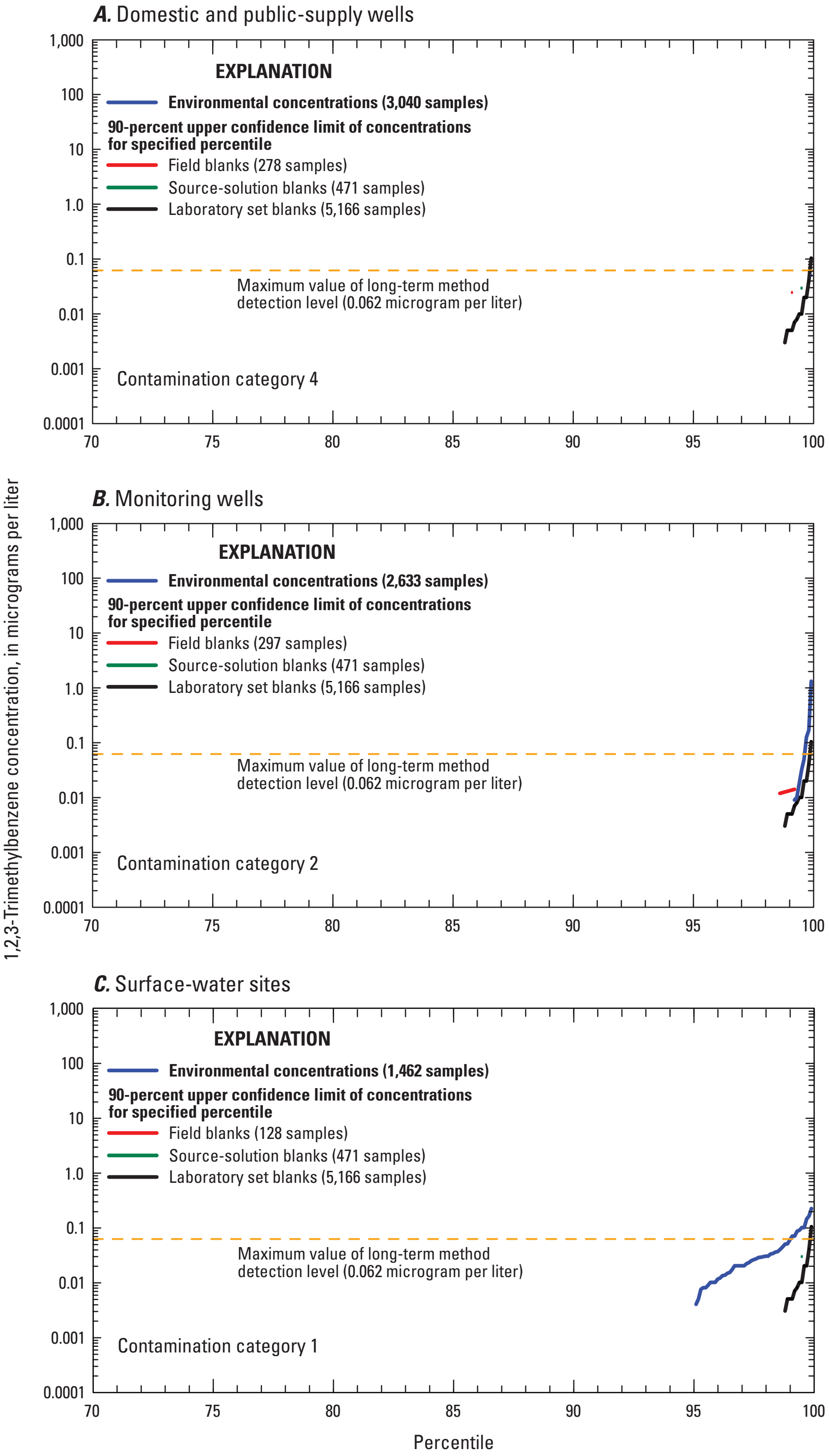


Figure A1–43. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2,3-trimethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

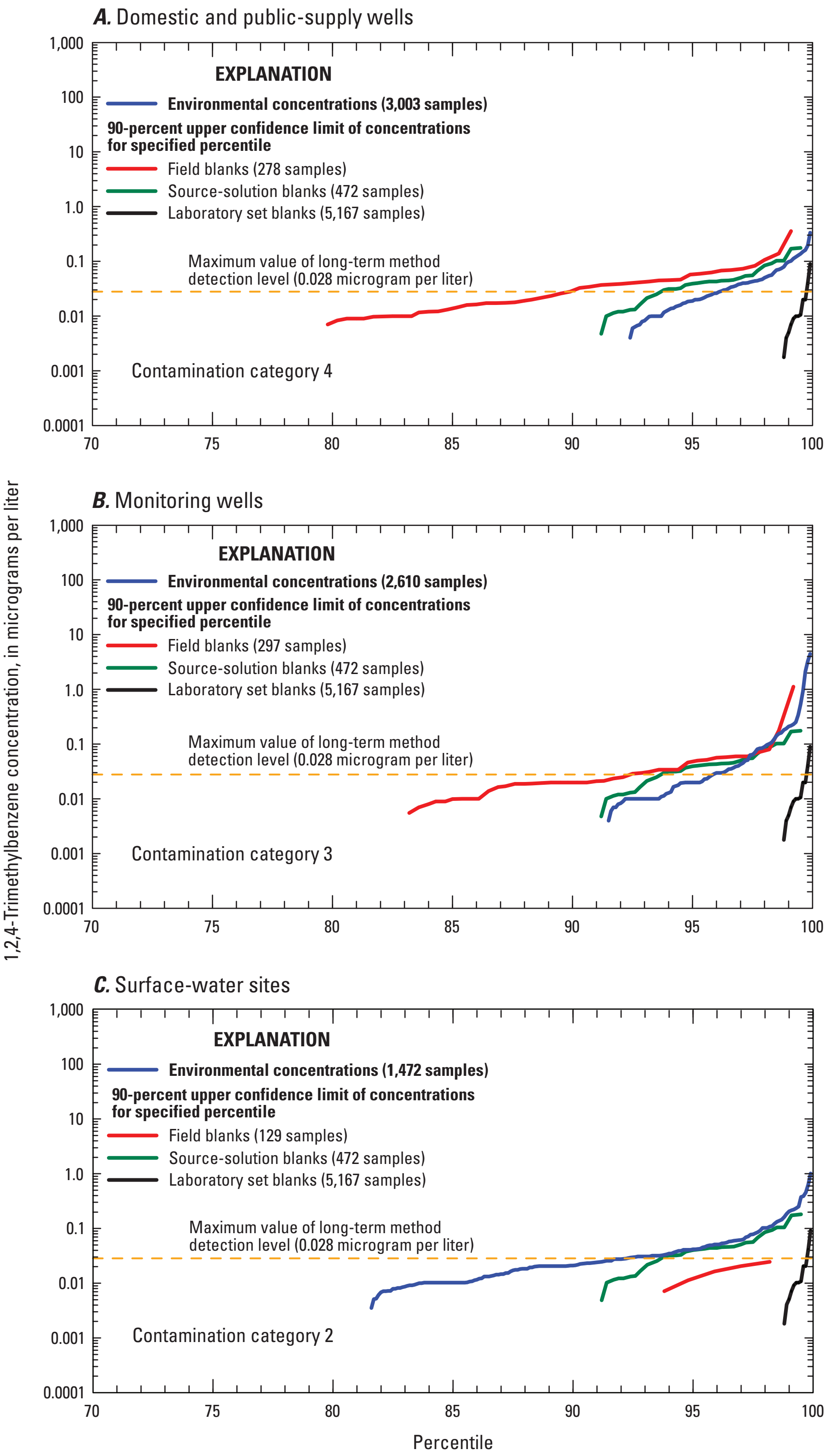


Figure A1–44. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,2,4-trimethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

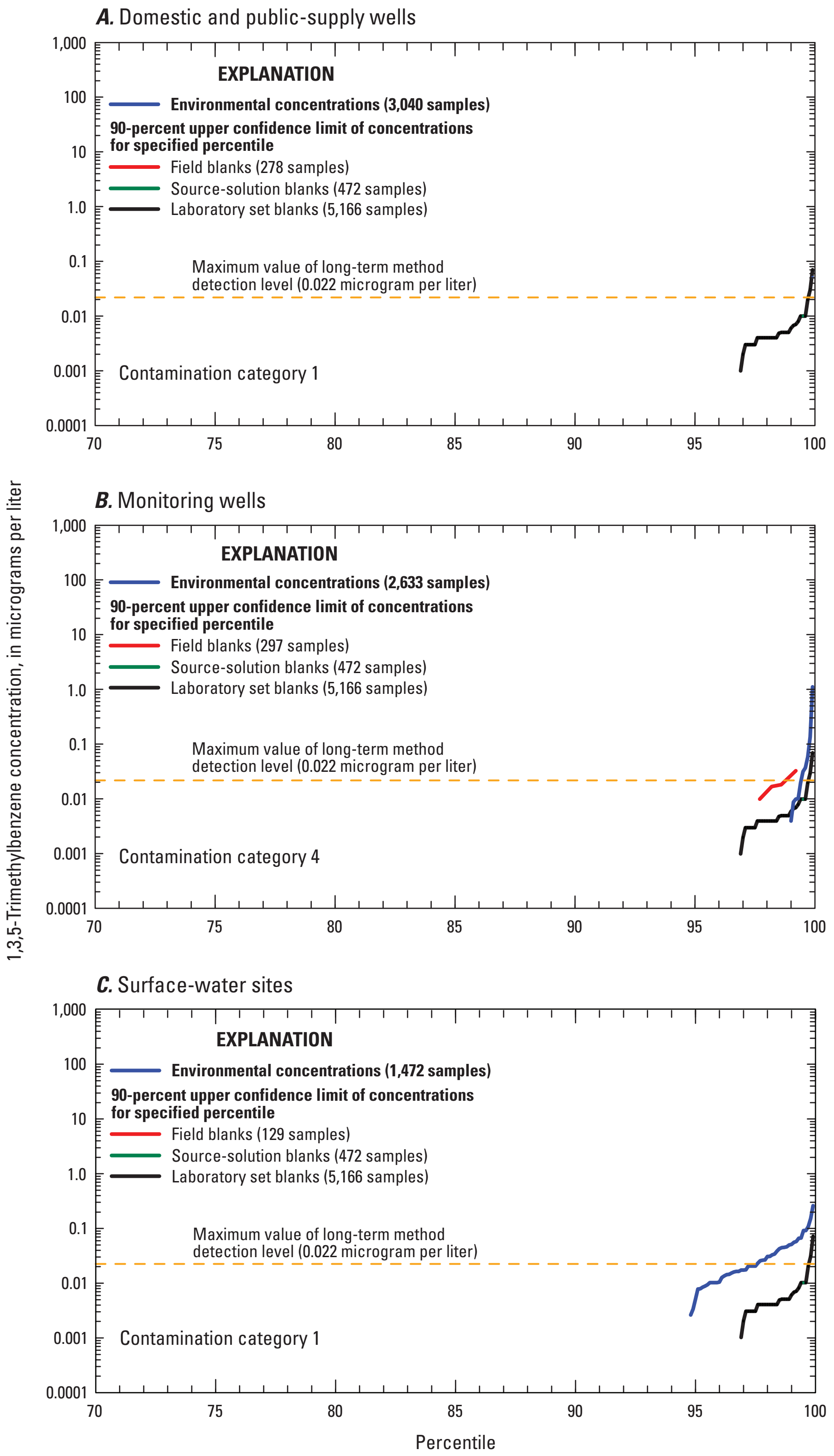


Figure A1–45. Distribution of environmental concentrations and 90-percent upper confidence limits of 1,3,5-trimethylbenzene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

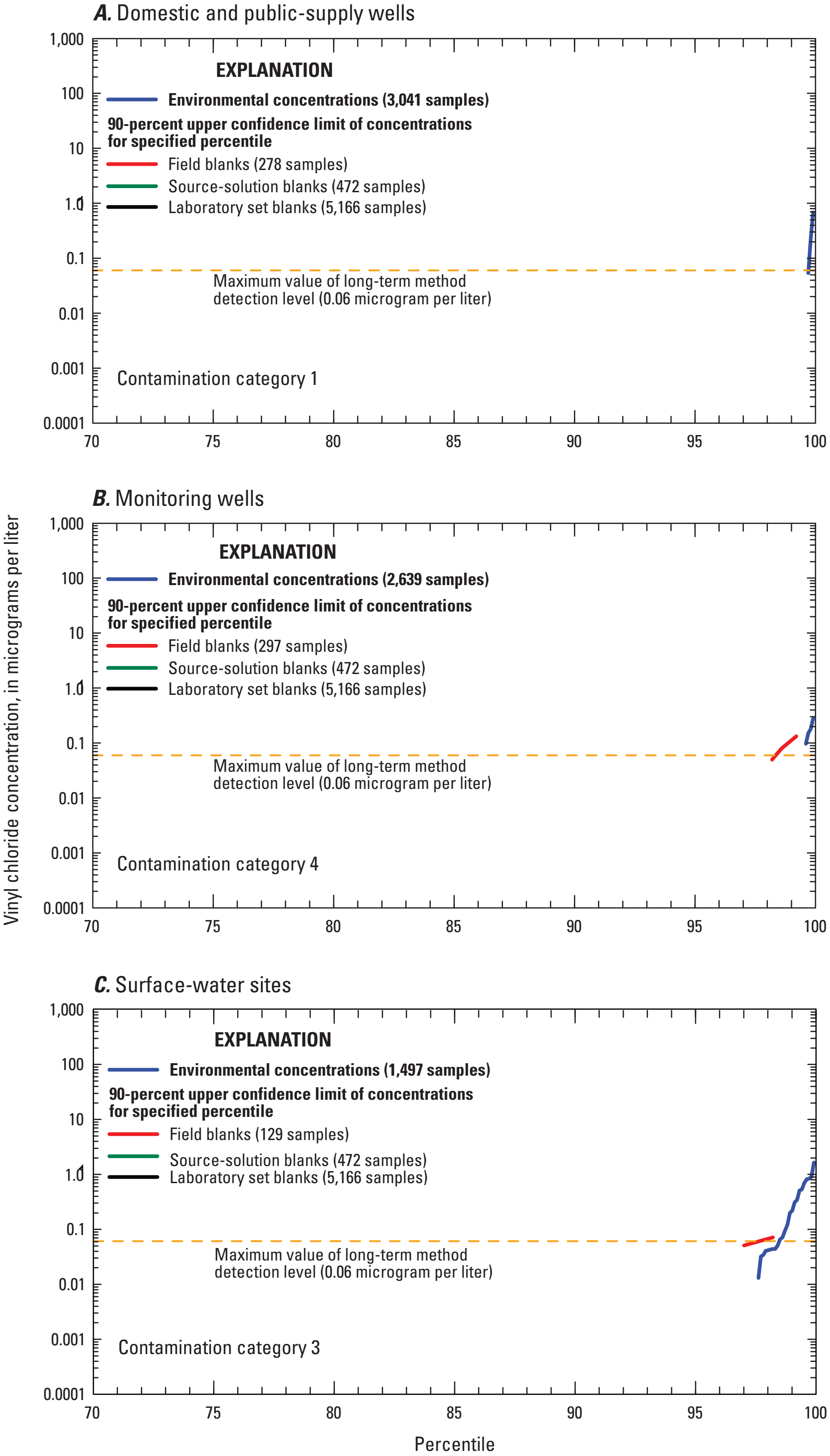
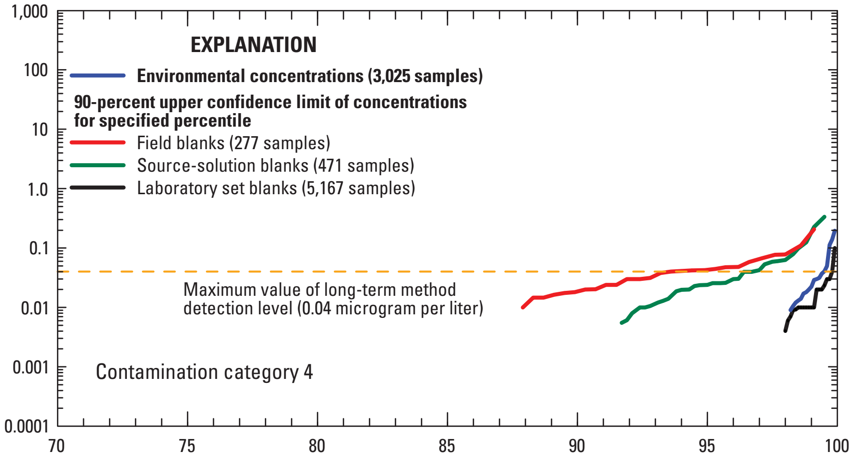
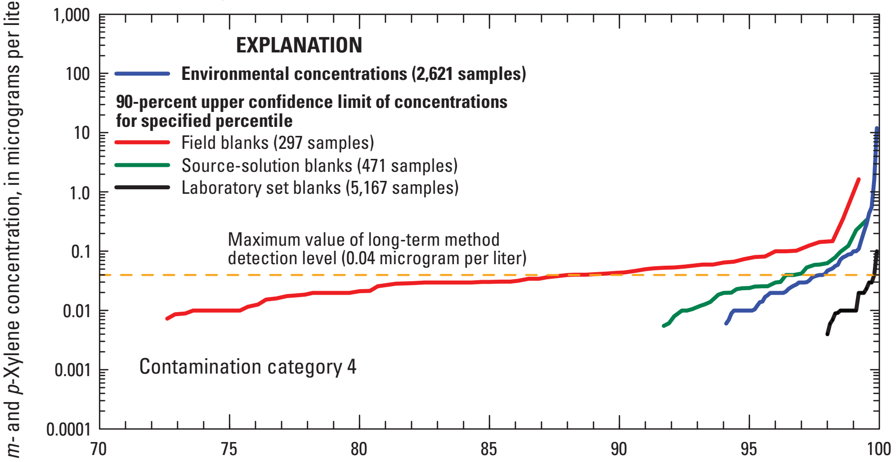


Figure A1–46. Distribution of environmental concentrations and 90-percent upper confidence limits of vinyl chloride concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

A. Domestic and public-supply wells



B. Monitoring wells



C. Surface-water sites

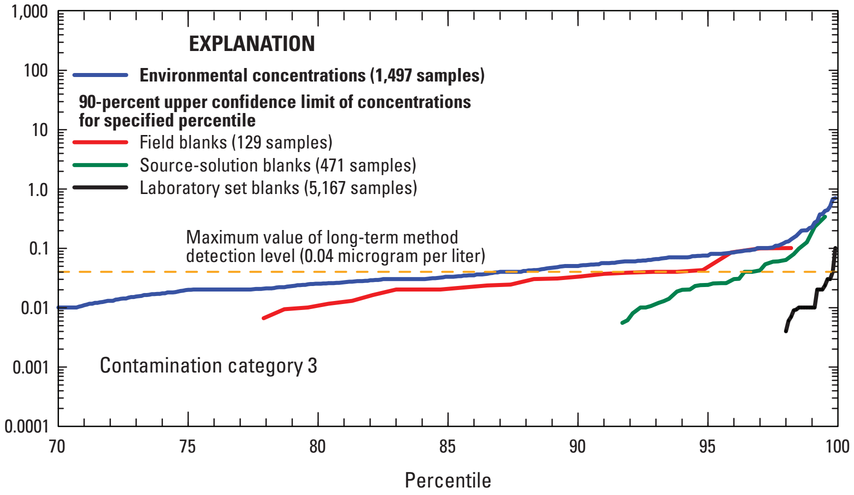


Figure A1–47. Distribution of environmental concentrations and 90-percent upper confidence limits of *m*- and *p*-xylene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

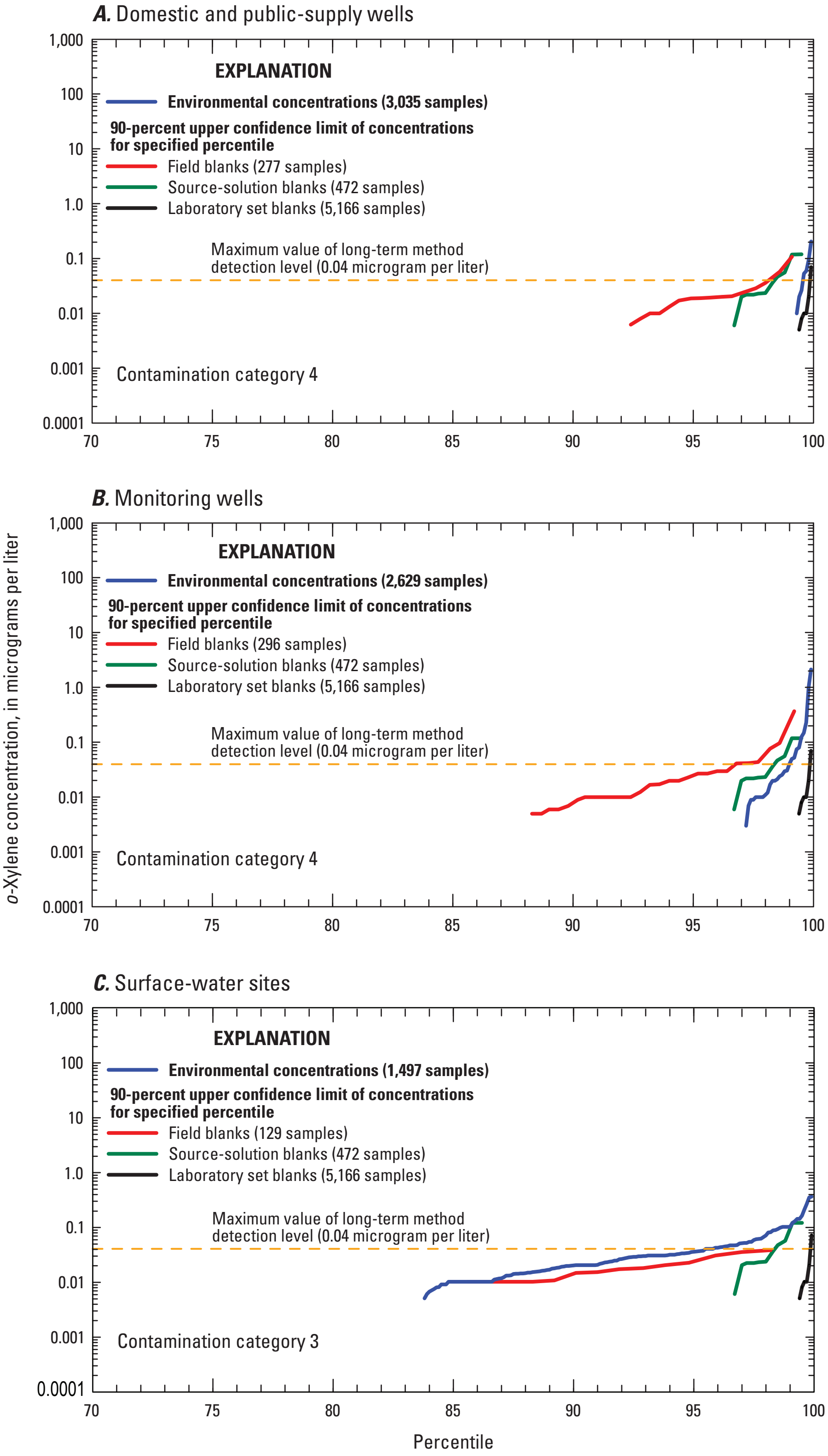


Figure A1–48. Distribution of environmental concentrations and 90-percent upper confidence limits of *o*-xylene concentrations in field blanks, source-solution blanks, and laboratory set blanks *A*, domestic and public-supply wells; *B*, monitoring wells; and *C*, surface-water sites. Nondetections were ranked lower than any low-level detection for calculation of percentiles. Nondetections are not shown. Upper confidence limits indicate how extensive contamination might be in the population of blanks.

Appendix 2. One-to-One Concentration Plots of Paired Field Blank Concentrations to Source-Solution Blank and Environmental Concentrations, October 1996 to December 2008

Figures A2–1 to A2–19. Relation of concentrations between field blanks and paired samples of *A*, source-solution blanks, and *B*, environmental samples, October 1996 to December 2008 for the following volatile organic compounds. Nondetections are plotted at 0.001 microgram per liter.

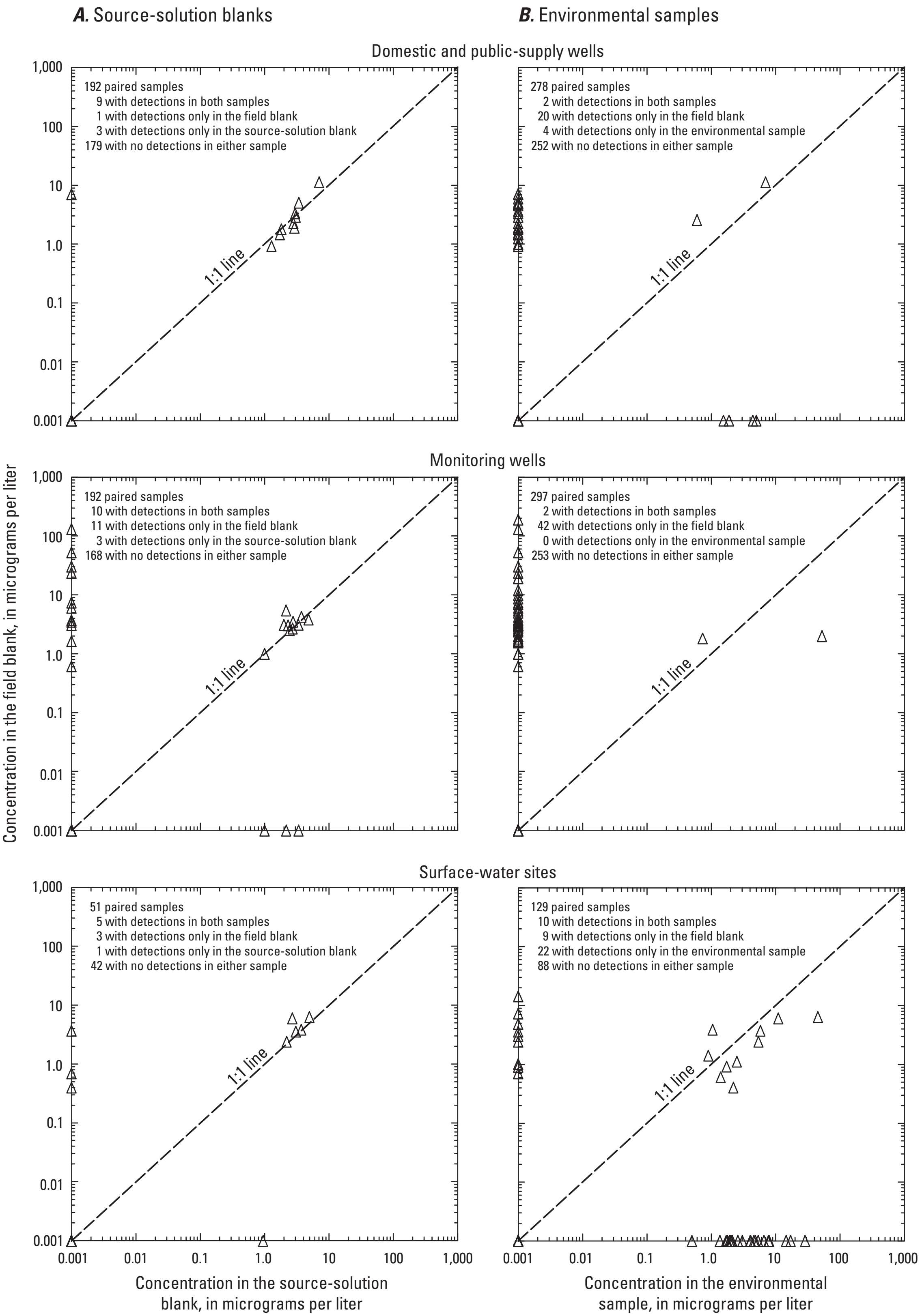


Figure A2–1. Relation of acetone concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 4 micrograms per liter.

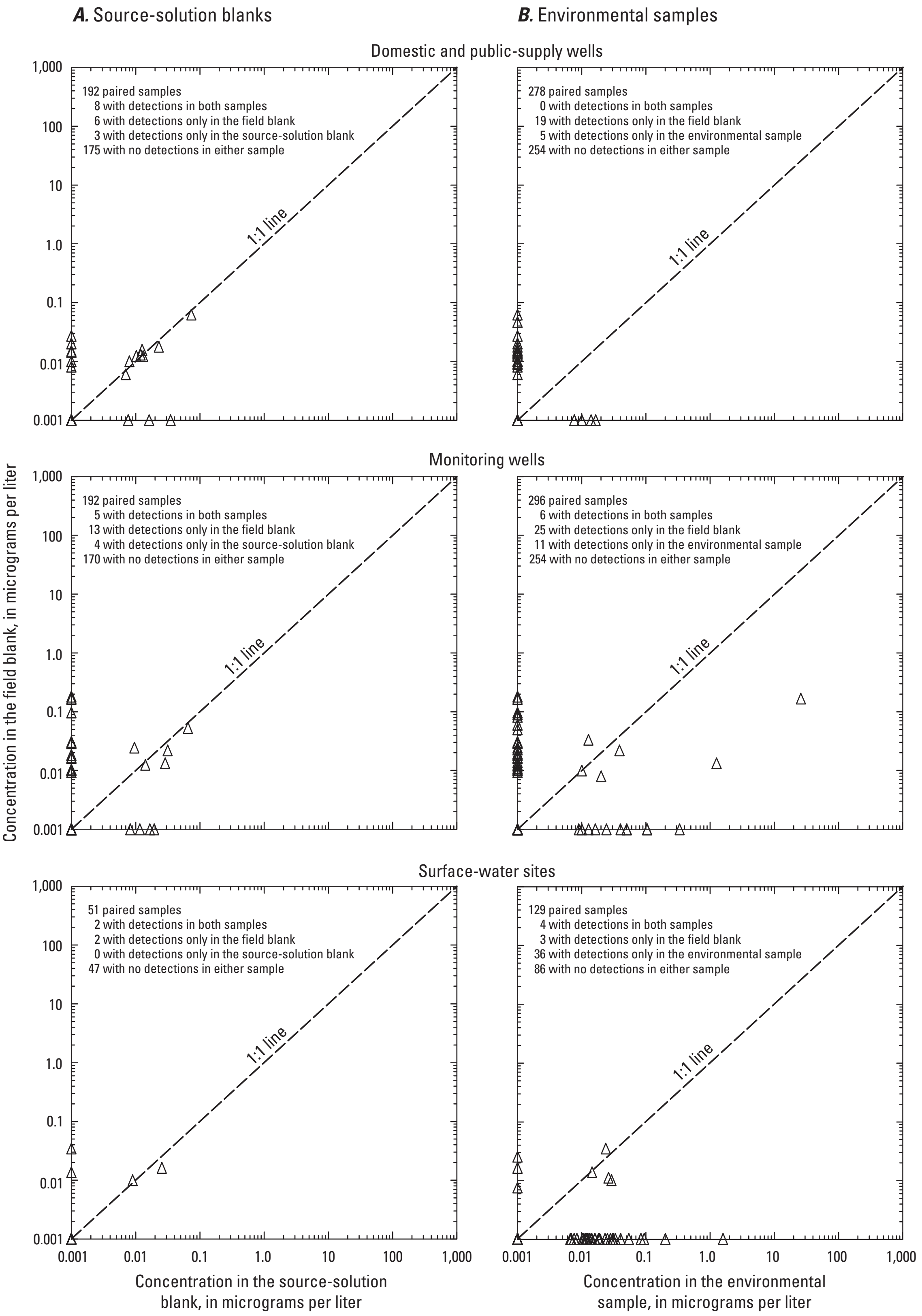


Figure A2–2. Relation of benzene concentrations in field blanks to paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.05 microgram per liter.

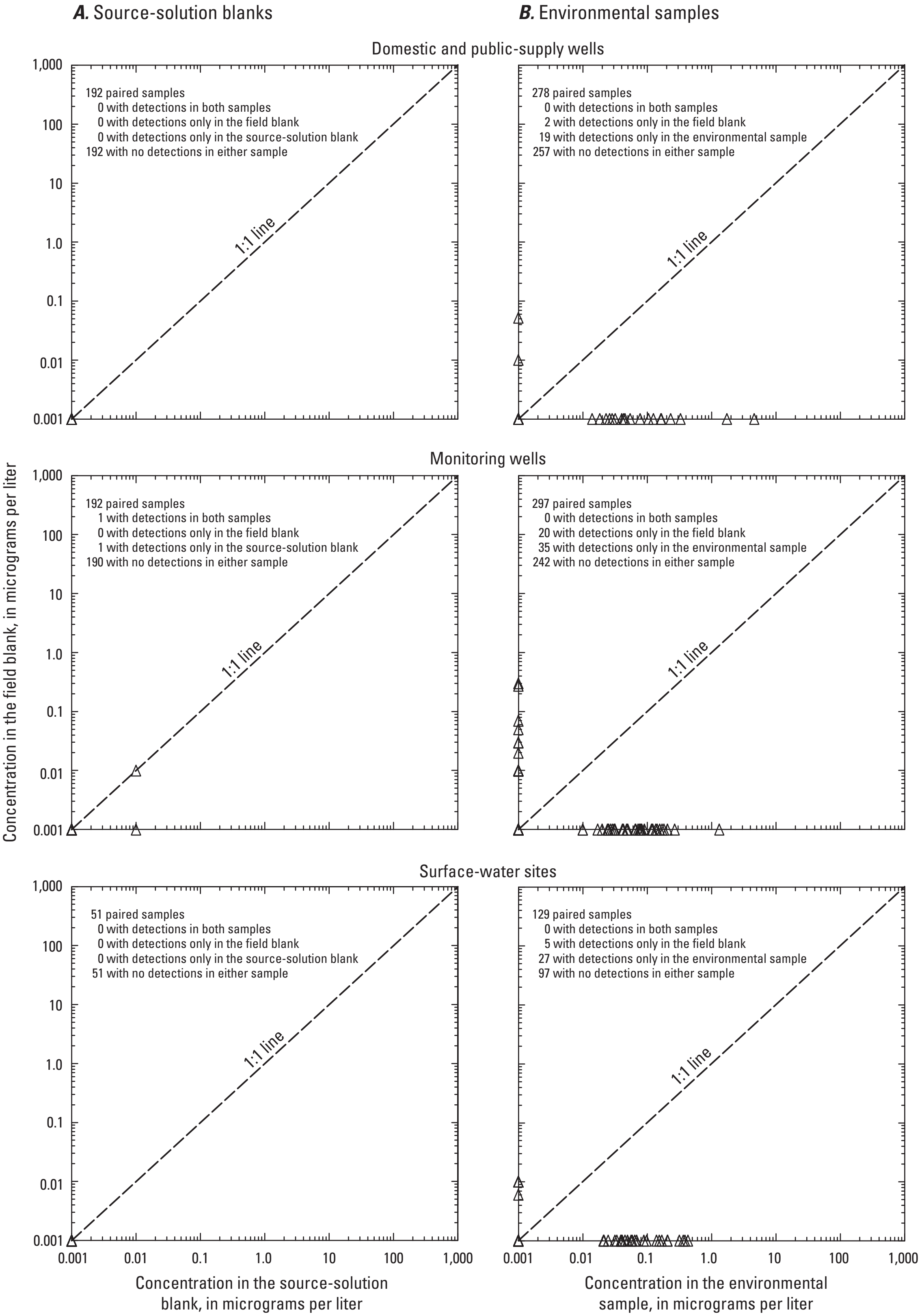


Figure A2–3. Relation of bromodichloromethane concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.024 microgram per liter.

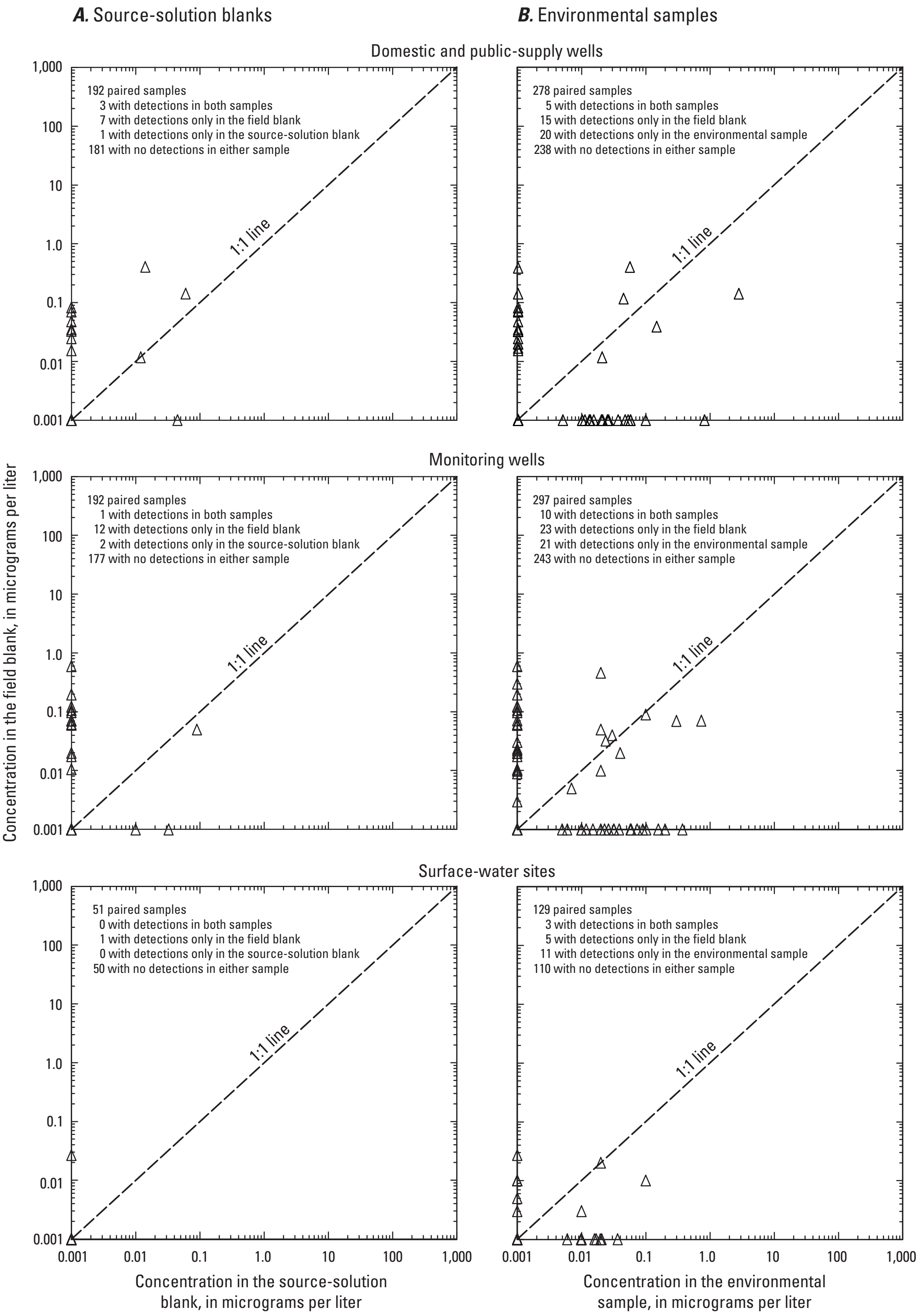


Figure A2–4. Relation of carbon disulfide concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.185 microgram per liter.

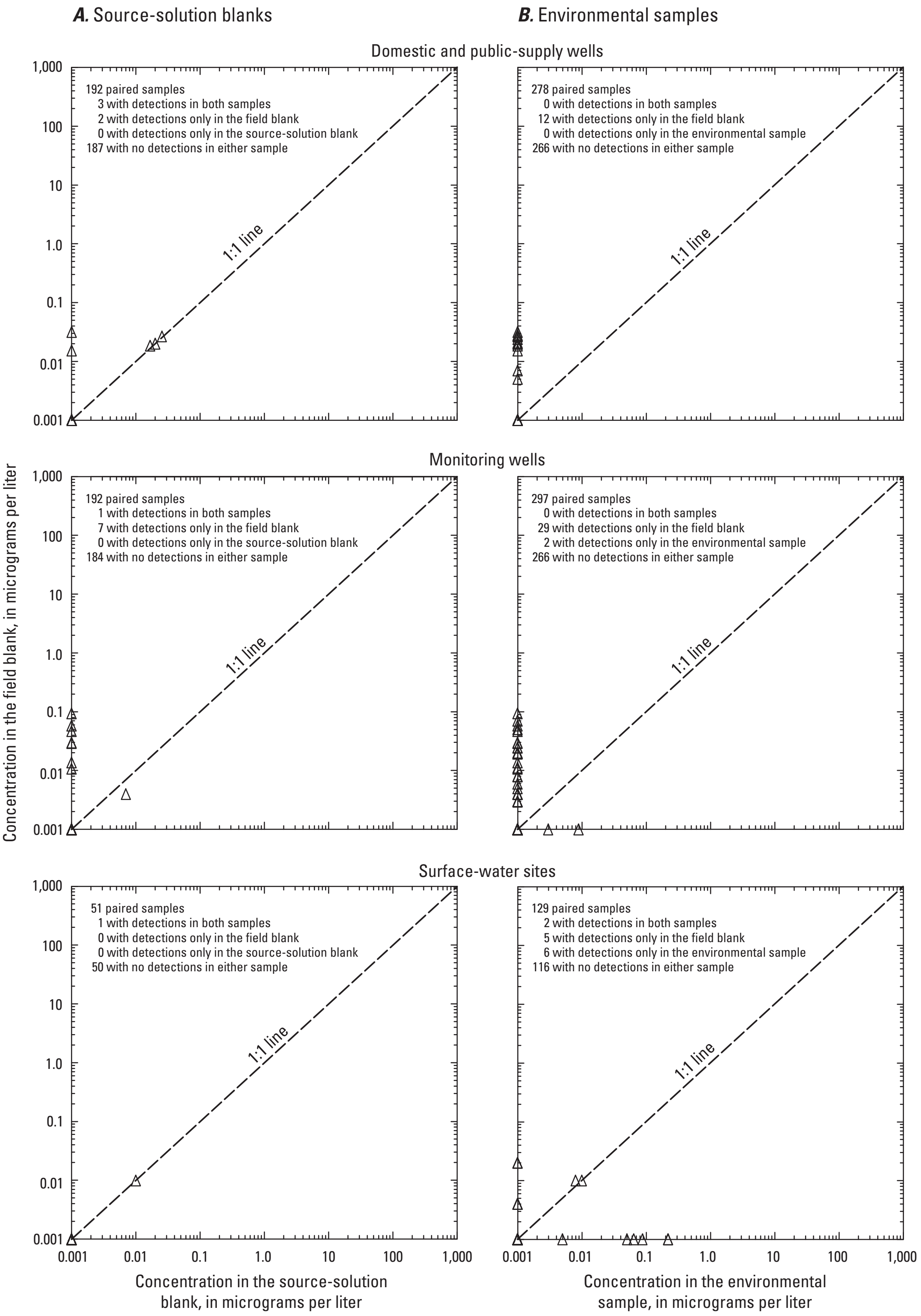


Figure A2–5. Relation of chlorobenzene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.014 microgram per liter.

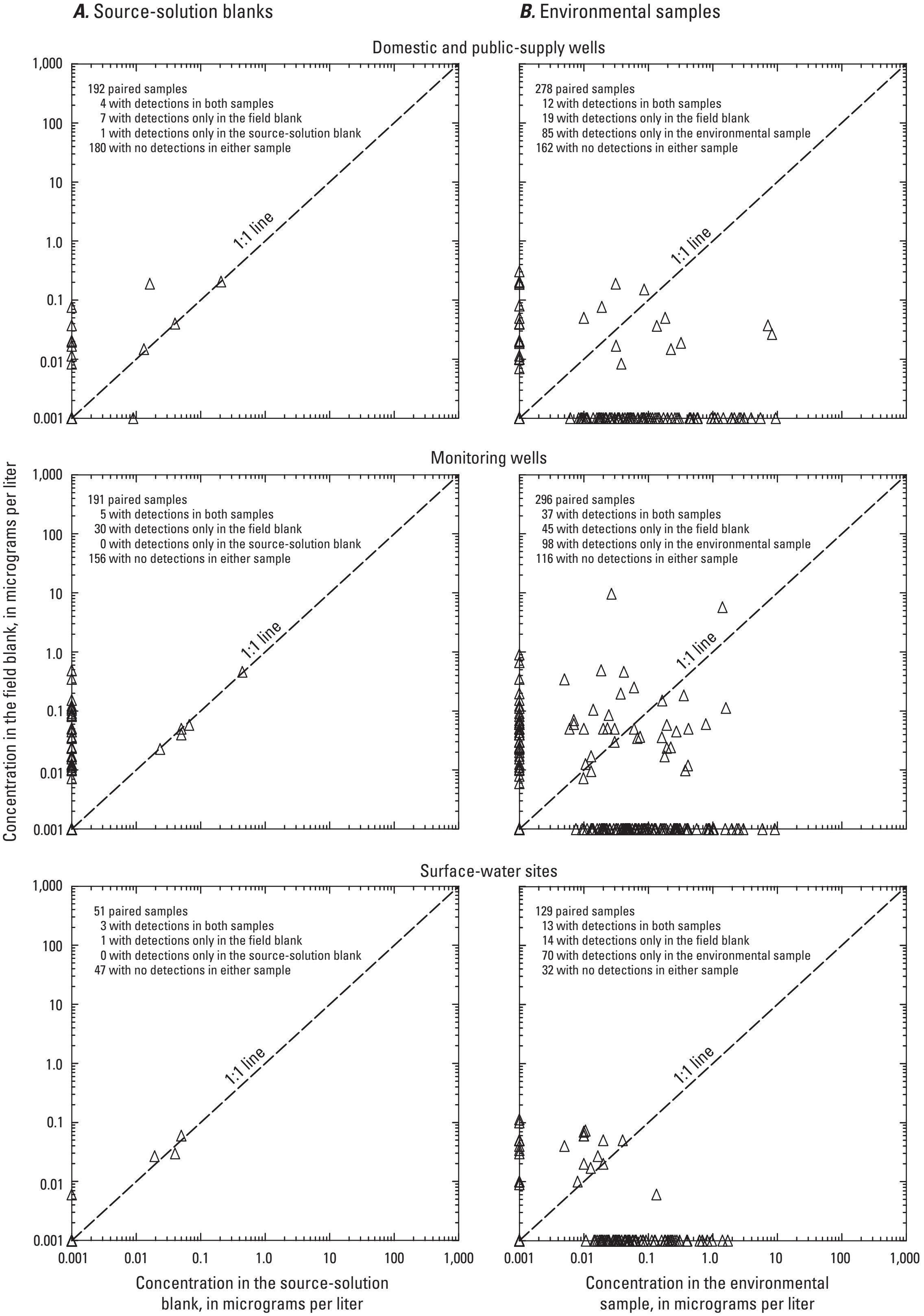


Figure A2–6. Relation of chloroform concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.026 microgram per liter.

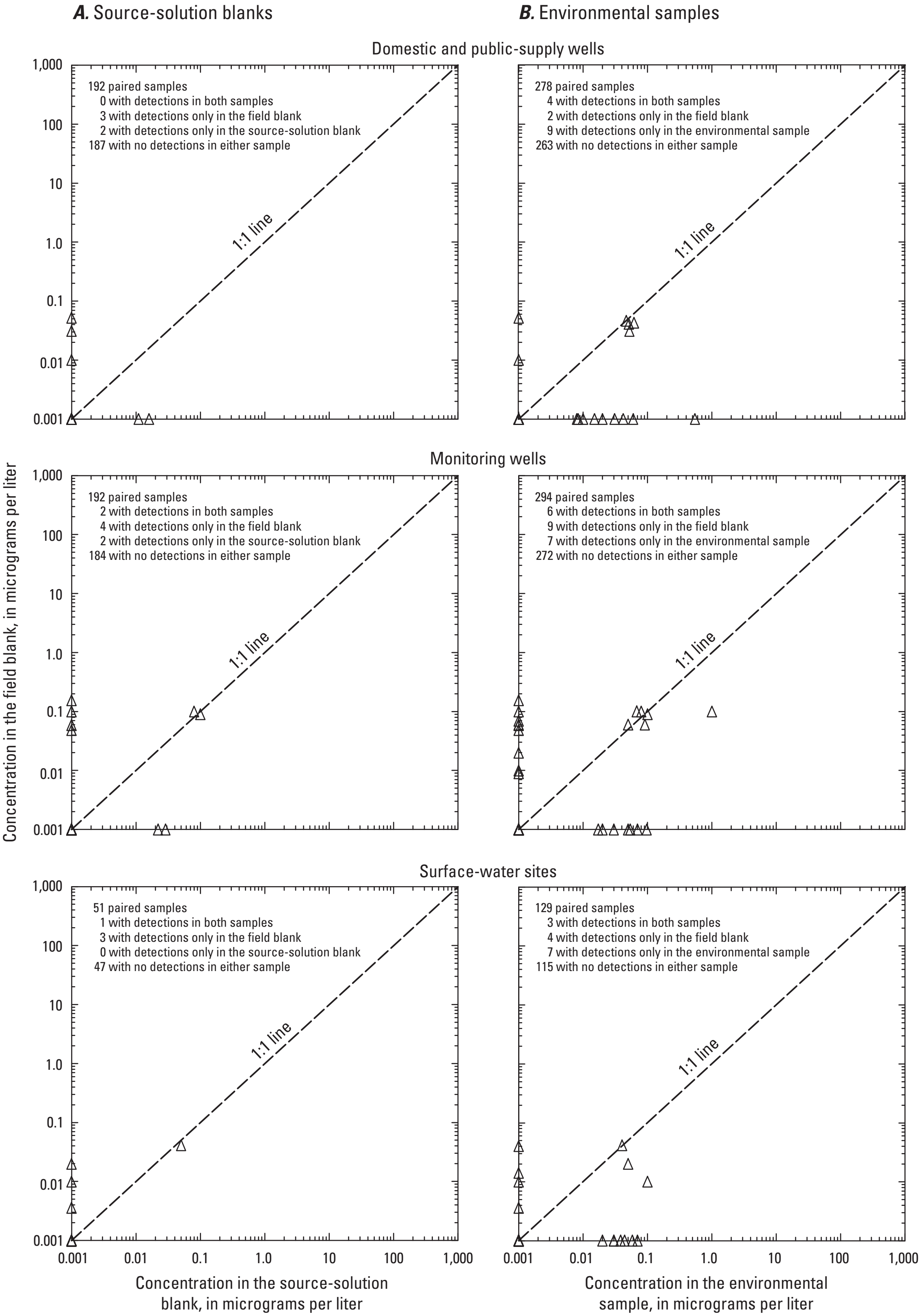


Figure A2–7. Relation of chloromethane concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.3 microgram per liter.

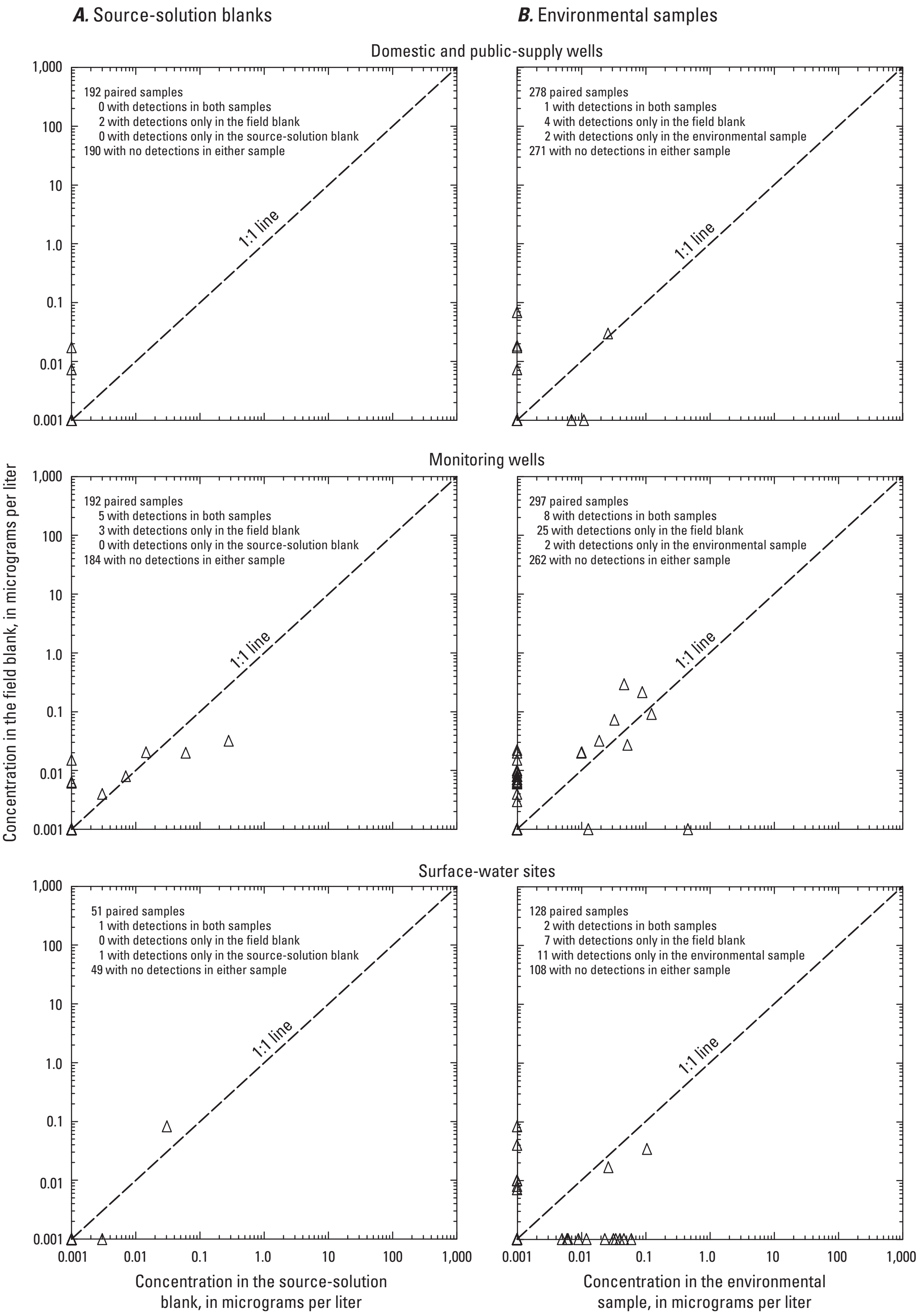


Figure A2–8. Relation of 1,4-dichlorobenzene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.025 microgram per liter.

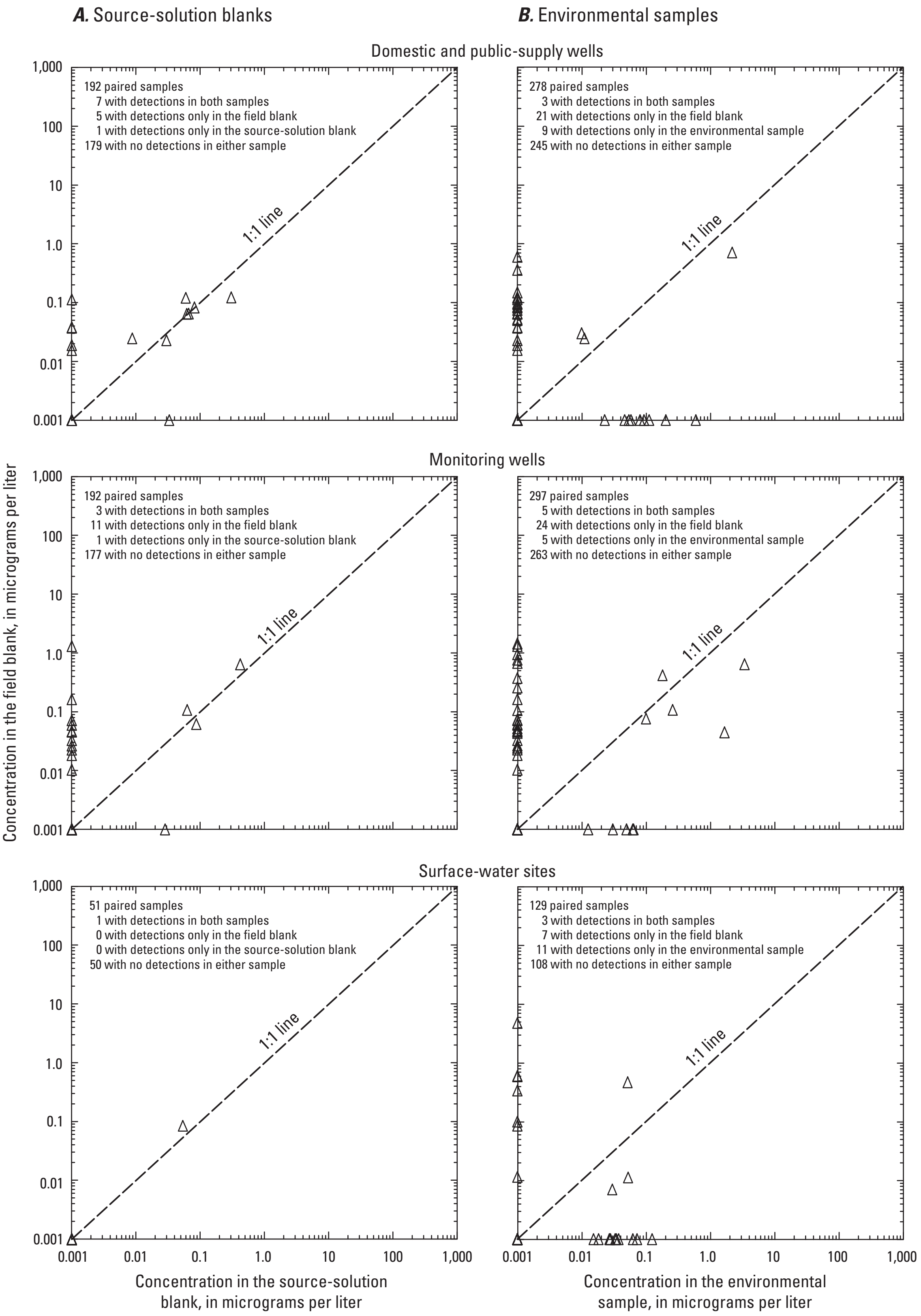


Figure A2–9. Relation of dichloromethane concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.191 microgram per liter.

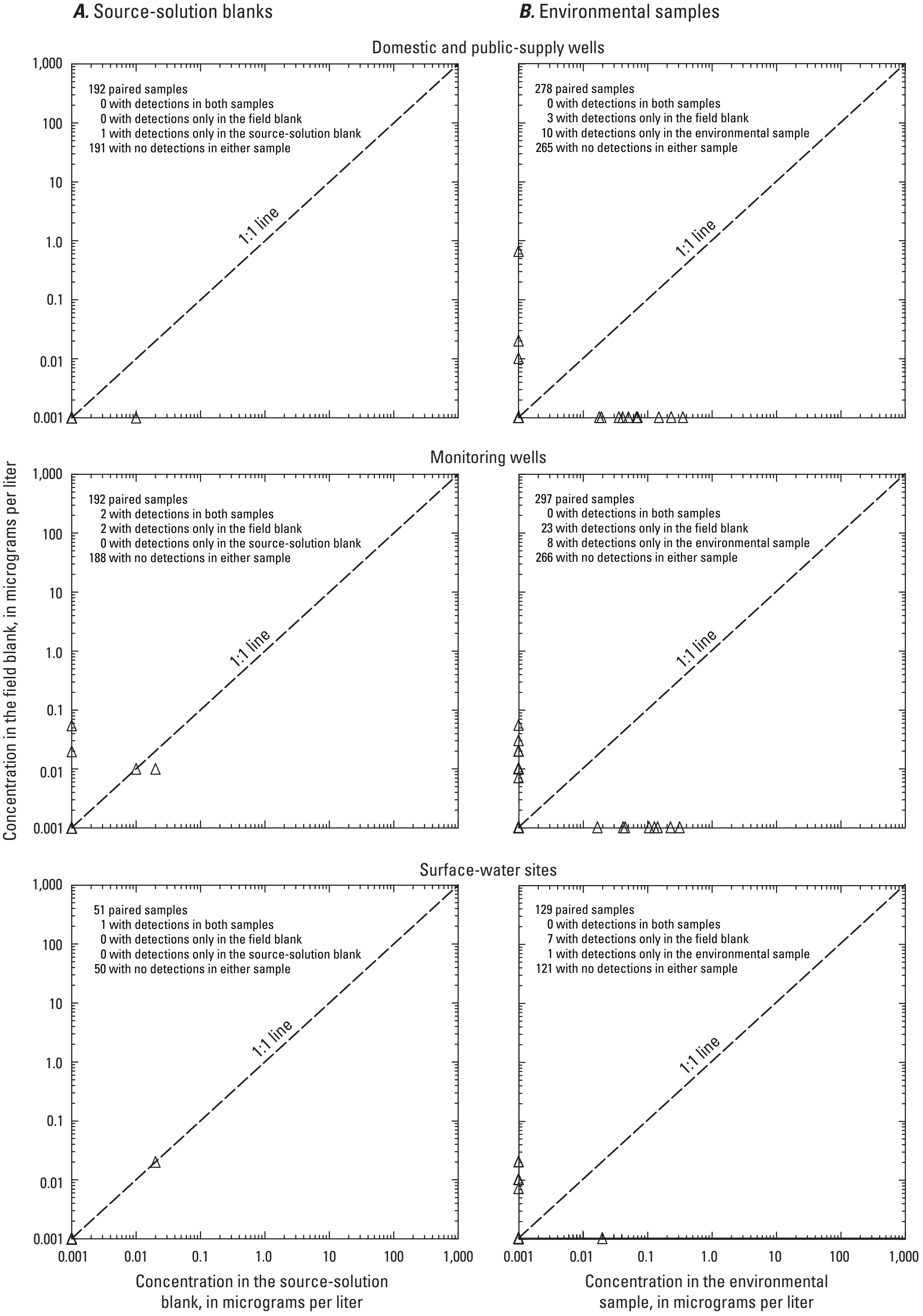


Figure A2–10. Relation of 1,2-dichloropropane concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.034 microgram per liter.

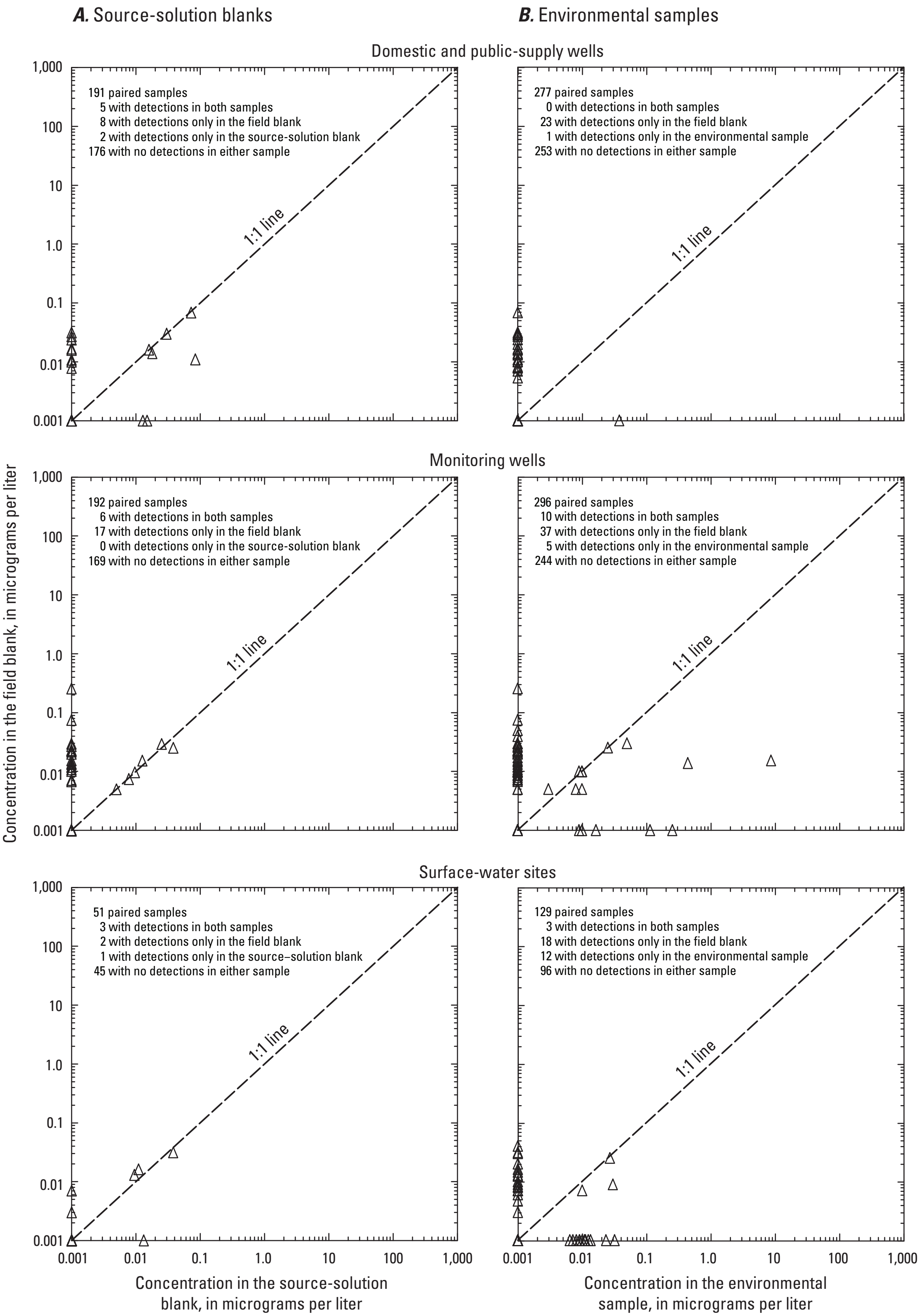


Figure A2–11. Relation of ethylbenzene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.02 microgram per liter.

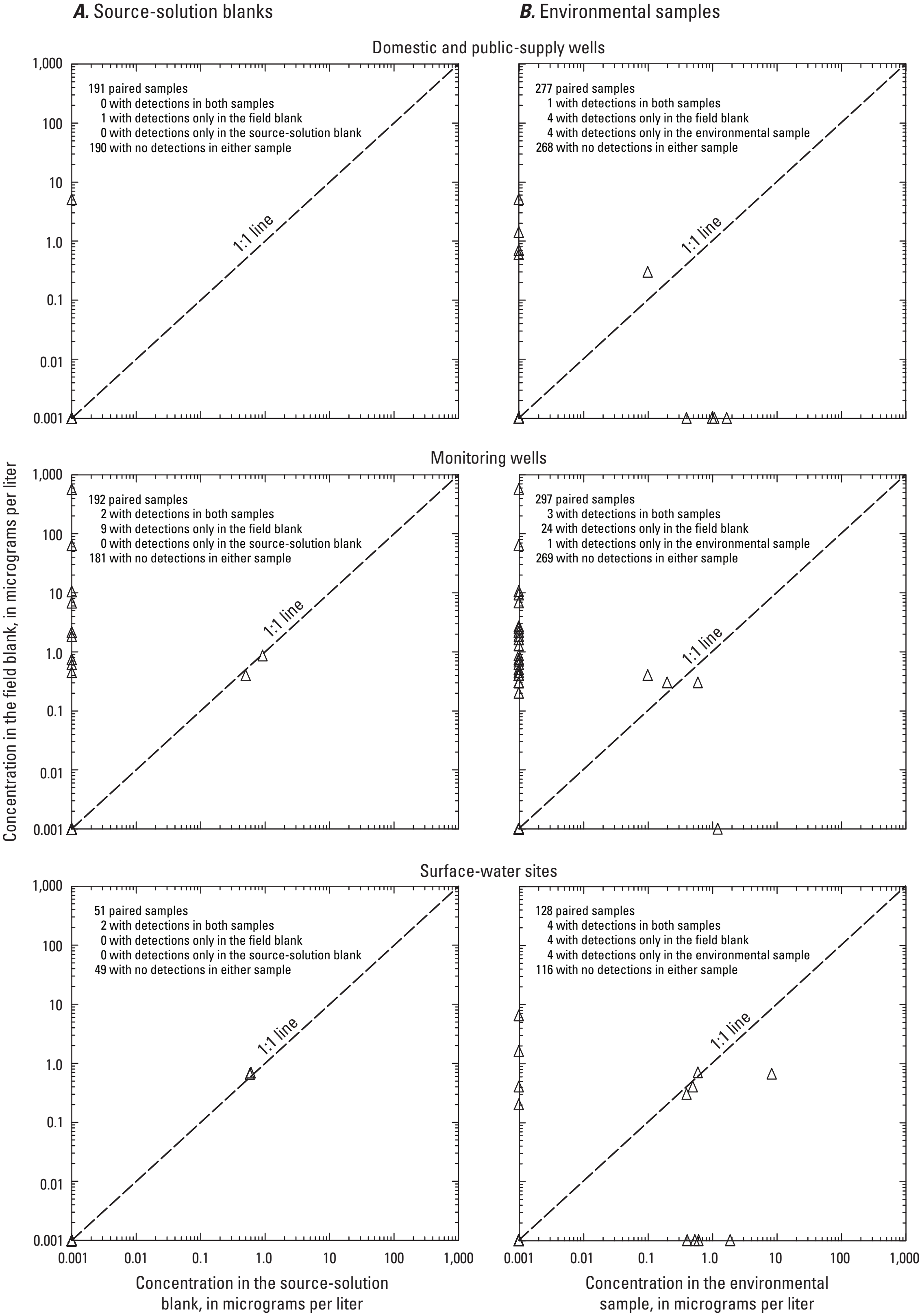


Figure A2–12. Relation of methyl ethyl ketone concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 2.5 micrograms per liter.

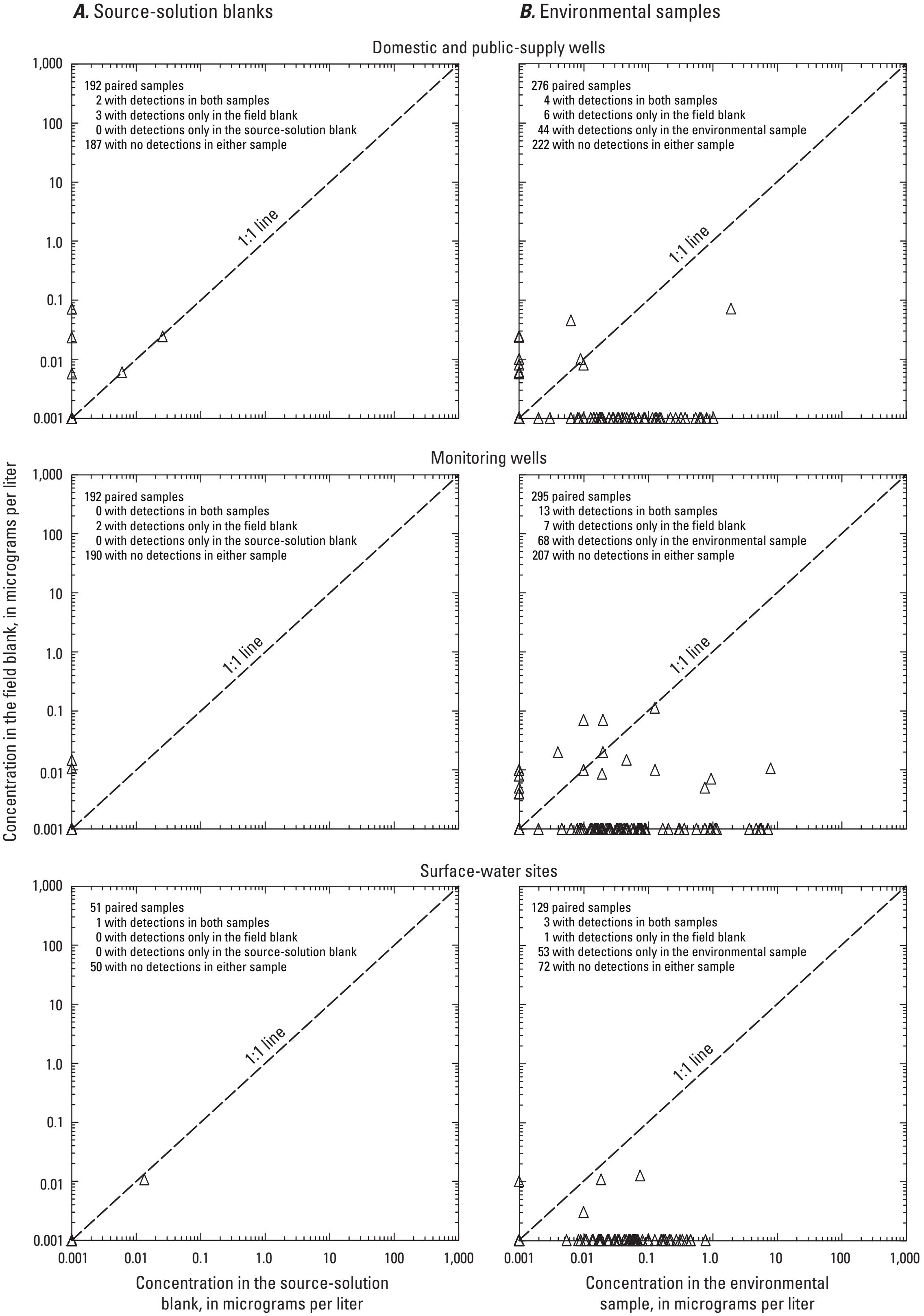
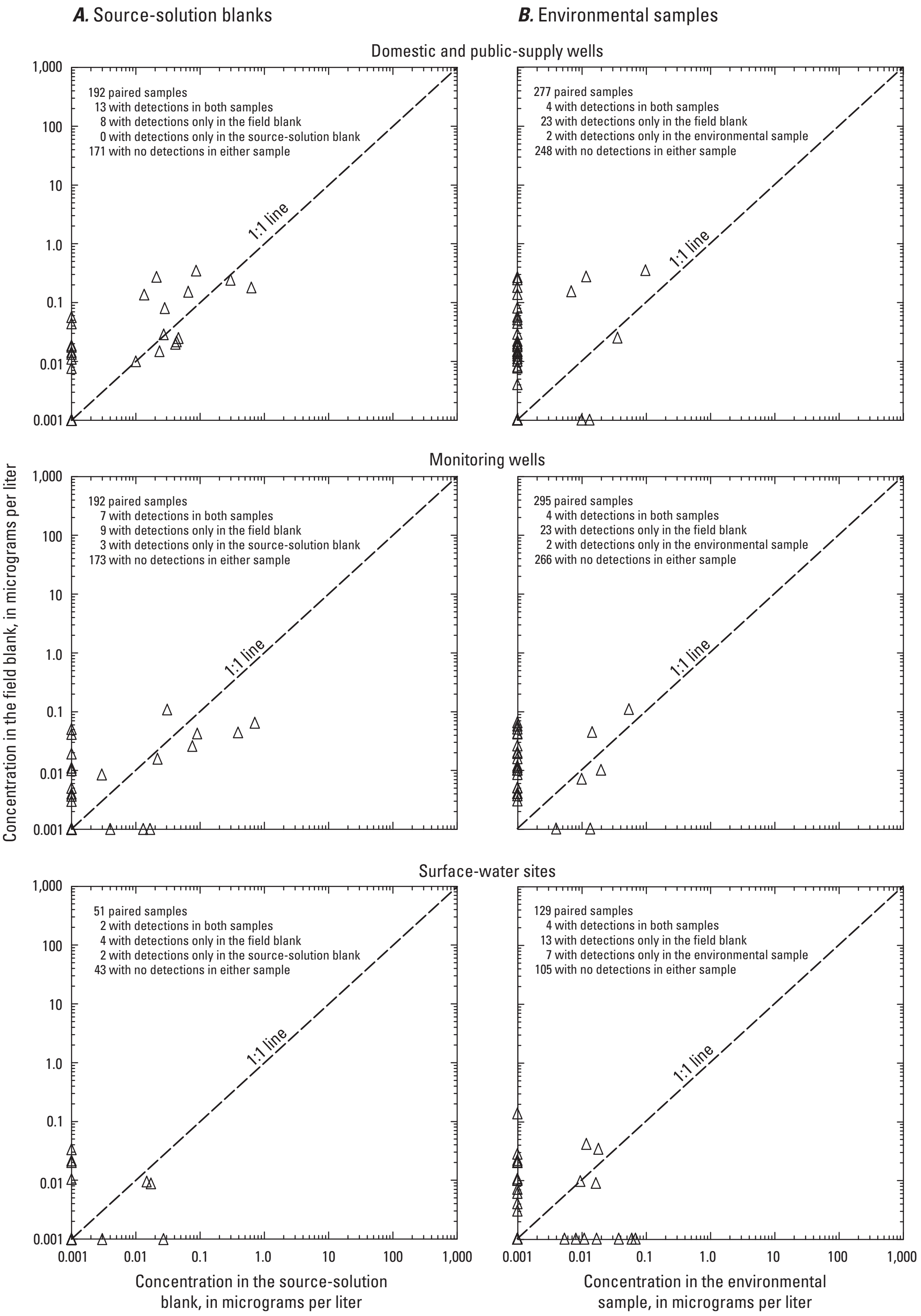


Figure A2–13. Relation of perchloroethene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.05 microgram per liter.



A. Source-solution blanks

B. Environmental samples

Domestic and public-supply wells

Monitoring wells

Surface-water sites

Figure A2–14. Relation of styrene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.021 microgram per liter.

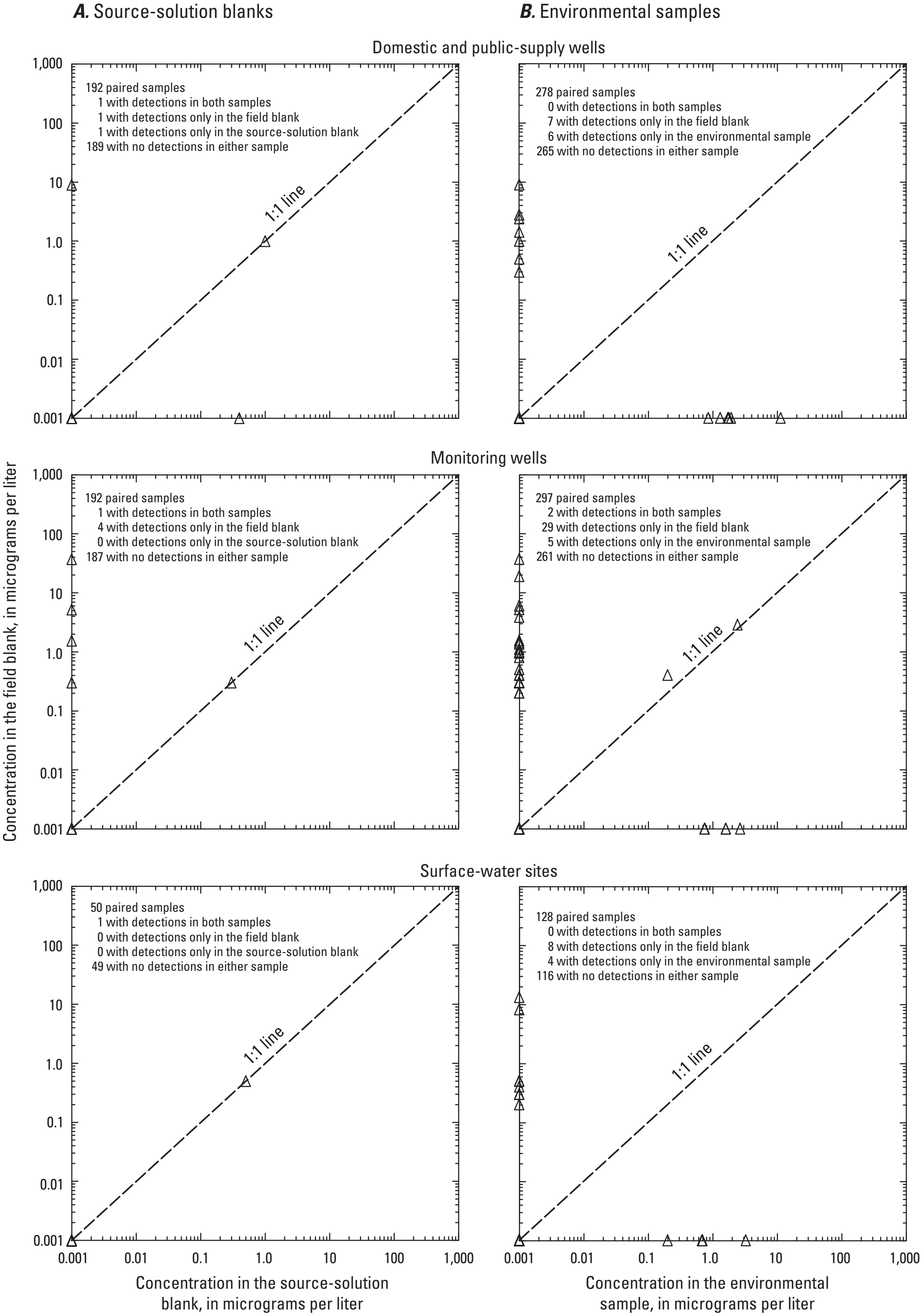


Figure A2–15. Relation of tetrahydrofuran concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 4.5 micrograms per liter.

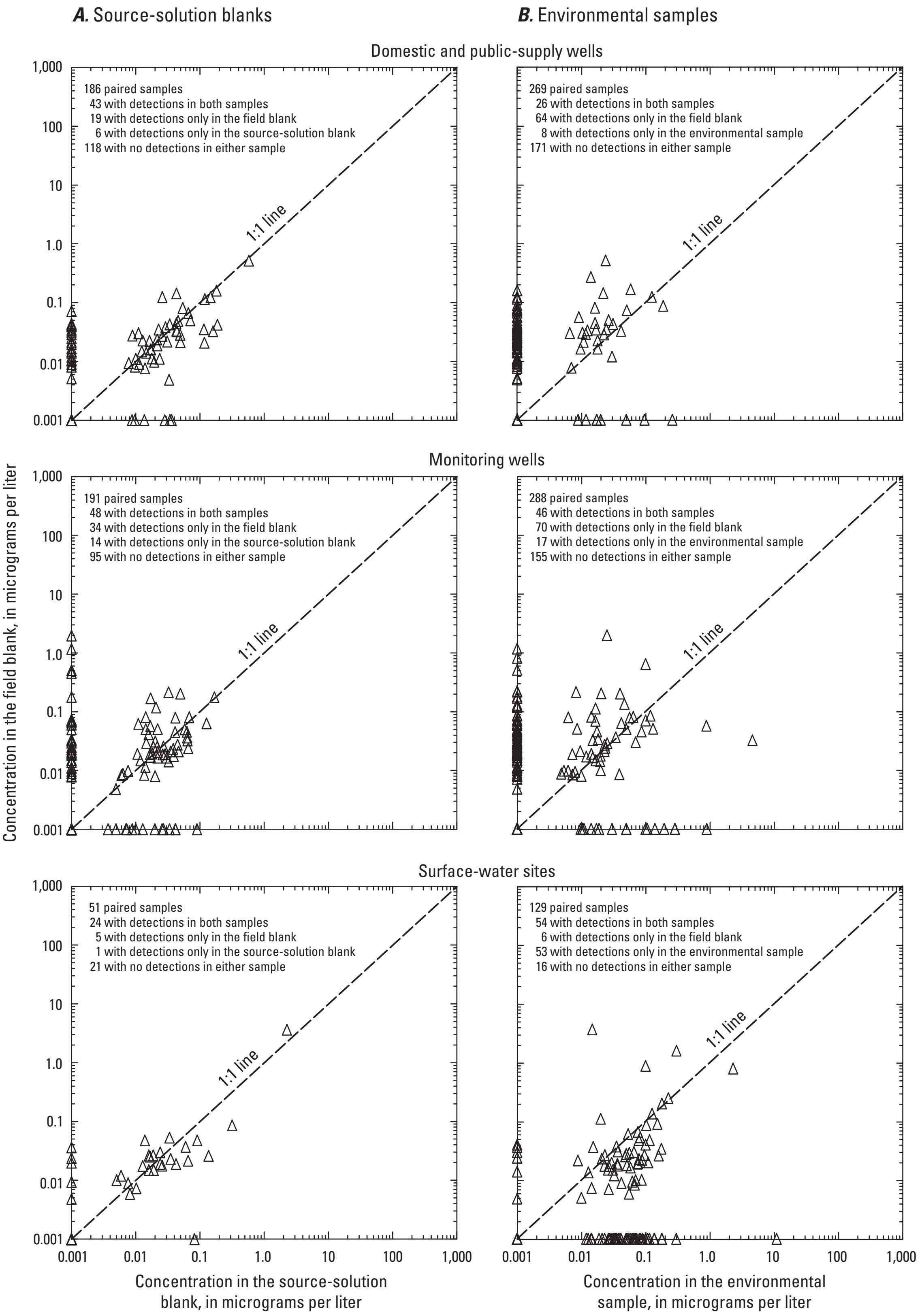


Figure A2–16. Relation of toluene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.038 microgram per liter.

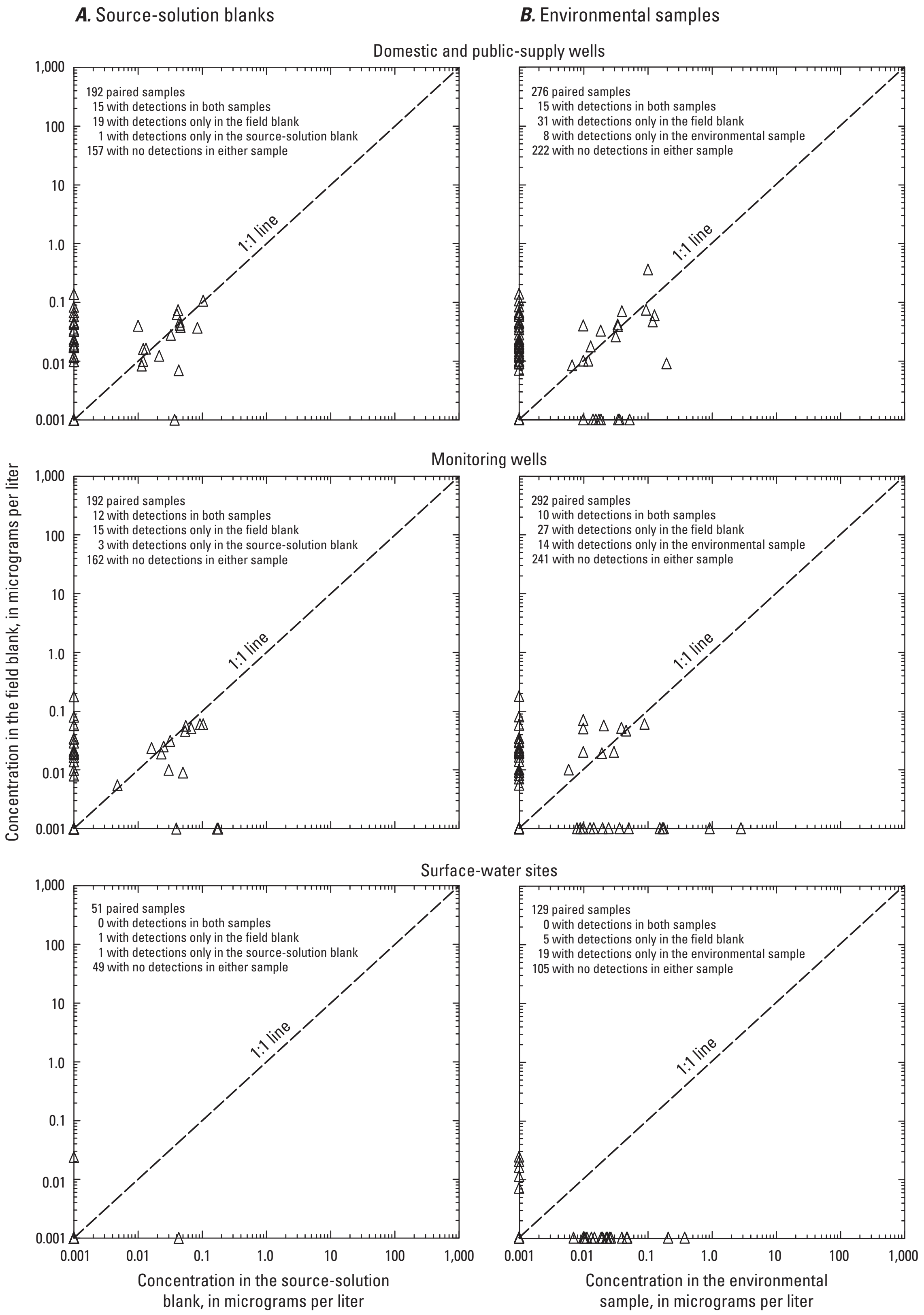
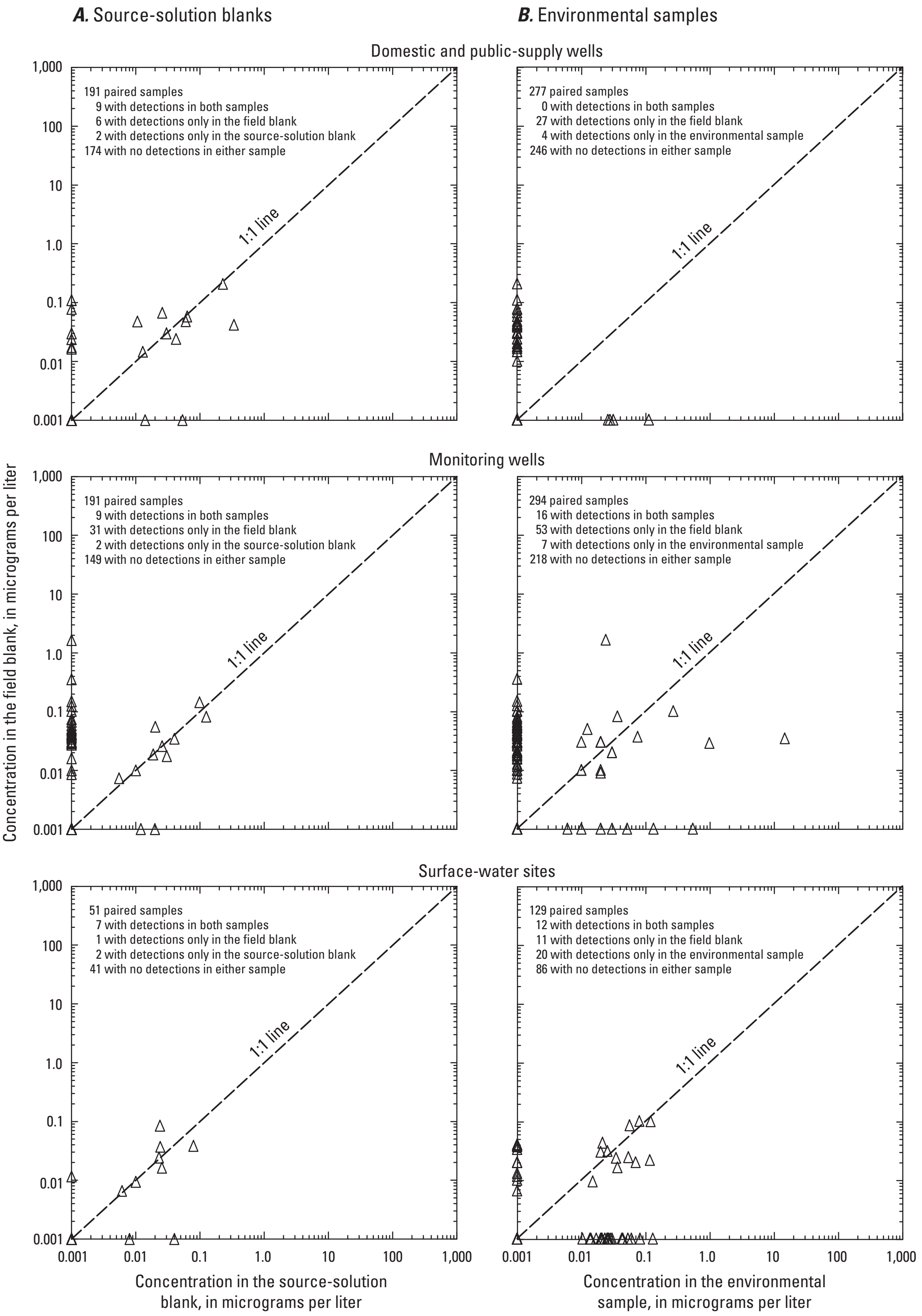


Figure A2–17. Relation of 1,2,4-trimethylbenzene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.028 microgram per liter.



Domestic and public-supply wells, A:

191 paired samples
9 with detections in both samples
6 with detections only in the field blank
2 with detections only in the source-solution blank
174 with no detections in either sample

Domestic and public-supply wells, B:

277 paired samples
0 with detections in both samples
27 with detections only in the field blank
4 with detections only in the environmental sample
246 with no detections in either sample

Monitoring wells, A:

191 paired samples
9 with detections in both samples
31 with detections only in the field blank
2 with detections only in the source-solution blank
149 with no detections in either sample

Monitoring wells, B:

294 paired samples
16 with detections in both samples
53 with detections only in the field blank
7 with detections only in the environmental sample
218 with no detections in either sample

Surface-water sites, A:

51 paired samples
7 with detections in both samples
1 with detections only in the field blank
2 with detections only in the source-solution blank
41 with no detections in either sample

Surface-water sites, B:

129 paired samples
12 with detections in both samples
11 with detections only in the field blank
20 with detections only in the environmental sample
86 with no detections in either sample

Figure A2–18. Relation of *m*- and *p*-xylene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.04 microgram per liter.

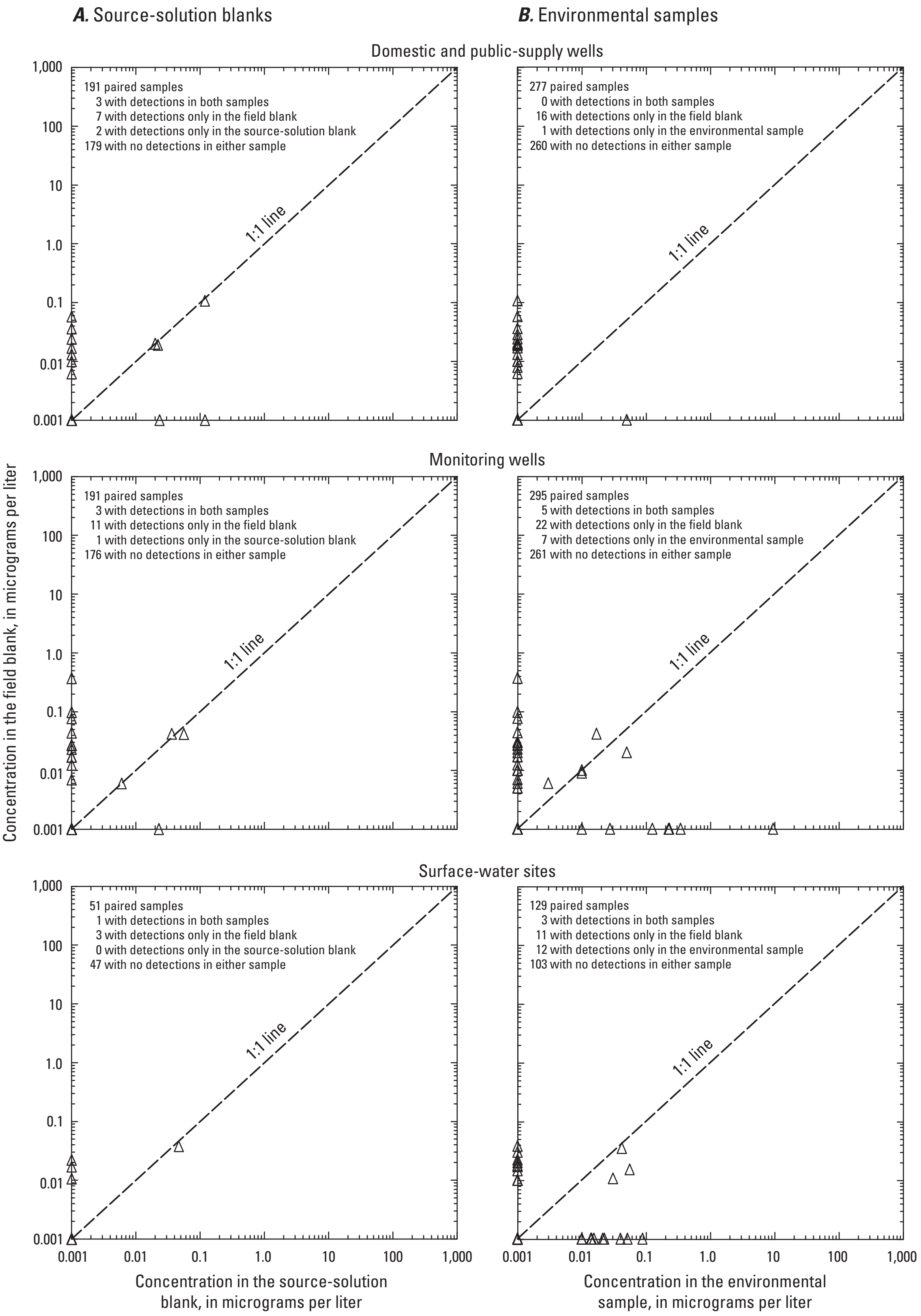


Figure A2–19. Relation of *o*-xylene concentrations between field blanks and paired samples of *A*, source-solution blanks and *B*, environmental samples, October 1996 to December 2008. Nondetections are plotted at 0.001 microgram per liter. The maximum value of the long-term method detection level during 1996–2008 is 0.04 microgram per liter.

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