# PLAN FOR ASSESSMENT OF THE OCCURRENCE, STATUS, AND DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN AQUIFERS OF THE UNITED STATES

By Wayne W. Lapham and Saeid Tadayon

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For addtional information write to:

District Chief
U.S. Geological Survey
1608 Mt. View Rd.
Rapid City, SD 57702

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# FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

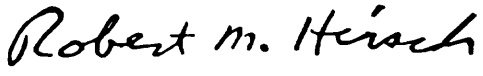
- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as Study Units. These Study Units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 Study Units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National Synthesis of data analysis, based on aggregation of comparable information obtained from the Study Units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the National Synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Chief Hydrologist

# CONTENTS



## ILLUSTRATIONS



## TABLES

TABLES—Continued



## CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| | **Length** | |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| | **Area** | |
| square mile ($mi^2$) | 2.590 | square kilometer |
| | **Hydraulic Conductivity** | |
| inch per year (in/yr) | 25.4 | millimeter per year |
| foot per day (ft/d) | 0.3048 | meter per day |
| | **Flow** | |
| million gallons per day (Mgal/d) | 0.04381 | cubic meter per second |
| | **Transmissivity** | |
| foot squared per day ($ft^2/d$) | 0.09290 | meter squared per day |

## ABBREVIATIONS AND ACRONYMS

Listed below are abbreviations and acronyms that are used frequently in this report:

| | |
|---|---|
| CAS | Chemical Abstract Services |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| DD | National Water-Quality Assessment Program Data Dictionary |
| GIS | Geographic Information System |
| GWSI | U.S. Geological Survey Ground-Water Site Inventory |
| IUPAC | International Union of Pure and Applied Chemistry |
| LSD | Land-surface datum |
| NAWQA | National Water-Quality Assessment Program |
| NWIS | U.S. Geological Survey National Water Information System |
| QWDATA | U.S. Geological Survey Water-Quality Data Base |
| RCRA | Resource Conservation and Recovery Act |
| USEPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| VOC | Volatile organic compound |

# Plan for Assessment of the Occurrence, Status, and Distribution of Volatile Organic Compounds in Aquifers of the United States

*By* Wayne W. Lapham *and* Saeid Tadayon

## ABSTRACT

The occurrence of volatile organic compounds (VOCs) in water is of national concern because of their relatively high aqueous solubility, mobility, and persistence, because many are known or suspected carcinogens, because of their widespread use, and because they have been found in drinking-water supplies. Because of this national concern, VOCs were selected for National investigation (hereafter termed "National Synthesis") by the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program in 1994.

The broad goals of this National Synthesis are to: (1) describe current water-quality conditions with respect to VOCs; (2) define trends, or lack of trends, in VOCs in surface and ground water; and (3) identify, describe, and explain causal relations among the occurrence and distribution of VOCs in surface water and ground water, and natural and human factors.

The National Synthesis of VOCs in ground water has three objectives: (1) to describe their occurrence, status, and distribution; (2) to determine relations among VOCs in shallow ground water and natural and human factors; and (3) to determine, compare, and contrast the occurrence, transformation, transport, and fate of selected VOCs in the hydrologic cycle for several regionally or nationally important aquifer systems.

The description of VOC occurrence, status, and distribution in ground water focuses on major aquifers of the United States. Occurrence describes the presence or absence of VOCs, their frequency of occurrence, and their ranges of concentrations. Status compares the concentrations of VOCs detected in relation to water-quality regulations or advisories, such as Maximum Contaminant Levels, Proposed Maximum Contaminant Levels, Maximum Contaminant Level Goals, and Health Advisories. Distribution describes the variability of VOCs in ground water, areally and by depth. This report describes the study design for conducting such an assessment.

The assessment focuses on aquifers, or parts of aquifers, that are currently used or have the potential to be used as sources of water supplies, using data collected as part of local, State, and Federal ground-water monitoring programs since 1985. Assessment by aquifer and comparison of results among aquifers will be completed for those aquifers for which adequate spatial or depth-related data are available. Assessment of VOCs in aquifers also will be completed at regional and national scales.

A set of criteria for well-network design, well construction, sample-collection methods, and methods of laboratory analysis must be met before VOC data are used for assessment. An appropriate well-network design will provide a generally unbiased, random, equal-area distribution of sampling sites throughout the aquifer, or part of the aquifer, of interest. Well-construction

information must be sufficient to ensure that the hydrogeologic unit (or units) represented by the water level measured and the hydrologic unit (or units) contributing water to the well are known. In addition, the well construction and pumping equipment in the well need to be of a type that are not likely to affect concentrations of VOCs in the water sample. VOC data will be considered suitable for use in the occurrence assessment if nationally accepted methods for collection and analysis were used and if the quantitation level for VOC analytes was less than about 5 micrograms per liter; laboratory analysis was done by a laboratory certified by the U.S. Environmental Protection Agency; and the sample was collected from untreated (raw) water at or near the well head before being held in a pressure tank or holding tank.

## INTRODUCTION

In 1991, the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program began the transition from a pilot program to full-scale implementation. The long-term goals of the NAWQA Program are to describe the status and trends in the quality of a large, representative part of the Nation's surface-water and ground-water resources and to provide an improved understanding of the primary natural and human factors that affect the quality of these resources. The concepts, implementation, and design of the NAWQA Program are described in Hirsch and others (1988), Leahy and others (1990); Leahy and Thompson (1994), and Gilliom and others (1995).

The NAWQA Program has two major components: (1) hydrologic investigations of large river basins and aquifer systems, referred to as Study-Unit Investigations (fig. 1), and (2) a National Synthesis that is organized to provide information about water-quality topics of regional and national concern.

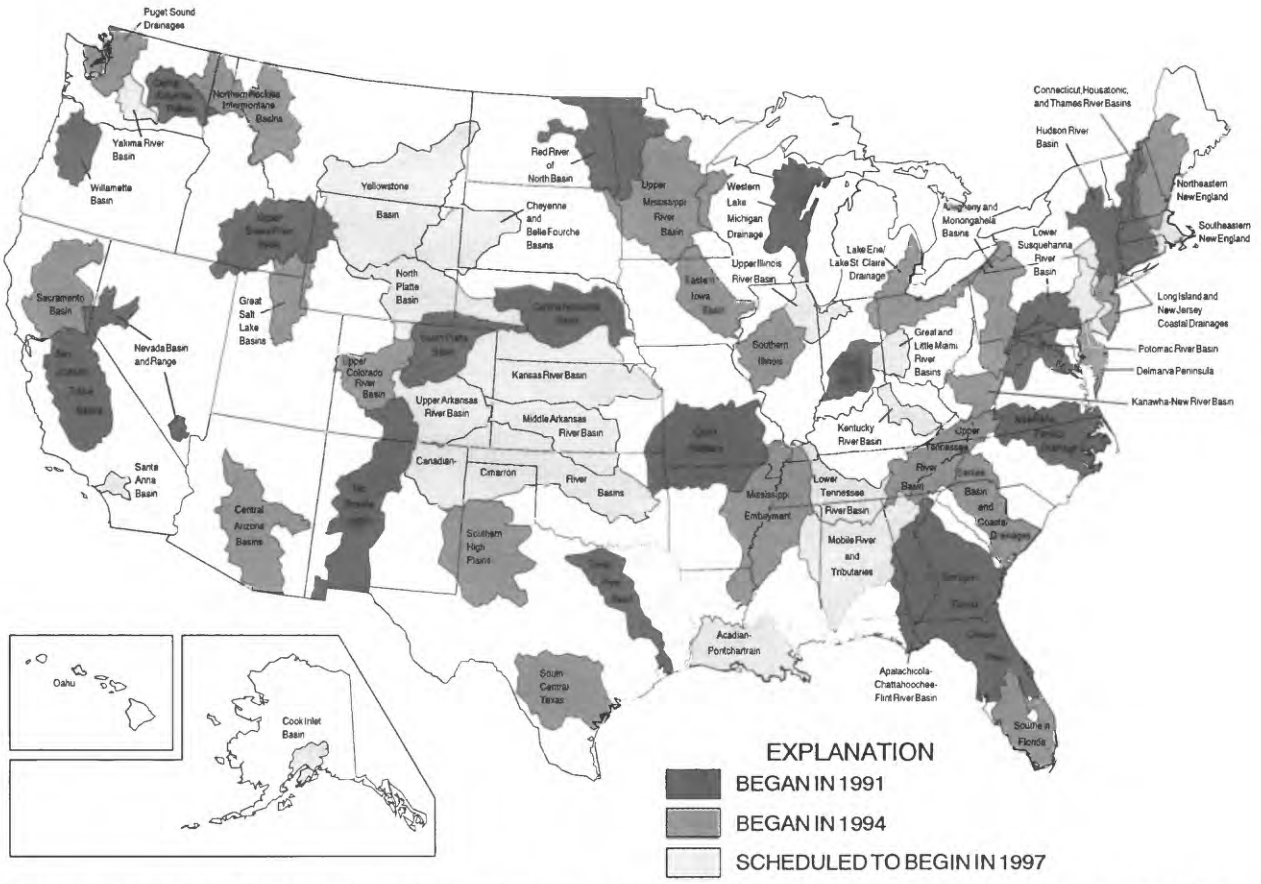



**Figure 1.** Location of National Water-Quality Assessment Program Study Units and their proposed implementation dates (from Gilliom and others, 1995).

Study-Unit Investigations and their scheduling are described in Leahy and others (1990). As of 1995, four water-quality topics of regional and national concern have been selected for NAWQA's National Synthesis. Studies of pesticides and nutrients began in 1991, and studies of volatile organic compounds (VOCs) and of aquatic ecosystems began in 1994.

## Purpose and Scope

The purpose of this report is to describe the plan for national assessment of the occurrence, status, and distribution of VOCs in ground water of the United States, with a focus on major aquifers. The assessment relies largely on data collected by NAWQA Study Units (fig. 1). Seven pilot NAWQA Study-Unit Investigations began in 1986. Three of these pilot investigations collected ground-water-quality data. Twenty additional Study-Unit Investigations began in 1991 and 15 began in 1994. Additional investigations are scheduled to begin in 1997, some of which might be continuations of the pilot investigations that began in 1986.

During 1995, a major effort of the investigations that began in 1994 is analysis of existing water-quality data. Results of this Retrospective Analysis will help guide the Study-Unit ground-water design by developing an understanding of the occurrence, status, and distribution of VOC target analytes and other chemical constituents in ground water in the Study Unit. These Retrospective Analyses also are anticipated to be a primary source of data for the planned national assessment described in this report. Because of the importance of these Retrospective Analyses to this assessment, the plan described herein is presented as guidance to the 1994 Study Units for compilation of VOC data during their Retrospective Analyses. However, the guidance also generally applies for all other VOC-data compilations that will be used by the VOC National Synthesis for the assessment described in this report.

## Acknowledgments

The authors would like to thank James Stark of the NAWQA Upper Mississippi River Basin Study Unit and Anthony J. Tesoriero of the NAWQA Puget Sound Study Unit for their technical reviews of this plan. The authors also thank Lanna Combs of the USGS in Lawrence, Kansas for providing an editorial review of the report and Ella Decker of the USGS in Huron, South Dakota, for preparing it for publication.

# NATIONAL SYNTHESIS OF VOLATILE ORGANIC COMPOUNDS

VOCs were selected for National Synthesis because of the occurrence of this constituent group in many of the Nation's water supplies (Tennant and others, 1992; Pankow and Cherry, 1996). The broad goals of the VOC National Synthesis reflect those of the entire NAWQA Program: (1) to describe current water-quality conditions; (2) to define trends, or lack of trends; and (3) to identify, describe, and explain causal relations among the occurrence and distribution of VOCs in surface water and ground water and natural and human factors. Fifty-five VOCs, including of halogenated alkanes, halogenated alkenes, alkyl benzenes, aromatic hydrocarbons, halogenated aromatics, ethers, and others (table 1), have been identified for study (John Zogorski, written commun., 1995). The VOCs in table 1 are collectively called the NAWQA "VOC target analytes" in this report.

VOCs are of concern in ground water because of their relatively high aqueous solubility, mobility, and persistence, because many VOCs are known or suspected carcinogens, and because of their widespread use. The National Synthesis of VOCs in ground water has three objectives: (1) describe their occurrence, status, and distribution (VOC occurrence assessment); (2) determine relations between VOC target analytes in shallow ground water and natural and human factors; and (3) determine, compare, and contrast the occurrence, transformation, transport, and fate of selected VOC target analytes in ground water for several regionally or nationally important aquifer systems.

# PLAN FOR ASSESSMENT OF OCCURRENCE, STATUS, AND DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN GROUND WATER

The objective of the assessment of VOCs in ground water discussed in this report is to describe the occurrence, status, and distribution of VOCs in major

**Table 1.** Volatile organic compound target analytes[1] in the National Water-Quality Assessment Program

[CAS, Chemical Abstract Services; U.S. EPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; VOC, volatile organic compound; N/A, there is no parameter code for this compound; IUPAC, International Union of Pure and Applied Chemistry]

| VOC compound, by compound class[2] | CAS number | U.S. EPA and USGS parameter code |
|---|---|---|
| **Halogenated Alkanes** | | |
| Tetrachloromethane (Carbon Tetrachloride) | 56-23-5 | 32102 |
| Trichloromethane (Chloroform) | 67-66-3 | 32106 |
| Hexachloroethane | 67-72-1 | 34396 |
| 1,1,1-Trichloroethane | 71-55-6 | 34506 |
| Bromomethane | 74-83-9 | 34413 |
| Chloromethane | 74-87-3 | 34418 |
| Chloroethane | 75-00-3 | 34311 |
| Dichloromethane (Methylene Chloride) | 75-09-2 | 34423 |
| Tribromomethane (Bromoform) | 75-25-2 | 32104 |
| Bromodichloromethane | 75-27-4 | 32101 |
| 1,1-Dichloroethane (1,1-DCA) | 75-34-3 | 34496 |
| Trichlorofluoromethane (CFC 11) | 75-69-4 | 34488 |
| Dichlorodifluoromethane (CFC 12) | 75-71-8 | 34668 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113) | 76-13-1 | 77652 |
| 1,2-Dichloropropane | 78-87-5 | 34541 |
| 1,1,2-Trichloroethane (1,1,2-TCA) | 79-00-5 | 34511 |
| 1,2-Dibromo-3-chloropropane (DBCP) | 96-12-8 | 82625 |
| 1,2,3-Trichloropropane | 96-18-4 | 77443 |
| 1,2-Dibromoethane (EDB) | 106-93-4 | 77651 |
| 1,2-Dichloroethane | 107-06-2 | 32103 |
| Chlorodibromomethane | 124-48-1 | 32105 |
| **Halogenated Alkenes** | | |
| Chloroethene (Vinyl Chloride) | 75-01-4 | 39175 |
| 1,1-Dichloroethene | 75-35-4 | 34501 |
| Trichloroethene (TCE) | 79-01-6 | 39180 |
| 1,1,2,3,4,4-Hexachloro-1,3-butadiene (Hexachlorobutadiene) | 87-68-3 | 39702 |
| Tetrachloroethene (PCE) | 127-18-4 | 34475 |
| *cis*-1,2-Dichloroethene | 156-59-2 | 77093 |
| *trans*-1,2-Dichloroethene | 156-60-5 | 34546 |
| Bromoethene | 593-60-2 | 50002 |
| *cis*-1,3-Dichloropropene | 10061-01-5 | 34704 |
| *trans*-1,3-Dichloropropene | 10061-02-6 | 34699 |
| **Aromatic Hydrocarbons** | | |
| Benzene | 71-43-2 | 34030 |
| Naphthalene | 91-20-3 | 34696 |
| Styrene (Vinyl Benzene) | 100-42-5 | 77128 |

**Table 1.** Volatile organic compound target analytes[1] in the National Water-Quality Assessment Program—Continued

| VOC compound, by compound class[2] | CAS number | U.S. EPA and USGS parameter code |
|---|---|---|
| **Alkyl Benzenes** | | |
| 1,2-Dimethylbenzene (o-Xylene) | 95-47-6 | 77135 |
| 1,2,4-Trimethylbenzene (Pseudocumene) | 95-63-6 | 77222 |
| Isopropylbenzene (Cumene) | 98-82-8 | 77223 |
| Ethylbenzene | 100-41-4 | 34371 |
| n-Propylbenzene | 103-65-1 | 77224 |
| n-Butylbenzene | 104-51-8 | 77342 |
| 1,4-Dimethylbenzene (p-Xylene) | 106-42-3 | [3]85795 |
| 1,3-Dimethylbenzene (m-Xylene) | 108-38-3 | [3]85795 |
| Methylbenzene (Toluene) | 108-88-3 | 34010 |
| **Halogenated Aromatics** | | |
| 1,2,3-Trichlorobenzene | 87-61-6 | 77613 |
| 1,2-Dichlorobenzene (o-Dichlorobenzene) | 95-50-1 | 34536 |
| 1,4-Dichlorobenzene (p-Dichlorobenzene) | 106-46-7 | 34571 |
| Chlorobenzene | 108-90-7 | 34301 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 34551 |
| 1,3-Dichlorobenzene (m-Dichlorobenzene) | 541-73-1 | 34586 |
| **Ethers and Other Oxygenated Compounds** | | |
| Diisopropyl ether (DIPE) | 108-20-3 | 81577 |
| Ethyl *tert*-butyl ether (ETBE) | 637-92-3 | 50004 |
| *tert*-Amyl methyl ether (TAME) | 994-05-8 | 50005 |
| Methyl *tert*-butyl ether (MTBE) | 1634-04-4 | 78032 |
| **Others (Aldehydes and Nitriles)** | | |
| 2-Propanal (Acrolein) | 107-02-8 | 34210 |
| 2-Propenenitrile (Acrylonitrile) | 107-13-1 | 34215 |
| **Other Halogenated Alkenes[1]** | | |
| 1,2-Dichloroethene (mixed isomers) | 540-59-0 | N/A |
| Dichloroethene (all isomers) | 25323-30-2 | N/A |
| 1,3-Dichloropropene (mixed isomers) | 542-75-6 | N/A |
| **Other Alkyl Benzenes[1]** | | |
| Xylene (mixed isomers) | 1330-20-7 | 81551 |
| **Other Halogenated Aromatics[1]** | | |
| Dichlorobenzene (mixed isomers) | 25321-22-6 | N/A |

[1]Mixed isomers are not target analytes. Volatile organic compound mixed isomers of the target analytes in the U.S. Geological Survey National Water-Quality Assessment Program are included in this table for reference because they are commonly measured or reported.

[2]IUPAC nomenclature (Synonym).

[3]This is a combination of p- and m-Xylene. These compounds do not elute separately with the current analytical procedure.

aquifers of the United States, both for individual aquifers and collectively. Occurrence describes the presence or absence of VOCs, their frequency of occurrence, and their ranges of concentrations. Status compares the concentrations of VOCs detected in relation to water-quality regulations or advisories, such as Maximum Contaminant Levels, Proposed Maximum Contaminant Levels, Maximum Contaminant Level Goals, and Health Advisories. Distribution describes the variability of VOCs in ground water, areally and by depth.

Analysis of temporal trends in VOCs is not a primary objective of the assessment described in this report because identifying temporal trends, or lack of trends, and interpreting those trends requires historic VOC and ancillary data that most likely are not widely available. However, VOC data sets suitable for trend assessment might be identified during the conduct of the assessment described herein.

The assessment will be nationwide for aquifers, or those parts of aquifers that are currently used or have the potential to be used as sources of water supplies. Parts of aquifers at or immediately downgradient of known sources of contamination generally are unsuitable for use as a water supply, and assessment of these parts of aquifers is beyond the scope of this assessment. Assessment of the quality of these parts of aquifers is being done in other programs, such as the U.S. Environmental Protection Agency (USEPA) RCRA (Resource Conservation and Recovery Act) and CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) Programs.

Interpretations of the reasons for observed occurrence and distribution of VOCs, such as the relation of the occurrence and distribution of VOCs to natural factors and human activities, probably will be minimal. Interpretation will be difficult because of a number of complicating factors, including the lack of consistency in design and conduct of the studies from which the VOC data are derived and because of the lack of detailed, ancillary information associated with the VOC data that would be required for this type of interpretation. Data deficiencies will be identified as part of the assessment. When feasible, enhancements to the data sets, such as subsequent compilation of important ancillary data, will be completed.

This assessment will be done by collective analysis of data from monitoring programs across the Nation. Data from these monitoring programs will be compiled into a national data base for this analysis. Criteria for monitoring-program design, sample-collection methods, and methods of laboratory analysis will be met before data are entered into this data base. The assessment will be based on data collected since 1985, for as many of the 55 VOCs currently (1996) on the list of NAWQA VOC target analytes (table 1) as possible. Assessment by aquifer and comparisons of results among aquifers also will be completed for those aquifers that have adequate data, spatially or by depth.

The proposed timeline for data collection, compilation and analysis, and reporting of results of this assessment is shown in table 2. A relatively limited assessment of VOC occurrence, status, and distribution will be reported in 1997, using: (1) data compiled by 1994 NAWQA Study Units during their year of Retrospective Analysis in 1995; (2) data from Study-Unit Surveys completed by 1991 NAWQA investigations; (3) data compiled by 1991 NAWQA investigations during Retrospective Analysis in 1992, to the extent that data were compiled; and (4) data compiled by NAWQA VOC National Synthesis from the pilot NAWQA investigations and selected retrospective data from State, multi-State, and Federal programs not covered by items (1) to (3). A subsequent assessment of VOC occurrence, status, and distribution will be reported in 2001. This last assessment will use all of the data from items (1) through (4) plus data compiled from States not covered in item (4), as well as (5) retrospective data compiled by NAWQA Study Units in States covered by 1997 NAWQA investigations, if not already completed by the VOC National Synthesis, (6) data from Study-Unit Surveys completed by 1994 NAWQA investigations, and (7) data from Study-Unit Surveys by the 1997 NAWQA investigations that have been collected by the year 2000 (table 2).

The plan for the assessment of occurrence, status, and distribution of VOCs in ground water consists of selecting VOC and related data from wells, submitting those data to a national data base, and analyzing and summarizing those data. Data selection consists of an inventory of local, State, and Federal monitoring programs followed by an evaluation of the suitability of data collected in those monitoring programs or well networks for the assessment. VOC and ancillary data subsequently are selected from suitable programs or well networks. Submittal of the data into a national VOC data base is completed in a

**Table 2.** Timeline for data collection, compilation, and reporting of results for the assessment of occurrence, status, and distribution of volatile organic compounds in ground water

[VOCs, volatile organic compounds; NAWQA, National Water-Quality Assessment]

| Data source for assessment of occurrence, status, and distribution of VOCs in ground water | Data collection completed | Data compilation into national VOC occurrence data base completed | Data analysis by VOC National Synthesis completed |
|---|---|---|---|
| (1) Retrospective data compiled by 1994 NAWQA Study Units. | 1995 | 1996 | 1997 |
| (2) Data from Study-Unit Surveys by 1991 NAWQA Study Units. | 1995 | 1996 | 1997 |
| (3) Retrospective data compiled by 1991 NAWQA Study Units[1]. | 1992 | 1995 or later | 1997 and 2000 |
| (4) Retrospective data compiled by NAWQA VOC National Synthesis from the pilot NAWQA studies and selected State, multi-State, and Federal programs not covered by 1991 or 1994 NAWQA Study Units. | Ongoing until 2000. | Some compilation in 1995 and 1996. Total compilation in 2000. | 1997 and 2000 |
| (5) Retrospective data compiled by NAWQA Study Units in States covered by 1997 NAWQA Study Units, if not already completed by VOC National Synthesis | 1998 | 1999 | 2000 |
| (6) Data from Study-Unit Surveys by 1994 NAWQA Study Units | 1998 | 1999 | 2000 |
| (7) Data from Study-Unit Surveys by 1997 NAWQA Study Units[2]. | 2001 | 2001 | [2]2001 |

[1]Compilation of retrospective VOC data by the 1991 NAWQA Study Units into a national occurrence data base was not part of their plans for Retrospective Analysis. However, compilations that were completed and that meet criteria described in this report will be used in the assessment of occurrence, status, and distribution of VOCs in ground water. Also, some additional compilation might be completed by the 1991 Study Units as part of their low-level assessment activities from 1997 to 2000.

[2]The intensive data-collection period for the 1997 NAWQA Study Units is from 1999 through 2001. Therefore, data collection for some Study-Unit Surveys will be completed during 1999 and 2000. These data will be available for analysis in the year 2001.

prescribed format. Once all data are in the national VOC data base, the occurrence, status, and distribution of VOCs will be summarized and presented at aquifer, regional, and national scales.

## Data Selection

### Inventory of local, State, and Federal Monitoring Programs

The purpose of the inventory of local, State, and Federal monitoring programs (see "Supplemental Information" section) is to identify programs in which VOC and associated ancillary data, such as well location, well construction, and hydrogeologic information, are being collected that are suitable for describing the occurrence, status, and distribution of VOCs in major aquifers. The inventory also might identify programs in which VOC and associated ancillary data are being collected for (1) analyses of relations among VOCs in shallow ground water and natural and human factors and (2) analysis of temporal trends of VOCs in ground water.

### Data Needs

Concentration data for all VOC analytes available from those on the target list (table 1) need to be compiled. In addition, ancillary data are needed for the National Synthesis to describe and interpret the occurrence, status, and distribution of VOCs in major aquifers across the Nation. Compilation of well location, well construction, hydrogeologic, and other data (table 3) is needed for this analysis to the extent that these ancillary data are available. Data in table 3 were requested in 1995 for compilations being done by the 1994 Study Units during their year of Retrospective Analysis. These data will be entered into a national VOC occurrence data base. Additional information about the data elements listed in table 3 and probable formats for data submittal are given in table 4.

**Table 3.** Data requested for submittal to the national volatile organic compound (VOC) occurrence data base for use in assessment of occurrence, status, and distribution of VOCs in ground water

[VOC, volatile organic compounds; NWIS, U.S. Geological Survey National Water Information System; rdb, relational data base; GIS, geographic information system; LSD, land-surface datum; NGVD, National Geodetic Vertical Datum; C, component in U.S. Geological Ground-Water Site Inventory; P, U.S. Environmental Protection Agency parameter code; N/A, No parameter code for this compound]

| Description of component, parameter, or other data | NWIS component (C) or parameter (P) code, or other description |
|---|---|
| Cross reference of well to monitoring program | As an rdb table |
| Monitoring program description from VOC inventory table | As an rdb table |
| Cross reference of well to aquifer in which the monitoring well is screened | As an rdb table |
| Description and ancillary information about the aquifer/hydrogeologic unit for which VOC data are compiled and submitted to the National data base | As an rdb table |
| Boundary of each aquifer/hydrogeologic unit for which VOC data are compiled and submitted to the national data base | GIS coverage |
| Source agency code | C004 |
| Site ID (station number) | C001 |
| Latitude | C009 |
| Longitude | C010 |
| Local well number | C012 |
| District code | C006 |
| State code | C007 |
| County code | C008 |
| Type of site | C002 |
| Record classification | C003 |
| Altitude of land surface | C016 (same as P72000) |
| Primary use of site | C023 |
| Primary use of water | C024 |
| Depth of well | C028 (same as P72008) |
| Agency use of site code | C803 |
| Locator sequence number | C815 |
| Casing material | C080 |
| Depth to top of this open interval | C083 (same as P72015) |
| Depth to bottom of this open interval | C084 (same as P72016) |
| Type of openings in this interval | C085 |
| Depth to top of interval | C091 (same as P72002) |
| Depth to bottom of interval | C092 (same as P72003) |
| Aquifer code | C093 |
| Lithology code | C096 |
| Description of material | C097 |
| Contributing unit | C304 |
| Aquifer-type code | C713 |
| Aquifer code | C714 |
| Site ID (only needed if the water-quality data are from a different data base than the well-construction data) | STAID (same as C001) |

**Table 3.** Data requested for submittal to the national volatile organic compound (VOC) occurrence data base for use in assessment of occurrence, status, and distribution of VOCs in ground water—Continued

| Description of component, parameter, or other data | NWIS component (C) or parameter (P) code, or other description |
|---|---|
| Date | DATES |
| Time | TIMES |
| Agency collecting sample (code number) | P00027 |
| Agency analyzing sample (code number) | P00028 |
| Well selection criteria, code | P84144 |
| Project component, code | P84145 |
| Sampler type, code | P84164 |
| Sample purpose code | P71999 |
| Elevation of land surface datum (LSD, in feet NGVD) | P72000 (same as C016) |
| Depth of hole, total (in feet) | P72001 |
| Depth to top of water-bearing zone sampled (in feet) | P72002 (same as C091) |
| Depth to bottom of water-bearing zone sampled (in feet) | P72003 (same as C092) |
| Pump or flow period prior to sampling (in minutes) | P72004 |
| Sample source (codes) | P72005 |
| Sampling condition (code) | P72006 |
| Depth of well, total (in feet) | P72008 (same as C092) |
| Depth to top of sample interval (in feet below LSD) | P72015 (same as C083) |
| Depth to bottom of sample interval (in feet below LSD) | P72016 (same as C084) |
| Depth below land surface to water level (in feet) | P72019 |
| VOC-concentration data for all analytes on the target list, as available (see table 1 for list of target analytes) | See table 1 for P codes |

**Table 4.** Details of data requested for submittal to the national volatile organic compound (VOC) occurrence data base for use in assessment of occurrence, status, and distribution of VOCs in ground water

[See footnote 1 for additional data elements required for creation of a site file in the U.S. Geological Survey Ground-Water Site Inventory (GWSI) data base; QWDATA, U.S. Geological Survey Water-Quality Data Base; GIS, geographic information system; LSD, land-surface datum; DD, National Water-Quality Assessment Program (NAWQA) data dictionary; NWIS, U.S. Geological Survey National Water Information System]

| Data element or other information | Source for definition of data element[2] | Example of data element | Suggested storage location of data element[3] |
|---|---|---|---|
| **Monitoring Program/Network and Aquifer Information** | | | |
| Cross reference of well to monitoring program | See "Supplemental Information" | See "Supplemental Information" | netsite.rdb file |
| Monitoring program description from VOC inventory (form B) | do. | do. | netdes.rdb file |
| Cross reference of well to aquifer in which the monitoring well is screened | do. | do. | aqsite.rdb file |
| Description and ancillary information about the aquifer/hydrogeologic unit for which VOC data are compiled and submitted to the national data base | do. | do. | aqdes.rdb file |
| Boundary of each aquifer/hydrogeologic unit for which VOC data are compiled and submitted to the national data base | Table 17 in DD. GIS coverages: Hydrogeologic unit boundaries polygons 1:100,000, UNITNAME 40, 40, C: Name of aquifer or hydrogeologic unit | Upper glacial aquifer | GIS coverage |
| **Well Site and Construction, and Hydrogeologic Data Associated with the Analyte-Concentration Data** | | | |
| Site (Station) identification number | C001 | 431209100501701 | GWSI |
| Station name | C012 (C900 also is automatically populated when C012 is populated) | 120N69W14ACCD or Cuny well near Rapid City, SD. | GWSI |
| Latitude | C009 | 431209 | GWSI |
| Longitude | C010 | 1005017 | GWSI |
| State | C007 | SD | GWSI |
| Monitoring program well-selection criteria | P84144 in DD<br>100 for site selected because near/within local problem area<br>200 for site selected without regard to local problem area | 200 | QWDATA |
| Altitude of land surface (if readily available) | C016 | 1000 | GWSI |
| Use of site | C023 | O (for observation) | GWSI |
| Use of water (primary use) | C024 | P (for public supply) | GWSI |
| Aquifer type (for the aquifer that was sampled) | C713 | C (for confined single aquifer) | GWSI |
| Primary aquifer (for the aquifer that was sampled) | C714 | 100CNZC (for Cenozoic) | GWSI |
| Well depth (in feet below land surface) | C028 | 140.5 | GWSI |

**Table 4.** Details of data requested for submittal to the national volatile organic compound (VOC) occurrence data base for use in assessment of occurrence, status, and distribution of VOCs in ground water—Continued

| Data element or other information | Source for definition of data element[2] | Example of data element | Suggested storage location of data element[3] |
|---|---|---|---|
| **Well Site and Construction, and Hydrogeologic Data Associated with the Analyte-Concentration Data—Continued** | | | |
| Water level (in depth below land surface) and date of measurement | P72019 (In the event that no water level was measured at the time of sampling, use GWSI water-level components - C237 with date C235. If there are no data in C237 and C235, use data in C30 and C31.) | 75.3 | QWDATA |
| Collecting agency | P00027 | 1028 | QWDATA |
| Analyzing agency | P00028 | 1028 | QWDATA |
| Casing material | C080 | S (for steel) | GWSI |
| Depth to top of open interval (perforated or screened, in feet below LSD) | C083 | 132 | GWSI |
| Depth to bottom of open interval (perforated or screened, in feet below LSD) | C084 | 137 | GWSI |
| Type of opening | C085 | R (for wire-wound screen) | GWSI |
| **Hydrogeologic Data for the Aquifer that was Sampled** | | | |
| Contributing unit (for the aquifer that was sampled) | C304 | P (for primary) | GWSI |
| Depth to top of unit (that was sampled, in feet below LSD) | C091 | 80 | GWSI |
| Depth to bottom of unit (that was sampled, in feet below LSD) | C092 | 155 | GWSI |
| Unit identifier | C093 | 100CNZC (for Cenozoic) | GWSI |
| Lithology | C096<br>About 90 possible terms are listed under this C code to describe the principal lithology of the aquifer that was sampled. To the extent possible, without incorrectly identifying the lithology, categorize lithology by broad categories, such as igneous, metamorphic, sedimentary, basalt, granite, sandstone, shale, limestone, dolomite, sand and gravel, silt and clay, till. | SDGL (for sand and gravel) | GWSI |
| Lithologic modifier | C097 | Brownish red | GWSI |
| **Hydrogeologic Data Repeated for Major Hydrogeologic Units Overlying the Sampled Aquifer to Record Hydrogeologic Information About Those Units That Might Affect or Provide Explanation for Concentrations of VOCs in the Sampled Aquifer** | | | |
| Contributing unit | C304 | N (for contributes no water) | GWSI |
| Depth to top of unit (in feet below LSD) | C091 | 15 | GWSI |
| Depth to bottom of unit (in feet below LSD) | C092 | 80 | GWSI |

**Table 4.** Details of data requested for submittal to the national volatile organic compound (VOC) occurrence data base for use in assessment of occurrence, status, and distribution of VOCs in ground water—Continued

| Data element or other information | Source for definition of data element[2] | Example of data element | Suggested storage location of data element[3] |
|---|---|---|---|
| **Hydrogeologic Data Repeated for Major Hydrogeologic Units Overlying the Sampled Aquifer to Record Hydrogeologic Information About Those Units That Might Affect or Provide Explanation for Concentrations of VOCs in the Sampled Aquifer—Continued** | | | |
| Aquifer code (geologic age and unit identifier) | C093 | 100CNZC (for Cenozoic) | GWSI |
| Lithology | C096<br><br>About 90 possible terms are listed under this C code to describe the principal lithology of the major hydrogeologic units overlying the sampled aquifer. To the extent possible, without incorrectly identifying the lithology, categorize lithology by broad categories, such as igneous, metamorphic, sedimentary, basalt, granite, sandstone, shale, limestone, dolomite, sand and gravel, silt and clay, till. | CLSD (for clay, some sand) | GWSI |
| Lithologic modifier | C097 | Grey, soft | GWSI |
| | **For Each VOC Analyte** | | |
| Analyte concentration[4] | P codes (including Remarks code) and value for each analyte.<br><br>If the analyte was not measured, but cannot be easily removed from the list of analytes, indicate this missing value as --. Do not enter nonmeasured values as = 0.<br><br>Concentrations reported as non-detections (ND) will be of limited value for this assessment of occurrence, status, and distribution of VOCs in ground water because of the wide possible range of quantitation levels that could be associated with an ND. **For this reason, it is requested that an extra effort be made to determine the quantitation level.** If the analyte was measured but not detected (ND) or if a nondetection is indicated as a zero value, then the value (0 or ND) should be modified to indicate the value is less than the quantitation level for that analyte. If the quantitation level absolutely cannot be obtained, indicate as ND. | P34235 = 0.1(<:::) or P34235=<0.1 for benzene dissolved that was measured and was below the quantitation level of 0.1 µg/L. | QWDATA |
| Date sample was collected (YearMonthDay) | At a minimum, the year that the sample was collected should be listed. Include month and day, when that information is available. | 930723 (for YYMMDD) | QWDATA |

[1]The following additional GWSI data elements - C codes are required for establishing a site file for entry of data into GWSI; Station locator sequence number - C815; Agency code - C004; District - C006; County - C008; Agency use - C803; Station type - C802; Data reliability - C003; Site type - C002.

[2]Source : C, component number in GWSI; P, parameter code in QWDATA; DD, see NAWQA data dictionary.

[3]Suggested storage location: rdb file, relational data base file for submittal to IDB (NAWQA Interim Data Base), QWDATA, or GWSI in the U.S. Geological Survey's National Water Information System (NWIS).

[4]Do not include analyses of quality-control samples.

## Criteria for Selection of Wells and Volatile Organic Compound Data

### General Selection Criteria

After the VOC inventory described in "Supplemental Information" (at back of this report) is completed, the suitability of existing VOC data for use in the assessment of occurrence, status and distribution of VOCs in ground water is evaluated by each Study Unit in consultation with the VOC National Synthesis staff. In general, the criteria for selection of wells for NAWQA Study-Unit Surveys (Lapham and others, 1995) should be followed when selecting wells for the assessment described in this report. VOC data are selected for the assessment on the basis of well-network design, well construction, and sample-collection and laboratory-analysis criteria that need to be met for each well (table 5). Selected VOCs that are measured by several different laboratory schedules or methods are listed in table 6. Not all schedules and methods that include measurements of the indicated compounds are included in table 6. Some or all of the VOC data that meet these criteria will be compiled by the 1994 Study-Unit Staff. The same approach will be used by the VOC National Synthesis to compile data from selected local, State, multi-State, and Federal programs not compiled by Study Units.

### Well-Network Design

A well network is best suited for this national assessment of occurrence, status, and distribution of VOCs in ground water if its design results in a generally unbiased, areally distributed, random selection of sampling sites throughout the aquifer or part of the aquifer of interest (table 5). This network design is based on random selection with equal-area distribution (Alley, 1993). Computerized methods for random site selection are presented in Scott (1990).

It is unlikely that many existing monitoring programs follow the ideal design because of the inability to install wells exactly at randomly located sites. Thus, a common compromise is to install wells as close as possible to the randomly located sites. In many monitoring programs, the cost of drilling precludes well installation. In this case, rather than installing wells, existing wells that are located as near as possible to the randomly located site and that meet certain construction criteria are selected for sampling. This approach is used for NAWQA Study-Unit Surveys (Gilliom and others, 1995; Lapham and others, 1995). For the assessment described in this report, deviation from the ideal network design is complicated further by the fact that VOC data must have been collected. Thus existing wells need to be found that collectively result in a network of wells that closely fits the ideal network design, that have been sampled for VOCs, and that meet the other suitability criteria in table 5.

**Table 5.** Criteria for selection of volatile organic compound (VOC) data for assessment of occurrence, status, and distribution of VOCs in ground water

**Well-Network Design**

- Wells are suitably located in relation to the desired spatial and depth design.
- All wells or a subset of wells from one or more well networks collectively result in a generally unbiased, random, equal-area distribution of sampling sites throughout the aquifer or part of the aquifer of interest.

**Well Construction[1]**

- The hydrogeologic unit (or units) represented by the water level measured and the hydrologic unit (or units) contributing water to the well are known.
- The well construction and pumping equipment in the well are known to be of a type that are not likely to affect concentrations of VOCs in the water sample.

**Criteria for Selection of VOC Data**

VOC data are considered suitable for use in the assessment if:

- National methods for collection and analysis of VOCs were used (information on analytes measured by different methods is presented later in this report). The method detection limits or the reporting levels for VOC analytes should be less than about 5 micrograms per liter.
- Laboratory analysis was done by a laboratory certified by the U.S. Environmental Protection Agency.
- The location of the well from which the sample was collected is known by latitude and longitude.
- The sample was collected from untreated (raw) water.
- The water sample was collected at or near the well head before being held in a pressure tank or holding tank.
- The analyte name is identified by P code (see table 1) and the analyte concentration is known.
- The date (at a minimum, the year) of sample collection is known. (In general, the latest measured concentration of the analyte from a well after January 1, 1985, is requested. However, in some cases this criteria may not apply. See "Selection of a Volatile Organic Compound Analysis From Several Available for a Well" for further guidance.)
- Quality-control data have been used to evaluate and, if necessary, to censor the environmental data prior to its compilation at a national level to the extent that quality-control data are available.

[1]See Lapham and others (1995) for discussion of possible effects of well construction on the chemistry of a water-quality sample.

**Table 6.** Selected volatile organic compounds (VOCs) measured by indicated U.S. Geological Survey National Water-Quality Laboratory schedules and U.S. Environmental Protection Agency methods[1]

[NWQL, U.S. Geological Survey National Water-Quality Laboratory; U.S. EPA, U.S. Environmental Protection Agency; CAS, Chemical Abstracts Services; RCRA, Resource Conservation and Recovery Act; x, analyte measured by that schedule or method; VOC, Volatile Organic Compound; GC/MS Gas Chromatography/Mass Spectrometry]

| CAS number | Compound name | NWQL schedule numbers | | | | | U.S. EPA method numbers | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Drinking water | | | | | | | | | | | | | | RCRA | | Ground water, soil, and so forth | | | | | | |
| | | 2090 | 1380 | 9090 | 1307 | 1401 | 502.1 | 502.2 | 503.1 | 504 | 505 | 524.1 | 524.2 | 525.1 | 603 | 611 | 612 | 625 | 1624 | 1625 | 8240 | 8270 | 8010 | 8015 | 8020 | 8030 | 8100 | 8120 |
| 56-23-5 | Tetrachloromethane (carbon tetrachloride) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 67-66-3 | Trichloromethane (chloroform) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 67-72-1 | Hexachloroethane | | | x | | | | | | | | | | | | | x | x | | x | | x | | | | | | x |
| 71-55-6 | 1,1,1-Trichloroethane | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 74-83-9 | Bromomethane | x | x | x | | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 74-87-3 | Chloromethane | x | x | x | | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-00-3 | Chloroethane | x | x | x | | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-09-2 | Dichloromethane (methylene chloride) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-25-2 | Tribromomethane (bromoform) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-27-4 | Bromodichloromethane | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-34-3 | 1,1-Dichloroethane | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-69-4 | Trichlorofluoromethane (CFC 11) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-71-8 | Dichlorodifluoromethane (CFC 12) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | | | | | | |
| 76-13-1 | 1,1,2-Trichloro-1,2,2-trifluoroethane (CFC 113) | x | x | x | x | | | | | | | | | | | | | | | | | | | | | | | |
| 78-87-5 | 1,2-Dichloropropane | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 79-00-5 | 1,1,2-Trichloroethane | x | x | x | | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 96-12-8 | 1,2-Dibromo-3-Chloropropane (DBCP) | x | x | x | | | | x | | x | | x | x | | | | | | | | x | | | | | | | |
| 96-18-4 | 1,2,3-Trichloropropane | x | x | x | | | x | x | | | | x | x | | | | | | | | x | | | | | | | |
| 106-93-4 | 1,2-Dibromoethane (EDB) | x | x | x | | | x | x | | x | | x | x | | | | | | | | x | | | | | | | |
| 107-06-2 | 1,2-Dichloroethane | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 124-48-1 | Dibromochloromethane | x | x | | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-01-4 | Chloroethene (vinyl chloride) | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 75-35-4 | 1,1-Dichloroethene | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |

**Table 6.** Selected volatile organic compounds (VOCs) measured by indicated U.S. Geological Survey National Water-Quality Laboratory schedules and U.S. Environmental Protection Agency methods[1]—Continued

| CAS number | Compound name | NWQL schedule numbers | | | | | U.S. EPA method numbers | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Drinking water | | | | | | | | | | | | | | RCRA | | Ground water, soil, and so forth | | | | | | |
| | | 2090 | 1380 | 9090 | 1307 | 1401 | 502.1 | 502.2 | 503.1 | 504 | 505 | 524.1 | 524.2 | 525.1 | 603 | 611 | 612 | 625 | 1624 | 1625 | 8240 | 8270 | 8010 | 8015 | 8020 | 8030 | 8100 | 8120 |
| 79-01-6 | Trichloroethene (TCE) | x | x | x | x | | x | x | x | | | x | x | | | | | | | | x | | x | | | | | |
| 87-68-3 | 1,1,2,3,4,4-Hexachloro-1,3-Butadiene | x | x | x | | | | x | x | | | x | x | | | | | | | | | x | | | | | | x |
| 127-18-4 | Tetrachloroethene | x | x | x | x | | x | x | x | | | x | x | | | | | | | | x | | x | | | | | |
| 156-59-2 | cis-1,2-Dichloroethene | x | x | x | x | | x | x | | | | x | x | | | | | | | | | | | | | | | |
| 156-60-5 | trans-1,2-Dichloro-ethene | x | x | x | x | | x | x | | | | x | x | | | | | | | | x | | x | | | | | |
| 593-60-2 | Bromoethene | | | x | | | | | | | | | | | | | | | | | | | | | | | | |
| 10061-01-5 | cis-1,3-Dichloro-1-propene | x | x | x | | | x | x | | | | x | | | | | | | | | x | | x | | | | | |
| 10061-02-6 | trans-1,3-Dichloro-1-propene | x | x | x | | | x | x | | | | x | | | | | | | | | x | | x | | | | | |
| 71-43-2 | Benzene | x | x | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 91-20-3 | Naphthalene | x | x | x | | | | x | x | | | | x | | | | | | | | | x | | | | | x | |
| 100-42-5 | Styrene (vinyl benzene) | x | x | x | x | | | x | x | | | x | x | | | | | | | | x | | | | | | | |
| 95-47-6 | 1,2-Dimethylbenzene (o-xylene) | x | | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 95-63-6 | 1,2,4-Trimetylbenzene | x | x | x | | | | x | x | | | | x | | | | | | | | | | | | | | | |
| 98-82-8 | Cumene (isopropylbenzene) | x | x | x | | | | x | x | | | x | | | | | | | | | | | | | | | | |
| 100-41-4 | Ethylbenzene | x | x | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 103-65-1 | n-Propylbenzene | x | x | x | | | | x | x | | | x | | | | | | | | | | | | | | | | |
| 104-51-8 | n-Butylbenzene | x | x | x | | | | x | x | | | x | | | | | | | | | | | | | | | | |
| 106-42-3 | 1,4-Dimethylbenzene (p-xylene) | x | | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 108-38-3 | 1,3-Dimethylbenzene (m-xylene) | x | | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 108-88-3 | Methylbenzene (toluene) | x | x | x | x | | | x | x | | | x | x | | | | | | | | x | | | | x | | | |
| 87-61-6 | 1,2,3-Trichlorobenzene | x | x | x | | | | x | x | | | | x | | | | | | | | | | | | | | | |
| 95-50-1 | 1,2-Dichlorobenzene | x | x | x | x | | x | x | x | | | x | x | | | | | | | | | x | x | | x | | | x |
| 106-46-7 | 1,4-Dichlorobenzene | x | x | x | x | | x | x | x | | | x | x | | | | | | | | | x | x | | x | | | x |
| 108-90-7 | Chlorobenzene | x | x | x | x | | x | x | x | | | x | x | | | | | | | | x | | x | | x | | | |
| 120-82-1 | 1,2,4-Trichlorobenzene | x | x | x | | | | x | x | | | | x | | | | | | | | | x | | | | | | x |
| 541-73-1 | 1,3-Dichlorobenzene | x | x | x | x | | x | x | x | | | x | x | | | | | | | | | x | x | | x | | | x |
| 108-20-3 | Diisopropyl ether (DIPE) | | | x | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 6.** Selected volatile organic compounds (VOCs) measured by indicated U.S. Geological Survey National Water-Quality Laboratory schedules and U.S. Environmental Protection Agency methods[1]—Continued

| CAS number | Compound name | NWQL schedule numbers | | | | | U.S. EPA method numbers | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Drinking water | | | | | | | | | | | | | | RCRA | | Ground water, soil, and so forth | | | | | | | |
| | | 2090 | 1380 | 9090 | 1307 | 1401 | 502.1 | 502.2 | 503.1 | 504 | 505 | 524.1 | 524.2 | 525.1 | 603 | 611 | 612 | 625 | 1624 | 1625 | 8240 | 8270 | 8010 | 8015 | 8020 | 8030 | 8100 | 8120 |
| 111-44-4 | Bis (2-chloroethyl) ether | | | | | | | | | | | | | | | x | | x | | x | | x | | | | | | | |
| 123-91-1 | 1,4-Dioxane | | | | | | | | | | | | | | | | | | x | | x | | | | | | | | |
| 637-92-3 | Ethyl *tert*-butyl ether (ETBE) | | | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| 762-75-4 | *tert*-Butyl formate (TBF) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 994-05-8 | *tert*-Amyl methyl ether (tame), (2-Methoxy-2-methyl-butane) | | | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1634-04-4 | Methyl *tert*-butyl ether (MTBE) | x | x | x | | | | | | | | | | | | | | | | | | | | | | | | | |
| 107-02-8 | 2-Propenal (acrolein) | | x | x | | x | | | | | | | | | x | | | | x | | x | | | | | x | | | |
| 107-13-1 | 2-Propenenitrile (acrylonitrile) | | x | x | | x | | | | | | | | | x | | | | x | | x | | | | | x | | | |

[1]Not all schedules and methods that include measurements of the indicated compounds are included in this table.

NOTES:

The xylene concentrations are reported as totals using U.S. EPA methods.

Method 502.1: Title: Halogenated VOCs in Water. Matrix: Drinking water (finished or any treatment stage) and raw source water.
Method 502.2: Title: Halogenated VOCs in Water. Matrix: Drinking water (finished or any treatment stage) and raw source water.
Method 503.1: Title: Aromatic and Unsaturated VOCs in Water. Matrix: Drinking water (finished or any treatment stage) and raw source water.
Method 504: Title: 1,2-Dibromoethane and Dibromochloropropane in Water by Microextraction. Matrix: Finished drinking water and unfinished ground water.
Method 505: Title: Organohalide Pesticides and PCBs.
Method 524.1: Title: VOCs in Water by Purge and Trap GC/MS. Matrix: Drinking water (finished or any treatment stage) and raw source water.
Method 524.2: Title: VOCs in Water by Purge and Trap GC/MS. Matrix: Drinking water (finished or any treatment stage) and raw source water.
Method 525.1: Title: General Purpose Organics.
Method 603: Title: Acrolein/Acrylonitrile.
Method 611: Title: Haloethers.
Method 612: Title: Chlorinated Hydrocarbons.
Method 625: Title: Acids (Phenols), Base/Neutral Organochloride Pesticides and PCBs.
Method 1624: Title: VOCs by Isotope Dilution GC/MS.
Method 1625: Title: Semi-Volatile Organic Compounds by Isotope Dilution GC/MS.
Method 8010: Title: Halogenated Volatile Organics. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8015: Title: Nonhalogenated Volatile Organics. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8020: Title: Aromatic Volatile Organics. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8030: Title: Other Nonhalogenated VOCs. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8100: Title: Polynuclear Aromatic Hydrocarbons. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8120: Title: Chlorinated Hydrocarbons. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8310: Title: Polynuclear Aromatic Hydrocarbons. Matrix: Ground water, soils, sludges (water miscible liquid wastes and nonwater miscible wastes).
Method 8240: Appendix IX Volatiles (RCRA).
Method 8270: Appendix IX Semivolatile (RCRA).

Well networks used in monitoring programs for which objectives are different from the objectives for this assessment might be based on a design other than unbiased, areally distributed, random selection of sampling sites. Nevertheless, monitoring programs designed either for similar assessments of VOCs or for other objectives still might be considered if, by selecting all or a subset of wells from one or more of these programs, the resulting network collectively produces a network design based on random selection with equal-area distribution.

Different approaches for design of a well network from one or more monitoring programs might be necessary to fit local situations. For purposes of illustration, six hypothetical situations (table 7) are described in the following paragraphs with suggested approaches for selection of wells and data compilation for this assessment. The approaches are intended to result in networks of wells that are based on random selection with equal-area distribution (table 5). The monitoring-program/well-network characteristics described as example monitoring programs 1 and 6 of table 7 cover anticipated end members of types of

**Table 7.** Examples of monitoring-program or well-network characteristics, requested data compilation, and anticipated analysis of the data

[VOCs, volatile organic compounds]

| Example monitoring program | Total number of wells in the network(s) | Distribution of wells across the hydrogeologic unit/ aquifer/part of the aquifer | Amount of data[1] that are readily available in an electronic data base | Requested number of wells for which data are compiled | Requested amount of data[1] compiled | Anticipated analysis of data |
|---|---|---|---|---|---|---|
| 1 | Much greater than 100. | Approximate equal-area distribution. | All. | All wells in the network. | All. | Aquifer- and national-scale analyses of occurrence, status, and distribution of VOCs. |
| 2a or | do. | do. | Very little. | All wells in the network. | Data in the electronic data base. | Aquifer- and national-scale analyses of occurrence, status, and distribution of VOCs. |
| 2b | do. | do. | do. | About 100 wells randomly selected with equal-area distribution. | As much as possible. | Aquifer- and national-scale analyses of occurrence, status, and distribution of VOCs to the extent supported by the available ancillary data. |
| 3 | do. | Highly variable. | All | do. | All. | Aquifer- and national-scale analyses of occurrence, status, and distribution of VOCs. |
| 4 | do. | do. | Very little. | do. | As much as possible. | Aquifer- and national-scale analyses of occurrence, status, and distribution of VOCs to the extent supported by the available ancillary data. |
| 5 | Much less than 100. | Approximate equal-area distribution. | All. | As many wells as possible. | All. | National-scale analyses of occurrence, status, and distribution of VOCs. |
| 6 | do. | Highly variable. | Very little. | do. | As much as possible. | National-scale analyses of occurrence, status, and distribution of VOCs to the extent supported by the available ancillary data. |

[1]Data for assessment of occurrence, status, and distribution of VOCs in ground water described in tables 3 and 4.

monitoring programs/well networks for which data might be compiled. It is assumed that the criteria for selection of VOC data in table 5 are met in all examples.

Example 1 in table 7 describes a ground-water-quality monitoring program designed to describe the occurrence and distribution of VOCs. The well network consists of a large number of wells that are distributed uniformly throughout the aquifer of interest. Sampling sites were selected randomly by equal-area distribution with respect to both location and depth in the aquifer, and wells were installed at those sites. A broad suite of VOCs were analyzed in water from all wells. Nondetections are reported as values less than the quantitation level. Extensive ancillary data about each well are in an electronic data base. All wells in the network are selected for compilation of all available VOC and ancillary data requested by the VOC National Synthesis (table 3).

Example 6 in table 7 describes a situation in which one or more well networks are used. Each network consists of small numbers of wells, distributed vertically and horizontally throughout the aquifer of interest. Some networks might be biased toward a specific well type, for example, public-supply, domestic-supply, or wells installed at or near known sources of contamination. The total number of wells available is small, and the distribution of wells across the aquifer is highly variable. Few VOC analyses and (or) little ancillary data are available. The approach is to select as many wells as possible from the combined monitoring programs such that there is a reasonably equally distributed number of randomly selected wells across the aquifer.

Well networks that have the characteristics described in example 6 will be the least useful of the six listed in table 7 for this assessment because of the small number of wells and the small amount of ancillary information available for each well. Data from these programs will be useful in aggregate, but little or no interpretation of the occurrence, status, and distribution of VOCs for an individual aquifer will be possible. Nevertheless, compilation of data from these programs is preferred to no compilation at all.

### Well Construction

Well construction, including construction materials, the design of the well, and (or) installation methods can result in a well being unsuitable for sampling of targeted water-quality constituents, such as VOCs (Lapham and others, 1995). For example, glued PVC monitoring wells, to the extent possible, should not be selected as part of a well network for this assessment because organic compounds, such as tetrahydrofuran, methylethylketone, methylisobutylketone, and cyclohexanone, can leach from the glue used to bond unthreaded polyvinylchloride casing. Wells that are screened in several units, that contain multiple screens in different units, or that have long well screens make determination of the source of water to the well difficult. Therefore, wells with these types of design should not be selected, if possible. Oil, grease, and other foreign materials on drilling and associated equipment can be introduced to water-bearing units during drilling, well completion, and well development if not removed from the equipment prior to its use. This potential for contamination needs to be considered when gathering and interpreting information about candidate wells. Low-capacity wells should be selected in preference to high-capacity wells because high-capacity wells can draw water from units other than the unit of interest.

It is important to document information regarding construction of a well when submitting the VOC data to the national VOC occurrence data base (table 3), particularly for those wells where construction likely might affect concentrations of VOCs in the water sample.

### Well Type

An additional complication to the assessment described in this report, which can result from using a network of existing wells, is that well type can bias the results (Alley, 1993; Gilliom and others, 1995; Lapham and others, 1995). For example, although pre-screening of water quality prior to well installation of small public-supply wells probably is not done, pre-screening of water quality from test wells might be performed prior to installing large municipal water-supply wells. A result of pre-screening would be the absence of large municipal supply wells in areas of ground-water contamination. In addition, public-supply wells in areas of contaminated ground water might be removed from service once a contaminant is detected. Consequently, well networks that consist only of large municipal water-supply wells could result in a bias in the assessment toward areas of aquifers that are not contaminated with VOCs. Conversely, well networks for this assessment that consist only of wells installed immediately downgradient of sources of known contamination could result

in a biased interpretation that the aquifer is largely contaminated with VOCs.

One of the most common types of wells sampled for VOCs are monitoring wells installed at and near sites of known contamination. Therefore, this well type probably will be one of the most common types from which VOC data are available. Because the focus of this assessment is on aquifers, or those parts of aquifers, that are currently used or have the potential to be used as sources of water supplies, selection of monitoring wells that were installed at or immediately downgradient of sources of known contamination would not be appropriate. However, wells installed upgradient of these sources to determine "background" water quality in the aquifer might be selected.

Wells should be selected to minimize bias attributable to well type. Often one of several alternative wells of different types that have been sampled for VOCs could be selected at or near a randomly located site. If several wells are available near a randomly located site, the established priority for selecting a well (table 8) is applied. In these situations, the well selected should be the one that is most likely to have been installed with the least regard to the presence or absence of VOCs. Thus, monitoring wells installed to meet the objective of the assessment described in this report, or wells installed to meet other objectives, but without regard to the presence or absence of VOCs, have a higher priority for selection than wells installed in areas where it is assumed that VOCs are absent or than wells installed in areas where data indicate that VOCs are present (table 8). For example, in a situation where the alternative is to select either a domestic well or a large municipal-supply well, the domestic well probably is the one most likely to have been installed with the least regard to the presence or absence of VOCs and would be the well selected for this assessment.

**Table 8.** Suggested priority for well selection for assessment of occurrence, status, and distribution of volatile organic compounds (VOCs) to minimize bias attributable to well type

| Well selection based on type, from highest (1) to lowest (4) priority |
|---|
| (1) Wells that were installed without regard to the presence or absence of VOCs, such as monitoring wells installed based on random selection of sites with equal-area distribution throughout an aquifer. |
| (2) Wells that were installed for objectives other than assessment of the occurrence and distribution of VOCs, but were installed without regard to the presence or absence of VOCs, such as observation wells installed for water-level measurements, public-supply wells installed without pre-screening for VOCs, and some domestic- and industrial-supply wells. |
| (3) Wells that were installed at locations where it is assumed that VOCs are absent, such as test wells for locating future water supplies. |
| (4) Wells that were installed in areas where data indicate that VOCs might be present, such as monitoring wells installed upgradient of sources of known contamination to measure "background" conditions. |

## Selection of Volatile Organic Compound Data

### Selection of a Volatile Organic Compound Analysis from Several Available for a Well

In some cases, a well might have been sampled multiple times. In these cases, a single VOC analysis is selected to represent the well. The decision of which VOC analysis to select is based on the objectives and sampling design of the monitoring program in which the well is located. Following are examples of monitoring programs in which wells are sampled multiple times, and the suggested approaches for selecting an analysis to represent each well in that program. The intent of the suggested approaches is to minimize bias in the analyses selected with respect to describing the occurrence and distribution of VOCs in aquifers. Other approaches might need to be developed by Study Units for specific monitoring programs. In these cases, an approach should be developed that minimizes bias in the data with respect to the occurrence-and-distribution objective. The Study Unit needs to document that approach for future reference.

In some monitoring programs, all wells are sampled at about the same time (synoptically) and at the same frequency. For example, every well in the network is sampled every year in October. In this case, the most recent analysis is selected. However, in all cases, analyses collected prior to January 1985 are not selected. The reason for this is to obtain the most recent data within the last decade describing the occurrence and distribution of VOCs for all aquifers studied. In some monitoring programs, the frequency of sampling might depend on the detection of VOCs in the well. For example, the frequency of sampling might be increased (for example, to quarterly

sampling) if a VOC is detected, whereas other wells in the monitoring program would continue to be sampled at a lower, routine frequency (for example, once every year). In this case, it is suggested that the latest measurement after January 1, 1985, at the low, routine frequency be selected. In some monitoring programs, a "stopping rule" is used to determine if sampling of a well can be discontinued. In this example, sampling is continued only as long as VOCs are detected. If the latest analysis is selected, results will be biased toward nondetections. In this case, it is recommended that one analysis from the well be selected randomly from all analyses made after January 1, 1985.

#### Censoring Volatile Organic Compound Data Using Quality-Control Data

Quality-control (QC) samples might be included as part of some monitoring programs used for National Synthesis of VOCs. QC samples for VOCs include equipment blanks, field blanks, trip blanks, and field-spiked, replicate samples. Bias and precision measurements from these QC samples reflect combined on-site and laboratory errors that occur during data collection. Other QC samples might be collected to estimate errors associated with a specific on-site or laboratory procedure. To the extent that data from QC samples are available, these data need to be used to evaluate and document the quality of the environmental data.

Data from QC samples are used to make general inferences about bias and measurement precision for selected VOC analytes (Koterba and others, 1995). QC data can be used to demonstrate the effectiveness of equipment-decontamination procedures, to measure changes that occur in analyte concentrations from time of collection to time of analysis, and to support the decision to censor environmental data. For example, use of QC data to isolate and eliminate sources of sample contamination or bias that occur as a result of sample collection and processing are described in Koterba and others (1991) and Christenson and Rea (1993). Use of the magnitude of error estimates from QC data to provide an indication of the quality of ground-water data collected is described in Koterba and others (1991; 1993).

#### Instrument and Method Detection Limits and Reporting Levels

The magnitudes of the method detection limits or reporting levels for VOC analytes are criteria for selection of an analysis. The method detection limit or the reporting level for a VOC analyte should not be greater than about 5 µg/L (micrograms per liter) for that data to be selected for use by the National Synthesis (table 5).

Confusion about differences between instrument detection limits, method detection limits, and reporting levels warrants brief repetition here of a discussion in U.S. Geological Survey (1994). An instrument detection limit is an analyte's mass equivalent that would correspond to a signal equal to three times the standard deviation of a series of 10 replicate measurements of a reagent blank signal (Currie, 1988; U.S. Geological Survey, 1994). This detection limit is for a pure analyte and refers only to the sensitivity of the instrument. This is the lowest detection limit that can be achieved and is usually the one reported by instrument manufacturers.

The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a matrix containing the analyte (U.S. Environmental Protection Agency, 1992). The 99-percent confidence is defined as three times the standard deviation calculated from seven replicate analyses of a matrix spiked at a concentration of 2.5 to 5 times the instrument signal-to-noise ratio, or 1 to 5 times the estimated detection limit. In this definition of MDL, the analyte has been through all steps of the method (extraction, isolation, analysis). In addition, the MDL is matrix specific. Given these matrix effects and the unavoidable analyte losses throughout the analytical procedure, the MDL can be 2 to 100 times higher than the instrument detection limit.

The reporting level cited by the U.S. Geological Survey's National Water-Quality Laboratory (NWQL) is the concentration that the laboratory feels it can reliably report, regardless of varying sample matrices in a given medium. In some cases, the NWQL reporting levels are lower than their corresponding U.S. EPA MDL's for regulated analytes. The choice of a reporting level reflects many variables, not all of them quantifiable. For some schedules, the NWQL might report reporting levels equal to MDL's. Also, for some new methods, for those analytes for which identity is assured, the NWQL will report all concentrations determined that are greater than the instrument detection limit (uncensored) whether or not they are less than, equal to, or greater than the MDL.

## Submittal of Data to the Volatile Organic Compound Occurrence Data Base

Submittal of the VOC and ancillary data to the national VOC occurrence data base is accomplished through a formal request. This request was made in the summer of 1995 for data compiled by the 1994 Study Units from their Retrospective Analysis. The request was similar to the environmental and quality-control data requests made to the 1991 Study Units by National Synthesis in 1994. Detailed instructions describing the submittal procedure and format were provided at the time of the data request.

VOC concentration and ancillary data at each well that are requested are listed in table 3. Additional information about the VOC concentration and ancillary data requested is provided in table 4. In addition, general information about the monitoring programs/networks from which data were compiled and about the aquifers/hydrogeologic units investigated are requested. This general information is requested as rdb files similar to those in tables 9-12. Table 9 is a cross reference between wells for which VOC data are submitted and monitoring program(s) from which these wells were sampled; the information in table 10 describes each inventoried monitoring program in table 9; table 11 is a cross reference between wells for which VOC data are submitted and the aquifer in which each well is screened; and table 12 describes information about each aquifer in table 11. The information in table 12 will be used for reporting on general characteristics of the aquifers studied and for grouping of aquifers with common characteristics during analysis.

## Analysis of Data

The amount of VOC and ancillary data available will determine the extent of the description and interpretation of the occurrence, status, and distribution of VOCs in major aquifers across the Nation (table 7). Example programs that have the characteristics described in example 1 of table 7 will be the most useful types of programs for analysis by the VOC National Synthesis because of the large number of wells sampled and the large amount of ancillary data known about each well. A large number of analyses of VOCs from an aquifer is desirable because the percentage of an aquifer contaminated by VOCs is likely to be small. The large amount of ancillary data is desirable because more data will enable more extensive analysis at the aquifer scale—for example, analysis of occurrence, status, and distribution of VOCs in relation to factors such as depth to the water table, well depth, and well type. The situation described in example 6 of table 7 is probably a common situation that might be encountered. However, programs that have the characteristics described in example 6 will be the least useful for the assessment of those listed in table 7 because of the small number of VOC analyses and the small amount of ancillary information available about each well. Data from these programs will be useful in a national aggregation, but little or no interpretation of occurrence of VOCs for an individual aquifer will be possible. Nevertheless, compilation of data from these programs is preferred to no compilation at all.

**Table 9.** Example of a relational data-base file (called netsite.rdb) that identifies each well, for which volatile organic compound (VOC) analyte-concentration data are submitted, in relation to the monitoring program/network from the VOC data-inventory tables (see "Supplemental Information" section)

[Information in this table is for illustrations purposes only; GWSI, U.S. Geological Survey Ground-Water Site Inventory]

```
# netsite.rdb
# Tab-delimited RDB table for each well submitted to the VOC occurrence data base.
# Gives STAID for each well for which VOC data are submitted and NETCODE value
#    identifying monitoring program(s) in which the well was sampled from Study Unit
#    VOC data-inventory table (See "Supplemental Information" section).
#
# STAID = Station identification number of well in the network (GWSI C001)
# NETCODE = Network code value or prefix that identifies the monitoring-program number
#    recorded in the Study Unit VOC Inventory Table (see "Supplemental Information" section).
#    This number is the four-letter Study-Unit identification followed by an arbitrary sequence
#    number assigned by the Study Unit; for example, LINJ03.
#
#
STAID                NETCODE
15s                   8s
450715074230101       LINJ01
450715074230101       LINJ03
450715074230101       LINJ05
452043074445601       LINJ02
450715072301102       LINJ02
450715072301102       LINJ03
450715072301102       LINJ05
451134074012301       LINJ02
441220074221102       LINJ02
450715074230101       LINJ03
451043074445701       LINJ03
450725072301202       LINJ03
451434074013301       LINJ03
451434074013301       LINJ05
441220074221102       LINJ05
450715074230101       LINJ05
461043074446701       LINJ05
460725072301202       LINJ05
451734074012901       LINJ05
          .                .
          .                .
          .                .
```

**Table 10.** Example of a relational data-base file (called netdes.rdb) that describes general information about each monitoring program in the volatile organic compound (VOC) data-inventory tables for which VOC analyte-concentration data are submitted

[Information in this table is for illustrations purposes only; RCRA, Resource Conservation and Recovery Act; GWSI, U.S. Geological Survey Ground-Water Site Inventory]

```
# netdes.rdb
# Tab-delimited rdb table of descriptions of MONITORING PROGRAMS/WELL NETWORKS
#   from which VOC and associated ancillary data were compiled for the national Retrospective
#   Analysis of occurrence, status, and distribution of VOCs in ground water. This information is from
#   the VOC data-inventory tables (see "Supplemental Information" section). Additional
#   information is compiled about these programs/networks in the VOC data-inventory tables.
#
#
# NETCODE = Network code value or prefix that identifies the monitoring-program number
#   recorded in the Study Unit VOC data-inventory tables. This number is the four-letter Study-Unit
#   identification followed by an arbitrary sequence number assigned by the Study Unit; for
#   example, LINJ03.
# NETDESC = Descriptive text describing monitoring program.
# STATE = State(s) covered by the monitoring program (use two-letter postal State
#   abbreviations, in caps; if program covers more than one State, separate States by
#   commas, for example, NY,NJ).
# DEPT = Department conducting the program.
# EXTENT = Areal extent of program (if statewide, give State name; if county-wide,
#     give county name; if aquifer-wide, give aquifer name; RCRA-site name; and so forth).
# SQMILES = Area covered by the program, in square miles.
# BEGINYR = Year monitoring program began.
# ENDYR = Year monitoring program ended or '- year'(for example '-1995') if program is ongoing
#   (use four digits for year; do not enter future dates).
# USE = Primary use(s) of water from the wells in the network (use GWSI C24 codes)
#   as entered in the VOC data-inventory tables, in order of largest to smallest use (separate
#   uses by commas, for example, H, I, N, P).
# NUMSITE = Number of sites (wells) sampled in the network (VOC data are submitted
#   for all or for a subset of these total number of sites).
#
NETCODE  NETDESC                                                STATE  DEPT        EXTENT      SQMILES  BEGINYR  ENDYR  USE  NUMSITE
8s       132s                                                   8s     12s         12s         8n       15s      10s    12s  8n
LINJ02   Aquifer monitoring program since early 1980's in Nassau Cty using monitoring wells    NY,NJ  Nassau Cty  Nassau Cty
  200    1981   -1995   P   450
LINJ04   Monitoring of domestic supply wells since 1986                NJ     Ocean Cty   Health Dept  500      1986     1986   H    10000
```

**Table 11.** Example of a relational data-base file (called aqsite.rdb) that identifies each well, for which volatile organic compound (VOC) analyte-concentration data are submitted, in relation to the aquifer in which the monitoring well is screened

[Information in this table is for illustrations purposes only; GWSI, U.S. Geological Survey Ground-Water Site Inventory]

```
# aqsite.rdb
# Tab-delimited rdb table for each well submitted to the VOC occurrence data base.
# Gives HYDROGEO-UNIT NAME identifying aquifer associated with each well for
#   which VOC data are submitted to the national data base.
#
# STAID = Station identification number of the well (GWSI C001)
# HYDROGEO-UNIT NAME = Short name assigned by the Study Unit that identifies the
  #    aquifer (or hydrogeologic unit or subunit)  in which  each well is screened and for which
  #    VOC data are submitted.
#
#    To the extent possible, the National Synthesis objective is to describe the occurrence, status,
  #    and distribution of VOCs by aquifer and to summarize these data nationally.  In some cases,
  #    the amount of existing VOC data might not be sufficient to warrant description  at the aquifer
  #    scale (for example, analyses from a minimum of about 20 to 30 wells distributed throughout the
  #    aquifer), but data might be sufficient to describe VOC occurrence at a more regional scale; for
  #    example, by a hydrogeologic unit that consists of a group of aquifers, or by a subunit defined
  #    by the Study Unit on the basis of stratification by physiographic division and geology.
#
#
STAID                   HYDROGEO-UNIT NAME
15s                      20s
450715074230101
450715074230102
450715074230103
452043074445601
450715072301102
450715072301103
450715072301104
451134074012301
441220074221102
450715074230101
451043074445701
450725072301202
451434074013301
451434074013302
441220074221102
450715074230101
461043074446701
460725072301202
451734074012901
        .                    .
        .                    .
        .                    .
```

**Table 12.** Example of a relational data-base file (called aqdes.rdb) that describes information about each aquifer/hydrogeologic unit for which volatile organic compound (VOC) analyte-concentration data are submitted

[Information in this table is for illustrations purposes only; GWSI, U.S. Geological Survey Ground-Water Site Inventory]

```
# aqdes.rdb
# Tab-delimited rdb table of descriptions of aquifers (hydrogeologic units or subunits) for
#  which VOC and associated ancillary data were compiled.
# This table describes properties of each aquifer (or hydrogeologic unit or subunit)
#  as a whole, not at individual wells. This information in this table is repeated for each aquifer.
# For example, if data are submitted for three aquifers, this table would have three rows of
    #  information, one row for each aquifer.
#
# Following is a list of information for each aquifer/hydrogeologic unit to be included in an
#  rdb table. The format is the: VARIABLE NAME (field length and type) = Description of
#  requested information [example of how information is coded].
#
# HYDROGEO-UNIT NAME (20s) = Short name assigned by the Study Unit that identifies
#   the aquifer (or hydrogeologic unit or subunit) in which each well is screened, and for
#   which VOC data are submitted [Canoe River aquifer].
# AQDES (132s) = Descriptive text describing the aquifer (or hydrogeologic unit or subunit)
#    [Unconfined, stratified-drift aquifer composed of sand and gravel up to 150 feet thick].
# LITH (4s) = Lithologic description of the aquifer/hydrogeologic unit as a whole (use definitions
#    in GWSI C096) [SDGL].
# CONSOL (2s) = Degree of consolidation of the aquifer/hydrogeologic unit (UC,
#   unconsolidated; SC, semiconsolidated; CN, consolidated) [UC].
# ATC (1s) = Aquifer type code for aquifer/hydrogeologic unit as a whole using the definitions
#    in GWSI (Ground-Water Site Inventory - C713: U, Unconfined single aquifer; N,
#    unconfined multiple aquifers; C, confined single aquifer; M, confined multiple
#    aquifers; X, Mixed (confined and unconfined) multiple aquifers) [U].
# DPTHTOP (10s) = Approximate range in depth to top of (saturated part of) aquifer, in feet
#    below land surface [0-20].
# SATTHK (10s) = Approximate range in saturated thickness, in feet [0-120].
# K (10s) = Approximate range in hydraulic conductivity, in feet per day [50-350].
# T (10s) = Approximate range in transmissivity, in thousands of feet squared per day [0-300].
# RECH (5n) = Approximate average (annual) recharge to the aquifer, in inches per year [22].
# AQAREA (6n) = Area of aquifer/hydrogeologic unit, in thousands of square miles [2000].
# PUMPT (5n) = Total pumping from the aquifer in 1990, in millions of gallons per day [12].
# PPWS (5n) = Percentage of PUMPT used for public drinking-water supply [75].
# PDWS (5n) = Percentage of PUMPT used for domestic drinking-water supply [20].
# PIC (5n) = Percentage of PUMPT used for industrial and commercial water supply [5].
# PIR (5n) = Percentage of PUMPT used for irrigation [0].
# POPT (5n) = Total population served by pumping from the aquifer in 1990, in thousands [3200].
# PPOPP (5n) = Percentage of POPT served by public water supply [50].
# PPOPD (5n) = Percentage of POPT served by domestic water supply [50].
# AQSTATE (12s) = State(s) that the aquifer covers, use two-letter postal abbreviations,
#    in caps) [NY,NJ].
# PRECIP (6n)= Average annual precipitation over the aquifer, in inches per year [45].
# LANDUSES (25s) = Predominate land uses overlying the aquifer (use Level II-classifications in
#   Anderson and others, 1976, table 2). For example, for cropland and pasture, use code
#   221) [111-117, 221, 223].
# POPUL (6n) = Population overlying the aquifer, in thousands [5000].
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## SUMMARY

Volatile organic compounds (VOCs) were selected for National Synthesis by NAWQA because of the widespread occurrence of this constituent group in many of the Nation's water supplies. The broad goals of the VOC National Synthesis are (1) to describe current water-quality conditions; (2) to define trends, or lack of trends; and (3) to identify, describe, and explain causal relations among the occurrence and distribution of VOCs in surface water and ground water and natural and human factors. Fifty-five VOCs, including of halogenated alkanes, halogenated alkenes, aromatic hydrocarbons, alkyl benzenes, halogenated aromatics, ethers, and others, have been identified for study.

VOCs are of concern in ground water because of their relatively high aqueous solubility, mobility, and persistence, because many VOCs are known or suspected carcinogens, and because of their widespread use. The National Synthesis of VOCs in ground water has three objectives: (1) describe their occurrence, status, and distribution; (2) determine relations between VOC target analytes in shallow ground water and natural and human factors; and (3) determine and compare the occurrence, transformation, transport, and fate of selected VOC target analytes in ground water for several regionally or nationally important aquifer systems.

The objective of the assessment of VOCs in ground water discussed in this report is to describe the occurrence, status, and distribution of VOCs in major aquifers of the United States, both for individual aquifers and collectively. The assessment will be nationwide for aquifers, or those parts of aquifers, that are currently used or have the potential to be used as sources of water supplies. Occurrence describes the presence or absence of VOCs, their frequency of occurrence, and their ranges of concentrations. Status compares the concentrations of VOCs detected in relation to water-quality regulations or advisories, such as Maximum Contaminant Levels, Proposed Maximum Contaminant Levels, Maximum Contaminant Level Goals, and Health Advisories. Distribution describes the variability of VOCs in ground water, areally and by depth.

A set of criteria for well-network design, well construction, sample-collection methods, and methods of laboratory analysis need to be met for data to be used in this assessment. A well network suitable for this assessment is one in which all wells or a subset of wells from one or more well networks collectively results in a generally unbiased, random, equal-area distribution of sampling sites throughout the aquifer, or part of the aquifer, of interest. Well-construction information must be sufficient to ensure that the hydrogeologic unit (or units) represented by the water level measured and the hydrologic unit (or units) contributing water to the well are known. In addition, the well construction and pumping equipment in the well need to be of a type that are not likely to affect concentrations of VOCs in the water sample. VOC data are considered suitable for use in this assessment if: (1) national methods for collection and analysis of VOCs were used and the method detection limits or the reporting levels for VOC analytes are less than about 5 µg/L; (2) laboratory analysis was done by a laboratory certified by the U.S. EPA; (3) the location of the well from which the sample was collected is known by latitude/longitude; (4) the sample was collected from untreated (raw) water; (5) the water sample was collected at or near the well head before being held in a pressure tank or holding tank; (6) the analyte name is identified by parameter code, and the analyte concentrations are known; (7) the date (at a minimum, the year) of sample collection is known; and (8) quality-control data have been used to evaluate and, if necessary, to censor the environmental data prior to its compilation at a national level to the extent that quality-control data are available

This assessment will be done by collective analysis of data from monitoring programs across the Nation. Data from these monitoring programs will be compiled into a national data base for this analysis. Criteria for monitoring-program design, sample-collection methods, and methods of laboratory analysis will be met for data to be entered into this data base. The assessment will be based on data collected since 1985, for as many of the 55 VOCs currently (1996) on the list of NAWQA VOC target analytes as possible. Assessment by aquifer and comparisons of results among aquifers also will be completed for those aquifers that have adequate data, spatially or by depth.

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# SUPPLEMENTAL INFORMATION

# Instructions and blank forms for completing the data inventory for volatile organic compounds (VOCs) in ground water

## Instructions for filling out data-inventory Forms A and B

Inventory as many local, State, and Federal programs as possible in and near the Study Unit by filling out Form A during discussions with those agencies. If the answer on Form A, page 3, column entitled "Useful for Study Unit or National Synthesis?" is yes "Y," fill out Form B as completely as possible. Filling out Form B may require visits to the agency and (or) review of references describing the program in question. **No column should be left completely blank**. Write out repeated information in columns rather than using "ditto" or "do." If after a reasonable attempt, information for a particular column is not known, write "NK" in that column; if the answer to a column is yes, write "Y"; if no, write "N." Following these guidelines will result in consistent information compiled by all Study Units. If there are any questions, call NAWQA VOC National Synthesis at (605) 394-1780. Details on selected columns on Forms A and B are described below.

Form A, Column entitled: "Arbitrary number" — This is an arbitrary sequential number for every contact. Start with the four-letter Study-Unit abbreviation (for example, LINJ01, LINJ02, LINJ03, and so forth, where LINJ stands for Long Island/New Jersey Study Unit; 01 stands for the first inventory, 02 for the second inventory, 03 for the third inventory, and so forth).

Form A, Column entitled: "Agency contacted" — List alphabetically by two-letter postal abbreviation for the State, for example, NJ Department of Environmental Protection or NJ USGS District office, and so forth.

Form A, Column entitled: "Short program/network/study name commonly referred to by agency" — Unique name to keep track of multiple monitoring program by one agency (for example, statewide ground-water-quality monitoring programs, ambient ground-water-quality network, public water-supply monitoring, and so forth).

Form A, Column entitled: "Useful for Study Unit or National Synthesis (Y/N)?" — Will the program possibly provide VOC data useful to meet either or all of the three following objectives at a Study Unit, regional or national scale? (1) To assess the occurrence, status (for example, comparison to drinking water-quality regulations or advisories), and distribution of VOCs in ground water; (2) to determine causal relations among VOCs in shallow ground water and natural and human factors; or (3) to determine trends in VOCs. If the answer is yes (Y), complete Form B for that program.

Form B, Column entitled: "Arbitrary number" — Use the same arbitrary number that was assigned in Form A (for example, LINJ01).

Form B, Column entitled: "Agency conducting program" — List alphabetically by two-letter postal abbreviation for the State or a county name, and so forth., U.S. first, then agency name (for example, NJ Dept of Health, U.S. EPA, NJ USGS District office, and so forth).

Form B, Column entitled: "Was the selection of wells random or targeted?" — Were wells selected randomly or was the selection targeted to a specific type of well (for example, targeted to only public water-supply wells), or other factors (for example, targeted to only to a particular land-use setting, and so forth)?

Form A. Record of first screen of possible monitoring programs for volatile organic compounds (VOCs) in ground water for ____ Study Unit

[Y=yes, N=no]

| Arbitrary number (example: LINJ01) | Agency contacted (list alphabetically by two-letter postal abbreviation for the State, US government agency, County, and so forth) | Date contact made (for example, 11/25/94) | Person contacted/ phone number | Short program/network/study name commonly referred to by the agency | Useful for Study Unit or National Synthesis (Y/N)? | Explain indication of Y or N in previous column relative to the three objectives. (Fill out Form B if data will be useful) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit

[Y=Yes; N=No; NK=Not Known; QA/QC, quality assurance/quality control; GC/MS, gas chromatography/mass spectrometry; µg/L, micrograms per liter; GIS, geographic information system; PC, personal computer; GWSI, U.S. Geological Survey ground-water site inventory]

| Arbitrary number (example: LINJ01) | State(s) covered by program (use 2-letter postal abbreviation for each State) | Agency conducting program (list alphabetically by 2-letter postal abbreviation for the State, U.S. government agency, and so forth) | Short program/network/study name commonly referred to by the agency | Mailing address |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | Brief statement of the objective(s) of the program, network, or study | List types of analyses available other than VOCs (for example, pesticides, nutrients, major ions, trace elements) | Is there a written description of the network design (Y/N/NK)? If Yes, give reference (author, date) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | What is the areal extent or coverage of the program? (e.g, statewide, countywide, aquifer name) | Give approximate area of coverage, in square miles | Indicate the sampling period for the VOC component of the program, network, or study (for example, 01/1991 to 07/1994) | List the VOC sampling frequency (for example, one-time sampling only, monthly, quarterly, annually) | Was the selection of wells random or targeted? |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | List uses of sites in the network (for example, O=observation, M=mine, and so forth; use GWSI C023 codes) | List uses of water from wells in the network (for example, C=commercial, H=domestic, I=irrigation, N=industrial, P=public, and so forth; use GWSI C024 codes) | Are ground-water sampling protocols documented (Y/N/NK)? If Yes, give reference (author, date) | Were wells installed or were existing wells sampled or both? (I=installed, E=existing, B=both) | For wells with pumps, were samples collected at the well head, before holding tank or treatment (Y/N/MIX)? |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | What types of sampling device was used for wells without existing pumps? (B=bailer, S=suction, PD=positive displacement, DH=downhole sampler; O=Other) | List the number of individual wells sampled | Is there a QA/QC plan for this program (Y/N/NK)? If Yes, give reference (author, date) | List the types of VOC quality-control data collected during sampling. (for example, field blanks, trip blanks, duplicates, field spikes) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | Is there any information on how this field QC data is used during data analysis (Y/N/NK)? If there is a written document, give reference (author, date) | What schedule was used for analyses of VOCs? (for example, EPA 524.2, USGS SH 1380, USGS SH 2090) | If a schedule is used where the method of laboratory analysis is not prescribed, list the method of laboratory analysis. (for example, purge and trap with GC/MS) | List the general reporting level for analytes on the VOC schedule (µg/L) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | Are nontarget VOCs analyzed? (Y/N/NK) | Are samples analyzed by a certified laboratory? (Y/N/NK) | List the type of VOC quality-control data collected during analytical procedures in the laboratory (for example, matrix spikes, surrogates, blanks) | If VOCs are detected in a well, is the well removed from the program? (Y/N/NK) | Do other programs subsequently sample these abandoned wells? (Y/N/NK) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | How are the VOC data stored for this program (for example, paper file, ascii file, PC data base, STORET, NWIS)? | What quality-control checks are used to ensure accurate transcription of the data? | Indicate how accessible VOC data are? Easy (digital), difficult (paper or proprietary), or already on USGS system? | Are there well-location data in the database? If yes, indicate by latitude and longitude (lat/long) or other (O). |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | List the types of network-scale ancillary information that are available which affect ground-water quality (for example, land use, land cover, population, soil type, mean annual precipitation, recharge areas, recharge rates, and so forth) | How are the network-scale ancillary information stored? (for example, maps, GIS coverages, PC database, and so forth) | What types of hydrogeologic or specific well information are available with this program data base? If most are available, indicate limitations. If data are limited, list what is available. (for example, lithology, hydraulic properties, water levels, well depth/diameter/logs, casing size/material, screen type/interval/depth, and so forth) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | What types of hydrogeologic or well data are available from other data bases? Indicate how these other data are stored (for example, GWSI, paper files/reports, State data base) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | List references describing the program (author, date) | List references describing published data. Indicate annual or periodical publication (author, date) | List references describing any interpretative report (author, date) |
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Form B. Summary of monitoring-program information for volatile organic compounds (VOCs) in ground water for ____ Study Unit—Continued

| Arbitrary number (example: LINJ01) | Comment on the suitability of this VOC and accompanying data for assessment of occurrence, status, and distribution of VOCs in ground water, and for describing the relations among VOCs in shallow ground water and natural and human factors. |
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