Methods for Comparing Water-Quality Conditions Among National Water-Quality Assessment Study Units, 1992–1995

By Robert J. Gilliom, David K. Mueller, *and* Lisa H. Nowell

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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

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS AND ABBREVIATIONS AND ACRONYMS

Multiply	By	To obtain
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile

Temperature is given in degrees Celsius (°C) which can be converted to degrees Fahrenheit (°F) by the following equation: $°F = (1.8 \times °C) + 32$

Abbreviations and Acronyms

gal/d, gallon per day
µg/g, microgram per gram
µg/kg, microgram per kilogram
µg/L, microgram per liter
mg/L, milligram per liter
mg/L as N, milligram of nitrogen per liter
pCi/L, picocuries per liter

AET-H, apparent effects threshold-high
AS, aquifer surveys
AVHRR, Advanced Very High Resolution Radiometer
CAS, Chemical Abstracts Service
CCREM, Canadian Council of Resources and Environmental Ministers
DWA, drinking-water aquifer
ER-M, effects range-median
FSV, factor summary value
GCMS, gas chromatography/mass spectroscopy
HA-L, lifetime health advisary
HPLC, high-pressure liquid chromatography
IBI, Index of Biotic Integrity
IJC, International Joint Commission
LUS, land-use studies
MCL, maximum contaminant level
NAWQA, National Water-Quality Assessment
NM, national median
PAH, polycyclic aromatic hydrocarbon
PCBs, polychlorinated biphenyls
PEL, probable effects level
PTD, mean point-to-tree distance for a reach, in meters
RD, relative density of riparian vegetation
RSD, risk specific dose
SGW, shallow ground water
SMCL, secondary maximum contaminant level
SQAL, sediment-quality advisory level
SQC, sediment-quality criterion
SVOC, semivolatile organic compound
USEPA, U.S. Environmental Protection Agency
USGS, U.S. Geological Survey
VOC, volatile organic compound
WQS, water quality score

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Abstract

The National Water-Quality Assessment is based on intensive investigations of stream and ground-water quality in selected major hydrologic basins (study units) of the United States. One objective of the national assessment is to comparatively evaluate water-quality conditions within and among the different study units. Methods were developed to compare the water-quality conditions of 20 study units that were studied during 1992–1995. Two approaches were taken: (1) water-quality conditions for each study unit were ranked in relation to the findings for all study units, and (2) water-quality conditions for each study unit were compared to established criteria for the protection of human health and aquatic life.

Separate rankings were developed for several major characteristics of water quality by using selected combinations of measured values for individual constituents or properties. The water-quality characteristics that were evaluated for streams were nutrients and pesticides in water, organochlorine pesticides and polychlorinated biphenyls in bed sediment and tissue, semivolatile organic compounds and trace elements in bed sediment, fish community degradation, and stream habitat degradation. The water-quality characteristics that were evaluated for ground water were nitrate, pesticides, volatile organic compounds, dissolved solids, and radon. The water-quality rankings are relative strictly to the distribution of conditions measured at sampling sites included in developing the method. Sites in the first 20 National Water-Quality Assessment study units include a broad range of environmental settings, but are not a statistically representative sample of the Nation. To supplement the relative rankings, established water-quality criteria were used to indicate where particular constituents may have adverse effects, and thus merit further investigation. Established water-quality criteria, which provide consistent benchmarks for national comparisons of individual constituents, were selected from a variety of sources and applied to specific constituents in the specific medium (water or sediment) appropriate for each criterion.

INTRODUCTION

The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) is designed to assess the status of, and trends in, the quality of the Nation's surface- and ground-water resources, and to link the status and trends with an understanding of the natural and human factors that affect the quality of water (Hirsch and others, 1988; Leahy and others, 1990; Gilliom and others, 1995). The study design balances the unique assessment requirements of individual hydrologic systems with a nationally consistent design structure that incorporates a multiscale, interdisciplinary approach. The building blocks of the national assessment are investigations in major hydrologic basins of the Nation, designated as study units. The goal for the first phase of investigation in each study unit is to characterize, in a nationally consistent manner, the broad-scale geographic and seasonal distributions of water-quality conditions in relation to major contaminant sources and background conditions.

The NAWQA study units cover about 40 percent of the conterminous United States, encompass 60 to 70 percent of both national water use and the population served by public water supplies, and include diverse hydrologic systems that differ widely in the natural and human factors that affect water quality. The study units are divided into three groups, which are studied on a rotational schedule of 3-year periods of intensive data collection. About one-third of the study units are in the intensive data collection phase at any given time, and the 9-year cycle is designed to be repeated perennially. The first complete cycle of intensive data collection in the study units began during 1992 and 1993 and is scheduled to be completed in 2002.

The national assessment goals of NAWQA are being accomplished in two main ways. First, the accumulation of consistent and comparable water-quality assessments for the most significant hydrologic systems of the Nation will stand alone as a major contribution to our knowledge of regional and national water-quality conditions. Second, the NAWQA national synthesis builds on and expands the findings from individual study units by combining and interpreting results from multiple study units together with historical information reported by the USGS and other agencies and researchers. National synthesis analyses produce regional and national assessments for priority water-quality issues.

One component of the NAWQA strategy for analyzing and reporting findings is to produce summary reports on water-quality conditions in each study unit at the end of each intensive study cycle. The first cycle of intensive data collection for the first 20 NAWQA study units occurred during 1992–1995. In concert with the national assessment goals, the summary reports highlight findings specific to each study unit in a consistent format. In particular, each study-unit summary report includes standardized analyses of how water-quality conditions in the particular study unit compare with those in other study units and with established criteria for the protection of human health and aquatic life.

Purpose and Scope

The purpose of this report is to describe methods used to compare water-quality conditions for streams and ground water among the 20 NAWQA study units that were studied during 1992–1995 (fig. 1). The results support consistent comparisons among study units and can be used to identify and prioritize water-quality issues for further investigation.

Acknowledgments

Many people in the NAWQA Program contributed to the information in this report. We would like to thank Jack E. Barbash, Daniel P. Bauer, Edward Callender, Kevin F. Dennehy, Lawrence R. DeWeese, O. Lehn Franke, Elisabeth A. Graffy, Martin E. Gurtz, Dana W. Kolpin, Steven J. Larson, Thomas J. Lopes, Walton H. Low, Michael R. Meador, Naomi Nakagaki, Bernard T. Nolan, Patrick J. Phillips, Curtis V. Price, Karen C. Rice, Barbara C. Ruddy, Sarah J. Ryker, Jonathon C. Scott, Terry M. Short, Timothy B. Spruill, Paul J. Squillace, Cathy M. Tate, William G. Wilber, Alex K. (Sandy) Williamson, David M. Wolock, and John S. Zogorski.

We would also like to thank Jurate M. Landwehr and Ivan C. James II, of the U.S. Geological Survey, Water Resources Division, for their substantial contributions as technical reviewers.

OVERVIEW OF APPROACH

Comparisons of water-quality conditions among NAWQA study units were made by two different approaches: (1) relative ranking of major water-quality characteristics, and (2) evaluation of individual constituents in relation to established water-quality criteria. The relative ranking system was developed solely with data collected from the study units evaluated. The relative ranking system has the advantage of providing a simplified and highly aggregated evaluation of major water-quality characteristics in relation to other areas studied, but has the disadvantages of being entirely relative to the development data, of not being directly related to an absolute scale of high and low water quality, and of not retaining the identity of individual constituents. The evaluation of individual constituents in relation to established water-quality criteria has the advantage of yielding constituent-specific comparisons to fixed thresholds chosen to define the terms high and low, but has the disadvantages that criteria are not available for many constituents, derivations of criteria are inconsistent and not always comparable, and some potential influences on water quality, such as the effects of mixtures, are not considered. Together, the relative rankings and criteria comparisons provide a complementary assessment of water-quality conditions.

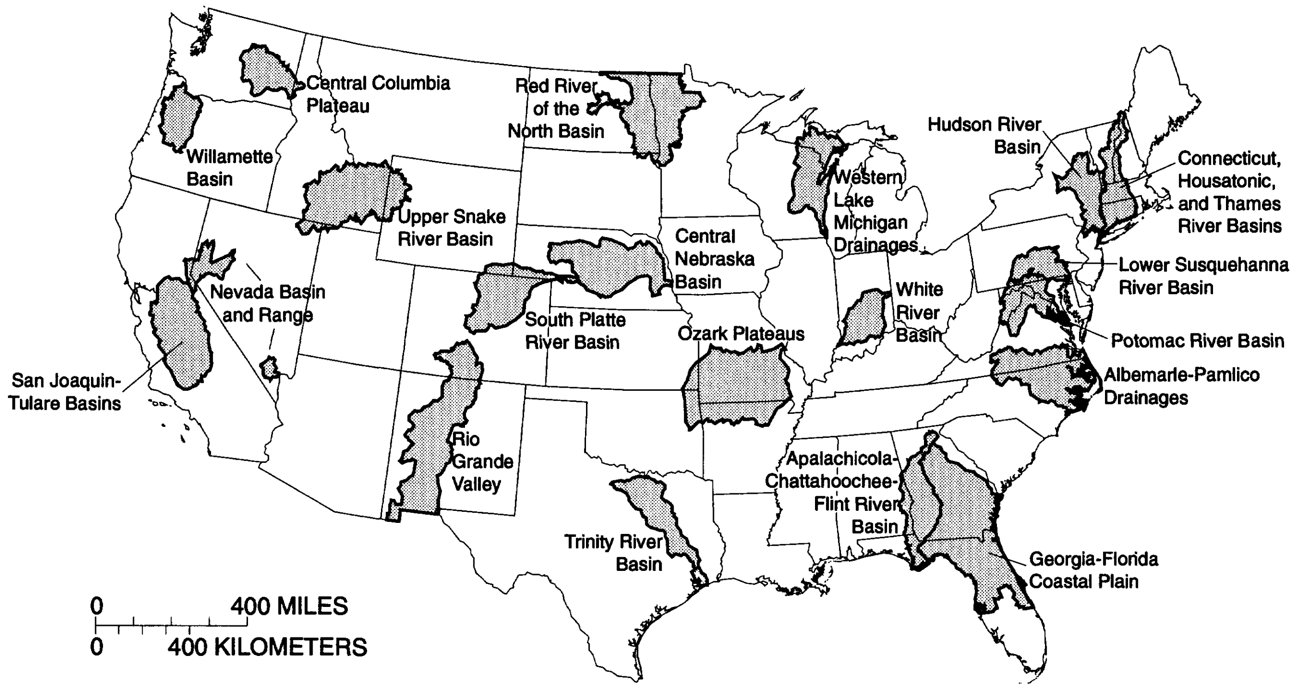


Figure 1. Locations and names of the first 20 National Water-Quality Assessment study units.

NAWQA Design

Interpretation of results from a relative ranking of water-quality conditions is highly dependent on the nature of the areas and hydrologic systems included in the analysis and how they were sampled. Although it was not the intent of this study to fully characterize how conditions in the first 20 NAWQA study units relate to those in the rest of the Nation, it is useful to compare some general characteristics to gain a perspective on this relationship.

Study-Unit Characteristics

The first 20 NAWQA study units were selected to establish a balance of many factors, including population and water use, importance of water-quality issues, and geographic distribution. Examination of cultural and environmental characteristics of study units in relation to the rest of the Nation provides a perspective on the relevance of water-quality findings in the study units to other parts of the Nation. Table 1 shows that, relative to their area of 16 percent of the conterminous United States, the first 20 NAWQA study units contain a proportionally high share of the Nation's population (20 percent) and water use (22 percent), which is also consistent with the greater significance of agricultural and urban land use in study units compared with the rest of the Nation. In general, the 20 study units are widespread throughout the United States and include a broad diversity of environmental settings, but the study units are biased toward areas where the population, water use, and agricultural and urban land uses are greater-than-average.

Sampling Design

Relative rankings of water-quality characteristics for NAWQA study units, and comparisons of constituent concentrations to water-quality criteria were based on data from a consistent sampling design to support equitable comparisons among study units. The analyses described in this report focus on results from the most standardized components of the NAWQA study design. The complete design of these components, including site selection, sampling strategy, and analytical strategy, is described in Gilliom and others (1995), and only a brief outline is provided here.

Table 1. Characteristics of the first 20 National Water-Quality Assessment study units compared with the entire conterminous United States

[NAWQA, National Water-Quality Assessment; km^2, square kilometer; gal/d, gallon per day]

Characteristic	Conterminous United States	NAWQA study units	Proportion in NAWQA study units (percentage of United States)
Land area (km^2)	7,852,154	1,288,960	16
Water use (billion gal/d)	344	75	22
Population (millions of people)	246	50	20
Land Use (percentage of area):			
Urban	1.5	2.0	22
Agriculture	31	38	20
Range	30	17	9
Forest	33	41	20

Streams

The national study design for surface water focuses on water-quality conditions in rivers and streams (hereinafter referred to only as streams) using the following interrelated components:

- Water-column studies assess physical and chemical characteristics, which include suspended sediment, major ions and metals, nutrients, organic carbon, and dissolved pesticides.
- Bed sediment and tissue studies assess trace elements and organic contaminants that are hydrophobic (tend to associate with particles and accumulate in biological tissues rather than be dissolved in water).
- Ecological studies evaluate characteristics of biological communities and physical habitat in streams.

Sampling designs for all three components rely on coordinated sampling of varying intensity and scope at integrator sites, which are chosen to represent water-quality conditions of streams with large basins often affected by complex combinations of land-use settings, and at indicator sites, which are chosen to represent water-quality conditions of streams associated with specific environmental settings. The most complete data collection for the three components is at a selected core of three to five integrator sites and four to eight indicator sites in each study unit, which constitute the fixed-site monitoring network for regular collection of samples over time. A subset of two to five sites in each study unit, usually one integrator site and two to four indicator sites, is sampled more intensively than the rest, and these are the only sites where pesticides in water are routinely measured. All 226 stream sampling sites used to compare water quality among study units, and included in this report, are part of the fixed-site monitoring network of one of the first 20 study units. A listing of all sites and their characteristics is shown in appendix A, and the distribution of sites among study units is shown in table 2.

The 226 stream sampling sites in the first 20 study units include a wide range of stream sizes, types, and land-use settings in major regions of the Nation, but the sites were not selected to be a statistically representative sample of the Nation's streams. The water-quality rankings developed for these sites are relative strictly to the distribution of water-quality conditions found at the sites that are included in the analysis of each characteristic. Data requirements for analysis of each water-quality characteristic further restrict the number of stream sites that are included for a particular characteristic. Thus, the results for each characteristic are relative only to the subset of sites for which there are adequate data. Stream sites included in the analysis of each water-quality characteristic are indicated in appendix A. Most water-quality characteristics for streams were evaluated using data from the majority of sites in the fixed site network. Only pesticides in water were evaluated for a much smaller subset.

Figures 2 and 3 show the distribution of land-use characteristics for NAWQA stream sites compared with all basins of a similar size in the conterminous United States. The basin-size categories represent the ranges of the smallest 50 percent (fig. 2) and largest 50 percent (fig. 3) of the 226 NAWQA sites. Land use was determined from a classification of land cover derived from spectral information collected in 1990 by Advanced Very High Resolution Radiometer

Table 2. Distribution of stream sites and ground-water study areas among National Water-Quality Assessment study units

Study Unit	Streams (number of sites)		Ground Water (number of studies)	
	All sites	Pesticide sites	Drinking-water aquifers	Shallow ground water
Albemarle-Pamlico Drainage	12	4	4	2
Apalachicola-Chattahoochee-Flint Basin	9	3	2	5
Central Columbia Plateau	14	4	4	4
Central Nebraska Basins	9	4	1	1
Connecticut, Housatonic, and Thames River Basins	12	1	1	3
Georgia–Florida Coastal Plain	9	4	0	3
Hudson River Basin	14	3	2	2
Lower Susquehanna River Basin	7	3	6	6
Nevada Basin and Range	10	1	3	4
Ozark Plateaus	14	2	9	8
Potomac River Basin	11	4	4	4
Red River of the North Basin	15	5	6	2
Rio Grande Valley	17	2	1	3
San Joaquin–Tulare Basins	10	4	4	3
South Platte River Basin	12	2	1	2
Trinity River Basin	10	3	3	1
Upper Snake River Basin	12	2	7	4
Western Lake Michigan Drainages	11	3	1	2
White River Basin	11	4	2	4
Willamette Basin	7	4	1	3

(AVHRR) on National Oceanic and Atmospheric Administration earth-orbiting satellites (U.S. Geological Survey, 1993). The AVHRR data were used to identify over 150 land-cover classes, which were grouped into eight land-use categories: agriculture, range, forest, water, wetland, barren, tundra, and snow. Urban land use was identified from the 1990 population data as land areas with population density greater than 386 people per square kilometer. The amounts of each land use in each basin were determined by overlaying basin boundaries on a 1-km resolution grid of land use. The drainage basin boundaries for each size category in the conterminous United States were determined by using automatic basin delineation tools and a 1-km resolution digital elevation model of the conterminous United States.

NAWQA sites with relatively small drainage basins (17–1,243 km^2), have a greater prevalence of basins with large proportions of agricultural and urban land compared with all similarly sized basins in the United States, particularly the subset of pesticide sites (fig. 2). NAWQA sites with large basins (1,244–221,497 km^2), which are mainly integrator sites, also have a greater prevalence of agricultural land compared with similarly sized basins in the United States (fig. 3), although the pattern is less clear than for the smaller basins. This bias toward agricultural and urban land use is the expected consequence of the NAWQA design.

Ground Water

The national study design for ground water focuses on water-quality conditions in major aquifers and in recently recharged shallow ground water associated with current and recent land uses:

- Aquifer surveys assess the quality of water in the major aquifer systems of each study unit. Aquifer surveys are referred to as "study-unit surveys" in Gilliom and others (1995) and in some study-unit reports as "subunit surveys."
- Land-use studies assess the quality of recently recharged shallow ground water associated with specific combinations of land uses and hydrogeologic conditions.

Generally, each aquifer survey and land-use study consists of sampling about 30 randomly selected sites (wells or springs) within the geographic area and aquifer zone targeted for the specific study. One sample was collected from most of the sites. For the first 20 study units, results from 36 aquifer surveys

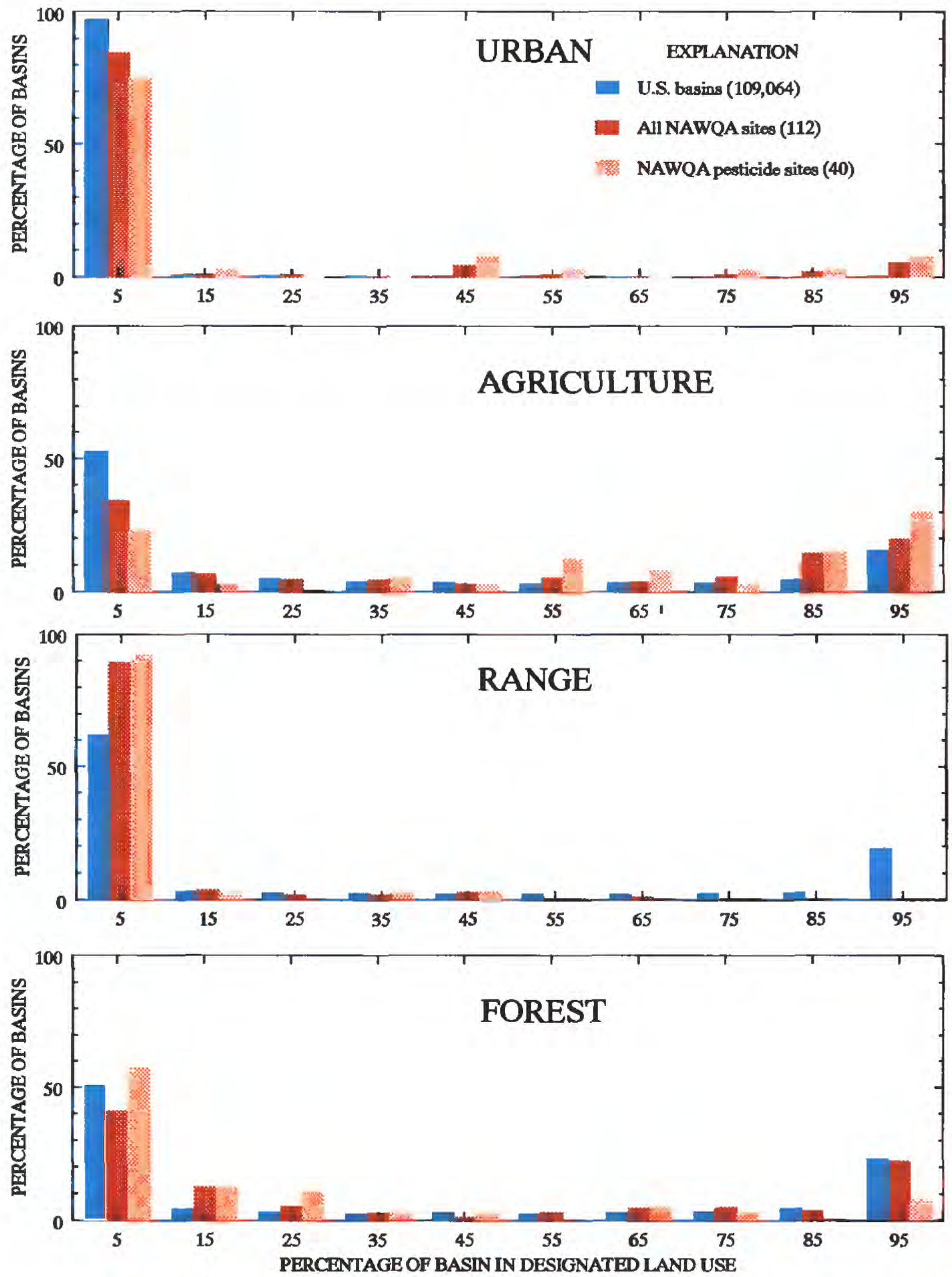


Figure 2. Land-use characteristics of National Water-Quality Assessment stream-site basins compared with all basins in the conterminous United States for small basins (17 to 1,243 square kilometers). Numbers in parentheses indicate number of basins in each group.

and 56 land-use studies were used to compare water-quality conditions among study units.

All ground-water study areas and their characteristics are listed in appendix B. The 36 aquifer surveys have mixed land-use influences. Of the 56 land-use studies, 41 targeted agricultural settings, 14 targeted urban settings, and 1 targeted a forested setting. Most water-quality characteristics were evaluated for all ground-water studies. Although suitable geographic delineation of aquifer boundaries throughout the United States is not available to enable comparison of NAWQA ground-water study areas to ground-water resources of the entire United States (as it was for stream drainage basins), the focus of the NAWQA ground-water design on agricultural and urban settings is similar to surface water.

For evaluating water-quality characteristics and comparing constituent concentrations to established water-quality criteria, aquifer surveys and land-use studies were reclassified according to two categories of ground-water resources:

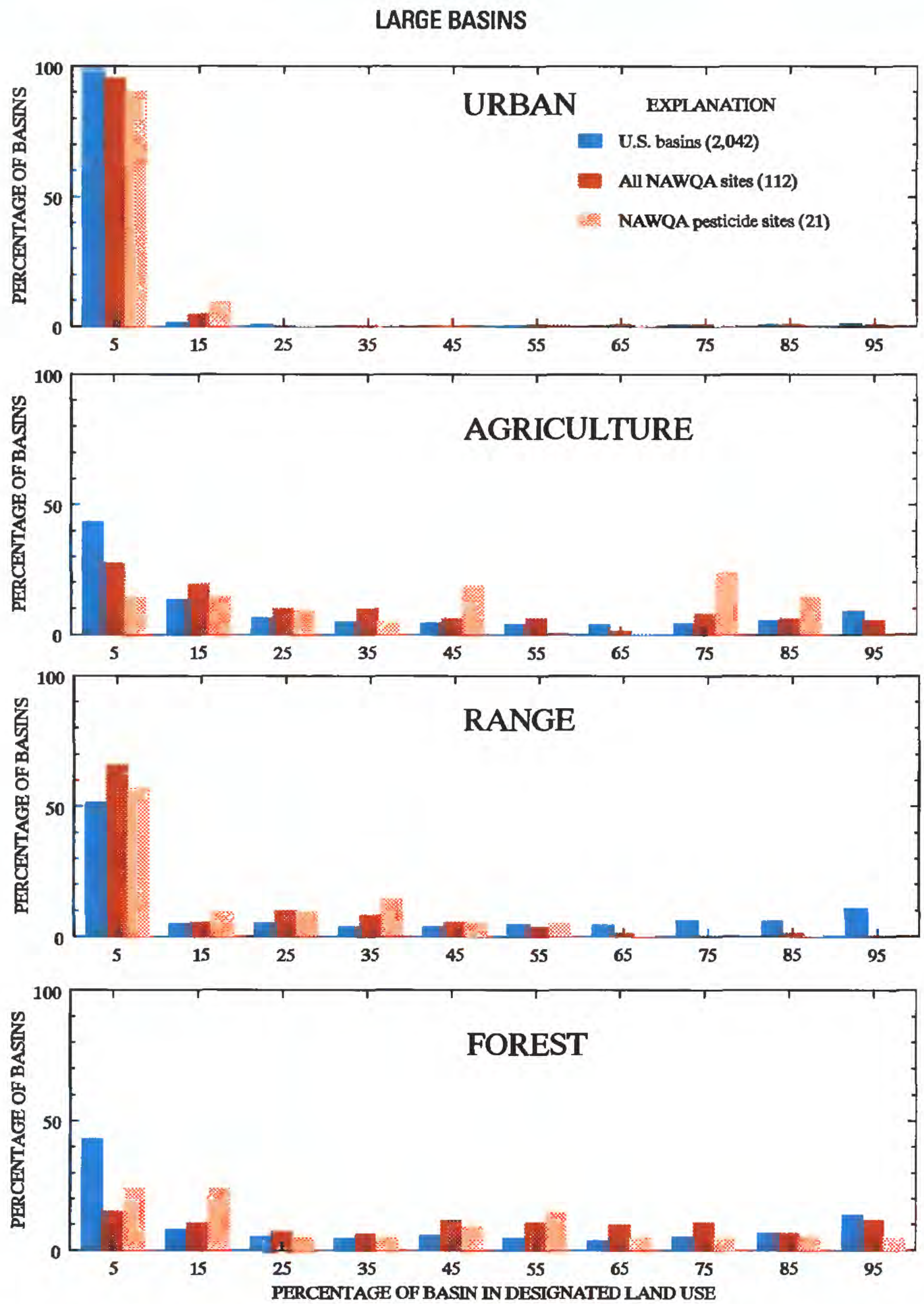


Figure 3. Land-use characteristics of National Weter-Quality Assessment stream-site besins compared with all basins in the conterminous United States for large basins (1,244 to 221,497 square kilometers). Numbers in parentheses indicate number of basins in each group.

1. Drinking-water aquifers (DWA), which are currently used as sources of drinking water (though wells sampled by NAWQA were not necessarily drinking-water supply wells).
2. Shallow ground water (SGW), which is recently recharged ground water that may or may not be currently used as a source of drinking water.

Classification of NAWQA ground-water study areas as DWAs or SGW was determined as follows:

- All land-use studies, which were specifically designed to study shallow ground water underlying particular land uses, were classified as SGW studies.
- Selected land-use studies also were classified as DWA studies if the sampled wells tap water in an aquifer currently used for drinking-water supply.
- All aquifer surveys, except for one, were classified as DWA studies. The lone

exception, which is in the Georgia–Florida coastal plain, targets a shallow aquifer that is not presently used for drinking water and, therefore, was classified solely as a SGW study.
- Selected aquifer surveys also were classified as SGW studies if the wells sampled showed evidence of being influenced by recent recharge and were of generally comparable depth to land-use study wells in the same area.

Classification and characteristics of 92 ground-water study areas in the first 20 NAWQA study units are listed in the appendix B. A total of 62 study areas were classified as DWAs and 66 study areas were classified as SGW, with 36 in both categories. The distribution of ground-water studies among study units is shown in table 2.

Relative Ranking of Water-Quality Conditions

Methods for ranking water-quality conditions in a consistent and comparable manner among all study units were developed for each of several major characteristics of water quality by using selected combinations of measured values for individual constituents or properties that relate to the particular characteristic. For each water-quality characteristic, the measured constituents or properties that represent the particular characteristic were chosen and, if necessary, grouped into a few major factors that define the characteristic. The purpose of grouping is to simplify the data and reduce computational problems with nondetections and high variability, while also producing a balanced assessment of each water-quality characteristic. For example, the constituents used to define pesticides in streams are grouped into two factors, herbicides and insecticides. For some characteristics, such as nutrients in streams, each factor consists of only a single constituent. A few characteristics, such as nitrate in ground water, are represented by only a single factor determined by a single constituent. Water-quality characteristics and the factors included in each are summarized in table 3.

For a particular stream site or ground-water study area, the water-quality score was computed for each characteristic according to:

$$WQS_i = \frac{\sum_{f=1}^{n_i} \frac{FSV_f}{NM_f}}{n_i} \qquad (1)$$

where

WQS_i = the water-quality score for characteristic i

n_i = the number of factors f in characteristic i

FSV_f = the factor summary value for factor f

NM_f = the NAWQA median of FSV_f for all stream sites or ground-water study areas.

Although scores for all water-quality characteristics were computed by equation 1, the method of determining the FSV_f for different water-quality characteristics varied, depending on the constituents involved and the sampling design. The general procedure for determining FSV_f and for applying equation 1 is summarized below, but variations and details are explained later in separate discussions of each characteristic.

1. The value of each factor was determined for each individual sample collected at a site. For factors that include several constituents, this evaluation is commonly a sum of concentrations or a percentage of detections.
2. A factor summary value (FSV_f) for a site (such as an annual median or other percentile) was computed for each factor from the factor values for all samples collected at each stream site or ground-water study area. Factor summary values were computed somewhat differently for different characteristics. For example, the annual 75th percentile was calculated as the factor summary value for herbicides and insecticides at stream sites because of the strong seasonality of pesticide concentrations, whereas the annual median was used for nutrients.
3. The NAWQA median (NM_f) was determined from factor summary values for all NAWQA stream sites or ground-water study areas. Median values for each factor are reported with varying significant figures, depending on laboratory reporting practices and whether or not the value was interpolated.
4. The factor summary values for each site or study area were standardized by dividing FSV_f for each site by the corresponding value of NM_f, thus expressing the score for the factor as a multiple of the NAWQA median.

Table 3. Water-quality characteristics and associated factors

[PCBs, polychlorinated biphenyls; VOC, volatile organic compound]

Water-quality characteristic	Number of factors	Factors that define the characteristics
Streams:		
Nutrients in water	3	Concentrations of ammonia, nitrite plus nitrate, and total phosphorus
Pesticides in water	2	Total concentrations of insecticides and herbicides
Organochlorine pesticides and PCBs in bed sediment and tissue	3	Total concentrations in bed sediment, fish tissue, and freshwater clams
Semivolatile organic compounds in bed sediment	3	Total concentrations of polycyclic aromatic hydrocarbons, phenols, and phthalates
Trace elements in bed sediment	9	Total concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc
Fish community degradation	4	Percentages of tolerant species, omnivorous species, nonnative species, and external anomalies
Stream habitat degradation	4	Stream modification, bank erosion, bank vegetative stability, and riparian vegetation density
Ground Water:		
Nitrate	1	Concentration of nitrite plus nitrate
Pesticides	1	Frequency of detection of any pesticide
VOC	1	Frequency of detection of any VOC
Dissolved solids	1	Concentration of dissolved solids
Radon	1	Concentration of radon 222

5. The standardized factor scores were summed for each site (streams) or study area (ground water) and divided by the number of factors to derive the final water-quality score (WQS_i) for the particular water-quality characteristic i.

For each NAWQA stream site and ground-water study area, the water-quality scores for each characteristic were categorized by the national quartiles of the scores for the particular characteristic. A rank of 1 (lowest scores, "best" water quality) through 4 (highest scores, "worst" water quality) was assigned to each site or study area, for each water-quality characteristic, on the basis of the quartile in which the site or area score occurred. In the study-unit summary reports, final ranks are displayed on separate maps for each water-quality characteristic with site-location symbols color coded according to rank.

Comparison of NAWQA Results to Water-Quality Criteria

In addition to evaluating general characteristics of water quality by relative comparisons, established water-quality criteria were used as fixed benchmarks for evaluation of NAWQA results and to indicate where particular constituents might cause adverse effects, thus meriting further investigation. The term "water-quality criteria," as used in this report, refers to commonly used standards or guidelines established by national or international agencies or organizations in North America that have regulatory responsibilities or expertise in water quality. Thus, the term is used in a general sense in this report and does not necessarily refer to U.S. Environmental Protection Agency (USEPA) water-quality criteria for protection of human health and aquatic organisms.

Water-quality criteria are established for specific constituents, such as nitrate or a particular pesticide, and in a specific medium, such as water or sediment. Furthermore, water-quality criteria may be divided into two general categories: those for protection of human health and those for protection of aquatic life. For summarizing study-unit results in a nationally comparable manner, aquatic-life criteria were applied to concentrations of constituents measured in the water and bed sediment of streams, and human-health criteria were applied to concentrations of constituents measured in drinking water aquifers.

There is no single source of established and consistently derived criteria for all constituents. Moreover, different types of criteria may have different sampling and analytical requirements. In many instances, the characteristics of water-quality data collected for NAWQA studies, such as sampling frequency or analytical strategy, do not exactly match the requirements of a particular type of water-quality criteria. Although these can be crucial issues in regard to regulatory monitoring and enforcement, water-quality criteria are used in this study only as indicators of potential problems. The established criteria provide consistent benchmarks, with which most water-quality managers are already familiar, for national comparison of individual constituents.

In the study-unit summary reports, NAWQA results are compared to water-quality criteria in two ways. First, on maps for each water-quality characteristic, sites are highlighted if any individual criterion was exceeded for any constituent included in the particular characteristic. Second, in a tabular summary, the distributions of all measured concentrations of each constituent in the study unit are shown in relation to corresponding criteria values and to the national range of concentrations measured in all 20 study units.

RELATIVE RANKING OF STREAM WATER QUALITY

The water-quality characteristics that were evaluated for streams are nutrients in water, pesticides in water, organochlorine pesticides and polychlorinated biphenyls (PCBs) in bed sediment and tissue, semivolatile organic compounds (SVOC) in bed sediment, trace elements in bed sediment, fish community degradation, and stream habitat degradation (table 3). The methods for ranking each water-quality characteristic are described below, preceded by general characteristics and methods for each type of media evaluated.

Water

Data for concentrations of constituents in stream water consist of multiple measurements over a period of 1 to 3 years during 1993–1995 at each sampling site in the fixed-site monitoring network. For each particular site, data are available from several different types of sample collection strategies that were designed for different purposes. The primary types of samples are listed below.

- Fixed frequency—collected on a predetermined time schedule without regard to flow conditions or other significant biases. The frequency varies among sites and seasons, from as frequent as twice weekly, to as sparse as bimonthly or quarterly when expected variability is low.
- High flow—individual samples collected during selected high-flow conditions within a particular season to supplement fixed-frequency samples.
- Low flow—individual samples collected during selected extreme low-flow conditions within a particular season to supplement fixed-frequency samples.
- Storm hydrograph (not used in the analysis described here)—multiple samples collected during an individual storm runoff period, usually several samples within 1 to 3 days.

Data used for evaluating nutrient and pesticide water-quality characteristics were restricted to fixed-frequency, high-flow, and low-flow samples to make the analysis as consistent as possible among sites and to avoid biases caused by extensive and extreme storm hydrograph data for some periods at some sites. Most of the data used are from fixed-frequency samples. For nutrients, there are 2 to 3 years of data at about a monthly sampling frequency for most sites. For pesticides, there are commonly 1 to 2 years of data at a minimum monthly sampling frequency, supplemented by more frequent sampling during 3- to 6-month seasonal periods. Pesticide data are available only for a subset of two to five intensive sampling sites in each study unit.

Concentration values for evaluating water-quality characteristics were simplified by determining the monthly median concentration for each month within the period of record analyzed. This approach gives equal weight to each month with data, regardless of the amount of data. Thus, for months with one sample, the median is the value for that sample, for months with two samples, the median is the mean of the two values, and so forth, using the standard method for determining medians. Concentrations for nondetections were set to zero prior to computing medians. Reduction of data to monthly medians decreases the influence of extreme events and uneven sampling frequency.

Nutrients in Stream Water

Comparison of nutrients among NAWQA stream sites was based on three factors: ammonia, nitrite plus nitrate, and total phosphorus concentrations in water (appendix C). The period of record was restricted to a 2-year period (April 1993 to March 1995), and the analysis was limited to sites that had samples in at least 12 months during that period. Of the 226 NAWQA fixed sites, 219 met these data requirements (see appendix A). The relative regularity and completeness of the data sets for nutrients justified inclusion of all months with available data during the defined 2-year period.

For each site included in the analysis, monthly median values were determined from the measured concentrations for each of the three factors:

$$MC_{f,m} = med\{C_{f,1} \ldots C_{f,n_{sm}}\} \qquad (2)$$

where

$MC_{f,m}$ = the median concentration of factor f in month m

$C_{f,1} \ldots C_{f,n_{sm}}$ = the measured concentrations of factor f in samples 1 through n_{sm}

n_{sm} = number of samples in month m.

In most months, only one sample was collected, and $MC_{f,m}$ is merely the single measured concentration.

The factor summary value for each factor was determined for each site as the median of all monthly median concentrations:

$$FSV_f = med\{MC_{f,1} \ldots MC_{f,n_m}\} \qquad (3)$$

where n_m is the number of months with data. The national median for each nutrient factor was determined from the factor summary values at the 219 sites:

- Ammonia: 0.035 mg/L
- Nitrite plus nitrate: 0.58 mg/L
- Total phosphorus: 0.060 mg/L

The nutrient score for each site was calculated by equation 1 as the average of standardized factor values (ratio of FSV_f to NM_f). Nutrient scores for all sites were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 4.

Table 4. Water-quality scores and ranks for nutrients in stream water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.62
2	>25 – 50	>0.62 – 1.32
3	>50 – 75	>1.32 – 2.58
4 (worst)	>75	>2.58

Pesticides in Stream Water

Comparison of pesticides among NAWQA stream sites was based on two factors: total herbicide concentration and total insecticide concentration (including selected degradation products). Pesticides included in these totals are listed in appendix D. Samples selected for this computation were required to include pesticide analysis by gas chromatography/mass spectroscopy, which accounted for most detections.

For each sample, concentrations of all detected herbicides and all detected insecticides were summed separately to yield total concentrations for each of these factors. Similar to nutrients, medians for each factor in each month were computed from the resulting values:

$$MC_{f,m} = med\left\{\sum_{p=1}^{n_p} C_{p,1} \ldots \sum_{p=1}^{n_p} C_{p,n_{sm}}\right\}_f \qquad (4)$$

where

$MC_{f,m}$ = the median concentration of factor f in month m

$C_{p,1} \ldots C_{p,n_{sm}}$ = the detected concentrations of pesticide p in samples 1 through n_{sm}

n_p = number of herbicides or insecticides detected in each sample 1 through n_{sm}.

Monthly medians for each site were grouped into 1-year periods, usually starting with the onset of sampling at the particular site (most commonly March or April of 1993 or 1994). For a site to be included in the national analysis, it had to have at least 1 year with more than six monthly medians and a reasonable probability that no missing months would affect the 75th percentile for the year. Several sites that met these criteria were excluded because there were other similar sites in the same study unit, which could introduce undo bias into the national analysis. Of the 226

NAWQA stream sites, 61 were selected (see appendix A), 56 of which have 9 or more months of data in at least 1 year, and 5 of which have 7 or 8 months of data in at least 1 year.

For all sites, annual 75th-percentile concentrations were determined from the monthly medians of both factors (total herbicides and total insecticides) for the first year of data:

$$AC_{f,1} = prob_{0.75}\{MC_{f,1}...MC_{f,n_m}\} \quad (5)$$

where

$AC_{f,1}$ = the 75th-percentile concentration of factor f in year 1

n_m = the number of months with data.

Each of the 61 sites was then evaluated to determine if there were second or third years with enough data to compute valid 75th percentiles. Subsequent years were retained in the national analysis if the year included at least 4 months of data and had one of the following characteristics:

1. Data for as many months as the first year and covered the same portion of the year.
2. Data for fewer months than the first year, but the 75th percentile was higher than the first year.
3. Data for fewer months than the first year and a lower 75th percentile, but the months available included all or the most important months for determining the 75th percentile (on the basis of the first year and nearby sites).

Decisions on including or excluding additional years of data were made independently for herbicides and insecticides because their seasonal timing frequently differs.

The factor summary values for herbicides and insecticides were determined for each site as the median of annual values for years 1 through n_y:

$$FSV_f = med\{AC_{f,1}...AC_{f,n_y}\} \quad (6)$$

The national median for each pesticide factor was determined from the factor summary values at the 61 sites:

- Total herbicides: 0.297 µg/L
- Total insecticides: 0.012 µg/L

The pesticide score for each site was calculated by equation 1 as the average of standardized factor summary values (ratio of FSV_f to NM_f). Pesticide scores for all sites were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 5.

Table 5. Water-quality scores and ranks for pesticides in stream water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.43
2	>25 – 50	>0.43 – 1.75
3	>50 – 75	>1.75 – 6.69
4 (worst)	>75	>6.69

Bed Sediment and Tissues

Most data for bed sediment and tissues of aquatic organisms consist of one sample from one or more media (sediment, fish, or clam) for each site. Most sites had data for sediment and either fish or Asiatic clams (genus *Corbicula*) collected at approximately the same time. If multiple samples of a given medium (sediment, fish, or clam) were collected at a site, the median total concentration of constituents in that medium was used for that site. The site median for each medium was determined by equation 7. Samples were grouped by year of sampling, the median concentration was determined for each year, and the site median is the median of the available annual medians:

$$FSV_f = med[med\{TC_{f,1}...TC_{f,n_{sy}}\}_1 \quad (7)$$
$$...med\{TC_{f,1}...TC_{f,n_{sy}}\}_{n_y}]$$

where

$TC_{f,s}$ = the total concentration for factor f in sample s

n_y = the number of years with data

n_{sy} = the number of samples in a year.

Organochlorine Pesticides and PCBs in Bed Sediment and Tissue

Comparison of organochlorine pesticides and PCBs in stream bed sediment and biological tissue among NAWQA stream sites was based on three factors: total concentration in bed sediment, total concentration in fish tissue, and total concentration in clam tissue. One, two, or all three of these media might have been analyzed at a particular site. Compounds included in this analysis are listed in appendix E. Samples of a medium with missing data for any one of the most commonly detected analytes (total DDT, total chlordane, dieldrin, or total PCBs) were excluded because sums for these samples might be biased low. Total DDT was considered missing if concentrations of any of the *p,p'*-isomers of DDT, DDD, and DDE (typically the most abundant components of this mixture) were missing. Total chlordane was considered missing if concentrations for any one of its components (*cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane) were missing. Of the 226 stream sites in the NAWQA fixed-site monitoring network, 202 had adequate samples from at least one sediment or tissue medium (see appendix A).

For each sample of each medium, the total concentration of organochlorine pesticides and PCBs was calculated by summing the concentrations of all detected compounds. The total concentration in fish tissue was normalized by dividing by lipid content. This normalization decreases the bias that might result from comparing different species in the fish-tissue data set, and is reasonable because of the significant correlation between total concentration and fish lipid content (Spearman rho=0.31, p=0.0003). The clam-tissue data also were normalized to be consistent with the fish data. The correlation between total concentration and lipid content in clam tissue is about the same as in fish tissue (Spearman rho=0.38, p=0.039), although the sample size is much smaller.

The factor summary value for each available medium was computed for all sites by equation 7. National comparison values were determined for total organochlorine pesticides and PCBs in each medium at the 202 sites. For fish tissue, the comparison value was determined as the median of the factor values for all sites that had adequate data. Exact medians could not be determined for bed sediment and clam tissue, however, because more than 50 percent of the samples had no detections. The lowest detected concentration for each medium was used in place of the median for these factors, but the values used are not far removed from the 50th percentile (median). The national comparison concentrations of organochlorine pesticides and PCBs are:

- Bed sediment: 0.7 mg/kg total sediment (56th percentile)
- Fish tissue: 2,780 mg/kg lipid (median)
- Clam tissue: 218 mg/kg lipid (59th percentile)

The score for organochlorine pesticides and PCBs for each site was calculated by equation 1 as the average of the standardized factor summary values (ratio of FSV_f to NM_f or the alternate comparison value). If samples from all media were not available from a site, *WQS* was computed from as many media as possible. Individual site scores were categorized according to ranks 1 to 4 on the basis of percentiles of the national distribution of NAWQA site scores. Scores were zero for 32 percent of the sites. All of these sites were included in the lowest category, and only 18 percent of the sites were included in the second category. Categories are summarized in table 6.

Table 6. Water-quality scores and ranks for organochlorine pesticides and PCBs in bed sediment and tissue

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤32	0.00
2	>32 – 50	>0.00 – 0.63
3	>50 – 75	>0.63 – 9.67
4 (worst)	>75	>9.67

Semivolatile Organic Compounds in Bed Sediment

Comparison of SVOCs in bed sediment among NAWQA sampling sites was based on three factors: total polycyclic aromatic hydrocarbons (PAH), total phenols, and total phthalates. Compounds included in the analysis of each factor are listed in appendix F. Several analytes were corrected for laboratory contamination by subtracting the 95th percentile concentration in laboratory blanks from the measured concentration in each environmental sample. The corrections applied to these analytes were:

- *bis*(2-Ethylhexyl) phthalate: 100 µg/kg
- Di-*n*-butyl phthalate: 54 µg/kg
- Butylbenzyl phthalate: 64 µg/kg
- Phenol: 27 µg/kg
- Diethyl phthalate: 25 µg/kg

Of the 226 NAWQA fixed sites, 198 have sufficient data for SVOC comparison (see appendix A).

The factor summary value for each site was computed by equation 7, after summing the detected concentrations of compounds in each factor group in the sample from that site. The national median for each SVOC factor was determined from the factor summary values at these sites. The national median concentrations of SVOCs in bed sediment are:

- PAHs: 104 µg/kg
- Phenols: 73 µg/kg
- Phthalates: 20 µg/kg

The SVOC score for each site was calculated by equation 1 as the average of the standardized factor summary values (ratio of FSV_f to NM_f). Individual site scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 7.

Table 7. Water-quality scores and ranks for semivolatile organic compounds in bed sediment

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.45
2	>25 – 50	>0.45 – 1.58
3	>50 – 75	>1.58 – 5.43
4 (worst)	>75	>5.43

Trace Elements in Bed Sediment

Comparison of trace elements in bed sediment among NAWQA sampling sites was based on nine elements: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc (appendix G). Of the 226 NAWQA fixed sites, 198 had data for trace elements in bed sediment (see appendix A).

The factor summary value for each element at each site was computed using equation 7. The national median for each trace-element factor was determined from the factor summary values at the 198 sites. The national median concentrations of trace elements in bed sediment are:

- Arsenic: 6.35 µg/g
- Cadmium: 0.4 µg/g
- Chromium: 62 µg/g
- Copper: 26 µg/g
- Lead: 24.3 µg/g
- Mercury: 0.06 µg/g
- Nickel: 25 µg/g
- Selenium: 0.7 µg/g
- Zinc: 110 µg/g

The trace element score for each site was calculated by equation 1 as the average of the standardized factor summary values (ratio of FSV_f to NM_f). Individual site scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 8.

Table 8. Water-quality scores and ranks for trace elements in bed sediment

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.85
2	>25 – 50	>0.85 – 1.07
3	>50 – 75	>1.07 – 1.57
4 (worst)	>75	>1.57

Fish and Habitat

Water-quality scores for fish community degradation and stream habitat degradation were based on previously published index systems for rating stream quality. To retain comparability of factor values for individual sites with existing index systems, values for individual factors for each site were summed instead of averaged, as was done for other water-quality characteristics. Rankings by quartiles are the same using either averages or sums. The characteristics of the index systems and their application to NAWQA data are described below.

Fish Community Degradation

The water-quality score for fish community degradation is based on a modification of the Index of Biotic Integrity (IBI), which was developed by Karr (1981) to assess the biological condition of streams. The IBI is a broadly based ecological index that integrates a number of fish community attributes and is sensitive to different sources of degradation (Fausch and others, 1990). Although the IBI must be modified for use in different ecological regions (Miller and others, 1988), the approach retains the same basic ecological foundation. The IBI is based on assumptions of how fish communities respond to increasing environmental degradation (Fausch and others, 1990; Yoder and Rankin, 1995). The attributes that are assumed to increase with increasing environmental degradation are:

1. The proportion of individuals that are members of tolerant species;
2. The proportion of trophic generalists, especially omnivores;

3. The proportion of individuals that are members of introduced species;
4. The incidence of externally evident disease, parasites, and morphological anomalies, excluding blackspot; and
5. The proportion of individuals that do not require silt-free substrate to spawn.

Of these five attributes, information is available from NAWQA data and the literature for all except the reproductive-habitat requirements associated with item 5. Therefore, comparison of fish communities among NAWQA stream sites is based on the first four factors only. Of the 226 NAWQA fixed sites, 172 have sufficient data to evaluate these factors (see appendix A).

The factor summary value (FSV_f) for each factor was assigned a value of 1, 3, or 5 according to whether the measured percentage at a site approximated, deviated moderately from, or deviated strongly from the expected percentage at a comparable site that has been relatively undisturbed. Expected percentages for undisturbed conditions were estimated from previous studies. Factor summary values were summed to determine the total value for the fish community at each site. If the value for one of the four factors was missing, or considered to misrepresent conditions at that site, that factor was omitted and the sum of the remaining three factors was multiplied by 1.33. The result is a unitless value ranging from 4 to 20, and the larger the number, the greater the degradation.

The national median (NM) determined from the values for fish communities at the 172 sites was 10. The score for fish community degradation (WQS) at each site was computed by a modification of equation 1, dividing the factor summary values by the national median, rather than averaging the standardized factor summary values:

$$WQS = \frac{\sum_{f=1}^{4} FSV_f}{NM} \qquad (8)$$

Individual site scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 9.

Table 9. Water-quality scores and ranks for fish community degradation

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.60
2	>25 – 50	>0.60 – 1.00
3	>50 – 75	>1.00 – 1.33
4 (worst)	>75	>1.33

Stream Habitat Degradation

Several approaches to assessing stream habitat conditions have been developed for biomonitoring programs (Rankin, 1995). Three commonly applied habitat indices are (1) the Rapid Bioassessment Protocol (Plafkin and others, 1989), (2) the Riparian, Channel, and Environmental Inventory (Peterson, 1992), and (3) the Qualitative Habitat Evaluation Index (Rankin, 1989). These indices, however, may not be broadly applicable beyond the regions for which they were developed. Rankin (1995) recommends seven metrics that could be widely used as indicators of habitat condition: substrate type, instream cover, stream modification, riparian vegetation, bank erosion, streamflow, and characteristics of geomorphic channel units such as pool, riffle, and run. Stauffer and Goldstein (1997) suggest that habitat index approaches should reflect dominant geomorphic processes of stream systems to improve upon making assessments of environmental change across large geographic areas. Characteristics of stream channel and bank geomorphology and riparian vegetation can be used as diagnostic factors to assess environmental changes in stream systems (Simon and Downs, 1995). Environmental changes can be the result of natural occurrences such as floods, or of human activities such as bridge construction, dredging, or land use. Environmental changes of sufficient magnitude and extent can initiate stream-channel and stream-bank responses in the size, shape, and morphology of channel features and in the condition of riparian vegetation (Simon and Hupp, 1992).

Comparison of habitat conditions among NAWQA stream sites was based on four factors: stream modification, bank erosion, bank vegetative stability, and riparian vegetation density. Of the 226 NAWQA fixed sites, 181 have sufficient data to evaluate these factors (see appendix A). Stream modification refers to alterations to a stream channel that include, but are not limited to, channelization, artificial banks, and artificial stream beds. Streams were classified as unmodified (low degradation) when there was no observable channel alteration along or near the sampled reach; moderately modified when streams have had modifications some distance upstream or downstream from the sampled reach; and highly modified for streams that had modifications within the sampled reach.

Bank erosion was assessed by using recorded observations of multiple types of bank failure along a reach. These observations were grouped by percentile, and bank erosion at each site was classified according to low (<25th percentile), moderate (25th–75th percentile), or high (>75th percentile) groupings.

Vegetative bank stability was assessed using the procedures described in Meador and others (1993). A mean vegetative bank-stability rating was calculated from the sampling points along a stream reach at each site, then classified according to three groupings: low (4.0–3.5), moderate (3.4–2.5), and high (< 2.5) stability.

The relative density of woody riparian vegetation (all species combined) was calculated for the reach using the formula:

$$RD = \frac{100\ m^2}{(PTD)^2} \qquad (9)$$

where

RD = relative density of riparian vegetation

PTD = mean point-to-tree distance for a reach, in meters.

On the basis of the distribution of computed densities for all sites, the density values for each site were classified into three groups: low (>75th percentile), moderate (25th–75th percentile), or high (<25th percentile).

Each habitat degradation factor was assigned a value of 1 (low), 3 (medium), or 5 (high) on the basis of the factor classifications determined for each site. The four factors then were summed to determine the factor summary value for habitat degradation at each site. If the value for one of the four factors was missing, or considered to misrepresent conditions at that site, that factor was omitted and the sum of the remaining three factors was multiplied by 1.33. The result is a unitless value ranging from 4 to 20, with higher numbers representing greater degradation.

The national median of the factor summary value, determined from the values for habitat degradation at the 181 sites, was 12. The score for habitat degradation at each site was computed by equation 8. Individual site scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA site scores. Categories are summarized in table 10.

Table 10. Water-quality scores and ranks for stream habitat degradation

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score
1 (best)	≤25	≤0.75
2	>25 – 50	>0.75 – 1.00
3	>50 – 75	>1.00 – 1.16
4 (worst)	> 75	>1.16

RELATIVE RANKING OF GROUND-WATER QUALITY

The water-quality characteristics that were evaluated for ground water are nitrate, pesticides, volatile organic compounds (VOCs), dissolved solids, and radon (table 3). Water-quality characteristics were evaluated for ground water using an approach similar to that for streams, but with water as the only medium and with each characteristic evaluated on the basis of only one factor. Thus, FSV_f is reduced to FSV in equations for ground water. Data from a minimum of 10 sampling sites (wells or springs) were required for a ground-water study to be included in the analysis. For ground water, only the data from the most recent sampling of each well or spring were included so that bias toward sites with multiple samples was eliminated. Classification and characteristics of the 92 qualifying ground-water study areas in the first 20 NAWQA study units are listed in appendix B. A total of 62 study areas are classified as drinking water aquifers (DWA) and 66 are classified as shallow ground water (SGW), with 36 in both categories.

Nitrate in Ground Water

Comparison of nitrate in ground water among NAWQA ground-water study areas was based on measured concentrations of dissolved nitrite plus nitrate, which are strongly dominated by nitrate in most samples. The factor summary value (FSV) for each study area was determined as the median of concentrations in samples from all wells and springs in the study area:

$$FSV = med\{C_1 \ldots C_{n_w}\} \tag{10}$$

where

$C_1 \ldots C_{n_w}$ = the concentration of dissolved nitrite plus nitrate in a single sample each from wells (or springs) 1 through n_w.

n_w = the total number of wells (or springs) in the study area.

Nondetections were assigned concentrations of zero to ensure that they were the lowest rank. Adequate data were available to evaluate nitrate for 62 DWAs and 65 SGW study areas (appendix B).

The national median for each group of study areas was determined from the factor summary values. The national median concentrations of nitrate in ground water are:

- Drinking water aquifers (DWA): 1.0 mg/L
- Shallow ground water (SGW): 2.0 mg/L

The nitrate score for each study area was calculated by equation 1 as the ratio of the study-area median concentration to the national median. The national median used in this calculation was determined by the classification of the study area as either a DWA or an SGW. In some cases, a study area was classified as both, and two nitrate scores were calculated. Study-area scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA study-area scores. Categories are summarized in table 11.

Pesticides in Ground Water

Comparison of pesticides in ground water among NAWQA ground-water study areas was based on the detection frequency of one or more pesticide compounds in samples collected in each study area. Pesticides included in this analysis are listed in appendix D. Most of the pesticides detected in ground water were herbicides.

The factor summary value for each study area was determined as the percentage of wells or springs in which at least one pesticide was detected:

$$FSV = 100\left(\frac{\sum_{i=1}^{n_w} D_i}{n_w}\right) \tag{11}$$

where

n_w = the total number of wells (or springs) in the study area

D_i = 1 if any pesticide was detected in a single sample from well (or spring) i, or 0 if no pesticides were detected.

Adequate data were available for pesticides for 62 DWAs and 66 SGW study areas (see appendix B).

The national median for each group of study areas was determined from the factor summary values. The national median detection frequencies of pesticides in ground water are:

- Drinking water aquifers (DWA): 39.6 percent
- Shallow ground water (SGW): 45.9 percent

The pesticide score for each study area was calculated as the ratio of the study-area detection frequency to the national median, using equation 1. The national median used in this calculation was determined by the classification of the study area as either a DWA or an SGW. In some cases, a study area was classified as both, and two pesticide scores were calculated. Study-area scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA study-area scores. Categories are summarized in table 12.

Table 11. Water-quality scores and ranks for nitrate in ground water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score: Drinking-water aquifers	Water-quality score: Shallow ground water
1 (best)	≤25	≤0.09	≤0.25
2	>25 – 50	>0.09 – 1.00	>0.25 – 1.00
3	>50 – 75	>1.00 – 4.27	>1.00 – 2.33
4 (worst)	>75	>4.27	>2.33

Table 12. Water-quality scores and ranks for pesticides in ground water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score: Drinking-water aquifers	Water-quality score: Shallow ground water
1 (best)	≤25	≤0.52	≤0.65
2	>25 – 50	>0.52 – 1.00	>0.65 – 1.00
3	>50 – 75	>1.00 – 1.64	>1.00 – 1.56
4 (worst)	>75	>1.64	>1.56

Volatile Organic Compounds in Ground Water

Comparison of VOCs in ground water among NAWQA study areas was based on the detection frequency of one or more VOCs in samples collected at each study area. Compounds included in this analysis are listed in appendix H.

The factor summary value for each study area was determined as the percentage of wells or springs in which at least one VOC was detected:

$$FSV = 100\left(\frac{\sum_{i=1}^{n_w} D_i}{n_w}\right) \qquad (12)$$

where

n_w = the total number of wells (or springs) in the study area

D_i = 1 if any VOC was detected in a single sample from well (or spring) i, or 0 if no VOCs were detected.

Adequate data were available for VOCs for 45 DWAs and 50 SGW study areas (appendix B).

The national median for each group of study areas was determined from the factor summary values. The national median detection frequencies of VOCs in ground water are:

- Drinking water aquifers (DWA): 10.0 percent
- Shallow ground water (SGW): 12.2 percent

The VOC score for each study area was calculated as the ratio of the study-area detection frequency to the national median, using equation 1. The national median used in this calculation was determined by the classification of the study area as either a DWA or an SGW. In some cases, a study area was classified as both, and two VOC scores were calculated. Study-area scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA study-area scores. Categories are summarized in table 13

Table 13. Water-quality scores and ranks for volatile organic compounds in ground water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score	
		Drinking-water aquifers	Shallow ground water
1 (best)	≤25	0.44	0.00
2	>25 – 50	>0.44 – 1.00	>0.00 – 1.00
3	>50 – 75	>1.00 – 2.33	>1.00 – 2.19
4 (worst)	>75	>2.33	>2.19

Dissolved Solids in Ground Water

Comparison of dissolved solids in ground water among NAWQA study areas was based on measurements of residue on evaporation of filtered samples at 180°C. The factor summary value for each study area was determined as the median concentration in samples from all wells and springs in the study area:

$$FSV = med\{C_1 \ldots C_{nw}\} \qquad (13)$$

where

$C_1 \ldots C_{n_w}$ = the concentration of dissolved solids in a single sample each from wells (or springs) 1 through n_w.

Adequate data were available for dissolved solids for 60 DWAs and 65 SGW study areas (appendix B).

The national median for each group of study areas was determined from the factor summary values. The national median concentrations of dissolved solids in ground water are:

- Drinking water aquifers (DWA): 298 mg/L
- Shallow ground water (SGW): 290 mg/L

The dissolved-solids score for each study area was calculated as the ratio of the study-area median concentration to the national median, using equation 1. The national median used in this calculation was determined by the classification of the study area as either a DWA or an SGW. In some cases, a study area was classified as both, and two dissolved-solids scores were calculated. Study-area scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA study-area scores. Categories are summarized in table 14.

Table 14. Water-quality scores and ranks for dissolved solids in ground water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score	
		Drinking-water aquifers	Shallow ground water
1 (best)	≤25	≤0.69	≤0.67
2	>25 – 50	>0.69 – 1.00	>0.67 – 1.00
3	>50 – 75	>1.00 – 1.32	>1.00 – 1.46
4 (worst)	>75	>1.32	>1.46

Radon in Ground Water

Comparison of radon in ground water among NAWQA study areas was based on measured concentrations of radon 222. The factor summary value for each study area was determined as the median concentration in samples from all wells and springs in the study area:

$$FSV = med\{C_1 \ldots C_{n_w}\} \quad (14)$$

where

$C_{f,1} \ldots C_{n_w}$ = the concentration of radon in a single sample each from wells (or springs) 1 through n_w.

Adequate data were available for radon 222 for 47 DWAs and 43 SGW study areas (see appendix B).

The national median for each group of study areas was determined from the factor summary values. The national median concentrations of radon in ground water are:

- Drinking water aquifers (DWA): 450 pCi/L
- Shallow ground water (SGW): 470 pCi/L

The radon score for each study area was calculated by equation 1 as the ratio of the study-area median concentration to the national median. The national median used in this calculation was determined by the classification of the study area as either a DWA or an SGW. In some cases, a study area was classified as both, and two radon scores were calculated. Study-area scores were categorized according to ranks 1 to 4 on the basis of quartiles of the national distribution of NAWQA study-area scores. Categories are summarized in table 15.

Table 15. Water-quality scores and ranks for radon in ground water

[≤, less than or equal to; >, greater than]

Rank	Percentile	Water-quality score	
		Drinking-water aquifers	Shallow ground water
1 (best)	≤25	≤0.71	≤0.70
2	>25 – 50	>0.71 – 1.00	>0.70 – 1.00
3	>50 – 75	>1.00 – 1.53	>1.00 – 1.89
4 (worst)	>75	>1.53	>1.89

COMPARISON OF NAWQA RESULTS TO WATER-QUALITY CRITERIA

Results from NAWQA studies can be compared to established water-quality criteria to supplement the relative rankings for the highly aggregated water-quality characteristics with an absolute and more specific indication of which individual constituents may be of concern and, thus, merit further investigation. As noted previously, water-quality criteria consist of commonly used standards or guidelines that have been established by agencies or organizations with regulatory responsibilities or expertise in water quality. Generally, a criterion is assumed to be a threshold concentration at which there is some estimated significant risk of adverse effects on the basis of evidence from toxicological studies, with an increasing risk of adverse effects at concentrations above that threshold.

Each water-quality criterion is based on a finite data set of measured effects, but the quantity and type of data vary, depending on the constituent and the type of criterion. The scope of these data is limited to effects of individual constituents, almost always (except for sediment criteria) measured in laboratory studies. The criteria used in this report were developed by considering acute and chronic toxicity to aquatic organisms (for aquatic-life criteria) or chronic toxicity and carcinogenicity for humans (for human-health criteria). These criteria generally do not consider certain more complex issues related to toxicity, such as the effect of chemical mixtures on toxicity and the potential for endocrine-disrupting effects on development, reproduction, and behavior of fish and wildlife populations. In addition, criteria have not been established for many constituents. Thus, the absence of criteria exceedances (concentrations that exceed one or more water-quality criteria) at a site does not necessarily mean that there are no issues of concern at that site.

Different types of criteria have different sampling and analytical requirements. For example, USEPA chronic water-quality criteria for the protection of aquatic organisms are designed for comparison with the 4-day average concentration of a contaminant in a water body. Sampling and analytical requirements for determining compliance with federal drinking-water standards depend upon the water system, the compound, and the frequency of exceedances (Code of Federal Regulations, v. 40, part 141, subpart C). Data collected for the NAWQA Program do not always match the conditions specified or implied in the definition of a particular type of criterion. These conditions can include the sample collection or processing method, the frequency of collection, and the type of chemical analysis.

Although differences in methods and sampling may limit the use of NAWQA data in regulatory monitoring and enforcement in some situations, they do not preclude the comparison of NAWQA data to water-quality criteria to signal potential water-quality problems.

Established water-quality criteria are consistent benchmarks for national comparisons with observed concentrations for many individual constituents considered important in management of water resources. Because most of the streams sampled are not used as primary drinking-water sources, and because aquatic life is a vital resource in virtually all streams, water and bed-sediment concentrations for streams are compared with aquatic-life criteria to identify potential water-quality problems at NAWQA stream sites. Ground-water concentrations, on the other hand, are compared to human-health criteria.

The water-quality criteria referred to in this report were compiled from various sources developed by federal or international agencies in North America, including USEPA, the Canadian Council of Resource and Environment Ministers, and the International Joint Commission (IJC) of Canada and the United States. State and Canadian provincial criteria were not used because of the wide variability in the methods used in their derivation. If more than one type of criterion was available for a constituent, several rules were used to prioritize criteria. In general, USEPA criteria were given preference over criteria from other agencies. Also, USEPA standards (enforceable regulatory limits) were given preference over USEPA criteria and guidelines (issued in an advisory capacity). For constituents in sediment, a slightly different approach was used because no single type of sediment-quality guideline is generally accepted in the scientific literature, and there may be substantial differences (up to three orders of magnitude) between different guideline values for a given constituent. Therefore, on the basis of the available criteria for a given constituent, procedures developed by USEPA are used to determine a threshold concentration above which there was a high probability of adverse effects on aquatic life.

Aquatic-Life Criteria for Stream Water

Aquatic-life criteria for stream water were evaluated for ammonia, the only nutrient species with an established aquatic-life criterion, and for all pesticides with established criteria. Regarding nutrients, a significant limitation is the lack of available water-quality criteria that reflect the eutrophication influences of nutrient enrichment on streams, such as nuisance algal growth, reduced water clarity, and depressed dissolved oxygen; thus, these types of effects are not considered in the analysis of nutrient effects on streams at NAWQA sites. For pesticides, the most significant weaknesses are that (1) no criteria are available for many pesticides and (2) existing criteria assess the effects of single chemicals only and do not consider effects of chemical mixtures. Nonetheless, the criteria used here represent the state-of-the-art in defining acceptable water quality for specific uses. Because of the above limitations, however, the available criteria do not take into account all potential effects on aquatic life in streams from nutrients or pesticides.

The three types of aquatic life criteria used are USEPA chronic water-quality criteria for protection of aquatic organisms (U.S. Environmental Protection Agency, 1986, 1991), Canadian water-quality guidelines (Canadian Council of Resource and Environment Ministers, 1996), and Great Lakes water-quality objectives (International Joint Commission, 1977). All criteria values used for nutrients and pesticides in stream water are for protection of freshwater aquatic life. The USEPA chronic water-quality criterion for protection of aquatic organisms is the estimated highest concentration of a constituent that aquatic organisms can be exposed to for a 4-day period, once every 3 years, without deleterious effects. If no USEPA chronic water-quality criterion for protection of aquatic organisms exists for a given constituent, then Canadian water-quality guidelines are used, if available. The older Great Lakes water-quality objectives are used only if neither USEPA chronic water-quality criteria for protection of aquatic organisms nor Canadian water-quality guidelines are available for that constituent. The Canadian water-quality guidelines and the Great Lakes water-quality objectives are defined as specifying maximum concentrations that should not be exceeded at any time.

Data for ammonia and pesticide concentrations in streams were simplified to a time series of monthly median concentrations, as previously described for the development of water-quality scores. Monthly medians were compared to water-quality criteria to identify sites with the greatest potential water-quality effects attributable to ammonia or pesticides and to estimate the number of months during a year that one or more criteria were exceeded. This approach is an approximation for examining broad patterns and prioritizing further investigations. The frequency of exceedances is reduced by using monthly medians rather than individual sample values because individual high values might not influence a monthly median. For NAWQA study-unit summary reports, stream sites are designated as having an exceedance if the median concentration in any month exceeds the criterion for ammonia or for any pesticide.

Ammonia in Water

The only applicable aquatic-life criterion for nutrients in streams is for ammonia. In water, ammonia exists in equilibrium between its un-ionized form and the ammonium ion; this equilibrium is dependent on temperature and pH. The USEPA water-quality criterion for protection of aquatic organisms is based on toxicity of un-ionized ammonia, so its value varies with temperature and pH. The USGS measures the sum of un-ionized ammonia and ammonium ion in solution, and expresses concentrations in units of milligrams of nitrogen per liter (mg/L as N). The USEPA chronic water-quality criterion for protection of aquatic organisms for ammonia, expressed in this form, varies from 0.07 to 2.1 mg/L as N, depending on temperature and pH (U.S. Environmental Protection Agency, 1986). Computation of the appropriate criterion value was made for each month at each site, using median water temperature and pH, according to methods reported by the U.S. Environmental Protection Agency (1986). The criterion was then compared with the monthly median dissolved-ammonia concentrations for the period of record.

Pesticides in Water

Aquatic-life criteria have been established for only 28 pesticides (table 16) of the 83 pesticides included in analysis of NAWQA water samples (appendix D). Of these, 6 have USEPA chronic water-quality criteria for protection of aquatic organisms, 21 have Canadian water-quality guidelines or Canadian interim guidelines, and 1 has a Great Lakes water-quality objective. The minimum data requirements for a site to be included in comparisons with pesticide water-quality criteria were the same as those imposed for evaluating the relative water-quality scores with the additional requirement that there be at least 8 months of data for a year to be included. If data for a site met the requirements for more than 1 year, data from all suitable years were included in the analysis. For each year of data for a site, the number of months with exceedances was divided by 12 to estimate the percentage of the year with one or more criteria exceeded.

Aquatic-Life Criteria for Bed Sediment

Aquatic-life criteria were evaluated for two groups of constituents in bed sediment: (1) organochlorine pesticides and PCBs and (2) SVOCs. Sediment-quality guidelines have been proposed by several agencies and organizations in different parts of the United States and Canada to assess potential effects of sediment contamination on aquatic life. A number of different approaches have been used to develop these guidelines, and no single approach is generally accepted (Persaud and others, 1993; U.S. Environmental Protection Agency, 1996c). For a given constituent in sediment, the available guideline values can vary by as much as 3 orders of magnitude. Therefore, the criteria used in this analysis were selected using procedures developed and used by U.S. Environmental Protection Agency (1996c) to analyze data in the National Sediment Inventory. These procedures use the available sediment-quality guidelines for a given constituent to classify sites into probability-of-adverse-effects classes (or tiers) on the basis of measured concentrations at those sites. Tier 1 sites have a high probability of adverse effects on aquatic life; tier 2 sites have an intermediate probability of adverse effects on aquatic life; and tier 3 sites have no indication of adverse effects on aquatic life.

In the NAWQA data analysis, criteria were determined using the procedures described by the U.S. Environmental Protection Agency (1996c) for establishing tier 1 sites. For two pesticides and three SVOCs at some sites, the USEPA procedures had to be modified slightly to suit the available data, as described below.

The USEPA procedure for classifying sites calls for assembling available sediment guidelines for a given constituent and designating each guideline as either an upper screening value (above which adverse effects may be severe or frequent) or a lower screening

Table 16. Aquatic-life criteria used for pesticides in surface water and human-health criteria used for pesticides in ground water

[HA-L, lifetime health advisory; USEPA, U.S. Environmental Protection Agency; CCREM, Canadian Council of Resources and Environmental Ministers; MCL, maximum contaminant level; RSD(10^{-5}), risk-specific dose at a cancer risk level of 1 in 100,000; IJC, International Joint Commission. µg/L, micrograms per liter; —, no established criteria]

Compound	Aquatic-life criteria for surface water			Human-health criteria for ground water		
	Criterion (µg/L)	Type of criterion	Reference	Criterion (µg/L)	Type of criterion	Reference
			Herbicides			
Acifluorfen	—	—	—	10	RSD(10^{-5})	USEPA (1996a)
Alachlor	—	—	—	2	MCL	USEPA (1996a)
Atrazine	2	Canadian	CCREM (1996)	3	MCL	USEPA (1996a)
Bentazon	—	—	—	200	HA-L	USEPA (1996a)
Bromacil	—	—	—	90	HA-L	USEPA (1996a)
Bromoxynil	5	Canadian[1]	CCREM (1996)	—	—	—
Butylate	—	—	—	350	HA-L	USEPA (1996a)
Chloramben	—	—	—	100	HA-L	USEPA (1996a)
Cyanazine	2	Canadian interim	CCREM (1996)	1	HA-L	USEPA (1996a)
2,4-D	4	Canadian	CCREM (1996)	70	MCL	USEPA (1996a)
Dicamba	10	Canadian interim	CCREM (1996)	200	HA-L	USEPA (1996a)
Dinoseb	1.75	Canadian	CCREM (1996)	7	MCL	USEPA (1996a)
Diuron	—	—	—	10	HA-L	USEPA (1996a)
Fluometuron	—	—	—	90	HA-L	USEPA (1996a)
Linuron	7	Canadian interim[2]	CCREM (1996)	—	—	—
MCPA	2.6	Canadian interim[3]	CCREM (1996)	10	HA-L	USEPA (1996a)
Metolachlor	8	Canadian interim	CCREM (1996)	70	HA-L	USEPA (1996a)
Metribuzin	1	Canadian interim	CCREM (1996)	100	HA-L	USEPA (1996a)
Picloram	29	Canadian interim	CCREM (1996)	500	MCL	USEPA (1996a)
Prometon	—	—	—	100	HA-L[4]	USEPA (1996a)
Pronamide	—	—	—	50	HA-L	USEPA (1996a)
Propachlor	—	—	—	90	HA-L	USEPA (1996a)
Propham	—	—	—	100	HA-L	USEPA (1996a)
Simazine	10	Canadian	CCREM (1996)	4	MCL	USEPA (1996a)
2,4,5-T	—	—	—	70	HA-L	USEPA (1996a)
Tebuthiuron	1.6	Canadian interim	CCREM (1996)	500	HA-L	USEPA (1996a)
Terbacil	—	—	—	90	HA-L	USEPA (1996a)
2,4,5-TP	—	—	—	50	MCL	USEPA (1996a)
Triallate	0.24	Canadian interim	CCREM (1996)	—	—	—
Trifluralin	0.1	Canadian	CCREM (1996)	5	HA-L	USEPA (1996a)
			Insecticides and Fungicides			
Aldicarb	1	Canadian interim[5]	CCREM (1996)	7	draft MCL	USEPA (1996a)
Aldicarb sulfone	1	Canadian interim[5]	CCREM (1996)	7	draft MCL	USEPA (1996a)
Aldicarb sulfoxide	1	Canadian interim[5]	CCREM (1996)	7	draft MCL	USEPA (1996a)
Azinphosmethyl	0.01	USEPA	USEPA (1986)	—	—	—
Carbaryl	—	—	—	700	HA-L	USEPA (1996a)
Carbofuran	1.75	Canadian	CCREM (1996)	40	MCL	USEPA (1996a)
Chlorothalonil	0.18	Canadian interim[6]	CCREM (1996)	15	RSD(10^{-5})	USEPA (1996a)
Chlorpyrifos	0.041	USEPA	USEPA (1986)	20	HA-L	USEPA (1996a)
p,p′-DDE	—	—	—	0.1	RSD(10^{-5})	USEPA (1996b)
Diazinon	0.08	Great Lakes	IJC (1977)	0.6	HA-L	USEPA (1996a)
Dieldrin	0.0625	USEPA[7]	USEPA (1993)	0.02	RSD(10^{-5})	USEPA (1996a)

Table 16. Aquatic-life criteria used for pesticides in surface water and human-health criteria used for pesticides in ground water—Continued

Compound	Aquatic-life criteria for surface water			Human-health criteria for ground water		
	Criterion (μg/L)	Type of criterion	Reference	Criterion (μg/L)	Type of criterion	Reference
Disulfoton	—	—	—	0.3	HA-L	USEPA (1996a)
Fonofos	—	—	—	10	HA-L	USEPA (1996a)
α-HCH	0.01	Canadian[8]	CCREM (1996)	0.06	RSD(10^{-5})	USEPA (1996b)
γ-HCH	0.08	USEPA	USEPA (1986)	0.2	MCL	USEPA (1996a)
Malathion	0.1	USEPA	USEPA (1986)	200	HA-L	USEPA (1996a)
Methomyl	—	—	—	200	HA-L	USEPA (1996a)
Methyl parathion	—	—	—	2	HA-L	USEPA (1996a)
Oxamyl	—	—	—	200	MCL	USEPA (1996a)
Parathion	0.013	USEPA	USEPA (1986)	—	—	—
Terbufos	—	—	—	0.9	HA-L	USEPA (1996a)

[1] Value applies to total bromoxynil, including the phenol, octanoate, and heptanoate forms.
[2] Value applies to total linuron, including linuron and its transformation products.
[3] Value applies to all forms of MCPA and all their transformation products.
[4] Value is under review.
[5] Value applies to sum of aldicarb, aldicarb sulfoxide, and aldicarb sulfone.
[6] Value applies to chlorothalonil plus its 4-hydroxy transformation product.
[7] Final chronic value from the proposed sediment-quality criterion document for dieldrin (U.S. Environmental Protection Agency, 1993). This is a more recent criterion for chronic aquatic toxicity than the 1980 chronic water-quality criterion for protection of aquatic life.
[8] Value applies to total HCH isomers.

value (above which adverse effects may begin or occur occasionally). The first step in determining tier 1 classification for organic constituents is to determine whether the measured concentration exceeds the USEPA proposed sediment-quality criterion (SQC) for protection of benthic organisms (available only for acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene) with site-specific adjustment for total organic carbon in sediment. For organic constituents with no USEPA SQC, or for any site without information on the total organic carbon content of the bed sediment, the USEPA procedure for tier 1 classification requires that the second lowest of the upper screening values be exceeded. Thus, tier 1 classification requires some consistency among available sediment guidelines in that two upper screening values must be exceeded for a site to be classified in tier 1. The U.S. Environmental Protection Agency (1996c) used the following upper screening values in its analysis of data in the National Sediment Inventory:

1. USEPA SQC (with a default value of 1 percent total organic carbon in sediment for sites with no organic carbon data).
2. USEPA sediment-quality advisory level (SQAL) for freshwater aquatic life (with a default value of 1 percent total organic carbon in sediment for sites with no organic carbon data).
3. Effects range-median (ER-M) developed by Long and others (1995).
4. Probable effect level (PEL) developed by MacDonald (1994) for the Florida Department of Environmental Protection.
5. Apparent effects threshold-high (AET-H) developed by Barrick and others (1988).

For NAWQA data analysis, the USEPA procedures were slightly modified to facilitate the most consistent site-to-site comparisons possible and to include the greatest possible number of constituents. Total organic carbon measurements were available for about 93 percent of NAWQA sites, thus allowing assessment of tier 1 classification from the USEPA SQC using site-specific organic carbon data for the five compounds with USEPA SQCs. For the remaining 7 percent of NAWQA sites, the five compounds with USEPA SQCs were evaluated using organic carbon values estimated from data for nearby sites (instead of using the default 1-percent sediment organic carbon value and applying the second-lowest upper screening value). This modification makes comparisons of USEPA SQCs for the sites with missing organic carbon data as similar as possible to other sites in the national data set. In addition, although not used in the USEPA procedures described in U.S. Environmental Protection Agency (1996c), Canadian freshwater PEL values (Environment Canada, 1995) were included as a sixth upper screening value for the determination of tier 1 criteria values for NAWQA data analysis. Also, some additional ER-M values from Long and Morgan (1991) were used for a few constituents that do not have ER-M values listed in Long and others (1995). Use of the Canadian PEL values and the additional ER-M values increases the number of constituents for which at least two upper screening values were available. Inclusion of the Canadian PEL values also increases the number of upper screening values determined specifically for freshwater species.

Most of the bed-sediment chemistry data for NAWQA stream sites are based on one sample per site. For sites with multiple samples, median values were computed as described in the development of water-quality scores (*WQS*). In the study-unit summary reports, sites are designated as exceeding an aquatic-life criterion if the concentration of one or more constituents exceeds the applicable tier 1 boundary concentration.

Organochlorine Pesticides and PCBs in Bed Sediment

Following the procedures described above, sufficient criteria were available to determine a criterion (tier 1 boundary concentration) for the most commonly detected organochlorine pesticides and PCBs. Criteria used are listed with references in table 17. Note that criteria are included for total chlordane (the sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane) rather than for the individual components of this mixture. Similarly, criteria are included for total DDT (the sum of *o,p′*-DDD, *p,p′*-DDD, *o,p′*-DDE, *p,p′*-DDE, *o,p′*-DDT, and *p,p′*-DDT) and for *p,p′*-DDE (which is the most commonly detected component of total DDT) rather than for all individual isomers of DDT and metabolites. In table 17, the values listed for USEPA SQC have a default value of 1-percent sediment organic carbon.

Semivolatile Organic Compounds in Bed Sediment

Following the procedures described above, sufficient criteria were available to determine a criterion (tier 1 boundary concentration) for 18 of 66 SVOCs analyzed in NAWQA studies (appendix F). Criteria used are listed with references in table 18. The USEPA SQC and USEPA SQAL values listed in table 18 have a default value of 1-percent sediment organic carbon.

Human-Health Criteria for Ground Water

Most concern about contaminants in ground water stems from the potential effects of contaminants on drinking-water supplies. Accordingly, human-health criteria are the focus for evaluating potential problems and determining the need for further investigation of ground-water quality. Only USEPA criteria were used to assess human health effects associated with drinking-water contaminants. There is no single type of USEPA criteria available for the broad array of constituents measured in NAWQA studies. Therefore, four types of USEPA criteria are used for evaluating NAWQA ground-water data: (1) maximum contaminant level (MCL), (2) secondary maximum contaminant level (SMCL), (3) risk specific dose (RSD), and (4) lifetime health advisory (HA-L). Values for these criteria were obtained from U.S. Environmental Protection Agency (1996a,b). The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. The SMCL is a guideline for contaminants that can adversely affect the odor or appearance of water for drinking-water use. The RSD is a guideline for potential carcinogens on the basis of drinking-water exposure over a 70-year lifetime; an RSD value is always associated with a specified cancer risk (maximum acceptable incidence of excess cancer). The RSD values used for NAWQA analysis are associated with a cancer risk of 1 in 100,000. The HA-L is a guideline for drinking-water exposure over a 70-year lifetime, considering noncarcinogenic adverse health effects. More detail on these types of criteria, their derivation, and their underlying assumptions is provided in Nowell and Resek (1994). For some constituents, more than one of these four criteria are available. For these constituents, the MCL was used if available; otherwise, the lowest of the SMCL, RSD (at 1 in 100,000 cancer risk), and HA-L values was selected.

Criteria for all constituents that have an established MCL, SMCL, RSD, or HA-L were compared with concentrations in ground-water sampled from NAWQA study areas. Comparisons

Table 17. Aquatic-life criteria used for organochlorine pesticides and PCBs in bed sediment

[ER-M, effects range-median; AET-H, apparent effects threshold-high; USEPA, U.S. Environmental Protection Agency; SQC, sediment-quality criterion; PEL, probable effect level; PCBs, polychlorinated biphenyls]

Compound	Aquatic-life criteria for surface water		
	Criterion (µg/kg dry weight)	Type of criterion	Reference
Total chlordane	6	ER-M	Long and Morgan (1991)
p,p'-DDE	15	AET-H	Barrick and others (1988)
Total DDT	46.1	ER-M	Long and others (1995)
Dieldrin	110	USEPA SQC[1]	USEPA (1996c)
Endrin	42	USEPA SQC[1]	USEPA (1996c)
γ-HCH (Lindane)	1.38	Canada PEL	Environment Canada (1995)
Total PCBs	189	Florida PEL	MacDonald (1994)

[1]Value in table assumes 1-percent sediment organic carbon.

Table 18. Aquatic-life criteria used for semivolatile organic compounds in bed sediment

[USEPA, U.S. Environmental Protection Agency; SQC, sediment-quality criterion; SQAL, sediment-quality advisory level; ER-M, effects range-median; PEL, probable effect level. µg/kg, microgram per kilogram]

Compound	Criterion (µg/kg dry weight)	Type of criterion	Reference
Polycyclic aromatic hydrocarbons (PAH)			
Acenaphthene	1,300	USEPA SQC[1]	USEPA (1996c)
Acenaphthylene	640	ER-M	Long and others (1995)
Anthracene	1,100	ER-M	Long and others (1995)
Benzo(a)anthracene	693	Florida PEL	MacDonald (1994)
Benzo[*a*]pyrene	782	Canada PEL	Environment Canada (1995)
Chrysene	862	Canada PEL	Environment Canada (1995)
Dibenzo(a,h)anthracene	260	ER-M	Long and others (1995)
Fluoranthene	6,200	USEPA SQC[1]	USEPA (1996c)
Naphthalene	470	USEPA SQAL[1]	USEPA (1996c)
Phenanthrene	1,800	USEPA SQC[1]	USEPA (1996c)
Pyrene	1,398	Florida PEL	MacDonald (1994)
Phthalates			
Butylbenzyl phthalate	11,000	USEPA SQAL[1]	USEPA (1996c)
Diethyl phthalate	630	USEPA SQAL[1]	USEPA (1996c)
Di-n-butyl phthalate	11,000	USEPA SQAL[1]	USEPA (1996c)
bis (2-Ethylhexyl) phthalate	2,650	Florida PEL	MacDonald (1994)
Other SVOCs			
1,2-Dichlorobenzene	340	USEPA SQAL[1]	USEPA (1996c)
1,4-Dichlorobenzene	350	USEPA SQAL[1]	USEPA (1996c)
1,2,4-Trichlorobenzene	9,200	USEPA SQAL[1]	USEPA (1996c)

[1]Value in table asssumes a 1-percent sediment to organic carbon.

were limited to study areas that are classified as representative of drinking-water aquifers. Criteria are compared to single measurements from individual sampling sites (wells or springs). Because ground water moves and changes relatively slowly, even a single sample can provide a useful evaluation of ground-water quality in relation to criteria designed for long-term exposure. The percentage of sampling sites at which one or more constituents exceeded the applicable criteria was computed for each ground-water study area.

Of the constituents considered for NAWQA ground-water quality scores, human-health criteria are available for nitrite plus nitrate, dissolved solids, some pesticides, and some VOCs. The MCL for radon is under review by the USEPA and is not used in this analysis. Of 83 pesticides analyzed (appendix D), 13 have MCLs, 5 have RSDs, 28 have HA-Ls, and 37 have no established USEPA human-health criteria. The 60 VOCs analyzed (appendix H) include four trihalomethane compounds (bromodichloromethane, dibromochloromethane, tribromomethane, and trichloromethane), which were summed and compared to the MCL for total trihalomethanes. Of the remaining 56 VOCs analyzed, 23 have MCLs, 3 have RSDs, and 12 have HA-Ls. No USEPA human-health criteria have been established for 18 of the analyzed VOCs. The human-health criteria used for nitrite plus nitrate and dissolved solids are listed in table 19, for pesticides in table 16, and for VOCs in table 20.

Table 19. Human-health criteria used for nitrite plus nitrate and dissolved solids in ground water

[Criteria are from U.S. Environmental Protection Agency (1996a). MCL, maximum contaminant level; SMCL, secondary maximum contaminant level. mg/L, milligram per liter]

Constituent	Criterion (mg/L)	Type of criterion
Nitrite plus nitrate	10	MCL
Dissolved solids	500	SMCL

APPLICATION OF WATER-QUALITY RANKINGS AND CRITERIA FOR SUMMARIZING NAWQA RESULTS

Scores for each water-quality characteristic were computed for each NAWQA stream site and ground-water study area with adequate data. Sites (or study areas) were assigned a rank of 1 to 4 on the basis of the quartiles of the scores for all NAWQA sites in the 20 study-units investigated during 1992–1995. The lowest category, with a rank of 1, contains the 25 percent of sites with the lowest scores for the particular water-quality characteristic, and thus, generally represents the best quality for the particular characteristic in comparison with other NAWQA sites. The highest category, with a rank of 4, contains the 25 percent of sites with the highest scores, and thus, the poorest quality for the particular characteristic in comparison with other NAWQA sites. Symbols plotted on a map at the site or study area location show the quartile classification, with color coding to facilitate visual comparisons within and among study units. Concentrations of individual constituents are compared with established water-quality criteria for

Table 20. Human-health criteria used for volatile organic compounds in ground water

[Criteria are from U.S. Environmental Protection Agency (1996a). MCL, maximum contaminant level; HA-L, lifetime health advisory; RSD (10^{-5}), risk-specific dose at a cancer risk of 1 in 100,000. μg/L, microgram per liter]

Compound	Criterion (μg/L)	Type of criterion
Benzene	5	MCL
Bromochloromethane	10	HA-L
Bromomethane	10	HA-L
Chlorobenzene	100	MCL
Chloroethene	2	MCL
Chloromethane	3	HA-L
1-Chloro-2-methylbenzene	100	HA-L
1-Chloro-4-methylbenzene	100	HA-L
1,2-Dibromo-3-chloro-propane	0.2	MCL
1,2-Dibromoethane	0.05	MCL
1,2-Dichlorobenzene	600	MCL
1,3-Dichlorobenzene	600	HA-L[1]
1,4-Dichlorobenzene	75	MCL
Dichlorodifluoromethane	1,000	HA-L
1,2-Dichloroethane	5	MCL
1,1-Dichloroethene	7	MCL
cis-1,2-Dichloroethene	70	MCL
trans-1,2-Dichloroethene	100	MCL
Dichloromethane	5	MCL
1,2-Dichloropropane	5	MCL
cis-1,3-Dichloropropene	2	RSD(10^{-5})
trans-1,3-Dichloropropene	2	RSD(10^{-5})
Dimethylbenzenes	10,000	MCL
Ethenylbenzene	100	MCL
Ethylbenzene	700	MCL
Hexachlorobutadiene	1	HA-L
Methylbenzene	1,000	MCL
Methyl *tertbutyl* ether	20	HA-L[2]
Naphthalene	20	HA-L
1,1,1,2-Tetrachloroethane	10	RSD(10^{-5})
Tetrachloroethene	5	MCL
Tetrachloromethane	5	MCL
1,2,4-Trichlorobenzene	70	MCL
1,1,1-Trichloroethane	200	MCL
1,1,2-Trichloroethane	5	MCL
Trichloroethene	5	MCL
Trichlorofluoromethane	2,000	HA-L
1,2,3-Trichloropropane	40	HA-L
Total Trihalomethanes	100	MCL[3]

[1] Based on data for 1,2-Dichlorobenzene.
[2]Value in table is minimum; standard varies from 20 to 200 μg/L.
[3]Applies to the sum of bromodichloromethane, dibromochoromethane, tribromomethane, and trichloromethane.

each water-quality characteristic, and stream sites or ground-water study areas with exceedances are indicated.

Results for the Central Columbia Plateau study unit (fig. 1) are presented and summarized as an example of the format used in study-unit summary reports (Williamson and others, 1998). Figure 4 shows results for water-quality characteristics of streams in the Central Columbia Plateau study unit. Figure 5 shows results for characteristics of ground-water study areas in the Central Columbia Plateau study unit. Four ground-water studies were done in the Central Columbia Plateau—three land-use studies of shallow ground water and one aquifer survey of public supply wells throughout the study unit. All four are classified as drinking-water aquifers (DWA) because the three land-use studies assessed shallow ground water that is tapped by domestic wells in the area. In study-unit summary reports, all ground-water study areas are evaluated for water-quality characteristics and all those classified as DWAs are included in comparisons with water-quality criteria.

SUMMARY AND CONCLUSIONS

Methods were developed to compare the water-quality conditions within and among 20 study units of the National Water-Quality Assessment (NAWQA) Program that were investigated during 1992–1995. Comparisons were made using two different approaches: (1) a relative ranking of major water-quality characteristics, and (2) an evaluation of individual constituents relative to established water-quality criteria. The relative ranking system was developed solely with data collected from the study units evaluated; the individual constituents were evaluated on the basis of established criteria, which are fixed values that are independent of the data from the study units.

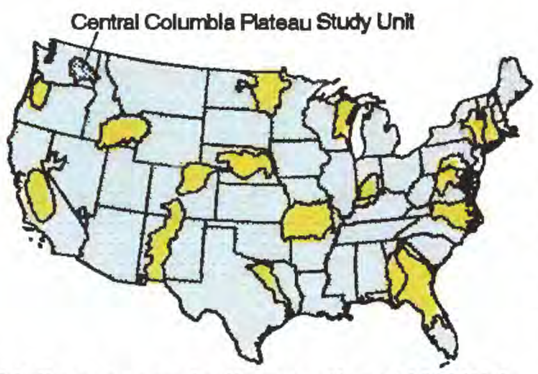
For relative rankings, major characteristics of water quality were evaluated by using selected combinations of measured values for individual constituents or properties. Water-quality characteristics evaluated for streams were nutrients in water, pesticides in water, organochlorine pesticides and PCBs in bed sediment and tissue, semivolatile organic compounds in bed sediment, trace elements in bed sediment, fish community degradation, and stream habitat degradation. Water-quality characteristics evaluated for ground water were nitrate, pesticides, volatile organic compounds, dissolved solids, and radon.

Scores were computed for each water-quality characteristic for all stream sites and ground-water study areas for which adequate data were available. A rank of 1, 2, 3, or 4 was assigned to each characteristic for each site or study area on the basis of the quartiles of the water-quality scores for all sites or study areas. The rankings of water-quality conditions are based strictly on the values for the characteristics of stream sites and ground-water study areas included in the method-development data set. In general, the 20 NAWQA study units are widespread throughout the United States and include a broad diversity of environmental settings, but they are biased toward areas with greater-than-average population, water use, and agricultural and urban land use. The rankings serve as an initial comparative framework for summarizing the results of each study unit in relation to the other study units.

The water-quality rankings are designed to be updated and refined as the data on which they are based become more complete. As additional NAWQA studies are completed, data from many more sites in different areas of the Nation will be added to the database. Over time, updated evaluations will be increasingly representative of the Nation's water resources. Separate rankings can be developed (using the same general process) for more specific subcategories of the Nation's water resources, such as urban or agricultural streams, so that more specific questions about particular types of hydrologic systems can be addressed. In addition, the representation of water-quality characteristics can be improved, such as by standardizing contaminants by toxicity.

Established water-quality criteria were used as benchmarks for comparison and to indicate where particular constituents may cause adverse effects and thus merit further investigation. Established water-quality criteria were selected from a variety of sources and applied to specific constituents in the specific medium (water or sediment) appropriate for each criterion. Water-quality criteria change over time, however, as existing criteria are modified in response to new data, and legislative mandates and new criteria are added. The selection process described in this report will guide continued evaluation and updating of criteria used for assessing the environmental significance of NAWQA results.

Comparison of Stream Quality in the Central Columbia Plateau with Nationwide NAWQA Findings



Yellow areas indicate other NAWQA study units sampled during 1992–95.

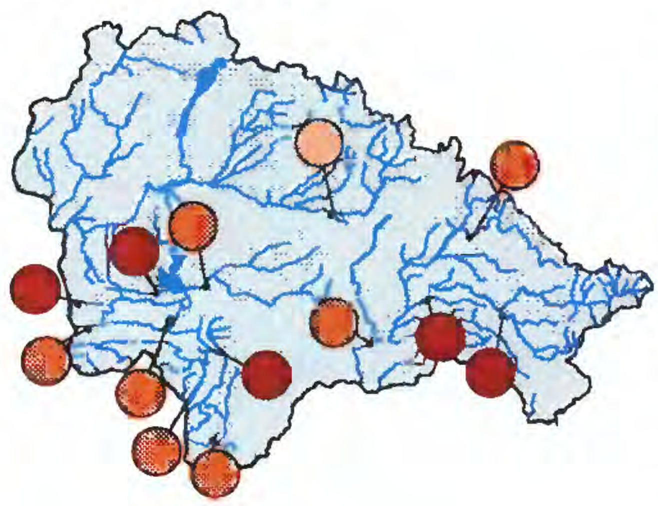
Seven major water-quality characteristics were evaluated for stream sites in each NAWQA study unit. Summary scores for each characteristic were computed for all sites that had adequate data. Scores for each site in the Central Columbia Plateau were compared with scores for all sites sampled in the 20 NAWQA study units during 1992–95 (see map at left). Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water, and semivolatile organic compounds, organochlorine pesticides, and PCBs in sediment.

EXPLANATION

Ranking of stream quality relative to all NAWQA stream sites — Darker colored circles generally indicate poorer quelity. Bold outline of circle indicates one or more aquatic life criteria were exceeded.

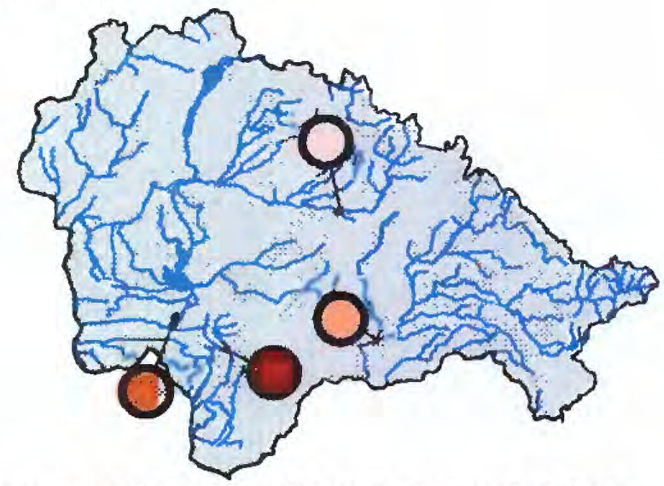
- **Greater than the 75th percentile (among the highest 25 percent of NAWQA stream sites)**
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile (among the lowest 25 percent of NAWQA stream sites)**

NUTRIENTS in water



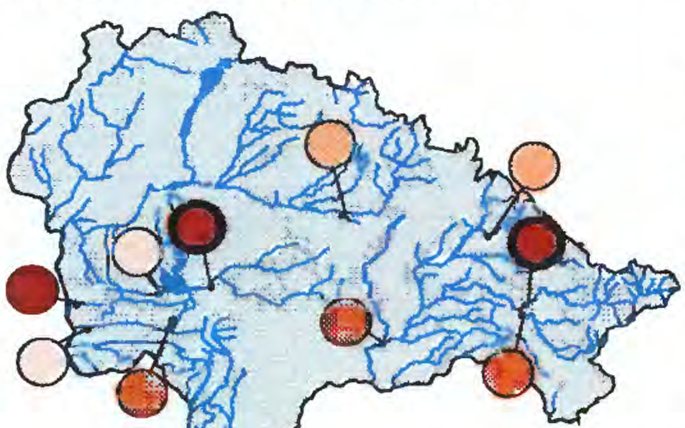
Nutrient levels are greater than the national median at all but one site, with 5 of 13 sites in the upper 25 percent of NAWQA sites. Elevated nutrient concentrations, primarily caused by fertilizer application on fields upstream of most sites and municipal wastewater at a few sites, are causing eutrophication. Effects of eutrophication include reduced dissolved oxygen, which can adversely affect fish, and nuisance growth of aquatic plants.

PESTICIDES in water



Many pesticides (12–45) were detected at four sites; the detection frequency at one of the sites is in the upper 25 percent of NAWQA sites. The two sites with the highest detection frequencies are in the Quincy-Pasco subunit, where irrigation and high chemical use combine to increase transport of pesticides to surface waters. Pesticide detection frequencies at sites in the dryland farming areas of the North-Central and Palouse subunits are below the national median for NAWQA sites. All of the sites had at least one pesticide concentration that exceeded a water-quality standard or guideline.

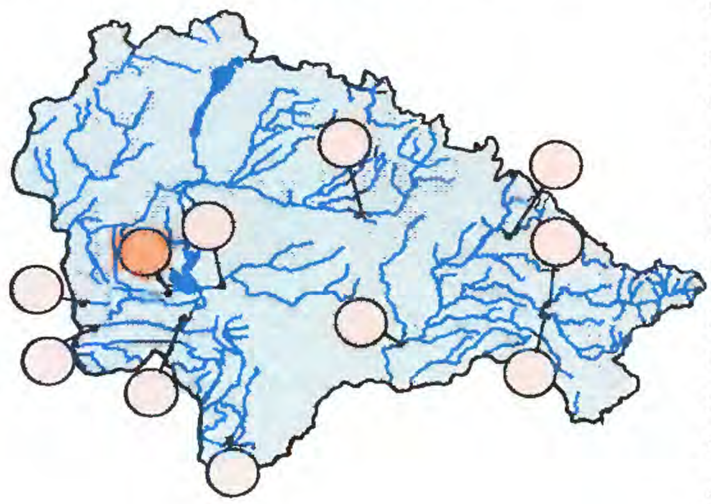
ORGANOCHLORINE PESTICIDES and PCBs in bed sediment and biological tissue



Concentrations of organochlorine pesticides and PCBs are higher than the national median (50th percentile) at 7 of 11 sites, with 4 sites in the upper 25 percent of all NAWQA sites. Elevated concentrations were observed in dryland farming areas as well as in irrigated areas. One or more environmental guidelines were exceeded at one of the sites in the Palouse River basin that is affected by urban wastewater as well as at Lind Coulee. Although most of these compounds have been banned, they still persist in the environment.

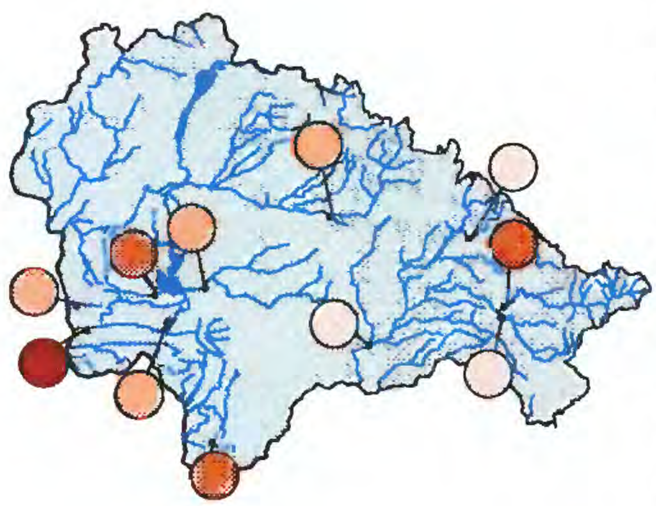
Figure 4. Application of water-quelity rankings end criteria comperisons for streems in the Central Columbie Plateau study unit.

TRACE ELEMENTS in bed sediment



Trace elements, such as the metals lead and chromium, are low in the Central Columbia Plateau compared to other NAWQA study units because of the minimal influence of mining and urban sources and the low natural background concentrations in soils. All sites have trace element levels below the national median for NAWQA sites.

SEMIVOLATILE ORGANIC COMPOUNDS in bed sediment



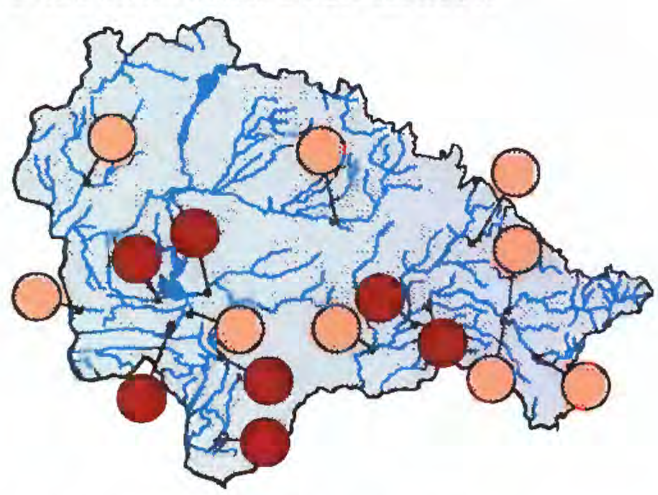
At 7 of 11 sites, concentrations of semivolatile organic compounds are lower than the national median. Three of four sites in the Palouse River drainage basin have levels in the lowest 25 percent of NAWQA sites. At Crab Creek near Beverly in the Quincy-Pasco subunit, levels are in the upper 25 percent of NAWQA sites.

CONCLUSIONS

In the Central Columbia Plateau, compared to other NAWQA study units:

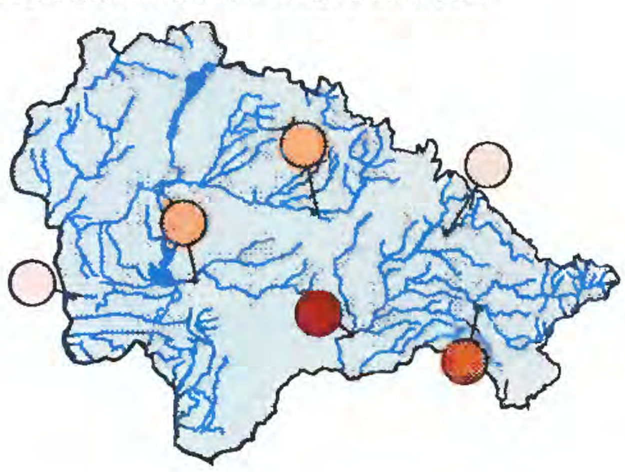
- High levels of nutrients, primarily from fertilizer, are causing eutrophication.
- Levels of pesticides in water and organochlorine compounds in bed sediment and fish tissue are relatively high: at all four sites where pesticides in water were measured over one year, a median concentration exceeded a freshwater-chronic criterion in at least one month; at 2 of 11 bed sediment sites, one or more organochlorine compounds exceeded an aquatic-life guideline.
- Habitat degradation is relatively high: seven of sixteen sites are in the upper 25th percentile, mainly because of reduced canopy cover and increased bank erosion.
- Fish community degradation is moderate.
- Levels of trace elements and semivolatile organic compounds in bed sediment are relatively low.

STREAM HABITAT DEGRADATION



All 16 sites for which stream habitat degradation was evaluated in the Central Columbia Plateau showed some signs of habitat degradation; 44 percent are in the upper 25 percent. Streams in this study unit area have an average of only 20 percent canopy cover, with most having far less. The loss of riparian vegetation, combined with other land use practices, has resulted in streams having an average of 70 percent bank erosion. These factors, combined with high nutrient and sediment loading, have resulted in the majority of streams in this study unit having habitat conditions that are unsuitable for many native species.

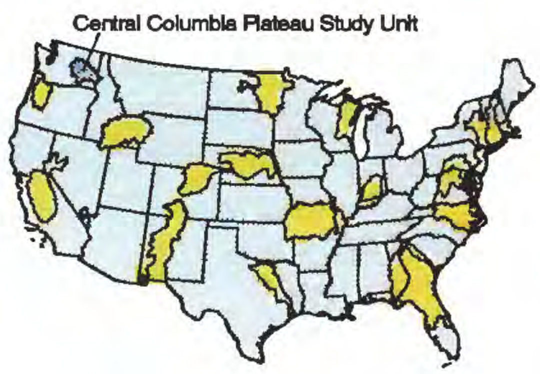
FISH COMMUNITY DEGRADATION



Fish community degradation in the Central Columbia Plateau varies across the national range. Fish communities can be influenced by multiple factors, including pesticides, increased aquatic plant growth due to nutrients, reduced riparian habitat, and sediment runoff from agricultural practices. The two sites with the most impacted fish communities were a wastewater-dominated urban stream and a large dryland farming stream. Small dryland streams associated with spring systems contained the most trout.

Figure 4. Continued.

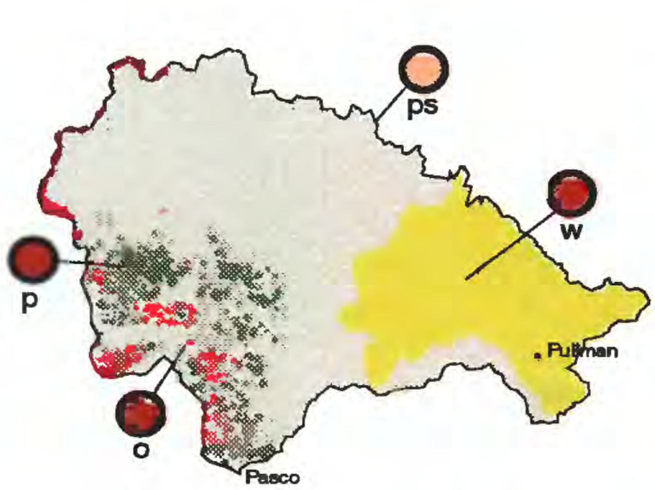
Comparison of Ground-Water Quality in the Central Columbia Plateau with Nationwide NAWQA Findings



Yellow areas indicate other NAWQA study units sampled during 1992–95.

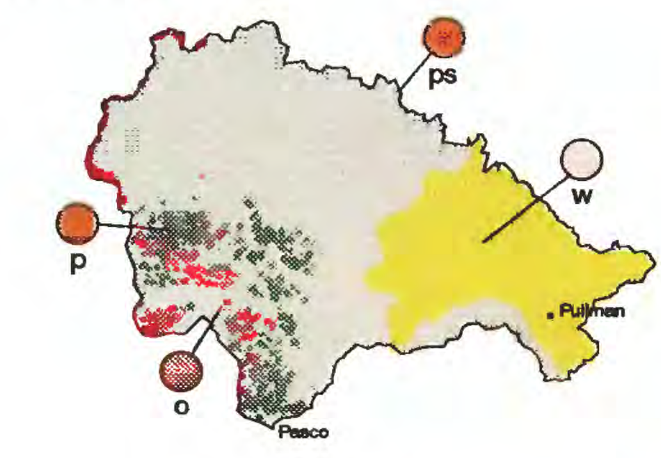
Five major water-quality characteristics were evaluated for ground-water studies in each NAWQA study unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that had adequate data. Scores for each aquifer and shallow ground-water area in the Central Columbia Plateau were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA study units during 1992–95 (see map at left). Results are summarized by percentiles; higher percentile values generally indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer are also compared to established drinking-water standards and criteria for protection of human health.

NITRATE



Median nitrate concentrations in deeper public supply wells are below the national median (50th percentile) for NAWQA drinking water sites. Shallow ground water associated with agricultural land use (wheat, orchards, and potatoes) have median nitrate concentrations that are in the upper 25 percent of NAWQA study median values. In the Central Columbia Plateau, high nitrate concentrations are due primarily to high rates of fertilizer application. Grazing and application of food processing-plant wastes are lesser influences.

PESTICIDES



At three of four sites, pesticide detection frequencies in ground water were greater than the national median. Detection frequencies varied in shallow wells depending on the land use. Pesticide detections associated with potatoes are above the national median, but lower than those associated with orchards. The lowest pesticide detection frequency in shallow ground water was in the Palouse subunit, where wheat is the dominant crop.

EXPLANATION

Shallow wells were sampled in:

- Wheat and small grains (w) (domestic wells)
- Potatoes and corn (p) (domestic and very shallow monitoring wells)
- Orchards (o) (domestic and very shallow monitoring wells)

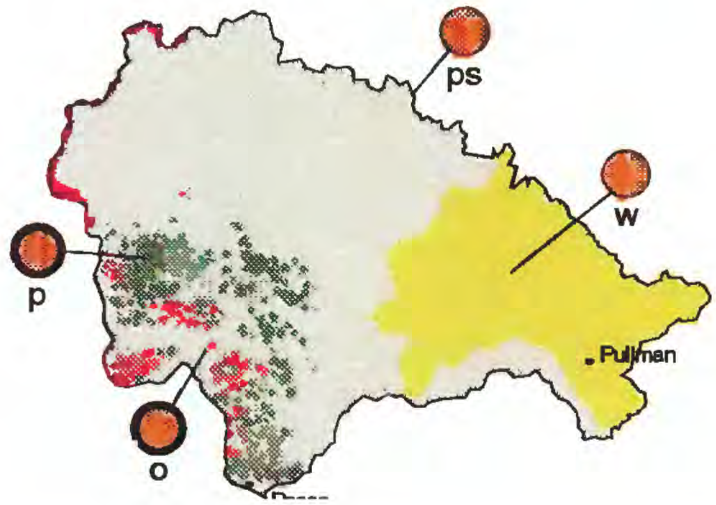
Public supply wells (ps) were sampled across the entire Study Unit

Ranking of ground-water quality relative to ell NAWQA ground-water sites — Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more ground-water standerds were exceeded in at least one wall.

- **Greater than the 75th percentile** (among the highest 25 percent of NAWQA ground-water studies)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile** (among the lowest 25 percent of NAWQA ground-water studies)

Figure 5. Application of water-quality rankings and criteria comparisons for ground water in the Centrel Columbia Plateau study unit.

VOLATILE ORGANIC COMPOUNDS



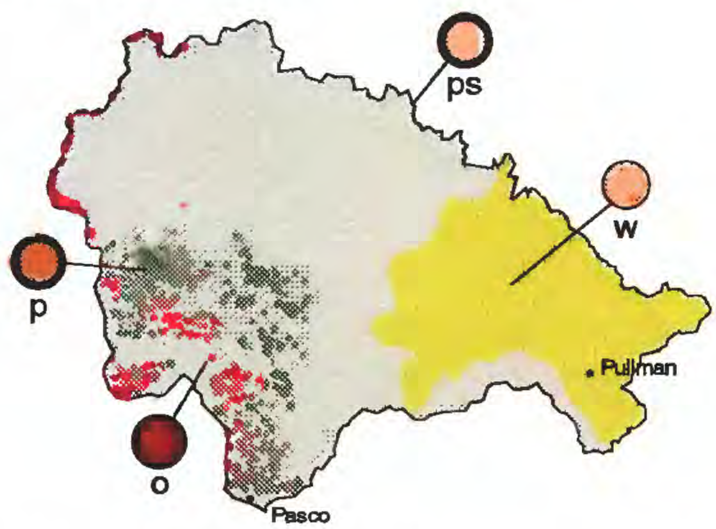
Concentrations of volatile organic compounds (VOCs) in both public supply wells and the more shallow land use wells are generally higher than the national median. The high application rate of fumigants on potatoes may explain the high concentrations of VOCs in the irrigated Quincy-Pasco subunit. Concentrations of several compounds (primarily older, discontinued fumigants) exceed water-quality standards or guidelines in land use wells in the Quincy-Pasco subunit.

CONCLUSIONS

In the Central Columbia Plateau, compared to other NAWQA study units:

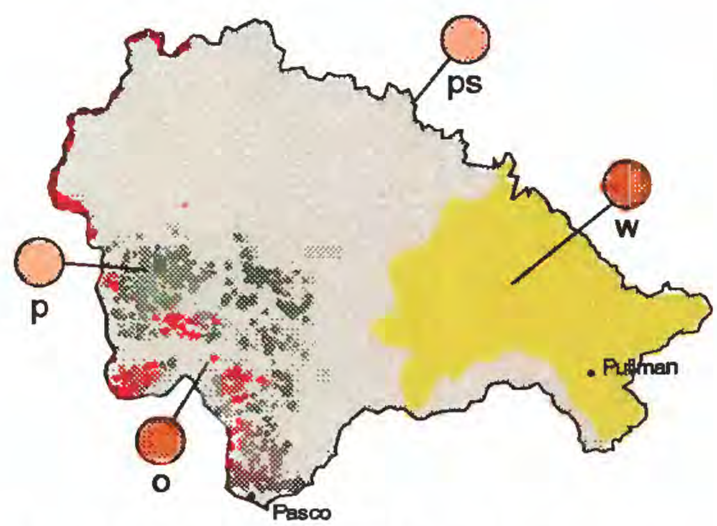
- Nitrate concentrations in ground water are high, with more than 20 percent of the wells exceeding the drinking water standard.
- Pesticides, though frequently detected, are generally at concentrations less than 10 percent of drinking water standards. However, pesticide-related health risks are difficult to assess because standards do not exist for about 40 percent of the pesticides analyzed, or for combinations of pesticides.

DISSOLVED SOLIDS



Dissolved solids in the public supply wells and in the more shallow, dryland farming Palouse subunit wells are below the national median for NAWQA sites. In contrast, dissolved-solids concentrations are greater than the national medians for both potatoes and orchards, with orchards in the upper 25 percent of NAWQA sites. The higher levels in the Quincy-Pasco subunit reflect the influence of irrigation waters.

RADON



Radon, a decay product of radium, occurs naturally in soils. Radon concentrations in public supply wells and potato land use wells are below the national median for NAWQA sites. Wells associated with orchards in the Quincy-Pasco subunit and dryland wheat in the Palouse subunit exceed the national median.

Figure 5. Continued.

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APPENDICES

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units

[N, nutrients in water; P, pesticides in water; O, organochlorine pesticides and polychlorinated biphenyls (PCB) in sediment and tissue; S, semivolatile organic compounds in sediment; T, trace elements in sediment; F, fish communities; H, habitat in stream. km^2, square kilometer; nd, no data]

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km^2)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
Albemarle-Pamlico Drainage								
02047000	3,731	41,417	3	22	0	71	4	N,O,S,T,F,H
02049500	1,583	30,683	3	30	0	60	5	N,O,S,T,F,H
02082731	35	762	1	61	0	37	0	N,P,O,S,T,F,H
02083500	5,754	198,624	5	38	0	50	6	N,P,O,S,T,F,H
02083833	44	617	2	59	0	35	4	N,P,O,S,T,F,H
02084160	109	2,702	3	41	0	40	15	N,O,S,T,F,H
02084540	115	1,193	2	6	0	40	52	O,S,T,F,H
02084557	56	545	0	5	0	81	13	N,O,S,T,F,H
02084558	191	1,272	0	58	0	38	4	N,P,O,S
0208925200	152	9,081	7	60	0	28	3	N,O,F,H
02089500	7,021	738,747	11	37	0	49	2	N,O,S,T,F,H
02091500	1,909	92,917	5	50	0	37	7	N,O,S,T,F,H
Apalachicola-Chattahoochee-Flint Basin								
02332830	47	2,068	1	41	0	57	0	N,O,S,T,F,H
02335000	3,026	180,481	6	16	0	71	0	N,O,S,T
02335870	80	63,157	98	0	0	1	0	N,P,O,S,T,F,H
02336300	221	269,167	99	0	0	1	0	N,O,S,T,F,H
02337500	92	4,035	1	16	0	83	0	N,O,S,T,F,H
02338000	6,245	1,412,481	23	14	0	59	0	N,O,S,T
02350080	161	3,298	0	67	0	28	4	N,P,O,S,T,F,H
02356980	273	2,094	0	59	0	34	6	N,P,O,S,T,F,H
02359170	49,835	2,637,785	6	30	0	58	4	N,O,S,T
Central Columbia Plateau								
12464606	121	332	0	93	5	0	0	N,O,S,T,F,H
12464770	1,188	4,699	0	73	19	7	0	N,P,O,S,T,F,H
12471090	523	1,723	1	73	7	0	3	N,O,S,T,H
12471400	1,820	4,192	1	93	6	0	0	N,O,S,T,F,H
12472380	146	1,643	1	96	3	0	0	N,P,O,S,T,H
12472600	999	5,734	1	44	51	0	3	N,O,S,T
12473508	305	3,362	1	58	38	0	1	N

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km^2)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
12473740	377	6,381	2	96	2	0	0	N,P,H
12513650	1,230	4,172	0	88	12	0	0	N,O,S,T,H
13346000	1,262	4,537	1	49	1	50	0	O,S,T,H
13349200	709	47,013	4	91	0	5	0	N,O,S,T,F,H
13349320	204	1,109	1	99	0	0	0	N,H
13349410	792	2,628	1	93	0	6	0	N,O,S,T,F,H
13351000	6,380	64,093	1	74	11	13	0	N,P,O,S,T,F,H
Central Nebraska Basins								
06765698[6]	nd	nd	nd	nd	nd	nd	nd	F,H
06770500[7]	151,378	2,601,933	2	25	58	13	1	N,O,S,T,F,H
06773050	364	1,633	0	92	8	0	0	N,P,O,S,T,F,H
06775900[7]	2,503	780	0	6	93	0	0	O,S,T,F,H
06791150	32,866	39,351	0	26	73	0	0	N,O,S,T,F,H
06795500	762	3,446	0	98	1	0	0	N,P,O,S,T,F,H
06800000	955	4,050	0	99	0	0	0	N,P,O,S,T,F,H
06800500[7]	17,989	133,918	1	84	14	1	0	N,O,S,T,F,H
06805500[7]	221,496	3,154,705	1	34	53	9	1	N,P,O,S,T,F,H
Connecticut, Housatonic, and Thames River Basins								
01135300	111	1,618	0	28	0	72	0	N,O,S,T,F,H
01137500	229	953	2	1	0	94	0	N,F,H
01144000	1,790	20,879	1	19	0	80	0	N,O,S,T,F,H
01170100	107	1,123	1	7	0	92	0	N,O,S,T,F,H
01184000[8]	25,050	1,107,031	5	11	0	83	2	N,O,S,T
01184490	38	5,348	8	55	0	32	0	N,O,S,T,F,H
01189000	116	58,586	43	7	0	48	0	N,O,S,T,F,H
01192500	191	94,655	51	11	0	35	0	N,O,S,T,F,H
01199900	499	19,289	3	43	0	52	0	N,O,S,T,F,H
01200600	2,647	131,944	8	20	0	68	2	N,O,S,T
01208873	26	45,726	98	0	0	1	0	N,O,S,T,F,H
01209710	85	21,498	50	4	0	44	0	N,P,O,S,T,F,H
Georgia–Florida Coastal Plain								
02215100	420	3,807	2	56	0	41	1	N,P,O,S,T,F,H
02216180	129	1,358	1	30	0	69	0	N,O,S,T,F,H

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km^2)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
02226160	36,541	1,811,554	5	26	0	63	5	N,O,S,T
02229000	326	1,100	1	0	0	65	31	N,O,S,T,F,H
02300700	74	5,334	7	52	25	10	5	N,O,S,T,F,H
02317797	335	6,498	1	67	0	12	20	N,P,O,S,T,F,H
02318500	3,864	127,367	3	56	0	34	7	N,P,O,S,T,F,H
02320500	20,415	304,922	2	31	0	48	19	N,O,S,T
02326838	25	16,955	91	0	0	8	0	N,P,O,S,T,H
Hudson River Basin								
01325010	7,046	44,303	1	1	0	91	3	N,O,S,T
01334500	1,324	73,393	9	21	0	70	0	N,O,S,T,H
01335770	11,978	331,685	4	15	0	76	2	N,O,S,T
01349150	155	2,796	1	66	3	29	0	N,P,O,S,T,F,H
01351450	2,266	39,461	2	30	2	64	0	N,O,S,T
01356190	40	20,961	77	7	0	15	0	N,P,O,S,T,F,H
01357500	9,113	608,972	7	33	2	55	2	N,P,O,S,T
01361200	158	5,496	11	42	0	46	1	N,O,S,T,F,H
01362200	169	1,014	2	1	3	94	0	N,O,S,T,F,H
01371500	1,866	194,273	10	53	0	34	0	N,O,S,T,F,H
01372043	30,890	1,812,159	7	25	1	63	1	N,O,S,T
01372051	49	20,147	29	28	0	43	0	N,O,S,T,F,H
01376304	34,570	2,595,169	9	25	1	62	1	N,O,S,T
01376500	63	65,879	85	0	0	13	0	N,O,S,T,F,H
Lower Susquehanna River Basin								
01555400	116	1,642	0	69	0	31	0	N,P,O,S,T,F,H
01559795	43	642	0	14	0	86	0	N,F,H
01564997	149	5,899	1	59	0	40	0	N,O,S,T,F,H
01571490	33	23,246	78	21	0	1	0	N,P,F,H
01573095	20	1,214	1	84	0	15	0	N,O,S,T,F,H
01576540	141	23,189	16	77	0	7	0	N,P,O,S,T,F,H
01577300	186	10,085	1	75	0	24	0	N,O,S,T,F,H
Nevada Basin and Range								
094196783	2,640	472,393	9	0	68	22	0	N,P,O,S,T
09419790	4,028	709,791	11	0	74	14	0	N

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km²)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
10309010	970	1,006	0	0	24	72	0	N,O,S,T,F,H
10311400	2,483	60,591	2	8	31	55	1	N,O,S,T,F,H
10312000	3,196	66,372	2	7	37	51	1	N,O,S,T,F,H
10312275[6]	nd	nd	nd	nd	nd	nd	nd	N,O,S,T
10346000	2,416	62,931	5	0	8	61	1	N,O,S,T,H
10348200	2,762	113,942	6	0	14	57	1	N,O,S,T,F,H
10350500	4,122	282,979	7	2	29	45	1	N,O,S,T,F,H
10351690	4,680	284,873	6	2	36	41	1	N,O,S,T,F,H
Ozark Plateaus								
06923150	106	788	1	57	0	42	0	N,P,O,S,T,F,H
06923250	873	11,968	2	58	0	40	0	N,O,S,T,F,H
06929315	79	211	0	11	0	89	0	N,O,S,T,F,H
07050500	1,367	8,900	1	30	0	68	0	N,O,S,T,F,H
07053250	134	2,075	1	73	0	24	0	N,P,O,S,T,F,H
07055646	153	240	0	4	0	96	0	N,O,S,T,F,H
07056000	2,149	7,800	0	13	0	86	0	N,O,S,T,F,H
07060710	150	325	0	2	0	98	0	N,O,S,T,F,H
07061600	1,282	3,945	0	6	0	93	0	N,O,S,T,F,H
07065495	789	5,140	1	25	0	74	0	N,O,S,T,F,H
07067000	4,349	17,014	0	17	0	83	0	O,S,T,F,H
07186480	763	27,732	4	77	0	16	0	N,O,S,T,F,H
07189000	2,201	47,611	2	46	0	51	0	N,O,S,T,F,H
07196500	2,454	135,214	6	56	0	36	0	N,O,S,T,F,H
Potomac River Basin								
01603000	2,268	86,637	4	12	0	81	0	N,O,T,F
01608000	724	2,671	0	14	0	86	0	N,O,S,T,F,H
01608500	3,784	28,591	1	22	0	78	0	N,O,S,T,F,H
01614500	1,305	78,475	5	59	0	36	0	N,O,S,T,F,H
01621050	37	997	5	72	0	22	0	N,P,O,S,T,F,H
01636500	7,880	292,594	7	40	0	51	0	N,P,O,S,T
01638480	233	5,851	1	81	0	18	0	N,O,S,T,F,H
01639000	457	30,120	3	77	0	20	0	N,P,O,S,T,F,H
01643020	2,121	174,137	5	71	0	23	0	N,O,S,T,F,H

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km^2)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
01646580	29,975	1,695,481	6	39	0	54	0	N
01654000	60	85,667	98	0	0	2	0	N,P,O,S,T,F,H
Red River of the North Basin								
05030150	870	5,800	0	25	0	53	9	N,O,S,T,F,H
05046000	4,501	55,667	1	56	0	23	5	N
05051300	4,022	12,121	0	94	0	0	3	N,F,H
05053800	17,131	100,859	1	85	1	6	2	P,F,H
05058700[7]	11,636	25,687	0	85	10	1	2	N,O,S,T,F,H
05059000[7]	12,966	28,517	0	84	11	1	1	N
05062500	2,407	7,717	0	50	0	37	8	N,P,O,S,T,F,H
05064500	44,735	302,426	1	85	4	5	2	N
05079000	13,644	43,742	0	43	0	23	24	N,F,H
05082500[7]	66,501	435,719	1	78	3	9	6	N,O
05082625	658	1,737	1	96	1	1	1	N,P,O,S,T,F,H
05085900	566	2,177	1	91	0	4	3	N,P,O,S,T,F,H
05099600[8]	8,293	6,200	0	90	2	6	2	N,O,S,T,F,H
05102490[8]	92,086	500,737	1	83	2	8	6	N,P,O,S,T
05112000[8]	4,030	8,699	0	54	0	16	30	N,O,S,T,F,H
Rio Grande Valley								
08220000	3,398	1,339	0	2	25	62	0	N,F,H
08227000	1,327	149	0	1	29	67	0	N,O,S,T,F,H
08240000	7,119	26,750	0	14	39	40	0	N
08249000	2,043	3,155	0	10	43	44	0	N,F,H
08251500	11,876	33,018	0	12	41	41	0	N
08276500	16,911	52,976	1	10	42	43	0	N,O,S,T,F,H
08290000	7,958	8,528	0	2	19	78	0	N,O,S,T,F,H
08313000	28,381	102,560	1	7	32	57	0	N
08313350	47	485	0	0	3	97	0	N,H
08317200	591	71,310	13	1	25	59	0	N,O,S,T,H
08331000	37,994	729,122	2	6	30	60	0	N,P,O,S,T,F,H
08353000	15,725	30,483	0	1	55	43	0	N,O,S,T
08358300[6]	nd	nd	nd	nd	nd	nd	nd	N,O,S,T
08358400	63,713	823,672	1	4	42	50	0	N

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km²)	Population[2] (1990)	Land use[3] (percentage of basin area) Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	Characteristics included
08363500	74,747	837,958	1	4	47	46	0	N
08364000	77,556	1,035,105	2	4	48	44	0	N,F,H
374752105300801	40	17	0	0	1	88	0	N,O,S,T,H
			San Joaquin–Tulare Basins					
11261100[9]	1,224	26,205	2	79	2	0	16	N,P,O,S,T,F,H
11262900[9]	1,224	26,205	2	79	2	0	16	N,O,S,T,F,H
11273500	3,619	39,393	1	13	15	68	0	N,P,O,S,T,F,H
11274538	27	181	0	96	3	0	0	N,P,O,S,T,F,H
11274554	56	1,183	3	97	0	0	0	N,O,S,T,F
11274560	224	42,106	14	84	0	0	0	N,O,S,T
11274570	9,677	239,864	2	32	24	37	4	N,O,S,T,F,H
11290000	4,770	115,194	3	4	17	68	0	N,O,S,T,F,H
11303000	2,877	47,567	2	7	14	71	0	N,O,S,T,F,H
11303500	19,024	620,848	3	23	21	48	2	N,P,O,S,T,F,H
			South Platte River Basin					
06713500	61	111,912	96	2	1	0	0	N,P,O,S,T,F,H
06714000	10,009	826,753	6	5	34	48	0	N,O,S,T,F,H
06719505	1,003	10,321	3	0	10	66	0	N,O,S,T,F,H
06720500	12,510	1,635,471	10	7	31	44	0	N,O,S,T,F,H
06731000	2,562	225,940	9	28	9	44	0	N,O,S,T,F,H
06752000	2,664	1,952	0	1	27	66	0	N,O,S,T,F,H
06753400	445	339	2	2	95	1	0	N,O,S,T,F,H
06753990	1,473	2,543	1	33	65	0	0	N,P,O,S,T,H
06754000	25,144	2,180,427	7	20	28	38	0	N,O,S,T,F,H
06759910	43,519	2,289,779	4	28	40	23	0	N,O,S,T,F,H
06765500	62,486	2,350,364	3	36	41	16	1	N,O,S,T,F,H
402114105350101	99	25	0	0	0	44	2	O,F,H
			Trinity River Basin					
08044000	870	11,292	2	44	31	21	0	N,O,S,T,F,H
08048543	6,918	390,992	5	38	38	15	0	N,O,S,T,F,H
08049240	73	60,528	63	30	1	5	0	N,P,O,S,T,F,H

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km^2)	Population[2] (1990)	Land use[3] (percentage of basin area)					Characteristics included
			Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	
08051500	773	4,719	0	53	38	8	0	N,O,S,T,F
08057410	16,293	2,818,193	14	50	23	11	0	N,P,O,S,T,F
08058900	439	6,590	2	93	0	4	0	N,O,S,T,F,H
08064100	2,131	60,163	3	92	2	2	0	N,P,O,S,T,F,H
08065800	867	7,339	1	67	7	24	0	N,O,S,T,F,H
08066295	284	2,453	1	5	0	93	0	N,O,S,T,F,H
08066500	44,660	4,168,168	8	56	10	23	0	N,O,S,T,F,H
Upper Snake River Basin								
13010065	1,324	122	0	0	9	83	1	N,O,S,T,F,H
13027500	2,206	6,489	0	18	30	51	0	N,O,S,T,F,H
13055000	2,294	4,546	0	39	15	38	2	N,P,O,S,T
13056500	8,337	35,017	0	26	19	50	2	N,O,S,T,F
13069500	31,558	173,754	1	19	29	45	1	N,O,S,T,F
13073000	1,523	1,968	0	34	53	11	0	N,O,S,T,F,H
13081500	48,830	259,235	1	23	38	33	1	N,O,S,T,F
13092747	623	8,150	2	22	52	23	0	N,P,O,S,T,F,H
13094000	76,104	358,626	1	21	46	25	1	N,O,S,T,F
13120500	1,144	226	0	0	49	31	1	N,O,S,T,F,H
13152500	8,607	20,224	0	14	65	13	0	N,O,S,T,F
13154500	92,941	401,127	1	20	50	23	1	N,O,S,T,F
Western Lake Michigan Drainages								
04062085	114	100	0	0	0	88	10	N,O,S,T,F,H
04063700	363	488	0	3	0	61	35	N,O,S,T,F,H
04067500	10,156	59,422	1	6	0	75	16	N,O,S,T,H
04071795	87	1,087	0	86	0	4	9	N,O,S,T,F,H
04072050	247	7,052	1	89	0	5	5	N,P,O,S,T,F,H
04080798	114	1,186	0	58	0	31	9	N,O,S,T,F,H
04085109	122	2,274	1	91	0	5	2	N,O,S,T,H
04085139	16,429	645,015	3	52	0	26	13	N,O,S,T,H
040863075	133	2,838	1	88	0	6	4	N,P,O,S,T,F,H
040869415	26	56,680	100	0	0	0	0	N,O,S,T,F,H
04087000	1,804	352,027	13	73	0	8	4	N,P,O,S,T,H

Appendix A: Characteristics of surface-water sampling sites in the first 20 National Water-Quality Assessment study units—Continued

Site number (see fig. 1 for study-unit locations)	Basin area[1] (km²)	Population[2] (1990)	Land use[3] (percentage of basin area) Urban[4]	Cropland and pasture[5]	Range-land	Forest	Wetland	Characteristics included
White River Basin								
03353637	45	25,491	57	42	0	0	0	N,P,O,S,T,F,H
03354000	6,325	1,292,245	18	78	0	3	0	N,O,S,T,H
03360895	146	2,101	2	94	0	4	0	N,P,O,S,T,F,H
03366500	755	12,182	4	71	0	24	0	N,O,S,T,F,H
03373500	12,751	526,776	5	69	0	25	0	N,O,S,T,F,H
03373530	90	957	1	94	0	5	0	N,O,S,T,F,H
03374100	29,291	2,072,945	7	69	0	22	0	N,P,O,S,T,F,H
385234087071801	12,434	1,462,323	10	70	0	19	0	N,O,S,T,H
391732085414401	228	2,396	1	98	0	1	0	N,O,S,T,F,H
393306086585201	825	19,859	1	83	0	14	0	N,O,S,T,F,H
394340085524601	246	8,291	3	95	0	1	0	N,P,O,S,T,F,H
Willamette Basin								
14200400	25	86	0	4	0	96	0	N,O,S,T,F,H
14201300	39	2,134	1	98	0	0	0	N,P,O,S,T,F,H
14202000	1,261	65,313	5	58	0	36	0	N,P,O,S,T,F,H
14203750	18	67	0	0	0	100	0	N,O,S,T,F,H
14206950	80	96,508	92	2	0	5	0	N,P,O,S,T,F,H
14207500	1,832	358,665	17	35	0	48	0	N,O,S,T,F,H
14211720	28,937	1,611,539	6	23	0	70	0	N,P,O,S,T,F,H

[1]Contributing area of the basin.
[2]Population is based on 1990 Census of Population and Housing (Bureau of the Census, 1991).
[3]Land use information is based on U.S. Geologcial Survey's Land Use and Land Cover data (U.S. Geological Survey, 1990). The land use land cover categories that were applied are based on the classification system developed by Anderson and others (1975). The land use classifications not included in this table are water, barren land, tundra, and perennial snow or ice.
[4]Urban percentages include refinements to residential areas based upon the 1990 Census of Population and Housing (Bureau of the Census, 1991). Methods are described by Hitt (1994).
[5]Cropland and pasture includes orchards, groves, vineyards, nurseries, and ornamental horticultural areas.
[6]Drainage areas for these sites could not be delineated because stream flow is controlled by man-made structures and water management decisions.
[7]Drainage basin includes some noncontributing areas.
[8]Land use in Canadian part of the basin estimated from data for the United States part.
[9]These two sloughs drain varying areas of the same basin during different times of the year.

APPENDIX B: Ground-water studies and their characteristics

[DWA, drinking-water aquifer; SGW, shallow ground water; LUS, land-use studies; AS, aquifer surveys; N, nutrients in water; P, pesticides in ground water; V, volatile organic compounds in water; D, dissolved solids in water; R, radon in water]

Study-area code (see fig. 1 for study-unit location)	Number of sampling sites	Type of resource	Type of study	Primary land use	Characteristics included
		Albemarle-Pamlico Drainage			
albelus1	20	DWA, SGW	LUS	agriculture	N,P,V,D
albelusur	15	DWA, SGW	LUS	urban	N,P,V,D
albesus1	12	DWA	AS	mixed	N,P,V,D
albesus2	15	DWA	AS	mixed	N,P,V,D
		Apalachicola-Chattahoochee-Flint Basin			
acfblusag1	18	SGW	LUS	agriculture	N,P,V,D,R
acfbluscr1	10	SGW	LUS	agriculture	N,P,D
acfbluscr2	10	SGW	LUS	agriculture	N,P,D
acfblusur1	21	SGW	LUS	urban	N,P,V,D,R
acfblusur2	19	SGW	LUS	urban	N,P,V,D,R
acfbsus1	26	DWA	AS	mixed	N,P,V,D,R
acfbsus2	15	DWA	AS	mixed	N,P,V,D,R
		Central Columbia Plateau			
ccptlusag1a	19	DWA, SGW	LUS	agriculture	N,P,V,D,R
ccptlusag1b	10	SGW	LUS	agriculture	P
ccptlusag2	49	DWA, SGW	LUS	agriculture	N,P,V,D,R
ccptlusor1	40	DWA, SGW	LUS	agriculture	N,P,V,D,R
ccptsus1d	139	DWA	AS	mixed	N,P,V,D,R
		Central Nebraska Basins			
cnbrsus1	11	DWA, SGW	AS	mixed	N,P,V,D
		Connecticut, Housatonic, and Thames River Basins			
connlusag	40	SGW	LUS	agriculture	N,P,V,D
connlusfo	40	SGW	LUS	forest	N,P,D
connlusur	40	SGW	LUS	urban	N,P,V,D
connsus1	30	DWA	AS	mixed	N,P,V,D,R
		Georgia-Florida Coastal Plain			
gaflluscr	23	SGW	LUS	agriculture	N,P,V,D,R
gafllusur3a	16	SGW	LUS	urban	N,P,V,D,R
gaflsus	37	SGW	AS	mixed	N,P,V,D,R
		Hudson River Basin			
hdsnlusag1	15	SGW	LUS	agriculture	N,P,D
hdsnlusur	29	DWA, SGW	LUS	urban	N,P,V,D,R
hdsnsus1	48	DWA	AS	mixed	N,P,V,D,R
		Lower Susquehanna River Basin			
lsuslus1	30	DWA, SGW	LUS	agriculture	N,P,V,D,R
lsuslus2	30	DWA, SGW	LUS	agriculture	N,P,D,R
lsuslus3	30	DWA, SGW	LUS	agriculture	N,P,V,D,R

APPENDIX B: Ground-water studies and their characteristics—Continued

Study-area code (see fig. 1 for study-unit location)	Number of sampling sites	Type of resource	Type of study	Primary land use	Characteristics included
lsuslus4	20	DWA, SGW	LUS	urban	N,P,V,D,R
lsussus1	29	DWA, SGW	AS	mixed	N,P,V,D,R
lsussus2	30	DWA, SGW	AS	mixed	N,P,V,D,R
		Nevada Basin and Range			
nvbrlusag1	20	SGW	LUS	agriculture	N,P,V,D,R
nvbrlusag2	10	SGW	LUS	agriculture	N,P,V,D
nvbrlusur1	33	SGW	LUS	urban	N,P,V,D,R
nvbrlusur2	28	SGW	LUS	urban	N,P,V,D,R
nvbrsus1	22	DWA	AS	mixed	N,P,V,D,R
nvbrsus2	18	DWA	AS	mixed	N,P,V,D,R
nvbrsus3	17	DWA	AS	mixed	N,P,V,D,R
		Ozark Plateaus			
ozrklusag1a	20	DWA, SGW	LUS	agriculture	N,P,D
ozrklusag1b	22	DWA, SGW	LUS	agriculture	N,P,D
ozrklusag2a	20	DWA, SGW	LUS	agriculture	N,P,D
ozrklusag2b	20	DWA, SGW	LUS	agriculture	N,P,D
ozrksus1	20	DWA	AS	mixed	N,P,D,R
ozrksus2a1	33	DWA, SGW	AS	mixed	N,P,V,D,R
ozrksus2a2	30	DWA, SGW	AS	mixed	N,P,D
ozrksus2b1	16	DWA, SGW	AS	mixed	N,P,V,D,R
ozrksus2b2	20	DWA, SGW	AS	mixed	N,P,D
		Potomac River Basin			
potolusag1	29	DWA, SGW	LUS	agriculture	N,P,V,D,R
potolusag2	25	DWA, SGW	LUS	agriculture	N,P,D,R
potosus1	25	DWA, SGW	AS	mixed	N,P,D,R
potosus2	23	DWA, SGW	AS	mixed	N,P,D,R
		Red River of the North Basin			
rednlus1	29	DWA, SGW	LUS	agriculture	N,P,D,R
rednlus2	29	DWA, SGW	LUS	agriculture	N,P,V,D,R
rednsus1	29	DWA	AS	mixed	N,P,D,R
rednsus2	25	DWA	AS	mixed	N,P,V,D,R
rednsus3	26	DWA	AS	mixed	N,P,D
rednsus5	42	DWA	AS	mixed	N,P,D,R
		Rio Grande Valley			
rioglusag	30	SGW	LUS	agriculture	N,P,V,D,R
riogluscr	35	SGW	LUS	agriculture	N,P,V,D,R
rioglusur	24	SGW	LUS	urban	N,P,V,D,R
riogsus	30	DWA	AS	mixed	N,P,V,D,R

APPENDIX B: Ground-water studies and their characteristics—Continued

Study-area code (see fig. 1 for study-unit location)	Number of sampling sites	Type of resource	Type of study	Primary land use	Characteristics included
		San Joaquin–Tulare Basins			
sanjlus41	20	DWA, SGW	LUS	agriculture	N,P,V,D,R
sanjlus51	20	DWA, SGW	LUS	agriculture	N,P,V,D,R
sanjlus61	20	DWA, SGW	LUS	agriculture	N,P,V,D,R
sanjsus1	30	DWA	AS	mixed	N,P,V,D,R
		South Platte River Basin			
spltluscr	30	SGW	LUS	agriculture	N,P,V,D,R
spltlusur	30	SGW	LUS	urban	N,P,V,D,R
spltsus1	27	DWA	AS	mixed	N,P,V,D,R
		Trinity River Basin			
trinlusur1	20	SGW	LUS	urban	N,P,V,D
trinsus1	24	DWA	AS	mixed	N,P,V,D
trinsus2	23	DWA	AS	mixed	N,P,V,D
trinsus3	24	DWA	AS	mixed	N,P,V,D
		Upper Snake River Basin			
usnkluscr1	29	DWA, SGW	LUS	agriculture	N,P,V,D,R
usnkluscr2	31	DWA, SGW	LUS	agriculture	N,P,V,D,R
usnkluscr3	30	DWA, SGW	LUS	agriculture	N,P,V,D,R
usnkluscr4	15	DWA, SGW	LUS	agriculture	N,P,V,D,R
usnksus1	43	DWA	AS	mixed	N,P,R
usnksus2	39	DWA	AS	mixed	N,P,R
usnksus3	20	DWA	AS	mixed	N,P,V,D,R
		Western Lake Michigan Drainages			
wmiclusag11	26	SGW	LUS	agriculture	N,P,V,D
wmiclusag21	30	SGW	LUS	agriculture	N,P,V,D
wmicsus1	29	DWA	AS	mixed	N,P,V,D,R
		White River Basin			
whitlus1	23	SGW	LUS	agriculture	N,P,V,D
whitlus2	22	SGW	LUS	agriculture	N,P,V,D
whitlus3	24	DWA, SGW	LUS	agriculture	N,P,V,D,R
whitlus4	25	DWA, SGW	LUS	urban	N,P,V,D,R
		Willamette Basin			
willlus1	15	SGW	LUS	agriculture	N,P,V,D,R
willlus2	28	SGW	LUS	agriculture	N,P,V,D,R
willlusur	10	SGW	LUS	urban	N,P,V,D
willsus	70	DWA	AS	mixed	N,P,V,D,R

APPENDIX C: Nutrients included in chemical analysis of water samples and used in computing water-quality scores

[CAS, Chemical Abstracts Service. mg/L, milligrams per liter; NA, not available]

Compound	CAS number	WATSTORE code	Method reporting limit (mg/L)
Ammonia	7664-41-7	00608	0.02
Nitrite plus nitrate	NA	00631	0.05
Total phosphorus	7723-14-0	00666	0.01

APPENDIX D: Pesticide compounds included in chemical analysis of water samples and used in computing water-quality scores

[CAS, Chemical Abstracts Service; HPLC, high-pressure liquid chromatography; GCMS, gas chromatography/mass spectroscopy. µg/L, microgram per liter]

Compound	CAS number	WATSTORE code	Analytical method	Method reporting limit (µg/L)
		Herbicides		
Acetochlor	34256-82-1	49260	GCMS	0.002
Acifluorfen	50594-66-6	49315	HPLC	0.035
Alachlor	15972-60-8	46342	GCMS	0.002
Atrazine	1912-24-9	39632	GCMS	0.001
Benfluralin	1861-40-1	82673	GCMS	0.002
Bentazon	25057-89-0	38711	HPLC	0.014
Bromacil	314-40-9	04029	HPLC	0.035
Bromoxynil	1689-99-2	49311	HPLC	0.035
Butylate	2008-41-5	04028	GCMS	0.002
Clopyralid	1702-17-6	49305	HPLC	0.23
Chloramben	133-90-4	49307	HPLC	0.42
Cyanazine	21725-46-2	04041	GCMS	0.004
2,4-D	94-75-7	39732	HPLC	0.15
Dacthal monoacid	887-54-7	49304	HPLC	0.017
2,4-DB	94-82-6	38746	HPLC	0.24
DCPA (Dacthal)	1861-32-1	82682	GCMS	0.002
Deethylatrazine	6190-65-4	04040	GCMS	0.002
Dicamba	1918-00-9	38442	HPLC	0.035
Dichlobenil	1194-65-6	49303	HPLC	1.20
Dichlorprop	120-36-5	49302	HPLC	0.032
2,6-Diethylaniline	579-66-8	82660	GCMS	0.003
Dinoseb	88-85-7	49301	HPLC	0.035
Diuron	330-54-1	49300	HPLC	0.02
DNOC	534-52-1	49299	HCLP	0.42
EPTC (Eptam)	759-94-4	82668	GCMS	0.002
Ethalfluralin	55283-68-6	82663	GCMS	0.004
Fenuron	101-42-8	49297	HPLC	0.013
Fluometuron	2164-17-2	38811	HPLC	0.035
Linuron	330-55-2	82666	GCMS	0.002
MCPA	94-74-6	38482	HPLC	0.17
MCPB	94-81-5	38487	HPLC	0.14
Metolachlor	51218-45-2	39415	GCMS	0.002
Metribuzin	21087-64-9	82630	GCMS	0.004
Molinate	2212-67-1	82671	GCMS	0.004
Napropamide	15299-99-7	82684	GCMS	0.003
Neburon	555-37-3	49294	HPLC	0.015
Norfurazone	27314-13-2	49293	HPLC	0.024
Oryzalin	19044-88-3	49292	HPLC	0.31
Pebulate	1114-71-2	82669	GCMS	0.004
Pendimethalin	40487-42-1	82683	GCMS	0.004
Picloram	1918-02-1	49291	HPLC	0.05
Prometon	1610-18-0	04037	GCMS	0.018
Pronamide (Propyzamide)	23950-58-5	82676	GCMS	0.003
Propachlor	709-98-8	82679	GCMS	0.007

APPENDIX D: Pesticide compounds included in chemical analysis of water samples and used in computing water-quality scores—Continued

Compound	CAS number	WATSTORE code	Analytical method	Method reporting limit (μg/L)
Propanil	2312-35-8	82685	GCMS	0.004
Propham	122-42-9	49236	HPLC	0.035
Simazine	122-34-9	04035	GCMS	0.005
2,4,5-T	93-76-5	39742	HPLC	0.035
Tebuthiuron	34014-18-1	82670	GCMS	0.01
Terbacil	5902-51-2	82665	GCMS	0.007
Thiobencarb	28249-77-6	82681	GCMS	0.002
2,4,5-TP (Silvex)	93-72-1	39762	HPLC	0.021
Triallate	2303-17-5	82678	GCMS	0.001
Triclopyr	55335-06-3	49235	HPLC	0.25
Trifluralin	1582-09-8	82661	GCMS	0.002
	Insecticides and Fungicides			
Aldicarb	116-06-3	49312	HPLC	0.55
Aldicarb sulfone	1646-88-4	49313	HPLC	0.10
Aldicarb sulfoxide	1646-87-3	49314	HPLC	0.021
Azinphos-methyl	86-50-0	82686	GCMS	0.001
Carbaryl	63-25-2	82680	GCMS	0.003
Carbofuran	1563-66-2	82674	GCMS	0.003
Chlorothalonil	1897-45-6	49306	HPLC	0.48
Chlorpyrifos	2921-88-2	38933	GCMS	0.004
p,p´-DDE	72-55-9	34653	GCMS	0.006
Diazinon	333-41-5	39572	GCMS	0.002
Dieldrin	60-57-1	39381	GCMS	0.001
Disulfoton	298-04-4	82677	GCMS	0.017
Ethoprop	13194-48-4	82672	GCMS	0.003
Fonofos	944-22-9	04095	GCMS	0.003
α-HCH	319-84-6	34253	GCMS	0.002
γ-HCH (Lindane)	58-89-9	39341	GCMS	0.004
3-Hydroxycarbofuran	16655-82-6	49308	HPLC	0.014
Malathion	121-75-5	39532	GCMS	0.005
Methiocarb	2032-65-7	38501	HPLC	0.026
Methomyl	16752-77-5	49296	HPLC	0.017
Methyl parathion	298-00-0	82667	GCMS	0.006
Oxamyl	23135-22-0	38866	HPLC	0.018
Parathion	56-38-2	39542	GCMS	0.004
Permethrin	5264-55-3	82687	GCMS	0.005
Phorate	298-02-2	82664	GCMS	0.002
Propargite	23950-58-5	82676	GCMS	0.013
Propoxur	114-26-1	38538	HPLC	0.035
Terbufos	13071-79-9	82675	GCMS	0.013

APPENDIX E: Organochlorine pesticides and PCBs included in chemical analysis of bed sediment samples and used in computing water-quality scores

[PCBs, polychlorinated biphenyls; CAS, Chemical Abstracts Service. µg/kg, microgram per kilogram; na, not analyzed]

Compound	CAS number	Bed sediment	
		WATSTORE code	Method reporting limit (µg/kg dry weight)
Aldrin	309-00-2	49319	1
cis-Chlordane	5103-71-9	49320	1
trans-Chlordane	5103-74-2	49321	1
Chloroneb	2675-77-6	49322	5
DCPA (Dacthal)	1861-32-1	49324	5
o,p′-DDD	53-19-0	49325	1
p,p′-DDD	72-45-8	49326	1
o,p′-DDE	3424-82-6	49327	1
p,p′-DDE	72-55-9	49328	1
o,p′-DDT	789-02-6	49329	2
p,p′-DDT	50-29-3	49330	2
Dieldrin	60-57-1	49331	1
Endosulfan I	959-98-8	49332	1
Endrin	72-20-8	49335	2
α-HCH	319-84-6	49338	1
β-HCH	319-85-7	49339	1
γ-HCH (Lindane)	58-89-9	49345	1
δ-HCH	319-86-8	na	na
Heptachlor	76-44-8	49341	1
Heptachlor epoxide	1024-57-3	49342	1
Hexachlorobenzene	118-74-1	49343	1
Isodrin	465-73-6	49344	1
o,p′-Methoxychlor	30667-99-3	49347	5
p,p′-Methoxychlor	72-43-5	49346	5
Mirex	2385-85-5	49348	1
cis-Nonachlor	5103-73-1	49316	1
trans-Nonachlor	39765-80-5	49317	1
Oxychlordane	27304-13-8	49318	1
total PCBs	1336-36-3	49459	100
Pentachloroanisole	1825-21-4	49460	1
cis-Permethrin	52774-45-7	49349	5
trans-Permethrin	51877-74-8	49350	5
Toxaphene	8001-35-2	49351	200
α-HCH	319-85-7	49339	1
γ-HCH (Lindane)	58-89-9	49345	1
δ-HCH	319-86-8	na	na

APPENDIX F: Semivolatile organic compounds included in chemical analysis of bed sediment samples and used in computing water-quality scores

[CAS, Chemical Abstracts Service; PAH, polycyclic aromatic hydrocarbon. µg/kg, microgram per kilogram. NA, not available]

Compound	CAS number	WATSTORE code	Method reporting limit (µg/kg dry weight)
	PAHs		
Acenaphthene	83-32-9	49429	50
Acenaphthylene	208-96-8	49428	50
Anthracene	120-12-7	49434	50
Benz[*a*]anthracene	56-55-3	49436	50
Benzo[*b*]fluoranthene	205-99-2	49458	50
Benzo[*k*]fluoranthene	207-08-9	49397	50
Benzo[*ghi*]perylene	191-24-2	49408	50
Benzo[*a*]pyrene	50-32-8	49389	50
2-Chloronaphthalene	91-58-7	49407	50
Chrysene	218-01-9	49450	50
Dibenzo[*ah*]anthracene	53-70-3	49461	50
Dibenzothiophene	132-65-0	49452	50
1,2-Dimethylnaphthalene	573-98-8	49403	50
1,6-Dimethylnaphthalene	575-43-9	49404	50
2,6-Dimethylnaphthalene	581-42-0	49406	50
2-Ethylnaphthalene	939-27-5	49490	50
Fluoranthene	206-44-0	49466	50
Fluorene	86-73-7	49399	50
Indeno[1,2,3-*cd*]-pyrene	193-39-5	49390	50
2-Methylanthracene	613-12-7	49435	50
4,5-Methylenephenanthrene	203-64-5	49411	50
1-Methyl-9*H*-fluorene	1730-37-6	49398	50
1-Methylphenanthrene	832-69-9	49410	50
1-Methylpyrene	2381-21-7	49388	50
Naphthalene	91-20-3	49402	50
Phenanthrene	85-01-8	49409	50
Pyrene	129-00-0	49387	50
2,3,6-Trimethylnaphthalene	829-26-5	49405	50
	Phenols		
C_8-Alkylphenol	NA	49424	50
4-Chloro-3-methylphenol	59-50-7	49422	50
2-Chlorophenol	95-57-8	49467	50
p-Cresol	106-44-5	49451	50
3,5-Dimethylphenol	108-68-9	49421	50
Phenol[1]	108-95-2	49413	50
2,4,6-Trichlorophenol	88-06-2	49415	50
2,4-Dichlorophenol	120-83-2	49417	50

APPENDIX F: Semivolatile organic compounds included in chemical analysis of bed sediment samples and used in computing water-quality scores—Continued

Compound	CAS number	WATSTORE code	Method reporting limit (µg/kg dry weight)
	Phthalates		
Butylbenzyl phthalate[1]	85-68-7	49427	50
Diethyl phthalate[1]	84-66-2	49383	50
Dimethyl phthalate	131-11-3	49384	50
Di-*n*-butyl phthalate[1]	84-74-2	49381	50
Di-*n*-octyl phthalate	117-84-0	49382	50
bis(2-Ethylhexyl) phthalate[1]	117-81-7	49426	50
	Other SVOCs		
1,2-Dichlorobenzene[2]	95-50-1	49439	50
1,4-Dichlorobenzene[2]	106-46-7	49442	50
1,2,4-Trichlorobenzene[2]	120-82-1	49438	50

[1]Concentrations in environmental samples were corrected for contamination measured in blanks.
[2]Concentrations of this compound were not used in computing water-quality scores, but were compared with applicable aquatic-life criteria (table 18).

APPENDIX G: Trace elements included in chemical analysis of bed sediment samples and used in computing water-quality scores

[CAS, Chemical Abstracts Service. µg/g, microgram per gram]

Compound	CAS number	WATSTORE code	Method reporting limit (µg/g)
Arsenic	7440-38-2	34800	0.1
Cadmium	7440-43-9	34825	0.1
Chromium	7440-47-3	34840	1
Copper	7440-50-8	34850	1
Lead	7439-92-1	34890	4
Mercury	7439-97-6	34910	0.02
Nickel	7440-02-0	34925	2
Selenium	7782-49-2	34950	0.1
Zinc	7440-66-6	35020	4

APPENDIX H: Volatile organic compounds included in chemical analysis of ground-water samples and used in computing water-quality scores

[CAS, Chemical Abstracts Service. µg/L, microgram per liter]

Compound	CAS number	WATSTORE code	Method reporting limit (µg/L)
Benzene	71-43-2	34030	0.2
Bromobenzene	108-86-1	81555	0.2
Bromochloromethane	74-97-5	77297	0.2
Bromodichloromethane	75-27-4	32101	0.2
Bromomethane (Methyl bromide)	74-83-9	34413	0.2
n-Butylbenzene	104-51-8	77342	0.2
sec-Butylbenzene	135-98-8	77350	0.2
tert-Butylbenzene	98-06-6	77353	0.2
Chlorobenzene	108-90-7	34301	0.2
Chloroethane	75-00-3	34311	0.2
Chloroethene (Vinyl chloride)	75-01-4	39175	0.2
Chloromethane (Methyl chloride)	74-87-3	34418	0.2
1-Chloro-2-methylbenzene (2-Chlorotoluene)	95-49-8	77275	0.2
1-Chloro-4-methylbenzene (4-Chlorotoluene)	106-43-4	77277	0.2
Dibromochloromethane (Chlorodibromomethane)	124-48-1	32105	0.2
1,2-Dibromo-3-chloropropane (DBCP)	96-12-8	82625	1.0
1,2-Dibromoethane (Ethylene dibromide, EDB)	106-93-4	77651	0.2
Dibromomethane (Methylene dibromide)	74-95-3	30217	0.2
1,2-Dichlorobenzene (*o*-Dichlorobenzene)	95-50-1	34536	0.2
1,3-Dichlorobenzene (*m*-Dichlorobenzene)	541-73-1	34566	0.2
1,4-Dichlorobenzene (*p*-Dichlorobenzene)	106-46-7	34571	0.2
Dichlorodifluoromethane (CFC 12)	75-71-8	34668	0.2
1,1-Dichloroethane	75-34-3	34496	0.2
1,2-Dichloroethane (Ethylene dichloride)	107-06-2	32103	0.2
1,1-Dichloroethene (Vinylidene chloride)	75-35-4	34501	0.2
cis-1,2-Dichloroethene	156-59-2	77093	0.2
trans-1,2-Dichloroethene	156-60-5	34546	0.2
Dichloromethane (Methylene dichloride)	75-09-2	34423	0.2
1,2-Dichloropropane (Propylene dichloride)	78-87-5	34541	0.2
1,3-Dichloropropane (Trimethylene dichloride)	142-28-9	77173	0.2
2,2-Dichloropropane	594-20-7	77170	0.2
1,1-Dichloropropene	563-58-6	77168	0.2
cis-1,3-Dichloropropene	10061-01-5	34704	0.2
trans-1,3-Dichloropropene	10061-02-6	34699	0.2
Dimethylbenzenes (Xylenes, total)	1330-20-7	81551	0.2
Ethenylbenzene (Styrene)	100-42-5	77128	0.2
Ethylbenzene	100-41-4	34371	0.2
Hexachlorobutadiene	87-68-3	39702	0.2
Isopropylbenzene (Cumene)	98-82-8	77223	0.2
p-Isopropyltoluene (*p*-Cymene)	99-87-6	77356	0.2
Methylbenzene (Toluene)	108-88-3	34010	0.2
Methyl *tert*-butyl ether (MTBE)	1634-04-4	78032	0.2
Naphthalene	91-20-3	34696	0.2
n-Propylbenzene (Isocumene)	103-65-1	77224	0.2
1,1,1,2-Tetrachloroethane	630-20-6	77562	0.2

APPENDIX H: Volatile organic compounds included in chemical analysis of ground-water samples and used in computing water-quality scores—Continued

Compound	CAS number	WATSTORE code	Method reporting limit (μg/L)
1,1,2,2-Tetrachloroethane	79-34-5	34516	0.2
Tetrachloroethene (Perchloroethene, PCE)	127-18-4	34475	0.2
Tetrachloromethane (Carbon tetrachloride)	56-23-5	32102	0.2
Tribromomethane (Bromoform)	75-25-2	32104	0.2
1,2,3-Trichlorobenzene	87-61-6	77613	0.2
1,2,4-Trichlorobenzene	120-82-1	34551	0.2
1,1,1-Trichloroethane (Methylchloroform)	71-55-6	34506	0.2
1,1,2-Trichloroethane (Vinyl trichloride)	79-00-5	34511	0.2
Trichloroethene (TCE)	79-01-6	39180	0.2
Trichlorofluoromethane (CFC 11, Freon 11)	75-69-4	34488	0.2
Trichloromethane (Chloroform)	67-66-3	32106	0.2
1,2,3-Trichloropropane (Allyl trichloride)	96-18-4	77443	0.2
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC 113)	76-13-1	77652	0.2
1,2,4-Trimethylbenzene (Pseudocumene)	95-63-6	77222	0.2
1,3,5-Trimethylbenzene (Mesitylene)	108-67-8	77226	0.2