Prepared in cooperation with the
KANSAS WATER OFFICE

# Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

Water-Resources Investigations Report 03–4316

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

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Gale A. Norton, Secretary

**U.S. Geological Survey**
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**Prepared by the U.S. Geological Survey in Lawrence, Kansas (http://ks.water.usgs.gov)**

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# Conversion Factors, Abbreviations, and Datum

| Multiply | By | To obtain |
|---|---|---|
| inch (in.) | 2.54 | centimeter (cm) |
| mile (mi) | 1.609 | kilometer (km) |
| microgram per liter (µg/L) | 1.0 | part per billion (ppb) |
| micrometer (µm) | 0.00003937 | inch (in.) |
| milligram per kilogram (mg/kg) | 0.002 | pound per ton (lb/ton) |
| milligram per liter (mg/L) | 1.0 | part per million (ppm) |
| milliliter (mL) | 0.0338 | ounce, fluid (oz) |
| pound per acre (lb/acre) | 1.121 | kilogram per hectare (kg/ha) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |

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

$$°F = (1.8 \times °C) + 32.$$

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

$$°C = (°F - 32) / 1.8.$$

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

# Summary of Available State Ambient Stream-Water-Quality Data, 1990–98, and Limitations for National Assessment

By Larry M. Pope, Stacy M. Rosner, Darren C. Hoffman, and Andrew C. Ziegler


## Abstract

The investigation described in this report summarized data from State ambient stream-water-quality monitoring sites for 10 water-quality constituents or measurements (suspended solids, fecal coliform bacteria, ammonia as nitrogen, nitrite plus nitrate as nitrogen, total phosphorus, total arsenic, dissolved solids, chloride, sulfate, and pH). These 10 water-quality constituents or measurements commonly are listed nationally as major contributors to degradation of surface water. Water-quality data were limited to that electronically accessible from the U.S. Environmental Protection Agency Storage and Retrieval System (STORET), the U.S. Geological Survey National Water Information System (NWIS), or individual State databases. Forty-two States had ambient stream-water-quality data electronically accessible for some or all of the constituents or measurements summarized during this investigation. “Ambient” in this report refers to data collected for the purpose of evaluating stream ecosystems in relation to human health, environmental and ecological conditions, and designated uses. Generally, data were from monitoring sites assessed for State 305(b) reports.

Comparisons of monitoring data among States are problematic for several reasons, including differences in the basic spatial design of monitoring networks; water-quality constituents for which samples are analyzed; water-quality criteria to which constituent concentrations are compared; quantity and comprehensiveness of water-quality data; sample collection, processing, and handling; analytical methods; temporal variability in sample collection; and quality-assurance practices. Large differences among the States in number of monitoring sites precluded a general assumption that statewide water-quality conditions were represented by data from these sites. Furthermore, data from individual monitoring sites may not represent water-quality conditions at the sites because sampling conditions and protocols are unknown. Because of these factors, a high level of uncertainty exists in a national assessment of water quality.

The purpose of this report is to present a summary of electronically available State ambient stream-water-quality data for 10 selected constituents and measurements from monitoring sites with nine or more analyses for 1990–98 and to discuss limitations for use of the data for national assessment. These analyses were statistically summarized by monitoring site and State, and the results presented in tabular format. Most of the selected constituents or measurements have U.S. Environmental Protection Agency criteria or guidelines for aquatic-life or drinking-water purposes. A significant finding of this investigation is that for a large percentage of monitoring sites in the Nation, there are insufficient data to meet U.S. Environmental Protection Agency recommendations for determining if water-quality conditions are degraded and for making informed decisions regarding total maximum daily loads.


## Introduction

In 1972, Congress passed the Federal Water Pollution Control Act (Public Law 92–500), commonly referred to as the Clean Water Act (U.S. Environmental Protection Agency, 1972). This act and subsequent amendments set goals for eliminating the discharge of contaminants into the Nation’s waters, provided Federal funding for construction of municipal sewage-treatment plants, directed the States to set water-quality criteria for waters within their boundaries, and funded development of programs to control nonpoint sources of contamination. The act also directed the States to submit biannual reports to the U.S. Environmental Protection Agency (USEPA) that presented a comprehensive water-quality assessment (305(b) report) and listed the water-quality impaired (degraded) streams or stream segments (303(d) report) within the States. These reports were named after the sections in the Clean Water Act that required their preparation (U.S. Environmental Protection Agency, 1972).

In response to the provisions of the Clean Water Act, States established, modified, or enhanced their ambient stream-water-quality monitoring networks to provide the data necessary to assess stream water quality relative to State-established criteria. Data from these monitoring networks have been used to produce the biannual 305(b) and 303(d) reports to USEPA and, ultimately, to the Congress in the form of National Water Quality Inventory reports (compilation of State 305(b) reports). State networks have been operated to meet the specific goals and objectives established by the individual States. However, a national summarization of water quality can be accomplished in one of two ways. One approach would require that the States design and execute their individual monitoring approaches using identical designs so that the results can be summed to provide a national assessment. The other would be an analytical approach (some combination of statistical and deterministic models) that combine the 50 data sets in a manner that produces inferences about water quality that take into consideration the different sampling designs. Neither of these requirements has been met to date, and thus, the data are not suitable for national assessment or State-to-State intercomparisons, even though the data sets may be highly useful for purposes of State assessments and management.

The U.S. General Accounting Office (USGAO, 2000) examined USEPA's National Water Quality Inventory reports and the adequacy of water-quality data for key water-quality decisions required by the Clean Water Act. The USGAO concluded that assessment data in State 305(b) reports are incomplete because the data do not represent all of the States' waters. Additionally, USGAO identified substantial differences among States in virtually every aspect of monitoring and assessment. These differences stem from a combination of factors including variability in the (1) water-quality criteria (including designated or beneficial uses) for determining which water is degraded; (2) types of monitoring practices used to ascertain whether or not the criteria are exceeded; and (3) procedures used to assess water-quality data for determining if water-quality conditions are degraded. Much of this variability is the result of the flexibility allowed the States by the Clean Water Act to decide which streams to assess, what uses to designate for streams, and what water-quality criteria to assign for the designated uses.

USEPA (2002a) has attempted to minimize some of these State-to-State differences through the development and recommendation of consistent methodology in network design, sampling protocols, and evaluation criteria. Targeted, statistically based (probabilistic), and geographically based sampling designs are used in some State monitoring programs to provide the water-quality information required by the Clean Water Act to evaluate potential stream-water-quality degradation relative to designated uses and appropriate water-quality criteria. When appropriate designs are used, this information also may be used to describe cause-and-effect relations, seasonal variability and time trends, mass transport, and as an aid to management decisions. However, the variability in network designs and operational characteristics, such as the distribution of sites and frequency of sampling, among the States inhibits the use of available information for comparison of results among the States.

Because of the aforementioned differences in State ambient stream-water-quality monitoring networks and programs, water-quality officials in Kansas generally questioned the validity of previous national water-quality comparisons, such as those of Hall and Kerr (1991) and Brown and Marshall (1993), produced on the basis of information presented in State 305(b) and (or) 303(d) reports and, specifically, previous summaries of water-quality conditions in Kansas. In 2001, the U.S. Geological Survey (USGS) in cooperation with the Kansas Water Office (KWO), supported in part by the State Water Plan Fund, conducted an investigation of the comparability and representativeness of State ambient stream-water-quality databases for assessment of national water-quality conditions. However, it was beyond the scope of this investigation to evaluate the adequacy of the network designs, field and laboratory activities, and quality-assurance practices used in the various State monitoring programs. The investigation described in this report will provide additional information to support or contrast with previous investigations by the USGS that indicated data in many electronically accessible databases are of unknown quality and hydrologic context (Childress and others, 1989; Norris and others, 1992; Rinella and others, 1992).

For example, a comparison of data availablity in Colorado and Ohio indicated that fewer than 15 percent of water-quality analyses met the screening criteria judged necessary for the data to be included in a consistent database suitable for addressing broad-scope water-quality questions (Norris and others, 1992). Norris and others (1992) also determined that for 12 evaluated water-quality constituents an average of only 22 percent of stream-water-quality monitoring sites in Colorado and 8 percent in Ohio had 10 or more analyses with concurrent streamflow data during 1977–84. Concurrent streamflow data are necessary for hydrologic assessment such as water-quality trend analysis and constituent transport (load) calculations. Furthermore, Norris and others (1992) concluded that, on average, less than 10 percent of the stream-water-quality monitoring sites in Colorado and Ohio yield sufficient data for determining changes in water-quality conditions.

# Purpose and Scope

The purpose of this report is to present a summary of available State ambient stream-water-quality data, 1990–98, and to examine some of the characteristics of the data that would limit its use in producing a national evaluation of stream water quality. Ambient stream-water-quality data are information collected by an integrated activity for the purpose of evaluating the physical, chemical, and biological character of water ecosystems in relation to human health, environmental and ecological conditions, and designated uses. Therefore, "ambient" in this report refers to data collected for those purposes and does not mean or is it used to indicate pristine water-quality conditions. On the contrary, States may have established monitoring sites in their ambient networks for many reasons to include the documentation of stream-water-quality effects from human-related sources. These sources may be both point and nonpoint sources of contamination. Water-quality conditions determined in many or all State ambient stream networks probably are biased toward the water-quality effects generated from human-related activities because of the interest in these effects and their general pervasiveness.

The scope of this report is limited to States with electronically available water-quality data for sampling sites in their ambient stream-water-quality monitoring networks for 1990–98 (a maximum of 42 States). Water-quality data are statistically summarized by State.

# General Investigative Approach

The water-quality data used for the investigation described in this report were from monitoring sites representing each State's ambient stream-water-quality monitoring network for a common time period. No attempt was made to normalize for how and why monitoring sites were selected such as targeted or probabilistic-based selection, the number of sites within each State, spatial distribution of sites, or temporal distribution of streamflow samples collected at those sites. Procedures used for accounting for differences in constituents analyzed (dissolved or total constituent concentrations) and laboratory reporting methods are discussed in the "Summary of Available State Ambient Stream-Water-Quality Data" and "Quality Assurance of Data" sections of this report. A general schematic of the procedures used and assessment steps taken in the conduct of this investigation is presented in figure 1.

## Selection of Water-Quality Constituents

Water-quality constituents considered for summary in this report (table 1) were those most commonly responsible for

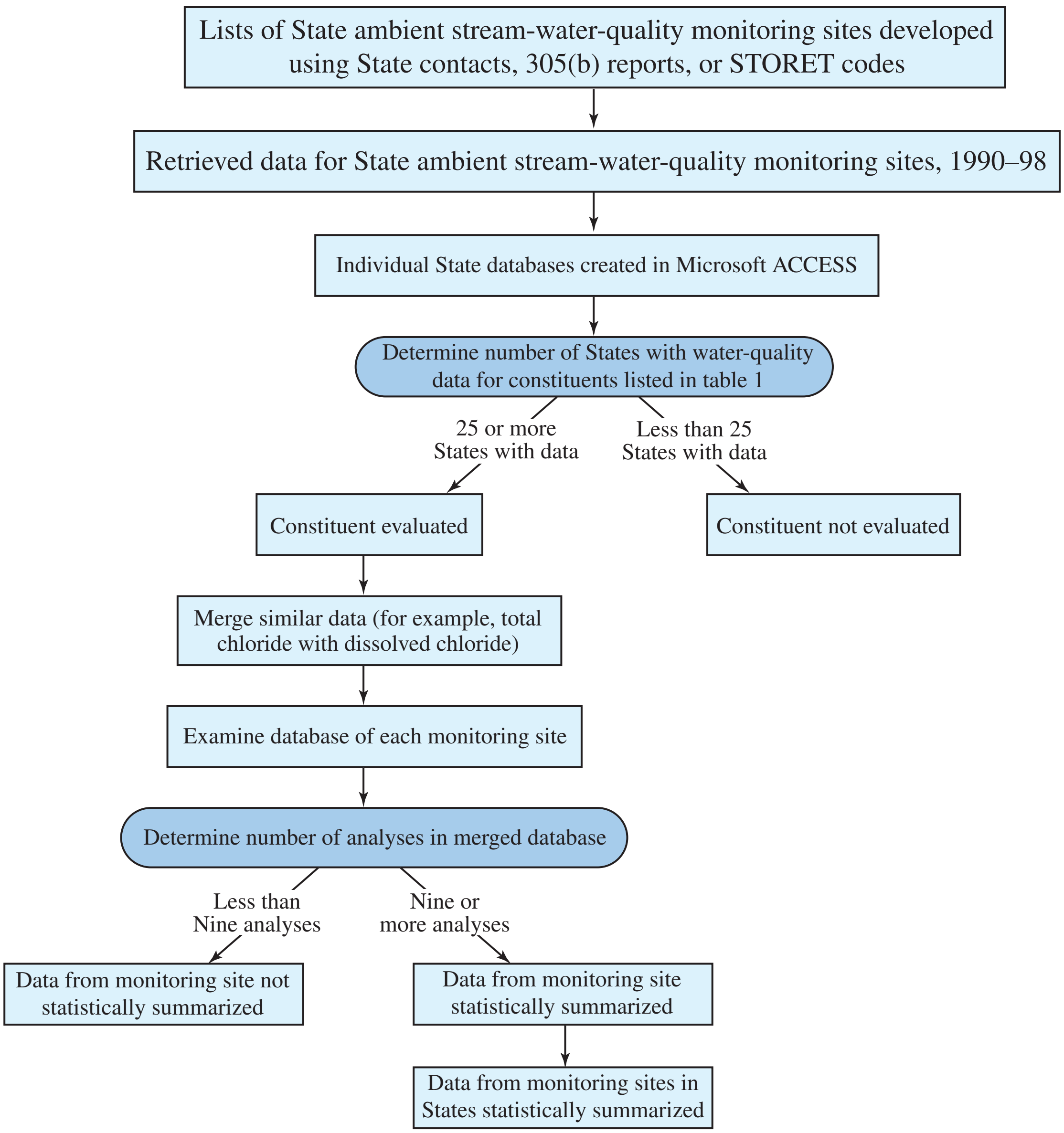


**Figure 1.** General procedures and decision processes used for data acquisition, handling, and summary of State ambient stream-water-quality monitoring sites for selected water-quality consituents.

**Table 1.** Water-quality constituents and physical measurements considered for summary.

| Constituent or measurement |
|---|
| **Sediment** |
| Suspended solids |
| **Bacteria** |
| Fecal coliform |
| **Nutrients** |
| Ammonia as nitrogen |
| Nitrite plus nitrate as nitrogen |
| Total phosphorus |
| **Trace elements** |
| Arsenic |
| Selenium |
| **Dissolved solids and major ions** |
| Dissolved solids |
| Chloride |
| Sulfate |
| **Pesticides** |
| Alachlor |
| Atrazine |
| **Physical measurements** |
| Water temperature |
| pH |

water-quality degradation in the Nation's streams. In preparation for the 1998 USEPA National Water-Quality Inventory Report to Congress, States and tribes assessed 840,402 mi of rivers and streams in the Nation and determined that 35 percent of those miles (291,263 mi) were degraded with respect to some water-quality factor. Of the degraded river and stream miles in 1998, 38 percent were degraded by sediment/siltation, 36 percent by fecal bacteria, and 29 percent by nutrients (species of nitrogen and phosphorus). Smaller percentages were degraded by trace metals and pesticides. River and stream miles may have been degraded by more than one water-quality constituent (U.S. Environmental Protection Agency, 2000b).

## Selection of Time Period and Acquisition of Data

The data summary period for the investigation described in this report was 1990–98. The ending date of 1998 was selected because it represented the date of closure on USEPA's STORET (short for STOrage and RETrieval) data-management system, which traditionally has been the repository for State ambient stream-water-quality data. Currently (2004), this historical system is known as the USEPA STORET Legacy Data Center and since 1998 has been a static system; no additional data entry or update to existing data is allowed. Data submitted to USEPA after 1998 have been stored in a more modern, relational-based version of the original STORET database now (2004) known as STORET (U.S. Environmental Protection Agency, 2003a). When this investigation began in 2001, many States were not using or had not submitted post-1998 ambient stream-water-quality data into the modern STORET system; therefore, a decision was made to limit the data for the study to 1998 for consistency.

The beginning date (1990) for data used in the investigation described in this report was selected to provide a timeframe of sufficient length to produce State databases of reasonable size for statistical analysis. The purposes for which monitoring sites were selected vary among the States. Associated with these purposes are certain operational characteristics that may affect or establish the timing and frequency of water-quality sample collection. Some States have long-term monitoring sites that are sampled several to many times annually. Other States have sites that are part of a rotational network established on the basis of watersheds or geographic areas. These rotational sites may be sampled one to several times every 3 to 5 years, thereby taking several rotations to produce a database sufficient to document natural within-site water-quality variability and to produce a reasonable estimate of central tendency of this variability. Some States have a combination of these or other approaches.

An ideal data time period for a water-quality investigation such as described in this report is one that maximizes the potential for collection of water-quality samples. However, long time periods may introduce water-quality variability associated with time trends (water-quality changes over time resulting from changes in natural or human factors). Time trends at monitoring sites increase the degree of water-quality variability over a time period and reduce the prospect of commonality and comparability among monitoring sites. A 9-year (1990–98) time period was selected for the acquisition of data for the investigation described in this report. Admittedly, this time period was somewhat subjectively selected, but it was believed that a 9-year period would provide two or three sampling cycles for rotational sites and be short enough to mitigate the effect of time trends in water-quality data.

The main source of water-quality data used for the investigation described in this report was the USEPA STORET Legacy Data Center (table 2). Of the 42 States with electronically available water-quality data, 28 State databases were acquired from the Legacy system. Data were acquired for five States (Colorado, Montana, New Hampshire, North Dakota, and Utah) from the modern STORET system that currently (2004) contains the 1990–98 data, and from State-located databases for three States (Maryland, Oklahoma, and Virginia). The USGS National Water Information System (NWIS) served as the primary or ancillary source of water-quality data for seven States

**Table 2.** Number of ambient stream-water-quality monitoring sites per State with electronically available data for at least one of the selected water-quality constituents or measurements and source of data and Internet uniform resource locator (URL), 2001–02.

[USEPA, U.S. Environmental Protection Agency; STORET, U.S. Environmental Protection Agency STOrage and RETrieval data-management system; USGS, U.S. Geological Survey; NWIS, National Water Information System; --, not available]

| State | Number of sites | Source of data | Internet uniform resource locator (URL) |
|---|---|---|---|
| Alabama | 49 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Alaska | -- | No ambient stream-water-quality network | -- |
| Arizona | -- | State database not electronically accessible | -- |
| Arkansas | 133 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| California | -- | No centralized database | -- |
| Colorado | 537 | USEPA modern STORET | http://oaspub.epa.gov/storpubl/warehousemenu |
| Connecticut | 32 | USGS NWIS | http://waterdata.usgs.gov/ct/nwis/qw |
| Delaware | 109 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Florida | 874 | do. | Do. |
| Georgia | 421 | do. | Do. |
| Hawaii | -- | No ambient stream-water-quality network | -- |
| Idaho | 53 | USGS NWIS | http://waterdata.usgs.gov/id/nwis/qw |
| Illinois | 373 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Indiana | 107 | do. | Do. |
| Iowa | 68 | do. | Do. |
| Kansas | 290 | do. | Do. |
| Kentucky | 89 | do. | Do. |
| Louisiana | 174 | do. | Do. |
| Maine | -- | Bioassessment ambient network only | -- |
| Maryland | 40 | Chesapeake Bay Program | http://www.chesapeakebay.net/data/index.htm |
| Massachusetts | -- | State database not electronically accessible | -- |
| Michigan | 295 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Minnesota | 68 | do. | Do. |
| Mississippi | 85 | do. | Do. |
| Missouri | 44 | USGS NWIS | http://waterdata.usgs.gov/mo/nwis/qw |
| Montana | 1,114 | USEPA modern STORET | http://oaspub.epa.gov/storpubl/warehousemenu |
| Nebraska | 22 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Nevada | 71 | do. | Do. |
| New Hampshire | 435 | USEPA modern STORET | http://oaspub.epa.gov/storpubl/warehousemenu |
| New Jersey | 96 | USGS NWIS | http://waterdata.usgs.gov/nj/nwis/qw |
| New Mexico | 16 | do. | http://waterdata.usgs.gov/nm/nwis/qw |
| | 517 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| New York | 19 | do. | Do. |
| North Carolina | -- | State database not electronically accessible | -- |
| North Dakota | 91 | USEPA modern STORET | http://oaspub.epa.gov/storpubl/warehousemenu |
| Ohio | 42 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Oklahoma | 261 | Oklahoma Conservation Commission | http://www.okcc.state.ok.us |
| Oregon | 148 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| Pennsylvania | 202 | do. | Do. |
| Rhode Island | 5 | USGS NWIS | http://waterdata.usgs.gov/ri/nwis/qw |
| South Carolina | 351 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| South Dakota | 100 | do. | Do. |
| Tennessee | 109 | do. | Do. |
| Texas | 980 | do. | Do. |
| Utah | 64 | USEPA modern STORET | http://oaspub.epa.gov/storpubl/warehousemenu |
| Vermont | -- | Bioassessment ambient network only | -- |
| Virginia | 1,997 | Virginia Department of Environmental Quality | http://www.deq.state.va.us/water/monitoring.html |
| Washington | 208 | USEPA STORET Legacy Data Center | www.epa.gov/storpubl/legacy/gateway.htm |
| West Virginia | 26 | do. | Do. |
| Wisconsin | 50 | do. | Do. |
| Wyoming | 47 | USGS NWIS | http://waterdata.usgs.gov/wy/nwis/qw |

(Connecticut, Idaho, Missouri, New Jersey, New Mexico, Rhode Island, and Wyoming). These seven States had cooperative agreements with the USGS to collect and analyze all or part of the water-quality samples for their ambient stream-water-quality monitoring networks. The repository for USGS-collected data is NWIS.

Eight States (Alaska, Arizona, California, Hawaii, Maine, Massachusetts, North Carolina, and Vermont) did not have electronically available data (table 2). Alaska and Hawaii did not have ambient stream-water-quality networks during 1990–98. Arizona, Massachusetts, and North Carolina had ambient stream-water-quality networks, but chemical and physical data were not stored in the STORET system or in a State-located database that was electronically accessible. Maine and Vermont conducted only biological water-quality assessments; therefore, they did not have data for the chemical and physical characteristics summarized during the investigation described in this report. California did not have a centralized, electronically accessible State database. Ambient stream-water-quality responsibilities in California were divided among nine Regional Water-Quality Control Boards, each of which varied as to amount, availability, and accessibility of data.

Water-quality data were acquired for ambient stream-water-quality monitoring sites in each of 42 States. Ambient stream-water-quality monitoring sites generally were those sites assessed for State 305(b) reports and were identified either through direct contact with the State agencies responsible for water-quality assessment and preparation of 305(b) reports, through information contained in 305(b) reports, or as identified in the STORET system. Water-quality data for identified monitoring sites were retrieved from the sources listed in table 2, generally, through Internet access to those sources.

State 305(b) reports provide, in part, an assessment of the number of stream miles that meet or fail water-quality criteria for designated uses. These assessments are conducted using water-quality data from many or all of the stream-water-quality monitoring sites used for the investigation described in this report. These monitoring sites, however, provide data to assess only a small percentage of the total stream miles (a combination of perennial and intermittent streams) in many States (table 3) (U.S. Environmental Protection Agency, 2000b; Appendix A–1). Percentages of assessed stream miles, reported by the States, ranged from 0 percent in Alaska to 100 percent in Hawaii, Maine, and New York with a median for all States of 20 percent. These percentages included stream miles assessed on the basis of macroinvertebrate surveys or other biological indices.

The information presented in table 3 (as reported by the States to USEPA) was not calculated consistently among the States and should be used only as a general comparison. For instance, Arizona did not include river miles on Indian lands in their estimate of total river miles; Hawaii used assessed stream miles as total miles because total miles were unknown; the percentage of stream miles assessed in Missouri was calculated on the basis of the number of perennial miles (not shown in table 3) instead of total miles; and the number of perennial stream miles was used for the number of total miles in Virginia (U.S. Environmental Protection Agency, 2000b; Appendix A–1). In some States, intermittent streams account for a large percentage of total stream miles, particularly in the arid and semiarid western States. Water-quality conditions for intermittent streams may not be determined in many of these States; therefore, percentages of assessed stream miles calculated on the basis of total stream miles may be small in these States relative to States with fewer intermittent streams.

The number of stream miles assessed for water-quality conditions in many States is determined from an assumption that conditions at stream monitoring sites represent the conditions for some defined stream segment. This assumption imparts uncertainty in statewide water-quality assessments. If monitoring sites are to be used to assess statewide conditions, there must be a process whereby water-quality measurements are used to infer conditions throughout the network of stream reaches in the State. Although statistical methods exist that provide the means of extending these data (Smith and others, 1997; Larson and Gilliom, 2001; National Research Council, 2001), it seems that these methods have not been used by the States. Rather, the States use point (monitoring-site) data to infer conditions over some finite reach upstream and downstream from the monitoring site and then assume that they have no knowledge beyond those reaches, referring to this remaining part of the stream network as unassessed. The use of statistical or deterministic models is necessary if the monitoring data are to achieve their full utility in providing meaningful estimates of water-quality statewide or nationwide or to achieve any understanding of the uncertainty of the statewide or nationwide estimates.

The number of ambient stream-water-quality monitoring sites with data for constituents or measurements listed in table 1 varied among the States. Some of this variation may be attributed to geographical size differences among the States. State surface areas reported in this paragraph are from the U.S. Bureau of Census (2002). For example, the smaller States of Rhode Island (1,231 $mi^2$) and Connecticut (5,544 $mi^2$) have few monitoring sites (table 2) relative to many of the larger States such as Montana (147,046 $mi^2$) and Texas (267,277 $mi^2$). However, many exceptions are evident such as New York (53,989 $mi^2$) with 19 monitoring sites and Nebraska (77,358 $mi^2$) with 22 monitoring sites. Clearly, factors other than size determine the number of ambient stream-water-quality monitoring sites in some States. These factors may be economic, political, a limitation in surface-water resources, or, as in the case of New York, a function of monitoring-network design and operation. New York, during 1990–98, operated a monitoring network consisting of sites for both water-quality chemical and biological assessments with the major emphasis on the latter. Consequently, New York had few monitoring sites with data available for the investigation described in this report. In contrast to New York, Virginia (42,326 $mi^2$) operated almost 2,000 ambient stream-water-quality monitoring sites during 1990–98. The number of monitoring sites indicated in table 2 represents the number with at least one analysis of any

**Table 3.** Total miles of streams in the States and percentage assessed for water-quality degradation in 1998 (U.S. Environmental Protection Agency, 2000b; Appendix A–1).

| State | Total stream miles | Percentage assessed | State | Total stream miles | Percentage assessed |
|---|---|---|---|---|---|
| Alabama | 77,274 | 5 | Alaska | 365,000 | 0 |
| Arizona | 90,373 | 5 | Arkansas | 87,617 | 10 |
| California | 211,513 | 8 | Colorado | 107,403 | 27 |
| Connecticut | 5,830 | 16 | Delaware | 2,509 | 95 |
| Florida | 51,858 | 10 | Georgia | 70,150 | 12 |
| Hawaii | 3,905 | 100 | Idaho | 115,595 | 11 |
| Illinois | 87,110 | 33 | Indiana | 35,673 | 24 |
| Iowa | 71,665 | 14 | Kansas | 134,338 | 12 |
| Kentucky | 49,105 | 19 | Louisiana | 66,294 | 9 |
| Maine | 31,752 | 100 | Maryland | 17,000 | 39 |
| Massachusetts | 8,229 | 18 | Michigan | 51,438 | 40 |
| Minnesota | 91,944 | 13 | Mississippi | 84,003 | 47 |
| Missouri | 51,978 | 42 | Montana | 176,750 | 10 |
| Nebraska | 81,573 | 5 | Nevada | 143,578 | 1 |
| New Hampshire | 10,881 | 24 | New Jersey | 6,450 | 59 |
| New Mexico | 110,741 | 4 | New York | 52,337 | 100 |
| North Carolina | 37,853 | 89 | North Dakota | 54,373 | 22 |
| Ohio | 29,113 | 10 | Oklahoma | 78,778 | 14 |
| Oregon | 114,823 | 47 | Pennsylvania | 83,260 | 15 |
| Rhode Island | 1,392 | 54 | South Carolina | 29,898 | 65 |
| South Dakota | 9,937 | 32 | Tennessee | 61,075 | 88 |
| Texas | 191,228 | 7 | Utah | 85,916 | 10 |
| Vermont | 7,099 | 16 | Virginia | 49,350 | 39 |
| Washington | 70,439 | 98 | West Virginia | 32,278 | 24 |
| Wisconsin | 57,698 | 40 | Wyoming | 108,767 | 87 |

constituent or measurement listed in table 4. Data were retrieved for a total of 10,812 sites from 42 States.

The data retrieved for this investigation came from multiple sources—STORET, NWIS, or State databases. Data for a given constituent may have been associated with one or more parameter codes that resulted from the analysis of different phases or mode of transport (total and dissolved, or whole water and filtered) or from different analytical methods. Parameter codes are the five-digit numbers that uniquely identify a chemical constituent or water-quality measurement in STORET or NWIS. A total analysis of a water-quality constituent was determined on a whole (unfiltered) water sample and included all occurrence or transport phases of the constituent as defined by the analytical laboratory method. A dissolved analysis of a water-quality constituent was determined on a filtered water sample, most commonly water filtered through a 0.45-µm pore-size filter. Data were retrieved for all available constituents or measurements listed in table 4.

The modern STORET system, however, does not distinguish water-quality constituents by parameter code. Data in the modern STORET system are organized by constituent characteristic name and cannot be retrieved by parameter code. Therefore, water-quality data acquired from modern STORET for Colorado, Montana, New Hampshire, North Dakota, and Utah were retrieved on the basis of characteristic name (suspended solids, fecal coliform, and so forth) and not by parameter codes. A total or dissolved analysis in modern STORET was identified on the basis of a sample fraction characteristic.

# Data Management

Data management and selection or development of common data-summary criteria were essential components of the investigation described in this report. The management of data

**Table 4.** Constituent or measurement descriptions and parameter codes for data retrieved from U.S. Environmental Protection Agency, U.S. Geological Survey, or State databases.

[STORET, U.S. Environmental Protection Agency STOrage and RETrieval system; NWIS, U.S. Geological Survey National Water Information System; °C, degrees Celsius; mg/L, milligrams per liter; MF, membrane filtration; M-TEC, fecal coliform agar; col/100 mL, colonies per 100 milliliters of water; M-FC, fecal coliform broth or agar; MPN, most probable number; EC, fecal coliform agar; µm, micrometer or micron; N, nitrogen; $NO_3$, nitrate; P, phosphorus; µg/L, micrograms per liter; As, arsenic; Se, selenium]

| Constituent or measurement description | STORET/NWIS parameter code[1] |
|---|---|
| **Suspended solids** | |
| Residue, total nonfilterable, residue on evaporation at 105 °C, mg/L | 00530 |
| Solids, suspended, residue on evaporation at 180 °C, mg/L | 70299 |
| **Bacteria** | |
| Fecal coliform, MF, M–TEC, 44.5 °C, col/100 mL | 31611 |
| Fecal coliform, MF, M–FC agar, 44.5 °C, 24 hour, col/100 mL | 31613 |
| Fecal coliform, MPN, EC medium, 44.5 °C, col/100 mL | 31615 |
| Fecal coliform, MF, M–FC broth, 44.5 °C, col/100 mL | 31616 |
| Fecal coliform, MF, M–FC, 0.7-µm porosity filter, 44.5 °C, col/100 mL | 31625 |
| **Nutrients** | |
| Ammonia, dissolved, mg/L as N | 00608 |
| Ammonia, total, mg/L as N | 00610 |
| Nitrite, dissolved, mg/L as N | 00613 |
| Nitrite, total, mg/L as N | 00615 |
| Nitrate, dissolved, mg/L as N | 00618 |
| Nitrate, total, mg/L as N | 00620 |
| Nitrate, total, mg/L as $NO_3$ | 71850 |
| Nitrate, dissolved, mg/L as $NO_3$ | 71851 |
| Nitrite plus nitrate, total, mg/L as N | 00630 |
| Nitrite plus nitrate, dissolved, mg/L as N | 00631 |
| Phosphorus, total, mg/L as P | 00665 |
| Phosphorus, dissolved, mg/L as P | 00666 |
| **Trace elements** | |
| Arsenic, total recoverable in water, µg/L as As | 00978 |
| Arsenic, total, µg/L as As | 01002 |
| Selenium, total recoverable in water, µg/L as Se | 00981 |
| Selenium, total, µg/L as Se | 01147 |
| **Dissolved solids and major ions** | |
| Residue, total filterable, dried at 105 °C, mg/L | 00515 |
| Residue, total dissolved, unspecified calculation, mg/L | 70294 |
| Residue, total filterable, dried at any temperature, mg/L | 70295 |
| Residue, total filterable, dried at 180 °C, mg/L | 70300 |
| Solids, dissolved, sum of constituents, mg/L | 70301 |
| Chloride, total, mg/L | 00940/none |
| Chloride, dissolved, mg/L | 00941/00940 |
| Sulfate, total, mg/L | 00945/none |
| Sulfate, dissolved, mg/L | 00946/00945 |
| **Pesticides** | |
| Alachlor, dissolved, µg/L | 46342 |
| Alachlor, whole water, µg/L | 77825 |
| Atrazine, whole water, µg/L | 39033 |
| Atrazine, dissolved, µg/L | 39632 |
| **Physical measurements** | |
| Temperature, water, °C | 00010 |
| pH, standard units | 00400 |

[1]NWIS code is the same as the STORET code unless otherwise indicated. STORET codes are used in the Legacy system and State databases but are not used in the modern STORET system.

from more than 10,000 ambient stream-water-quality monitoring sites in 42 States required a relational-based data-management system to store data and to produce the site and State summaries necessary for the investigation.

Data retrieved from STORET, NWIS, or State databases were placed into a Microsoft ACCESS data-management system at the USGS office in Lawrence, Kansas. Separate ACCESS databases were created for each State. Data in each State ACCESS database consisted of ambient stream-water-quality analyses for the constituents and measurements listed in table 4. A merged database for water-quality constituents and measurements of interest (table 1) was prepared by combining data for multiple parameter codes, and the combined data for each constituent or measurement were used for statistical summary. The utility and comparability of multiple parameter codes for selected constituents and measurements for the merged database will be discussed later in the “Summary of Available State Ambient Stream-Water-Quality Data” section of this report.

Water-quality constituents or measurements from ambient stream-water-quality monitoring sites were summarized only if the site databases contained nine or more constituent analyses or measurements (fig. 1). The nine-analysis threshold was selected as a compromise between the desire to include as many ambient stream-water-quality monitoring sites per State as possible but still have enough analyses to provide an estimate of range and central tendency (median value) for each site’s data population. Additionally, nine samples represent an average of one sample per year for the selected time period (1990–98). This low threshold for data quantity is not consistent with USEPA recommendations or compatible with data quantity preferred by USGS (Hooper and others, 2001; Gilliom and others, 1995). USEPA (2002a) recommends at least 30 analyses per monitoring site for determining water-quality degradation for the 305(b) assessment cycle (2 years); however, the number of analyses required by the States for these determinations varies. For example, Kansas currently (2004) requires a minimum of 12 analyses (Kansas Department of Health and Environment, 2002). Some States require a minimum data set of 10 analyses, whereas other States, such as Nevada and Arizona, require as few as four analyses for determining degradation (U.S. General Accounting Office, 2002). Time frames within which the minimum number of samples can be collected also vary. Wyoming requires 10 samples collected over 3 years, whereas Nebraska requires 10 samples collected over 5 years (U.S. General Accounting Office, 2002). Although States generally require analysis of data collected over 1 to 3 years in determining water-quality degradation, USEPA (2002a) recommends that States analyze data over longer time periods when available.

Relative to the 30 analyses recommended by USEPA (2002a), the minimum of nine analyses required to summarize data from an ambient stream-water-quality monitoring site for the investigation described in this report is small. The potential disadvantage of a relatively small number of analyses is the possibility that the range and central tendency in sample analyses may not be representative of the population range and central tendency in water-quality constituent concentrations or measurements at monitoring sites. The implication of this possibility is that water-quality summaries made on the basis of a few analyses may be biased.

# Quality Assurance of Data

The ambient stream-water-quality merged database assembled for the investigation described in this report consists of more than 2 million individual water-quality constituent analyses or measurements from more than 10,000 monitoring sites in 42 States (table 2). An assumption was made for this investigation that the States or their cooperators had reviewed and approved the ambient stream-water-quality data prior to submission to the STORET, NWIS, or State database systems. Normal quality-assurance procedures include an examination of (1) “outlier” data values to determine erroneous or incorrectly entered data; (2) historical variability in sample collection methods; (3) accuracy, precision, and detection levels of analytical methods; (4) potential for positive or negative bias in the data sets; and (5) verification of entered data with laboratory results.

Qualitative data remark codes (table 5) were retrieved with water-quality data from the STORET or NWIS data-management systems. These remark codes document instances where analytical values are less than or greater than an analytical method or reporting limit; presumptive evidence of material (chemicals) is present but not quantifiable; bacterial enumeration is outside ideal counting ranges; or bacterial colonies are too numerous to count. There were many qualified data in the merged database used in this investigation (table 5). For instance, most chemical data values coded as “less than” an analytical method or reporting level were used for calculation of water-quality constituent median values for ambient stream-water-quality monitoring sites.

Fecal coliform bacteria densities retrieved from the STORET or NWIS data-management systems frequently were qualified “less than” or “greater than” a large range of numeric values. This range was from less than 1 to greater than several hundreds or thousands of bacteria.

Chemical concentrations or bacteria densities qualified with “less than” or “greater than” were used in calculation of median values in water from ambient stream-water-quality monitoring sites. These qualified data were ranked according to their numeric value either before (in the case of “less than”; <) or after (in the case of “greater than”; >) the corresponding non-qualified numeric values (assuming a ranking order from smallest to largest); for example, 1, 5, <10, 10, 20, 40, >40, 50, and so forth.

**Table 5.** Data remark codes and descriptions and statistical summary action for remarked water-quality data from the U.S. Environmental Protection Agency STORET (STOrage and RETrieval), U.S. Geological Survey National Water Information System (NWIS), or State data-management systems.

[U, data used for assessment; NU, data not used for assessment]

| Data remark code | Description | Statistical summary action |
|---|---|---|
| | STORET System[1] | |
| A | Value reported is the mean of two or more determinations. | U |
| B | Results are based upon colony counts outside the acceptable range. | U |
| C | Calculated. Value stored was not measured directly but was calculated from other available data. | U |
| I | Value reported is less than the practical quantification limit and greater than or equal to the method detection limit. | U |
| J | Estimated. | NU |
| K | Off-scale low. Actual value not known but known to be less than value shown. | U |
| L | Off-scale high. Actual value not known but known to be greater than value shown. | U |
| M | Presence of material verified but not quantified. Indicates a positive detection at a level too low to permit accurate quantification. | NU |
| N | Presumptive evidence of presence of material. | NU |
| O | Sampled for, but analysis lost. Accompanying value is not meaningful for analysis. | NU |
| P | Too numerous to count. | NU |
| Q | Sample held beyond normal holding time. | U |
| T | Value reported is less than the criteria of detection. *(Best judgement value).* | U |
| U | Material was analyzed for but not detected. Value stored is the limit of detection for process in use. (*Added "less than" qualifier to data value*). | U |
| Z | Too many colonies were present to count (TNTC); the numeric value represents the filtration volume. | NU |
| $ | Calculated by retrieval software. Numerical value was neither measured nor reported in the database but was calculated from other available data during generation of the retrieval report. | U |
| | NWIS System[2] | |
| < | Actual value is known to be less than the value shown. | U |
| > | Actual value is known to be greater than the value shown. | U |
| A | Average value. | U |
| E | Estimated value. | U |
| M | Presence of material verified but not quantified. | NU |
| N | Presumptive evidence of presence of material. | NU |
| S | Most probable value. | U |
| V | Value affected by contamination. | NU |
| U | Analyzed for, not detected. | U |

[1]U.S. Environmental Protection Agency (2001a).

[2]U.S. Geological Survey (2003).

# Summary of Available State Ambient Stream-Water-Quality Data

Water-quality data for selected constituents (table 1) from ambient stream-water-quality monitoring sites in 42 States were statistically summarized. Water-quality constituents and measurements were summarized only if 25 or more States (one-half of the States) had electronically available data. Monitoring-site median values were calculated for each assessed water-quality constituent or measurement, statistically summarized by State, and presented in tabular format. Because of few data among the States for selenium, alachlor, and atrazine, these constituents were not summarized. Water temperature was not summarized because national climatic differences in water temperature make comparability among monitoring sites difficult.

## Suspended Solids

Suspended solids in water samples may consist of organic or inorganic materials from sources such as decaying vegetation, algae, solids discharged by industries and municipalities, urban and agricultural runoff, soil erosion, and physical degradation of geologic formations (Mays, 1996). Suspended solids in streams can serve as a heat sink by absorbing solar radiation, which ultimately may increase water temperatures, stress aquatic organisms, and may create conditions favorable to disease in fish populations. Suspended solids also can serve as a transport mechanism for toxic water-quality constituents such as mercury, pesticides, and industrial organic compounds. When transported to and deposited in lakes or reservoirs, suspended solids can shorten the useful life of a lake or reservoir by increasing the rate of sedimentation, thereby reducing storage volume, smothering rooted vegetation, and adversely affecting the ecosystem of aquatic benthic (bottom-dwelling) organisms. Also, suspended solids in lake and reservoir water can increase turbidity, reduce the available light that reaches aquatic plants and organisms, restrict biodiversity, and inhibit photosynthesis and primary productivity (Horne and Goldman, 1994).

All States with suspended solids concentrations in water from ambient stream-water-quality monitoring sites analyzed suspended solids according to the methodology associated with parameter code 00530 (table 4) and subsequently stored those data in STORET Legacy, NWIS, or State databases under that parameter code or as “suspended solids” in the modern STORET system. Florida is the lone exception, which also had two monitoring sites with suspended solids concentrations stored under parameter code 70299. For the purpose of the summary presented in this report, it was assumed that data under both parameter codes were analytically comparable and, therefore, were merged into one database.

Forty States had electronically accessible suspended solids concentrations for water from ambient stream-water-quality monitoring sites with at least nine analyses. State medians of monitoring-site median concentrations of suspended solids ranged from 2.0 mg/L in New Hampshire to 42.5 mg/L in Nebraska (table 6).

## Fecal Coliform Bacteria

Fecal coliform bacteria are indigenous to the intestinal tract of all warmblooded animals, and their presence in stream water indicates fecal contamination and possible presence of pathogenic microorganisms, such as *entero-*, *rota*, *reovirus*, that may cause human disease, ranging from mild diarrhea to respiratory disease, meningitis, and polio (Pepper and others, 1996). Possible sources of fecal coliform bacteria contamination in streams include municipal-wastewater discharges, seepage from domestic septic systems, runoff or seepage from livestock-producing areas, and wildlife. Because of the potential human-health implications of fecal bacteria contamination, all States have implemented an ambient stream-water-quality criterion for either fecal coliform or *Escherichia coli* (*E. coli*) bacteria densities. *E. coli* is the predominant bacterium in the fecal coliform group (McKinney, 1962) and may be more indicative of fecal contamination from warmblooded animals than the fecal coliform group (Cabelli, 1977; Dufour and Cabelli, 1984). The fecal coliform bacteria group may include species of the *Klebsiella*, *Enterobacter*, and *Citrobacter* genera (Gleeson and Gray, 1997). Rasmussen and Ziegler (2003) developed site-specific relations and ratios between *E. coli* and fecal coliform bacteria such that densities of one may be used to estimate densities of the other. Historically, most States relied on the enumeration of fecal coliform bacteria as an indicator of sanitary quality particularly for the time period 1990–98. Therefore, indicator bacteria for most States consisted of the fecal coliform group in this report. In 1986, USEPA revised the ambient water-quality criteria for marine and freshwater (U.S. Environmental Protection Agency, 1986) and recommended that criteria for either *E. coli* or *Enterococci* organisms replace criteria for fecal coliform bacteria. However, many States may have been reluctant to switch from a fecal coliform criteria because of concern of long-term comparability.

Thirty-nine States had electronically accessible fecal coliform bacteria densities in water from ambient stream-water-quality monitoring sites stored in STORET Legacy, NWIS, or State databases under one or more parameter codes (table 7) or as “fecal coliform” in the modern STORET system. Although monitoring sites for most States had fecal coliform bacteria densities stored under only one parameter code (most commonly 31616), five States (Connecticut, Florida, Rhode Island, South Carolina, Virginia) had data from monitoring sites stored under two parameter codes, and Texas had data stored under three parameter codes. The division of fecal coliform bacteria densities among more than one parameter code within and among the States necessitated a data-merging procedure prior to the monitoring-site and State summaries presented in this report.

The merging procedure of ambient stream-water-quality monitoring sites with different parameter codes for fecal coliform bacteria densities was, for the most part, a simple

**Table 6.** Summary of median suspended solids concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 45 | 1.0 | 9.0 | 32.0 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 1.0 | 7.5 | 116 |
| California | -- | -- | -- | -- |
| Colorado | 214 | <10 | <10 | 260 |
| Connecticut | 0 | -- | -- | -- |
| Delaware | 103 | 2.0 | 10.5 | 111 |
| Florida | 602 | <1.0 | 4.0 | 153 |
| Georgia | 196 | <1.0 | 9.0 | 37.0 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 0 | -- | -- | -- |
| Illinois | 11 | 8.0 | 26.0 | 108 |
| Indiana | 105 | <4.0 | 19.0 | 93.0 |
| Iowa | 26 | 12.5 | 40.5 | 190 |
| Kansas | 124 | 5.0 | 33.0 | 108 |
| Kentucky | 60 | 3.0 | 15.0 | 48.5 |
| Louisiana | 171 | 4.0 | 22.0 | 251 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | 4.0 | 8.0 | 18.0 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 96 | <4.0 | 12.0 | 54.1 |
| Minnesota | 63 | 1.2 | 25.0 | 145 |
| Mississippi | 66 | 1.0 | 13.5 | 140 |
| Missouri | 22 | 2.5 | 10.8 | 181 |
| Montana | 132 | <1.0 | 5.2 | 340 |
| Nebraska | 22 | 5.0 | 42.5 | 254 |
| Nevada | 67 | 1.0 | <10.0 | 108 |
| New Hampshire | 25 | <1.0 | 2.0 | 6.5 |
| New Jersey | 65 | 3.0 | 6.0 | 27.0 |
| New Mexico | 219 | <3.0 | 8.0 | 832 |
| New York | 19 | 2.0 | 10.0 | 41.0 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 28 | <5.0 | 25.8 | 1,030 |
| Ohio | 41 | <5.0 | 14.0 | 65.0 |
| Oklahoma | 182 | <1.0 | 7.9 | 129 |
| Oregon | 144 | <1.0 | 4.0 | 62.5 |
| Pennsylvania | 173 | <2.0 | 6.0 | 26.0 |
| Rhode Island | 5 | 2.0 | 5.0 | 6.0 |
| South Carolina | 52 | 1.4 | 6.7 | 27.0 |
| South Dakota | 96 | 2.0 | 17.0 | 2,160 |
| Tennessee | 68 | 3.0 | 11.8 | 101 |
| Texas | 396 | <1.0 | 21.0 | 622 |
| Utah | 64 | <3.0 | 34.2 | 938 |
| Vermont | -- | -- | -- | -- |
| Virginia | 945 | <3.0 | 6.5 | 64.0 |
| Washington | 204 | 1.0 | 5.0 | 114 |
| West Virginia | 26 | <5.0 | 8.8 | 29.0 |
| Wisconsin | 46 | 3.0 | 10.2 | 56.0 |
| Wyoming | 1 | 13.0 | 13.0 | 13.0 |

[1]Nine or more analyses per site.

**Table 7.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of fecal coliform bacteria densities in water, 1990–98.

[M–TEC, fecal coliform agar; M–FC, fecal coliform agar or broth; MPN, most probable number; MPF, micrometer porosity filter; --, not available]

| State | Number of sites with data for parameter code[1] | | | | | Number of sites in merged database |
|---|---|---|---|---|---|---|
| | 31611 (M–TEC) | 31613 (M–FC agar) | 31615 (MPN) | 31616 (M–FC broth) | 31625 (M–FC, 0.7 MPF) | |
| Alabama | -- | 45 | -- | -- | -- | 45 |
| Alaska | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- |
| Arkansas | -- | -- | -- | 113 | -- | 113 |
| California | -- | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | -- | 124 |
| Connecticut | -- | -- | -- | 32 | 3 | 32 |
| Delaware | -- | -- | -- | -- | -- | 0 |
| Florida | -- | 108 | -- | 268 | -- | 372 |
| Georgia | -- | -- | 255 | -- | -- | 255 |
| Hawaii | -- | -- | -- | -- | -- | -- |
| Idaho | -- | -- | -- | -- | 42 | 42 |
| Illinois | -- | -- | -- | 3 | -- | 3 |
| Indiana | -- | -- | -- | -- | -- | 0 |
| Iowa | -- | -- | -- | 17 | -- | 17 |
| Kansas | -- | -- | -- | 249 | -- | 249 |
| Kentucky | -- | -- | -- | 59 | -- | 59 |
| Louisiana | -- | -- | 103 | -- | -- | 103 |
| Maine | -- | -- | -- | -- | -- | -- |
| Maryland | -- | -- | -- | 40 | -- | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- |
| Michigan | -- | -- | -- | -- | -- | 0 |
| Minnesota | -- | 63 | -- | -- | -- | 63 |
| Mississippi | -- | -- | -- | 50 | -- | 50 |
| Missouri | -- | -- | -- | -- | 39 | 39 |
| Montana | -- | -- | -- | -- | -- | 2 |
| Nebraska | -- | -- | -- | 22 | -- | 22 |
| Nevada | -- | 60 | -- | -- | -- | 60 |
| New Hampshire | -- | -- | -- | 8 | -- | 8 |
| New Jersey | -- | -- | -- | -- | 5 | 5 |
| New Mexico | -- | -- | -- | -- | 9 | 9 |
| New York | -- | 8 | -- | -- | -- | 8 |
| North Carolina | -- | -- | -- | -- | -- | -- |
| North Dakota | -- | -- | -- | -- | -- | 39 |
| Ohio | -- | -- | -- | 40 | -- | 40 |
| Oklahoma | 14 | -- | -- | -- | -- | 14 |
| Oregon | -- | 83 | -- | -- | -- | 83 |
| Pennsylvania | -- | -- | -- | 53 | -- | 53 |
| Rhode Island | -- | -- | -- | 1 | 5 | 5 |
| South Carolina | -- | -- | 43 | 276 | -- | 310 |
| South Dakota | -- | -- | -- | 96 | -- | 96 |
| Tennessee | -- | -- | -- | 60 | -- | 60 |
| Texas | -- | 33 | -- | 422 | 67 | 457 |
| Utah | -- | -- | -- | -- | -- | 16 |
| Vermont | -- | -- | -- | -- | -- | -- |
| Virginia | -- | -- | 460 | 790 | -- | 1,086 |
| Washington | -- | -- | -- | 202 | -- | 202 |
| West Virginia | -- | -- | -- | 26 | -- | 26 |
| Wisconsin | -- | 44 | -- | -- | -- | 44 |
| Wyoming | -- | -- | -- | -- | 18 | 18 |

[1]See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

combining of monitoring sites into a single State database. Occasionally, however, individual water-quality samples from monitoring sites contained fecal coliform bacteria densities analyzed and stored under more than one parameter code. In these situations, densities stored under parameter code 31616 were selected in preference over densities stored under other parameter codes. Generally, densities under parameter code 31616 were the most commonly occurring for monitoring sites within the six States with multiple parameter codes for fecal coliform bacteria and, therefore, the most reasonable selection. For the purpose of summaries presented in this report, it was assumed that densities under all fecal coliform bacteria parameter codes among or within the States were analytically comparable even though there may be analytical variability between the methods associated with the different parameter codes. State medians of monitoring-site median densities of fecal coliform bacteria ranged from 19.2 col/100 mL in Colorado to 2,650 col/100 mL in Montana (on the basis of two sites) (table 8).

## Ammonia

Ammonia as nitrogen (hereinafter referred to as ammonia) is a reduced form of nitrogen. Rooted aquatic plants and algae require dissolved forms of nitrogen as nutrients essential for growth and reproduction (Horne and Goldman, 1994). Compounds of nitrogen such as ammonia or the oxidized forms of nitrogen such as nitrite and nitrate are the basic building blocks for protein synthesis. However, large inputs of nitrogen compounds into the aquatic environment may cause excessive algal growth. This growth ultimately may produce taste-and-odor problems in drinking water, reduce the aesthetic and recreational value of water, and stress aquatic organisms resulting from depleted dissolved oxygen concentrations when algal blooms die.

Concentrations of ammonia ranging from 0.44 to 18.7 mg/L (uncorrected for pH) were shown to be acutely toxic to 19 freshwater invertebrate species, whereas acute toxicity among 29 fish species ranged from 0.068 to 3.78 mg/L, uncorrected for pH (U.S. Environmental Protection Agency, 1986). Concentrations of ammonia acutely toxic to fish may cause increases in respiratory activity, oxygen uptake, and heart rate; reductions in hatching success and growth and morphological development; and injury to gills, liver, and kidneys. At larger concentrations, fish may experience convulsions, coma, or death (U.S. Environmental Protection Agency, 1986). Therefore, it is desirable to mitigate the introduction of excessive ammonia.

Major nonpoint sources of ammonia include agricultural activities such as the application of synthetic fertilizers (anhydrous ammonia) and pasturing and confined feeding of livestock. Farm livestock can produce large amounts of nitrogenous organic waste (urine, manure, and organic wastes) in areas where large numbers of animals are pastured or confined. The decomposition of organic waste can release ammonia and other nutrients into the aquatic environment. Discharges from industrial and municipal-wastewater treatment plants also may be a major point source of ammonia and other nutrients to streams in the United States.

Unionized ammonia ($NH_3$) readily dissolves in water to form its derivative ionic species ammonium ion ($NH_4^+$). Because the acid-base ionization constant for $NH_4^+$ is relatively large (9.26), most ammonia in water within natural environmental pH ranges (6.0 to 9.0 standard units) is present as $NH_4^+$ rather than $NH_3$ (Manahan, 1994). Analytical methods for ammonia (as nitrogen) are conducted on either a whole water sample (total ammonia analysis) or a filtered water sample (dissolved ammonia analysis). In both cases, the resultant analytical determination will represent a combined concentration of unionized and ionized forms of ammonia. However, because of the large solubility of ammonia in water at natural pH ranges and the preponderance of the dissolved ionic species ($NH_4^+$), analytical determinations of ammonia (as nitrogen) in whole (total) and filtered (dissolved) water samples will produce similar ammonia concentrations.

Forty-one States reported ammonia concentrations (as nitrogen) in water from ambient stream-water-quality monitoring sites (table 9). Most States reported ammonia concentrations determined from whole water samples (total ammonia; parameter code 00610) for 1990–98. Two States (Nevada and Wisconsin) reported ammonia concentrations determined only on filtered samples of water (dissolved ammonia; parameter code 00608), whereas 12 States reported both total and dissolved ammonia concentrations. Total and dissolved ammonia analyses were assumed to produce similar concentrations of ammonia in water from most monitoring sites; therefore, data for parameter codes 00608 and 00610 were combined to create merged State databases prior to the water-quality summary for ammonia. Ammonia data acquired from the modern STORET system included total and dissolved analyses for Colorado and Montana and required a similar merging procedure.

Creation of merged databases for ammonia concentrations determined in water from ambient stream-water-quality monitoring sites consisted of merging dissolved ammonia determinations into the database for total ammonia determinations. In situations where both a total and dissolved concentration existed for a water sample, the total concentration was included rather than the dissolved concentration. Total ammonia concentrations were preferred for inclusion because of the preponderance of these data among the State water-quality databases. Merged State databases (table 9) were used for the water-quality summary of ammonia presented in this report. State medians of monitoring-site median concentrations of ammonia ranged from 0.003 mg/L in Colorado to 0.46 mg/L in Rhode Island (table 10).

## Nitrite Plus Nitrate

Nitrite and nitrate are inorganic oxidized forms of nitrogen produced during various stages of the nitrogen cycle (Manahan, 1994, p. 41). In most oxygenated surface water, nitrate is by far

**Table 8.** Summary of median fecal coliform bacteria densities in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[mL, milliliters; --, not available; <, less than; >, greater than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median density (colonies per 100 mL of water) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 45 | 18.0 | 115 | 1,950 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 113 | 8.5 | 75.5 | 500 |
| California | -- | -- | -- | -- |
| Colorado | 124 | <2.0 | 19.2 | 4,300 |
| Connecticut | 32 | 11.0 | 148 | 5,650 |
| Delaware | 0 | -- | -- | -- |
| Florida | 372 | <1.0 | 80.0 | 2,250 |
| Georgia | 255 | <20.0 | 200 | 7,900 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 42 | 2.0 | 24.0 | 265 |
| Illinois | 3 | 220 | 230 | 2,450 |
| Indiana | 0 | -- | -- | -- |
| Iowa | 17 | 3.0 | 200 | 1,900 |
| Kansas | 249 | <10.0 | 155 | 6,000 |
| Kentucky | 59 | 10.0 | 128 | 650 |
| Louisiana | 103 | 8.0 | 200 | 30,000 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | 4.0 | 265 | 2,300 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 0 | -- | -- | -- |
| Minnesota | 63 | <4.0 | 64.0 | 950 |
| Mississippi | 50 | 10.0 | 152 | 640 |
| Missouri | 39 | 4.0 | 57.0 | 1,000 |
| Montana | 2 | 2,260 | 2,650 | 3,040 |
| Nebraska | 22 | 17.0 | 71.2 | 720 |
| Nevada | 60 | <10.0 | 20.0 | 3,100 |
| New Hampshire | 8 | 55.0 | 230 | 430 |
| New Jersey | 5 | 7.0 | 28.0 | 210 |
| New Mexico | 9 | 14.0 | 51.0 | 330 |
| New York | 8 | 20.0 | 48.0 | 600 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 39 | <10.0 | 30.0 | 160 |
| Ohio | 40 | 72.5 | 235 | 2,700 |
| Oklahoma | 14 | 50.0 | 450 | 2,150 |
| Oregon | 83 | <4.0 | 140 | >600 |
| Pennsylvania | 53 | 10.0 | 60.0 | 1,800 |
| Rhode Island | 5 | 27.0 | 56.0 | 160 |
| South Carolina | 310 | 1.0 | 170 | 2,600 |
| South Dakota | 96 | <2.0 | 65.0 | 1,100 |
| Tennessee | 60 | <2.0 | 210 | 4,250 |
| Texas | 457 | <3.0 | 106 | 13,000 |
| Utah | 16 | 2.0 | 40.0 | 750 |
| Vermont | -- | -- | -- | -- |
| Virginia | 1,086 | <1.8 | 100 | 16,000 |
| Washington | 202 | <1.0 | 20.8 | 510 |
| West Virginia | 26 | <10.0 | 144 | 3,000 |
| Wisconsin | 44 | <10.0 | 47.5 | 1,300 |
| Wyoming | 18 | 11.0 | 69.5 | 325 |

[1]Nine or more analyses per site.

**Table 9.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of ammonia as nitrogen concentrations in water, 1990–98.

[--, not available]

| State | Number of sites with data for parameter code[1] | | Number of sites in merged databases |
|---|---|---|---|
| | 00608 (dissolved) | 00610 (total) | |
| Alabama | -- | 18 | 18 |
| Alaska | -- | -- | -- |
| Arizona | -- | -- | -- |
| Arkansas | -- | 131 | 131 |
| California | -- | -- | -- |
| Colorado | -- | -- | 163 |
| Connecticut | 29 | 24 | 29 |
| Delaware | 17 | 103 | 103 |
| Florida | 284 | 566 | 793 |
| Georgia | -- | 283 | 283 |
| Hawaii | -- | -- | -- |
| Idaho | 45 | 12 | 47 |
| Illinois | -- | 11 | 11 |
| Indiana | -- | 106 | 106 |
| Iowa | -- | 39 | 39 |
| Kansas | -- | 251 | 251 |
| Kentucky | -- | 60 | 60 |
| Louisiana | -- | -- | 0 |
| Maine | -- | -- | -- |
| Maryland | -- | 40 | 40 |
| Massachusetts | -- | -- | -- |
| Michigan | -- | 70 | 70 |
| Minnesota | -- | 66 | 66 |
| Mississippi | -- | 58 | 58 |
| Missouri | 14 | 35 | 39 |
| Montana | -- | -- | 140 |
| Nebraska | -- | 22 | 22 |
| Nevada | 67 | -- | 67 |
| New Hampshire | -- | -- | 41 |
| New Jersey | 67 | 80 | 82 |
| New Mexico | 14 | 223 | 228 |
| New York | -- | 19 | 19 |
| North Carolina | -- | -- | -- |
| North Dakota | -- | -- | 55 |
| Ohio | -- | 41 | 41 |
| Oklahoma | -- | 38 | 38 |
| Oregon | -- | 143 | 143 |
| Pennsylvania | 2 | 174 | 174 |
| Rhode Island | 5 | 5 | 5 |
| South Carolina | -- | 337 | 337 |
| South Dakota | -- | 96 | 96 |
| Tennessee | -- | 65 | 65 |
| Texas | 90 | 444 | 446 |
| Utah | -- | -- | 64 |
| Vermont | -- | -- | -- |
| Virginia | 67 | 902 | 957 |
| Washington | -- | 204 | 204 |
| West Virginia | -- | 26 | 26 |
| Wisconsin | 40 | -- | 40 |
| Wyoming | 21 | 11 | 21 |

[1]See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

**Table 10.** Summary of median ammonia as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[<, less than; --, not available]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 18 | <0.01 | <0.01 | 0.27 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | <.05 | <.05 | 4.2 |
| California | -- | -- | -- | -- |
| Colorado | 163 | <.001 | .003 | .12 |
| Connecticut | 29 | .02 | .08 | .85 |
| Delaware | 103 | .03 | .07 | .66 |
| Florida | 793 | <.01 | .04 | 3.1 |
| Georgia | 283 | .02 | .03 | 2.3 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 47 | .007 | .03 | .09 |
| Illinois | 11 | .02 | .12 | .40 |
| Indiana | 106 | <.10 | <.10 | .60 |
| Iowa | 39 | .05 | <.10 | .11 |
| Kansas | 251 | <.02 | <.05 | .88 |
| Kentucky | 60 | <.05 | <.05 | .19 |
| Louisiana | 0 | -- | -- | -- |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | .01 | .03 | .14 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 70 | .01 | .04 | .30 |
| Minnesota | 66 | <.02 | .04 | .22 |
| Mississippi | 58 | <.10 | .16 | .46 |
| Missouri | 39 | .01 | .03 | .10 |
| Montana | 140 | <.01 | <.01 | 2.9 |
| Nebraska | 22 | .02 | .06 | .20 |
| Nevada | 67 | .006 | <.10 | 9.7 |
| New Hampshire | 41 | <.01 | <.10 | <.10 |
| New Jersey | 82 | .03 | .07 | .76 |
| New Mexico | 228 | .02 | <.10 | 5.3 |
| New York | 19 | .008 | .04 | .17 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 55 | <.01 | .03 | .94 |
| Ohio | 41 | <.05 | <.05 | .48 |
| Oklahoma | 38 | .01 | .07 | 1.4 |
| Oregon | 143 | <.02 | .02 | .31 |
| Pennsylvania | 174 | <.02 | .02 | .74 |
| Rhode Island | 5 | .03 | .46 | 1.3 |
| South Carolina | 337 | <.05 | <.05 | .18 |
| South Dakota | 96 | <.02 | <.03 | 10.6 |
| Tennessee | 65 | <.02 | .03 | .23 |
| Texas | 446 | <.01 | <.05 | .68 |
| Utah | 64 | <.05 | <.05 | .59 |
| Vermont | -- | -- | -- | -- |
| Virginia | 957 | .01 | <.04 | 10.4 |
| Washington | 204 | <.01 | .01 | 2.9 |
| West Virginia | 26 | <.50 | <.50 | <.50 |
| Wisconsin | 40 | <.02 | .05 | .19 |
| Wyoming | 21 | .02 | .03 | 2.6 |

[1]Nine or more analyses per site.

the most predominant ion because of the rapid oxidation of nitrite to nitrate.

Nitrate is the form of nitrogen most easily used by rooted green plants and algae and usually occurs in relatively small concentrations in uncontaminated surface water with a world average of 0.30 mg/L as nitrogen (Reid and Wood, 1976, p. 235). Larger concentrations may stimulate the growth of rooted plants or accelerate algal production to an extent that algae may produce a taste-and-odor problem in finished drinking water. Because most aquatic organisms can tolerate nitrite plus nitrate concentrations far in excess of what normally might be found even in contaminated surface water, no water-quality criteria have been established for protection of aquatic life. Adverse human-health effects of large concentrations of nitrate (greater than 10 mg/L) in drinking water include methemoglobinemia (blue-baby syndrome) in infants (U.S. Environmental Protection Agency, 1986).

Sources of nitrite plus nitrate nitrogen in the aquatic environment are similar to those for ammonia. Point sources include municipal and industrial discharges, and nonpoint sources are mostly related to agricultural activities such as crop (fertilizer application) and livestock (manure distribution) production and urban uses such as lawn fertilizers.

Nitrite ($NO_2^-$) and nitrate ($NO_3^-$) ions are completely soluble in water (Follett, 1995). Therefore, determinations of nitrite plus nitrate as nitrogen concentrations in whole (total) or filtered (dissolved) water from ambient stream-water-quality monitoring sites generally should be comparable. Nitrite, generally, is an insignificant component of the nitrite plus nitrate determination because in most natural water nitrite is readily oxidized to nitrate (Hem, 1992).

Historically, States have reported nitrite and nitrate determinations in several ways—only nitrate, nitrite and nitrate individually, and (or) combined determinations of nitrite and nitrate (table 11). These determinations have been made on filtered and unfiltered stream-water samples. Kansas, for example, currently (2004) determines concentrations of nitrite plus nitrate as nitrogen on unfiltered water samples (parameter code 00630) but historically had reported nitrate concentrations on filtered water samples (parameter code 00618). For the purpose of this report, the representation of inorganic oxides of nitrogen in stream-water samples was concentrations of nitrite plus nitrate as nitrogen (either parameter code 00630 or 00631). In the absence of either of these determinations, however, concentrations of nitrate as nitrogen (parameter codes 00618 or 00620) or as nitrate (parameter code 71851, subsequently expressed as nitrogen in this report) were used as surrogates for nitrite plus nitrate as nitrogen determinations under the assumptions that nitrite concentrations were small (relative to nitrate concentrations) in natural stream water and that no substantial differences existed between determinations made on filtered or unfiltered water samples. Hereinafter, all determinations of nitrate or nitrite and nitrate used in this report will be referred to as nitrite plus nitrate as nitrogen.

Most of the 42 States with electronically accessible nitrite plus nitrate as nitrogen concentrations analyzed for total concentrations (table 11). Some States, however, also analyzed for dissolved concentrations of nitrite plus nitrate either in combination with or instead of total concentrations. Because of the similarity in total and dissolved concentrations of nitrite plus nitrate as nitrogen, monitoring sites with these data were combined into merged State databases using a merge procedure identical to that used for merging ammonia data, with total concentrations having preference. State medians of monitoring-site median concentrations of nitrite plus nitrate as nitrogen ranged from 0.05 mg/L in Nevada to 5.7 mg/L in Iowa (table 12).

## Phosphorus

Phosphorus is an essential nutrient for plant growth; however, in excess of critical concentrations, it may contribute to the eutrophication of surface-water resources. Eutrophication (nutrient enrichment) is characterized by an abundance of nutrients, decreases in dissolved oxygen, excess growth of algae, and an acceleration of the normal rate of ecological succession (Reid and Wood, 1976). Sources of phosphorus in surface water are similar to those previously identified for ammonia and nitrite plus nitrate as nitrogen.

Phosphorus is ubiquitous in streams in much of the Nation. Some of this occurrence is due to the natural weathering of phosphorus in soil and rock, but a large part of the phosphorus in streams is the result of human activities. These activities may include point-source discharges from municipal and industrial facilities or nonpoint-source contributions related to runoff from urban and agricultural areas. Fertilizers containing phosphorus are routinely applied in crop production, often in conjunction with nitrogen fertilizers. Phosphorus compounds also are a component of livestock manure, and the land disposal of manure from confined animal-feeding operations and pasturing of livestock establish a substantial source of nonpoint-source phosphorus to the Nation's rivers and streams (Heathwaite, 1997; Sharpley and Rekolainen, 1997; U.S. Geological Survey, 1999).

Data from 41 States were summarized for total phosphorus concentrations in water from ambient stream-water-quality monitoring sites. All phosphorus data retrieved were stored under a single parameter code (00665, table 4) or retrieved as "total phosphorus" from the modern STORET system. Therefore, a data-merge procedure was not necessary for total phosphorus concentrations. State medians of monitoring-site median concentrations of total phosphorus ranged from 0.02 mg/L in West Virginia to 0.33 mg/L in Illinois (table 13).

## Arsenic

Arsenic is a nonmetallic element that has potential toxicological effects on aquatic organisms (U.S. Environmental Protection Agency, 1986). Arsenic occurs in the Earth's crust at concentrations of about 2 to 5 mg/kg and has been distributed throughout the environment by natural weathering and human activities. One distribution mechanism is the burning of fossil

**Table 11.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of nitrate and nitrite plus nitrate as nitrogen concentrations in water, 1990–98.

[--, not available]

| State | Number of sites with data for parameter code[1] | | | | | Number of sites in merged database |
|---|---|---|---|---|---|---|
| | 00618 (dissolved) | 00620 (total) | 00630 (total) | 00631 (dissolved) | 71851[2] (dissolved) | |
| Alabama | -- | 44 | -- | -- | -- | 44 |
| Alaska | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- |
| Arkansas | -- | -- | 131 | -- | -- | 131 |
| California | -- | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | -- | 210 |
| Connecticut | -- | -- | 24 | 28 | -- | 30 |
| Delaware | -- | 3 | 103 | 17 | -- | 103 |
| Florida | 11 | 351 | 696 | 105 | -- | 825 |
| Georgia | -- | -- | 283 | -- | -- | 283 |
| Hawaii | -- | -- | -- | -- | -- | -- |
| Idaho | -- | -- | 9 | 41 | -- | 45 |
| Illinois | -- | -- | 11 | -- | -- | 11 |
| Indiana | -- | -- | 106 | -- | -- | 106 |
| Iowa | -- | -- | 39 | -- | -- | 39 |
| Kansas | 152 | -- | 168 | -- | -- | 251 |
| Kentucky | -- | -- | 60 | -- | -- | 60 |
| Louisiana | -- | -- | 172 | -- | -- | 172 |
| Maine | -- | -- | -- | -- | -- | -- |
| Maryland | -- | -- | 40 | -- | -- | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- |
| Michigan | -- | 51 | 73 | 28 | -- | 85 |
| Minnesota | -- | -- | 66 | -- | -- | 66 |
| Mississippi | -- | -- | 65 | -- | -- | 65 |
| Missouri | -- | -- | 37 | 25 | -- | 40 |
| Montana | -- | -- | -- | -- | -- | 235 |
| Nebraska | -- | -- | 22 | -- | -- | 22 |
| Nevada | 63 | -- | -- | -- | 64 | 64 |
| New Hampshire | -- | -- | -- | -- | -- | 46 |
| New Jersey | -- | -- | 85 | 72 | -- | 87 |
| New Mexico | -- | -- | 221 | 13 | -- | 230 |
| New York | -- | -- | 19 | -- | -- | 19 |
| North Carolina | -- | -- | -- | -- | -- | -- |
| North Dakota | -- | -- | -- | -- | -- | 57 |
| Ohio | -- | -- | 41 | -- | -- | 41 |
| Oklahoma | -- | -- | [3] 111 | -- | -- | 111 |
| Oregon | -- | -- | 143 | -- | -- | 143 |
| Pennsylvania | 1 | 171 | -- | -- | -- | 171 |
| Rhode Island | -- | -- | 5 | 5 | -- | 5 |
| South Carolina | -- | -- | 340 | -- | -- | 340 |
| South Dakota | -- | 47 | 50 | -- | -- | 96 |
| Tennessee | -- | -- | 65 | -- | -- | 65 |
| Texas | -- | 266 | 180 | 102 | -- | 449 |
| Utah | -- | -- | -- | -- | -- | 64 |
| Vermont | -- | -- | -- | -- | -- | -- |
| Virginia | 85 | 901 | -- | 55 | -- | 957 |
| Washington | -- | -- | 204 | -- | -- | 204 |
| West Virginia | -- | -- | -- | -- | -- | [4] 24 |
| Wisconsin | -- | -- | -- | 42 | -- | 42 |
| Wyoming | -- | -- | 6 | 29 | -- | 29 |

[1]See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

[2]Reported nitrate as nitrate ($NO_3$) concentrations were converted to nitrate as nitrogen concentrations for use in this report.

[3]Concentrations of nitrite plus nitrate as nitrogen at some monitoring sites were calculated from individual nitrite and nitrate as nitrogen concentrations.

[4]No single monitoring site had nine or more analyses for any one parameter, but when merged, 24 monitoring sites had nine or more analyses of the combined parameters.

**Table 12.** Summary of median nitrite plus nitrate as nitrogen concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98

[--, not available; <, less than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 44 | <0.01 | 0.45 | 3.7 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | <.02 | .21 | 8.8 |
| California | -- | -- | -- | -- |
| Colorado | 210 | <.05 | <.50 | 6.0 |
| Connecticut | 30 | .13 | .46 | 3.7 |
| Delaware | 103 | .08 | 1.7 | 15.2 |
| Florida | 825 | 0 | .07 | 9.7 |
| Georgia | 283 | <.02 | .26 | 3.5 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 45 | .06 | .22 | 2.4 |
| Illinois | 11 | .18 | 4.3 | 11.4 |
| Indiana | 106 | <.10 | 2.5 | 7.2 |
| Iowa | 39 | .50 | 5.7 | 11.0 |
| Kansas | 251 | .04 | .54 | 6.8 |
| Kentucky | 60 | .13 | .48 | 5.3 |
| Louisiana | 172 | <.02 | .16 | 2.2 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | .39 | 1.4 | 5.7 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 85 | .01 | .90 | 9.0 |
| Minnesota | 66 | <.05 | .53 | 32.0 |
| Mississippi | 65 | <.02 | .16 | .64 |
| Missouri | 40 | .08 | .47 | 10.5 |
| Montana | 235 | 0 | .07 | 33.5 |
| Nebraska | 22 | .06 | 1.2 | 1.9 |
| Nevada | 64 | 0 | .05 | 3.0 |
| New Hampshire | 46 | <.02 | .19 | .68 |
| New Jersey | 87 | .10 | 1.1 | 4.4 |
| New Mexico | 230 | <.04 | <.10 | 7.2 |
| New York | 19 | .18 | .44 | 1.2 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 57 | <.005 | .08 | .47 |
| Ohio | 41 | .32 | 2.7 | 5.2 |
| Oklahoma | 111 | .02 | .24 | 7.1 |
| Oregon | 143 | <.02 | .12 | 4.1 |
| Pennsylvania | 171 | <.04 | .71 | 12.8 |
| Rhode Island | 5 | .25 | .71 | .90 |
| South Carolina | 340 | <.02 | .18 | 6.5 |
| South Dakota | 96 | <.10 | .30 | 19.2 |
| Tennessee | 65 | .07 | .38 | 2.8 |
| Texas | 449 | <.01 | .39 | 29.0 |
| Utah | 64 | <.02 | .25 | 3.0 |
| Vermont | -- | -- | -- | -- |
| Virginia | 957 | 0 | .19 | 71.7 |
| Washington | 204 | <.01 | .20 | 9.4 |
| West Virginia | 24 | .16 | .43 | 2.0 |
| Wisconsin | 42 | .05 | .45 | 4.1 |
| Wyoming | 29 | .06 | .16 | 3.3 |

[1]Nine or more analyses per site.

**Table 13.** Summary of median total phosphorus concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 45 | 0.01 | 0.09 | 4.5 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | <.03 | .07 | 4.7 |
| California | -- | -- | -- | -- |
| Colorado | 209 | <.01 | .05 | 2.7 |
| Connecticut | 32 | .01 | .05 | .52 |
| Delaware | 103 | .03 | .10 | .62 |
| Florida | 790 | .002 | .07 | 5.8 |
| Georgia | 283 | <.02 | .07 | 3.4 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 44 | .005 | .04 | .49 |
| Illinois | 11 | .06 | .33 | 2.8 |
| Indiana | 106 | <.03 | .10 | .38 |
| Iowa | 28 | .10 | .20 | .50 |
| Kansas | 251 | .04 | .15 | 1.9 |
| Kentucky | 60 | <.005 | .04 | .74 |
| Louisiana | 172 | .03 | .15 | 1.0 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | <.01 | .05 | .24 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 83 | .009 | .06 | .35 |
| Minnesota | 63 | .01 | .15 | 3.5 |
| Mississippi | 65 | .03 | .08 | .39 |
| Missouri | 34 | .02 | .05 | 4.1 |
| Montana | 175 | <.01 | .04 | 2.7 |
| Nebraska | 22 | .02 | .18 | .80 |
| Nevada | 67 | .01 | .06 | .48 |
| New Hampshire | 46 | .007 | .03 | .12 |
| New Jersey | 82 | .02 | .07 | .45 |
| New Mexico | 225 | <.01 | <.09 | 4.6 |
| New York | 0 | -- | -- | -- |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 57 | <.02 | .17 | .64 |
| Ohio | 41 | <.05 | .11 | 1.2 |
| Oklahoma | 194 | <.01 | .04 | .64 |
| Oregon | 141 | .01 | .05 | .44 |
| Pennsylvania | 174 | .02 | .03 | .64 |
| Rhode Island | 5 | .02 | .22 | .34 |
| South Carolina | 339 | <.02 | .05 | 1.2 |
| South Dakota | 96 | .01 | .12 | 1.8 |
| Tennessee | 65 | <.01 | .05 | .45 |
| Texas | 439 | <.01 | .12 | 4.7 |
| Utah | 64 | <.01 | .06 | .98 |
| Vermont | -- | -- | -- | -- |
| Virginia | 936 | .01 | <.10 | 13.8 |
| Washington | 206 | <.01 | .03 | 3.1 |
| West Virginia | 26 | <.02 | .02 | .14 |
| Wisconsin | 44 | .03 | .09 | .35 |
| Wyoming | 21 | .02 | .05 | 2.4 |

[1]Nine or more analyses per site.

fuels (particularly coal) with potential contamination of surface-water resources (Manahan, 1994). Arsenic also has been introduced into the aquatic environment through industrial discharges and use as a component in some pesticides, most of which are currently (2004) banned (Manahan, 1994). However, arsenic (roxarsone) is still used as a feed additive for poultry for increased weight gain, feed efficiency, improved pigmentation, and prevention of parasites (Miller and others, 2000). Some ground water, particularly of geothermal origin, may contain relatively large natural concentrations of arsenic (Hem, 1992). Discharge of arsenic-enriched ground water may contaminate surface-water resources.

Data from 28 States were summarized for total arsenic concentrations in water from ambient stream-water-quality monitoring sites. All total arsenic data from monitoring sites with at least nine analyses had these data stored in STORET Legacy, NWIS, or State databases under parameter code 00978 (total recoverable arsenic) or parameter code 01002 (total arsenic) or as "total arsenic" in the modern STORET system. However, only Washington stored data under parameter code 00978 for a total of five monitoring sites. Total and total recoverable analyses generally are distinguished by the degree of digestion of a water/sediment sample. Total is used when the analytical procedure assures measurement of at least 95 percent of a constituent in both the dissolved and suspended phases. Total recoverable is used to represent something less than the "total" amount (less than 95 percent) (Fishman and Friedman, 1989). However, for the purpose of the summary presented in this report, it was assumed that total arsenic concentrations stored under both parameter codes were analytically comparable. Because no monitoring site in Washington contained both total and total recoverable concentrations of arsenic, a merging procedure and selection of a preferred parameter were not required. State medians of monitoring-site median concentrations of total arsenic ranged from 0.80 μg/L in Washington to 11.5 μg/L in South Dakota (table 14).

## Dissolved Solids

Dissolved solids in surface water result from natural dissolution of rocks and minerals or discharges from municipal, industrial, or agricultural sources. The major constituents of dissolved solids are the cations (positively charged ions) calcium, magnesium, sodium, and potassium, and the anions (negatively charged ions) bicarbonate, carbonate, sulfate, and chloride. Natural variability in dissolved-solids concentrations depends on chemical characteristics of drainage-basin soils, composition of surficial material, and in some situations the minerals in deeper geologic strata. Larger dissolved-solids concentrations in surface water may be expected in areas underlain by ancient marine sediment containing large salt deposits (Bevans, 1989; Gillespie and Hargadine, 1994). Ground water dissolves the salt, which eventually discharges into surface water. Point-source discharges such as from industrial or municipal wastewater-treatment plants (Pope and Putnam, 1997) and nonpoint-source discharges from areas of extensive irrigation (Klein and Bradford, 1980; Libermann and others, 1989) also may increase dissolved-solids concentrations in surface water.

Excessively large concentrations of dissolved solids may be objectionable in drinking water because of possible physiological effects, unpalatable mineral taste, and greater cost because of (1) corrosion of plumbing, boilers, or other water-transfer or utility equipment, or (2) the necessity for additional treatment to remove the ions responsible for objectionable taste or corrosion. Because dissolved solids may not be removed from source water during traditional drinking-water treatment processes, more expensive reverse osmosis procedures (Chu and others, 1986, for example) may be required to produce drinking water of desirable quality.

Twenty-nine States had electronically accessible dissolved-solids concentrations in water from ambient stream-water-quality monitoring sites (table 15). Data from monitoring sites with nine or more analyses for dissolved solids were stored in STORET Legacy, NWIS, or State databases under one or more of four parameter codes for dissolved solids (00515, 70294, 70300, 70301) or as "dissolved solids" in the modern STORET system. Although monitoring sites for most States had dissolved-solids concentrations stored under only one parameter code (most commonly 70300), Florida also had calculated dissolved-solids concentrations (parameter code 70301). For the purpose of the summary presented in this report, it was assumed that all State analytical and calculated determinations of dissolved-solids concentrations were comparable and, therefore, were merged into State databases with a common dissolved-solids parameter (table 15). During the merge process for Florida, parameter code 70300 was used in preference over parameter code 70301. State medians of monitoring-site median concentrations of dissolved solids ranged from 37.2 mg/L in Mississippi to 711 mg/L in South Dakota (table 16).

Although an assumption of comparability of State analytical and calculated results was made for the statistical summary of dissolved-solids concentrations (table 16), there may be evidence of an inconsistency in this assumption. The small median dissolved-solids concentration (37.2 mg/L) for Mississippi was determined from the medians of 46 monitoring sites that used the somewhat ambiguous parameter code 70294 (unspecified calculation). Relative to the bordering States of Alabama and Louisiana, which had median concentrations of 204 and 196 mg/L, respectively, the median for Mississippi seems anomalous and possibly the result of a lack of computational comparability (not all of the same constituents may have been included in the dissolved-solids calculation).

## Chloride

Chloride ion is the most common oxidation state (-1) of the element chlorine and is the only ion of major environmental significance in the hydrologic cycle. Chloride occurs mostly in small concentrations in all natural freshwater except for those

**Table 14.** Summary of median total arsenic concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[<, less than; >, greater than; --, not available]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (micrograms per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 27 | <5.0 | <10.0 | <10.0 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 0 | -- | -- | -- |
| California | -- | -- | --- | -- |
| Colorado | 0 | -- | -- | -- |
| Connecticut | 0 | -- | -- | -- |
| Delaware | 20 | <10.0 | <10.0 | <10.0 |
| Florida | 128 | .57 | <1.5 | <10.0 |
| Georgia | 0 | -- | -- | -- |
| Hawaii | -- | -- | -- | -- |
| Idaho | 0 | -- | -- | -- |
| Illinois | 2 | <1.0 | 1.1 | 1.1 |
| Indiana | 61 | .30 | 1.5 | 3.2 |
| Iowa | 1 | <10.0 | <10.0 | <10.0 |
| Kansas | 251 | <1.0 | 4.0 | <21.0 |
| Kentucky | 59 | <2.0 | <2.0 | 3.0 |
| Louisiana | 12 | 2.4 | 3.2 | 5.8 |
| Maine | -- | -- | -- | -- |
| Maryland | 0 | -- | -- | -- |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 48 | <1.0 | 1.2 | 2.9 |
| Minnesota | 0 | -- | -- | -- |
| Mississippi | 22 | <3.0 | <5.0 | <5.0 |
| Missouri | 0 | -- | -- | -- |
| Montana | 8 | <1.0 | >1.0 | 15.5 |
| Nebraska | 13 | 2.9 | 5.0 | 6.8 |
| Nevada | 59 | <3.0 | 4.0 | 251 |
| New Hampshire | 1 | <5.0 | <5.0 | <5.0 |
| New Jersey | 4 | 1.0 | 1.5 | 3.0 |
| New Mexico | 15 | <1.0 | <5.0 | <5.0 |
| New York | 0 | -- | -- | -- |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 24 | 1.4 | 3.2 | 7.9 |
| Ohio | 41 | <2.0 | <2.0 | 4.0 |
| Oklahoma | 0 | -- | -- | -- |
| Oregon | 0 | -- | -- | -- |
| Pennsylvania | 31 | <4.0 | <4.0 | <4.0 |
| Rhode Island | 1 | 2.0 | 2.0 | 2.0 |
| South Carolina | 0 | -- | -- | -- |
| South Dakota | 20 | <5.0 | 11.5 | 37.1 |
| Tennessee | 70 | <1.0 | <2.0 | 6.0 |
| Texas | 9 | 1.0 | 2.0 | 3.0 |
| Utah | 54 | <5.0 | <5.0 | 20.0 |
| Vermont | -- | -- | -- | -- |
| Virginia | 75 | <5.0 | <10.0 | <10.0 |
| Washington | 5 | .58 | .80 | 3.7 |
| West Virginia | 0 | -- | -- | -- |
| Wisconsin | 2 | <10.0 | <10.0 | <10.0 |
| Wyoming | 0 | -- | -- | -- |

[1]Nine or more analyses per site.

**Table 15.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for parameter codes of dissolved-solids concentrations in water, 1990–98.

[°C, degrees Celsius; --, not available]

| State | Number of sites with data for parameter code[1] | | | | Number of sites in merged database |
|---|---|---|---|---|---|
| | 00515 (dried at 105 °C) | 70294 (unspecified calculation) | 70300 (dried at 180 °C) | 70301 (sum of constituents) | |
| Alabama | 42 | -- | -- | -- | 42 |
| Alaska | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- |
| Arkansas | -- | -- | 131 | -- | 131 |
| California | -- | -- | -- | -- | -- |
| Colorado | -- | -- | -- | -- | 212 |
| Connecticut | -- | -- | 32 | -- | 32 |
| Delaware | -- | -- | -- | -- | 0 |
| Florida | -- | -- | 246 | 6 | 253 |
| Georgia | -- | -- | -- | -- | 0 |
| Hawaii | -- | -- | -- | -- | -- |
| Idaho | -- | -- | 32 | -- | 32 |
| Illinois | -- | -- | -- | -- | 0 |
| Indiana | -- | -- | 23 | -- | 23 |
| Iowa | 28 | -- | -- | -- | 28 |
| Kansas | -- | -- | -- | 251 | 251 |
| Kentucky | -- | -- | -- | -- | 0 |
| Louisiana | 172 | -- | -- | -- | 172 |
| Maine | -- | -- | -- | -- | -- |
| Maryland | 12 | -- | -- | -- | 12 |
| Massachusetts | -- | -- | -- | -- | -- |
| Michigan | -- | -- | -- | -- | 0 |
| Minnesota | -- | -- | -- | -- | 0 |
| Mississippi | -- | 46 | -- | -- | 46 |
| Missouri | -- | -- | 36 | -- | 36 |
| Montana | -- | -- | -- | -- | 84 |
| Nebraska | -- | -- | -- | -- | 0 |
| Nevada | 67 | -- | -- | -- | 67 |
| New Hampshire | -- | -- | -- | -- | 0 |
| New Jersey | -- | -- | 92 | -- | 92 |
| New Mexico | -- | -- | 228 | -- | 228 |
| New York | -- | -- | 19 | -- | 19 |
| North Carolina | -- | -- | -- | -- | -- |
| North Dakota | -- | -- | -- | -- | 52 |
| Ohio | -- | -- | 32 | -- | 32 |
| Oklahoma | -- | -- | -- | -- | 0 |
| Oregon | -- | -- | 1 | -- | 1 |
| Pennsylvania | 173 | -- | -- | -- | 173 |
| Rhode Island | -- | -- | 1 | -- | 1 |
| South Carolina | -- | -- | -- | -- | 0 |
| South Dakota | -- | -- | 96 | -- | 96 |
| Tennessee | 23 | -- | -- | -- | 23 |
| Texas | -- | -- | 284 | -- | 285 |
| Utah | -- | -- | -- | -- | 64 |
| Vermont | -- | -- | -- | -- | -- |
| Virginia | 82 | -- | -- | -- | 82 |
| Washington | -- | -- | -- | -- | 0 |
| West Virginia | -- | -- | -- | -- | 0 |
| Wisconsin | -- | -- | -- | -- | 0 |
| Wyoming | -- | -- | 11 | -- | 11 |

[1]See table 4 for complete descriptions of parameter codes. Data not organized by parameter code in the modern STORET system.

**Table 16.** Summary of median dissolved-solids concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 42 | 45.0 | 204 | 9,790 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 30.5 | 144 | 541 |
| California | -- | -- | -- | -- |
| Colorado | 212 | 28.0 | 190 | 3,500 |
| Connecticut | 32 | 51.0 | 98.5 | 248 |
| Delaware | 0 | -- | -- | -- |
| Florida | 253 | 2.0 | 201 | 5,960 |
| Georgia | 0 | -- | -- | -- |
| Hawaii | -- | -- | -- | -- |
| Idaho | 32 | 29.0 | 214 | 517 |
| Illinois | 0 | -- | -- | -- |
| Indiana | 23 | 167 | 350 | 476 |
| Iowa | 28 | 170 | 335 | 600 |
| Kansas | 251 | 143 | 435 | 6,250 |
| Kentucky | 0 | -- | -- | -- |
| Louisiana | 172 | 44.0 | 196 | 9,360 |
| Maine | -- | -- | -- | -- |
| Maryland | 12 | 72.0 | 238 | 642 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 0 | -- | -- | -- |
| Minnesota | 0 | -- | -- | -- |
| Mississippi | 46 | .02 | 37.2 | 252 |
| Missouri | 36 | 128 | 201 | 671 |
| Montana | 84 | 9.0 | 120 | 2,920 |
| Nebraska | 0 | -- | -- | -- |
| Nevada | 67 | 31.5 | 159 | 2,370 |
| New Hampshire | 0 | -- | -- | -- |
| New Jersey | 92 | 23.0 | 136 | 534 |
| New Mexico | 228 | 28.0 | 206 | 8,320 |
| New York | 19 | 42.0 | 159 | 438 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 52 | 158 | 634 | 2,190 |
| Ohio | 32 | 208 | 424 | 739 |
| Oklahoma | 0 | -- | -- | -- |
| Oregon | 1 | 140 | 140 | 140 |
| Pennsylvania | 173 | 20.0 | 160 | 780 |
| Rhode Island | 1 | 74.0 | 74.0 | 74.0 |
| South Carolina | 0 | -- | -- | -- |
| South Dakota | 96 | 122 | 711 | 3,540 |
| Tennessee | 23 | 85.5 | 162 | 262 |
| Texas | 285 | 62.0 | 507 | 35,100 |
| Utah | 64 | 98.0 | 437 | 3,450 |
| Vermont | -- | -- | -- | -- |
| Virginia | 82 | 26.5 | 185 | 773 |
| Washington | 0 | -- | -- | -- |
| West Virginia | 0 | -- | -- | -- |
| Wisconsin | 0 | -- | -- | -- |
| Wyoming | 11 | 65.0 | 244 | 1,890 |

[1]Nine or more analyses per site.

that receive discharge of salt-laden ground water, municipal or industrial discharges, or are affected by oceanic tides. Seawater normally contains about 19,000 mg/L of chloride (Hem, 1992).

Chloride in streams has several natural sources; the dominant source in noncoastal areas probably is the dissolution of marine salt from sedimentary rock formations, particularly evaporite deposits. In contrast, igneous rock is expected to yield little chloride to solution (Hem, 1992). Wet (precipitation) and dry (atmospheric) deposition are secondary sources of chloride to the land surface (Lynch and others, 1996). These sources would have the greatest effects in near-coastal or coastal areas where chloride had been entrained in the atmosphere during the evaporation of seawater or transported by tidal activity.

Natural concentrations of chloride may be enriched by human activities particularly those associated with urbanization. Municipal-sewage discharges may contribute chloride to streams (Phillips, 1994; Pope and Putnam, 1997). Road salt can be a major contaminant of streams in both urban and rural areas. Snowmelt runoff from roads and bridges treated with salt can transport large concentrations of sodium and chloride to streams that can change water chemistry and stress or kill aquatic organisms (U.S. Environmental Protection Agency, 1995).

The chloride ion is one of the most conservative of the major solutes in natural water and does not enter into oxidation or reduction reactions, form solute complexes with other ions, or form salts of low solubility (Hem, 1992). Therefore, concentrations of chloride determined from whole water (total analysis) samples and filtered water (dissolved analysis) samples should be similar.

An inconsistency in parameter codes exists for total and dissolved chloride concentrations between the STORET Legacy and NWIS data-management systems. The STORET Legacy parameter code for total chloride is 00940 (table 4), whereas this same code in the NWIS system represents dissolved chloride. Because of this inconsistency, parameter headings in table 17 were simplified to “Total” and “Dissolved.”

Thirty-nine States had ambient stream-water-quality monitoring sites with at least nine analyses for chloride concentrations (table 17). Most of these chloride concentrations were total analyses; however, 15 States had monitoring sites with determinations of total and (or) dissolved chloride concentrations. New Mexico had 15 monitoring sites operated by the USGS, with analyses for dissolved chloride concentrations only. Other States with USGS-operated monitoring sites with dissolved chloride concentrations only included Connecticut, Idaho, Missouri, New Jersey, Rhode Island, and Wyoming. Because of the suspected similarity in total and dissolved concentrations of chloride, total and dissolved data were combined to create merged State databases with a procedure similar to that used to combine total and dissolved ammonia concentrations previously discussed in this report except that total chloride concentrations (the most commonly reported among the States) was used in preference over dissolved concentrations. The water-quality summary for chloride was conducted on these merged State databases. State medians of monitoring-site median concentrations of chloride ranged from 0 mg/L in Montana to 7,740 mg/L in Georgia (table 18). The exceptionally large monitoring-site median concentration for Georgia probably is due to its seven monitoring sites being located near the coast on tidal-affected streams subject to chloride fluxes from marine water.

## Sulfate

Sulfate is an oxidized form of sulfur and occurs naturally in surface water as a result of weathering of metallic sulfides in igneous and sedimentary rocks. Pyrite (iron disulfide) commonly occurs in sedimentary rocks and coal deposits and can be a major source of sulfate ion when oxidized. This natural oxidation process can be enhanced due to mineral- or coal-mining operations that may expose large quantities of pyrite to weathering. Gypsum (calcium sulfate) also is a source of sulfate in sedimentary rocks (Hem, 1992).

In addition to natural sources, sulfate concentrations in streams may be increased as a result of human activities. As previously indicated, sulfate concentrations in streams in mined areas may be larger than in unmined areas because of weathering of sulfide- or sulfate-bearing minerals (Powell, 1988). Drainage water from irrigated areas, particularly in semiarid lands, may contain large sulfate concentrations as a result of leaching of solutes (Orlob and Ghorbanzadeh, 1981; Sorenson and Schwarzbach, 1991). The additional water supplied by irrigation accelerates the natural leaching process and is especially evident in areas that receive little natural precipitation. The release of sulfur dioxide during the combustion of fossil fuels (Johnson, 1986) may increase stream sulfate concentrations (Smith and Alexander, 1986). The conversion of sulfur dioxide to particulate sulfate is believed to be an aqueous-enhanced chemical reaction in the atmosphere (Lamb and others, 1987). Subsequent wet and dry deposition may increase concentrations of sulfate in surface water.

Determination of sulfate concentrations in whole (total analysis) and filtered (dissolved analysis) water samples should provide similar results because of the ionic nature and solubility of sulfate (Hem, 1992) and because most of the methods for sulfate analysis incorporate a turbidity removal step (Clesceri and others, 1998). Because of the suspected similarity in total and dissolved concentrations of sulfate, total and dissolved data were combined to create merged State databases with a procedure similar to that used to combine State total and dissolved ammonia concentrations previously discussed in this report except total sulfate concentrations (the most commonly reported among the States) was included in preference over dissolved concentrations. The water-quality summary for sulfate was conducted on these merged State databases (table 19).

An inconsistency in parameter codes exists for total and dissolved sulfate concentrations between the STORET Legacy and NWIS data-management systems. The STORET Legacy parameter code for total sulfate is 00945 (table 4), whereas this same code in the NWIS represents dissolved sulfate. Because of this inconsistency, parameter headings in table 19 were simplified to “Total” and “Dissolved.”

**Table 17.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for total and dissolved chloride concentrations in water, 1990–98.

[--, not available]

| State | Number of sites with indicated analysis | | Number of sites in merged database |
|---|---|---|---|
| | Total | Dissolved | |
| Alabama | 45 | -- | 45 |
| Alaska | -- | -- | -- |
| Arizona | -- | -- | -- |
| Arkansas | 131 | -- | 131 |
| California | -- | -- | -- |
| Colorado | -- | -- | 0 |
| Connecticut | -- | 31 | 31 |
| Delaware | 95 | -- | 95 |
| Florida | 600 | 149 | 653 |
| Georgia | 7 | -- | 7 |
| Hawaii | -- | -- | -- |
| Idaho | -- | 35 | 35 |
| Illinois | 7 | -- | 7 |
| Indiana | 15 | -- | 15 |
| Iowa | 6 | -- | 6 |
| Kansas | 168 | 152 | 251 |
| Kentucky | 60 | -- | 60 |
| Louisiana | 172 | -- | 172 |
| Maine | -- | -- | -- |
| Maryland | -- | -- | 0 |
| Massachusetts | -- | -- | -- |
| Michigan | 93 | -- | 93 |
| Minnesota | 10 | -- | 10 |
| Mississippi | 56 | -- | 56 |
| Missouri | -- | 35 | 35 |
| Montana | 48 | 84 | 132 |
| Nebraska | 22 | -- | 22 |
| Nevada | -- | 67 | 67 |
| New Hampshire | 12 | -- | 12 |
| New Jersey | -- | 92 | 92 |
| New Mexico | 116 | 15 | 131 |
| New York | 19 | -- | 19 |
| North Carolina | -- | -- | -- |
| North Dakota | -- | 52 | 52 |
| Ohio | 40 | -- | 40 |
| Oklahoma | 177 | -- | 177 |
| Oregon | -- | 4 | 4 |
| Pennsylvania | 41 | -- | 41 |
| Rhode Island | -- | 5 | 5 |
| South Carolina | 14 | -- | 14 |
| South Dakota | 8 | -- | 8 |
| Tennessee | 1 | -- | 1 |
| Texas | 495 | -- | 495 |
| Utah | -- | 64 | 64 |
| Vermont | -- | -- | -- |
| Virginia | 897 | -- | 897 |
| Washington | -- | -- | 0 |
| West Virginia | 25 | -- | 25 |
| Wisconsin | 47 | 1 | 47 |
| Wyoming | -- | 19 | 19 |

**Table 18.** Summary of median chloride concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 45 | 3.0 | 12.0 | 5,160 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 1.9 | 4.8 | 124 |
| California | -- | -- | -- | -- |
| Colorado | 0 | -- | -- | -- |
| Connecticut | 31 | 9.6 | 19.0 | 51.0 |
| Delaware | 95 | 8.0 | 27.0 | 12,900 |
| Florida | 653 | 1.6 | 23.0 | 4,260 |
| Georgia | 7 | 67.1 | 7,740 | 14,500 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 35 | .25 | 5.0 | 67.0 |
| Illinois | 7 | 24.8 | 99.6 | 144 |
| Indiana | 15 | 11.0 | 41.0 | 190 |
| Iowa | 6 | 21.1 | 22.8 | 23.4 |
| Kansas | 251 | 4.6 | 29.6 | 3,220 |
| Kentucky | 60 | 2.3 | 6.5 | 36.5 |
| Louisiana | 172 | 2.8 | 18.3 | 5,320 |
| Maine | -- | -- | -- | -- |
| Maryland | 0 | -- | -- | -- |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 93 | 2.0 | 31.5 | 188 |
| Minnesota | 10 | 7.2 | 12.0 | 25.0 |
| Mississippi | 56 | 0 | 5.6 | 19.7 |
| Missouri | 35 | 2.2 | 6.4 | 136 |
| Montana | 132 | 0 | 0 | 36.0 |
| Nebraska | 22 | 1.0 | 16.6 | 52.4 |
| Nevada | 67 | 0 | 5.6 | 395 |
| New Hampshire | 12 | 10.0 | 26.5 | 69.0 |
| New Jersey | 92 | 4.3 | 23.5 | 220 |
| New Mexico | 131 | 1.6 | 5.2 | 2,140 |
| New York | 19 | 3.8 | 18.0 | 96.0 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 52 | <3.0 | 14.6 | 922 |
| Ohio | 40 | 10.0 | 36.0 | 162 |
| Oklahoma | 177 | 2.1 | <10.0 | 1,720 |
| Oregon | 4 | 1.6 | 2.8 | 17.0 |
| Pennsylvania | 41 | .66 | 10.0 | 63.0 |
| Rhode Island | 5 | 14.0 | 51.0 | 57.8 |
| South Carolina | 14 | 8.5 | 12.9 | 10,000 |
| South Dakota | 8 | 2.0 | 24.4 | 92.0 |
| Tennessee | 1 | 18.0 | 18.0 | 18.0 |
| Texas | 495 | 5.0 | 73.0 | 17,600 |
| Utah | 64 | 2.5 | 31.6 | 792 |
| Vermont | -- | -- | -- | -- |
| Virginia | 897 | .6 | 9.5 | 16,700 |
| Washington | 0 | -- | -- | -- |
| West Virginia | 25 | 1.6 | 6.0 | 24.4 |
| Wisconsin | 47 | 2.0 | 11.4 | 158 |
| Wyoming | 19 | .20 | 4.5 | 140 |

[1]Nine or more analyses per site.

**Table 19.** Number of State ambient stream-water-quality monitoring sites with data (nine or more analyses) for total and dissolved sulfate concentrations in water, 1990–98.

[--, not available]

| State | Number of sites with indicated analysis | | Number of sites in merged database |
|---|---|---|---|
| | Total | Dissolved | |
| Alabama | -- | -- | 0 |
| Alaska | -- | -- | -- |
| Arizona | -- | -- | -- |
| Arkansas | 131 | -- | 131 |
| California | -- | -- | -- |
| Colorado | 215 | -- | 215 |
| Connecticut | -- | 32 | 32 |
| Delaware | -- | -- | 0 |
| Florida | 506 | 144 | 593 |
| Georgia | -- | -- | 0 |
| Hawaii | -- | -- | -- |
| Idaho | -- | 37 | 37 |
| Illinois | 3 | -- | 3 |
| Indiana | 12 | -- | 12 |
| Iowa | 6 | -- | 6 |
| Kansas | 168 | 152 | 251 |
| Kentucky | -- | 59 | 59 |
| Louisiana | 172 | -- | 172 |
| Maine | -- | -- | -- |
| Maryland | 12 | -- | 12 |
| Massachusetts | -- | -- | -- |
| Michigan | 64 | -- | 64 |
| Minnesota | 1 | -- | 1 |
| Mississippi | 2 | -- | 2 |
| Missouri | -- | 34 | 34 |
| Montana | 72 | 91 | 163 |
| Nebraska | -- | -- | 0 |
| Nevada | -- | 66 | 66 |
| New Hampshire | 8 | -- | 8 |
| New Jersey | -- | 92 | 92 |
| New Mexico | 58 | 59 | 132 |
| New York | 19 | -- | 19 |
| North Carolina | -- | -- | -- |
| North Dakota | -- | 52 | 52 |
| Ohio | 36 | -- | 36 |
| Oklahoma | 178 | -- | 178 |
| Oregon | -- | -- | 0 |
| Pennsylvania | 174 | -- | 174 |
| Rhode Island | -- | 5 | 5 |
| South Carolina | 5 | -- | 5 |
| South Dakota | 8 | -- | 8 |
| Tennessee | 2 | -- | 2 |
| Texas | 481 | -- | 481 |
| Utah | -- | 64 | 64 |
| Vermont | -- | -- | -- |
| Virginia | 894 | -- | 894 |
| Washington | -- | -- | 0 |
| West Virginia | 26 | -- | 26 |
| Wisconsin | 17 | -- | 17 |
| Wyoming | -- | 19 | 19 |

Thirty-six States had ambient stream-water-quality monitoring sites with at least nine analyses for sulfate concentrations in stream water (table 19). Most of these sulfate concentrations were total analyses; however, 14 States had monitoring sites with determinations of total and (or) dissolved sulfate concentrations. Many of the monitoring sites in States with dissolved sulfate concentrations were operated by the USGS, which only analyzed for dissolved sulfate concentrations. These USGS-operated monitoring sites were in the same States as previously identified in the "Chloride" section of this report. State medians of monitoring-site median concentrations of sulfate ranged from 6.5 mg/L in New Hampshire to 232 mg/L in North Dakota (table 20).

## pH

pH is a measure of the hydrogen-ion activity in a water sample and by definition is the negative base-10 logarithm of the hydrogen-ion activity ($-\log_{10} H^+$) (Hem, 1992). pH measurements of natural water serve as an indicator of acid-base equilibrium of various dissolved compounds, salts, and gases. The principal equilibrium system controlling pH in natural water is the carbonate system—carbon dioxide ($CO_2$), carbonic acid ($H_2CO_3$), bicarbonate ion ($HCO_3^{-1}$), and carbonate ion ($CO_3^{-2}$) (U.S. Environmental Protection Agency, 1986). The degree of dissociation of weak acids, bases, and salts (compounds) is affected by changes in pH that subsequently can affect the toxicological properties of those and other compounds (Franklin and others, 2000; Pyle and others, 2002). Therefore, knowledge of the pH of natural water may provide insight into the potential for detrimental effects on aquatic ecosystems.

Uncontaminated stream water generally has a pH in the range of 6.5 to 8.5 standard units (Hem, 1992) and may display diurnal fluctuations similar to those for dissolved oxygen (Simonsen and Harremoes, 1978). These diurnal pH fluctuations probably are associated with photosynthetic/respiratory processes of aquatic organisms that use dissolved carbon dioxide during the day and release it at night. Snowmelt runoff, which may increase during the warmth of the day and decrease during the cool of the night, also may produce diurnal pH fluctuations.

All 42 States with electronically accessible pH measurements in water from ambient stream-water-quality monitoring sites had these data stored in STORET Legacy, NWIS, or State databases under a single parameter code (00400, table 4) or as "pH" in the modern STORET system. Therefore, a data-merge procedure was not necessary for pH measurements. State medians of the monitoring-site median measurements of pH ranged from 6.7 standard units in Rhode Island and South Carolina to 8.2 standard units in several other States (table 21).

# Limitations of State Ambient Stream-Water-Quality Data for National Assessment

The use of stream-water-quality data from State ambient monitoring networks has certain inherent limitations for producing a "picture" of national water-quality conditions. The Clean Water Act granted the States the independence to establish stream-water-quality monitoring networks to fulfill the requirements of the act and to develop monitoring procedures and protocols to satisfy unique blends of ecological, social, political, and economic conditions within each State. The very nature of this independence, however, created potential variability in the factors necessary to produce a nationally consistent water-quality assessment. These factors include (1) the basic spatial design of monitoring networks (selection of streams and location of monitoring sites); (2) water-quality constituents for which samples are analyzed; (3) water-quality criteria to which constituent concentrations are compared; (4) quantity and comprehensiveness of water-quality data; (5) sample collection, processing, and handling; (6) analytical methods; (7) temporal variability in sample collection; and (8) quality-assurance practices implemented to ensure reliability in data produced. National assessment of ambient stream-water quality using State-generated databases, therefore, consists of a compilation of 50 individual monitoring networks with varying degrees of comparability. Furthermore, in a study of water-quality assessment procedures of the Great Lake States, the Environmental Integrity Project (2004) concluded that no meaningful attempt to standardize or analyze widely disparate State approaches to water-quality assessment has been conducted and that the biannual National Water Quality Inventory reports may not present a true picture of national or regional water-quality conditions. USEPA (2004) also has recognized that many of these factors make it "...difficult to use existing data to give a complete and accurate picture of the state of U.S. surface waters to support aquatic life... ." Although a detailed evaluation of the variability among States in all these factors was beyond the resources and scope of the investigation described in this report, aspects of factors 1–4 will be discussed relative to the variability among State ambient stream-water-quality programs identified in this or previous reports.

## Design of Monitoring Networks

The implementation of water-quality monitoring is a key aspect of the Clean Water Act. Monitoring forms the basis of environmental assessment, the ability to determine time trends in water quality, and provides the information required for regulatory decisions related to contaminant-load allocation (total maximum daily loads), discharge permitting, and human health. Without reliable stream-water-quality data, government agencies, the Congress, and the public can not make the informed decisions necessary to protect and conserve the Nation's water resources.

**Table 20.** Summary of median sulfate concentrations in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available; <, less than]

| State | Number of assessed monitoring sites[1] | Monitoring-site median concentration (milligrams per liter) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 0 | -- | -- | -- |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 2.7 | 9.9 | 181 |
| California | -- | -- | -- | -- |
| Colorado | 215 | <5.0 | 41.0 | 1,920 |
| Connecticut | 32 | 5.5 | 11.0 | 31.0 |
| Delaware | 0 | -- | -- | -- |
| Florida | 593 | 0 | 12.1 | 651 |
| Georgia | 0 | -- | -- | -- |
| Hawaii | -- | -- | -- | -- |
| Idaho | 37 | .60 | 17.0 | 120 |
| Illinois | 3 | 70.0 | 85.0 | 108 |
| Indiana | 12 | 24.0 | 40.0 | 86.5 |
| Iowa | 6 | 38.8 | 58.1 | 78.4 |
| Kansas | 251 | 10.1 | 81.5 | 2,170 |
| Kentucky | 59 | 5.5 | 31.0 | 290 |
| Louisiana | 172 | 1.4 | 10.7 | 728 |
| Maine | -- | -- | -- | -- |
| Maryland | 12 | 27.8 | 122 | 650 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 64 | 3.0 | 29.0 | 82.0 |
| Minnesota | 1 | 12.0 | 12.0 | 12.0 |
| Mississippi | 2 | <10.0 | 15.4 | 15.4 |
| Missouri | 34 | 2.3 | 15.0 | 160 |
| Montana | 163 | 0 | 13.0 | 2,980 |
| Nebraska | 0 | -- | -- | -- |
| Nevada | 66 | 0 | 12.5 | 960 |
| New Hampshire | 8 | 1.0 | 6.5 | 7.0 |
| New Jersey | 92 | 4.2 | 18.0 | 54.0 |
| New Mexico | 132 | <5.0 | 21.6 | 4,700 |
| New York | 19 | 6.1 | 16.5 | 82.5 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 52 | 12 | 232 | 742 |
| Ohio | 36 | 38.0 | 85.2 | 160 |
| Oklahoma | 178 | 1.3 | 12.4 | 1,870 |
| Oregon | 0 | -- | -- | -- |
| Pennsylvania | 174 | 4.1 | 28.0 | 348 |
| Rhode Island | 5 | 6.8 | 19.0 | 20.9 |
| South Carolina | 5 | <10.0 | <10.0 | 22.0 |
| South Dakota | 8 | 15.6 | 208 | 400 |
| Tennessee | 2 | 107 | 147 | 187 |
| Texas | 481 | 2.3 | 52.6 | 3,340 |
| Utah | 64 | 9.8 | 75.4 | 1,640 |
| Vermont | -- | -- | -- | -- |
| Virginia | 894 | 1.2 | 11.8 | 2,240 |
| Washington | 0 | -- | -- | -- |
| West Virginia | 26 | 10.0 | 23.2 | 190 |
| Wisconsin | 17 | <5.0 | 31.0 | 76.0 |
| Wyoming | 19 | 2.2 | 54.4 | 940 |

[1]Nine or more analyses per site.

**Table 21.** Summary of median pH measurements in water from State ambient stream-water-quality monitoring sites (with nine or more analyses), 1990–98.

[--, not available]

| State | Number of assessed monitoring sites[1] | Monitoring-site median measurement (standard units) | | |
|---|---|---|---|---|
| | | Minimum | Median | Maximum |
| Alabama | 45 | 5.1 | 7.4 | 7.9 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 6.2 | 7.3 | 8.2 |
| California | -- | -- | -- | -- |
| Colorado | 205 | 4.6 | 8.1 | 9.1 |
| Connecticut | 32 | 7.1 | 7.4 | 8.2 |
| Delaware | 103 | 6.5 | 7.2 | 8.0 |
| Florida | 690 | 3.8 | 7.0 | 8.4 |
| Georgia | 284 | 3.9 | 7.0 | 7.9 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 51 | 7.1 | 8.2 | 8.7 |
| Illinois | 11 | 7.2 | 7.6 | 8.3 |
| Indiana | 101 | 7.4 | 7.8 | 8.2 |
| Iowa | 36 | 7.9 | 8.2 | 8.5 |
| Kansas | 247 | 6.9 | 8.0 | 8.6 |
| Kentucky | 60 | 6.6 | 7.5 | 8.0 |
| Louisiana | 172 | 5.9 | 7.1 | 8.0 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | 7.0 | 7.8 | 8.3 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 79 | 7.3 | 8.0 | 8.3 |
| Minnesota | 66 | 7.5 | 8.2 | 8.4 |
| Mississippi | 66 | 6.0 | 7.1 | 7.8 |
| Missouri | 38 | 7.2 | 7.9 | 8.2 |
| Montana | 276 | 2.8 | 7.6 | 8.8 |
| Nebraska | 22 | 7.9 | 8.1 | 8.3 |
| Nevada | 35 | 7.8 | 8.2 | 8.7 |
| New Hampshire | 55 | 6.1 | 7.0 | 7.6 |
| New Jersey | 89 | 4.3 | 7.6 | 8.3 |
| New Mexico | 211 | 4.6 | 8.2 | 9.0 |
| New York | 19 | 7.3 | 7.7 | 8.3 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 72 | 7.2 | 8.2 | 8.7 |
| Ohio | 39 | 7.0 | 8.0 | 8.3 |
| Oklahoma | 133 | 2.6 | 7.5 | 8.5 |
| Oregon | 140 | 6.8 | 7.6 | 8.6 |
| Pennsylvania | 174 | 4.6 | 7.4 | 8.3 |
| Rhode Island | 5 | 6.6 | 6.7 | 6.9 |
| South Carolina | 339 | 5.4 | 6.7 | 8.0 |
| South Dakota | 96 | 4.8 | 8.2 | 8.7 |
| Tennessee | 43 | 6.2 | 7.3 | 7.9 |
| Texas | 546 | 6.0 | 7.8 | 8.9 |
| Utah | 64 | 7.8 | 8.2 | 8.5 |
| Vermont | -- | -- | -- | -- |
| Virginia | 898 | 3.7 | 7.2 | 8.4 |
| Washington | 207 | 6.8 | 7.6 | 8.7 |
| West Virginia | 24 | 6.8 | 7.6 | 8.3 |
| Wisconsin | 38 | 7.1 | 7.9 | 8.6 |
| Wyoming | 36 | 7.6 | 8.2 | 8.6 |

[1]Nine or more analyses per site.

Stream-water-quality monitoring data are produced from networks composed of monitoring sites (specific locations on streams) from which streamflow samples are collected over some specified interval of time. Although this is a simplistic description, monitoring networks, in practice, are composed of a complex set of operational variables that can make individual State networks functionally unique and may restrict the State-to-State comparability necessary to produce a national assessment of stream-water quality. Network operational variables include (1) the basic design option (census, judgemental or targeted, statistical or probabilistic survey), (2) type of monitoring network (physical, chemical, biological), (3) selections of streams and sampling locations on streams, and (4) temporal coverage (hour, day, week, month, or year).

Variability in network design stems from a need for States to meet State-defined water-quality management objectives, which may not be limited solely to Clean Water Act goals. Other objectives may include acquisition of data to establish water-quality criteria, determination of water-quality status and trends—including areal and temporal extent of known contamination, identification of causes and sources of water-quality problems, implementation and evaluation of water-quality management programs, and calculation of constituent transport (U.S. Environmental Protection Agency, 2003b).

These objectives are met by the States, in part, through the design of their ambient stream-water-quality monitoring networks. The census option, or monitoring of all streams and rivers within a State, is rarely, if ever, used as the sole monitoring design because of the staff and funding necessary to conduct such an ambitious effort. More commonly used in State monitoring networks are the judgemental- or statistical-based design options (U.S. General Accounting Office, 2002). The judgemental design may target monitoring-site locations or limited monitoring resources on areas with suspected or known water-quality problems or on areas that are used frequently by the public. The statistical-based option uses randomized site-selection processes to provide statistically valid information that may be extrapolated to all State water of a similar type. In reality, States may use a combination of design options to fulfill the requirements of State-defined water-quality objectives.

The type of monitoring networks used for ambient stream-water-quality assessment may vary among States. Most States use some form of physical and chemical water-quality analysis for assessment purposes to meet the objectives of the Clean Water Act. Some of these physical and chemical water-quality constituents were summarized in this report, but States often analyze for a much broader suite of constituents to include pesticides, volatile organic chemicals, and toxic contaminants. Some States (Maine and Vermont, for example) rely almost exlusively on biological monitoring, whereas others such as Illinois, Kansas, New York, and Ohio incorporate physical, chemical, and biological data into their 305(b) assessments (U.S. General Accounting Office, 2002).

The criteria and rational used in selection of streams and sampling sites to assess may be keyed to the network design chosen by the States. For example, a substantial reliance on statistical-survey design will dictate stream and site selection on the basis of random selection, whereas target-based designs may incorporate more professional judgement in selection of suspected or known problem areas or areas with intensive human-use activity. Other factors that may control or limit site selection include the need for point- or nonpoint-source definition, a desire to "piggy back" upon other State or Federal water programs and sites such as the USGS streamgaging network, or requests or constraints mandated from political or economic entities. The variability among States in network design, type of monitoring, and stream and site selection makes a compilation of State data into a national picture of stream-water quality problematic.

Prior to the mid-1980s, no program existed to integrate information from the local or regional scale to the national scale to provide a consistent description of water quality across the Nation and insight on the major factors that control water quality in different regions. Hirsch and others (1988) outlined a national assessment design (program) that would integrate information from a large set of hydrologic systems to provide regional and national overviews. Results from hydrologic study units would be linked together by a core set of consistent operational protocols that include (1) study approaches, (2) sample collection, processing, and handling, (3) laboratory methods and quality assurance, (4) selection of water-quality constituents, (5) collection of ancillary information pertinent to the hydrologic setting and possible cause-and-effect relations, and (6) storage of all assessment data. This proposed design evolved into the USGS National Water-Quality Assessment (NAWQA) Program.

Implemented in 1991, the purpose of the NAWQA Program is to describe the status of current water-quality conditions, long-term trends (or lack of trends) in water quality, and to identify, describe, and explain possible cause-and-effect relations for the water-quality conditions (Gilliom and others, 1995). Information from individual hydrologic study units (river basins or ground-water systems) would provide detailed descriptions of local and regional water-quality conditions, identify water-quality concerns and problem areas, and provide the consistent data necessary for national assessments (national synthesis) of priority water-quality issues such as nutrients, pesticides, volatile organic contaminants, and trace elements.

National synthesis integrates information from individual study units into multiple study-unit analyses and incorporates existing information from other agencies and researchers to produce regional- and national-scale assessments. National synthesis develops comprehensive assessments issue by issue at the national scale by comparative analysis of study-unit findings (Gilliom and others, 1995). These comparative analyses are possible only because of the consistency in assessment network design and operation among the study units. The regular accumulation of consistent and comparable water-quality assessments for some of the largest and most important hydrologic systems of the Nation provides a major contribution to the knowledge of regional and national water quality (National Research Council, 2002).

## Selection of Water-Quality Constituents and Criteria

The selection of water-quality constituents for which States choose to analyze may have substantial effect on the utility of State ambient stream-water-quality data to provide a reliable national water-quality assessment. It was previously mentioned that the type of stream-water-quality monitoring (physical, chemical, biological) that States conduct may vary. This lack of commonality in monitoring practices makes direct State-to-State comparisons difficult. Not only is it difficult to make water-quality comparisons among States, but also, variability in monitoring practices within States (among monitoring sites) makes it difficult to get reliable pictures of within State water-quality conditions when the types and number of water-quality constituents vary among the sites.

USEPA (2002c) has determined that some of the most common causes of streams being listed in State 303(d) reports (degraded water quality) are the result of excessive concentrations of sediment, bacteria, nutrients, and metals. All States, however, do not analyze for the same set of water-quality constituents. For example, electronically accessible fecal coliform bacteria data were not available for Delaware, Indiana, or Michigan, seven other States had data for less than 10 monitoring sites (table 8), and total phosphorus concentrations were not available for monitoring sites in New York (table 13).

Differences in data collected among monitoring sites within States produce a skewed or biased overall assessment of water quality for the States. For example, Oklahoma had 14 monitoring sites with nine or more analyses for fecal coliform bacteria (table 8), but substantially more monitoring sites were analyzed for total phosphorus (194; table 13), chloride (177; table 17), and pH (133; table 21). Median monitoring-site densities of fecal coliform bacteria were relatively large in Oklahoma (50 to 2,150 col/100 mL; table 8), so it is possible that water at many of these sites may have been assessed as degraded, but because the 14 monitoring sites represent only a small percentage of all the sites potentially assessed, the percentage of stream miles degraded for sanitary quality may be small relative to what it may have been had more of the total number of monitoring sites been assessed. The variability in constituents analyzed among monitoring sites within a State and among the States also makes an assessment of national water-quality conditions from State databases problematic.

Most stream-water-quality constituents analyzed by States have associated criteria to measure whether the designated use of the stream is being achieved. USEPA (1999a; 1999b) has recommended water-quality criteria for aquatic-life protection for many of the constituents summarized in this report (table 22). Public drinking-water criteria (U.S. Environmental Protection Agency, 2002b) also exist for most of these constituents. USEPA currently (2004) has not implemented water-quality criteria for suspended solids, fecal coliform bacteria, or total phosphorus. States have the flexibility, however, to establish their own stream-water-quality criteria for aquatic-life protection on the basis of unique sets of conditions that include designated uses of streams, ecological characteristics such as aquatic-life community structure, and State-determined concentration levels necessary for protection of human health through direct or indirect contact. The resulting variability in these water-quality criteria among the States reduces the potential for State-generated assessments of ambient stream-water quality to produce a national perspective of water-quality conditions.

Some water-quality constituents, such as suspended solids, do not have numeric criteria in most States. Instead, these States use a narrative criteria that generally state that the occurrence of suspended material in rivers and streams shall not be of such magnitude as to inhibit the intended use of the water and shall not have a detrimental effect on growth or reproduction of aquatic life. However, five States (Hawaii, Nevada, New Jersey, South Dakota, and Utah) do have numeric criteria for suspended solids, which range from a minimum concentration of 35 mg/L in Utah to a maximum of 158 mg/L in South Dakota (U.S. Environmental Protection Agency, 2001b). The absence of numeric criteria for most States introduces subjectivity into the water-quality assessment process and reduces the comparability of State assessments and the potential for collating these assessments into a reliable national perspective of stream-water quality.

In contrast to the absence of State numeric criteria for suspended solids, the States generally had numeric criteria for fecal coliform bacteria (table 23). Primary contact recreation criteria range from 50 (Washington) to 1,000 col/100 mL (colonies per 100 mL of water) in four States. The larger criteria, however, generally are single-sample (SS) criteria, whereas most State criteria are expressed as a geometric mean (GM). The GM is the mean of the logarithms of data transformed back to the original unit of measure and, in positively skewed or log-normally distributed data, approximates the median (Helsel and Hirsch, 1995). As defined by USEPA, a GM for bacteria is the GM of at least five samples collected in separate 24-hour periods during a 30-day period (U.S. Environmental Protection Agency, 2000a). However, few States collect the required five bacteria samples in a 30-day period necessary for calculation of a USEPA-defined geometric mean; therefore, in practice States either have not assessed streams for degradation relative to fecal bacteria, used the geometric mean of the data available or some other measure of central tendency, or compared bacteria densities to the numeric value of the geometric mean. Because few sites had more than one bacteria sample in a single 30-day period, the geometric mean for that period is the same as the single-sample value.

Fewer States have a secondary contact recreation criterion for fecal coliform bacteria than have a primary contact recreation criterion (table 23). Secondary contact recreation is defined as activities where ingestion of water is unlikely, such as fishing or wading. State criteria for secondary contact recreation range from 200 col/100 mL in five States to 5,000 col/100 mL in Ohio.

The criteria discussion for bacteria presented in this report was restricted to fecal coliform bacteria, the most common measure of sanitary quality of streams in the 1990s. However,

**Table 22.** Selected water-quality criteria for State ambient stream-water-quality data.

[mg/L, milligrams per liter; col/100 mL, colonies per 100 milliliters of water; N, nitrogen; P, phosphorus; µg/L,micrograms per liter; CMC, Criterion Maximum Concentration; CCC, Criterion Continuous Concentration; MCL, Maximum Contaminant Level; SDWR, Secondary Drinking-Water Regulation (nonenforceable recommendations); HAL, Health Advisory Level; --, not available]

| Water-quality constituent or measurement | U.S. Environmental Protection Agency criteria | | | | | |
|---|---|---|---|---|---|---|
| | | Aquatic life[1] | | Public drinking water[2] | | |
| | Stream-water-quality goal | CMC | CCC | MCL | SDWR | HAL |
| Solids, suspended, mg/L | -- | -- | -- | -- | -- | -- |
| Bacteria, fecal coliform, col/100 mL | -- | -- | -- | 0 | -- | -- |
| Ammonia, total, as N, mg/L | -- | [3]-- | [4]-- | -- | -- | 30 |
| Nitrite plus nitrate, total, as N, mg/L | -- | -- | -- | 10 | -- | -- |
| Phosphorus, total, as P, mg/L | [5]0.10 | -- | -- | -- | -- | -- |
| Arsenic, total, µg/L | -- | 340 | 150 | 10 | -- | -- |
| Solids, dissolved, mg/L | -- | -- | -- | -- | 500 | -- |
| Chloride, total, mg/L | -- | 860 | 230 | -- | 250 | -- |
| Sulfate, total, mg/L | -- | -- | -- | -- | 250 | -- |
| pH, standard units | -- | -- | 6.5–9.0 | -- | 6.5–8.5 | -- |

[1]U.S. Environmental Protection Agency (1999a).

[2]Criteria apply to post-treatment water; U.S. Environmental Protection Agency (2002b).

[3]pH dependent; U.S. Enviromental Protection Agency (1999b).

[4]pH and temperature dependent; U.S. Environmental Protection Agency (1999b).

[5]U.S. Environmental Protection Agency (1986).

USEPA (1986, 2000a) has recommended and some States have adopted the use of *Escherichia coli* (*E. coli*) bacteria as the indicator organism for sanitary quality. For example, Kansas made the switch to *E. coli* in 2003.

USEPA currently (2004) has a recommended, nonenforceable water-quality goal of 0.10 mg/L for total phosphorus in rivers and streams (U.S. Environmental Protection Agency, 1986). Ecoregion-specific criteria for total phosphorus currently (2004) are being or have been developed through a collaborative partnership between the States and USEPA. These criteria range from 0.01 to 0.128 mg/L. Information concerning this development process and resultant ecoregion-specific criteria may be found on the World Wide Web at URL http://www.epa.gov/ost/standards/nutrient.html (accessed July 1, 2003).

Differences in water-quality constituents analyzed and the criteria to which the resultant concentrations are compared make it difficult to use State stream-water-quality data or State water-quality assessments to produce a national picture of ambient stream-water-quality conditions (U.S. General Accounting Office, 2002). These differences are the result of the selection of constituents that States choose to emphasize, the phase for which constituents are analyzed (total or dissolved), the designated uses that States apply to streams, and the water-quality critieria associated with these uses. Criteria differences among the States may result in different rates of stream degradation and limit State-to-State comparability. The reliance on narrative instead of numeric criteria also limits the comparability of State data or assessment results as presented in their biannual 305(b) reports. These limitations reduce the development of a reliable national water-quality assessment using these data.

## Quantity and Comprehensiveness of Water-Quality Data

States vary in the quantity of ambient stream-water-quality data collected and comprehensiveness in geographical coverage of those data and type and number of constituents analyzed. This variability, in part, limits the use of State water-quality data or assessments of those data to compile a reliable picture of national water-quality conditions and restricts the capability to

**Table 23.** Fecal coliform bacteria criteria for primary and secondary contact recreation for streams in 50 States.

[GM, geometric mean of at least five samples collected in separate 24-hour periods during a 30-day period; SS, single sample; --, no criteria or not available]

| State | Fecal coliform bacteria criteria[1] (colonies per 100 milliliters of water) | |
|---|---|---|
| | Primary contact | Secondary contact |
| Alabama | 200 (GM) | 2,000 (GM) |
| Alaska | 200 (GM) | -- |
| Arizona | 200 (GM) | 1,000 (GM) |
| | 800 (SS) | 4,000 (SS) |
| Arkansas | 200 (GM) | 1,000 (GM) |
| California | 200 (GM) | 2,000 (GM) |
| Colorado | 200 (GM) | 2,000 (GM) |
| Connecticut | 200 (GM) | -- |
| Delaware | -- | -- |
| Florida | 200 (GM) | -- |
| Georgia | 200 (GM) | 1,000 (GM) |
| | -- | 4,000 (SS) |
| Hawaii | 200 (GM) | -- |
| Idaho | -- | -- |
| Illinois | 200 (GM) | -- |
| Indiana | -- | -- |
| Iowa | 200 (GM) | -- |
| Kansas | 200 (GM) | 2,000 (SS) |
| Kentucky | 200 (GM) | 1,000 (GM) |
| Louisiana | 200 (GM) | 1,000 (GM) |
| Maine | -- | -- |
| Maryland | -- | -- |
| Massachusetts | 200 (GM) | 1,000 (GM) |
| Michigan | -- | -- |
| Minnesota | 200 (GM) | -- |
| Mississippi | 200 (GM) | 2,000 (GM) |
| Missouri | 200 (GM) | -- |
| Montana | 200 (GM) | -- |
| Nebraska | 200 (GM) | -- |
| Nevada | 200 (GM) | 2,000 (GM) |
| New Hampshire | -- | -- |
| New Jersey | 200 (GM) | -- |
| New Mexico | 200 (GM) | -- |
| | 400 (SS) | -- |
| New York | 200 (GM) | 2,000 (GM) |
| North Carolina | 200 (GM) | 200 (GM) |
| North Dakota | 200 | -- |
| Ohio | 1,000 (GM) | 5,000 (GM) |
| Oklahoma | 200 (GM) | -- |
| Oregon | 126 (GM) | -- |
| | 406 (SS) | -- |
| Pennsylvania | 200 (GM) | 2,000 (GM) |
| Rhode Island | 200 (GM) | 200 (GM) |
| South Carolina | 200 (GM) | 200 (GM) |
| South Dakota | 200 (GM) | 1,000 (GM) |
| | 400 (SS) | 2,000 (SS) |
| Tennessee | 200 (GM) | -- |
| | 1,000 (SS) | -- |
| Texas | 200 (GM) | 2,000 (GM) |
| Utah | 200 (GM) | 200 (GM) |
| Vermont | 200 (GM) | -- |
| | 1,000 (SS) | -- |
| Virginia | 200 (GM) | -- |
| | 1,000 (SS) | -- |
| Washington | 50–100 (GM) | 200 (GM) |
| West Virginia | 200 (GM) | 2,000 (GM) |
| Wisconsin | 200 (GM) | -- |
| Wyoming | 200 (GM) | -- |

[1]U.S. Environmental Protection Agency (2001b).

answer status and trends questions about the nation's stream-water quality.

An analysis of the quantity of electronically available water-quality data was conducted by determining the number of monitoring sites in each State that had selected numbers of analyses of the 10 water-quality constituents examined in this report (tables 25–34 in the "Supplemental Information" section at the back of this report). States do not necessarily analyze ambient stream-water samples for the same water-quality constituents or to the same extent. Nationally, more than 9,000 monitoring sites had one or more analysis for total phosphorus (table 29) and pH (table 34), but less than 3,500 sites had one or more analysis for total arsenic (table 30). The presence of arsenic in streams is found mostly near where it occurs naturally in soils and rocks, and the geographic variability in the natural occurrence of arsenic in soil and rocks is probably responsible for much of this difference in State emphasis on arsenic.

Relative to the number of monitoring sites with total phosphorus and pH data, other constituents showed marked reductions in the number of monitoring sites with electronically available data for 1990–98. For example, slightly less than 6,100 monitoring sites (nationally) had one or more analyses for fecal coliform bacteria (table 26), about a 33-percent reduction in the number of sites relative to those numbers of total phosphorus and pH. Much of this difference may be attributable to operational constraints in the collection and analysis of bacterial samples. Holding times (time between collection and analysis) for bacterial samples generally are short relative to many chemical constituents. These reduced holding times may increase sample transportation costs as well as staff time for collection and analysis. Increases in sample collection and analysis costs for some State programs may be offset with reductions in the number of sites at which data are collected.

In addition to differences in the number of monitoring sites with selected constituents, monitoring sites have different numbers of analyses of particular constituents (tables 25–34; fig. 2). USEPA (2002a) recommended a minimum of 30 water-quality analyses at monitoring sites for degradation assessment purposes; however, on average (for the 10 constituents evaluated in this report) only about 30 percent (fig. 3) of the monitoring sites (relative to the number with one or more analyses) examined had the quantity of electronically available data that met this minimum recommendation between 1990 and 1998. Substantial reduction in monitoring sites reduces the spatial distribution and (or) density of monitoring sites possibly to a point (1) that States may not meet the requirement of the Clean Water Act to assess all surface water (U.S. Environmental Protection Agency, 2002a), (2) that State assessments may be biased toward the water-quality characteristics of larger river systems where long-term (more samples collected) monitoring sites may predominate, or (3) that the overall quality or representativeness of the State assessment may be reduced.

The information presented in figures 2 and 3 provided some insight into the relation between the availability of monitoring sites and numbers of analyses; however, the figures do not provide information on the extent of State ambient stream-water-quality monitoring networks and the comprehensiveness of databases relative to the modest number of commonly collected water-quality constituents assessed in this report. An effort to describe this extent and comprehensiveness was conducted by determining the number of ambient stream-water-quality sites in each State that met selected combinations of number of available constituents and minimum number of analyses of each constituent (table 24).

The first category of ambient stream-water-quality monitoring sites in table 24 (sites with 1 or more of the 10 constituents assessed in this report each with nine or more analyses) represents the maximum in available monitoring sites and, potentially, the minimum in comprehensive data requirements. The nine or more required analyses is the same summary criterion used in previous sections of this report. The other three categories are attempts to increase the overall comprehensiveness of State databases relative to the constituents summarized in this report and required either 8 or more constituents or all 10 constituents. Also required are either 9 or more analyses per constituent or 30 or more analyses per constituent. The nine-analysis criterion was chosen to represent an average of one analysis per year for the period used in this report (1990–98). The 30-analysis criterion was chosen to correspond to the minimum number of analyses recommended by USEPA (2002a) for decisions on water quality.

The number of ambient stream-water-quality monitoring sites with at least one water-quality constituent (or measurement) with nine or more analyses ranged from 5 in Rhode Island to 1,139 in Virginia (table 24). Possible reasons for this variability among the 42 States assessed were discussed in previous sections of this report. Nationally, these 42 States had 6,783 monitoring sites that met the aforementioned criteria.

Large reductions in numbers of available monitoring sites occurred as the minimum requirements for both numbers of constituents per site and number of analyses per constituent increased. The number of available monitoring sites with 8 or more of the 10 constituents assessed in this report with at least nine analyses decreased to a national total of 3,148 (decrease of 54 percent) in 37 States (table 24). Five States with data used in this report had no sites that met this data criteria, and eight States had less than 10 sites. Only 230 monitoring sites nationally (in nine States) had at least 9 analyses for all 10 constituents assessed in this report. When the USEPA minimum recommendation of 30 analyses per constituent was factored in (10 constituents each with 30 or more analyses, table 24), only 73 monitoring sites nationally (in five States) met those criteria. This analysis indicated that some State ambient stream-water-quality networks are lacking in the comprehensiveness of collected data, at least relative to the common constituents summarized in this report, and most monitoring sites in those networks do not have the number of analyses recommended by USEPA to make appropriate degradation and, ultimately, total maximum daily loads decisions.

USGAO (2002) identified differences in State approaches in identifying water-quality degraded surface water (rivers,

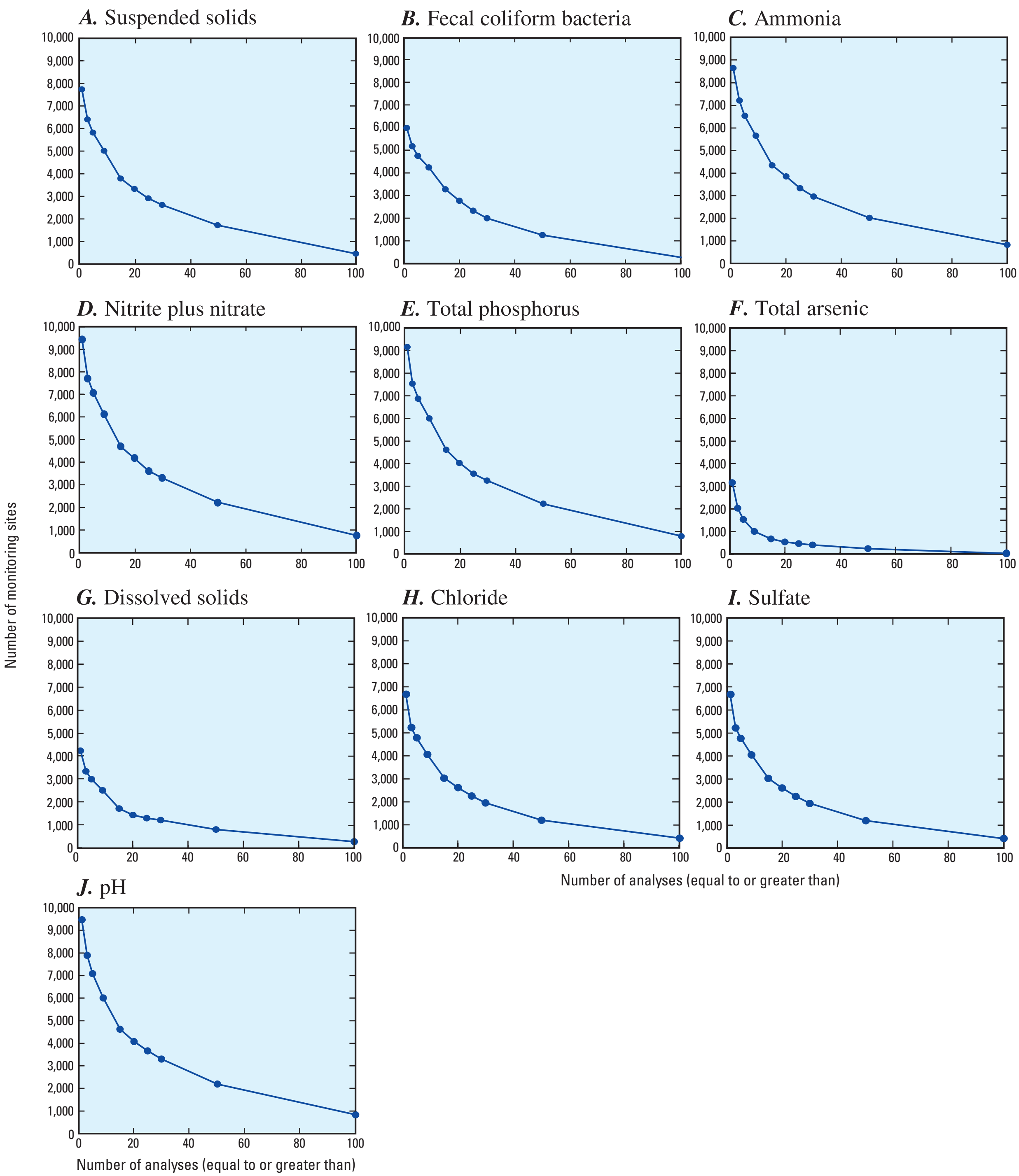


**Figure 2.** Relations between numbers of ambient stream-water-quality monitoring sites (nationally) and selected minimum numbers of electronically available data for 10 water-quality constituents or measurements.

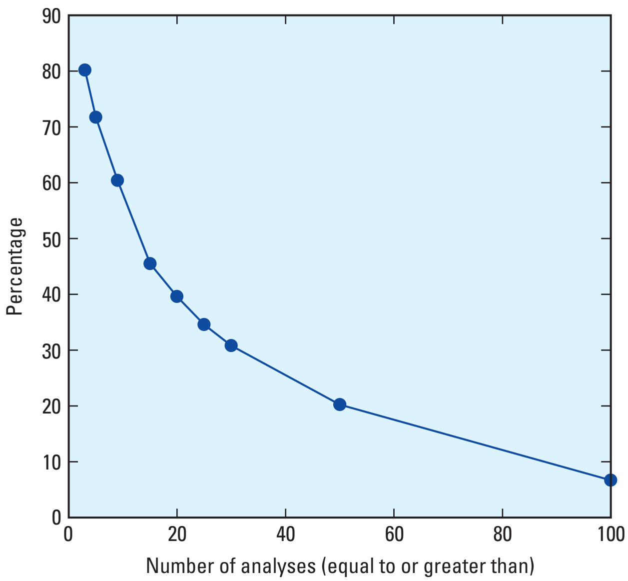


**Figure 3.** Relation between the national average percentage of monitoring sites for 10 water-quality constituents or measurements and selected minimum numbers of electronically available data.

streams, and lakes). Some of these differences among the States were inherent to the implementation of the Clean Water Act, which allowed USEPA, in administering the act, some flexibility for the States to develop assessment approaches that were appropriate to their specific ecological and environmental conditions. However, as noted by USGAO (2002), some of the variations in approach have no appropriate scientific basis.

Information obtained from the investigation described in this report verified some of the inconsistencies noted by USGAO (2002). Most notable is the variability in characteristics of State stream-water-quality monitoring networks such as the number of monitoring sites and water-quality analyses. Additional inconsistencies among States include numeric water-quality criteria, particularly for fecal coliform bacteria (table 23) and to a lesser degree the absence of or variability in numeric criteria for suspended solids. National monitoring is, in reality, a compilation of 50 State networks with varying degrees of comparability. Differences among the States in water-quality criteria and methodologies used in data assessment and water-quality degradation decisions restrict comparability among the States and limit the consistency needed to produce a national assessment of ambient water quality. An analysis of the extent and comprehensiveness of State ambient stream-water-quality networks for this report indicated that these networks may be lacking in the diversity of collected data and that many monitoring sites in those networks have few samples and do not have the number of analyses recommended by USEPA to make appropriate degradation and total maximum daily loads decisions.

Because of the differences and inconsistencies among State ambient stream-water-quality monitoring programs, a scientifically defensible national assessment of stream-water quality for 1990–98 could not be made with the State databases produced for the investigation described in this report. Some efforts have been made by USEPA (2002a) to produce a more uniform system of network operations and assessment of water-quality data. However, the task is enormous and will require much coordination with and cooperation between the States and USEPA to develop common ground in collection, analysis, evaluation, and assessment of stream-water-quality data before reliable, scientifically defensible national water-quality assessments are possible.

# Summary and Conclusions

Ambient stream-water-quality data were electronically acquired for 10 water-quality constituents or measurements, stored in a relational-based database (by State), and statistically summarized. The electronic availability of data varied among the States. Forty-two States had pH data from ambient stream monitoring sites, whereas only 26 States had total arsenic data. Electronically accessible data were not available for Alaska, Arizona, California, Hawaii, Maine, Massachusetts, North Carolina, and Vermont.

Data for State ambient stream-water-quality monitoring sites were retrieved for 1990–98 from the U.S. Environmental Protection Agency Storage and Retrieval System, the U.S. Geological Survey National Water Information System, or State-located databases. These data were assembled into individual State databases, and each monitoring site was assessed for the number of available analyses for 10 water-quality constituents or measurements. Monitoring sites with nine or more analyses for each of the constituents or measurements were statistically summarized, and median concentrations or measurements determined. The nine-analysis threshold was selected as a compromise between the desire to maximize spatial distribution but still have enough analyses to provide an estimate of range and central tendency (median values) for the site data population. Also, nine represented an average of one sample per year over the time period investigated. Subsequently, the median of monitoring-site medians was calculated for each constituent or measurement in each State, statistically summarized, and the result presented in tabular format.

Comparisons of monitoring data among States are problematic for several reasons, including differences in the basic spatial design of monitoring networks; water-quality constituents for which samples are analyzed; water-quality criteria to which constituent concentrations are compared; quantity and comprehensiveness of water-quality data; sample collection, processing, and handling; analytical methods; temporal variability in sample collection; and quality-assurance practices. Large differences among the States in number of monitoring sites precluded a general assumption that statewide water-quality conditions were represented by data from these sites. Furthermore, data from individual monitoring sites may not represent water-quality conditions at the sites because sampling

**Table 24.** Number of State ambient stream-water-quality monitoring sites available for selected combinations of water-quality constituents per monitoring site and analyses per constituent, 1990–98.

[Total number of monitoring sites in State databases (sites with one or more analyses of at least 1 of 10 constituents) were presented previously in table 2. --, not available]

| State | Number of ambient stream-water-quality monitoring sites | | | |
|---|---|---|---|---|
| | With 1 or more constituents with 9 or more analyses | With any 8 or more of 10 constituents with 9 or more analyses | With all 10 constituents with 9 or more analyses | With all 10 constituents with 30 or more analyses |
| Alabama | 45 | 41 | 0 | 0 |
| Alaska | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- |
| Arkansas | 131 | 131 | 0 | 0 |
| California | -- | -- | -- | -- |
| Colorado | 220 | 104 | 0 | 0 |
| Connecticut | 32 | 28 | 0 | 0 |
| Delaware | 103 | 0 | 0 | 0 |
| Florida | 868 | 405 | 8 | 0 |
| Georgia | 290 | 0 | 0 | 0 |
| Hawaii | -- | -- | -- | -- |
| Idaho | 51 | 21 | 0 | 0 |
| Illinois | 11 | 3 | 0 | 0 |
| Indiana | 106 | 14 | 0 | 0 |
| Iowa | 39 | 0 | 0 | 0 |
| Kansas | 251 | 251 | 118 | 40 |
| Kentucky | 61 | 59 | 0 | 0 |
| Louisiana | 172 | 105 | 0 | 0 |
| Maine | -- | -- | -- | -- |
| Maryland | 40 | 12 | 0 | 0 |
| Massachusetts | -- | -- | -- | -- |
| Michigan | 97 | 47 | 0 | 0 |
| Minnesota | 66 | 1 | 0 | 0 |
| Mississippi | 66 | 44 | 0 | 0 |
| Missouri | 40 | 31 | 0 | 0 |
| Montana | 334 | 54 | 0 | 0 |
| Nebraska | 22 | 13 | 0 | 0 |
| Nevada | 68 | 64 | 28 | 0 |
| New Hampshire | 56 | 8 | 0 | 0 |
| New Jersey | 96 | 65 | 0 | 0 |
| New Mexico | 239 | 115 | 1 | 1 |
| New York | 19 | 8 | 0 | 0 |
| North Carolina | -- | -- | -- | -- |
| North Dakota | 73 | 39 | 13 | 0 |
| Ohio | 41 | 40 | 27 | 6 |
| Oklahoma | 212 | 8 | 0 | 0 |
| Oregon | 144 | 1 | 0 | 0 |
| Pennsylvania | 174 | 63 | 27 | 24 |
| Rhode Island | 5 | 5 | 0 | 0 |
| South Carolina | 340 | 0 | 0 | 0 |
| South Dakota | 96 | 28 | 0 | 0 |
| Tennessee | 73 | 12 | 0 | 0 |
| Texas | 576 | 362 | 7 | 2 |
| Utah | 64 | 64 | 1 | 0 |
| Vermont | -- | -- | -- | -- |
| Virginia | 1,139 | 864 | 0 | 0 |
| Washington | 207 | 0 | 0 | 0 |
| West Virginia | 26 | 21 | 0 | 0 |
| Wisconsin | 48 | 13 | 0 | 0 |
| Wyoming | 42 | 4 | 0 | 0 |
| **Totals** | **6,783** | **3,148** | **230** | **73** |

conditions and protocols are unknown. Because of these factors, a high level of uncertainty exists in the results of this investigation.

Forty States had electronically accessible suspended solids concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of suspended solids ranged from 2.0 mg/L in New Hampshire to 42.5 mg/L in Nebraska.

Thirty-nine States had electronically accessible fecal coliform bacteria densities for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median densities of fecal coliform bacteria ranged from 19.2 col/100 mL in Colorado to 2,650 col/100 mL in Montana.

Forty-one States had electronically accessible ammonia concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of ammonia ranged from 0.003 mg/L in Colorado to 0.46 mg/L in Rhode Island.

Forty-two States had electronically accessible nitrite plus nitrate as nitrogen concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of nitrite plus nitrate as nitrogen ranged from 0.05 mg/L in Nevada to 5.7 mg/L in Iowa.

Forty-one States had electronically accessible total phosphorus concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of total phosphorus ranged from 0.02 mg/L in West Virginia to 0.33 mg/L in Illinois.

Twenty-eight States had electronically accessible total arsenic concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of total arsenic ranged from 0.80 µg/L in Washington to 11.5 µg/L in South Dakota.

Twenty-nine States had electronically accessible dissolved-solids concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of dissolved solids ranged from 37.2 mg/L in Mississippi to 711 mg/L in South Dakota.

Thirty-nine States had electronically accessible chloride concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of chloride ranged from 0 mg/L in Montana to 7,740 mg/L in Georgia.

Thirty-six States had electronically accessible sulfate concentrations for water from ambient stream-water-quality monitoring sites. State medians of monitoring-site median concentrations of sulfate ranged from 6.5 mg/L in New Hampshire to 232 mg/L in North Dakota.

Forty-two States had electronically accessible pH measurements for water from ambient stream-water-quality monitoring sites. State medians of the monitoring-site median measurements of pH ranged from 6.7 standard units in Rhode Island and South Carolina to 8.2 standard units in several States.

National monitoring is, in reality, a compilation of 50 State networks with varying degrees of comparability. Differences among the States in water-quality criteria and methodologies used in data assessment and decisions on water quality restrict comparability among the States and limit the consistency needed to produce an accurate national assessment of ambient stream-water quality. An analysis of the extent and comprehensiveness of State ambient stream-water-quality networks for this report indicated that these networks may be lacking in the diversity of collected data and that many monitoring sites in those networks have few samples and for many basic water-quality constituents do not have the number of analyses recommended (30) by the U.S. Environmental Protection Agency to make appropriate water-quality and total maximum daily loads decisions for 1990–98.

Targeted, statistically based (probabilistic), and geographically based sampling designs are used in some State monitoring programs to provide the water-quality information required by the Clean Water Act to evaluate potential stream-water-quality degradation relative to designated uses and appropriate water-quality criteria. When appropriate designs are used, this information also may be used to describe cause-and-effect relations, seasonal variability and time trends, mass transport, and as an aid to management decisions. However, the variability in network designs and operational characteristics, such as the distribution of sites and frequency of sampling, among the States prevented the use of available information for a scientifically defensible comparison of results among the States.

# References Cited


Bevans, H.E., 1989, Water resources of Sedgwick County, Kansas: U.S. Geological Survey Water-Resources Investigations Report 88–4225, 119 p.

Brown, R.S., and Marshall, Karen, 1993, Resource guide to State environmental management (3d ed.): Lexington, Kentucky, The Council of State Governments, 249 p.

Cabelli, V.J., 1977, Indicators of recreational water quality, *in* Hoadley, A.W., and Dutka, B.J., eds., Bacterial indicators/health hazards associated with water, 1977: American Society for Testing Materials, ASTM STP 635, p. 222–238.

Childress, C.J.O., Chaney, T.H., Myers, D.A., Norris, J.M., and Hren, Janet, 1989, Water-quality data-collection activities in Colorado and Ohio—phase II, evaluation of 1984 field and laboratory quality-assurance practices: U.S. Geological Survey Water-Supply Paper 2295–B, 49 p.

Chu, H.C., Chmielewski, R.D., and Light, W.G., 1986, Potable water production with low-pressure TFC reverse osmosis membrane elements: Proceedings of the first biennial conference of the National Water Supply Improvement Association, June 8–12, 1986, Washington, D.C., p. 178–209.

Clesceri, L.S., Greenberg, A.E., and Eaton, A.D., eds., 1998, Standard methods for the examination of water and wastewater (20th ed.): Washington, D.C., American Public Health Association, American Water Works Association, and Water Environment Federation, variously paged.

Dufour, A.P., and Cabelli, V.J., 1984, Health effects criteria for fresh recreational waters: Cincinatti, Ohio, U.S. Environmental Protection Agency, EPA 600/1–84–004, 33 p.

Environmental Integrity Project, 2004, Flying blind—water quality and assessment in the Great Lakes States: Washington, D.C., 39 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

Follett, R.F., 1995, Fate and transport of nutrients—nitrogen: Natural Resources and Conservation Service Working Paper No. 7, information available on the World Wide Web, accessed May 7, 2003, at URL http://www.nrcs.usda.gov/technical/land/pubs/wp07text.html

Franklin, N.M., Stauber, J.L., Markich, S.J., and Lim, R.P., 2000, pH-dependent toxicity of copper and uranium to a tropical freshwater alga (*Chlorella sp.*): Aquatic Toxicology, v. 48, no. 2–3, p. 275–289.

Gillespie, J.B., and Hargadine, G.D., 1994, Geohydrology and saline ground-water discharge to the South Fork Ninnescah River in Pratt and Kingman Counties, south-central Kansas: U.S. Geological Survey Water-Resources Investigations Report 93–4177, 51 p.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program—occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Gleeson, C., and Gray, N.F., 1997, The coliform index and waterborne disease—problems of microbial drinking water assessment: London, E. and F.N. Spon, LTD., 210 p.

Hall, Bob, and Kerr, M.L., 1991, 1991–1992 green index—a State-by-State guide to the Nation's environmental health: Washington, D.C., Island Press, 162 p.

Heathwaite, A.L., 1997, Sources and pathways of phosphorus loss from agriculture, *in* Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E., eds., Phosphorus loss from soil to water: New York, CAB International, p. 205–223.

Helsel, D.R., and Hirsch, R.M., 1995, Statistical methods in water resources: New York, Elsevier Science, 529 p.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a national water-quality assessment program: U.S. Geological Survey Circular 1021, 42 p.

Hooper, R.P., Aulenbach, B.T., and Kelly, V.J., 2001, The National Stream Quality Accounting Network—a flux-based aproach to monitoring the water quality of large rivers: Hydrologic Processes, v. 15, p. 1089–1106.

Horne, A.J., and Goldman, C.R., 1994, Limnology: New York, McGraw-Hill Co., 576 p.

Johnson, A.H., 1986, Acid deposition—trends, relationships, and effects: Environment, v. 28, no. 4, p. 6–11, 34–39.

Kansas Department of Health and Environment, 2002, Methodology for the evaluation and development of the 2002 Section 303(d) list of impaired water bodies for Kansas: Topeka, Kansas, Bureau of Water, 20 p.

Klein, J.M., and Bradford, W.L., 1980, Dissolved-solids concentrations and loads in return flows to the Colorado River from agricultural land in southern California: U.S. Geological Survey Water-Resources Investigations Report 80–52, 54 p.

Lamb, D., Miller, D.F., Robinson, N.F., and Gertler, A.W., 1987, Importance of liquid water concentration in the atmospheric oxidation of $SO_2$: Atmospheric Environment, v. 21, no. 11, p. 2333–2344.

Larson, S.J., and Gilliom, R.J., 2001, Regression models for estimating herbicide concentrations in U.S. streams from watershed characteristics: Journal of the American Water Resources Association, v. 37, no. 5, p. 1349–1368.

Libermann, T.D., Mueller, D.K., Kircher, J.E., and Choquette, A.F., 1989, Characteristics and trends of streamflow and dissolved solids in the upper Colorado River basin, Arizona, Colorado, New Mexico, Utah, and Wyoming: U.S. Geological Survey Water-Resources Investigations Report 87–568, 99 p.

Lynch, J.A., Bowersox, V.C., and Grimm, J.W., 1996, Trends in precipitation chemistry in the United States, 1983–94—an analysis of the effects in 1995 of Phase I of the Clean Air Act Amendment of 1990, Title IV: U.S. Geological Survey Open-File Report 96–0346, information available on the World Wide Web, accessed October 1, 2004, at URL http://water.usgs.gov/pubs/acidrain

Manahan, S.E., 1994, Environmental chemistry: Boca Raton, Florida, Lewis Publishers, 811 p.

Mays, L.W., 1996, Water resources handbook: New York, McGraw-Hill Co., various pagination.

McKinney, R.E., 1962, Microbiology for sanitary engineers: New York, McGraw-Hill Co., 153 p.

Miller, C.V., Hancock, T.C., and Denver, J.M., 2000, Environmental fate and transport of arsenical feed amendments for animal agriculture [abs.], Proceedings of American Geophysical Union, 2000 Spring Meeting, May 30–June 3, 2000: Information available on World Wide Web, accessed June 17, 2003, at URL http://va.water.usgs.gov/GLOBAL/Abst/hancock_agu_2000.htm

National Research Council, 2001, Assessing the TMDL approach to water quality management: Information available on World Wide Web, accessed July 16, 2004, at URL http://books.nap.edu/catalog/10146.html

National Research Council, 2002, Opportunities to improve the U.S. Geological Survey National Water-Quality Assessment Program: Information available on World Wide Web, accessed July 22, 2004, at URL http://books.nap.edu/books/0309083052/html/R1.html

Norris, J.M., Hren, Janet, Myers, D.N., Chaney, T.H., and Childress, C.J.O., 1992, Water-quality data-collection activities in Colorado and Ohio—phase III, evaluation of existing data for use in assessing regional water-quality conditions and trends: U.S. Geological Survey Water-Supply Paper 2295–C, 46 p.

Orlob, G.T., and Ghorbanzadeh, A., 1981, Impact of water resource development on salinization of semi-arid lands: Agricultural Water Management, v. 4, no. 1/3, p. 275–293.

Pepper, I.L., Gerba, C.P., and Brusseau, M.L., eds., 1996, Pollution science: New York, Academic Press, 397 p.

Phillips, P.J., 1994, Chloride concentrations as indicators of point source sewage discharges in the Hudson River basin, New York [abs.]: American Geophysical Union, 1994 Fall Meeting, EOS, v. 75, no. 44, p. 229.

Pope, L.M., and Putnam, J.E., 1997, Effects of urbanization on water quality in the Kansas River, Shunganunga Creek basin, and Soldier Creek, Topeka, Kansas, October 1993 through September 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4045, 84 p.

Powell, J.D., 1988, Origin and influence of coal mine drainage on streams of the United States: Environmental Geology and Water Sciences, v. 11, no. 2, p. 141–152.

Pyle, G.G., Swanson, S.M., and Lehmkuhl, D.M., 2002, The influence of water hardness, pH, and suspended solids on nickel toxicity to larval fathead minnows (*Pimephales promelas*): Water, Air, & Soil Pollution, v. 133, no. 1–4, p. 215–226.

Rasmussen, P.P., and Ziegler, A.C., 2003, Comparison and continuous estimates of fecal coliform and *Escherichia coli* bacteria in selected Kansas streams, May 1999 through April 2002: U.S. Geological Survey Water-Resources Investigations Report 03–4056, 80 p.

Reid, G.K., and Wood, R.D., 1976, Ecology of inland waters and estuaries: New York, D. Van Nostrand Co., 485 p.

Rinella, J.F., McKenzie, S.W., and Fuhrer, G.J., 1992, Surface-water-quality assessment of the Yakima River Basin, Washington—analysis of available water-quality data through 1985 water year: U.S. Geological Survey Open-File Report 91–453, 244 p.

Sharpley, A.N., and Rekolainen, S., 1997, Phosphorus in agriculture and its environmental implications, *in* Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E., eds., Phosphorus loss from soil to water: New York, CAB International, p. 1–53.

Simonsen, J.F., and Harremoes, P., 1978, Oxygen and pH fluctuations in rivers: Water Research, v. 12, no. 7, p. 477–489.

Smith, R.A., and Alexander, R.B., 1986, Correlations between stream sulfate and regional $SO_2$ emissions: Nature, v. 322, no. 6081, p. 722–724.

Smith, R.A., Schwarz, G.E., and Alexander, R.B., 1997, Regional interpretation of water-quality monitoring data: Water Resources Research, v. 33, no. 12, p. 2781–2798.

Sorenson, S.K., and Schwarzbach, S.E., 1991, Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Klamath Basins, California and Oregon, 1988–89: U.S. Geological Survey Water-Resources Investigations Report 90–4203, 64 p.

U.S. Bureau of Census, 2002, Statistical abstract of the United States—2001: Information available on World Wide Web, accessed January 22, 2003, at URL http://www.census.gov/prod/2002pubs/0lstatab/stat-ab01.html

U.S. Environmental Protection Agency, 1972, Water, *in* The challenge of the environment—a primer on EPA's statutory authority: Information available on World Wide Web, accessed January 29, 2003, at URL http://www.epa.gov/history/topics/fwpca/05.html

U.S. Environmental Protection Agency, 1986, Quality criteria for water, 1986: U.S. Environmental Protection Agency Report 440/5–86–001, unnumbered pages.

U.S. Environmental Protection Agency, 1995, Controlling non-point source runoff pollution from roads, highways, and bridges: Office of Water, U.S. Environmental Protection Agency Report EPA–841–F–95–008a, 6 p.

U.S. Environmental Protection Agency, 1999a, National recommended water quality criteria— correction: U.S. Environmental Protection Agency Report EPA–822–Z–99–001, 25 p.

U.S. Environmental Protection Agency, 1999b, 1999 update of ambient water quality criteria for ammonia: U.S. Environmental Protection Agency Report EPA–822–R–99–014, 147 p.

U.S. Environmental Protection Agency, 2000a, Implementation guidance for ambient water quality criteria for bacteria—1986: U.S. Environmental Protection Agency Report EPA–823–D–00–001, 37 p.

U.S. Environmental Protection Agency, 2000b, National water quality inventory—1998 report to Congress: U.S. Environmental Protection Agency Report EPA–841–R–00–001, 413 p.

U.S. Environmental Protection Agency, 2001a, STORET result remark: STORET Legacy Data Center, information available on World Wide Web, accessed June 21, 2001, at URL http://www.epa.gov/storpubl/legacy/rsultrmk.htm

U.S. Environmental Protection Agency, 2001b, Water quality standards: Office of Water, information available on World Wide Web, accessed February 26, 2003, at URL http://www.epa.gov/waterscience/standards/wqslibrary/

U.S. Environmental Protection Agency, 2002a, Consolidated assessment and listing methodology: Office of Water, Oceans, and Watersheds, variously paged.

U.S. Environmental Protection Agency, 2002b, 2002 edition of the drinking water standards and health advisories: U.S. Environmental Protection Agency Report EPA–822–R–02–038, 12 p.

U.S. Environmental Protection Agency, 2002c, Total maximum daily loads—national section 303(d) list fact sheet: Information available on World Wide Web, accessed December 16, 2002, at URL http://oaspub.epa.gov/waters/national_rept.control

U.S. Environmental Protection Agency, 2003a, About STORET: Office of Water, information available on World Wide Web, accessed March 6, 2003, at URL http://www.epa.gov/storet/about

U.S. Environmental Protection Agency, 2003b, Elements of a State water monitoring and assessment program: U.S. Environmental Protection Agency Report EPA–841–B–03–003, 14 p.

U.S. Environmental Protection Agency, 2004, Draft report on the environment: Information available on World Wide Web, accessed January 29, 2004, at URL http://www.epa.gov/indicators/roe/html/roeWaterLim.htm

U.S. General Accounting Office, 2000, Water quality—key EPA and State decisions limited by inconsistent and incomplete data: U.S. General Accounting Office Report GAO/RCED–00–54, 73 p.

U.S. General Accounting Office, 2002, Inconsistent State approaches complicate Nation's efforts to identify its most polluted waters: U.S. General Accounting Office Report GAO–02–186, 40 p.

U.S. Geological Survey, 1999, The quality of our Nation's waters—nutrients and pesticides: U.S. Geological Survey Circular 1225, 82 p.

U.S. Geological Survey, 2003, NWISWeb help system—code descriptions: Information available on World Wide Web, accessed April 10, 2003, at URL http://waterdata.usgs.gov/nwis/help?codes_help

# Supplemental Information

**Table 25.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for suspended solids, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 49 | 45 | 45 | 45 | 45 | 45 | 43 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 132 | 131 | 131 | 131 | 130 | 128 | 127 | 27 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 347 | 278 | 262 | 214 | 75 | 63 | 52 | 46 | 28 | 6 |
| Connecticut | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Delaware | 109 | 109 | 108 | 103 | 97 | 86 | 73 | 58 | 22 | 0 |
| Florida | 648 | 642 | 627 | 602 | 514 | 431 | 372 | 300 | 197 | 94 |
| Georgia | 284 | 244 | 233 | 196 | 79 | 78 | 76 | 75 | 61 | 11 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 367 | 141 | 24 | 11 | 3 | 3 | 1 | 1 | 1 | 0 |
| Indiana | 107 | 106 | 106 | 105 | 100 | 91 | 84 | 83 | 82 | 0 |
| Iowa | 55 | 55 | 55 | 26 | 14 | 14 | 14 | 14 | 14 | 14 |
| Kansas | 161 | 161 | 153 | 124 | 46 | 40 | 40 | 40 | 14 | 0 |
| Kentucky | 89 | 88 | 66 | 60 | 49 | 46 | 46 | 45 | 44 | 27 |
| Louisiana | 172 | 171 | 171 | 171 | 152 | 149 | 148 | 148 | 99 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 38 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 261 | 178 | 166 | 96 | 72 | 69 | 65 | 61 | 39 | 6 |
| Minnesota | 66 | 65 | 65 | 63 | 56 | 51 | 51 | 50 | 17 | 0 |
| Mississippi | 84 | 72 | 71 | 66 | 58 | 56 | 19 | 17 | 10 | 0 |
| Missouri | 37 | 33 | 30 | 22 | 14 | 9 | 5 | 5 | 1 | 0 |
| Montana | 323 | 187 | 162 | 132 | 93 | 81 | 66 | 56 | 13 | 1 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 69 | 69 | 69 | 67 | 64 | 56 | 53 | 53 | 35 | 10 |
| New Hampshire | 228 | 114 | 27 | 25 | 16 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 74 | 73 | 70 | 65 | 33 | 4 | 0 | 0 | 0 | 0 |
| New Mexico | 512 | 415 | 348 | 219 | 75 | 31 | 11 | 1 | 1 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 0 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 37 | 33 | 32 | 28 | 18 | 11 | 10 | 8 | 7 | 2 |
| Ohio | 42 | 42 | 41 | 41 | 40 | 40 | 40 | 40 | 37 | 10 |
| Oklahoma | 245 | 238 | 236 | 182 | 87 | 43 | 34 | 33 | 8 | 1 |
| Oregon | 148 | 148 | 147 | 144 | 126 | 119 | 114 | 98 | 64 | 12 |
| Pennsylvania | 200 | 196 | 191 | 173 | 173 | 173 | 173 | 171 | 153 | 8 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 3 | 3 | 2 | 0 | 0 |
| South Carolina | 119 | 62 | 56 | 52 | 48 | 46 | 44 | 39 | 34 | 9 |
| South Dakota | 100 | 96 | 96 | 96 | 93 | 88 | 86 | 83 | 50 | 31 |
| Tennessee | 101 | 97 | 90 | 68 | 52 | 40 | 25 | 7 | 2 | 0 |
| Texas | 769 | 576 | 486 | 396 | 314 | 235 | 147 | 96 | 22 | 2 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 63 | 60 | 8 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,342 | 1,127 | 1,086 | 945 | 807 | 748 | 645 | 569 | 341 | 133 |
| Washington | 205 | 205 | 205 | 204 | 106 | 105 | 91 | 91 | 57 | 0 |
| West Virginia | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 50 | 49 | 49 | 46 | 40 | 36 | 32 | 29 | 13 | 5 |
| Wyoming | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| **Totals** | **7,710** | **6,429** | **5,886** | **5,095** | **3,841** | **3,367** | **2,940** | **2,634** | **1,736** | **456** |
| **Percentage reduction** | | **16.6** | **23.7** | **33.9** | **50.2** | **56.3** | **61.9** | **65.8** | **77.5** | **94.1** |

**Table 26.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for fecal coliform bacteria, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 47 | 45 | 45 | 45 | 41 | 41 | 35 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 115 | 115 | 114 | 113 | 84 | 72 | 70 | 70 | 49 | 0 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 298 | 256 | 212 | 124 | 60 | 51 | 42 | 38 | 21 | 5 |
| Connecticut | 32 | 32 | 32 | 32 | 32 | 31 | 31 | 31 | 24 | 0 |
| Delaware | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 458 | 442 | 427 | 372 | 260 | 214 | 169 | 122 | 75 | 42 |
| Georgia | 392 | 317 | 270 | 255 | 155 | 141 | 132 | 116 | 87 | 5 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 47 | 47 | 47 | 42 | 36 | 22 | 12 | 7 | 1 | 0 |
| Illinois | 37 | 25 | 7 | 3 | 3 | 2 | 1 | 1 | 1 | 0 |
| Indiana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Iowa | 47 | 33 | 28 | 17 | 17 | 16 | 16 | 16 | 16 | 0 |
| Kansas | 289 | 288 | 276 | 249 | 171 | 145 | 145 | 144 | 54 | 6 |
| Kentucky | 87 | 83 | 70 | 59 | 48 | 46 | 45 | 44 | 44 | 0 |
| Louisiana | 167 | 166 | 142 | 103 | 52 | 28 | 0 | 0 | 0 | 0 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 18 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Minnesota | 63 | 63 | 63 | 63 | 56 | 50 | 50 | 50 | 18 | 0 |
| Mississippi | 68 | 63 | 61 | 50 | 49 | 38 | 4 | 0 | 0 | 0 |
| Missouri | 43 | 42 | 42 | 39 | 39 | 37 | 34 | 32 | 16 | 2 |
| Montana | 4 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 70 | 68 | 68 | 60 | 56 | 55 | 47 | 37 | 23 | 0 |
| New Hampshire | 104 | 40 | 8 | 8 | 1 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 18 | 10 | 5 | 5 | 5 | 3 | 2 | 0 | 0 | 0 |
| New Mexico | 175 | 56 | 19 | 9 | 8 | 5 | 4 | 2 | 2 | 0 |
| New York | 13 | 12 | 10 | 8 | 1 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 69 | 64 | 57 | 39 | 23 | 17 | 11 | 7 | 3 | 1 |
| Ohio | 41 | 40 | 40 | 40 | 39 | 36 | 30 | 25 | 13 | 0 |
| Oklahoma | 22 | 15 | 14 | 14 | 4 | 0 | 0 | 0 | 0 | 0 |
| Oregon | 132 | 128 | 120 | 83 | 37 | 24 | 11 | 7 | 0 | 0 |
| Pennsylvania | 88 | 77 | 72 | 53 | 50 | 49 | 47 | 46 | 42 | 1 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 |
| South Carolina | 338 | 337 | 337 | 310 | 226 | 203 | 197 | 192 | 130 | 5 |
| South Dakota | 100 | 96 | 96 | 96 | 88 | 83 | 74 | 56 | 47 | 0 |
| Tennessee | 107 | 99 | 89 | 60 | 41 | 32 | 18 | 3 | 2 | 0 |
| Texas | 784 | 659 | 560 | 457 | 346 | 251 | 195 | 140 | 77 | 11 |
| Utah | 18 | 16 | 16 | 16 | 15 | 12 | 10 | 6 | 0 | 0 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,420 | 1,195 | 1,151 | 1,086 | 943 | 834 | 695 | 584 | 335 | 83 |
| Washington | 208 | 208 | 208 | 202 | 106 | 105 | 91 | 89 | 57 | 0 |
| West Virginia | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 47 | 46 | 45 | 44 | 36 | 33 | 29 | 25 | 12 | 0 |
| Wyoming | 19 | 18 | 18 | 18 | 16 | 15 | 13 | 10 | 0 | 0 |
| **Totals** | **6,063** | **5,301** | **4,866** | **4,269** | **3,216** | **2,763** | **2,333** | **2,007** | **1,229** | **179** |
| **Percentage reduction** | | **12.6** | **19.7** | **29.6** | **47.0** | **54.4** | **61.5** | **66.9** | **79.7** | **97.0** |

**Table 27.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for ammonia as nitrogen, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 35 | 18 | 18 | 18 | 17 | 3 | 2 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 133 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 262 | 232 | 213 | 163 | 61 | 54 | 45 | 40 | 17 | 0 |
| Connecticut | 29 | 29 | 29 | 29 | 29 | 28 | 28 | 28 | 24 | 2 |
| Delaware | 109 | 109 | 108 | 103 | 97 | 86 | 72 | 57 | 22 | 0 |
| Florida | 823 | 823 | 823 | 793 | 647 | 538 | 438 | 353 | 243 | 99 |
| Georgia | 416 | 382 | 323 | 283 | 156 | 147 | 136 | 126 | 92 | 22 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 49 | 49 | 49 | 47 | 33 | 23 | 19 | 14 | 7 | 1 |
| Illinois | 368 | 142 | 24 | 11 | 3 | 3 | 1 | 1 | 1 | 0 |
| Indiana | 107 | 106 | 106 | 106 | 103 | 93 | 86 | 85 | 84 | 0 |
| Iowa | 68 | 68 | 68 | 39 | 27 | 27 | 27 | 27 | 27 | 27 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 145 | 89 | 6 |
| Kentucky | 89 | 88 | 66 | 60 | 49 | 46 | 46 | 45 | 44 | 24 |
| Louisiana | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 248 | 146 | 127 | 70 | 65 | 63 | 55 | 49 | 14 | 3 |
| Minnesota | 67 | 67 | 67 | 66 | 66 | 65 | 63 | 52 | 47 | 0 |
| Mississippi | 81 | 63 | 63 | 58 | 51 | 50 | 6 | 2 | 1 | 0 |
| Missouri | 43 | 43 | 42 | 39 | 38 | 37 | 26 | 20 | 12 | 0 |
| Montana | 380 | 199 | 173 | 140 | 89 | 77 | 53 | 49 | 22 | 0 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 69 | 69 | 69 | 67 | 64 | 56 | 53 | 53 | 36 | 11 |
| New Hampshire | 315 | 156 | 57 | 41 | 16 | 7 | 0 | 0 | 0 | 0 |
| New Jersey | 95 | 95 | 95 | 82 | 70 | 62 | 49 | 35 | 3 | 1 |
| New Mexico | 521 | 427 | 364 | 228 | 80 | 35 | 17 | 6 | 1 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 1 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 83 | 71 | 55 | 33 | 24 | 23 | 19 | 7 | 2 |
| Ohio | 42 | 42 | 41 | 41 | 40 | 40 | 40 | 40 | 37 | 10 |
| Oklahoma | 195 | 174 | 135 | 38 | 16 | 13 | 11 | 10 | 2 | 0 |
| Oregon | 148 | 148 | 147 | 143 | 126 | 119 | 115 | 99 | 64 | 13 |
| Pennsylvania | 201 | 196 | 192 | 174 | 174 | 174 | 174 | 172 | 169 | 142 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 |
| South Carolina | 339 | 339 | 339 | 337 | 276 | 228 | 197 | 196 | 193 | 135 |
| South Dakota | 97 | 96 | 96 | 96 | 92 | 88 | 86 | 83 | 46 | 10 |
| Tennessee | 107 | 99 | 88 | 65 | 44 | 40 | 26 | 9 | 2 | 0 |
| Texas | 903 | 663 | 561 | 446 | 358 | 282 | 207 | 157 | 67 | 10 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 59 | 8 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,424 | 1,143 | 1,094 | 957 | 809 | 748 | 643 | 566 | 342 | 133 |
| Washington | 207 | 205 | 205 | 204 | 106 | 105 | 91 | 91 | 57 | 0 |
| West Virginia | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 49 | 44 | 43 | 40 | 35 | 33 | 27 | 22 | 9 | 1 |
| Wyoming | 27 | 22 | 22 | 21 | 20 | 15 | 13 | 10 | 3 | 0 |
| **Totals** | **8,615** | **7,194** | **6,525** | **5,618** | **4,341** | **3,851** | **3,316** | **2,942** | **2,020** | **827** |
| **Percentage reduction** | | **16.5** | **24.3** | **34.8** | **49.6** | **55.2** | **61.5** | **65.9** | **76.6** | **90.4** |

**Table 28.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for nitrite plus nitrate as nitrogen, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 48 | 48 | 48 | 44 | 44 | 44 | 44 | 44 | 42 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 131 | 131 | 131 | 131 | 130 | 129 | 127 | 17 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 316 | 274 | 259 | 210 | 69 | 69 | 49 | 38 | 22 | 2 |
| Connecticut | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 23 | 2 |
| Delaware | 109 | 109 | 108 | 103 | 97 | 84 | 72 | 57 | 20 | 0 |
| Florida | 839 | 839 | 838 | 825 | 678 | 572 | 487 | 402 | 264 | 128 |
| Georgia | 416 | 382 | 323 | 283 | 156 | 144 | 136 | 127 | 93 | 16 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 50 | 50 | 49 | 45 | 35 | 25 | 19 | 18 | 5 | 0 |
| Illinois | 368 | 142 | 24 | 11 | 3 | 3 | 1 | 1 | 1 | 0 |
| Indiana | 106 | 106 | 106 | 106 | 103 | 93 | 86 | 85 | 84 | 0 |
| Iowa | 68 | 68 | 68 | 39 | 27 | 27 | 27 | 27 | 27 | 27 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 145 | 89 | 6 |
| Kentucky | 88 | 87 | 66 | 60 | 48 | 46 | 46 | 45 | 44 | 24 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 149 | 148 | 148 | 96 | 0 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 265 | 165 | 154 | 85 | 70 | 67 | 65 | 61 | 27 | 4 |
| Minnesota | 67 | 67 | 67 | 66 | 66 | 65 | 63 | 52 | 47 | 0 |
| Mississippi | 85 | 72 | 71 | 65 | 59 | 55 | 20 | 16 | 10 | 0 |
| Missouri | 44 | 43 | 43 | 40 | 37 | 37 | 34 | 32 | 14 | 0 |
| Montana | 880 | 418 | 347 | 235 | 165 | 113 | 72 | 65 | 29 | 0 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 66 | 66 | 66 | 64 | 61 | 54 | 51 | 51 | 34 | 10 |
| New Hampshire | 339 | 211 | 92 | 46 | 21 | 11 | 0 | 0 | 0 | 0 |
| New Jersey | 92 | 91 | 91 | 87 | 73 | 70 | 69 | 67 | 7 | 2 |
| New Mexico | 521 | 425 | 370 | 230 | 77 | 31 | 16 | 6 | 2 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 1 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 83 | 72 | 57 | 34 | 25 | 24 | 19 | 7 | 2 |
| Ohio | 42 | 42 | 41 | 41 | 40 | 40 | 40 | 40 | 37 | 10 |
| Oklahoma | 221 | 197 | 171 | 111 | 59 | 38 | 29 | 28 | 8 | 1 |
| Oregon | 148 | 148 | 147 | 143 | 126 | 119 | 115 | 98 | 62 | 13 |
| Pennsylvania | 198 | 193 | 189 | 171 | 171 | 171 | 171 | 170 | 167 | 142 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 |
| South Carolina | 340 | 340 | 340 | 340 | 301 | 270 | 226 | 216 | 209 | 167 |
| South Dakota | 97 | 96 | 96 | 96 | 92 | 88 | 86 | 83 | 45 | 0 |
| Tennessee | 106 | 97 | 88 | 65 | 43 | 40 | 26 | 9 | 2 | 0 |
| Texas | 889 | 655 | 571 | 449 | 331 | 257 | 181 | 139 | 72 | 10 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 63 | 60 | 7 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,419 | 1,143 | 1,095 | 957 | 812 | 749 | 649 | 568 | 343 | 134 |
| Washington | 206 | 205 | 205 | 204 | 106 | 105 | 91 | 90 | 57 | 0 |
| West Virginia | 24 | 24 | 24 | 24 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 50 | 44 | 43 | 42 | 38 | 37 | 32 | 32 | 18 | 3 |
| Wyoming | 36 | 32 | 31 | 29 | 22 | 14 | 10 | 9 | 0 | 0 |
| **Totals** | **9,408** | **7,736** | **7,067** | **6,107** | **4,696** | **4,169** | **3,639** | **3,294** | **2,240** | **767** |
| **Percentage reduction** | | **17.8** | **24.9** | **35.1** | **50.1** | **55.7** | **61.3** | **65.0** | **76.2** | **91.8** |

**Table 29.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total phosphorus, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 49 | 45 | 45 | 45 | 45 | 45 | 43 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 133 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 322 | 274 | 258 | 209 | 71 | 61 | 51 | 45 | 28 | 6 |
| Connecticut | 32 | 32 | 32 | 32 | 31 | 30 | 30 | 28 | 25 | 2 |
| Delaware | 109 | 109 | 107 | 103 | 96 | 83 | 73 | 57 | 20 | 0 |
| Florida | 807 | 806 | 805 | 790 | 655 | 547 | 459 | 406 | 276 | 129 |
| Georgia | 416 | 382 | 323 | 283 | 156 | 147 | 136 | 126 | 92 | 21 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 50 | 50 | 49 | 44 | 39 | 28 | 22 | 19 | 7 | 1 |
| Illinois | 368 | 141 | 24 | 11 | 3 | 3 | 1 | 1 | 1 | 0 |
| Indiana | 107 | 106 | 106 | 106 | 103 | 93 | 86 | 85 | 84 | 0 |
| Iowa | 57 | 57 | 57 | 28 | 16 | 16 | 16 | 16 | 16 | 16 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 145 | 89 | 6 |
| Kentucky | 89 | 88 | 66 | 60 | 49 | 46 | 46 | 45 | 44 | 26 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 149 | 148 | 148 | 98 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 272 | 165 | 155 | 83 | 69 | 67 | 65 | 61 | 28 | 4 |
| Minnesota | 66 | 65 | 65 | 63 | 56 | 51 | 51 | 51 | 17 | 0 |
| Mississippi | 85 | 72 | 71 | 65 | 59 | 56 | 20 | 16 | 10 | 0 |
| Missouri | 39 | 38 | 38 | 34 | 28 | 24 | 19 | 16 | 10 | 0 |
| Montana | 664 | 264 | 216 | 175 | 128 | 100 | 70 | 54 | 24 | 0 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 69 | 69 | 69 | 67 | 64 | 56 | 53 | 53 | 36 | 11 |
| New Hampshire | 347 | 220 | 93 | 46 | 21 | 15 | 2 | 0 | 0 | 0 |
| New Jersey | 95 | 95 | 93 | 82 | 71 | 69 | 66 | 58 | 7 | 2 |
| New Mexico | 521 | 426 | 346 | 225 | 74 | 33 | 17 | 10 | 3 | 0 |
| New York | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 83 | 72 | 57 | 34 | 25 | 24 | 19 | 8 | 2 |
| Ohio | 42 | 42 | 41 | 41 | 40 | 40 | 40 | 40 | 34 | 9 |
| Oklahoma | 258 | 247 | 245 | 194 | 91 | 45 | 35 | 34 | 12 | 1 |
| Oregon | 148 | 148 | 146 | 141 | 126 | 120 | 116 | 99 | 64 | 13 |
| Pennsylvania | 201 | 196 | 191 | 174 | 174 | 174 | 174 | 172 | 169 | 141 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 0 |
| South Carolina | 339 | 339 | 339 | 339 | 277 | 224 | 212 | 210 | 205 | 81 |
| South Dakota | 97 | 96 | 96 | 96 | 92 | 88 | 86 | 83 | 45 | 0 |
| Tennessee | 106 | 97 | 88 | 65 | 43 | 40 | 25 | 9 | 2 | 0 |
| Texas | 854 | 639 | 547 | 439 | 341 | 253 | 183 | 138 | 55 | 9 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 62 | 56 | 4 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,408 | 1,129 | 1,080 | 936 | 808 | 742 | 646 | 566 | 338 | 132 |
| Washington | 208 | 207 | 207 | 206 | 106 | 105 | 91 | 91 | 57 | 0 |
| West Virginia | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 50 | 47 | 46 | 44 | 39 | 37 | 34 | 32 | 18 | 6 |
| Wyoming | 31 | 28 | 28 | 21 | 16 | 10 | 9 | 7 | 3 | 0 |
| **Totals** | **9,148** | **7,557** | **6,891** | **6,015** | **4,604** | **4,030** | **3,558** | **3,244** | **2,197** | **790** |
| **Percentage reduction** | | **17.4** | **24.7** | **34.2** | **49.7** | **55.9** | **61.1** | **64.5** | **76.0** | **91.4** |

**Table 30.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for total arsenic, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 44 | 27 | 27 | 27 | 24 | 23 | 21 | 5 | 0 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 46 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Connecticut | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Delaware | 43 | 22 | 20 | 20 | 20 | 19 | 19 | 17 | 5 | 0 |
| Florida | 224 | 175 | 155 | 128 | 90 | 65 | 58 | 48 | 17 | 6 |
| Georgia | 66 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Illinois | 191 | 51 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 |
| Indiana | 71 | 67 | 66 | 61 | 41 | 40 | 38 | 38 | 35 | 0 |
| Iowa | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Kansas | 289 | 289 | 281 | 251 | 168 | 146 | 145 | 144 | 88 | 6 |
| Kentucky | 89 | 88 | 66 | 59 | 46 | 46 | 46 | 45 | 44 | 19 |
| Louisiana | 125 | 125 | 124 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 216 | 88 | 78 | 48 | 47 | 35 | 4 | 4 | 0 | 0 |
| Minnesota | 52 | 16 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mississippi | 72 | 69 | 64 | 22 | 9 | 0 | 0 | 0 | 0 | 0 |
| Missouri | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Montana | 96 | 9 | 8 | 8 | 3 | 3 | 3 | 3 | 0 | 0 |
| Nebraska | 17 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nevada | 71 | 70 | 70 | 59 | 48 | 19 | 8 | 8 | 7 | 0 |
| New Hampshire | 213 | 25 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 59 | 28 | 16 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Mexico | 323 | 152 | 42 | 15 | 3 | 1 | 1 | 1 | 1 | 0 |
| New York | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 68 | 38 | 31 | 24 | 12 | 7 | 5 | 0 | 0 | 0 |
| Ohio | 42 | 42 | 41 | 41 | 26 | 26 | 21 | 16 | 7 | 0 |
| Oklahoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oregon | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pennsylvania | 41 | 33 | 32 | 31 | 31 | 31 | 30 | 29 | 22 | 0 |
| Rhode Island | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| South Carolina | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| South Dakota | 52 | 44 | 23 | 20 | 20 | 19 | 19 | 19 | 7 | 1 |
| Tennessee | 108 | 99 | 92 | 70 | 56 | 41 | 34 | 12 | 2 | 0 |
| Texas | 101 | 33 | 23 | 9 | 8 | 4 | 4 | 4 | 3 | 0 |
| Utah | 60 | 58 | 57 | 54 | 50 | 7 | 2 | 2 | 0 | 0 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 692 | 399 | 226 | 75 | 14 | 4 | 4 | 4 | 0 | 0 |
| Washington | 14 | 12 | 11 | 5 | 2 | 1 | 0 | 0 | 0 | 0 |
| West Virginia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 4 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| Wyoming | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Totals** | **3,498** | **2,101** | **1,602** | **1,063** | **723** | **541** | **465** | **401** | **239** | **32** |
| **Percentage reduction** | | **39.9** | **54.2** | **69.6** | **79.3** | **84.5** | **86.7** | **88.5** | **93.2** | **99.1** |

**Table 31.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for dissolved solids, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 48 | 48 | 47 | 42 | 27 | 27 | 27 | 27 | 25 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 133 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 317 | 276 | 262 | 212 | 75 | 63 | 51 | 46 | 28 | 6 |
| Connecticut | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 27 | 2 |
| Delaware | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 273 | 267 | 260 | 253 | 196 | 151 | 100 | 84 | 44 | 8 |
| Georgia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 50 | 50 | 48 | 32 | 11 | 9 | 7 | 6 | 1 | 0 |
| Illinois | 197 | 63 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indiana | 30 | 23 | 23 | 23 | 21 | 20 | 20 | 20 | 19 | 0 |
| Iowa | 57 | 57 | 57 | 28 | 16 | 16 | 16 | 16 | 16 | 16 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 144 | 86 | 6 |
| Kentucky | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 149 | 148 | 148 | 99 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Minnesota | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mississippi | 62 | 49 | 49 | 46 | 42 | 8 | 7 | 4 | 0 | 0 |
| Missouri | 42 | 38 | 38 | 36 | 29 | 23 | 17 | 13 | 6 | 0 |
| Montana | 193 | 109 | 96 | 84 | 48 | 29 | 9 | 6 | 2 | 0 |
| Nebraska | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nevada | 69 | 69 | 69 | 67 | 64 | 56 | 53 | 53 | 35 | 10 |
| New Hampshire | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 95 | 95 | 95 | 92 | 76 | 74 | 73 | 70 | 7 | 2 |
| New Mexico | 521 | 424 | 355 | 228 | 82 | 39 | 16 | 5 | 1 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 1 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 82 | 70 | 52 | 29 | 19 | 17 | 11 | 0 | 0 |
| Ohio | 38 | 34 | 33 | 32 | 29 | 26 | 24 | 23 | 20 | 10 |
| Oklahoma | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oregon | 19 | 4 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Pennsylvania | 200 | 195 | 186 | 173 | 173 | 172 | 172 | 171 | 167 | 37 |
| Rhode Island | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| South Carolina | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| South Dakota | 100 | 96 | 96 | 96 | 93 | 88 | 86 | 83 | 50 | 30 |
| Tennessee | 48 | 34 | 31 | 23 | 19 | 16 | 12 | 7 | 0 | 0 |
| Texas | 690 | 476 | 387 | 285 | 124 | 62 | 50 | 38 | 2 | 0 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 63 | 58 | 2 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 246 | 107 | 86 | 82 | 71 | 63 | 61 | 42 | 16 | 0 |
| Washington | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| West Virginia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wyoming | 23 | 19 | 13 | 11 | 7 | 6 | 6 | 6 | 1 | 0 |
| **Totals** | **4,168** | **3,337** | **3,017** | **2,580** | **1,813** | **1,521** | **1,375** | **1,280** | **853** | **268** |
| **Percentage reduction** | | **19.9** | **27.6** | **38.1** | **56.5** | **63.5** | **67.0** | **69.3** | **79.5** | **93.6** |

**Table 32.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for chloride, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 49 | 45 | 45 | 45 | 45 | 45 | 43 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 132 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Connecticut | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 26 | 2 |
| Delaware | 106 | 103 | 102 | 95 | 88 | 81 | 69 | 45 | 17 | 0 |
| Florida | 693 | 687 | 677 | 653 | 507 | 380 | 302 | 257 | 187 | 78 |
| Georgia | 10 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 1 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 47 | 47 | 46 | 35 | 11 | 10 | 9 | 7 | 1 | 0 |
| Illinois | 202 | 50 | 8 | 7 | 3 | 2 | 1 | 1 | 1 | 0 |
| Indiana | 32 | 16 | 15 | 15 | 15 | 15 | 15 | 15 | 14 | 0 |
| Iowa | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 4 | 0 | 0 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 145 | 89 | 6 |
| Kentucky | 89 | 88 | 66 | 60 | 51 | 48 | 48 | 45 | 44 | 28 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 149 | 148 | 148 | 99 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 249 | 173 | 163 | 93 | 69 | 66 | 62 | 58 | 36 | 3 |
| Minnesota | 17 | 11 | 11 | 10 | 9 | 6 | 6 | 6 | 5 | 0 |
| Mississippi | 80 | 65 | 60 | 56 | 49 | 49 | 7 | 3 | 0 | 0 |
| Missouri | 43 | 39 | 39 | 35 | 25 | 20 | 17 | 9 | 5 | 0 |
| Montana | 523 | 250 | 198 | 132 | 65 | 28 | 21 | 17 | 4 | 0 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 69 | 69 | 69 | 67 | 64 | 56 | 53 | 53 | 35 | 10 |
| New Hampshire | 209 | 118 | 32 | 12 | 1 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 93 | 93 | 93 | 92 | 73 | 71 | 70 | 67 | 7 | 2 |
| New Mexico | 507 | 358 | 233 | 131 | 52 | 24 | 18 | 13 | 3 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 1 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 82 | 70 | 52 | 29 | 19 | 17 | 11 | 0 | 0 |
| Ohio | 42 | 42 | 40 | 40 | 39 | 38 | 37 | 35 | 30 | 3 |
| Oklahoma | 252 | 229 | 227 | 177 | 59 | 40 | 23 | 21 | 4 | 1 |
| Oregon | 53 | 6 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pennsylvania | 82 | 66 | 59 | 41 | 40 | 40 | 39 | 39 | 37 | 3 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 0 |
| South Carolina | 22 | 15 | 15 | 14 | 14 | 13 | 13 | 13 | 13 | 2 |
| South Dakota | 16 | 10 | 9 | 8 | 7 | 7 | 7 | 7 | 6 | 0 |
| Tennessee | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Texas | 910 | 697 | 597 | 495 | 394 | 319 | 247 | 198 | 77 | 15 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 61 | 61 | 58 | 1 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,216 | 1,079 | 1,042 | 897 | 765 | 702 | 605 | 511 | 284 | 55 |
| Washington | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| West Virginia | 26 | 26 | 26 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 50 | 49 | 48 | 47 | 41 | 39 | 34 | 33 | 18 | 4 |
| Wyoming | 25 | 23 | 22 | 19 | 18 | 14 | 13 | 12 | 7 | 0 |
| **Totals** | **6,569** | **5,290** | **4,761** | **4,066** | **3,140** | **2,708** | **2,349** | **2,088** | **1,288** | **342** |
| **Percentage reduction** | | **19.5** | **27.5** | **38.1** | **52.2** | **58.8** | **64.2** | **68.2** | **80.4** | **94.8** |

**Table 33.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for sulfate, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 132 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 342 | 277 | 263 | 215 | 73 | 60 | 51 | 39 | 23 | 2 |
| Connecticut | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 27 | 2 |
| Delaware | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 635 | 622 | 618 | 593 | 471 | 364 | 275 | 199 | 101 | 25 |
| Georgia | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 46 | 46 | 45 | 37 | | 8 | 7 | 6 | 1 | 0 |
| Illinois | 220 | 54 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 0 |
| Indiana | 22 | 13 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 0 |
| Iowa | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 0 | 0 | 0 |
| Kansas | 289 | 289 | 281 | 251 | 169 | 146 | 145 | 145 | 89 | 6 |
| Kentucky | 89 | 88 | 66 | 59 | 49 | 46 | 46 | 45 | 44 | 22 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 149 | 148 | 148 | 99 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 192 | 108 | 100 | 64 | 51 | 42 | 41 | 8 | 1 | 0 |
| Minnesota | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Mississippi | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 |
| Missouri | 42 | 38 | 38 | 34 | 24 | 20 | 17 | 9 | 5 | 0 |
| Montana | 614 | 265 | 240 | 163 | 98 | 41 | 30 | 23 | 3 | 0 |
| Nebraska | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nevada | 69 | 69 | 68 | 66 | 58 | 45 | 28 | 17 | 10 | 10 |
| New Hampshire | 201 | 43 | 10 | 8 | 1 | 0 | 0 | 0 | 0 | 0 |
| New Jersey | 93 | 93 | 93 | 92 | 74 | 72 | 71 | 68 | 7 | 2 |
| New Mexico | 511 | 364 | 234 | 132 | 52 | 24 | 18 | 13 | 4 | 0 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 1 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 82 | 70 | 52 | 29 | 19 | 17 | 11 | 0 | 0 |
| Ohio | 42 | 42 | 41 | 36 | 33 | 29 | 26 | 22 | 19 | 0 |
| Oklahoma | 245 | 229 | 227 | 178 | 58 | 40 | 23 | 21 | 6 | 1 |
| Oregon | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pennsylvania | 201 | 196 | 192 | 174 | 174 | 174 | 174 | 172 | 169 | 142 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 1 | 1 | 0 |
| South Carolina | 11 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 0 | 0 |
| South Dakota | 19 | 10 | 9 | 8 | 7 | 7 | 7 | 7 | 6 | 0 |
| Tennessee | 4 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| Texas | 898 | 684 | 584 | 481 | 382 | 304 | 232 | 182 | 72 | 10 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 63 | 58 | 1 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,219 | 1,079 | 1,042 | 894 | 764 | 701 | 604 | 512 | 284 | 56 |
| Washington | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| West Virginia | 26 | 26 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 20 | 18 | 18 | 17 | 12 | 9 | 9 | 9 | 6 | 0 |
| Wyoming | 25 | 23 | 22 | 19 | 18 | 16 | 13 | 12 | 7 | 0 |
| **Totals** | **6,652** | **5,218** | **4,761** | **4,065** | **3,043** | **2,603** | **2,264** | **1,943** | **1,197** | **418** |
| **Percentage reduction** | | **21.6** | **28.4** | **38.9** | **54.3** | **60.9** | **66.0** | **70.8** | **82.0** | **93.7** |

**Table 34.** Number of State ambient stream-water-quality monitoring sites with selected numbers of analyses for pH, 1990–98.

[--, not available]

| State | Number of analyses (equal to or greater than) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 5 | 9 | 15 | 20 | 25 | 30 | 50 | 100 |
| Alabama | 49 | 49 | 49 | 45 | 45 | 45 | 45 | 45 | 43 | 0 |
| Alaska | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arizona | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arkansas | 133 | 133 | 132 | 131 | 131 | 131 | 131 | 131 | 129 | 127 |
| California | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Colorado | 523 | 360 | 265 | 205 | 74 | 63 | 53 | 45 | 24 | 4 |
| Connecticut | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 27 | 2 |
| Delaware | 109 | 109 | 108 | 103 | 96 | 87 | 76 | 59 | 21 | 0 |
| Florida | 748 | 745 | 739 | 690 | 575 | 490 | 423 | 371 | 281 | 155 |
| Georgia | 391 | 377 | 330 | 284 | 154 | 146 | 132 | 122 | 80 | 8 |
| Hawaii | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Idaho | 51 | 51 | 51 | 51 | 48 | 32 | 24 | 19 | 9 | 0 |
| Illinois | 367 | 135 | 23 | 11 | 3 | 2 | 1 | 1 | 1 | 0 |
| Indiana | 105 | 105 | 101 | 101 | 87 | 82 | 81 | 80 | 61 | 0 |
| Iowa | 65 | 65 | 65 | 36 | 24 | 24 | 24 | 24 | 24 | 24 |
| Kansas | 289 | 288 | 280 | 247 | 169 | 145 | 145 | 144 | 76 | 6 |
| Kentucky | 87 | 84 | 65 | 60 | 48 | 47 | 47 | 45 | 44 | 15 |
| Louisiana | 173 | 172 | 172 | 172 | 152 | 148 | 148 | 148 | 84 | 1 |
| Maine | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Maryland | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Massachusetts | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Michigan | 218 | 157 | 147 | 79 | 65 | 64 | 59 | 57 | 11 | 1 |
| Minnesota | 67 | 67 | 67 | 66 | 66 | 65 | 63 | 52 | 48 | 0 |
| Mississippi | 83 | 72 | 71 | 66 | 63 | 60 | 25 | 23 | 10 | 0 |
| Missouri | 43 | 42 | 42 | 38 | 38 | 36 | 34 | 32 | 17 | 2 |
| Montana | 871 | 411 | 335 | 276 | 184 | 125 | 96 | 81 | 45 | 5 |
| Nebraska | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 0 | 0 |
| Nevada | 55 | 54 | 50 | 35 | 23 | 22 | 0 | 0 | 0 | 0 |
| New Hampshire | 429 | 277 | 136 | 55 | 21 | 15 | 5 | 0 | 0 | 0 |
| New Jersey | 94 | 94 | 94 | 89 | 75 | 74 | 73 | 70 | 8 | 2 |
| New Mexico | 527 | 425 | 360 | 211 | 65 | 27 | 14 | 14 | 5 | 1 |
| New York | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 16 | 0 | 0 |
| North Carolina | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| North Dakota | 90 | 86 | 82 | 72 | 42 | 35 | 30 | 21 | 9 | 0 |
| Ohio | 41 | 41 | 41 | 39 | 38 | 37 | 35 | 35 | 24 | 6 |
| Oklahoma | 256 | 250 | 224 | 133 | 71 | 41 | 38 | 36 | 12 | 3 |
| Oregon | 148 | 148 | 147 | 140 | 126 | 120 | 116 | 96 | 63 | 13 |
| Pennsylvania | 200 | 194 | 188 | 174 | 174 | 174 | 174 | 172 | 166 | 96 |
| Rhode Island | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 |
| South Carolina | 339 | 339 | 339 | 339 | 294 | 244 | 215 | 212 | 208 | 149 |
| South Dakota | 100 | 96 | 96 | 96 | 93 | 87 | 86 | 79 | 49 | 8 |
| Tennessee | 102 | 92 | 70 | 43 | 31 | 26 | 23 | 8 | 2 | 0 |
| Texas | 935 | 787 | 682 | 546 | 435 | 347 | 296 | 237 | 128 | 39 |
| Utah | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 64 | 63 | 60 |
| Vermont | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Virginia | 1,278 | 1,094 | 1,050 | 898 | 770 | 710 | 614 | 527 | 303 | 74 |
| Washington | 208 | 208 | 208 | 207 | 106 | 105 | 91 | 90 | 57 | 0 |
| West Virginia | 26 | 26 | 26 | 24 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wisconsin | 48 | 44 | 40 | 38 | 30 | 28 | 27 | 27 | 21 | 5 |
| Wyoming | 43 | 39 | 36 | 36 | 31 | 29 | 25 | 18 | 6 | 0 |
| **Totals** | **9,473** | **7,898** | **7,093** | **6,018** | **4,629** | **4,095** | **3,650** | **3,299** | **2,204** | **846** |
| **Percentage reduction** | | **16.6** | **25.1** | **36.5** | **51.1** | **56.8** | **61.5** | **65.2** | **76.7** | **90.1** |