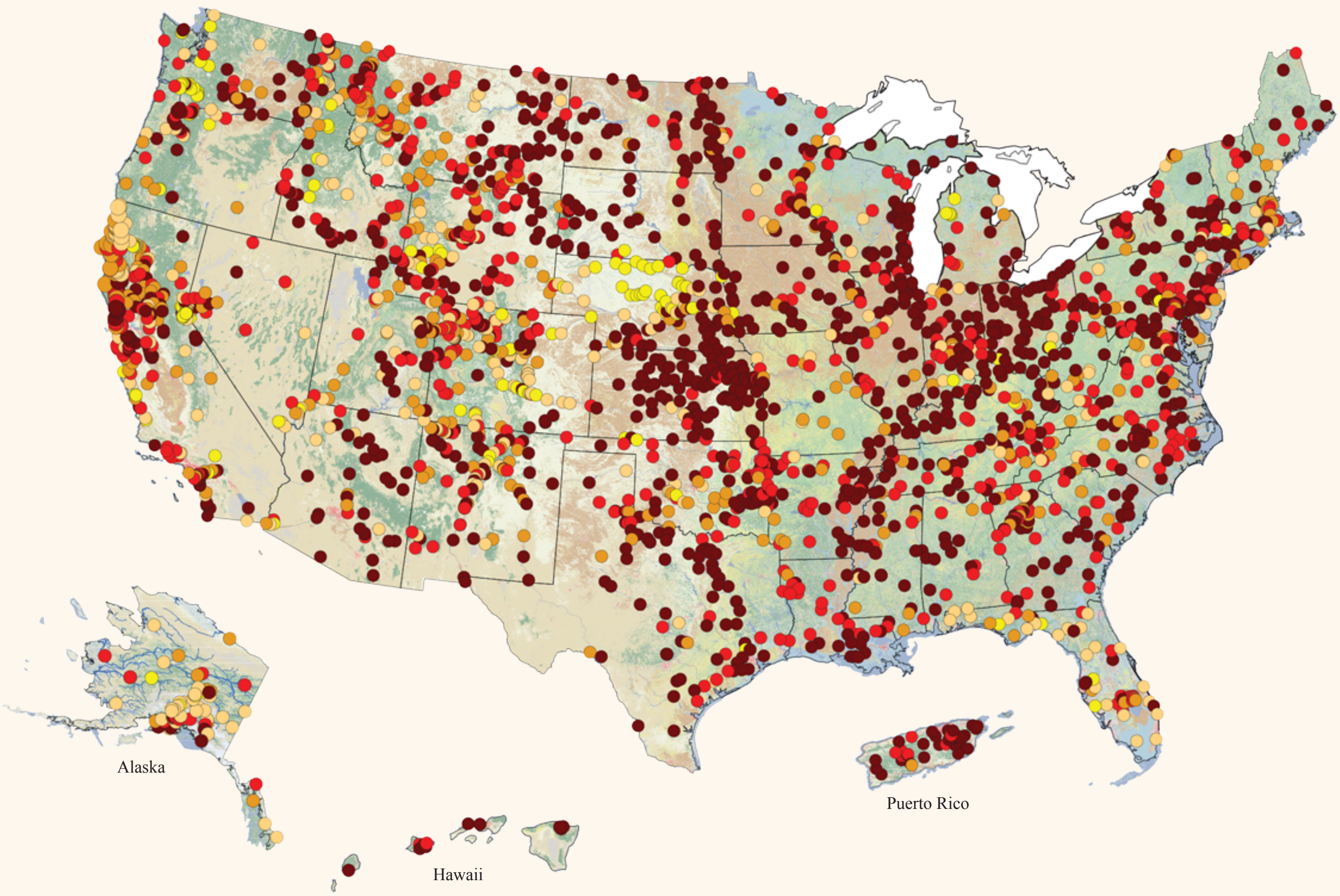
Compilation, Quality Control, Analysis, and Summary of Discrete Suspended-Sediment and Ancillary Data in the United States, 1901–2010



Data Series 776

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

EXPLANATION

Median percentage of silt/clay sediment at sites with five or more samples

- 0–49
- 50–69
- 70–79
- 80–89
- 90–100

Land cover classes

- Open water
- Perennial ice/snow
- Developed, open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren land
- Deciduous forest
- Evergreen forest
- Mixed forest
- Shrub/scrub
- Grassland/sedge/herbaceous
- Pasture/hay
- Cultivated crops
- Wetlands

From Homer and others, 2007

Cover illustration: figure 14 from this report.

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

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2013

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton per day (ton/d)	0.9072	megagram per day (Mg/d)

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

Concentrations of chemical constituents in water are in milligrams per liter (mg/L).

Compilation, Quality Control, Analysis, and Summary of Discrete Suspended-Sediment and Ancillary Data in the United States, 1901–2010

By Casey J. Lee and G. Douglas Glysson

Abstract

Human-induced and natural changes to the transport of sediment and sediment-associated constituents can degrade aquatic ecosystems and limit human uses of streams and rivers. The lack of a dedicated, easily accessible, quality-controlled database of sediment and ancillary data has made it difficult to identify sediment-related water-quality impairments and has limited understanding of how human actions affect suspended-sediment concentrations and transport. The purpose of this report is to describe the creation of a quality-controlled U.S. Geological Survey suspended-sediment database, provide guidance for its use, and summarize characteristics of suspended-sediment data through 2010. The database is provided as an online application at *http://cida.usgs.gov/sediment* to allow users to view, filter, and retrieve available suspended-sediment and ancillary data.

A data recovery, filtration, and quality-control process was performed to expand the availability, representativeness, and utility of existing suspended-sediment data collected by the U.S. Geological Survey in the United States before January 1, 2011. Information on streamflow condition, sediment grain size, and upstream landscape condition were matched to sediment data and sediment-sampling sites to place data in context with factors that may influence sediment transport. Suspended-sediment and selected ancillary data are presented from across the United States with respect to time, streamflow, and landscape condition. Examples of potential uses of this database for identifying sediment-related impairments, assessing trends, and designing new data collection activities are provided. This report and database can support local and national-level decision making, project planning, and data mining activities related to the transport of suspended-sediment and sediment-associated constituents.

Introduction

The character of stream and river systems is determined by interactions between water, sediment, and biota. The natural sedimentation cycle of erosion, transport, and deposition sustains habitats necessary for diverse aquatic ecosystems (Ward and others, 2002), whereas accelerated or artificially decreased transport of sediments to streams and rivers can harm infrastructure and aquatic life in many ways, including flooding, bridge scour, loss of wetlands, decreased primary productivity, decreased abundance of secondary consumers, and impaired feeding success of visual predators (Blevins, 2006; Blum and Roberts, 2009; Osterkamp and others, 1998; Lloyd, 1987; Wood and Armitage, 1997). Human-induced changes to sediment transport also can have substantial effects on water-quality, as sediment transport is a primary mechanism by which many of the chemical and biological agents that degrade water quality move through (or are deposited within) streams and rivers (Horowitz, 1991; Rasmussen and Ziegler, 2003).

Changes to natural sediment transport are a regularly cited cause of surface-water impairments. The U.S. Environmental Protection Agency (USEPA) reviews state-reported 305(b) assessments to classify the primary causes of surface-water impairments across the United States. These assessments have been summarized every other year since 2002 (U.S. Environmental Protection Agency, 2012b). From 2002 to 2010, sediment and turbidity (typically a direct result of sediment) were the third most-reported impairments of the 33 groups of impairment identified in 305(b) lists. Additionally, pathogens (1st-most-reported), metals (4th), nutrients (5th), and polychlorinated biphenyls (PCBs; 8th) are often transported by sediments. The USEPA wadeable streams assessment described excess loading of nutrients and sediment as the most substantial effects on benthic macroinvertebrate communities in wadeable streams across the United States (U.S. Environmental Protection Agency, 2006). Sediment and associated constituents add to water treatment costs and can negatively affect freshwater and saltwater fishing industries (Osterkamp and others, 1998). In addition, sedimentation is an increasing threat to many uses derived from reservoirs, which include the stability of public water supplies, flood control, and recreation (Morris and Fan, 1998; Osterkamp and others, 1998; Kansas Water Office, 2008).

Although national assessments can identify the relative importance of sediment as a water-quality stressor, effects resulting from human-induced changes to the natural sediment-transport regime are realized locally. For example, decreased sediment supplies in the lower Mississippi River attributed to upstream dams, changes to landscape management, and river engineering have been identified as a primary reason for the loss of thousands of square miles of wetlands off the Louisiana coast (Blum and Roberts, 2009; Meade and Moody, 2010). In the Chesapeake Bay, sunlight attenuation from suspended material has been associated with degradation of aquatic habitat (Kemp and others, 2004). In the Colorado River, sediment captured in Lake Powell coupled with regulated releases from the Glen Canyon Dam have contributed to the net erosion of sandbars downstream from the dam and the loss of backwater habitat for native fishes (Gloss and others, 2005). Similarly, sediment deficits in the lower Missouri River have resulted in the loss of aquatic habitat for fish and bird species and sediment deficits also have resulted in channel incisions that present risks to water-supply and infrastructure (Galat and others, 2005; Blevins, 2006; Jacobson and others, 2009).

Effects caused by human-induced changes to sediment transport emphasize the need to understand how natural conditions, such as soils, topography, and climate, as well as human actions, such as soil tillage, grazing, urbanization, and dam construction affect the movement of sediment in U.S. streams and rivers. To this end, monitoring of suspended-sediment in streams and rivers has been an integral part of the mission of the U.S. Geological Survey (USGS) for more than a century. The first measurements of streamflow and sediment were collected on the Rio Grande River in 1889 (10 years after the agency was founded) for purposes of reservoir construction and agricultural irrigation projects (Glysson, 1989). The USGS is a charter member of the Federal Interagency Sedimentation Project (FISP), which began in 1939, and worked to standardize sediment data-collection instruments and deployment protocols to ensure consistent, representative measurement of suspended-sediment, bedload, and bed material (Glysson, 1989). The USGS has been delegated the responsibility of water data collection in the United States by the U.S. Department of the Interior and is the primary entity collecting suspended-sediment data at gaged locations across small streams and large rivers throughout the United States. Since the mid-1940s, the USGS has collected the broadest, most consistent national set of suspended-sediment data. As of 2000, 12,115 surface-water sites had been sampled for sediment and streamflow (Turcios and Gray, 2001). At its peak in 1980, the USGS maintained a network of approximately 400 stations with daily information on suspended-sediment concentrations and loads.

Currently (2013), much of the USGS sediment and other water-quality data are collected by state water-science centers conducting cooperative studies in support of decision making by local, state, and federal policy makers. Although this issue-specific approach to sediment monitoring fulfills local information needs, it lacks coordination through a large-scale network design. Thus sediment data need to be summarized across state lines to help answer questions that are broader in scope. Examples of these questions include the following:

- How does sediment transport vary nationally over long (annual and greater) time scales?
- How should sediment data be best collected and interpreted?
- How much sediment was transported in streams and rivers before human development?
- To what degree have human-induced changes to natural landscapes altered sediment transport?
- Have improvements in soil conservation affected downstream sediment transport?
- How has the construction (or removal) of small and large reservoirs affected the movement of sediment, and how will continued sediment deposition affect reservoir capacity, function, and trapping efficiency?

These questions have been difficult to answer, in part because (1) sediment has rarely been a focus of national-level analyses, (2) the collection, processing, and transport of suspended-sediment and sediment-associated constituents differ from dissolved-phase water-quality constituents, and (3) the aggregation and analysis of the large databases needed to answer these questions has been resource intensive. However, increasing recognition of the importance of sediment transport in surface-water quality as well as advances in data-collection, data availability, and computing technologies are making it easier to answer science and management questions that are national in scope.

The USGS National Water Quality Assessment (NAWQA) program was implemented in 1991 to develop long-term consistent and comparable information on surface-water and groundwater systems to support decisions related to water-quality management and policy (Gilliom and others, 1995). During the first (1991–2001) and second (2001–2012) cycles of the NAWQA program, sediment was not considered in national water-quality status and trends assessments because of cost limitations (National Research Council, 2012). However, input from NAWQA stakeholders justified the inclusion of sediment in these assessments during the third cycle (2013–2022). The database described in this report is the first sediment-related product of NAWQA cycle 3, and was compiled to summarize and provide access to a screened, quality-controlled set of USGS sediment and sediment-related data through 2010.

Previous studies have described the availability of sediment data and the occurrence of suspended-sediment in streams and rivers across the U.S. Rainwater (1962) estimated annual discharge-weighted mean suspended-sediment concentrations across the United States The first national-level reconnaissance of USGS daily (U.S. Geological Survey, 1996) and discrete (Turcios and Gray, 2001) suspended- and bed-sediment data were performed through 1996 and 2000 (respectively). This report and database capitalize on improvements in data availability, analysis techniques, and geographic information systems to provide an enhanced understanding of factors affecting sediment transport across space and through time. These enhancements include the following:

- *Ability to contextualize sediment data using site-specific information on streamflow durations and annual exceedance probabilities.* Site-specific information on streamflow durations and annual exceedance (also called "flood-frequency") probabilities enables comparison of suspended-sediment data across sites during similar flow conditions, allowing analysts to better understand how other factors, such as land use, upstream drainage area, slope, and soil characteristics, affect suspended-sediment concentrations and loads. Streamflow duration and annual-exceedance data also can be used to characterize whether suspended-sediment samples have been collected sufficiently across observed streamflow conditions to allow accurate estimation of loads.

- *Ability to summarize data ancillary to suspended-sediment concentration.* Additional information on suspended-sediment grain-size distributions, sampling methods, total suspended-solids concentrations, turbidity, stream velocity, and other data can be used to quality assure available data, better understand sediment transport, and help guide new monitoring efforts.

- *Ability to match sediment data with corresponding streamflow data***.** Many suspended-sediment samples in the existing USGS National Water Information System (NWIS) (U.S. Geological Survey, 2012a) database lack concomitant streamflow information, which are essential data to compute suspended-sediment loads and compare sediment data across sites or through time. Instantaneous streamflow data (collected at hourly or finer time steps) is especially important when computing sediment loads at sites with flashy streamflow conditions often observed in small, urban, or arid basins. Retrieval and matching of daily and instantaneous flows where none were previously present greatly expand the utility of the existing suspended-sediment data within NWIS.

- *Ability to quality control existing sediment data***.** Despite the development of isokinetic samplers and sampling methods through the FISP by the mid-1940s, many sediment samples are still collected incorrectly using non-isokinetic methods. Additionally, some suspended-sediment data reflect obvious errors in sampling (such as biasing concentrations as a result of the sampler gouging bed material), clerical errors in data entry, or computational errors. Removal of obvious data errors and readily observable bias associated with sampling methods will give analysts more confidence in the interpretation of suspended-sediment concentrations and loads.

Improved ability to access and interpret an enhanced, quality-controlled sediment database is an important step to better understanding factors affecting the transport of sediment and sediment-associated constituents in the United States.

Purpose and Scope

The purpose of this report is to describe the compilation of a quality-controlled USGS suspended-sediment database, provide guidance for its use, and summarize characteristics of suspended-sediment data through 2010. This report describes methods used to screen, quality control, and interpret suspended-sediment data obtained from the USGS NWIS database (U.S. Geological Survey, 2012a) and illustrates ways this database can be used to understand factors influencing the occurrence and transport of sediment and sediment-associated constituents through U.S. streams and rivers. The database is provided as an online application (*http://cida.usgs.gov/sediment*) that allows users to view, filter, and retrieve available suspended-sediment and ancillary data. Ancillary information on streamflow condition, sediment grain size, sampling method, and landscape condition are provided to allow users to evaluate data quality, understand the size of sediment in transport, and compare sediment data across sampling sites, flow conditions, or through time. This report should improve the utility and accessibility of USGS sediment data for watershed managers, policy makers, researchers, and the public.

Methods Used to Recover, Screen and Quality Control Sediment Data

The primary problems identified with existing USGS sediment data were that (1) all known data sources were not made available to the public, (2) existing suspended-sediment concentration (SSC) data lacked corresponding information necessary for data interpretation, and (3) existing data may not adequately represent actual stream conditions because of inadequate sample collection or processing. The purpose of the recovery, screening, and quality-control process described herein is to identify, and to the extent possible correct these problems to create a database that facilitates comparison of SSC and ancillary data across sites, through time, and allow accurate computation of suspended-sediment loads. Figure 1 illustrates the number of samples and ancillary data retrieved from the USGS NWIS database and the process of removing or adding data through the screening and quality-control process.

Data Recovery

A data recovery process was performed to retrieve daily-record suspended-sediment data known to be missing from or unavailable in NWIS. Daily-record sediment data are daily mean estimates of suspended-sediment concentration and (or) load, and are computed at sites in which SSC samples are collected approximately daily or more frequently depending on the temporal variability of SSC (Koltun and others, 2006). It is important to note that these daily computations can be

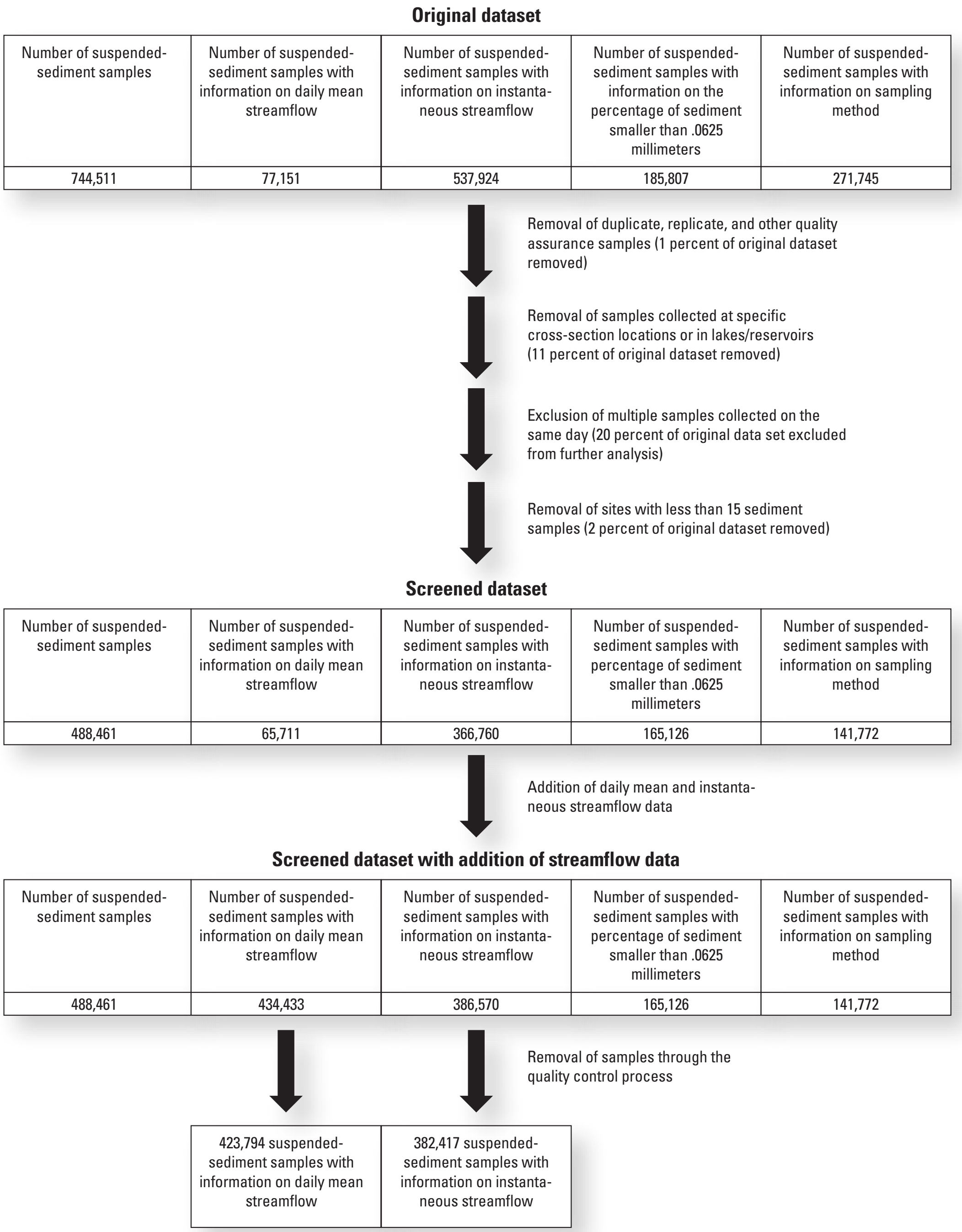


Figure 1. Number of suspended-sediment samples and ancillary data removed or added through the data filtration and quality-control process.

moderately to highly dependent on human interpretation of the relation between streamflow and sediment transport (Koltun and others, 2006). Recovered daily-record data not publically available in NWIS were identified from historical USGS publications and from a USGS daily values database (U.S. Geological Survey, 1996). After these data were identified, a representative from each USGS State-Water Science Center confirmed that their respective missing data were appropriate for publication, and the data were subsequently made available in NWIS. As of 2012, more than 8,977 years of daily suspended-sediment data were recovered and made public at 1,378 daily value stations.

Data Screening

Suspended-sediment data were retrieved from the USGS NWIS database if sampling sites were located at current or historical USGS streamgage sites with at least one sample with information on SSC (USGS parameter code 80154).

These data were then screened (1) to remove samples collected as part of a quality-control process (including blind, replicate, or duplicate samples), (2) to remove data that are part of composite samples collected across stream/river cross-sections, (3) to decrease the potential effect of particular days or flow conditions, and (4) to limit the database to sites with data adequate to compute statistical summaries or sediment loads (fig. 1). Suspended-sediment data associated with a quality-control process were screened by removing samples in which USGS sample types were coded as "Spike", "Blank", "Reference", "Blind", "Duplicate", "Reference material", "Replicate", "Spike solution", or "Other qa", and by removing samples with information on USGS parameter codes 99105 (type of replicate) or 99106 (type of spike). This removed approximately 1 percent of the originally retrieved dataset (fig. 1). Samples were then removed if there was information on the location(s) in the cross-section in which the sample was collected (USGS parameter codes 00001, 00002, 00005, 00009, or 72103). These samples were generally part of samples composited from multiple locations in the stream/river cross-section, and the mean value for the cross-section on the day of sampling was retained. Samples also were removed if they were collected in a lake or reservoir (USGS parameter codes 00049, 00062, or 72025). This step removed approximately 11 percent of the original dataset (fig. 1).

To limit the database to sites with data adequate to compute statistical summaries and compute loads, a qualitative judgment was made to limit the database to sampling sites with at least 15 samples. This step removed approximately 2 percent of the original dataset (fig. 1). To decrease the effect of particular days or storms, multiple samples collected on the same day were screened from further analysis by randomly selecting one sample from that day. Samples were randomly selected to avoid skewing data toward specific times or flow conditions. This step removed approximately 20 percent of the original dataset from further consideration (fig. 1). Although these data are not considered in further analyses, they are retained in the database for researchers interested in sub-daily variability in SSC. Despite the screening process, it is the responsibility of analysts to evaluate whether the SSC data adequately represent conditions at a particular sampling site to compute statistical summaries or suspended-sediment loads.

Retrieval of Sediment-Related Data

Sample Data

Ancillary information related to suspended-sediment transport are also included in the database. These data include information on sample collection method, sediment grain size, total suspended-solids, turbidity, water chemistry, and other data. The current (2013) list of USGS parameter codes, parameter abbreviations, and parameter names included in the database is described in table 1. Additional data may be added in the future.

Streamflow Data

The amount and size of sediment in transport typically vary relative to streamflow condition, and thus quality control and interpretation of suspended-sediment data require concomitant data on the rate of streamflow. However, many samples retrieved from the USGS NWIS database lacked corresponding information on either daily or instantaneous streamflow (fig. 1). Of the original set of SSC samples retrieved from NWIS, 10 percent had corresponding information on daily mean flows (the mean flow during the day of sediment sampling), and 72 percent had information on instantaneous flows (defined as the approximate flow at the time of sediment sampling). To increase the amount of streamflow data associated with SSC samples, continuous daily streamflow data were acquired from NWIS and continuous, instantaneous streamflow data (also referred to as "unit-value" flows) were acquired from the USGS Instantaneous Data Archive (U.S. Geological Survey, 2012b). Daily flow data represent the daily mean streamflow for a particular day, whereas instantaneous flow data represent flow conditions at intervals ranging from minutes to hours.

Daily and instantaneous streamflow data were matched to SSC samples when corresponding flow information was absent. Daily mean streamflow values were assigned to SSC samples if data were present on the date of sample collection. It is important to note that daily mean streamflows can misrepresent actual streamflow conditions at the time of sampling, especially at sampling sites with rapidly changing flow conditions, such as at sites downstream from small, urban, or arid watersheds. However daily mean values are the only continuous streamflow data available before the late 1980s, and thus it is necessary to evaluate relations between SSC and flow conditions before computation of suspended-sediment loads using daily streamflow values. For instantaneous flows, if the sample collection time exactly matched the time in which a flow value was recorded, the instantaneous flow was assigned to that sample. If the time of SSC sample collection was bracketed by instantaneous flows (at every hour or finer time scales) instantaneous flows were assigned to the suspended-sediment sample by linear interpolation. Using these methods, 368,722 additional SSC samples were assigned a daily flow value, 19,810 additional SSC samples were assigned an instantaneous flow value (fig. 1). The addition of corresponding information on continuous daily or instantaneous flows to discrete SSC samples substantially expand the amount of suspended-sediment data that can be analyzed relative to streamflow condition (fig. 1).

Sampling-Site Characteristics

Information on streamflow conditions and upstream basin characteristics of suspended-sediment sampling sites are included in the database to help provide context to SSC and other ancillary data. This information includes nationally

Table 1. List of U.S. Geological Survey parameter codes, abbreviations, and descriptions initially included in the quality-controlled suspended-sediment database.

[nm, nanometers; LED, light-emitting diode]

Parameter code	Parameter description	Parameter code	Parameter description
00028	Agency analyzing sample, code.	70328	Suspended sediment, fall diameter (native water), percent smaller than 0.008 millimeters.
00042	Altitude, feet above mean sea level.	72006	Sampling condition, code.
00060	Discharge, cubic feet per second.	71999	Sample purpose, code.
00065	Gage height, feet.	72005	Sample source, code.
00061	Discharge, instantaneous, cubic feet per second.	82398	Sampling method, code.
00505	Loss on ignition of total solids, water, unfiltered, milligrams per liter.	84171	Sample splitter type, field, code.
00063	Number of sampling points, count.	84164	Sampler type, code.
00403	pH, water, unfiltered, laboratory, standard units.	00095	Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius.
00400	pH, water, unfiltered, field, standard units.	90095	Specific conductance, water, unfiltered, laboratory, microsiemens per centimeter at 25 degrees Celsius.
70343	Suspended sediment, fall diameter (deionized water), percent smaller than 0.125 millimeters.	00530	Suspended solids, water, unfiltered, milligrams per liter.
70332	Suspended sediment, sieve diameter, percent smaller than 0.125 millimeters.	70299	Suspended solids dried at 110 degrees Celsius, water, unfiltered, milligrams per liter.
70340	Suspended sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters.	80154	Suspended sediment concentration, milligrams per liter.
70329	Suspended sediment, fall diameter (native water), percent smaller than 0.016 millimeters.	00540	Suspended solids remaining after ignition, water, unfiltered, milligrams per liter.
70335	Suspended sediment, sieve diameter, percent smaller than 1 millimeters.	00020	Temperature, air, degrees Celsius.
70346	Suspended sediment, fall diameter (deionized water), percent smaller than 1 millimeter.	00010	Temperature, water, degrees Celsius.
70344	Suspended sediment, fall diameter (deionized water), percent smaller than 0.25 millimeters.	00500	Total solids dried at 105 degrees Celsius, water, unfiltered, milligrams per liter.
70333	Suspended sediment, sieve diameter, percent smaller than 0.25 millimeters.	80180	Total sediment concentration, milligrams per liter.
70337	Suspended sediment, fall diameter (deionized water), percent smaller than 0.002 millimeters.	01350	Turbidity, severity, code.
70326	Suspended sediment, fall diameter (native water), percent smaller than 0.002 millimeters.	61028	Turbidity, water, unfiltered, field, nephelometric turbidity units.
70336	Suspended sediment, sieve diameter, percent smaller than 2 millimeters.	63675	Turbidity, water, unfiltered, broad band light source (400-680 nm), detection angle 90 +/- 30 degrees to incident light, nephelometric turbidity units (NTU).
70347	Suspended sediment, fall diameter (deionized water), percent smaller than 2 millimeters.	63676	Turbidity, water, unfiltered, broad band light source (400-680 nm), detectors at multiple angles including 90 +/- 30 degrees, ratiometric correction, NTRU.
70341	Suspended sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters.	63680	Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +/ -2.5 degrees, formazin nephelometric units (FNU).
70330	Suspended sediment, fall diameter (native water), percent smaller than 0.031 millimeters.	00070	Turbidity, water, unfiltered, Jackson Turbidity Units.
70338	Suspended sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters.	00075	Turbidity, water, unfiltered, Hellige turbidimeter, milligrams per liter as silicon dioxide.
70327	Suspended sediment, fall diameter (native water), percent smaller than 0.004 millimeters.	00076	Turbidity, water, unfiltered, nephelometric turbidity units.

Table 1. List of U.S. Geological Survey parameter codes, abbreviations, and descriptions initially included in the quality-controlled suspended-sediment database.—Continued

[nm, nanometers; LED, light-emitting diode]

Parameter code	Parameter description	Parameter code	Parameter description
70345	Suspended sediment, fall diameter (deionized water), percent smaller than 0.5 millimeters.	99872	Turbidity, water, unfiltered, laboratory, Hach 2100AN, nephelometric turbidity units.
70334	Suspended sediment, sieve diameter, percent smaller than 0.5 millimeters.	00055	Stream velocity, feet per second.
70342	Suspended sediment, fall diameter (deionized water), percent smaller than 0.0625 millimeters.	81904	Velocity at point in stream, feet per second.
70331	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters.	04119	Verticals in composite sample, number.
70339	Suspended sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters.	50280	Site visit purpose, code.
		00004	Stream width, feet.

available data on streamflow statistics from the USGS StreamStats database (U.S. Geological Survey, 2012c), streamflow statistics from individual state stream statistic programs (Jian, Xiaodong, USGS, written commun., 2011), and selected information on basin characteristics included in the GAGES II database (Falcone, 2011). Data obtained from national and state-by-state stream statistics databases include daily streamflow duration estimates (streamflow values exceeded 1, 5, 10, 25, 50, 75, 90 and 99 percent of the time) and estimates on the frequency in which instantaneous peak streamflow values are exceeded (streamflow values with annual exceedance probabilities of 2, 5, and 10 years). Climate and landscape characteristics of basins upstream from SSC sampling sites have been published by various sources and have been aggregated in the GAGES II database (Falcone, 2011). These data include information relevant to streamflow and sediment transport, including mean precipitation conditions, land use, soil characteristics, population, geology, dams, topography, and characterization of reference sites (Falcone, 2011).

Station-by-Station Quality-Control Process

USGS studies have identified the possibility of biasing suspended-sediment data through improper sample collection (Guy and Norman, 1970; Edwards and Glysson, 1999; Topping and others, 2011) or sample processing (Capel and Larson, 1995; Horowitz and others, 2001) methods. These biases are more likely with increasing concentrations of sand and larger-sized material, which tend to be less-equally mixed within the stream cross-section than silt and clay-sized material. The USGS NWIS database stores information on sample collection and processing methods needed to characterize the representativeness of sediment and sediment-associated data. However, this information was not recorded electronically before to the 1980s, and has not always been recorded since (fig. 2). Nonetheless, a quality-control process was performed that utilizes available data on sample collection methods, SSC, streamflow conditions, and sediment grain size. Sample processing methods were not evaluated because there is relatively little information (4,969 samples, 1.1 percent of samples screened from NWIS), and because potential biases are only associated with churn-splitting methods at relatively high SSC values (between 1,000 to 10,000 milligrams per liter) with substantial sand (Capel and Larson, 1995; U.S. Geological Survey, 1997; Horowitz and others, 2001).

To better understand the potential for bias in SSC data because of variation in sampling methods, the relative use of different USGS sample collection methods was quantified within the screened database (fig. 3). Information on sample collection methods was available for 141,772 samples, 29 percent of all samples from the screened SSC database. Among samples collected using unknown sampling methods, it is known that isokinetic samplers were not available for use before 1943. Equal-width and equal-discharge increment samples, which are composited from samples collected using isokinetic methods at equally-spaced increments of area (equal-width) or discharge (equal-discharge) across the stream cross section, are the most representative means for collecting suspended-sediment samples to represent a stream cross-section (Edwards and Glysson, 1999; Nolan and others, 2005), and comprise 50 percent of known sample collection methods (fig. 3). Samples collected by multiple and single verticals (13 and 6.3 percent of known sample collection, respectively, fig. 3) are likely the next best representative, as they are generally collected using isokinetic sampling methods, but may not accurately represent mean concentrations across the width of

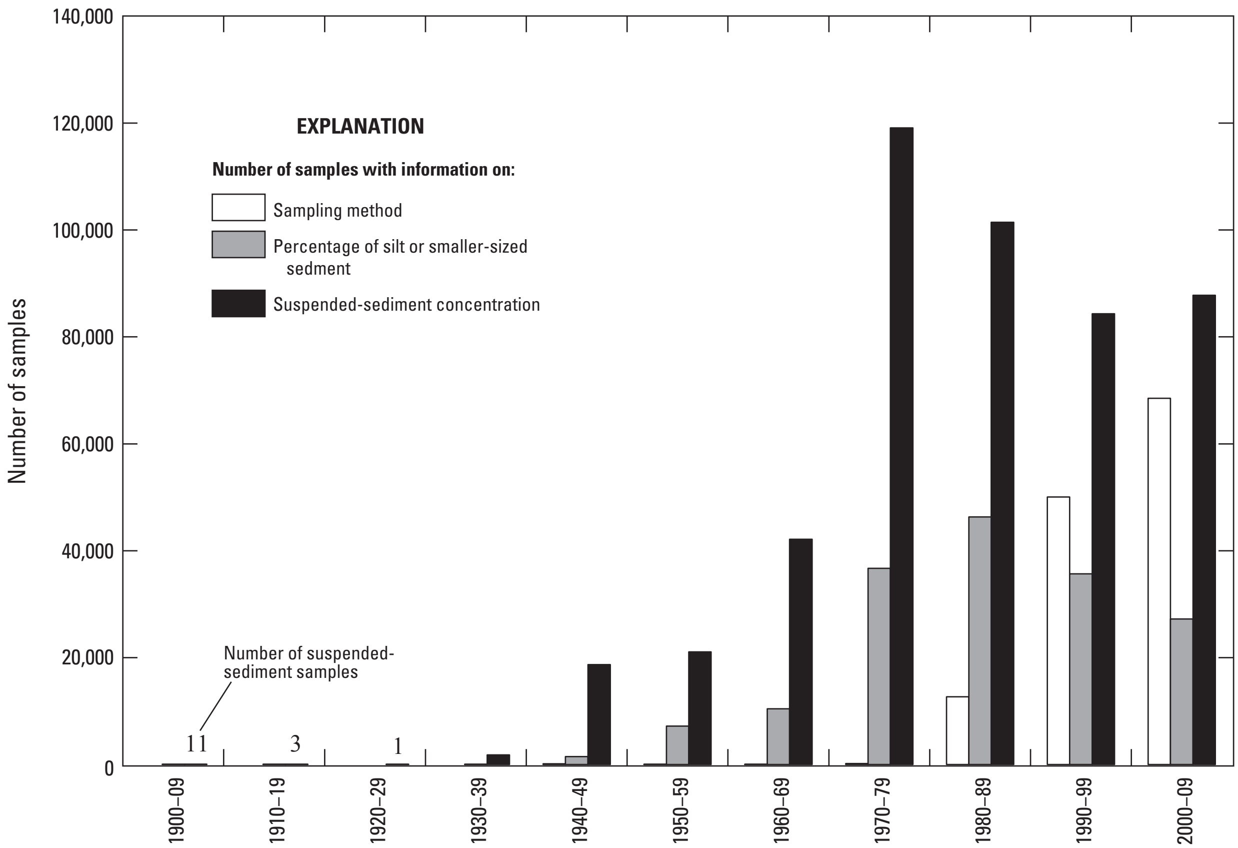


Figure 2. Number of suspended-sediment samples with ancillary information on sampling method and the percentage of silt or smaller-sized sediment in the screened sediment database, 1901–2009.

the stream. Point samples (19 percent of known sample collection methods, fig. 3) are likely the next-best representative, as they may be collected using isokinetic sampling methods, but do not attempt to represent either the depth of width of the stream (U.S. Geological Survey, 2006). Dip and pumped samples (6.3 and 4.3 percent of known sample collection respectively, fig. 3) have the most potential for bias, as they are collected non-isokinetically at a single point in the stream. Because one-half of SSC data with information on sample collection methods were collected using potentially less-than representative protocols, a quality-control process was developed to evaluate the potential for bias before computing loads or evaluating trends.

Because many samples lack information on collection methods and because all possible sources of bias could not be investigated, it is the responsibility of users of this database to further investigate potential sources of bias in SSC data, especially when evaluating potential trends. Bias may be further investigated by looking up historical sample collection methods in older reports (such as USGS Water-Supply Papers), contacting USGS Water Science Centers that collected the data, or by characterizing the magnitude of possible biases relative to observed differences in sediment transport (as done in Meade and Moody, 2010). As previously described, biases related to sample collection methods are most likely when substantial sand or larger-sized material is in transport. Despite potential biases, this database represents the best available compendium of discrete suspended-sediment data in the United States. Interpretations of SSC across space and through time using this database can provide valuable information regarding the natural and human factors affecting the movement of sediment in U.S. streams and rivers.

The quality-control process was performed through the use of an interactive graphing tool (Urbanek and Theus, 2003; *http://www.rosuda.org/iplots/*), which allowed SSC data to be selected and visualized as a function of daily and instantaneous streamflow condition (USGS parameter codes 00060 and 00061 respectively), sampling method (USGS parameter code 82398), the percentage of silt and smaller-sized sediment in transport (USGS parameter codes 70331 and 70342), and the year of sampling (figs. 4–7). Figure 4 illustrates an example of the four graphs used to quality control suspended-sediment data. Figure 4*A* illustrates the relation between the natural log of SSC and the natural log of daily streamflow at the USGS streamgage at the Fox River at Dayton, Illinois. Figure 4*B* indicates the number of samples collected using the different methods of sampling employed at this site. The codes corresponding to the various methods of sample

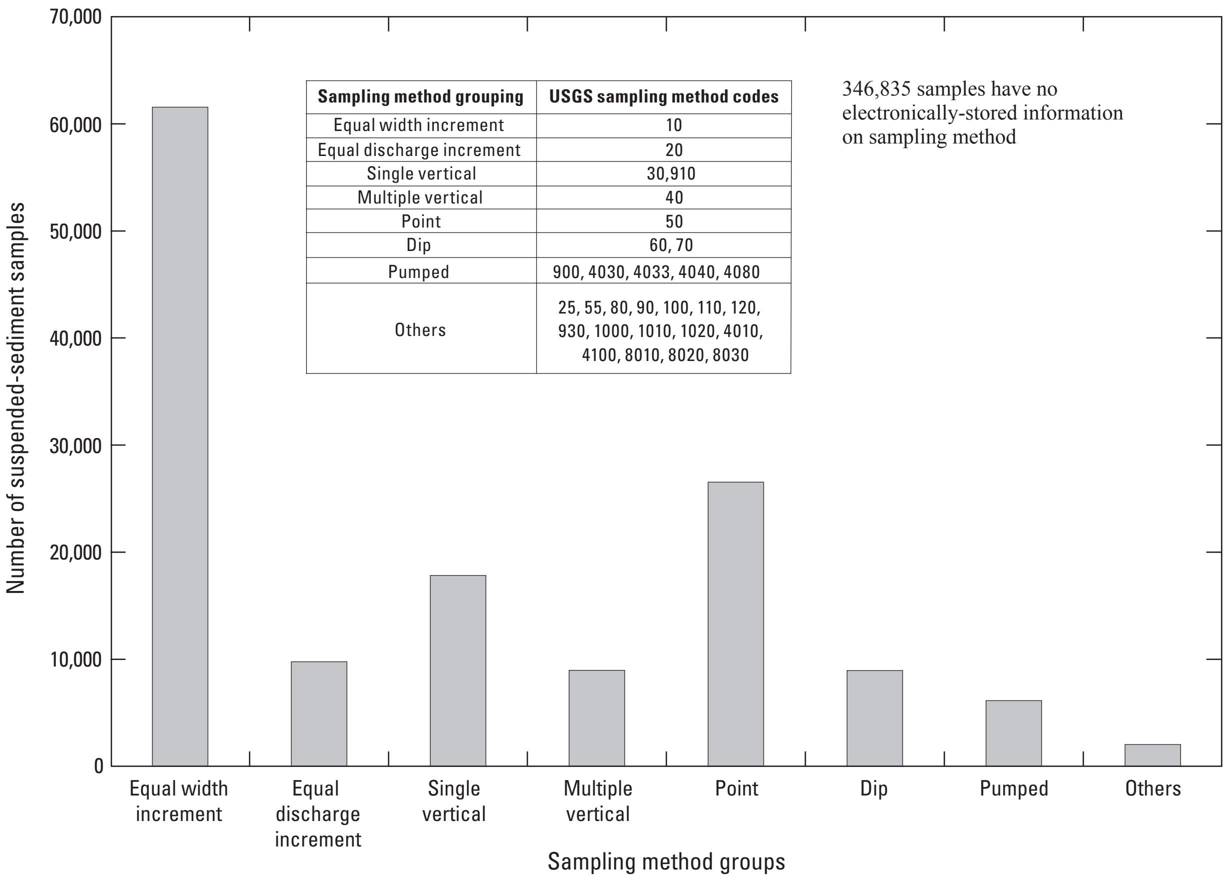


Figure 3. Number of suspended-sediment samples collected by different U.S. Geological Survey (USGS) sample.

collection are listed in figure 3 and at *http://waterdata.usgs.gov/usa/nwis/qwdata?codes_table26_help#82398*. Figure 4*C* shows the number of samples with various percentages of silt and smaller-sized sediments. These data are a combination of values from USGS parameter codes 70331 and 70342. Figure 4*D* shows the number of samples by year.

In the example shown in figure 4, all sample values associated with a pumping mechanism (likely an automated sampler, USGS sampling code 900) are highlighted in red on each of the four plots. Because most samples retrieved from NWIS were collected by unknown sample collection methods (fig. 3), and because site-specific conditions not evident in figure 4 may affect the relation between SSC and streamflow condition, the quality control process performed is only a “best guess” regarding potential biases in the screened dataset. In this example, with few exceptions, known pumped samples collected from 2006 through 2009 had higher SSC values across all streamflow conditions, including samples collected using other methods during the same time period (not illustrated in fig. 4). Samples collected through unknown methods from 1987 through 1993 also fit the same distribution as equal-width increment, equal-discharge increment, and multiple vertical samples collected from 2006 to 2009. Thus in this situation, SSC samples known to be obtained by a pumped sampler were removed from further consideration to eliminate the possibility of biasing SSC data high. In general, SSC data were removed when a particular sampling method (other than equal-width or equal-discharge increment methods) resulted in samples being biased high or low relative to samples obtained by methods that more accurately represent mean cross-sectional SSC across observed streamflow conditions.

Samples collected non-isokinetically or by methods that do not account for possible variation in SSC values across the width and depth of the stream were evaluated relative to more representative methods whenever possible. However, samples were retained if there were no obvious differences among more and less representative methods or if observed differences among methods could be attributed to changes in SSC through time. Figures 5 and 6 show an example at the USGS streamgage at Arcade Creek near Del Paso Heights, California, in which samples collected through non-isokinetic methods were retained. At this site, 9 dip samples collected from 2004 to 2008 were retained (fig. 5) because they were similar to 25 SSC samples collected using equal-width increment methods from 2001 to 2004 (fig. 6). Samples collected by unknown sampling methods generally were not identified as biased because they could have been collected by a variety of methods, but also because they were typically collected

[D90, natural log of the daily streamflow value exceeded 90 percent of the time; D50, natural log of the daily streamflow value exceeded 50 percent of the time; D10, natural log of the daily streamflow value exceeded 10 percent of the time; D5, natural log of the daily streamflow value exceeded 5 percent of the time; D1, natural log of the daily streamflow value exceeded 1 percent of the time; PK2, natural log the instantaneous streamflow value exceeded once every 2 years; PK5, natural log the instantaneous streamflow value exceeded once every 5 years; PK10, natural log the instantaneous streamflow value exceeded once every 10 years; N/A, unknown sample collection method, Station ID, station identifier]

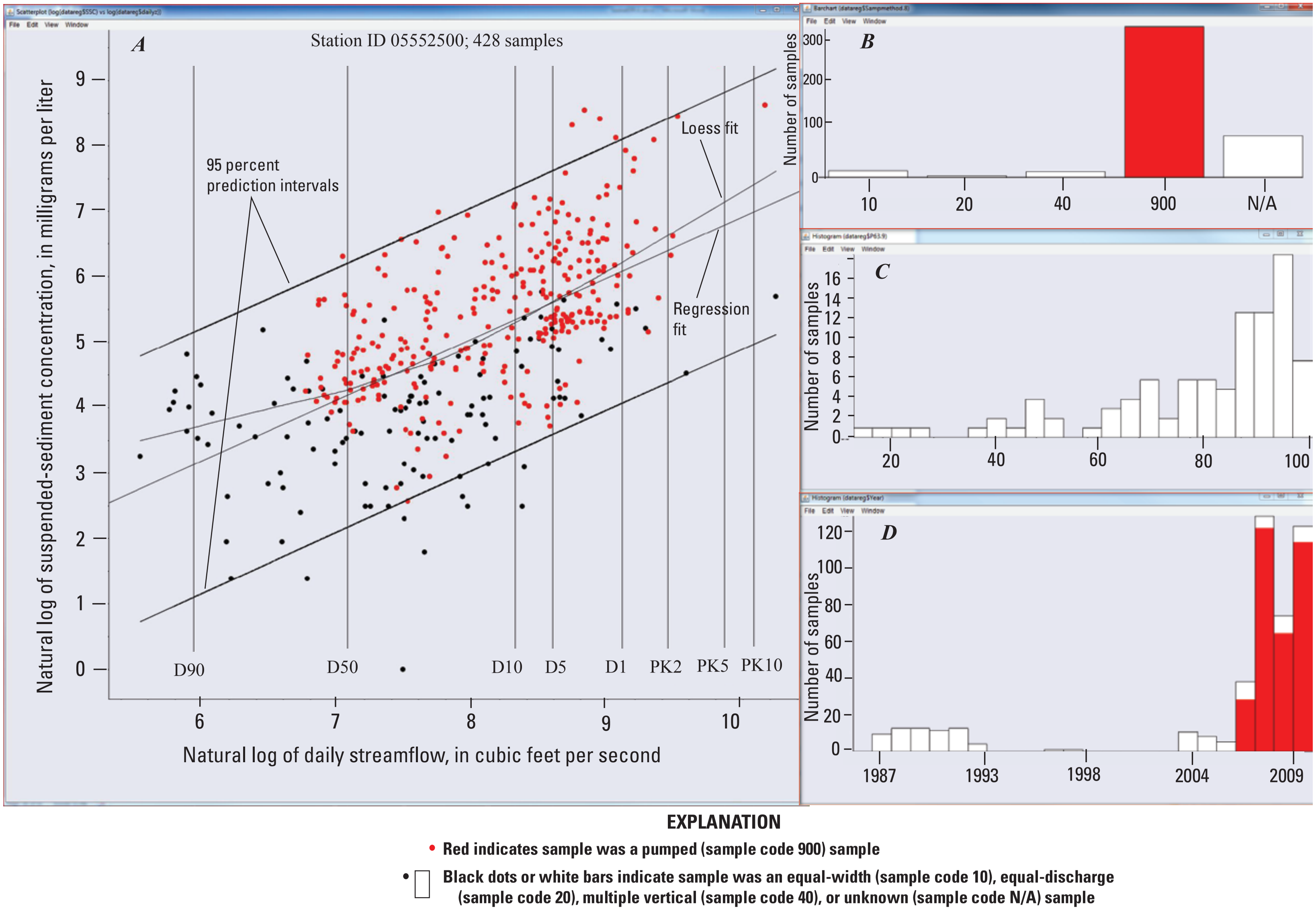


Figure 4. Quality control of suspended-sediment samples at the Fox River at Dayton, Illinois, 1987–2009 relative to *A*, daily streamflow condition, *B*, sampling method, *C*, the percentage of silt and clay, and *D*, year of sampling.

before the 1980s, when there were no samples collected by known sampling methods with which to evaluate potential bias. Because screening for potential sampling bias could not be performed before the 1980s without time consuming review of paper records maintained at USGS Water Science Centers, further investigation is required when interpreting these data, especially when evaluating trends.

Outlying values also were identified and removed when either streamflow or SSC values were deemed unreasonable with respect to other data collected at a particular sampling site. Although not necessarily incorrect, spurious data usually share the attribute of containing excessively large SSC values and (or) uncharacteristically large percentages of sand and larger-sized material. Adulterated samples often result from gouging the sampler nozzle in the streambed, resulting in the inclusion of an additional mass of bed material, which increases the resulting SSC value. When samples are shipped, sample water may inadvertently eject from the sample because of problems such as poor bottle cap seal or atmospheric pressure differential (if samples shipped by airplane)—discharging relatively clean water given that most sediments have settled to the bottom of the sample. These are a few common mechanisms that might conspire to remove sediment from the water-sediment mixture and result in a spuriously low concentration (J. Gray, USGS, written commun., 2012).

As an example of outlying data removal, a SSC sample of 35,200 mg/L is highlighted at 1.2 cubic feet per second at Dry Creek at Greybull, Wyoming (fig. 7). Although information on the sand/silt content of this sample was unavailable, it was nonetheless identified as erroneous because it was approximately 14,000 mg/L larger than any other value obtained from this site, more than 30,000 mg/L higher than values from samples collected at similar streamflow conditions.

After the completion of the data screening and quality-control process, 4,316 of the 4,352 sites (4,136 sites with daily flows, 4,028 sites with instantaneous flows) still had 15 or more SSC samples associated either with daily or instantaneous flows. Data from 514 sites (11.9 percent) were removed from further consideration through the quality-control process either because of potential bias or identification of outlying data. A total of 10,639 SSC samples associated with daily streamflows were removed (2.5 percent), and 4,153 SSC samples associated with instantaneous streamflows were removed (1.1 percent). All maps and analyses of data provided herein are based on data which passed the quality-control screening process.

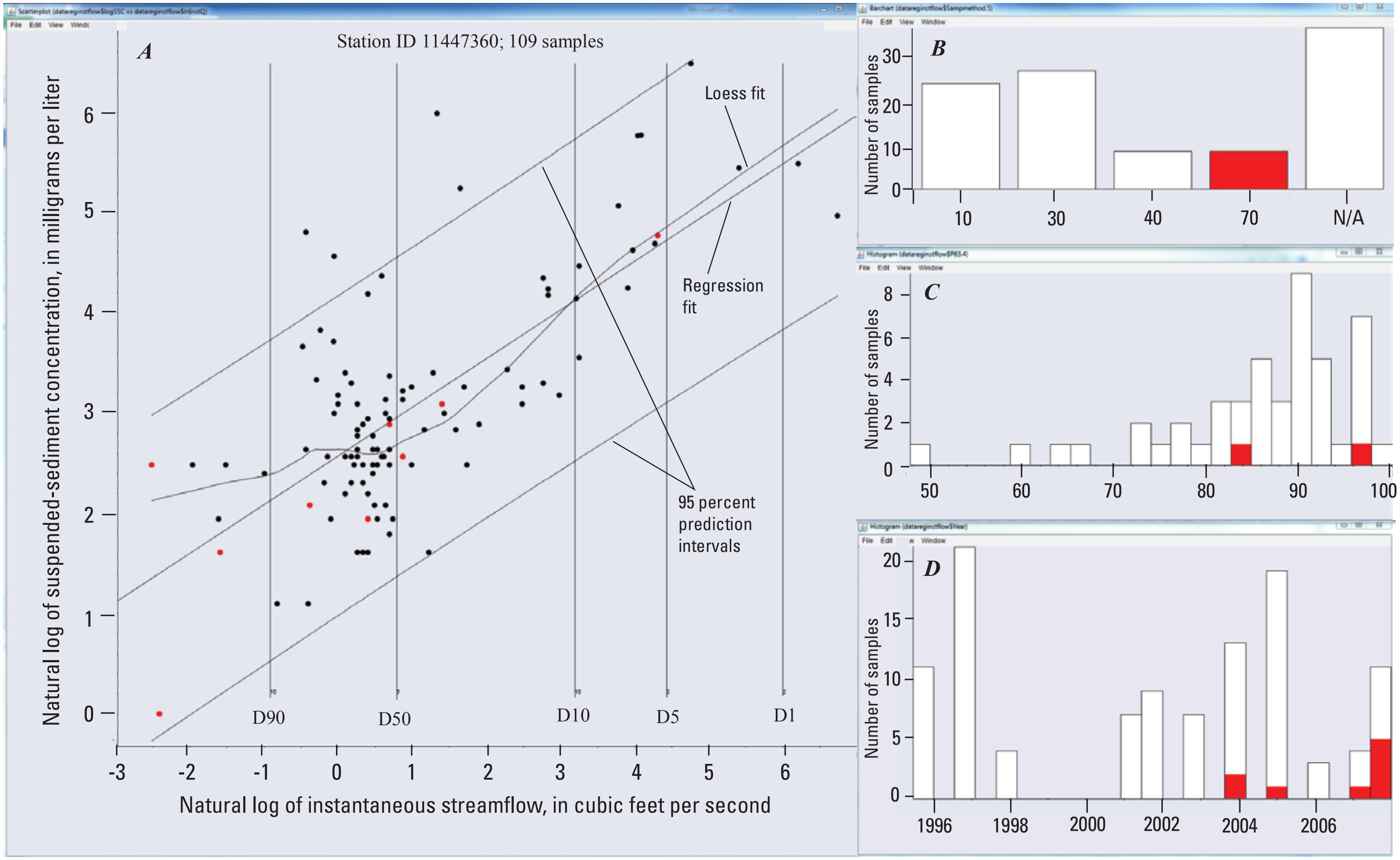
The final, quality-controlled database is hosted as an interactive web application at *http://cida.usgs.gov/sediment.* Because the details of how data will be provided are subject to change, the purpose of this report is limited to describing the creation of the database, providing guidance to its use, and summarizing characteristics of suspended-sediment data through 2010. Directions for viewing, analysis, and retrieval of this dataset are provided through the web application. The database may be periodically updated to reflect new sample collection and updates to ancillary data.

Suspended-Sediment Data Across the United States

Information on the availability of suspended-sediment data across space and through time are needed to guide data-mining efforts and new studies that improve the understanding of factors affecting the movement of sediment in surface waters. As previously shown, the number of discrete SSC samples collected by the USGS by decade declined by approximately 30 percent from the 1970s to the 1990s, slightly increasing during the 2000s (fig. 2). The majority of these samples (80–94 percent by decade) include information on daily or instantaneous streamflow conditions either from NWIS or through this effort (fig. 1). The number of SSC samples with information on the percentage of sand/silt increased from the 1930s to 46 percent of samples by the 1980s, subsequently decreasing to 31 percent of samples during the 2000s. Information on sampling methods used to collect suspended-sediment data is available for 29 percent of all screened samples, including 78 percent of samples collected in the 2000s (fig. 2). Continued improvements in sample documentation can improve the confidence with which future analysts characterize spatial and temporal patterns in the occurrence of sediment and sediment-associated constituents.

Documentation of potential changes in SSC through time (while accounting for differences across flow condition), or in response to environmental change necessitate data collection across decades. To better quantify the ability to document trends with existing data, daily-record SSC, daily record turbidity, and discrete sampling sites with at least 10 SSC samples are summarized by decade. The number of stations with at least 10 discrete SSC samples per decade declined by approximately 40 percent between the 1970s and 2000s, whereas the median number of daily-record sediment stations declined by approximately 60 percent from the 1970s to 2000s (fig. 8). Although the number of daily-record sediment sites declined, the number of continuous turbidity sites increased from the 1990s to a median of 57 sites during the 2000s (a maximum of 139 turbidity sites were identified in 2010). Continuous turbidity data can be used to compute suspended-sediment concentrations and loads at daily and finer time steps when paired with discrete SSC sample collection (Rasmussen and others, 2009). Because data from many continuously-operated turbidity sites have not been used to compute daily mean values, figure 8 likely underestimates the actual number of turbidity sites potentially available to compute suspended-sediment concentration or load. Additionally, a growing number of sites are equipped with in-situ acoustic Doppler sensors (U.S. Geological Survey, 2012a), which can be used to compute SSC and load, but the extent and number of these sites is unknown. Thus, although the increasing prevalence of continuous turbidity and acoustic sites may, in part, make up for the loss of daily-record sediment sites since the 1970s, decreasing long-term discrete SSC sampling sites may make

[D90, natural log of the daily streamflow value exceeded 90 percent of the time; D50, natural log of the daily streamflow value exceeded 50 percent of the time; D10, natural log of the daily streamflow value exceeded 10 percent of the time; D5, natural log of the daily streamflow value exceeded 5 percent of the time; D1, natural log of the daily streamflow value exceeded 1 percent of the time; PK2, natural log the instantaneous streamflow value exceeded once every 2 years; PK5, natural log the instantaneous streamflow value exceeded once every 5 years; PK10, natural log the instantaneous streamflow value exceeded once every 10 years; N/A, unknown sample collection method, Station ID, station identifier]



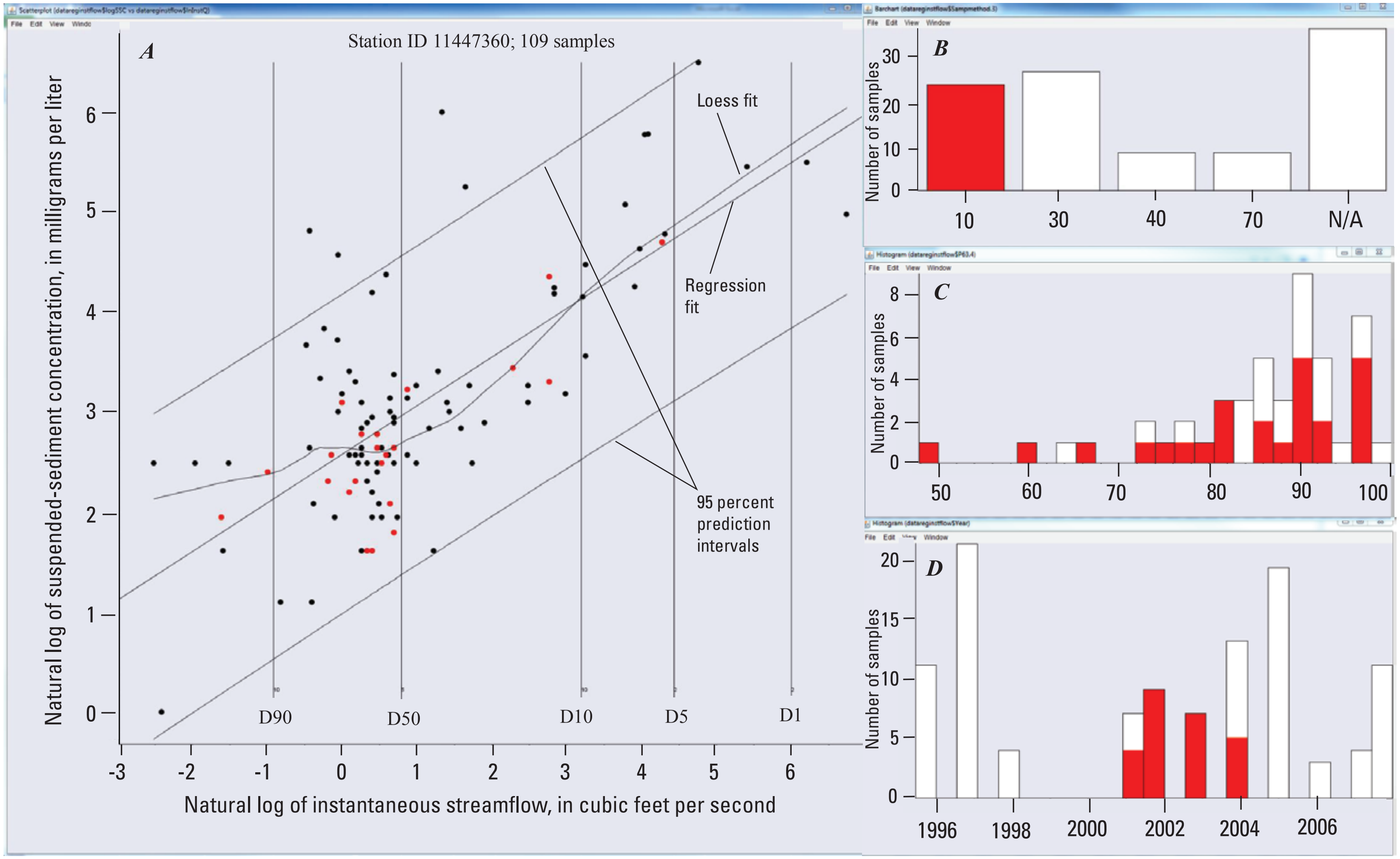
EXPLANATION

Red indicates samples was a dip (sample code 70) sample

Black dots or white bars indicate sample was an equal-width (sample code 10) single vertical (sample code 30), multiple vertical (sample code 40), or unknown (sample code N/A) sample

Figure 5. Quality control of suspended-sediment samples collected by dip sampling at Arcade Creek near Del Paso Heights, California, 1996–2008 relative to *A*, instantaneous streamflow condition, *B*, sampling method, *C*, the percentage of silt and clay, and *D*, year of sampling.

[D90, natural log of the daily streamflow value exceeded 90 percent of the time; D50, natural log of the daily streamflow value exceeded 50 percent of the time; D10, natural log of the daily streamflow value exceeded 10 percent of the time; D5, natural log of the daily streamflow value exceeded 5 percent of the time; D1, natural log of the daily streamflow value exceeded 1 percent of the time; PK2, natural log the instantaneous streamflow value exceeded once every 2 years; PK5, natural log the instantaneous streamflow value exceeded once every 5 years; PK10, natural log the instantaneous streamflow value exceeded once every 10 years; N/A, unknown sample collection method, Station ID, station identifier]



EXPLANATION

- **Red indicates sample was an equal-width increment (sample code 10) sample**
- **Black dots or white bars indicate sample was a single vertical (sample code 30), multiple vertical (sample code 40), dip sample (sample code 70) or unknown (sample code N/A) sample**

Figure 6. Quality control of suspended-sediment samples collected by equal-width increment sampling at Arcade Creek near Del Paso Heights, California, 1996–2008 relative to *A*, instantaneous streamflow condition, *B*, sampling method, *C*, the percentage of silt and clay, and *D*, year of sampling.

[D90, natural log of the daily streamflow value exceeded 90 percent of the time; D50, natural log of the daily streamflow value exceeded 50 percent of the time; D10, natural log of the daily streamflow value exceeded 10 percent of the time; D5, natural log of the daily streamflow value exceeded 5 percent of the time; D1, natural log of the daily streamflow value exceeded 1 percent of the time; PK2, natural log the instantaneous streamflow value exceeded once every 2 years; PK5, natural log the instantaneous streamflow value exceeded once every 5 years; PK10, natural log the instantaneous streamflow value exceeded once every 10 years; N/A, unknown sample collection method, Station ID, station identifier]

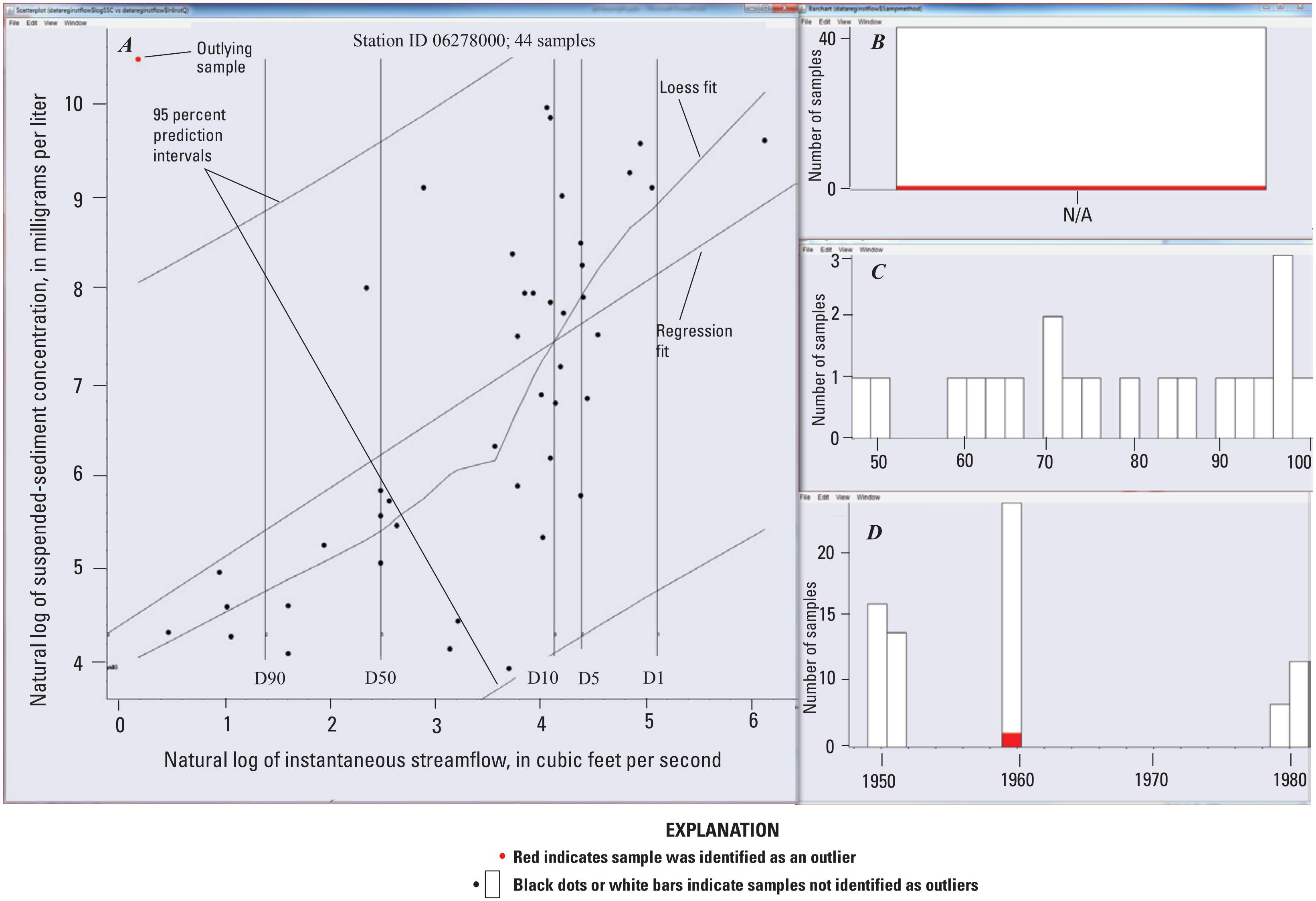


Figure 7. Quality-control process and identification of outlying data associated with pumped samples at Dry Creek at Greybull, Wyoming, 1950–1980 relative to *A*, instantaneous streamflow condition, *B*, sampling method, *C*, the percentage of silt and clay, and *D*, year of sampling.

it more difficult to identify changes in sediment transport through more recent decades.

Sediment size affects how sediment and sediment-associated constituents move through streams and rivers (Walling and Moorehead, 1989; Horowitz, 1991). In addition to previously shown reductions in the collection of data on sand-silt composition (fig. 2), collection of information on other sediment-size classes also has decreased since the 1970s (fig. 9). Approximately one-third of samples with information on the percentage of sediment finer than 63 microns were analyzed for at least one additional size fraction in the 1970s, decreasing to 7 percent of samples in the 2000s. Declines in sediment-size information will make it more difficult to quality-control SSC data and to characterize the transport of sediment and sediment-associated constituents through stream and river networks.

The number and areal distribution of sediment-sampling sites also has changed through time. The location of sediment sampling sites and number of sediment samples by decade starting in the 1930s is shown in figure 10. Sampling sites in the database underrepresent actual USGS data collected by an unknown degree, especially before the use of electronic data storage. For example, the USGS administered a sediment project on the Boise River in the 1930s (Love and Benedict, 1948) but the data produced by this project are not currently (2013) contained within NWIS. Maps of SSC sampling sites by decade from the 1930s reflect increasing sediment-sample collection to the 1970s, and a subsequent decrease through the 2000s (previous decades are not shown because there are few SSC data electronically available before the 1930s). Data collected from the 1930s through the 1960s are largely reflective of irrigation and reservoir building projects (Glysson, 1989). During the 1970s and into the 1980s, implementation of the USGS coal hydrology program substantially increased the number of sediment sampling sites and number of sediment samples (Glysson, 1989). Continued sample collection during the 1990s and 2000s reflect USGS Water Science Center cooperative projects and inclusion of suspended-sediment analysis as part of broader water-quality sampling studies conducted by programs such as NAWQA and the National Stream Quality Accounting Network (NASQAN; U.S. Geological Survey, 2013).

Suspended-sediment data need to be collected across flow conditions for long time periods to identify potential trends in suspended-sediment transport in relation to changes on the landscape (Parker and Osterkamp, 1995). Figure 11 illustrates discrete sampling sites across the United States through 2010, color coded by the number of unique years in which a SSC sample was collected, while figure 12 shows daily-record sediment data collected between 1901 and 2010 color coded by the number of years of data in NWIS. Figure 11 indicates that discrete data have been collected throughout the United States and that many sites (1,595 of 4,352) have had SSC samples collected during 10 or more years. There are also selected sites in the south-central and southwestern U.S. with more than 50 years of SSC sampling. Although there are several long-term daily-record sites, most (1,328 of 1,698) sites across the United States have been active for less than 10 years. Thus, although there are opportunities to evaluate historical trends in sediment transport, especially using discrete SSC data, there also is substantial potential to evaluate trends by reestablishing SSC sampling at historical sites. This is especially true when considering improvements in the certainty of hourly, daily, seasonal, or annual estimates of SSC and sediment flux obtained by newer, surrogate-based estimates of SSC and sediment flux (Lee and Foster, 2013) Increased temporal density of these data can allow improved identification of potential trends in sediment transport when compared to historic SSC samples.

Suspended-sediment and ancillary data also are summarized across space and flow condition. Median SSC as a function of daily streamflow condition across the United States is shown in figure 13. Maps show that median SSC values generally increase with higher streamflow conditions (which are exceeded less frequently; fig. 13). SSC values are generally higher during all flow conditions in streams and rivers in the central plains and in western Colorado, New Mexico, Wyoming, eastern Utah and Arizona than in the rest of the United States. The lowest SSC values, especially during high-flow conditions are on the south-eastern coastal plain, Florida, and east-coast of New England.

The predominant size of sediment in suspension affects how sediments move through streams and rivers and the manner in which sediments can be sampled or monitored. Changes to natural sediment size composition also can degrade aquatic habitat (Waters, 1995; Cech and Doroshov, 2004; Gelfenbaum and others, 2009). Across all samples (irrespective of flow condition), silt and smaller-sized sediments comprise the bulk of sediments in suspension across most sites in the United States (fig. 14). Ninety-three percent of sites have greater than 50 percent of silt and clay sediment in suspension, 71 percent of sites have 75 percent or more silt/clay material, and 39 percent of sites have more than 90 percent silt/clay when considering median values. The percentage of silt/clay in transport does not change consistently relative to streamflow conditions across the United States (fig. 15). This is consistent with observations by Walling and Moorehead (1989), who observed that although the sediment size may be observed to consistently change across streamflow condition at a particular sampling site, these changes often do not hold true among many sampling sites. Despite the predominance of fine-sediments in the United States, there are specific parts of the country in which sand or larger-sized material is a substantial portion of sediment in suspension regardless of flow condition. These regions include the much of Alaska, the Sand Hills in Nebraska, most of Florida, parts of the Appalachian Mountains, and parts of the mountainous regions in the western third of the United States.

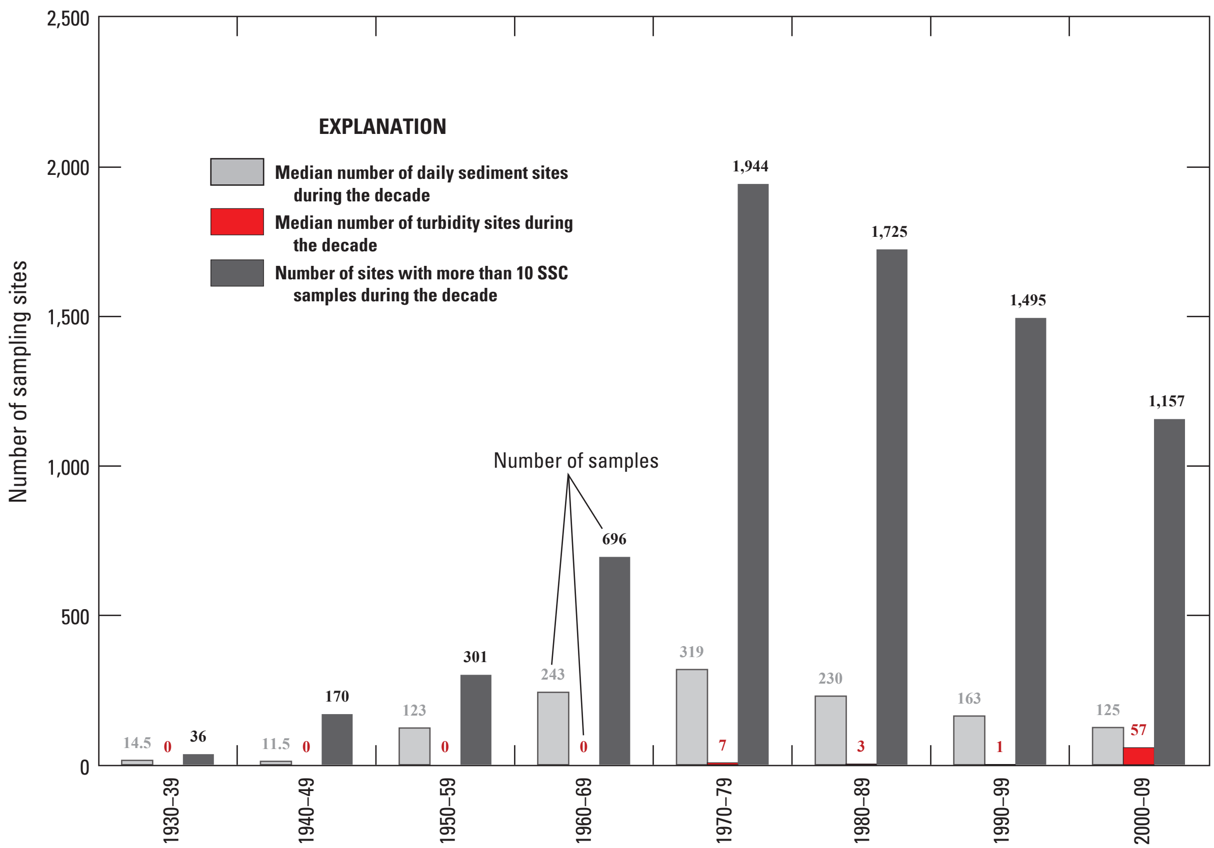


Figure 8. Number of sampling sites with at least 10 suspended-sediment samples, daily turbidity data, and daily suspended-sediment concentration record by decade from 1930 to 2009.

Examples of National and Regional Applications

This database and report are designed to improve the utility and accessibility of USGS sediment data to watershed managers, policy-makers, researchers, and the public. This section provides examples of how this database can be used to characterize factors affecting suspended-sediment concentrations in streams, establish new data collection programs, identify potential trends in sediment transport, and determine appropriate sediment sampling and monitoring techniques.

Interpretation of Sediment Data Among Sites and Across Streamflow Conditions

Because the erosion and transport of sediment is a natural process affected by anthropogenic changes on the landscape, and because monitoring programs have been implemented after much of the initial landscape development in the United States (Broussard and Turner, 2009), it is often difficult to quantify sediment-related impairments or to set targets for potential improvement. The most current (2010) location of sediment and turbidity-related impairments, as identified by States and Tribes through the Clean Water Act, primarily differ across political boundaries (U.S. Environmental Protection Agency, 2012b; fig. 16). This database makes USGS sediment data more widely available and easier to interpret by allowing users to filter and evaluate data across landscape condition, basin size, and streamflow condition (among other factors); improving the ability to compare historical or newly collected SSC data across similar watersheds. The following is an example in which this database was used to characterize if and how SSC varied across agricultural lands in small basins in Kansas.

Thirty USGS hydrologic benchmark network (HBN) sites are contained within the screened, discrete SSC dataset (fig. 17). The HBN was initiated in 1963 with a mission to establish a long-term database of sites that track changes in the flow and quality of undisturbed streams and rivers, and to serve as a reference for discerning natural variation from human-induced changes in streams and rivers (Murdoch and others, 2005).

To characterize how landscape development may have affected suspended-sediment transport in Kansas, sites similar to the HBN site in Kansas in terms of upstream basin size, geographic location, and soils (USGS streamgage at Kings Creek near Manhattan, Kansas, fig. 17) were identified. In this example, sites similar to the Kings Creek sampling site (Kings

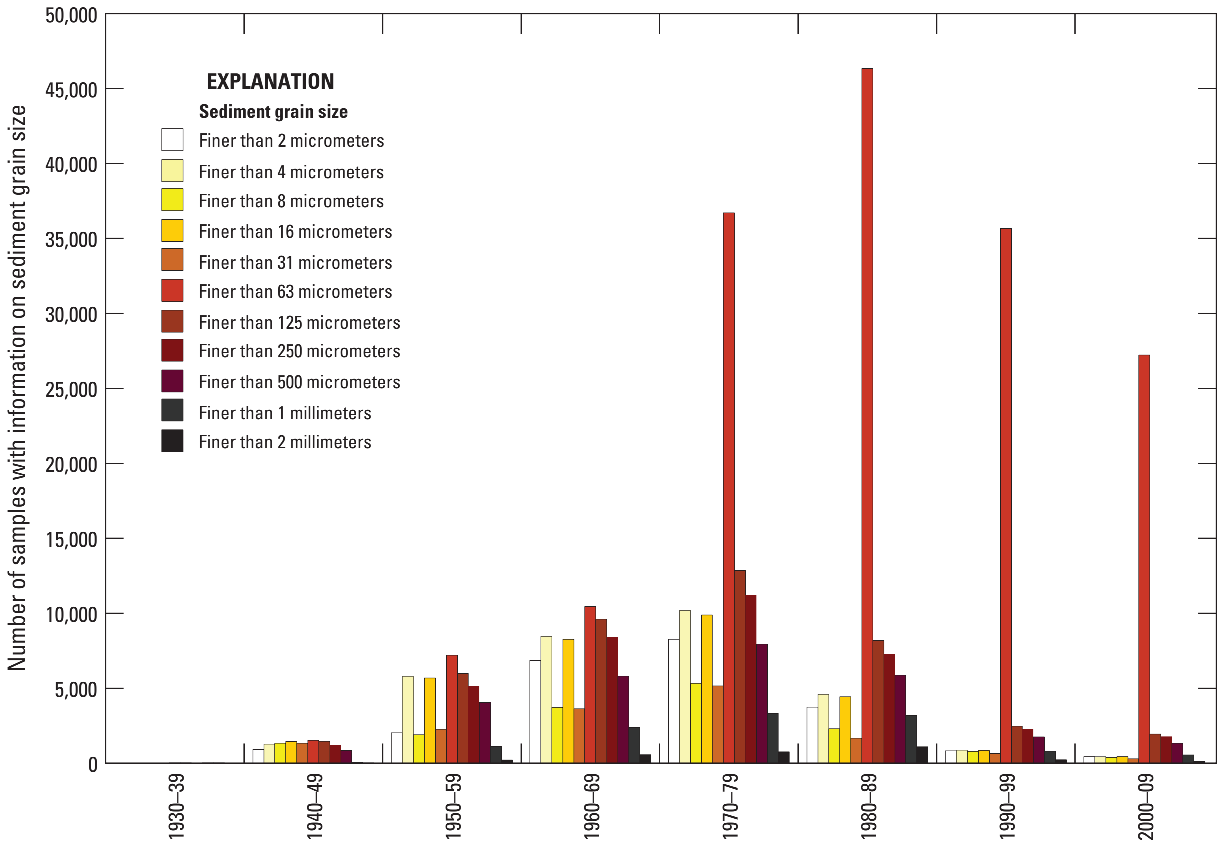


Figure 9. Number of samples with information on sediment grain size by decade from 1930 to 2009.

Creek) were identified if they (1) were within a 100-mile radius of the Kings Creek, (2) had upstream drainage areas within 20 square miles of that of the Kings Creek, (3) were within 15 percent of the Revised Universal Soil Loss Equation's (RUSLE; U.S. Department of Agriculture, 2012b) surface layer erodibility (K) factor of the basin upstream from the Kings Creek, and (4) were within 3 percent of the RUSLE rainfall and runoff (R) factor of the basin upstream from the Kings Creek. Data from the eight selected sites then were filtered to observe SSC values during high streamflow conditions (values exceeded 1–10 percent of the time). As agriculture is the predominant land use in Kansas, boxplots of SSC from the Kings Creek sampling site and eight surrounding sites were then plotted as a function of the percentage of upstream cropland listed in the 2001 national land cover database (NLCD; Homer and others, 2007; fig. 18).

During relatively high streamflow conditions (exceeded 1–10 percent of the time), SSC values were significantly (*t*-test *p*-value less than .05; Helsel and Hirsch, 2002) higher at the 8 sites with upstream cropland as compared to the Kings Creek sampling site; however the extent of cropland only significantly affected SSC values (*t*-test *p*-value greater than .05) among 2 of the 28 remaining possible pairs of sampling sites. Among other possible explanations, similarities in SSC values regardless of the extent of upstream cropland may indicate that cropland cover upstream from these sites (at least above 24 percent coverage) was not a primary influence on suspended-sediment transport or delivery at these sites, or that 2001 NLCD cropland percentage was not indicative of agricultural land at the time of sampling.

SSC values can be evaluated across multiple flow conditions to evaluate potential impairments or to plan data collection programs. Figure 19 compares previously displayed SSC boxplots in figure 18 with those measured during streamflow conditions exceeded 25–50 percent of the time (indicative of medium-flow conditions). SSC values tended to be lower during medium-flow conditions at all sites identified as being similar to Kings Creek, whereas the distribution of SSC values did not appreciably change at the Kings Creek site between medium and high-flow conditions. Thus in this instance, the discrete SSC database was used to indicate (1) that SSC values are significantly different among relatively pristine and nonpristine sites in this part of Kansas, that (2) differences in SSC were most pronounced between pristine and nonpristine sites during high-flow conditions, and (3) that SSC values were generally similar among small basins in this part of Kansas despite substantial differences in the recent (2001) extent of upstream agriculture. This database was created, in part, to facilitate comparisons of suspended-sediment characteristics across flow and landscape conditions, further aiding in the identification of sediment-related stream and river impairments in different regions of the country. Visualization

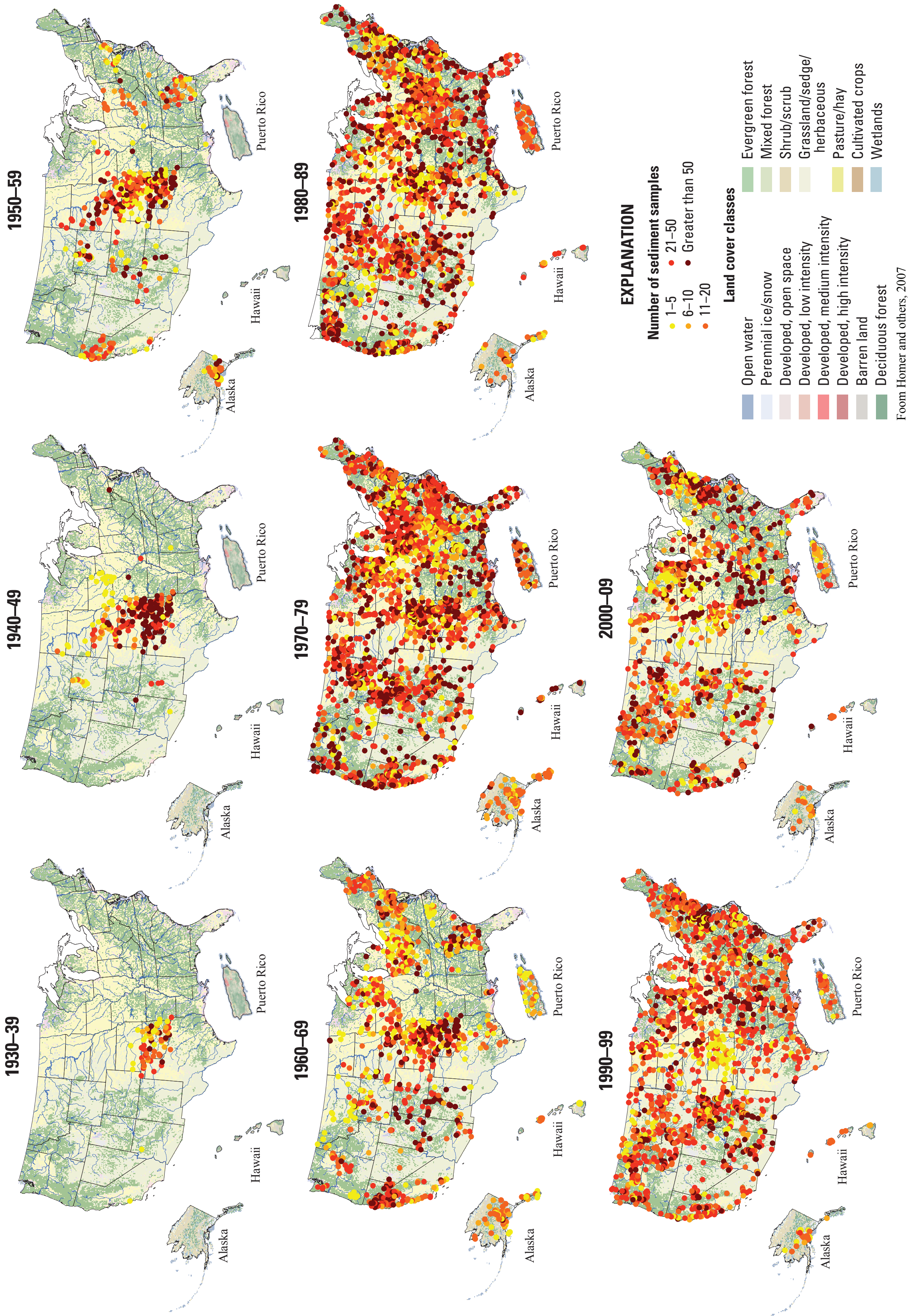


Figure 10. Location of suspended-sediment sampling sites and number of samples collected by decade from 1930 to 2009.

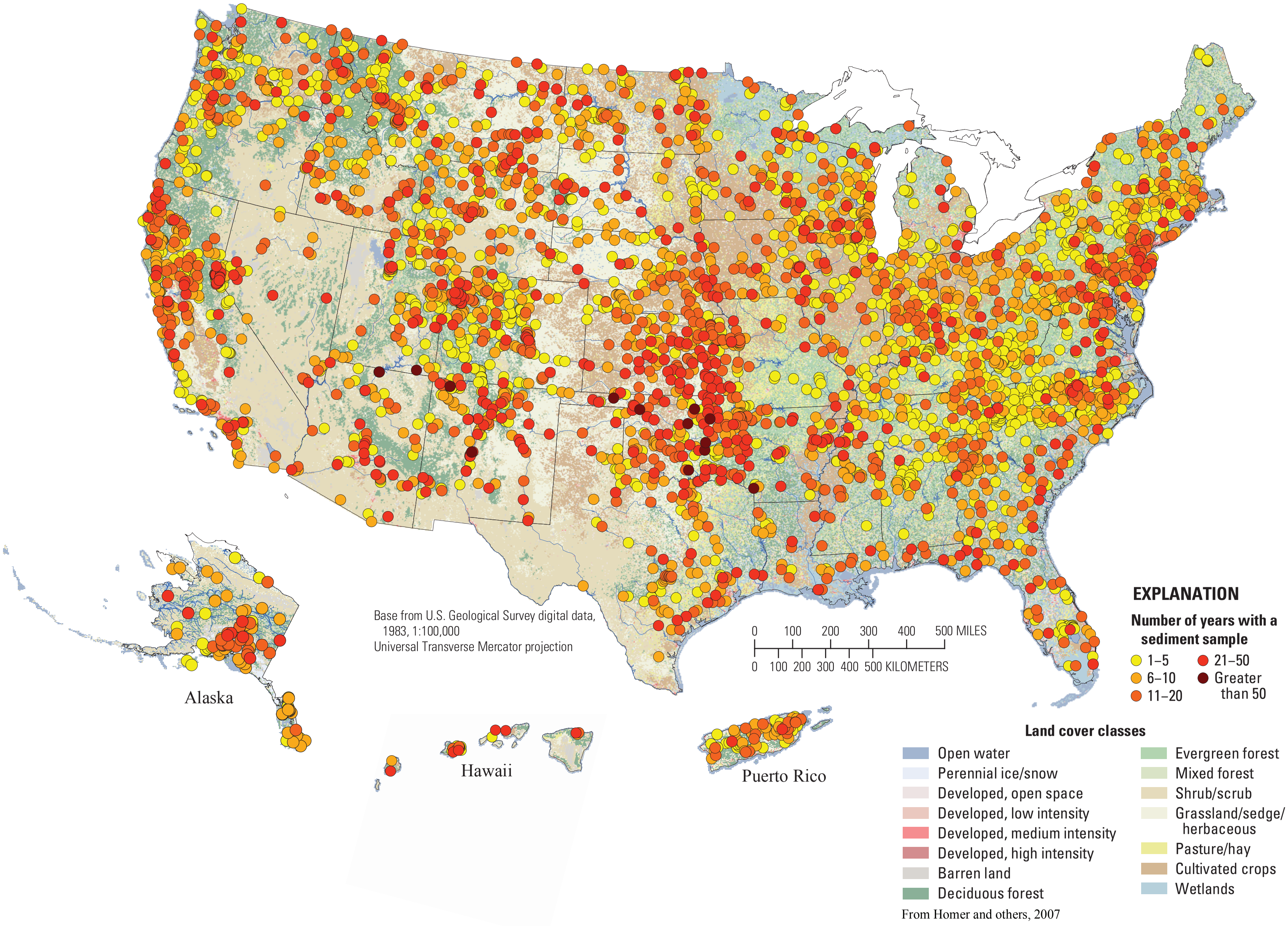


Figure 11. Location of suspended-sediment sampling sites and the number of years with discrete sediment sampling, 1901–2010.

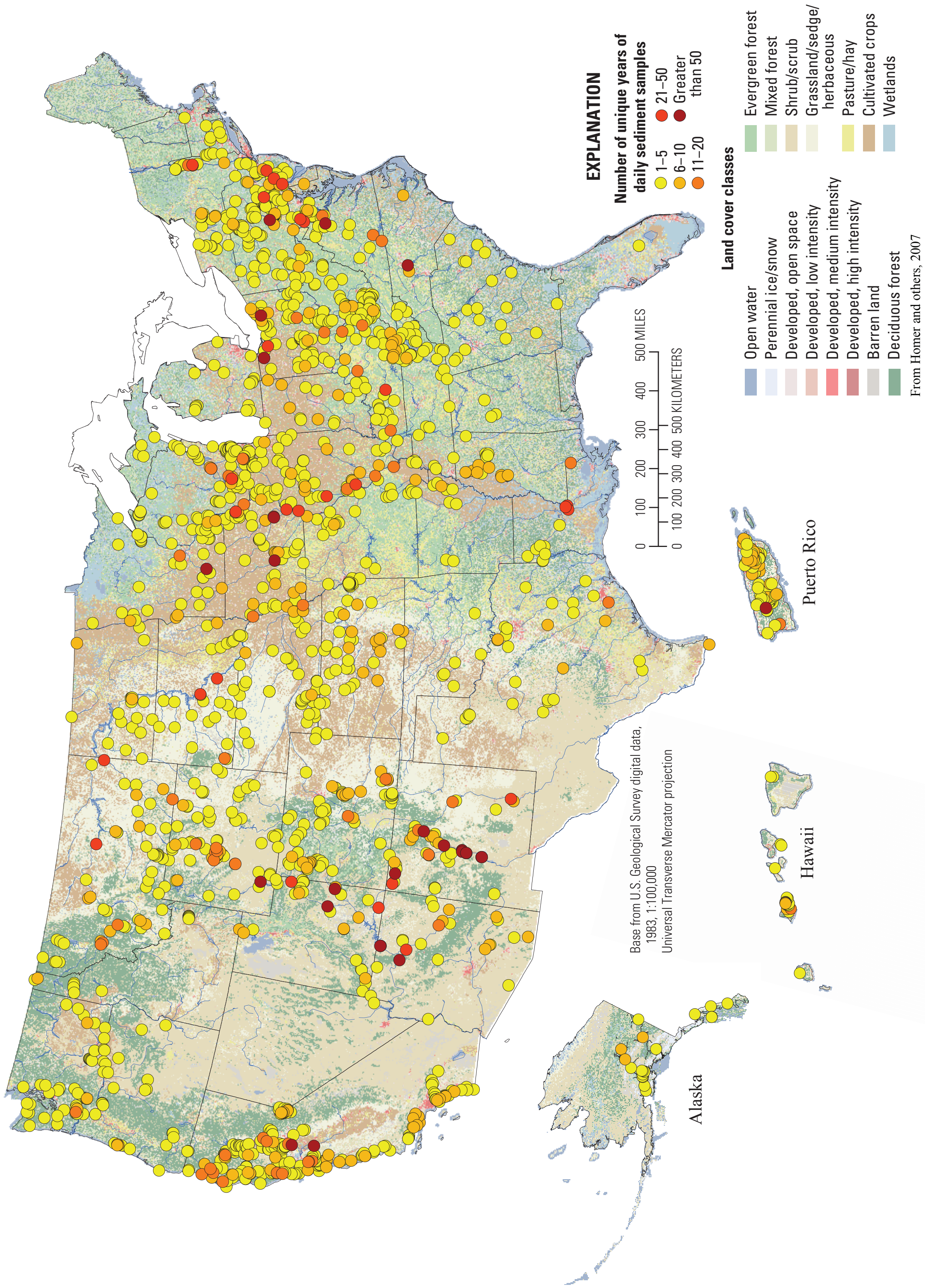


Figure 12. Location and the number of years of daily suspended-sediment sampling, 1901–2010 (U.S. Geological Survey, 2012a).

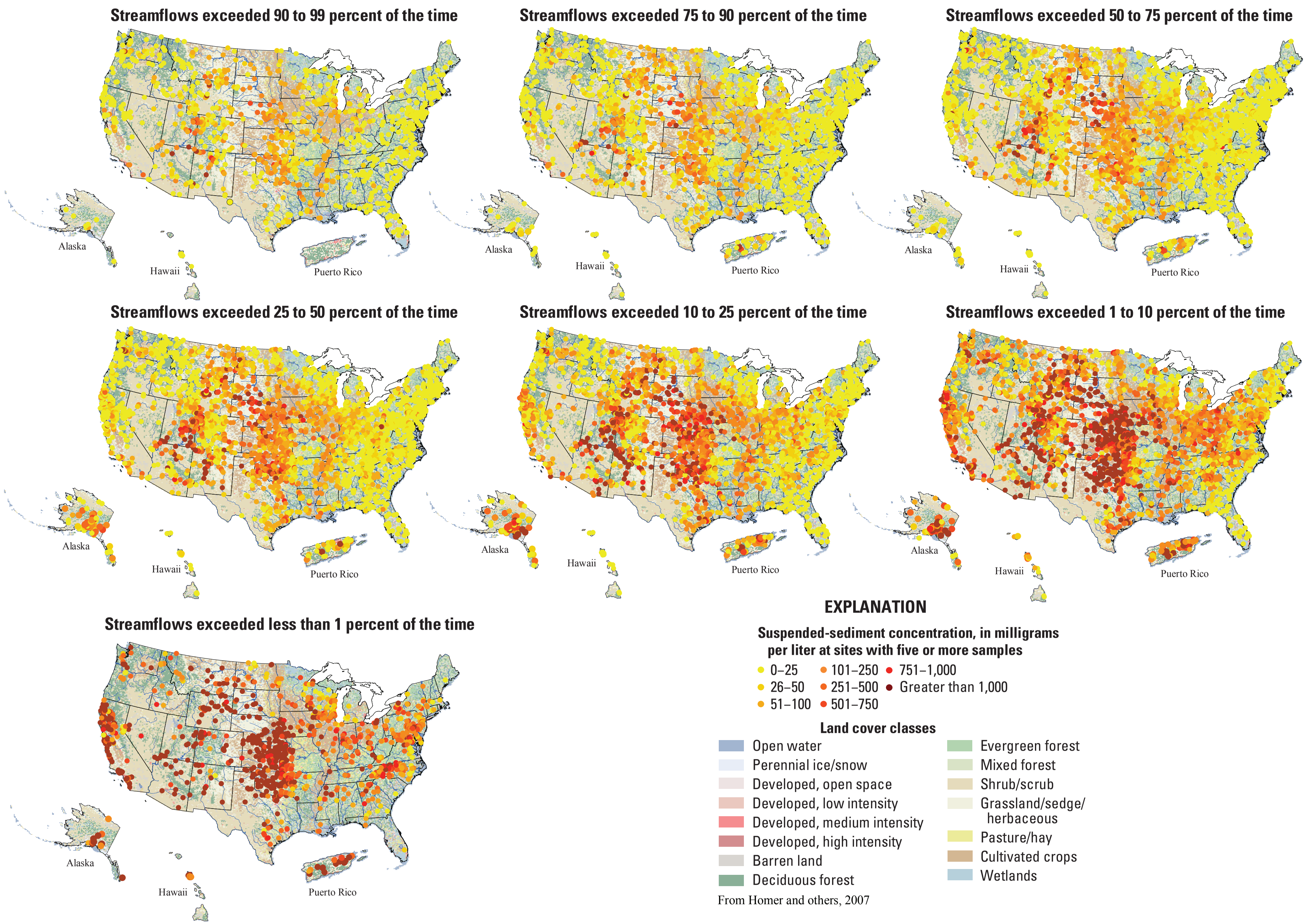


Figure 13. Median suspended-sediment concentration in the United States across streamflows exceeded more or less frequently, 1901–2010.

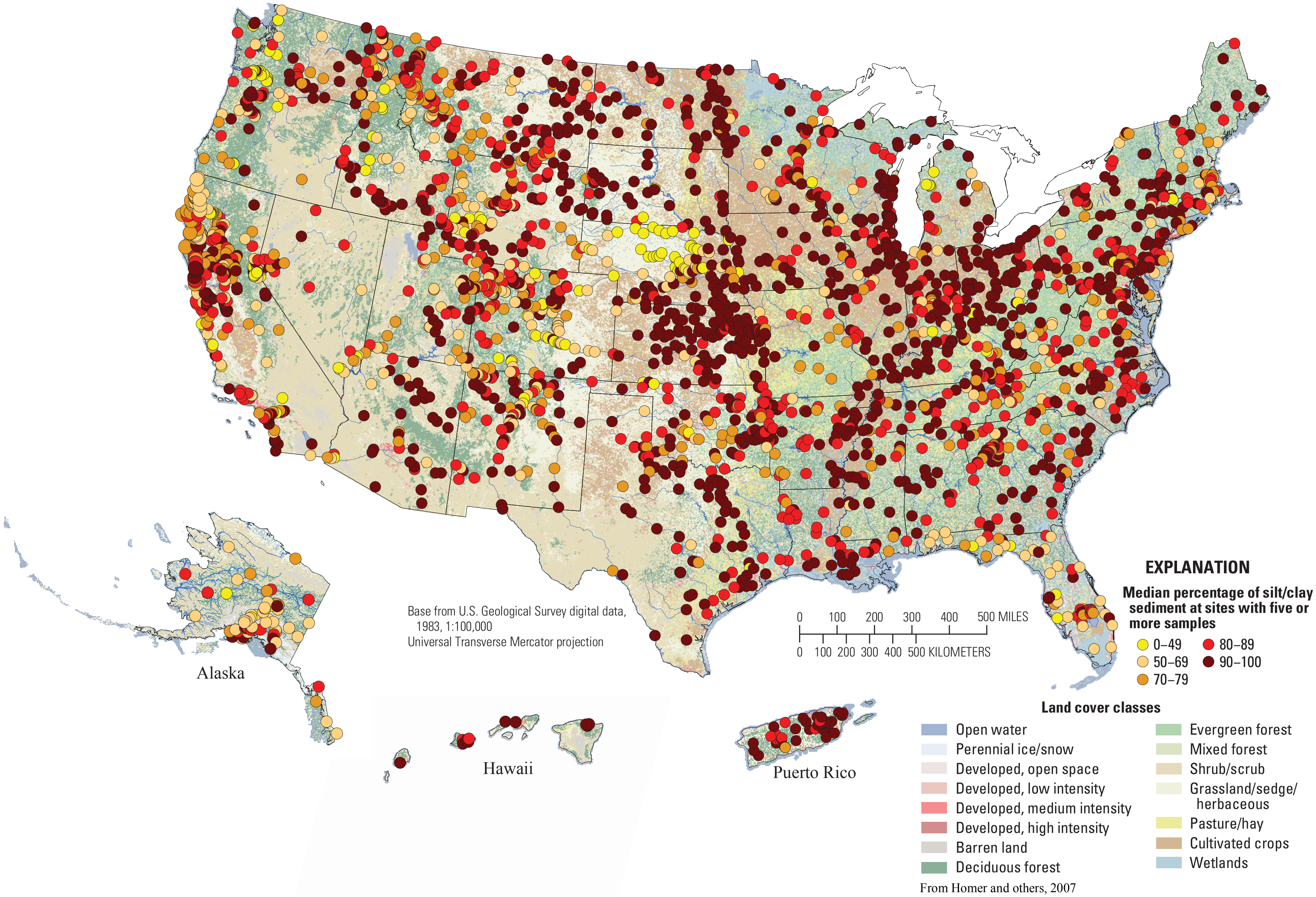


Figure 14. Median percentage of silt/clay suspended-sediment across the United States, 1901–2000 (U.S. Geological Survey, 2012a).

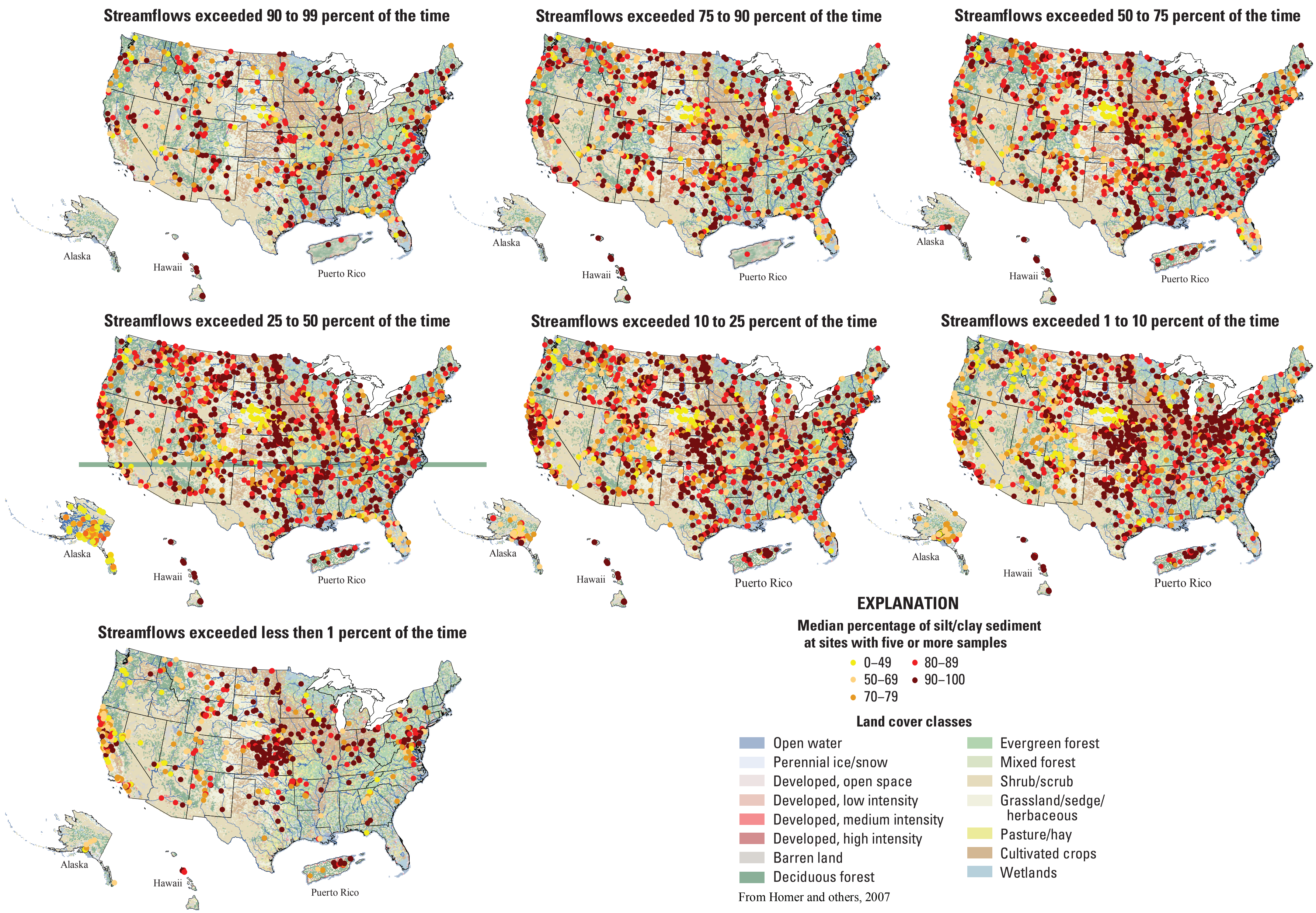


Figure 15. Median percentage of silt/clay suspended-sediment in the United States across streamflows exceeded more or less frequently, 1901–2000 (U.S. Geological Survey, 2012a).

of differences in SSC values across flow conditions may also help in the design of new monitoring programs tasked with identifying sediment-related impairments.

Identification of Data for New or Existing Data-Collection Programs

Knowledge of historical SSC sampling site locations can help program managers identify opportunities to assess whether changes in landscape condition or conservation programs have affected downstream sediment transport. As an example, the U.S. Department of Agriculture's Mississippi River Healthy Basins Initiative (MRBI) was implemented in 2010 to improve water quality and aquatic habitat in the Mississippi River Basin, and to reduce the transport of nutrients to the Gulf of Mexico (U.S. Department of Agriculture, 2012a). As of 2012, 54 hydrologic unit code (HUC) 8-sized watersheds have been identified through the MRBI for the implementation of landscape management practices designed to reduce soil erosion and nutrient transport. Locations of historical USGS sediment-sampling sites with data potentially amenable to trend analyses were identified from this dataset within or immediately downstream from MRBI HUC 8 watersheds, and are displayed with symbols that indicate ranges of the number of historical samples (fig. 20). Reestablishment of suspended-sediment monitoring at these locations may help assess whether erosion controls have measurably affected downstream suspended-sediment transport.

Evaluation of Suspended-Sediment Trends

This dataset can be used to identify sites with data sufficient to evaluate historical trends in SSC, characterize differences in SSC at a particular site with respect to time and flow condition, and begin to examine how human actions may affect SSC in streams. In this example, the dataset is used to identify sampling sites that may be used to evaluate potential trends in SSC resulting from a hypothetical change in landscape practices in the 1980s. Sampling sites with small upstream drainages (less than 300 square miles) were selected to examine trends because of potential confounding factors in larger basins, such as large reservoirs, increased stream-channel erosion, and heterogeneity of landscape conditions. Sites with less than 300 square miles of upstream drainage area and more than 10 SSC samples before 1980 and sites meeting the same criteria with more than 10 samples after 1989 are shown in figure 21.

To illustrate the use of historical data to identify potential trends, relations between SSC and instantaneous streamflow are compared using data before 1980 and after 1989 at the USGS streamgage at Baptism River near Beaver Bay, Minnesota (USGS station identifier 04014500; figs. 21 and 22). An analysis of covariance (ANCOVA; Helsel and Hirsch, 2002) indicated that independent of streamflow conditions, mean SSC values from 1974 to 1979 were significantly greater (p-value =.01) than SSC than collected from 1990 to 1993. It is important to note that samples during the 1990s were collected using equal-width and equal-discharge increment methods, whereas data collection methods in the 1970s are unknown, and thus this trend may be related to differences in sampling methods. However, particle-size analyses indicate that most sediments in transport are silt and clay-sized, and so are less likely to be affected by differences in sampling or processing methodologies. Samples among the two time periods were collected during similar seasons, and there are no known dams upstream from this site that might have caused a decreasing trend. Thus, this is an example in which an analyst could hypothesize that changes in the landscape, either before or during this period, resulted in decreasing SSC values relative to streamflow condition.

Evaluation of Sampling and Monitoring Methods

This database also may be useful in identifying appropriate and cost-effective methods to monitor sediment and sediment-associated contaminants. Previous analyses have indicated that different sediment sampling and processing methods (Capel and Larson, 1995; Edwards and Glysson, 1999; Horowitz and others, 2001) and different sediment-surrogate methods (such as turbidity or acoustics) can perform better or worse depending upon the predominant size of sediment in transport (Gartner, 2002; Downing, 2006). Because the methods and timing of water-quality sample collection are dictated by a specific objective (for example, evaluating aquatic habitat quality as compared to sediment-load computations), data often are purposely collected during specific seasons or flow conditions. In this example, silt and clay-sized sediments (material finer than 63 micrometers) are mapped across Montana during streamflows exceeded less than 25 percent of the time (relatively high-flow conditions) for a hypothetical water-quality study in which the analyst needs to choose a sediment-surrogate appropriate to compute loads of sediment and sediment-associated constituents (fig. 23).

Based on the following data, if one were to implement a suspended-sediment monitoring program in Montana, one might want to emphasize turbidity monitoring, because of increased response to fine-sized sediment and simple protocols (Downing, 2006; Rasmussen and others, 2009), in much of the eastern one-half of the State such as in the Yellowstone River, Tongue River, and Powder River. However in the western part of the State where more sand-sized sediments are in suspension, alternative methods such as acoustic attenuation and backscatter (Landers, 2010) may be more appropriate. Readily available information on sediment grain size across space and relative to flow condition can help with other project planning activities, such as choosing which sampling, processing, or laboratory methodologies are most appropriate given cost considerations. For example, automated-pumped sampling, which enables many samples to be collected in a cost-effective manner, would be more likely to bias sediment and sediment-associated data in the western part of Montana (fig. 23).

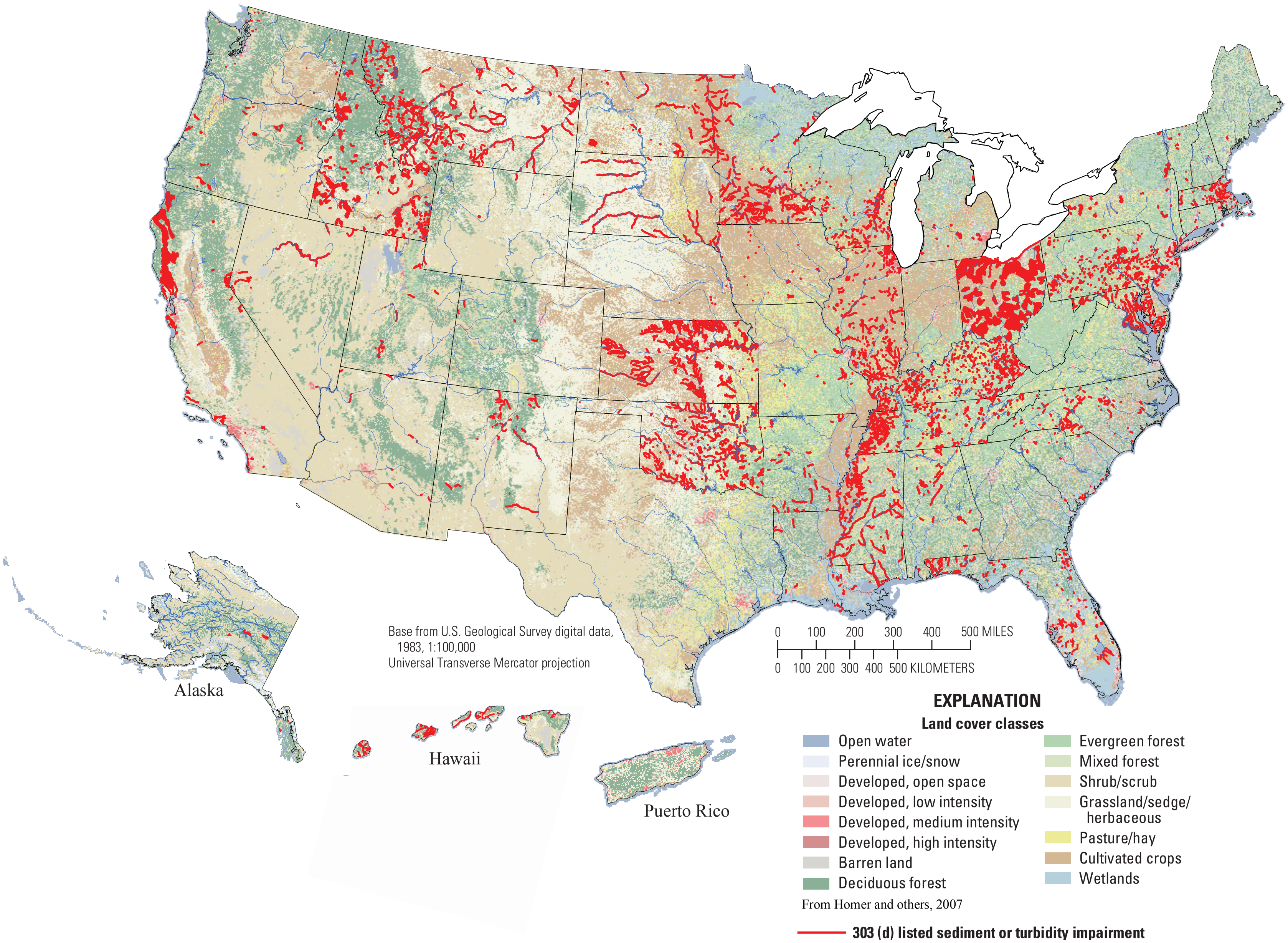


Figure 16. Location of sediment and turbidity-related impairments to water quality identified under the U.S. Environmental Protection Agency 303(d) list, 2010 (U.S. Environmental Protection Agency, 2012b).

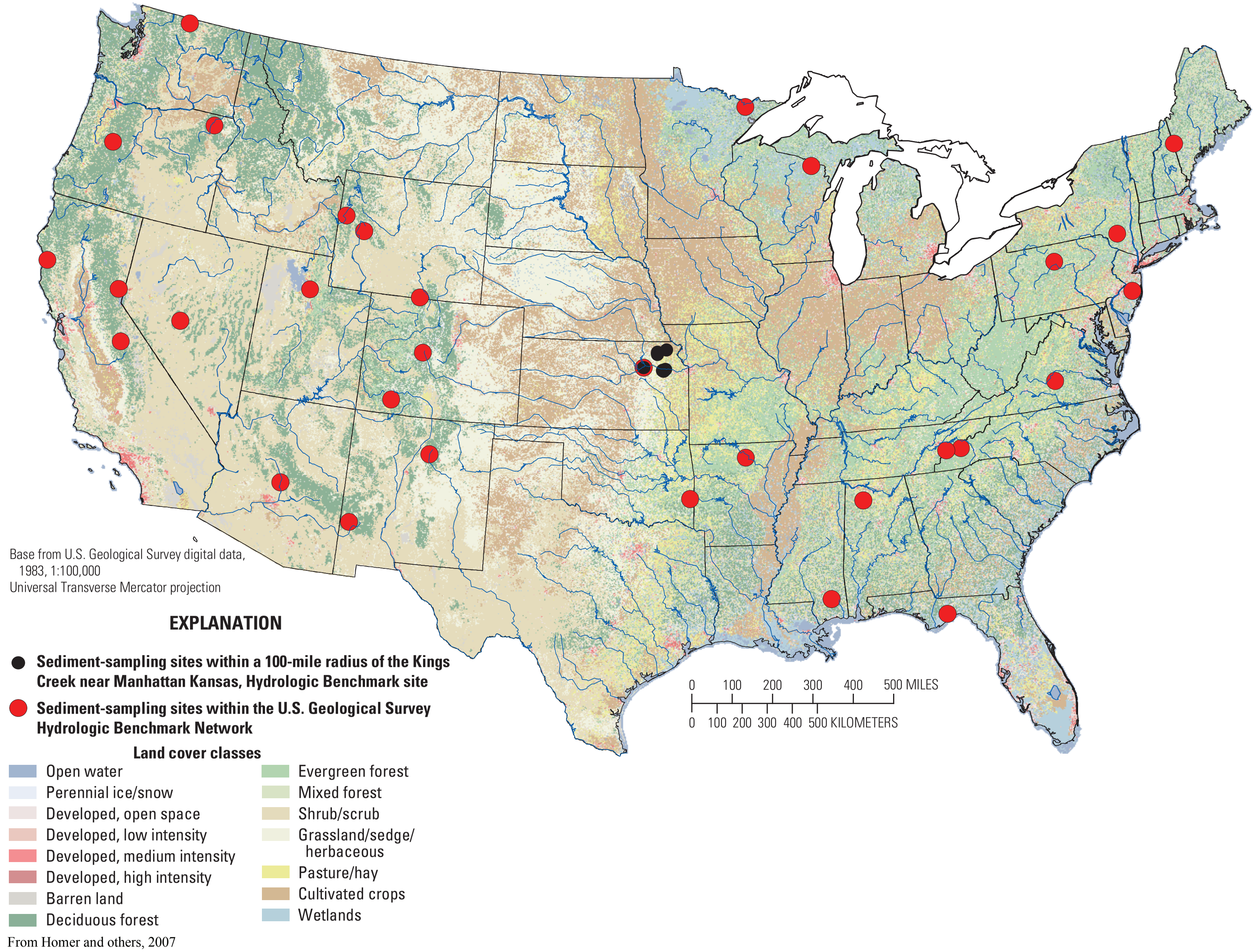


Figure 17. Location of U.S. Geological Survey (USGS) hydrologic benchmark network sites with suspended-sediment data across the United States along with suspended-sediment sites similar to Kings Creek near Manhattan, Kansas (Falcone, 2011).

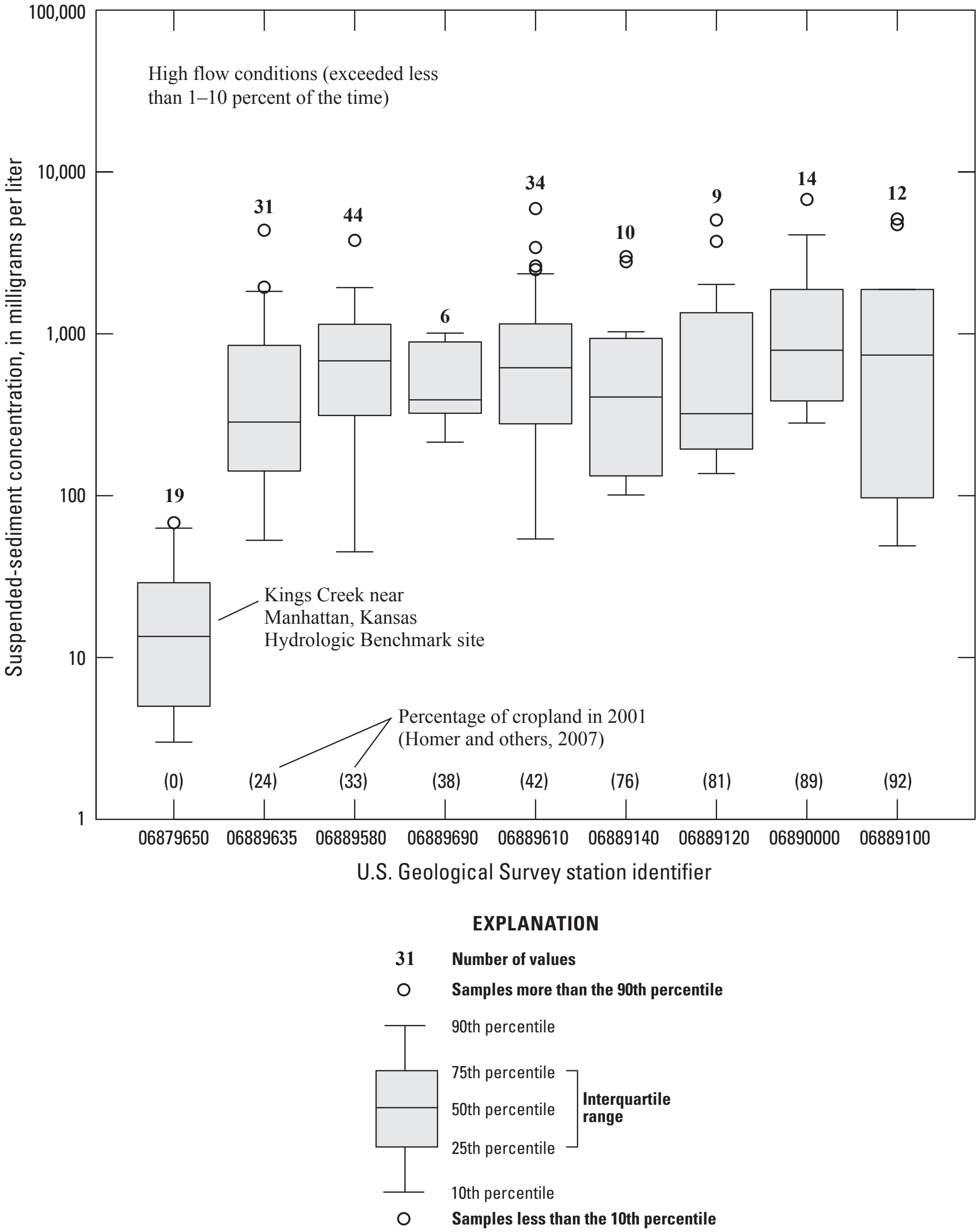


Figure 18. Suspended-sediment concentration during streamflow conditions exceeded 1 to 10 percent of the time at sites similar to (and including) Kings Creek, near Manhattan, Kansas, relative to percentage of cropland.

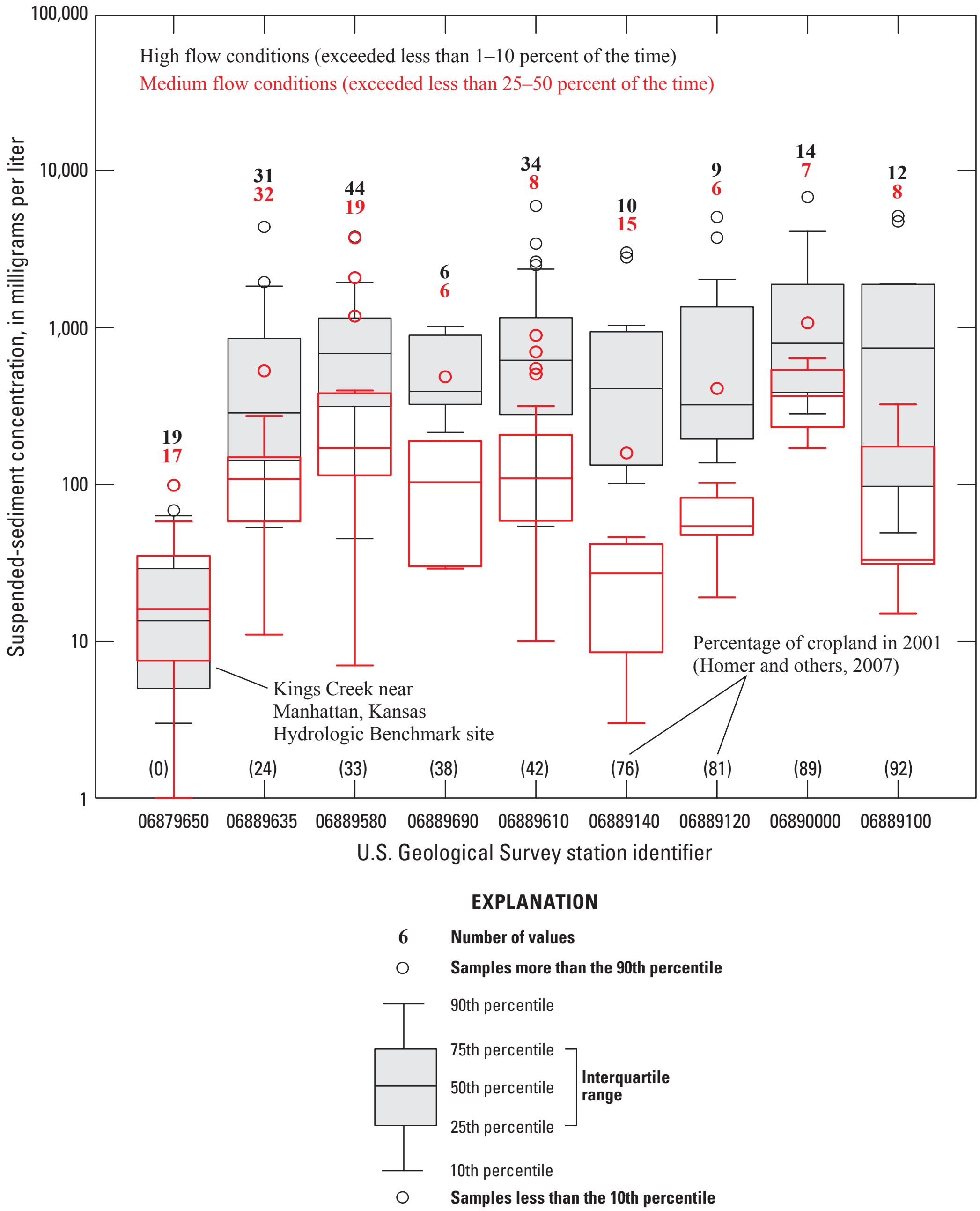


Figure 19. Suspended-sediment concentration during streamflow conditions exceeded 1 to 10 percent and 25 to 50 percent of the time at sites similar to (and including) Kings Creek, near Manhattan, Kansas, relative to percentage of cropland.

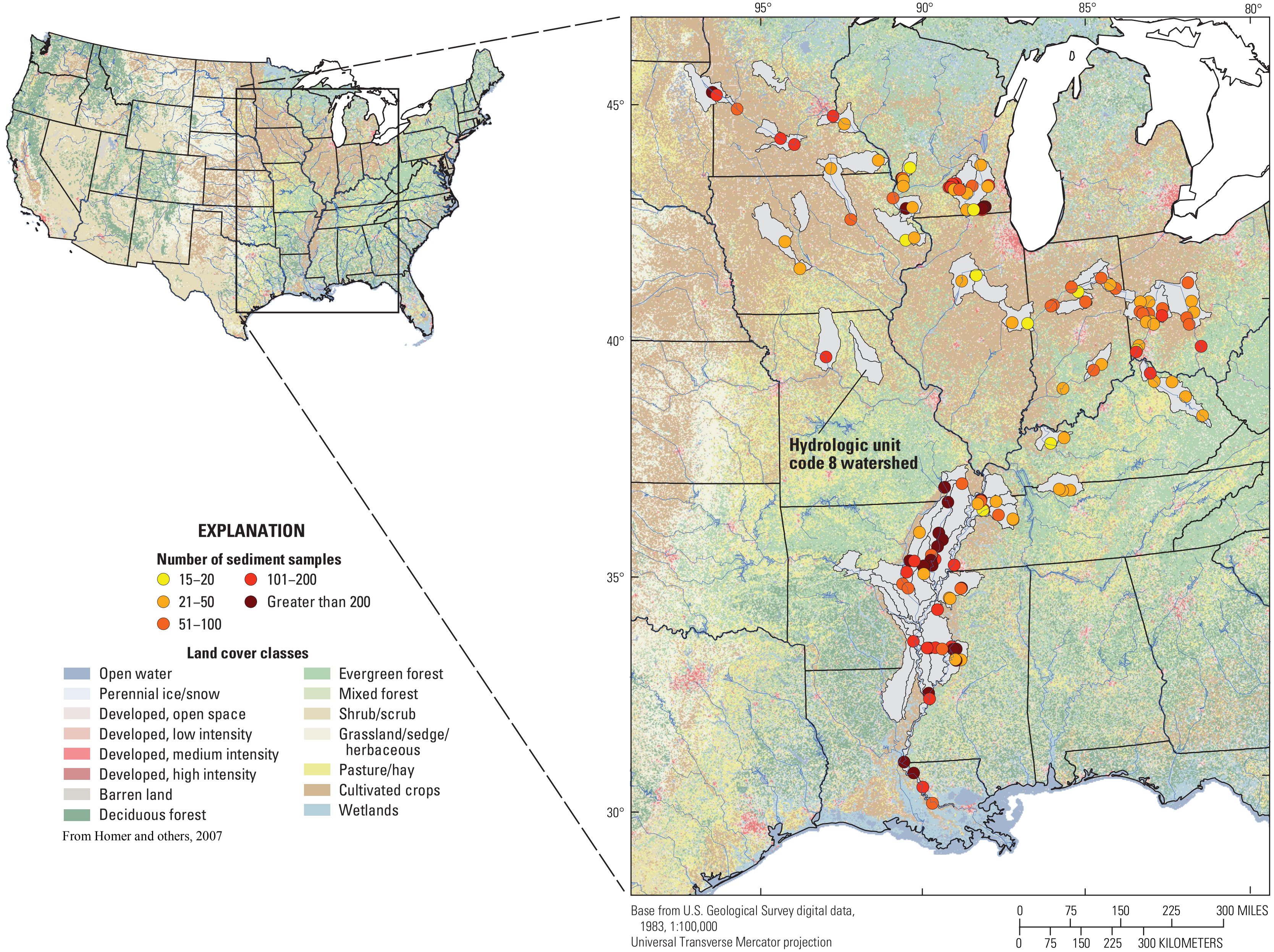


Figure 20. Sampling sites with more than 15 suspended-sediment samples within or immediately downstream from Mississippi River Basin Healthy Watershed Initiative hydrologic unit code eight watersheds.

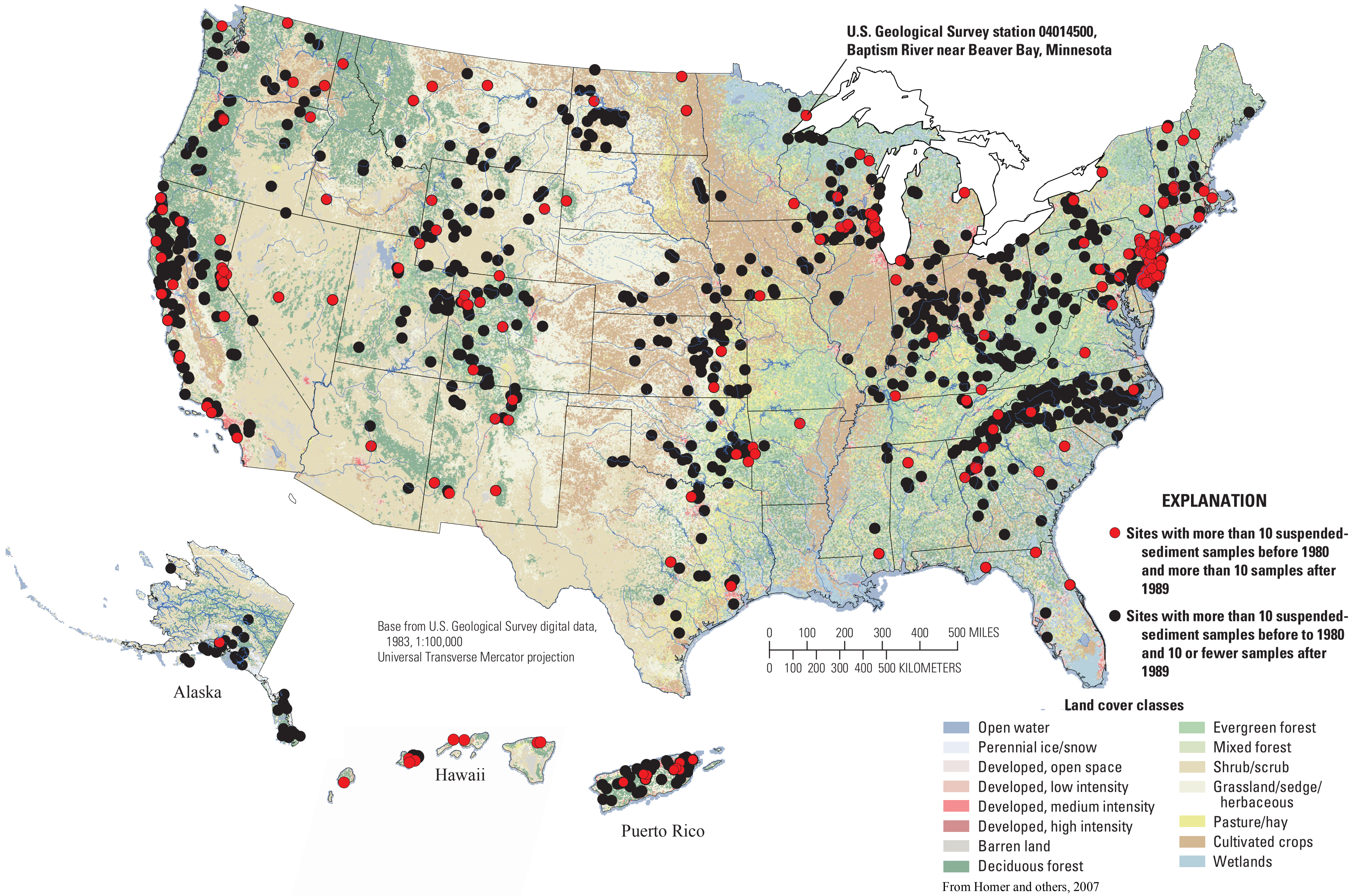


Figure 21. Sampling sites with more than 10 suspended-sediment samples and with less than 300 square miles of upstream drainage before 1980 and after 1989, and the sampling site evaluated at the Baptism River near Beaver Bay, Minnesota.

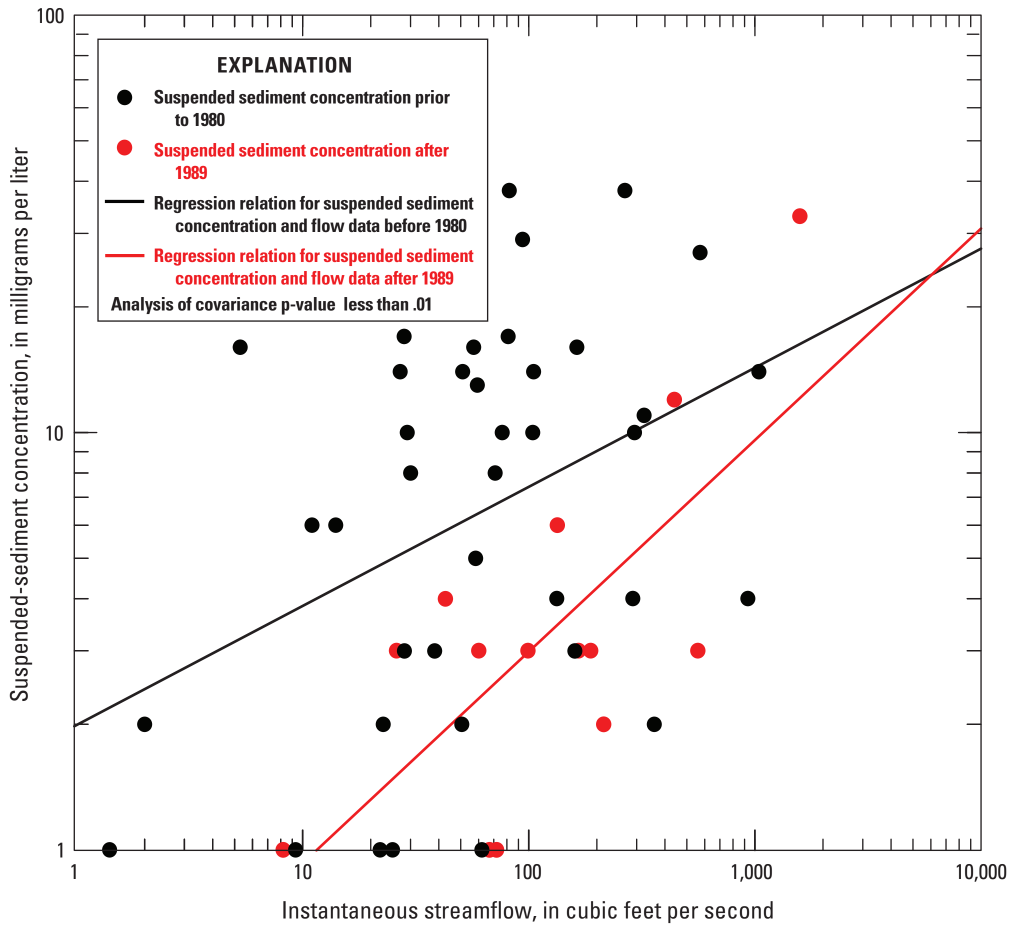


Figure 22. Comparison of suspended-sediment concentrations (SSC) across streamflow conditions at the Baptism River near Beaver Bay, Minnesota, before 1980 and after 1989.

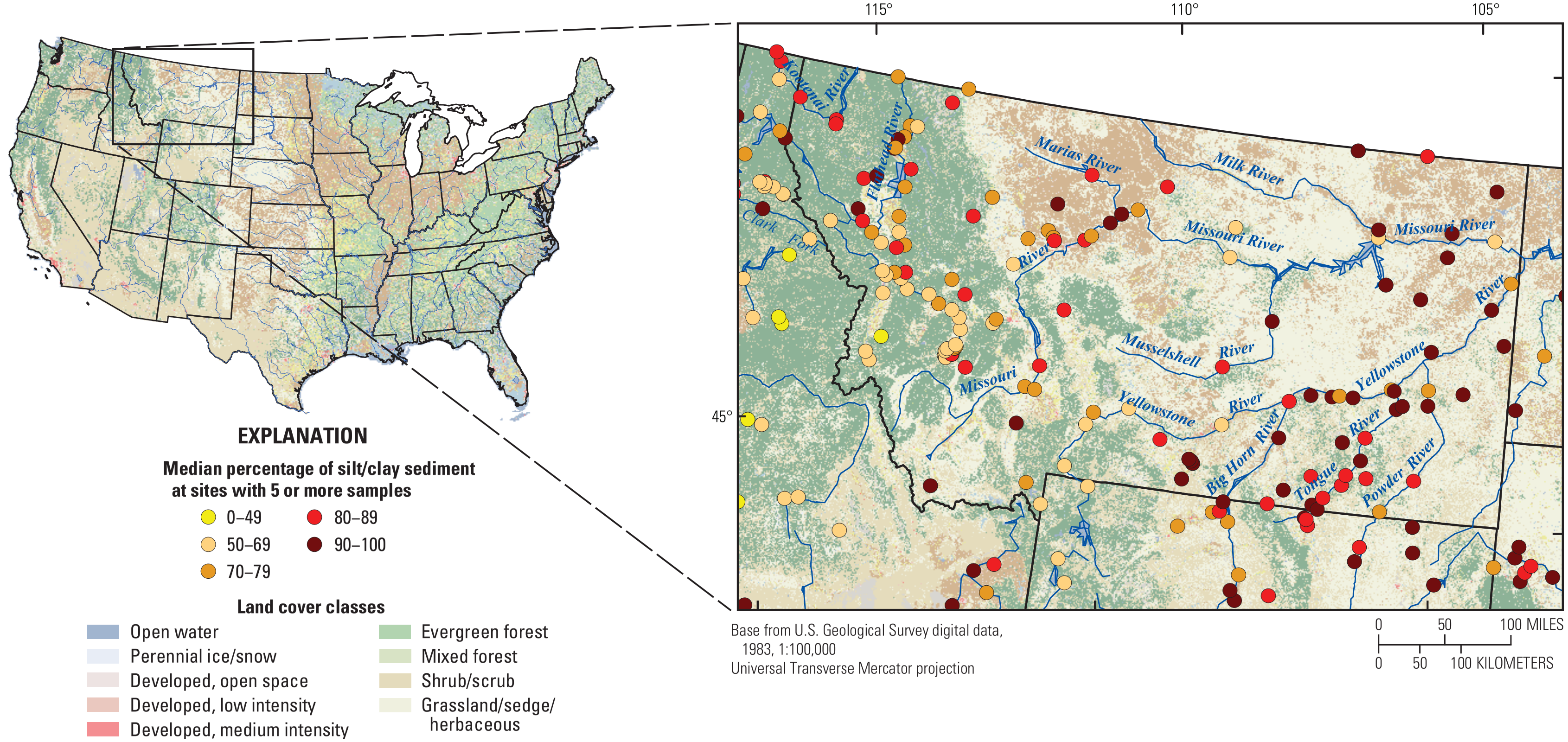


Figure 23. Median percentage of silt or smaller-sized sediments during daily streamflow exceeded less than 25 percent of the time in the State of Montana (U.S. Geological Survey, 2012).

Summary

Human-induced and natural changes to the transport of sediment and sediment-associated constituents can damage ecosystems and limit human uses of surface waters. The lack of a dedicated, easily accessible, quality-controlled database of sediment and ancillary data has made it difficult to identify sediment-related water-quality impairments and to understand how human actions affect suspended-sediment concentrations and transport. This report describes the process of creating a quality-controlled database of U.S. Geological Survey (USGS) suspended-sediment and ancillary data, provides examples as to its use, and summarizes suspended-sediment data across the United States.

The database was initialized by retrieving discrete suspended-sediment and ancillary data collected at USGS streamgage locations before January 1, 2011, from the USGS National Water Information System. These data underwent a screening and quality-control process to establish a sediment database that best represents stream conditions using available data. Site-specific data from the USGS StreamStats database and attributes from the GAGES II database were matched to suspended-sediment sampling sites to provide context regarding streamflow and landscape conditions. Maps were created that summarize suspended-sediment data across the United States with respect to time, streamflow, and landscape condition. Examples are included to illustrate how the dataset and accompanying report can help analysts more easily view, interpret, and access suspended-sediment and related data, with the goal of supporting local and national-level decision making, project planning, and data mining activities. The database is provided as an online application (*http://cida.usgs.gov/sediment*) that allows users to view, filter, and retrieve available suspended-sediment and ancillary data. This report and dataset can be used to identify sediment-related impairments to streams and rivers, evaluate factors affecting sediment transport, and better design new data collection activities.

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